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PRIMARY ENERGY ESTIMATION FOR CONTEMPORARY HOUSING IN NORTHERN INDIA

A THESIS

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DOCTOR OF PHILOSOPHY

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By

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CANDIDATE'S DECLARATION

I hereby certify that the work which is presented in the thesis entitled **PRIMARY ENERGY ESTIMATION FOR CONTEMPORARY HOUSING IN NORTHERN INDIA**, in fulfilment of the requirement for the award of the Degree of Doctor of Philosophy and submitted in the Department of Architecture and Planning of the Institute, is an authentic record of my own work carried out during a period from October 1994 to August 2000 under the supervision of Dr. (Mrs.) S. Sahu, Professor in Architecture and Planning (Retd.), Indian Institute of Technology, Roorkee and Dr. S.K. Kaushik, Professor in Civil Engineering, Indian Institute of Technology, Roorkee.

The matter presented in this thesis has not been submitted by me for the award of any other degree in this or any other Institute or University.

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This is to certify that the above statement made by the candidate is correct to the best of our knowledge.

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ABSTRACT

The construction sector is an important part of the Indian economy and makes a significant contribution to its development. But it is also a major consumer of energy, mainly required for the production of building materials, alongwith their transportation to and use at the site of construction.

There is also a rising demand for building materials, primarily due to housing, since it accounts for nearly 60% of the materials consumed by the construction sector in India. Moreover, the pressing need for housing in India cannot be met by the existing supply of building materials.

Therefore, it is imperative to:

1. Check the energy consumption of the construction sector by reducing the energy needed for construction
2. Provide larger quantities of building materials to meet their increasing demand

Both these objectives can be achieved by providing energy efficient substitutes for the conventional building materials. These alternatives will help to reduce the energy required in construction. Moreover, it will be possible to manufacture larger quantities of such materials within the existing levels of energy consumption of the construction sector. Since housing is the single largest segment of this sector, therefore it shall be the focus of this study.

Energy consumption can only be reduced by first estimating the energy required for construction, termed as the Construction Energy Cost (CEC).

The CEC comprises of:

1. Primary Energy Cost (PEC), i.e., the energy cost of civil work, which has the following components:

A. Total Embodied Energy Cost of civil work (EEC_T) includes the total energy embodied in the building materials, i.e., the sum of the energy needed to quarry the raw materials, transport them to the manufacturing units, manufacture the building materials and transport the materials to the distribution outlets.

B. Total Transport Energy Cost of civil work (TEC_T) includes the total energy required for transporting the building materials from the distribution outlet to the site of construction.

2. Secondary Energy Cost (SEC), which consists of the energy consumed in the construction work on site, the energy needed for the installation of electrical and sanitary fixtures, the energy needed for providing the infrastructure for the project and the energy consumed by the workers engaged in the construction work

Therefore, **CEC = PEC+ SEC**

Where, $\mathbf{PEC = EEC_T + TEC_T}$

Studies have shown that PEC is the larger component, generally accounting for nearly 80% of the CEC. Therefore, any reduction in the PEC will result in substantial savings in the CEC.

The aim of this research is, therefore, to estimate the PEC in housing construction and to study alternatives for its reduction. The scope of the work is restricted to the contemporary housing in the plains of Northern India.

The literature survey reveals that limited research has been done to determine the PEC. In India, researchers have obtained the energy values of building materials and carried out energy analysis of building components and some items of civil work, but no method has been developed so far to estimate the PEC of complete dwellings.

Therefore, a methodology has been developed in the present study for estimating the PEC, which can be directly applied to any housing. The approach that has been evolved is to estimate the energy components of the PEC, viz., the EEC_T and the TEC_T, by adopting the same format that is used for estimating the construction cost of civil work, i.e., the detailed cost estimate. Both EEC_T and TEC_T estimates have been prepared and totalled to give the PEC of any given dwelling or project.

The Embodied Energy Rates (EER) to estimate the EEC_T and the Transport Energy Rates (TER) for estimating the TEC_T have been computed. A 'Schedule of Energy Rates' has been compiled, listing the EER and TER.

This methodology for estimating the PEC has been applied to sixteen case studies ranging from single and double storeyed dwelling units to four storeyed housing projects. The single and double storeyed units are all in load bearing construction, whereas the four storeyed housing projects are both in load bearing and RCC structural frames.

Detailed PEC estimates have been prepared for all the projects, which reveal that masonry and RCC work are the major determiners of PEC for all the projects. Bricks and reinforcing steel, which are the main constituents of the masonry and RCC work, have an average combined share of 60% in the PEC.

Masonry work is found to be the single largest contributor to the PEC for nearly all the projects. The reason for its high energy and cost share is the use of traditional burnt clay bricks. They alone account for upto 80-85% in the energy share of the masonry work in the PEC.

The energy rates of all the projects have also been obtained. These reveal that the double storeyed load bearing housing construction has the lowest range of energy rates of the types that have been studied for the North Indian plains, whereas this range is the highest for single storeyed load bearing units.

The energy rates of the typical Indian projects studied are found to be comparable to those obtained by other authors internationally.

Both linear and quadratic Equations have been derived for providing a preliminary PEC estimate of any dwelling or project for a given plinth or floor area in the studied categories. The suitability of these Equations has been examined by computing the percentage deviations of the PEC obtained from them vis-à-vis the actual values from the detailed estimates.

Since masonry work is the single largest contributor to the PEC, it has been selected to study the energy savings that can be achieved by using alternatives. The results show that there is a fall of upto 35% in the PEC by using alternatives to the traditional bricks. Aerated or hollow concrete blocks (40 cm x 20 cm x 20 cm) with 1:6 cement mortar (1 cement: 6 fine sand) give energy savings in the range of 25-35% over traditional brick masonry, whereas masonry work in 1:6 cement mortar and clay flyash bricks or Fal-G blocks give energy savings of 15-25%. Other masonry units also provide energy savings, which range from as low as about 1.5% (using modular bricks) to as high as 23% (using solid concrete blocks). 1:6 cement mortar (1 cement: 6 fine sand) has the least energy value of all the mortar mixes considered.

Equations have also been derived for estimating the PEC of housing construction using the most suitable alternatives.

The reduction in energy cost means that, PEC remaining constant, more volume of masonry work can be achieved by replacing traditional bricks with these energy efficient alternatives. The added advantage is that materials like clay flyash bricks utilise flyash, thus reducing its ecological hazard. Moreover, replacement of clay with flyash saves topsoil and hence, prime agricultural land.

Further secondary energy savings occur in the plastering work because the mechanically produced alternate masonry units give fairly smooth external and internal wall surfaces due to their uniform shape and size, thus reducing the quantity of plastering needed for satisfactory coverage.

New light weight materials donot cause a major change in the PEC of housing construction in traditional brick masonry. But, since they show little change in the PEC of the projects (except for PVC), they can be suitable in a future scenario when bricks may not be sufficient to meet the growing demand.

It is evident from the foregoing discussion that the construction work using substitutes will compare favourably with traditional brick construction, particularly if the alternate masonry units are manufactured and used on a mass scale. Moreover, masonry work utilising bigger units like hollow concrete blocks (40cm x 20cm x 20cm) and aerated concrete blocks have the added advantage of having fewer joints, resulting in considerable savings in the mortar requirement.

Thus, the energy required by the construction sector will be checked, particularly with regard to housing, which is its single largest segment. The demand for more building materials for housing construction will also be met within the existing levels of its energy consumption and within the contemporary methods of construction.

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CHAPTER 1

INTRODUCTION

The construction sector in India makes a vital contribution to its social and economic development by providing housing and infrastructure. As the sector is growing continuously with a projected annual economic growth rate of about 5%, there has been a proportionate rise in the demand for building materials. This makes it a major consumer of energy for the production, transportation and use of building materials on the site of construction. A specific case is that of the four major building materials, viz., cement, steel, bricks and lime. The cumulative energy required for their production in 1989-'90 was 742.5PJ, as shown in Table 1.1. Future projections, based upon the existing manufacturing technologies, indicate that this requirement will increase to 2262.5.0 PJ by 2020 AD.

Table 1.1: Projections of the Demand of Materials and Their Energy Requirements upto 2020 AD[#]

	Material Quantity (mt)				Energy Requirement for Manufacture (PJ)			
Year	1989-90	2000	2010	2020	1989-90	2000	2010	2020
Cement	47.53	92.50	136.00	202.00	275.00	535.80	787.70	1173.10
Steel	8.09	9.60	14.90	23.00	256.00	303.40	469.90	726.80
Bricks (billion nos.)	45.31	61.20	72.90	89.10	190.00	257.00	306.20	374.20
Lime	3.30	5.10	8.30	13.60	21.50	33.30	51.20	88.40

[#] Source: Development Alternatives, 'The Construction Sector in India and Climate Change', DA Newsletter, Vol. 7, No. 1, Jan. 1997, pp.4-5

There is also the additional problem of the consumption of precious topsoil in the manufacture of traditional burnt clay bricks, which are the most commonly used masonry units, particularly in Northern India[1]. This is resulting in a steady wastage of prime agricultural land. It was estimated that bricks consumed in India's urban centres in 1995 required at least 160 million tonnes (mt) of topsoil, making barren about 3,050 hectares of fertile land (Suresh, 1995).

Nearly 60% of the building materials needed by the construction sector in India are for housing purposes. Therefore, the increasing demand for materials by the construction sector is primarily due to the galloping demand for housing. There was a need for 41 million dwelling units in India from 1991 to 2000 AD and around 3.9 million houses per annum will have to be provided from 2001 to 2021 AD. This pressing need for housing cannot be met by the existing supply of building materials.

A case in point is of traditional bricks. The projected demand for bricks in 1990 AD was 45.31 billion numbers per annum. This demand is expected to touch 61.2 billion numbers by 2001 AD and 89.1 billion numbers by 2020 AD (Development Alternatives, 1997), as shown in Table 1.1. But, according to the projection of the Planning Commission for the VIII Plan Period (1992-97), later verified by the Building Materials and Technology Promotion Council (BMTPC), brick production is likely to reach a saturation point at about 46.5 billion numbers per annum. This is attributed to the limited availability of clay of requisite quality, coupled with restricted availability of fuel. Hence, traditional bricks will either not be able to meet the demand of masonry work in the near future or will become economically unprofitable in production.

[1] The high quality of topsoil in this region yields bricks of good compressive strength, very suitable for load bearing masonry construction.

Therefore, it is imperative to:

1. Check the energy consumption of the construction sector by reducing the energy needed for construction

2. Provide larger quantities of building materials to meet their increasing demand

Both these objectives can be achieved by providing energy efficient substitutes for the conventional building materials. Such substitutes will reduce the energy needed for construction. Moreover, it will be possible to manufacture larger quantities of such materials within the existing levels of energy consumption of the construction sector. To achieve these objectives, it is essential to first estimate the energy required for construction or the Construction Energy Cost (CEC). Alternatives can then be studied to reduce the CEC. Since housing is the single largest segment of the construction sector, therefore it shall be the focus of this study.

1.1. ENERGY ESTIMATION IN HOUSING

The energy consumed in housing has been classified into two major categories, viz., the CEC (as mentioned above) and the energy needed to operate a dwelling or the Operating Energy Cost (OEC), i.e., the energy used by the occupants to heat, cool, ventilate, light and operate equipment etc.

The CEC for housing construction can be sub-divided into the following components:

1. Primary Energy Cost (PEC), i.e., the energy cost of civil work, which has the following components:

   A. Total Embodied Energy Cost of civil work (EEC_T) is the sum of the Embodied Energy Values (EEV) of all the building materials needed for the civil work.

The EEV# of a building material consists of the energy needed to:

i. quarry the raw material

ii. transport it to the manufacturing unit

iii. manufacture the building material

iv. transport the finished material to the distribution outlet

B. Total Transport Energy Cost of civil work (TEC_T) is the sum of the Transport Energy Values (TEV) of all the materials required for the civil work. The TEV$ of a building material is the energy needed to transport it from the distribution outlet to the site of construction.

2. Secondary Energy Cost (SEC), which consists of:

A. the energy consumed in the construction work on site

B. the energy needed for the installation of electrical and sanitary fixtures

C. the energy needed for providing the infrastructure for the project

D. the energy consumed by the workers engaged in the construction work

Therefore, **CEC = PEC+ SEC**

Where, $\mathbf{PEC = EEC_T + TEC_T}$

Studies have shown that PEC is the major component, generally accounting for nearly 80% of the CEC (Wright et. al., 1979). This is also true because the PEC includes the energy cost of the four major building materials, viz., cement, steel, bricks and lime, which are the largest consumers of energy in construction. Therefore, PEC is the determining factor for the estimation of the CEC and the main objective of the present work is to develop a methodology to estimate the PEC and find solutions for its reduction in housing construction.

EEV is expressed as embodied energy per unit quantity of the material

$ TEV is expressed as transport energy per kg of the material

1.2. OBJECTIVES AND SCOPE OF THE WORK

The broad objectives of this research are as follows:

1. To develop a methodology for estimating the components of the PEC, viz., EEC_T and TEC_T
2. To prepare a schedule of energy values of the building materials for estimating the PEC of housing construction
3. To estimate and analyse the PEC of housing construction through selected case studies
4. To obtain building material alternatives for reducing the PEC

The scope of this research is limited to finding solutions within the contemporary construction practices and manufacturing technologies in India. Within this framework, the work is restricted to the PEC estimation of housing construction for the plains of northern India, having composite climatic conditions. Moreover, the alternative building materials included in this work are only related to the study of the reduction in the PEC for housing construction. Hence, comprehensive life cycle assessments and other parameters related to housing such as their impact on land use and urban infrastructure fall outside the purview of this work.

CHAPTER 2

LITERATURE REVIEW

2.1. INTRODUCTION

The work on energy estimation and conservation in housing has been predominantly confined to the OEC, as mentioned in Chapter 1. But a few studies have been carried out regarding the energy required for construction. The basic energy values of building materials, i.e., the Embodied Energy Values (EEV) and the Transport Energy Values (TEV), have been estimated and these values have been used to estimate the energy required for making building elements[1] or complete dwellings.

2.2. ESTIMATION OF ENERGY VALUES

Brown et. al. (1974) have stated that the EEV of building materials are obtained through energy accounting or energy budgeting, based on the tenet that for an industrial process, the total energy costs of all inputs are equal to the energy costs of all outputs. They described the three methods used for accounting the EEV of building materials, viz., the Input-Output method, the Statistical Analysis method and the Process Analysis method. Appendix I gives a brief description of these methods. Though all the methods have their own drawbacks, the authors found that the Process Analysis method, in which the complete manufacturing process is thoroughly analysed, is the most suitable to determine the EEV. But they have also stated that different studies had shown a large range of values for some materials, as there were limitations in the information available about the manufacturing processes, particularly in some of the more complex industries. Moreover, it was not always possible to assess how representative the process being analysed is of the whole of the industry concerned. The

[1] Building elements refer to parts of the building like foundation, walling, flooring, roofing etc.

differences in the EEV from various studies was also because the authors had applied different methods of energy analysis.

Wright et. al. (1979) have also stated that these three methods did give varying energy values for building materials. Even the same method might give different EEV for the same material because of the differing processes used to manufacture it. But the remarkable feature, according to Brown et. al., was that there was substantial agreement in many instances. They have presented a comparative list of EEV of building materials obtained from various sources upto 1974. The other relevant data on the EEV after 1974 were presented by Haseltine (1975) and Wright et. al. The earliest figures of the EEV of materials in India were presented by Rai (1983). This data was later updated and compiled as a manual, 'Energy in Building Materials', by the Development Alternatives (DA) for the BMTPC (Building Materials and Technology Promotion Council), Ministry of Urban Affairs and Employment, Government of India, in 1995. The complete list of the EEV, including the Indian data, is presented in Table 2.1. All the values have been reduced to the common unit of MJ/ unit quantity of the material. It is evident from this comparison that there is much similarity in the EEV obtained from different sources. The comparison gains significance due to the fact that nearly all the researchers considered the same components for calculating the EEV, which were the energy needed to:

i. quarry the raw material
ii. transport it to the manufacturing unit
iii. manufacture the building material

But Wright et. al. have also included the TEV, i.e., the energy needed to transport the materials to the site of construction for an average round trip of 100 kms. DA/BMTPC have considered another vital component for the EEV, i.e., the energy required to transport the finished materials from the manufacturing unit to the distribution outlet. Moreover, DA/BMTPC have presented a very detailed analysis in the Energy Directory and evaluated the EEV of the building materials using the Process Analysis technique. The energy contents of materials were computed as functions of scale and technology of their production. For each scale of production, separate figures of energy were given for quarrying, production and transportation, which on addition, gave a single value for the total energy content or EEV of the material.

The analysis showed that the energy component for the production of the materials was about 90-98% of their EEV. The EEV of materials compiled by the DA/BMTPC are as shown in Table 2.1, while Table 2.2 presents a sample calculation for traditional bricks from the Energy Directory. This directory has, therefore, presented the most relevant and comprehensive data on the EEV of building materials in India and these values have been considered in this study. A few EEV, not listed in the directory, have been taken from the earlier work of Rai (1983).

The other important energy value is the TEV, i.e., the energy needed to transport the material to the site of construction. To evaluate the TEV, it is essential to know the energy needed to transport a unit quantity of material over a unit distance. Brown et. al. have listed the energy required by trucks with different tonnages to transport 100 kg of any material for 1 km. A similar list has also been presented by Haseltine and later, in India, by the DA/BMTPC. For the purpose of comparison, these energy figures have been reduced to the unit of MJ/kg/km[1] and the comparative list, presented in Table 2.3, again highlights the similarities between them. The TEV for the present study has been derived from the DA/BMTPC directory.

The researchers, except for Haseltine, have not accounted for the energy needed to place the material on site. All of them (including Haseltine) have also discounted human energy, i.e., the energy required by the construction workers on site. It needs to be mentioned here that in India, the site energy requirement, which is primarily the energy needed by the mechanised

[1] Transport energy has only one common value for all materials

Table 2.1: Embodied Energy Values (EEV) of Various Building Materials from Different Sources

S. No.	Building Material	Unit	Source of Information										
			Brown & Stellon (1968)	Makhijani & Lichtenberg (1972)	Bravord, Flora & Portal (1972)	McKillen (1972)	Hirst (1973)	Wright (1973)	Haseltine (1975)	Chapman (1979)	Wright & Gardiner (1979)	Rai (1983)	DA/BMTPC (1995)
1.	Cement	MJ/kg	7.34	9.14	-	19.11	-	5.69	7.81	8.28	7.25-8.25	8.11	6.70
2.	Steel	MJ/kg	-	50.00	55.15	28.30	26.75	23.76	31.03	47.52	30.0-50.0	26.46	32.00
3.	Bricks	MJ/Brick	10.04	-	-	5.18	-	6.26	8.61	10.80	2.75-4.13	4.29	4.50
4.	Lime	MJ/kg	-	-	-	-	-	-	-	4.68	-	6.34	6.50
5.	Stone Agg.	MJ/kg	-	-	-	-	-	-	0.08	-	0.03-0.30	0.22	0.24
6.	Glass	MJ/sqm	-	286.20	-	748.98	-	-	124.20	259.20	225.0-285.0	267.96	-

Table 2.2: Processwise Energy for Bricks #

Operation Scale	Quarrying (MJ/1000 nos.)	Production (MJ/1000 nos.)	Transportation of Raw Material (MJ/1000 nos.)	Transportation of Finished Material (MJ/1000 nos.)	Total Energy. (MJ/1000 nos.)	EEV (MJ/Brick)	Average EEV (MJ/Brick)
Bull's trench kiln with fixed chimney	-	3672.00	14.98	57.60	3744.58	3.74	4.15*
Bull's trench kiln with moveable chimney on side	-	4314.53	10.37	57.60	4382.50	4.38	
Bull's trench kiln with moveable chimney on roof	-	4959.61	9.83	57.60	5027.04	5.03	

Source: DA/BMTPC, Energy in Building Materials, 1995

* Rounded off to 4.5 MJ/brick in the final EEV given by DA/BMTPC

Table 2.3: Transport Energy Values (TEV) from Different Sources

S. No.	Laden Capacity of Vehicle (Tonnes)	Unit	Source of Information		
			Brown & Stellon (1974)	Haseltine (1975)	DA/BMTPC (1995)
1.	0.00	MJ/tonne/km	-	-	5.76
2.	0.35	MJ/tonne/km	-	12.13	-
3.	0.75	MJ/tonne/km	6.12	10.08	-
4.	1.00	MJ/tonne/km	-	5.36	-
5.	3.00	MJ/tonne/km	-	2.81	-
6.	5.00	MJ/tonne/km	-	-	1.80
7.	7.00	MJ/tonne/km	1.26	1.69	-
8.	7.50	MJ/tonne/km	-	-	1.48
9.	10.00	MJ/tonne/km	-	-	1.15
10.	12.00	MJ/tonne/km	1.08	1.40	-
11.	12.50	MJ/tonne/km	-	-	0.94
12.	15.00	MJ/tonne/km	-	-	0.83
13.	20.00	MJ/tonne/km	0.72	1.12	-
14.	22.00	MJ/tonne/km	-	1.04	-

equipment on site, is significantly low. This is particularly true for housing, where much of the contemporary site work is dependant on manual labour. This is mainly because of the availability of abundant and cheap labour, which is more economical than the mechanised processes. Human energy can also be neglected, as can be seen through a simple illustration. If a worker expends 2500 cal (or 10.5 MJ) of energy per day on the construction site, this would be only equal to the EEV of about two bricks or about 1½ kg of cement. Therefore, the overall contribution of human energy will be insignificant vis-à-vis the EEV of materials consumed in construction.

2.3. ESTIMATION OF ENERGY COSTS

Several authors have also presented the application of energy values of materials for estimating the energy needed to make building elements or complete dwellings.

2.3.1. Energy Cost of Building Elements

Haseltine has computed the energy needed to make unit areas of several building elements. For this, the combined energy value of each building material was computed, i.e., the sum of the EEV, the TEV and the energy required to place the material on site. The TEV in this case was taken for an average carriage distance of 50 kms (with 50 kms for return empty). The on-site energy has been estimated from a typical building, for which the total site energy for heating, lighting, transport, hoisting, mixing, to completion of the structure, has been calculated and proportioned over the weights of materials used in the structure. According to the author, this method was not entirely satisfactory, but was better than that of previous workers, who had only added site energy as a percentage of the total energy required for construction.

The combined energy values of the materials were used to calculate the energy required to make unit amounts of some building elements, like a brick wall, precast concrete panel, RCC slab, steel beam etc. But this data only provided a general impression of how the energy values of different materials compared in building elements. To arrive at a proper comparison for total structures, Haseltine has considered an example of a typical six-storeyed building, employing twelve different layouts of unclad structures. The material quantities for each layout in one storey height of one bay were calculated and their energy costs were then estimated, using the energy values of building materials. No allowance for waste was made, as it was considered to be approximately the same for each case.

A similar energy analysis has been done for eleven elevations of cladding suitable for use with the selected unclad structures. The energy costs of different unclad structures and corresponding appropriate elevations have been then combined to obtain the energy figures for the total structure. Conclusions have been drawn concerning the lowest amount of energy needed to build internal structures, elevations and total structures.

Haseltine's study has been quite comprehensive in its approach. The combined energy values for building materials obtained by Haseltine were also more accurate since their transport energy to the site and the on-site energy were specifically calculated. But, the wastage of materials on-site was neglected, which in actual construction forms a substantial amount. In fact, wastage of materials is accounted for within the analysis of rates of the building materials used in any building project.

Wright et. al. have also obtained the energy required per unit or the energy rates of several building elements from the quantities of the constituent materials and their corresponding energy values. The authors have considered the energy values of each material to be the sum of its EEV and TEV (for an average round trip of 100 kms). These calculations revealed the difficulties in estimating the energy cost of housing construction. A typical example was that of concrete. It was found that various grades of concrete had different energy values as they used different component materials. Therefore, according to the authors, it was incorrect to multiply the total concrete on the site by a mean figure.

In India, Rai (1983) has applied the EEV of materials to compute the energy rates of several types of building elements. However, he did not consider the TEV of the building materials on the assumption that the transport energy values varied from place to place. This assumption is erroneous because transport energy values are dependent on the calorific values of fuel, which are fairly constant. Moreover, they must be calculated to arrive at a conclusion whether they can be neglected or not. Thus, it would have been appropriate to assume an average carriage distance to the site for estimating the transport energy, as has been done by the other authors. DA/BMTPC have also presented data regarding the energy rates of certain building elements, but the TEV has not been considered in these calculations.

All the above studies have been limited to the energy computations and comparison of unit areas of buildings (as done by Haseltine) or building elements. It is possible to estimate the PEC of a complete dwelling by totalling the energy costs of building elements, obtained by multiplying the energy rates of the elements with their respective quantities in the construction. But the material requirements for a construction are not estimated as separate building elements, but as items of work[1] listed under various sub-heads[2] in a detailed building estimate. Therefore, PEC estimation using building elements will first require a database on the energy rates of the elements. Moreover, material requirements will also have to be estimated in terms of elements, which is a cumbersome procedure, having limited practical application for the professionals associated with construction.

2.3.2. Energy Cost of Dwellings

One of the earliest work for estimating the energy cost of a complete dwelling has been done by Brown et. al. They calculated the energy cost for a typical three bedroomed semi-detached house using a skeleton list of quantities of materials required in the construction. Using the quantities and, wherever possible, the corresponding UK EEV for building materials, the total embodied energy cost (EEC_T) for the basic materials required for the construction were obtained.

[1] Items of work are the various items listed under each sub-head, for eg., brick work in 1:6 cement mortar is an item of work under the sub-head of masonry work.
[2] Sub-heads of civil work are earthwork, masonry work, concrete work, RCC work, Flooring and Finishing

They also estimated the total transport energy cost (TEC_T) for the materials from the TEV. The total of EEC_T and the TEC_T gave the PEC. Another 10% of the EEC_T had been added to account for the on site energy expenditure to give the total energy required for constructing the dwelling.

Bricks accounted for nearly 56% of the PEC, making them the highest energy users in the construction. This was an important deduction because it revealed the best predictor of the energy cost in this project. The authors have also deduced that, assuming an arbitrary carriage distance of 185 kms, the TEC_T is only 1-8% of the total energy cost (PEC + on-site energy). In this example, TEC_T was about 8% of the EEC_T and about 7% of the total. It was also evident from their study that the PEC is the major component accounting for 90% of the total energy requirement.

The limitation in their method of energy estimation was that it was based on the list of materials required for the construction. But materials needed for construction are listed as constituents of different items of sub-works in a building estimate. Therefore, an energy estimator will first need to break up the items into the constituent materials and total the quantities of each material to obtain the list of materials required in construction for preparing the energy estimate.

Wright et. al. calculated the energy needed for housing construction, for which they used three different sources of information:

1. Detailed Bills of Quantities (BOQ) or building estimates
2. Working drawings
3. Building studies published in the "Architects' Journal"

In the energy calculations, as in other studies, they omitted standard invariable items, such as internal wiring, plumbing and sanitary ware. The energy used in the construction process on-site was also not included, because it amounted to only about 1% of the PEC[1] (EEC_T + TEC_T) of the two sites where information was obtainable and was considerably less than the margin of variations in the material calculations for the different projects.

According to them, there was a significant difference between their energy figures for flats and those previously obtained by other researchers. The authors, therefore, inferred that the differences in the results were due to the exclusion of many small, but essential items of construction; and secondly, in the underestimation of specific items such as foundation volumes. This means that the energy estimates will be more accurate if the quantities of materials in construction are calculated in detail.

From the analysis, they also obtained relationships between the PEC and the floor areas for the range of blocks studied by them, which included constructions in timber frames, steel frames and precast concrete etc. The Equation between the PEC and the total floor area of a dwelling was:

$$\text{Log PEC} = 0.18 + 1.1 \log a$$

where a = Floor area of the project

They also obtained the best predictors of the PEC. Moreover, they gave some broad indications of the relationship between the development density and the energy requirements of constructed dwellings. In these calculations, some allowance was made for the energy needed for providing infrastructure, which was deduced to be about 20% of the PEC.

The energy calculations carried out by Wright et. al. were based on the BOQ or the building estimates, which form the basis for detailed material calculations for any housing construction. Hence, their approach is more suited for professionals associated with building construction, viz., architects, civil engineers, quantity surveyors and contractors.

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[1] Wright et. al. used the term Total Capital Energy Requirement (CER) instead of the PEC, but both have the same definition and the same components of energy.

Another relevant study on energy estimation of complete dwellings was carried out by Donn et.al. (1983), in which the PEC involved in the building of new houses was investigated alongwith the renovation of existing ones. The purpose of this study was to give an example of a method by which the techniques of energy analysis could be routinely applied to the building process.

The authors estimated the energy cost for a standard single storey timber frame house of the N.Z. Building Industry Advisory Council (BIAC) for a range of common building materials to gauge the effect of differences in materials on the energy needed for construction. The energy cost, which they termed as the Gross Energy Requirement (GER), included the PEC, the on-site energy requirements and the energy of material wastes.

It was inferred that the energy required for housing construction could be about 65% more, simply due to the differences in the basic building materials. The authors concluded that the selection of basic building materials for mass housing could thus have important energy implications.

It was further stated that this analysis could be taken much further if more detailed data on energy values of individual building components was available. Such analysis could help in taking a rational decision about the building materials to be used, which could lower the energy required for housing construction.

The authors concluded by highlighting the significance of the building estimate for building construction stating that, though the principal purpose of this estimate was the control of money, it was possible to use it for a similar analysis in energy terms. Moreover, just as the building estimate could be used to compare options which have varying construction costs, it could also be used to carry out a similar comparison in energy terms. The authors had proposed the formulation of a New Zealand database, which could be readily accessed by the quantity surveyor (or energy planner) to carry out an energy analysis of a building project.

This data would provide the energy values per unit of a material. Thus, the construction cost and the energy cost for a particular amount of material could be simultaneously calculated.

Though no energy estimates for complete dwellings have been prepared by the DA/BMTPC, they mentioned about a similar method as used by Wright et. al. and Donn et. al. for energy estimation of housing construction. According to this method, the detailed estimate for a given building could be used to determine the quantities of materials needed in construction. The quantity of each material could then be multiplied by its EEV to get the energy cost for each material. The summation of all these energy costs would give the estimated EEC_T for constructing the building. They have not discussed about the TEC_T in construction.

According to the authors, such energy estimates would assist the planners/builders to make choices, which reflect material as well as energy usage. It would also be helpful in determining the choice of building materials, based on energy considerations.

2.4. CONCLUDING REMARKS

The studies undertaken by various researchers have highlighted the significance of the energy required in housing construction and also described methods for its estimation. PEC is clearly the major component, accounting for upto 80-90% of the CEC.

In this investigation, similar parameters for calculating the EEV and the TEV of building materials have been adopted. The values obtained by the DA/BMTPC have been adopted for the present work because of their detailed energy analysis for the building materials in India. Though several authors have used the EEV and the TEV to estimate the energy rates of building elements, no study provided the PEC estimate of a complete dwelling using these rates of elements. Moreover, PEC estimation using building elements, though possible, has limited practical application.

PEC could also be estimated by the breakup of materials required in construction, as shown by Brown et. al., but this also cannot be directly adopted for preparing PEC estimates. The most suitable method to estimate the PEC was using the detailed building estimates, as highlighted by Wright et. al., Donn et. al. and DA/BMTPC, as that is the standard format for providing the material requirements in any construction. But, as pointed out by Donn et. al. a database of basic energy values or rates is essential to estimate the PEC from a detailed estimate.

The works of Brown et. al. and Wright et. al. also revealed the best predictors of the energy needed in construction. This is a useful approach because it helps to know that material or part of construction, which needs to be targeted to give maximum energy savings. This is an important objective of the present work, i.e., to find out the major contributor to the PEC and study alternatives for its reduction.

CHAPTER 3

METHODOLOGY

3.1. INTRODUCTION

The literature review revealed that limited research has been done thus far to estimate the energy needed for construction. In India, Rai (1983) and DA/BMTPC (1995) obtained the energy values of building materials and carried out an energy analysis of building components and some items of civil work. But no method has been developed to estimate the energy required for constructing a complete dwelling.

Therefore, a methodology needs to be evolved to estimate the energy cost of housing construction. The methodology proposed is limited to the evaluation of the Primary Energy Cost of civil work (PEC) in housing construction in the composite climatic belt of the Northern Indian plains.

3.2. DEVELOPMENT OF METHODOLOGY

It is essential to know the quantities of various building materials required in a building to estimate its PEC. These quantities can be calculated and listed as individual building materials (Brown et. al., 1974), as building elements (Haseltine, 1975) or as items of work in a building estimate (Wright et. al.). All three approaches have been considered to develop the methodology.

In 1988, Singh et. al. had authored a handbook[1] on building economics, in which they presented statistical relationships to estimate the material requirements of several types of residential units. These relationships were derived by analysing the actual quantities of materials listed in the building estimates or Bills of Quantities (BOQ) of a large number of dwelling units, which were of the following types:

1. Load Bearing Construction
   i. Single storeyed dwelling units
   ii. Double storeyed dwelling units
2. RCC Framed Construction
   i. Four storeyed housing projects

These dwellings had varying plinth areas and layouts, viz., detached, semi-detached or row housing. The specifications of civil work in these units were the ones commonly adopted for housing construction in India. Relationships were then established between each building material and the corresponding plinth area of a dwelling. The relationships for load bearing construction were valid for plinth areas (PA) varying from 30-300 sqm. In case of four storeyed RCC framed construction, they were applicable for PA from 30-100 sqm only.

The formulae for estimating the energy costs of individual building materials have been obtained in the present study by multiplying each relationship listed by Singh et. al. with the Embodied Energy Values (EEV)[2] of the corresponding material, which are listed in Table 3.1. The formulae have been then summed up to obtain the equations for estimating the total embodied energy cost (EEC_T) for each type of construction. The derivation of the formulae and the final equations are shown in Table 3.2.

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[1] Singh, S.P. and Sofat, G.C., Handbook on Building Economics and Productivity, 1988.

[2] EEV consists of the energy needed to:

1. Quarry the raw material
2. Transport the raw material to the manufacturing unit
3. Manufacture the building material
4. Transport, the finished material to the distribution outlet

The EEV values were obtained from the two relevant studies conducted in India, viz, Rai (1983) and DA/BMTPC (1995).

Table 3.1: Embodied Energy Values (EEV) of Building Materials

S.No.	Building Material	Size (Dims in cms)	Unit	Embodied Energy Value (EEV) in MJ/Unit
1.	Traditional Brick	22.9 x 11.4 x 7.6	brick	4.50
2.	Modular Brick	20 x 10 x 10	brick	4.50
3.	Brick Tile	22.9 x 11.4 x 3.81	tile	2.25
4.	Brick Tile	20 x 10 x 5	tile	2.25
5.	Brick Tile	22.9 x 11.4 x 3.18	tile	1.90
6.	Brick Tile	25 x 25 x 2.5	tile	3.50
7.	Clay Flyash Brick	20 x 10 x 10	brick	2.32
8.	Sand Lime Brick	20 x 10 x 10	brick	2.79
9.	Hollow Concrete Block	40 x 20. x 10	block	10.80
10.	Hollow Concrete Block	40 x 20 x 20	block	11.00
11.	Aerated Block	40 x 20 x 20	block	11.50
12.	Solid Concrete Block	30 x 20 x 15	block	10.40
13.	Fal-G. Block	30 x 20 x 15	block	7.90
14.	Cement	-	kg	6.70
15.	Steel	-	kg	32.00
16.	Lime	-	kg	6.50
17.	Surkhi[1]	-	cum	1459.50
18.	Coarse Aggregate	-	cum	538.00
19.	Flyash	-	cum	0.00
20.	Fine Sand	-	cum	0.00
21.	Coarse Sand	-	cum	0.00
22.	Cinder	-	cum	0.00
23.	Stone Dust	-	cum	0.00
24.	Marble Dust	-	cum	0.00
25.	Mud	-	cum	0.00
26.	Sheet Glass	-	sqm	276.96

[1] Surkhi is made from burnt clay bricks by finely grinding them

Table 3.2: Derivation of EEC_T Equations for Residential Buildings from the Breakups of Materials

S.No.	Material	Unit	Single Storeyed Load Bearing Construction		Double Storeyed Load Bearing Construction		Four Storeyed RCC Framed Construction	
			(Relationship)[*] x EEV[#]	Energy Cost Formula	(Relationship) x EEV	Energy Cost Formula	(Relationship) x EEV	Energy Cost Formula
1.	Bricks	nos	(226 A[¥] + 6680) x 4.5	1017 A + 30060	(215 A + 6300) x 4.5	967.5 A + 28350	(-2620 A + 256 A - 0.96 A^2) x 4.5	1152 A - 11790 - 4.32 A^2
2.	Cement	kg	(153 A + 570) x 6.7	1025.1 A + 3819	(145 A + 540) x 6.7	971.5 A + 3618	(182 A - 350) x 6.7	1219.4 A - 2345
3.	Steel	kg	(21.3 A – 314) x 32	681.6 A - 10048	(21.97 A - 305) x 32	703.0 A - 9760	(-1491 + 92.0 A - 0.36 A^2) x 32	2944.0 A - 47712 - 11.52 A^2
4.	Sand (m^3)	cum	-	-	-	-	-	-
5.	Coarse Aggregate 20mm nom. size	cum	(0.176 A - 0.21) x 538	94.7 A – 113	(0.178 A - 0.21) x 538	95.8 A - 113.0	(0.295 A - 0.75) x 538	158.7 A - 403.5
	40mm nom. size	cum	(0.145 A + 1.5) x 538	78.01 A + 807	(0.075 A + 0.78) x 538	40.35 A + 419.6	(0.45 A + 0.0027 A - 0.0001 A^2) x 538	1.45 A + 242.1 - 0.05 A^2
6.	Brick Aggregate		(0.113 A - 0.83) x 2235	252.6 A - 1855.1	(0.056 A - 0.42) x 2235	125.2 A - 938.7	(0.021 A + 0.01) x 2235	47.0 A + 22.35
7.	Lime	kg	(14.5 A - 35) x 6.5	94.25 A - 227.5	(8.3 A - 17) x 6.5	54.0 A - 110.5	(6.3 A - 8) x 6.5	40.95 A - 52
8.	Surkhi		(0.052 A - 0.37) x 1459.5	75.9 A - 540	(0.026 A - 0.18) x 1459.5	38.0 A - 262.7	(0.01 A) x 1459.5	14.6 A
9.	Glass (m^2)		(0.047 A) x 267.96	12.6 A	(0.047 A) x 267.96	12.6 A	(0.047 A) x 267.96	12.6 A
Energy Cost Equations			EEC_T = 3331.76 A + 21902.40		EEC_T = 3008.00 A + 21202.70		EEC_T = 5590.70 A – 62308.05 – 15.89 A^2	

[*] Source: Singh, S.P. and Sofat, G.C., Ed., Handbook on Building Economics and Productivity, Central Building Research Institute, Roorkee, 1988, pp.12.
[#] Refer Table 3.1 for the EEV of building materials.
[¥] A = Plinth area of a dwelling in sqm

The equations are as follows:

1. Load Bearing Construction

   i. For a single storeyed dwelling unit:

   $$\mathbf{EEC_T = 3331.76\ A + 21902.40} \tag{3.1}$$

   where A = PA of the dwelling (30 sqm $\leq$ A $\leq$ 300 sqm)

   ii. For a double storeyed dwelling unit

   $$\mathbf{EEC_T = 3008.00\ A + 21202.70} \tag{3.2}$$

   where 30 sqm $\leq$ A $\leq$ 300 sqm

2. RCC Framed Construction

   i. For a four storeyed housing project

   $$\mathbf{EEC_T = 5590.70\ A - 62038.05 - 15.89\ A^2} \tag{3.3}$$

   where 30 sqm $\leq$ A $\leq$ 100 sqm

Singh and Sofat also carried out an elemental cost analysis of buildings to estimate the material requirements of the various elements[1] of building construction. Here again, the analysis was based on a set of reference specifications for each category of dwelling units. A large number of buildings of different sites and configurations were considered to arrive at a representative data. The types of dwellings considered were:

1. Load Bearing Construction
   i. Double storeyed dwelling units
   ii. Four storeyed dwelling units
2. RCC Framed Construction
   i. Four storeyed dwelling units

[1] The elements were (a) Foundation and plinth (b) Frame (c) Walling (d) Structural floors and slabs (e) Staircase (f) Flooring (g) Roofing and (h) Finishes

The material inputs for each element of the building were computed for a PA of 10 sqm. This data has been used in the present study to obtain the embodied energy required per sqm of each element using the EEV of building materials. Table 3.3 highlights a sample calculation for foundation and plinth for load bearing construction. Thus, the final equations for estimating the EEC_T have been derived, as shown in Table 3.4. They are as follows:

1. Load bearing construction

   i. For a double storeyed dwelling unit

$$\mathbf{EEC_T = 3261.18\ A} \tag{3.4}$$

   ii. For a four storeyed dwelling unit

$$\mathbf{EEC_T = 3059.84\ A} \tag{3.5}$$

2. RCC framed construction

   i. Four Storey dwelling unit

$$\mathbf{EEC_T = 3333.18\ A} \tag{3.6}$$

Both the Eqns. 3.2 and 3.4 are for estimating the EEC_T for double storeyed load bearing construction, but there is a difference in the values obtained from them for a given PA[1]. Similary, Eqns. 3.3 and 3.6, for four storeyed RCC framed construction also give different EEC_T values for a given PA[2]. Moreover, these equations do not account for the energy required for transporting the building materials to the site of construction (TEC_T), which is a component of the PEC. Thus, these equations can not be applied in their present form to estimate the PEC.

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[1] This comparison is further highlighted in Chapter 5
[2] This comparison further discussed in Chapter 6

Table 3.3: Material and Energy Inputs in Foundation and Plinth[1]
(Details for PA of 10 sqm)

S. No.	Material		Load Bearing Double Storeyed Dwellings – Element – Foundation and Plinth – Sub-element: Bed Concrete	Brickwork	DPC	Sub-total of Energy (in MJ)	Load Bearing Four Storeyed Dwellings – Element – Foundation and Plinth – Sub-element: Bed Concrete	Brickwork	DPC	Sub-total of Energy (in MJ)
1.	Cement	Qty.	130 kg	90 kg	10 kg	-	90 kg	80 kg	5 kg	-
		Energy (in MJ)	871.00	603.00	67.00	1541.00	603.00	536.00	33.50	1172.50
2.	Sand	Qty.	0.46 cum	0.39 cum	0.013 cum	-	0.32 cum	0.34 cum	0.007 cum	-
		Energy (in MJ)	-	-	-	-	-	-	-	-
3.	Coarse Aggregate	Qty.	0.87 cum	-	0.03 cum	-	0.61 cum	-	0.013 cum	-
		Energy (in MJ)	468.06	-	16.14	484.20	328.20	-	6.99	335.19
4.	Bricks	Qty.	-	716 nos	-	-	-	627 nos	-	-
		Energy (in MJ)	-	3222.00	-	3222.00	-	2821.50	-	2821.50
			Energy Inputs (MJ/10 sqm)			5247.20	Energy Inputs (MJ/10 sqm)			4329.19
			Energy Inputs (MJ/sqm)			524.72	Energy Inputs (MJ/sqm)			432.92

Table 3.4: Derivation of EEC_T Equations for Residential Buildings from Elemental Cost Analysis

S.No.	Element	Energy Inputs (MJ/sqm of PA) for Elements in: Double Storeyed Load Bearing Construction	Four Storeyed Load Bearing Construction	Four Storeyed RCC Framed Construction
1.	Foundation and Plinth	524.72#	432.92#	309.03
2.	Frame	-	-	917.09
3.	Walling	1513.57	1538.55	734.18
4.	Structural Floor & Slabs	674.68	674.68	39.37
5.	Staircase	39.37	39.37	971.14
6.	Flooring	132.85	132.85	132.85
7.	Roofing	251.32	125.66	176.58
8.	Finishes	124.67	115.81	52.94
Total Energy Input (MJ/sqm of PA)		3261.18	3059.84	3333.18
Energy Cost Equations		$EEC_T = 3261.18\ A$	$EEC_T = 3059.84\ A$	$EEC_T = 3333.18\ A$

Refer Table 3.3

[1] Source: Singh, S.P. and Sofat, G.C., Ed., Handbook on Building Economics and Productivity, Central Building Research Institute, Roorkee, 1988, pp.39-47.

Eqns 3.1 – 3.6 can prove useful for obtaining a preliminary estimate of the PEC for a given dwelling or project, if the TEC_T is introduced in them. But just as a preliminary cost estimate is insufficient and detailed construction cost estimates are needed for a project, similarly a detailed PEC estimate is needed to analyse the energy contributions of the various components of a civil work. This will provide clues for the reduction of the PEC by using alternative building materials.

3.3. ESTIMATION OF PEC

It was necessary to develop a methodology to provide a detailed estimate of the PEC, which could be directly applied to any dwelling/housing project. Moreover, since architects, civil engineers and builders are the professionals chiefly involved with construction, the method developed for PEC estimation has to be comprehensible to them to make it practically applicable. It is also evident that the estimation of PEC would first require the estimation of its components, viz., EEC_T and TEC_T.

3.3.1. Estimation of EEC_T

In India, Rai (1983) and DA/BMTPC(1995) carried out studies to estimate the embodied energy requirement of individual building elements. A similar study was carried out for walling elements of single brick thickness (Chani, et. al., 1997). In this method, the material input per sqm of each walling element was calculated, using nine types of masonry units and three different mortar mixes. The material inputs were then multiplied with their respective EEV to obtain the embodied energy needed per sqm of the walling elements. It was similarly possible to calculate the embodied energy required for the other elements in construction, such as foundation, walling, roofing and flooring etc.

This data could be used to prepare the EEC_T estimate of a project. For this, the estimator would be first required to calculate the area of each element of construction. The areas would then be multiplied with the respective embodied energy rates of elements to get the individual EEC, whose summation would give the EEC_T. The obvious drawback of this method is that it cannot be directly applied to a given project without carrying out the detailed area calculations of its elements. Hence, a more efficient method was required to calculate the EEC_T of a project. An approach that has been tried is to compute the EEC_T using the detailed building estimates of construction, similar to the method applied by Wright et. al. (1979) and Donn et. al. (1983).

All building construction works require detailed estimates to determine their material and labour requirements and the likely cost of construction. They are also helpful in carrying out modifications so that the estimated cost of the project falls within the allocated budget. These estimates generally have three main sections, viz., civil work, sanitation and electrification.

The essential requirements for preparing a <u>detailed estimate of civil work</u> are:

1. Drawings of the building/project
2. Specifications for the items of work
3. Schedule of rates

The estimate of civil work for a project is prepared by computing the quantities of materials required in construction through detailed measurements of the project's drawings. These quantities are listed under various sub-heads[1] as items of work[2]. The cost of each item is then calculated using their construction rates[3] listed in the 'Schedule of Rates' to get the total estimated cost of civil work or the construction cost estimate. The construction professionals are familiar with these estimates. Therefore, it would easier for them to understand about energy cost of construction if it was provided on a similar format as a construction cost

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[1] Sub-heads of civil work are earthwork, masonry work, concrete work, RCC work, Flooring and Finishing.
[2] Items of work are the various items listed under each sub-head, for eg., brick work in 1:6 cement mortar is an item of work under the sub-head of masonry work.
[3] Construction rate of an item of work is the cost per unit quantity of that work.

estimate.

This is possible if the Embodied Energy Rates (EER)[1] for the items of work are known. The individual EEC of the items can be then calculated by simply substituting the construction rates of the items by their corresponding EER. The total of these EEC values then gives the EEC_T. Hence, for a given house/project:

$$\mathbf{EEC_T = EEC_1 + EEC_2 + EEC_3 + EEC_4 + EEC_5}$$

where EEC_1 = EEC for masonry work

EEC_2 = EEC for concrete work

EEC_3 = EEC for RCC work

EEC_4 = EEC for Flooring

EEC_5 = EEC for Finishing

3.3.2. Estimation of TEC_T

The method evolved for estimating the TEC_T is similar to the EEC_T estimation. The Transport Energy Rates (TER)[2] can be used to estimate the Transport Energy Cost (TEC) of the listed items of civil work in the building estimate of any project. The sum of the individual TEC values gives the TEC_T. Therefore, for a given house/project:

$$\mathbf{TEC_T = TEC_1 + TEC_2 + TEC_3 + TEC_4 + TEC_5}$$

where TEC_1 = TEC of masonry work

TEC_2 = TEC of concrete work

TEC_3 = TEC of RCC work

TEC_4 = TEC of Flooring

TEC_5 = TEC of Finishing

[1] Embodied Energy Rate (EER) of an item of work is defined as the embodied energy needed per unit quantity of that work.

[2] Transport Energy Rate (TER) of an item of work is defined as the energy needed to transport a unit of that work to the construction site.

Hence, $\boxed{\mathbf{PEC = EEC_T + TEC_T}}$

3.4. ENERGY RATES

Secs. 3.3.1. and 3.3.2. showed that it was essential to know the EER and the TER of the items of civil work to estimate the EEC_T and the TEC_T and hence, the PEC of a dwelling. The derivation of these rates is shown below.

3.4.1. Embodied Energy Rates (EER)

The EER of the items of work have been derived from the 'Analysis of Rates' of the Central Public Works Department (CPWD). The analysis of rates give the complete breakup of material and labour requirements of the listed items of work. For the present study, only the material breakups have been considered and multiplied by their respective EEV. Since the scope of this research is mainly restricted to the four major building materials, energy calculations have been done for the items of work under the following sub-heads:

1. Mortar Work
2. Masonry work
3. Concrete work
4. Reinforced Cement Concrete (RCC) work
5. Flooring
6. Finishing

The energy values thus obtained are termed as Embodied Energy Rates (EER) of the items of work. Charts 3.1 and 3.2 highlight sample computations of the EER of some common items. The EER of some alternatives to masonry work have also been derived. This was done by first calculating their material breakups, similar to the breakups in the analysis of rates. The alternative masonry units considered in the present work are described in Section B of Appendix-I. The data on the EER of civil work has been compiled and presented in the **'Schedule of Energy Rates'** (Appendix-II).

Embodied Energy Values (EEV)

S.No.	Building Material	Size (Dim. in cm)	Unit	EEV (MJ/Unit)
1.	Traditional brick	22.9x11.4x7.6	nos	4.50[1]
2.	Cement	-	kg	6.70[2]
3.	Fine sand	-	cum	0.00[3]

Embodied Energy Rates (EER)

Item Code No.#	Description of Item of Work	Materials	Unit	Quantity	Energy Value (MJ/Unit)	Energy Value (MJ)	EER (MJ/Unit)
1.22.	Mortar Work Cement mortar 1:6 (1cement: 6 coarse sand) (Details for 1 cum)	Cement	kg	250.00	6.70[2]	1675.00	**1675.00[4] MJ/cum**
		Fine sand	cum	1.07	0.00[3]	0.00	
2.2.15.	Masonry Work 1st class brick work in foundations & plinth in cement mortar 1:6 (1 cement : 6 coarse sand) (Details for 1 cum)	1st class bricks	nos	494	4.50[1]	2223.00	**2641.75 MJ/cum**
		Cement mortar 1:6	cum	0.25	1675.00[4]	418.75	
5.2.	Flooring 1st class brick flooring in cement mortar 1:6 (1 cement: 6 coarse sand) (Details for 10 sqm)	1st class bricks	nos	500	4.50[1]	2250.00	**273.58 MJ/sqm**
		Cement mortar 1:6	cum	0.29	1675.00[4]	485.75	

As listed in the 'Schedule of Energy Rates' (Appendix-II)

Chart 3.1: Sample Derivations of EER for Masonry Work and Flooring

Embodied Energy Values (EEV)

S.No.	Building Material	Size (Dim. In cm)	Unit	EEV (MJ/Unit)
1.	Cement	-	kg	6.70[1]
2.	Coarse/fine sand	-	cum	0.00[2]
3.	Stone (coarse) aggregate	-	cum	538.00[3]

Embodied Energy Rate (EER)

Item Code No.#	Description of Item of Work	Materials	Unit	Quantity	Energy Value (MJ/Unit)	Energy Value (MJ)	EER (MJ/Unit)
3.18.	Concrete Work Providing & laying cement concrete 1:2:4 (1 cement: 2 coarse sand : 4 graded stone agg. 20 mm nom. size) – foundation and plinth (Details for 1cum)	Cement	kg	320.00	6.70[1]	2144.00	2622.82[4] MJ/cum
		Coarse sand	cum	0.47	0.00[2]	0.00	
		Stone agg. (20mm nom.size)	cum	0.89	538.00[3]	478.82	
6.1.18.	Plastering 6 mm cement plaster to ceiling 1:3 (1cement : 3 fine sand) (Details for 10 sqm)	Cement mortar	cum	0.072	(EER of item no. 1.14.) 3417.00	246.02	24.60[5] MJ/sqm
4.2.(c)	RCC Work Providing & laying RCC 1:2:4 (1 cement: 2 coarse sand : 4 graded stone agg. 20 mm nom. size) in lintels, beams etc. incl. finishing and plastering the exposed surface with cement mortar 1:3 (1cement: 3 fine sand) of thickness not exceeding 6mm (Details for 1cum)	Cement concrete	cum	1.00	2622.82[4]	2622.82	2827.74 MJ/cum
		Cement plaster	sqm	8.33	24.60[5]	204.92	

As listed in the 'Schedule of Energy Rates' (Appendix-II)

Chart 3.2: Sample Derivations of EER for Concrete Work, Plastering and RCC Work

The alternative masonry units are:

- Clay flyash bricks (20cm X 10cm X 10cm)
- Sand lime bricks (20cm X 10cm X 10cm)
- Hollow concrete blocks (40cm X 20cm X10cm)
- Hollow concrete blocks (40cm X 20cm X 20cm)
- Aerated concrete blocks (40cm X 20cm X 20cm)
- Solid concrete blocks (30cm X 20cm X 15cm)
- Fal-G Blocks (30cm X 20cm X 15cm)

Chart 3.3 presents sample derivations of the EER for masonry work using alternate units.

3.4.2. Transport Energy Rates (TER)

DA/BMTPC (1995) have presented data for the transport energy required by trucks of varying capacities to transport 1 tonne (t) of material over a distance of 1 km. This data has been used to compute the average energy needed to transport 1 kg of material to the site of construction, as shown in Table 3.5. Trucks of 10 t, 12.5 t and 15 t capacities have been considered and the energy needed by the fully laden trucks to transport materials over a km has been calculated from the DA/BMTPC data. The transport energy needed by an empty (0 t) truck for 1 km has also been computed. A round trip of 50 kms to the site has been assumed (25 km laden and 25 km unladen) and the energy required by the trucks for this trip has been calculated.

Thus, the energy required to transport 1 kg of building material to the construction site and the average value, i.e., the Transport Energy Value (TEV) of building materials has been obtained, as shown in Table 3.5. The Transport Energy Rates (TER) of the various items of work have been obtained by multiplying the TEV with their corresponding unit weights. The data on the TER of civil work is also presented in the **'Schedule of Energy Rates'** (Appendix-II).

Embodied Energy Values (EEV)

S.No.	Building Material	Size (Dim. in cm)	Unit	EEV (MJ/Unit)
1.	Hollow concrete block	40x20x20	nos	11.00[1]
2.	Fal-G block	30x20x15	nos	7.90[2]
3.	Cement	-	kg	6.70[3]
3.	Fine sand	-	cum	0.00[4]

Embodied Energy Rates (EER)

Item Code No.#	Description of Item of Work	Materials	Unit	Quantity	Energy Value (MJ/Unit)	Energy Value (MJ)	EER (MJ/Unit)
1.22.	Mortar Work Cement mortar 1:6 (1cement: 6 coarse sand) (Details for 1 cum)	Cement	kg	250.00	6.70[2]	1675.00	1675.00[5] MJ/cum
		Fine sand	cum	1.07	0.00[3]	0.00	
2.3.57.	Masonry Work Hollow block masonry work in foundation and plinth in 1:6 cement mortar (1 cement : 6 fine sand) (Details for 1 cum)	Hollow blocks (40cm x 20cm x 20cm)	nos	63	11.00[1]	693.00	969.38 MJ/cum
		Cement mortar 1:6	cum	0.165	1675.00[5]	276.38	
2.3.98.	Masonry Work Fal-G block masonry work in foundation and plinth in 1:6 cement mortar (1 cement : 6 fine sand) (Details for 1 cum)	Fal-G blocks (30cm x 20cm x 15cm)	nos	112	7.90[2]	884.80	1219.80 MJ/cum
		Cement mortar 1:6	cum	0.20	1675.00[5]	335.00	

As listed in the 'Schedule of Energy Rates' (Appendix-II)

Chart 3.3: Sample Derivations of EER for Masonry Work with Alternate Units

Table 3.5: Computation of Transport Energy Value (TEV)*

S. No.	Truck Tonnage (in t)	Transport Energy Required (in MJ/tonne/km)	Transport Energy Required by Fully Laden Truck (in MJ/km)	Transport Energy Required for Round Trip of 50 kms (25 kms laden + 25 kms unladen) (in MJ/trip)	Transport Energy Required (in MJ/kg/trip)	TEV (in MJ/kg/trip)
1.	0.0	5.76	5.76	144.00 + 144.00 = 288.00	-	
2.	10.0	1.152	11.52	288.00[#] + 144.00[$] = 420.75	0.043[¶]	0.036[¥]
3.	12.5	0.936	11.70	292.50 + 144.00 = 436.50	0.035	
4.	15.0	0.828	12.42	310.50 + 144.00 = 454.50	0.030	

[#] 11.52 x 25 = 288.0 MJ
[$] Transport energy for unladen truck
[¶] 420.75/10000 = 0.043 MJ/kg/trip
[¥] Average Value

3.5. APPLICATION OF THE SCHEDULE OF ENERGY RATES

Table 3.6 presents a sample sheet highlighting the application of the `Schedule of Energy Rates' for calculating the EEC_T of a given dwelling or project. As shown in the table, an EEC_T estimate is prepared from a detailed estimate by first substituting the construction rates (Rs/unit) of the items of civil work with their corresponding EER (MJ/unit). This provides the EEC of the individual items, which are then summed up to give the EEC_T estimate of the dwelling unit or project.

Similarly, the TER values are used to estimate the TEC of the listed items of civil work in the building estimate of any project. The TEC_T is estimated by totalling all the TEC values. Table 3.7 presents a sample sheet to highlight the use of the `Schedule of Energy Rates' to calculate the TEC_T for a given project. The summation of the EEC_T and TEC_T gives the PEC estimate of the project. Chart 3.4 sums up the methodology for computing the PEC from the basic energy values.

* Data source – 'Energy in Building Materials', DA/BMTPC Report, 1995.

Table 3.6: Sample Sheet Showing the Application of EER to Estimate the EEC_T

Table III.1.1: EEC_T Estimate for Project No. 1 - Dwelling Unit with One Room and a Front Verandah
(Plinth Area = 28.32 sqm; Floor Area = 23.64 sqm)

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
	MASONRY WORK					
1.	1st class brick work in foundation and plinth in cement mortar 1:6 (1 cement: 6 fine sand)	cum	7.05	2641.75	18624.34	2.2.11.
2.	1st class brick work in superstructure in cement mortar 1:6 (1 cement: 6 fine sand)	cum	16.07	2641.75	42452.92	2.2.11. + 2.2.17.
	EEC for Masonry Work (EEC_1)				61077.26	
	FINISHING					
8.	12 mm plastering in walls 1:6 (1 cement: 6 fine sand)	sqm	151.54	24.12	3655.15	6.1.9.
9.	20 mm cement plaster in steps with cement mortar 1:3 (1 cement : 3 coarse sand), finished with neat cement	sqm	2.37	91.28	216.33	6.1.26.
10.	White washing (3 coats) - inside	sqm	93.47	1.95	182.27	6.3.1.
11.	Colour washing (one coat) over one coat of white washing - outside	sqm	77.09	1.95	150.33	6.3.3.
	EEC for Finishing (EEC_5)				4204.08	
	$EEC_T = EEC_1 + EEC_2 + EEC_3 + EEC_4 + EEC_5$				108552.33 MJ	

Table 3.7: Sample Sheet Showing the Application of TER to Estimate the TEC_T

Table III.2.1: TEC_T Estimate for Project No. 1

S.No.	Item of Work	Unit	Quantity	TER in MJ/Unit	TEC in MJ	Schedule of TER Item Code No.
1.	Brick Masonry Work	cum	23.12	69.12	1598.05	7.1.1.(a)
	TEC for Masonry Work (TEC_1)				**1598.05**	
2.	Concrete Work					
	(a) Concrete work					
	– with stone agg.	cum	4.56	80.64	367.72	7.2.1.
	– with brick agg.	cum	1.96	66.24	129.83	7.2.2.
	(b) DPC (25 mm thick)	sqm	5.92	2.02	11.96	7.2.3.(a)
	TEC for Concrete Work (TEC_2)				**509.51**	
3.	Finishing					
	(a) Plastering					
	– 12 mm thick	sqm	151.54	0.90	136.39	7.5.1.(c)
	– 20 mm thick	sqm	2.37	1.49	3.53	7.5.1.(f)
	(b) White washing and colour washing	sqm	170.56	0.01	1.71	7.5.3.
	TEC for Finishing (TEC_5)				**141.63**	
	$TEC_T = TEC_1 + TEC_2 + TEC_3 + TEC_4 + TEC_5$				**2741.22 MJ**	

Embodied Energy Value **EEV**	The energy embodied in the building material; EEV includes the energy needed to: 1. Quarry the raw material 2. Transport the raw material to the manufacturing unit 3. Manufacture the building material 4. Transport the finished building material to the distribution outlet	**Transport Energy Value** **TEV**	The energy required to transport 1 kg of material for a round trip of 50 kms (includes energy needed for 25 kms laden and 25 kms unladen)
Embodied Energy Rate **EER**	The embodied energy needed per unit quantity of an item of civil work, obtained by applying the EEV values to the materials breakup of the item, as given in the 'CPWD Analysis of Rates'	**Transport Energy Rate** **TER**	The transport energy needed per unit quantity of an item of work, computed by multiplying the TEV with the unit weight of the item
Embodied Energy Cost **EEC**	The embodied energy value of an item of work listed in the detailed building estimate or BOQ of a project, obtained by multiplying the EER of that item with its given quantity	**Transport Energy Cost** **TEC**	The transport energy value of an item of work listed in the detailed building estimate or BOQ of a project, obtained by multiplying the TER of the item with its given quantity
Total Embodied Energy Cost **EEC_T**	Sum of the EEC values of all the items of civil work listed in the detailed building estimate or BOQ of a project	**Total Transport Energy Cost** **TEC_T**	Sum of the TEC values of all the items of civil work listed in the detailed building estimate or BOQ of a project

Primary Energy Cost of Civil Work

$$PEC = EEC_T + TEC_T$$

Chart 3.4: Computation of the PEC from the Basic Energy Values

3.6. ANALYSIS OF THE PEC

The methodology for estimating the PEC was proposed to be applied to sixteen case studies ranging from single and double storeyed dwellings to four storeyed housing projects. The PEC estimates will be helpful in understanding the energy contribution of each sub-head of civil work for a dwelling/project. The investigation is expected to reveal the sub-head that has to be targeted to achieve the maximum saving in the PEC. Moreover, the PEC values will be used to derive the energy rates of civil work for the case studies. The energy rates will be classified as Plinth Area (PA) energy rates and Floor Area (FA) energy rates. The rates are similar to the construction rates.

The PEC values of the units in each category are proposed to be plotted against their respective PA and FA to obtain trendlines. Both linear and quadratic trendlines will be plotted and Equations obtained by regression analysis. These Equations shall be useful for providing preliminary estimates of the PEC.

CHAPTER 4

ESTIMATION OF ENERGY COSTS FOR SINGLE STOREYED DWELLING UNITS

4.1. INTRODUCTION

The methodology described in Chapter 3 has been first applied to estimate the energy costs of civil work for selected single storeyed dwelling units. The energy rates have been obtained from the estimates. The rates have been analysed through their respective breakups under the various sub-heads of civil work. Equations to provide preliminary estimates of the PEC for single storeyed units have been also obtained and are presented at the end of the chapter.

The selected units are listed as Project Nos. 1-10 in Table 4.1. Project Nos. 1-6 had PA[1] upto 95 sqm and the corresponding FA[2] upto 80 sqm. Project Nos. 7-10 had PA between 120-170 sqm and the corresponding FA ranging from 28.0-170.0 sqm. The floor plans of the units are presented in Appendix-III (Figs. III.1-III.10). All the selected single storeyed units had load bearing masonry construction. The items of their civil work are the ones most commonly used for housing construction in the North Indian plains. Some typical items are listed in Table 4.2.

Detailed estimates for the EEC_T and TEC_T have been prepared for each project using their respective BOQ and are presented in Appendix-III (Tables III.1.1-III.1.10 and III.2.1-III.2.10).

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[1] PA – Plinth area of the unit
[2] FA – Floor area of the units

Table 4.1: List of Single Storeyed Dwelling Units

Project No.	Description	PA (sqm)	FA (sqm)
1	Dwelling Unit with One Room and a Front Verandah	28.32	23.64
2	Dwelling Unit with One Room, a Bathroom and a Front Verandah	45.54	36.35
3	Dwelling Unit with Two Rooms and a Front Verandah	61.32	52.68
4	Staff Residence, Navodaya Vidyalaya – a Block of Two Units	69.40	54.96
5	Principal's Residence , Navodaya Vidyalaya	90.20	73.13
6	Dwelling Unit with Three Rooms	93.72	78.66
7	Residence of O.N.Vidyarathi at II Phase Development, BHEL Yojna, Ranipur, Hardwar	120.49	104.48
8	Residence for Shri R.K. Bansal at Plot No. K-112, II Phase Development, BHEL Yojna, Ranipur, Hardwar	126.13	104.68
9	Single Storeyed Residence	159.44	132.63
10	Residence of Y.P. Sharma at Plot No. J-25, II Phase Development, BHEL Yojna, Ranipur, Hardwar	169.38	143.60

Table 4.2: Common Items of Civil Work in Northern India

S.No.	Sub-work	Item of Work
1.	Masonry Work	1st class brick work in cement mortar 1:6 (1 cement: 6 fine sand) (a) in foundation and plinth (b) in superstructure
		Half brick masonry (1st class) in foundation and plinth in cement mortar 1:4 (1 cement : 4 coarse sand)
		Half brick masonry (1st class) in foundation and plinth in cement mortar 1:3 (1 cement : 3 coarse sand) with hoop iron 25 mm x 1.6 mm or equivalent reinforcement at every 3rd course, embedded in the cement mortar
2.	Concrete Work	Cement concrete in foundation in the proportion 1:5:10 (1 cement: 5 coarse sand: 10 graded stone agg. 40 mm nom. size)
		Concrete in roof terracing with 25 mm gauge brick ballast, white lime and surkhi in the proportion of 100:18:36
		25 mm damp proof course DPC with cement concrete 1:2:4 (1 cement: 2 coarse sand: 4 stone agg. 10 mm nom. size)
		Making plinth protection 50 mm thick of cement concrete 1:3:6 (1 cement: 3 coarse sand: 6 graded stone agg. 20 mm nom. size) over 75 mm bed of dry grick ballast 40 mm nom. size, well rammed, consolidated and grouted with fine sand include. finishing the top smooth
3.	RCC Work	RCC work 1:2:4 (1 cement : 2 coarse sand: 4 graded stone agg. 20 mm nom. size) excl. reinforcement but incl. finishing and plastering the exposed surface with cement mortar 1:3 (1 cement: 3 fine sand) of thickness not exceeding 6 mm to give a smooth and even surface (a) Roof slab (b) Lintels
4.	Flooring	Cement concrete flooring 1:2:4 (1cement : 2 coarse sand : 4 graded stone agg. 20 mm nom. size) finished with a floating coat of neat cement (a) 40 mm thick (b) 50 mm thick (c) 75 mm thick
		Cement plaster skirting (up to 30 cm height) with cement mortar 1:3 (1 cement: 3 coarse sand) finished with a floating coat of neat cement, incl. rounding of junctions with floor (a) 18 mm thick (b) 21 mm thick
		40 mm thick marble chips flooring rubbed and polished to granolithic finish - under layer 31 mm thick cement concrete 1:2:4 (1 cement :2 coarse sand : 4 graded stone agg. 12.5 mm nom. size) and top layer 9 mm thick with white or black or white and black marble chips of size 4-7 mm nom. size laid in cement marble powder mix [3:1 (3 cement :1 marble powder) by wt.] in proportion of 4:7 (4 cement marble powder mix: 7 marble chips) by volume
5.	Plastering	12 mm cement plaster 1:6 (1 cement : 6 fine sand)
		6 mm cement plaster to ceiling 1:3 (1 cement : 3 fine sand)
		White washing with lime on new work (three or more coats) to give an even shade

4.2. BREAKUP OF ENERGY COST

Energy shares of the sub-works are analysed through the breakups of the energy costs. Breakups of the EEC_T and TEC_T, obtained from the detailed energy estimates, are presented in Tables 4.3 and 4.4. The breakups of the PEC ($EEC_T + TEC_T$) are shown in Table 4.5 (also refer Fig. 4.1). Table 4.6 shows the ranges of the percentage energy shares of sub-works in the EEC_T, TEC_T and PEC respectively (obtained from Tables 4.3, 4.4 and 4.5).

4.2.1. Analysis

The breakups clearly show that masonry work is the single largest contributor to the EEC_T and TEC_T and consequently, in the PEC also. Similarly, RCC work is the second largest contributor followed by concrete work, finishing and flooring in that order. The combined share of masonry and RCC work is about 78-82% in the PEC. The percentage breakup of the PEC also reveals that it is the same as the breakup for the EEC_T. This means that the TEC has a negligible impact on the breakup of the PEC. It can, therefore, be deduced that the average value of the TEC_T is 2.53% of the EEC_T (Table 4.4).

$\therefore$ As $PEC = EEC_T + TEC_T$

Or $\mathbf{PEC = 1.0253\ EEC_T}$ (4.1)

The masonry work has such a high energy cost because of the presence of traditional burnt clay bricks. Table 4.7 presents the quantity and the resultant energy costs of bricks for Project Nos. 1-10. This shows that bricks alone contribute about 43-52% to the PEC and have a share of about 84-85% in the total energy cost (EEC_1+TEC_1) of masonry work.

Similarly, the presence of steel increases the energy cost of RCC work substantially. Table 4.8 presents the quantity of steel required in each unit and its total energy cost. It is seen that steel makes a contribution of about 8.5-15.5% to the PEC. It is also the major energy component in RCC work, contributing about 47-56% to its total energy cost (EEC_3+TEC_3).

Thus, bricks and steel alone have an average share of about 60% in the PEC.

Table 4.3: Breakup of EEC_T for Single Storeyed Dwelling Units

Project No.		Breakup of EEC_T (MJ)					EEC_T (MJ)
		Masonry Work (EEC_1)	Concrete Work (EEC_2)	RCC Work (EEC_3)	Flooring (EEC_4)	Finishing (EEC_5)	
1	EEC	61077.26	14200.11	27114.46	1956.42	4204.08	108552.33
	%	56.27	13.08	24.98	1.80	3.87	100.00
2	EEC	105326.58	26033.74	31578.82	4447.22	7099.41	174485.77
	%	60.36	14.92	18.10	2.55	4.07	100.00
3	EEC	138480.54	39417.93	56679.19	6305.23	8039.33	248922.22
	%	55.63	15.84	22.77	2.53	3.23	100.00
4	EEC	142066.43	25769.68	64712.68	7914.31	12096.96	252560.06
	%	56.25	10.21	25.62	3.13	4.79	100.0
5	EEC	160608.61	31690.93	93829.00	14385.66	14487.76	315001.96
	%	50.99	10.06	29.78	4.57	4.60	100.00
6	EEC	228326.44	43332.14	71127.29	9708.94	13733.93	366228.74
	%	62.35	11.83	19.42	2.65	3.75	100.00
7	EEC	337671.64	82517.83	153909.46	20660.87	22208.98	616968.78
	%	54.73	13.37	24.95	3.35	3.60	100.00
8	EEC	328785.93	81987.75	147169.58	23659.83	20420.51	602023.60
	%	54.61	13.62	24.45	3.93	3.39	100.00
9	EEC	362911.82	80545.95	124406.77	22698.33	24057.18	614620.05
	%	59.05	13.11	20.24	3.69	3.91	100.00
10	EEC	371958.03	103597.73	171577.09	31043.05	26336.18	704512.08
	%	52.80	14.70	24.35	4.41	3.74	100.00

Table 4.4: Breakup of TEC_T for Single Storeyed Dwelling Units

Project No.		Breakup of TEC_T (MJ)					TEC_T (MJ)	TEC_T as % of EEC_T
		Masonry Work (TEC_1)	Concrete Work (TEC_2)	RCC Work (TEC_3)	Flooring (TEC_4)	Finishing (TEC_5)		
1	TEC	1598.05	509.51	442.80	49.23	141.63	2741.22	-
	%	58.30	18.59	16.15	1.79	5.17	100.00	2.53
2	TEC	2755.81	810.10	518.40	120.23	242.59	4447.13	-
	%	61.97	18.22	11.66	2.70	5.45	100.00	2.55
3	TEC	3623.27	1255.20	915.30	170.12	267.63	6231.52	-
	%	58.14	20.14	14.69	2.73	4.30	100.00	2.50
4	TEC	3729.72	1080.34	1026.00	202.37	409.32	6447.75	-
	%	57.84	16.76	15.91	3.14	6.35	100.00	2.55
5	TEC	4202.50	1376.05	1395.00	357.67	489.65	7820.87	-
	%	53.73	17.60	17.84	4.57	6.26	100.00	2.48
6	TEC	5974.04	1589.12	1167.30	288.43	480.75	9499.64	-
	%	62.89	16.73	12.29	3.03	5.06	100.00	2.59
7	TEC	8711.89	3498.89	1933.20	517.73	768.29	15430.00	-
	%	56.46	22.67	12.53	3.36	4.98	100.00	2.50
8	TEC	8502.45	3536.35	1857.60	606.05	706.06	15208.51	-
	%	55.91	23.25	12.21	3.99	4.64	100.00	2.53
9	TEC	9397.56	3043.04	2040.30	523.53	813.07	15817.50	-
	%	59.41	19.24	12.90	3.31	5.14	100.00	2.57
10	TEC	9609.75	4085.71	2165.40	791.44	919.29	17571.59	-
	%	54.69	23.25	12.32	4.51	5.23	100.00	2.49

Table 4.5: Breakup of PEC for Single Storeyed Dwelling Units

Project No.		Breakup of PEC (MJ)					Total PEC = $EEC_T + TEC_T$ (MJ)
		$(EEC_1 + TEC_1)$ for Masonry Work	$(EEC_2 + TEC_2)$ for Concrete Work	$(EEC_3 + TEC_3)$ for RCC Work	$(EEC_4 + TEC_4)$ for Flooring	$(EEC_5 + TEC_5)$ for Finishing	
1	EEC + TEC	62675.31	14709.62	27557.26	2005.65	4345.71	**111293.55**
	%	**56.32**	**13.22**	**24.76**	**1.80**	**3.90**	100.00
2	EEC + TEC	108082.39	26843.84	32097.22	4567.45	7342.00	178932.90
	%	**60.40**	**15.00**	**17.94**	**2.55**	4.11	100.00
3	EEC + TEC	142103.81	40673.13	57594.49	6475.35	8306.96	255253.74
	%	**55.69**	**15.94**	**22.57**	**2.54**	**3.26**	100.00
4	EEC + TEC	145796.15	26850.02	65738.68	8116.68	12506.28	259007.81
	%	**56.29**	**10.37**	25.38	**3.13**	4.83	100.00
5	EEC + TEC	164811.11	33066.98	95224.00	14743.33	14977.41	322822.83
	%	51.05	10.24	**29.50**	4.57	4.64	100.00
6	EEC + TEC	234300.48	44921.26	72294.59	9997.37	14214.68	375728.38
	%	62.36	11.96	**19.24**	**2.66**	**3.78**	**100.00**
7	EEC + TEC	346383.53	86016.72	155842.66	21178.60	22977.27	**632398.78**
	%	54.77	13.60	24.65	3.35	3.63	100.00
8	EEC + TEC	337288.38	85524.10	149027.18	24265.88	21126.57	617232.11
	%	54.65	13.86	24.14	3.93	3.42	100.00
9	EEC + TEC	372309.38	83588.99	126447.07	23221.86	24870.25	**630437.55**
	%	59.06	13.26	**20.06**	**3.68**	**3.94**	100.00
10	EEC + TEC	381567.78	107683.44	173742.49	31834.49	27255.47	722083.67
	%	52.84	**14.91**	24.06	**4.41**	**3.78**	**100.00**

Table 4.6: Percentage Shares of Sub-works in the EEC_T, TEC_T and PEC for Single Storeyed Dwelling Units

Project Nos.	Breakup of the EEC_T				
	EEC_1	EEC_2	EEC_3	EEC_4	EEC_5
1 - 10	51 - 62%	10 - 16%	18 - 30%	2 - 4.5%	3 - 5%
	Breakup of the TEC_T				
	TEC_1	TEC_2	TEC_3	TEC_4	TEC_5
	54 - 63%	16.75 - 23%	11.5 - 18%	1.75 - 4.5%	4.25 - 6.5%
	Breakup of the PEC				
	$EEC_1 + TEC_1$	$EEC_2 + TEC_2$	$EEC_3 + TEC_3$	$EEC_4 + TEC_4$	$EEC_5 + TEC_5$
	51-62%	10-16%	18-30%	2-4.5%	3-5%

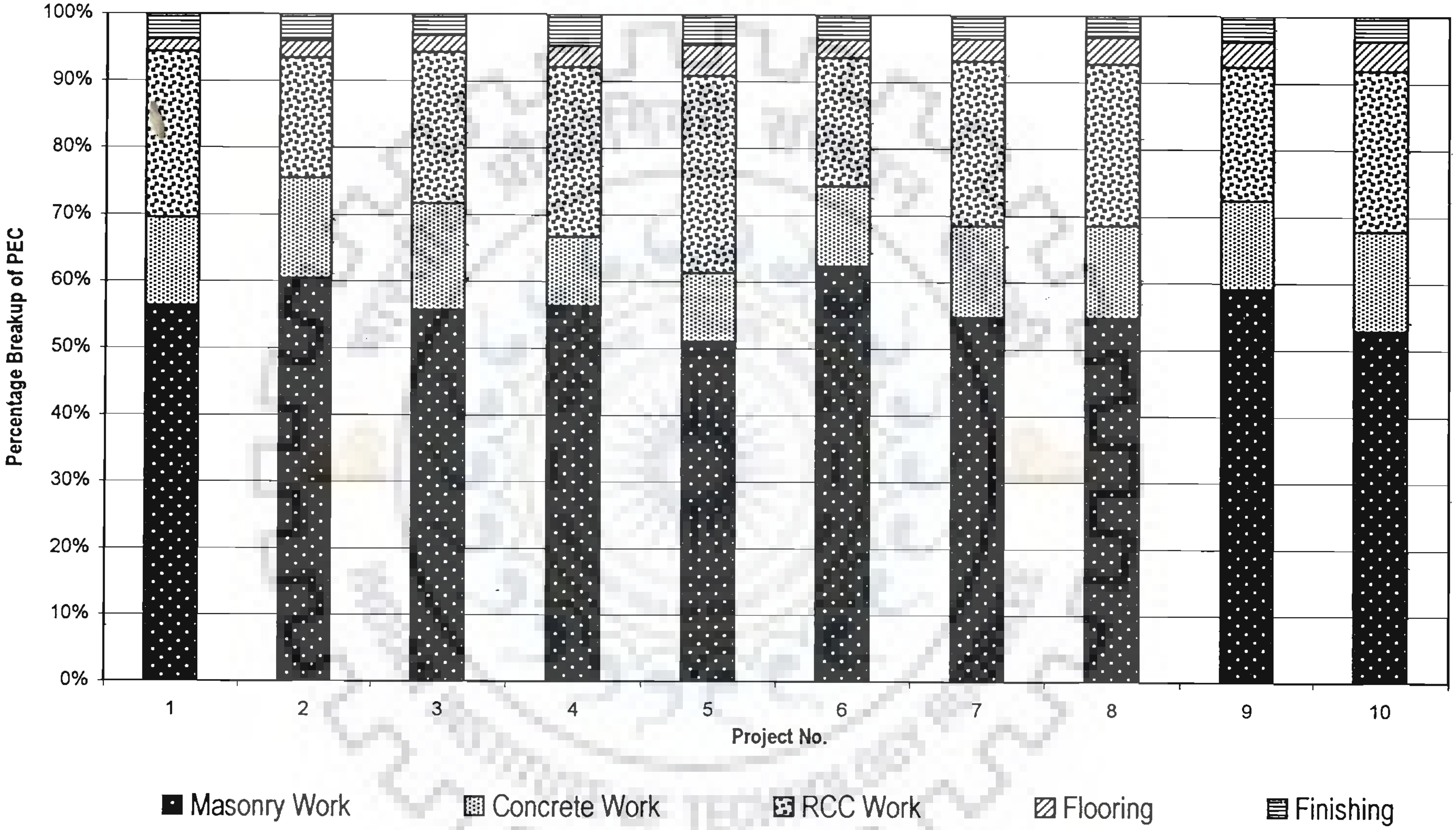

Fig. 4.1 : Breakup of PEC for Single Storeyed Dwelling Units

Table 4.7: Energy Costs of Bricks vis-à-vis Masonry Work and Total Civil Work for Single Storeyed Dwelling Units

Project No.	Qty. of Bricks (nos.)	Energy Cost of Bricks		
		(EEC# +TEC$) (MJ)	% of (EEC_1+TEC_1)	% of the PEC
1	11422	52529.78	83.81	47.20
2	19696	90581.90	83.81	50.62
3	25896	119095.70	83.81	46.68
4	26625	122448.38	83.99	47.28
5	30115	138498.89	84.03	42.90
6	42697	196363.50	83.81	52.26
7	63045	289943.96	83.71	45.85
8	61402	282387.80	83.72	45.75
9	69170	318112.83	85.44	50.46
10	69457	319432.74	83.72	44.24

EEV for bricks = 4.5 MJ/brick
Hence, EEC for bricks = (qty. of bricks x 4.5) MJ

$ TEV for one brick = wt. of brick x 0.036 MJ/kg
= 2.75 x 0.036 = 0.099 MJ
Hence, TEC for bricks = (qty. of bricks x 0.099) MJ

Table 4.8: Energy Costs of Steel vis-à-vis RCC Work and Total Civil Work for Single Storeyed Dwelling Units

Project No.	Qty. of Steel (X 10^2 kg)	Energy Cost of Steel		
		(EEC# +TEC$) (MJ)	% of (EEC_1+TEC_1)	% of the PEC
1	3.89	13084.40#	47.48	11.76
2	4.52	15203.47	47.37	8.50
3	8.10	27245.16	47.31	10.68
4	9.55	32122.38	48.86	12.40
5	14.75	49613.10	52.10	15.37
6	10.18	34241.45	47.36	9.11
7	26.02	87520.87	56.16	13.84
8	24.88	83686.37	56.16	13.56
9	17.80	59872.08	47.35	9.50
10	28.91	97241.68	55.97	13.47

EEV for steel = 3360.00 MJ/ 10^2 kg
Hence, EEC for steel = (qty. of steel x 3360.00) MJ
$ TEV for steel = 0.036 MJ/kg or 3.6 MJ/ 10^2 kg
Hence, TEC for steel = (qty. of steel x 3.6) MJ

4.3. ENERGY RATES

Energy estimates of the single storeyed projects have also provided the energy rates of civil work. Both PA and FA energy rates have been computed for each project, as described in Chapter 3. These rates are presented in Table 4.9. The individual contributions of the sub-works to the energy rates are presented in Table 4.10. The range of the energy rates is as follows:

1. For Project Nos. 1-6 having PA upto 95 sqm and corresponding FA upto 80 sqm:
   (a) PA energy rates = 3580 - 4160 MJ/sqm
   (b) FA energy rates = 4415 - 4920 MJ/sqm
2. For Project Nos. 7-10 having PA between 120-170 sqm and corresponding FA between 100-150 sqm:
   (a) PA energy rates = 3955 - 5250 MJ/sqm
   (b) FA energy rates = 4755 - 6055 MJ/sqm

4.3.1. Analysis

An increase of 375-1090 MJ/sqm (10.5-26%) is observed in the range of PA energy rates for Project Nos. 7-10 vis-à-vis Project Nos. 1-6. The corresponding increase in the range of FA energy rates is in the range of 340-1135 MJ/sqm (7.5-23%). Moreover, there is a rise in the individual energy rates of all the sub-works in Project Nos. 7-10 as compared to 1-6 (refer Table 4.10).

The energy rates for Project Nos. 7-10 are higher because of the additional elements of work present in them, viz., the boundary wall, alongwith the open to sky paved area and the stair well. The energy estimates of these elements has been carried out separately. Sample estimates of these elements are shown for Project No. 9 in Tables III.1.9 (a) & (b)[1] and Tables III.2.9 (a) & (b)[2] in Appendix-III.

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[1] EEC_T estimates of the elements
[2] TEC_T estimates of the elements

Table 4.9: Energy Rates for Single Storeyed Dwelling Units

Project No.	PA (sqm)	FA (sqm)	PEC = $EEC_T + TEC_T$ (MJ)	PA Energy Rate (MJ/sqm)	FA Energy Rate (MJ/sqm)
1	28.32	23.64	111293.55	**3929.86**	**4707.85**
2	45.54	36.35	178932.90	**3929.14**	**4922.50**
3	61.32	52.68	255153.74	**4161.02**	**4843.47**
4	69.40	54.96	259007.81	**3732.10**	**4712.66**
5	90.20	73.13	322822.83	**3578.97**	**4414.37**
6	93.72	78.66	375728.38	**4009.05**	**4776.61**
7	120.49	104.48	632398.78	**5248.56**	**6052.82**
8	126.13	104.68	617232.11	**4893.62**	**5896.37**
9	159.44	132.63	630437.55	**3954.07**	**4753.36**
10	169.38	143.60	722083.67	**4263.10**	**5028.44**

Table 4.10: Shares of Sub-works in Energy Rates for Single Storeyed Dwelling Units

Project No.	Share (MJ/sqm)						Total Energy Rate (MJ/sqm)
		Masonry Work	Concrete Work	RCC Work	Flooring	Finishing	
1	**PA**	2213.11	519.41	973.07	70.82	153.45	**3929.86**
	FA	2651.24	622.23	1165.71	84.84	183.83	**4707.85**
2	**PA**	2373.35	589.46	704.81	100.30	161.22	**3929.14**
	FA	2973.38	738.48	883.01	125.65	201.98	**4922.50**
3	**PA**	2317.41	663.29	939.25	105.60	135.47	**4161.02**
	FA	2679.49	772.08	1093.29	122.92	157.69	**4843.47**
4	**PA**	2100.81	386.89	947.24	116.96	180.21	**3732.10**
	FA	2652.77	488.54	1196.12	147.68	227.55	**4712.66**
5	**PA**	1827.17	366.60	1055.70	163.45	166.05	**3578.97**
	FA	2253.67	452.17	1302.12	201.60	204.81	**4414.37**
6	**PA**	2500.01	479.31	771.39	106.67	151.67	**4009.05**
	FA	2978.65	571.08	919.08	127.10	180.71	**4776.61**
7	**PA**	2874.79	713.89	1293.41	175.77	190.70	**5248.56**
	FA	3315.31	823.28	1491.60	202.71	219.92	**6052.82**
8	**PA**	2674.13	678.06	1181.54	192.39	167.50	**4893.62**
	FA	3222.09	817.01	1423.65	231.81	201.82	**5896.37**
9	**PA**	2335.11	524.27	793.07	145.65	155.99	**3954.07**
	FA	2807.1	630.24	953.38	175.09	187.52	**4753.36**
10	**PA**	2252.73	635.75	1025.76	187.95	160.91	**4263.10**
	FA	2657.16	749.88	1209.91	221.69	189.80	**5028.44**

Table 4.11 presents the energy costs of the additional elements, alongwith their cumulative percentage share in the PEC.

Table 4.11: Energy Cost of Elements vis-à-vis the PEC

Project No.	Element	Energy Cost (EEC+TEC) of Elements		
		Breakup (MJ)	Total (MJ)	As % of PEC
7	Boundary wall + paved area	47858.59	90307.07	14.28
	Stairwell	42448.48		
8	Boundary wall + paved area	48786.46	91234.94	14.78
	Stairwell	42448.48		
9	Boundary wall + paved area	74910.21	124713.23	19.78
	Stairwell	49803.02		
10	Boundary wall + paved area	51536.50	92981.78	12.88
	Stairwell	41445.28		

This shows that the boundary wall (alongwith the paved area) and the stairwell together contribute about 13-20% to the PEC, which is quite significant. Table 4.12 presents the energy rates of these elements.

Table 4.12: Energy Rates of Elements

Project No.	Element	PA Energy Rate (MJ/sqm)		FA Energy Rate (MJ/sqm)	
		Breakup	Total	Breakup	Total
7	Boundary wall + paved area	397.20	749.50	458.06	864.34
	Stairwell	352.30		406.28	
8	Boundary wall + paved area	386.80	723.35	466.05	871.56
	Stairwell	336.55		405.51	
9	Boundary wall + paved area	469.83	782.19	564.81	940.31
	Stairwell	312.36		375.50	
10	Boundary wall + paved area	304.27	548.96	358.89	647.51
	Stairwell	244.69		288.62	

The following inferences have been drawn from these calculations:

1. Since these elements are made up of all the five sub-works of construction, there is an increase in the energy rates of all the sub-works in Project Nos. 7-10 as compared to Project Nos. 1-6.
2. In the absence of these extra elements, the energy rates of Project Nos. 7-10 would

lie in the following ranges:

(a) PA energy rates = 3170 - 4500 MJ/sqm

(b) FA energy rates = 3815 - 5190 MJ/sqm

Thus, there would be a fall of about 13-20% in the energy rates, if the additional elements are excluded. The rates would then be comparable to those for Project Nos. 1-6. But in practice, single storeyed units with such large PA and FA are normally provided with a boundary wall, alongwith an open paved area and a stair well. So the estimated energy rates for Project Nos. 7-10 will still hold true.

4.4. PEC EQUATIONS

The data presented in Table 4.9 has been used to derive Equations, using the best-fit method, to estimate the PEC for single storeyed dwellings for a given PA or FA. The Equations are both linear and quadratic as mentioned in Chapter 3. The corresponding trendlines are shown in Figs. 4.2-4.9. The Equations obtained are as follows:

1. Project Nos. 1-6:

   - **PEC = 3711.5 A + 10169** (refer Fig. 4.2) (4.2)
   - **PEC = -3.9233 A² + 4201.8 A – 3024.9** (refer Fig. 4.3) (4.3)

   where A = Total PA of the unit (≤ 95 sqm)

   - **PEC = 4515.4 a + 10107** (refer Fig. 4.4) (4.4)
   - **PEC = -6.2374 a² + 5161.3 a –4309.1** (refer Fig. 4.5) (4.5)

   where a = Total FA of the unit (≤ 80 sqm)

2. Project Nos. 7-10:

   - **PEC = 1440.3 A + 443330** (refer Fig. 4.6) (4.6)
   - **PEC = 169.79 A² – 47610.77 A + 3911477.93** (refer Fig. 4.7) (4.7)

   where 120 sqm ≤ A ≤ 170 sqm

- $\mathbf{PEC = 1879.1\ a + 422510}$ (refer Fig. 4.8) (4.8)
- $\mathbf{PEC = 209.80\ a^2 - 49572.91\ a + 3514665.22}$ (refer Fig. 4.9) (4.9)

  where 100 sqm $\leq a \leq$ 145 sqm

Eqn. 3.1 (Chapter 3) has also been modified by factoring in the TEC_T so that it can be used to estimate the PEC, the TEC_T having already been determined as a fraction of the EEC_T.

$$PEC = 1.0253\ EEC_T \quad (4.1)$$

And $$EEC_T = 3331.76A + 21902.40 \quad (3.1)$$

$$\therefore \quad PEC = 1.0253\ (3331.76A + 21902.40)$$

- $\mathbf{PEC = 3416.05A + 22456.53}$ (4.10)

Table 4.13 presents the PEC values obtained from Eqns. 4.2-4.5 for Project Nos. 1-6. Similarly, the values obtained from Eqns. 4.6-4.9 for Project Nos. 7-10 are presented in Table 4.14. Eqns. 4.1 and 4.10 are common for all projects and are applied in both the Tables. The PEC obtained from the detailed estimates are presented in these Tables for comparison.

Tables 4.13 and 4.14 also show the percentage deviations of the PEC estimated from the Equations as compared to the PEC obtained from the detailed estimates.

4.4.1. Analysis

<u>For Project Nos. 1-6:</u>

The deviations reveal that Eqn. 4.1 is the most accurate, but it requires an EEC_T estimate before it can be applied. Eqns. 4.2-4.5 and Eqn. 4.10 are directly applicable for estimating the PEC. But the ranges of deviations from Eqns. 4.2, 4.3 and 4.10 are quite large and they are, therefore, considered unsuitable for estimating the PEC. The PEC values obtained from Eqns. 4.4 and 4.5 give lesser deviations. Out of these, <u>Eqn. 4.4 is preferable.</u>

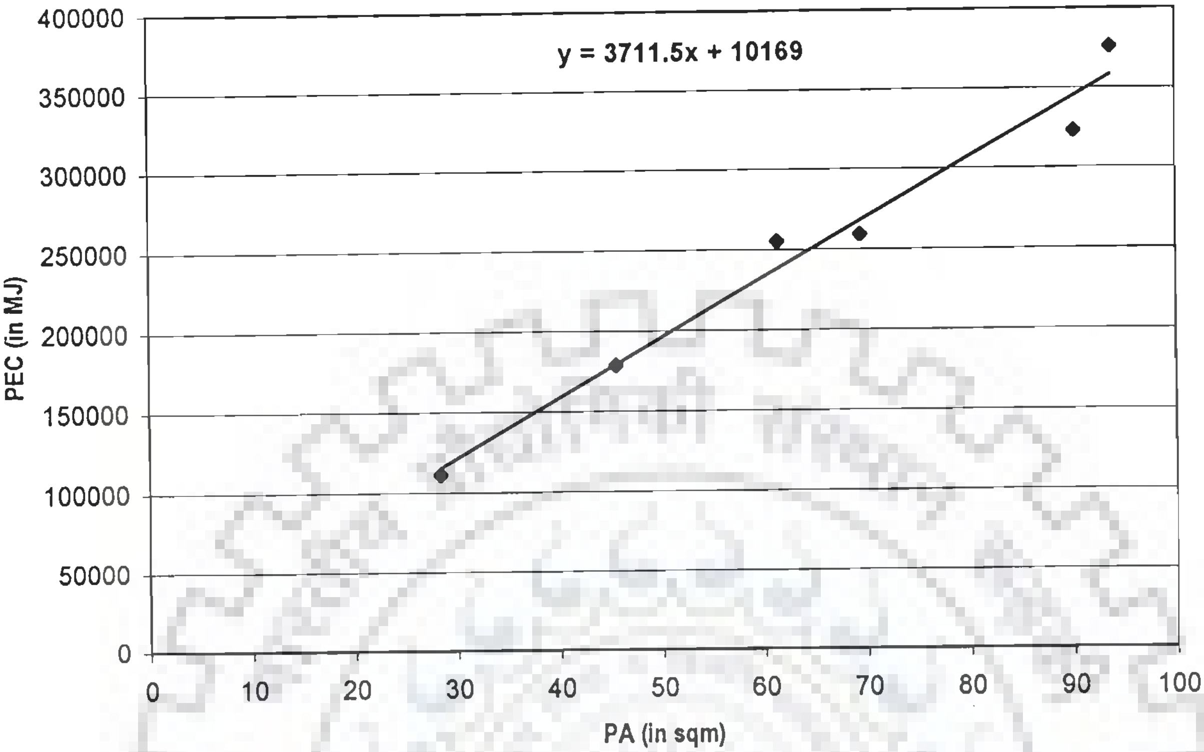

Fig. 4.2 : Linear Trend for PEC for Project Nos. 1 - 6 Using PA

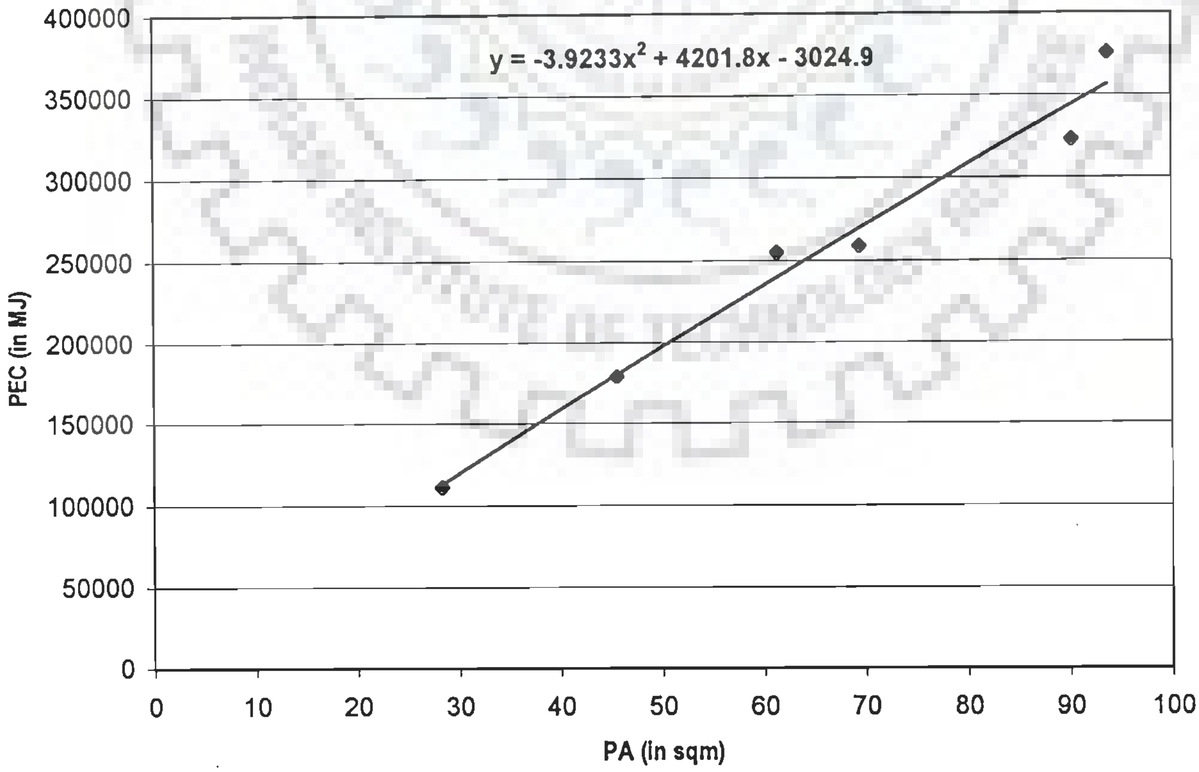

Fig. 4.3 : Quadratic Trend for PEC for Project Nos. 1 - 6 Using PA

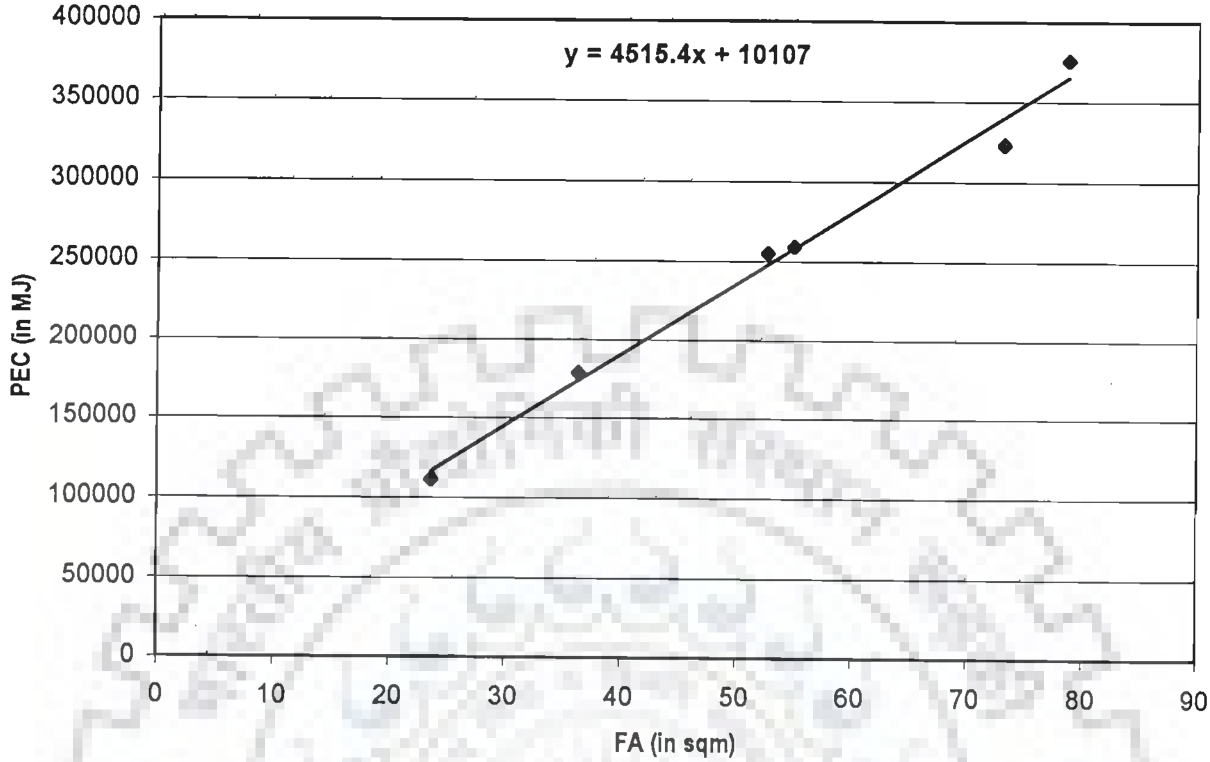

Fig. 4.4 : Linear Trend of PEC for Project Nos. 1 - 6 Using FA

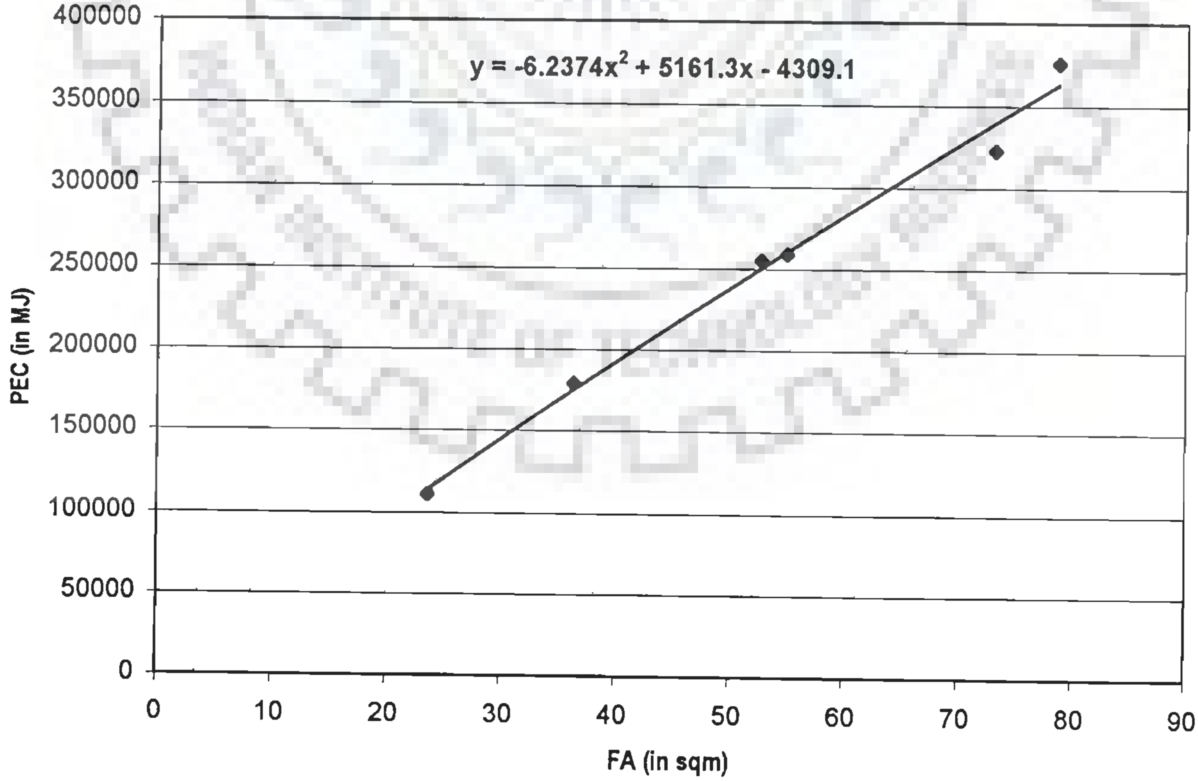

Fig. 4.5 : Quadratic Trend of PEC for Project Nos. 1 - 6 Using FA

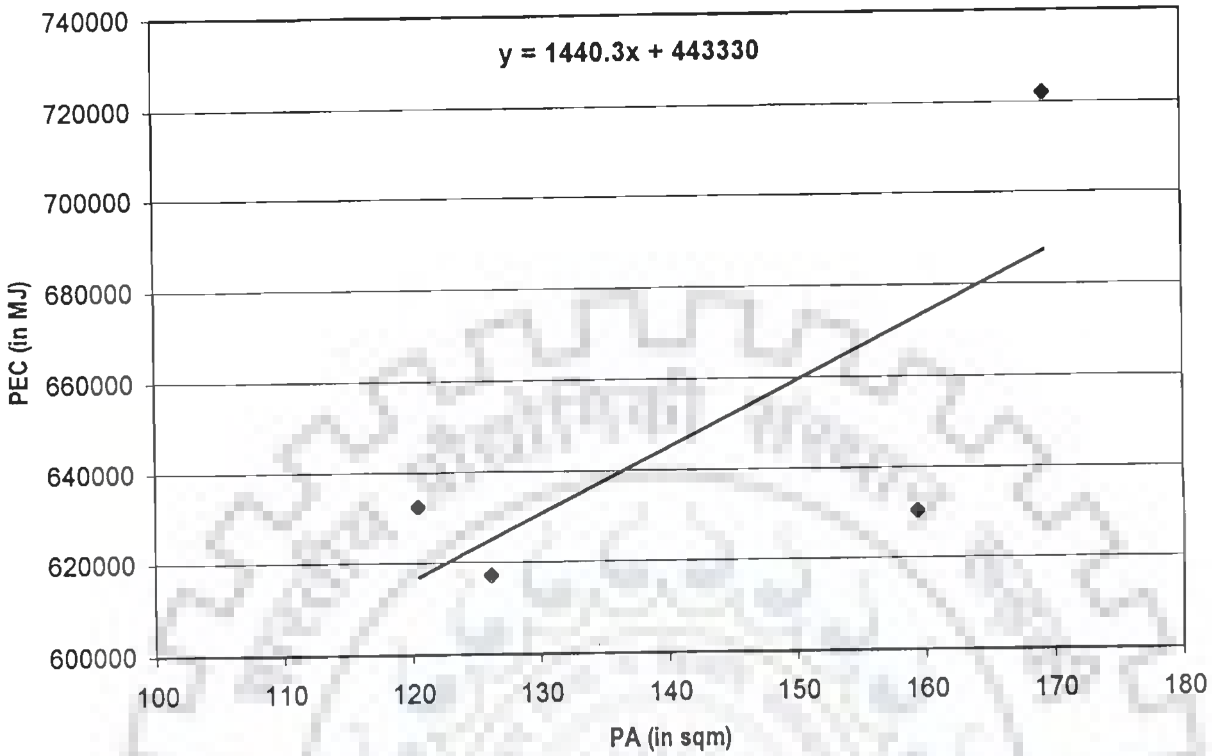

Fig. 4.6 : Linear Trend for PEC for Project Nos. 7-10

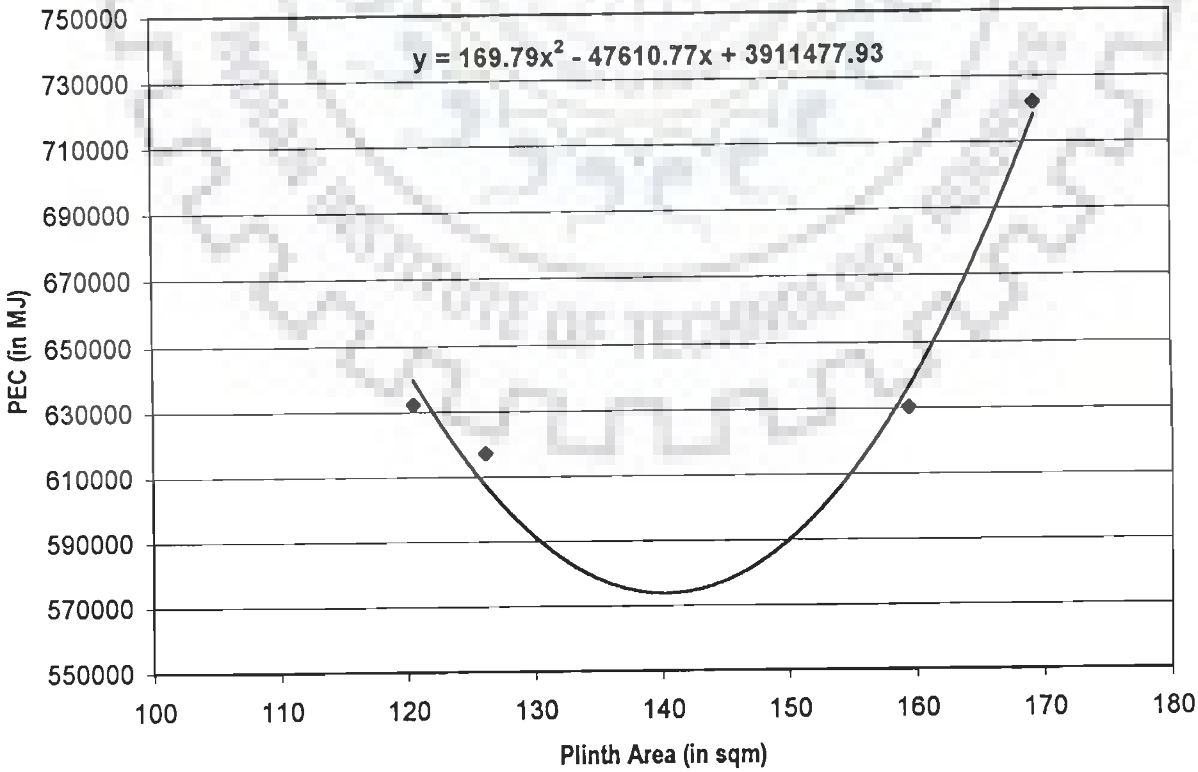

Fig. 4.7: Quadratic Trend for PEC for Project Nos. 7-10

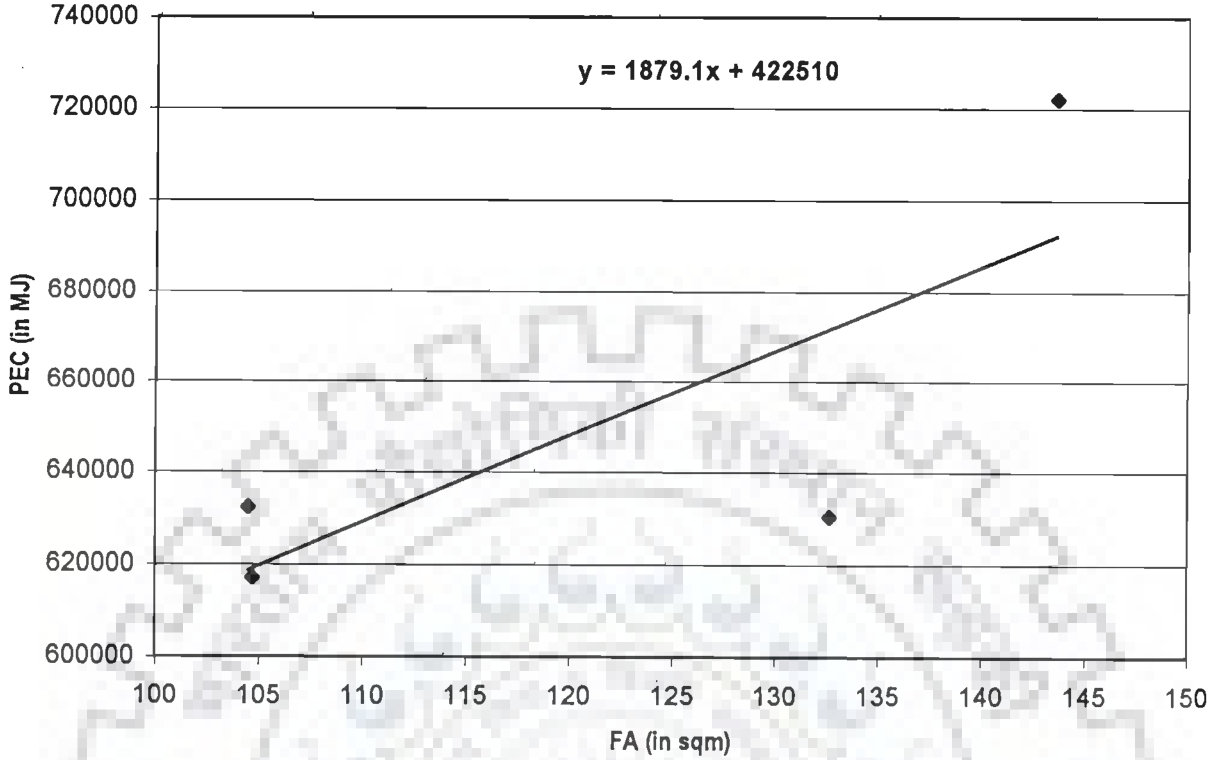

Fig. 4.8 : Linear Trend of PEC for Project Nos. 7-10 Using FA

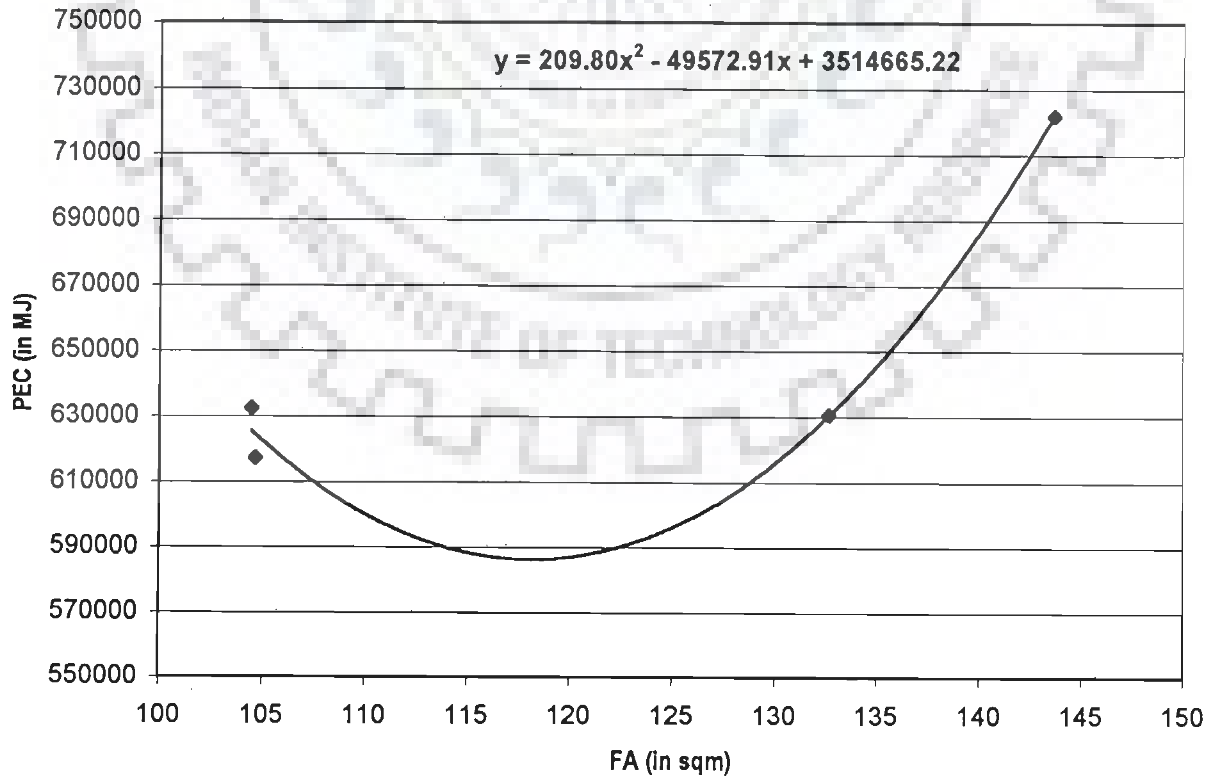

Fig. 4.9 : Quadratic Trend of PEC for Project Nos. 7-10 Using FA

Table 4.13: Estimated PEC from Equations vis-à-vis the Detailed Estimates for Single Storeyed Project Nos. 1-6

Project No.		Estimated PEC (MJ) from						
		Detailed Estimate	Eqn. 4.1	Eqn. 4.2	Eqn. 4.3	Eqn. 4.4	Eqn. 4.5	Eqn. 4.10
1	PEC	111293.55	111298.70	115278.68	112823.50	116851.06	114218.26	119199.07
	% Deviation	-	+0.005	+3.58	+1.37	+5.00	+2.63	+7.10
2	PEC	178932.90	178900.26	179190.71	180188.57	174241.79	170652.54	178023.45
	% Deviation	-	-0.02	+0.14	+0.70	-2.62	-2.16	-0.51
3	PEC	255253.74	255219.95	237758.18	239877.31	247978.27	250278.26	231928.72
	% Deviation	-	-0.01	-6.90	-6.02	-2.90	-1.95	-9.14
4	PEC	259007.81	258949.83	267747.10	269684.00	258273.38	260515.25	259530.40
	% Deviation	-	-0.02	+3.37	+4.12	-0.28	+0.58	+0.20
5	PEC	322822.83	322971.51	344946.30	344057.33	340318.20	339779.17	330584.24
	% Deviation	-	+0.05	+6.85	+6.58	+5.4	+5.25	+2.40
6	PEC	375728.38	375494.33	358010.78	356307.73	365288.36	363085.50	342608.74
	% Deviation	-	-0.06	-4.72	-5.20	-2.80	-3.40	-8.81
Range of % Deviation		-	-0.06 to +0.05	-6.90 to +6.85	-6.02 to +6.58	-2.90 to +5.40	-3.40 to +5.25	-9.14 to +7.10

Table 4.14: Estimated PEC from Equations vis-à-vis the Detailed Estimates for Single Storeyed Project Nos. 7-10

Project No.		Estimated PEC (MJ) from						
		Detailed Estimate	Eqn. 4.1	Eqn. 4.6	Eqn. 4.7	Eqn. 4.8	Eqn. 4.9	Eqn. 4.10
7	PEC	632398.78	632578.09	616871.75	639840.32	618838.37	625479.15	434056.39
	% Deviation	-	+0.03	-2.46	+1.18	-2.14	-1.09	-31.36
8	PEC	617232.11	617254.80	624995.04	607482.79	619214.19	624340.92	453322.92
	% Deviation	-	+0.004	+1.26	-1.58	+0.32	+1.15	-26.56
9	PEC	630437.55	630169.94	672971.43	636667.64	671735.03	630342.57	567111.54
	% Deviation	-	-0.04	+6.75	+0.99	+6.55	-0.02	-10.04
10	PEC	722083.67	722336.24	687288.01	718370.24	692348.76	722272.75	601067.08
	% Deviation	-	+0.03	-4.82	-0.51	-4.12	+0.03	-16.76
Range of % Deviation		-	-0.04 to +0.03	-4.82 to +6.75	-1.58 to +1.18	-4.12 to +6.55	-1.09 to +1.15	-31.36 to +10.04

For Project Nos. 7-10

Eqn. 4.1 is again the most accurate, but it has its limitations, as discussed above. Both the linear Eqns. 4.6 and 4.8 give much larger deviations and are therefore considered unsuitable. The worst results are again obtained from Eqn. 4.10. Eqns. 4.7 and 4.9 are, therefore, preferable. But out of them, Eqn. 4.9 is the better option for estimating the PEC.

4.5. CONCLUDING REMARKS

An overview of the study shows that the TEC_T, being only about 2.5% of the EEC_T, has very little impact in determining the PEC for single storeyed units. The masonry and RCC work have a combined share of about 78-82% in the PEC. They are, therefore, the major determiners of the PEC for single storeyed dwelling units. Masonry work is the single largest contributor to the PEC, accounting for nearly half it. This is because of the high EEV of traditional bricks, which alone constitute about 43-52% of the PEC. Bricks and steel together have an average share of about 60% in the PEC.

Single storeyed dwellings units, having PA >120 sqm and FA >100 sqm, have energy rates that are about 8-25% higher than those of units with PA upto 95 sqm and FA upto 80 sqm. This is primarily because of the additional elements of work, viz., the boundary wall with the open paved area and the stairwell, which together have a share of about 14-20% in the PEC.

The suitable Equations for obtaining a preliminary estimate of the PEC for single storeyed dwelling units are:

- **PEC = 4515.4 a + 10107** ; $a \leq 80$ sqm
- **PEC = 209.80 a^2 – 49572.91 a + 3514665.22** ; $100 \text{ sqm} \leq a \leq 145$ sqm

CHAPTER 5

ESTIMATION OF ENERGY COSTS FOR DOUBLE STOREYED DWELLING UNITS

5.1. INTRODUCTION

This chapter presents the estimation and analysis of energy costs for double storeyed dwelling units. The energy rates have been obtained from the estimates and their breakups have also been analysed. Equations have been derived to obtain preliminary estimates of the PEC for double storeyed units, which are presented at the end of this chapter. A comparative analysis has been done to obtain the most suitable Equations for computing the preliminary estimate of PEC for a given double storeyed unit.

The selected double storeyed units had PA ranging from 237.0-319.0 sqm and corresponding FA from 208.0-265.0 sqm. The units are listed in Table 5.1 as Project Nos. 11-13 and their floor plans are shown in Appendix-III (Figs. III.11 - III.13). All the units had four dwellings or flats each, in load bearing masonry construction. Their general items of work were the same as already listed in Table 4.2. The detailed estimates for the EEC and TEC are presented in Appendix-III (Tables III.1.11 - III.1.13 and III.2.11 - III.2.13).

5.2. BREAKUP OF ENERGY COST

The energy share of each sub-work has been studied through the breakups of the EEC_T and TEC_T, obtained from the detailed energy estimates. These breakups are presented in Tables 5.2 and 5.3 respectively. Breakups of the PEC are shown in Table 5.4 (also refer Fig. 5.1). The range of percentage shares of sub-works in the EEC_T, TEC_T and PEC are presented in Table 5.5.

Table 5.1: List of Double Storeyed Dwelling Units

Project No.	Description	Total PA (sqm)	Total FA (sqm)
11	Staff Residence at Navodaya Vidyalaya – a Unit of Four Dwellings	237.00	208.50
12	Staff Residence at Navodaya Vidyalaya - a Unit of Four Dwellings	296.90	249.40
13	A Double Storeyed Residence - a Unit of Four Dwellings	318.87	265.26

Table 5.2: Breakup of EEC_T for Double Storeyed Dwelling Units

Project No.		Breakup of EEC_T (MJ)					EEC_T (MJ)
		Masonry Work (EEC_1)	Concrete Work (EEC_2)	RCC Work (EEC_3)	Flooring (EEC_4)	Finishing (EEC_5)	
11	EEC	383979.65	50928.64	186176.90	27102.85	36639.24	**684827.28**
	%	**56.07**	**7.44**	**27.18**	**3.96**	**5.35**	**100.00**
12	EEC	453115.52	56439.27	279729.95	35895.90	43488.82	**868669.46**
	%	**52.16**	**6.50**	**32.20**	**4.13**	**5.01**	**100.00**
13	EEC	441187.83	71993.20	238270.91	31499.81	34656.76	**817608.51**
	%	**53.96**	**8.81**	**29.14**	**3.85**	**4.24**	**100.00**

Table 5.3: Breakup of TEC_T for Double Storeyed Dwelling Units

Project No.		Breakup of TEC_T (MJ)					TEC_T (MJ)	TEC_T as % of EEC_T
		Masonry Work (TEC_1)	Concrete Work (TEC_2)	RCC Work (TEC_3)	Flooring (TEC_4)	Finishing (TEC_5)		
11	TEC	10008.58	1983.86	2961.00	682.26	1235.63	**16871.33**	-
	%	59.23	11.90	**17.52**	**4.04**	**7.31**	100.00	2.46
12	TEC	11819.52	2145.68	4554.00	849.86	1463.78	**20832.84**	-
	%	**56.74**	**10.30**	**21.86**	**4.08**	**7.02**	**100.00**	**2.40**
13	TEC	11496.73	2434.20	3940.20	696.93	1166.70	**19734.76**	-
	%	**64.71**	**10.43**	**16.88**	**2.98**	**5.00**	**100.00**	**2.41**

Table 5.4: Breakup of PEC for Double Storeyed Dwelling Units

Project No.		Breakup of PEC (MJ)					Total PEC = EEC_T+ TEC_T (MJ)
		(EEC_1 + TEC_1) for Masonry Work	(EEC_2 + TEC_2) for Concrete Work	(EEC_3 + TEC_3) for RCC Work	(EEC_4 + TEC_4) for Flooring	(EEC_5 + TEC_5) for Finishing	
11	EEC + TEC	393988.23	52912.50	189137.90	27785.11	37874.87	**701698.61**
	%	**56.15**	**7.54**	**26.95**	**3.96**	5.40	**100.00**
12	EEC + TEC	464935.04	58584.95	284283.95	36745.76	44952.60	**889502.30**
	%	**52.27**	**6.59**	**31.96**	**4.13**	**5.05**	**100.00**
13	EEC + TEC	452684.56	74427.40	242211.11	32196.74	35823.46	**837343.27**
	%	**54.06**	**8.89**	**28.93**	**3.84**	**4.28**	**100.00**

Table 5.5: Percentage Shares of Sub-works in the EEC_T, TEC_T and PEC for Double Storeyed Dwelling Units

Project Nos.	Breakup of the EEC_T				
	EEC_1	EEC_2	EEC_3	EEC_4	EEC_5
11-13	52 – 56%	6.5 – 9%	27 –32%	4%	4.5 – 5%
	Breakup of the TEC_T				
	TEC_1	TEC_2	TEC_3	TEC_4	TEC_5
	57 - 65%	10 – 12%	17 – 22%	3 - 4%	5 – 7.5%
	Breakup of the PEC				
	EEC_1 + TEC_1	EEC_2 + TEC_2	EEC_3 + TEC_3	EEC_4 + TEC_4	EEC_5 + TEC_5
	52 – 56%	6.5 – 9%	27 –32%	4%	4.5 – 5%

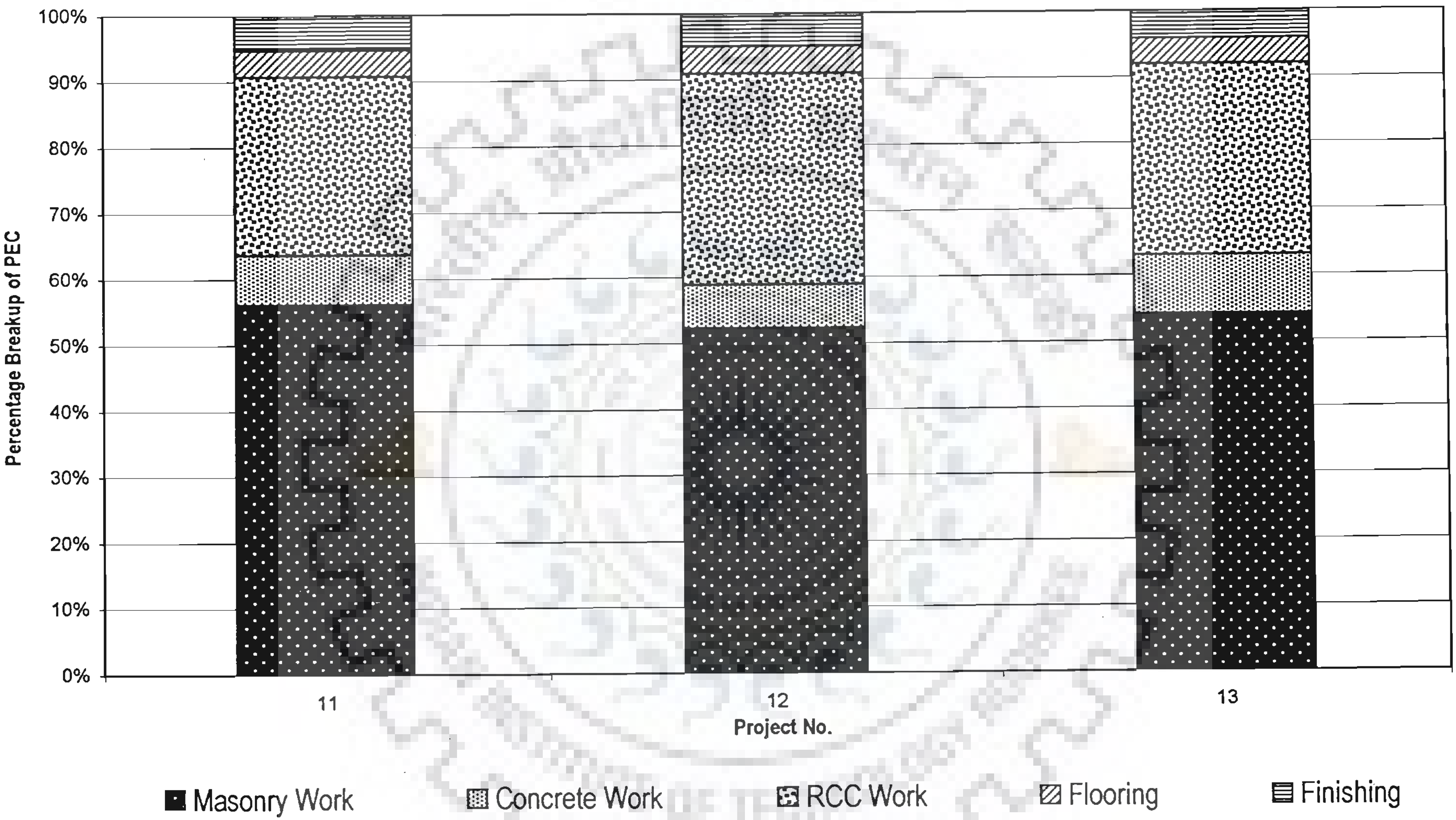

Fig. 5.1 : Breakup of PEC for Double Storeyed Dwelling Units

5.2.1. Analysis

It is observed that the breakup of PEC is the same as the EEC_T breakup. This means that the TEC_T has a negligible impact on the final percentage breakup of the energy cost. Moreover, the average value of the TEC_T is found to be 2.42% of the EEC_T (refer Table 5.4).

As $PEC = EEC_T + TEC_T$

$$\therefore \quad \mathbf{PEC = 1.0242\ EEC_T} \tag{5.1}$$

Masonry work is again the largest contributor to the EEC_T and the TEC_T and hence, in the PEC. This was also the case in single storeyed units. The RCC work is again the second largest contributor, followed by concrete work, finishing and flooring, in that order. The combined share of masonry and RCC work is about 83-84% of the PEC.

Masonry work has such a high energy cost because of the high EEV and large quantities of traditional bricks used in construction. Table 5.6 presents the quantity of bricks required for each double storeyed unit and their total energy cost, i.e., the sum of their embodied and transport energies. It is seen that bricks alone contribute about 44-47% to the PEC and have a share of about 84-85% in the total energy cost (EEC_1+TEC_1) of masonry work.

Similarly, the energy contribution of steel in RCC work is presented in Table 5.7. It shows that steel contributes about 13-17% to the PEC and is a major component of RCC work, contributing about 46-49% to the total energy cost (EEC_3+TEC_3) of RCC work.

Thus, bricks and steel alone have an average share of about 60% in the PEC, similar to the single storeyed units.

5.3. COMPARATIVE BREAKUP OF PEC

The share of sub-works in the PEC for single and double storeyed units were compared. The average comparative breakup is presented in the Table 5.8. It reveals that the total energy

Table 5.6: Energy Costs of Bricks vis-à-vis that of Masonry Work and Total Civil Work for Double Storeyed Dwelling Units

Project No.	Qty. of Bricks (nos.)	Energy Cost of Bricks		
		(EEC# +TEC$) (in MJ)	% of (EEC_1+TEC_1)	% of the PEC
11	72014	331192.39	**84.06**	**47.20**
12	84893	390422.91	**83.97**	**43.89**
13	83391	383515.21	**84.72**	**45.80**

\# EEV for bricks = 4.5 MJ/brick
Hence, EEC for bricks = (qty. of bricks x 4.5) MJ

$ TEV for one brick = wt. of brick x 0.036 MJ/kg
= 2.75 x 0.036 = 0.099 MJ
Hence, TEC for bricks = (qty. of bricks x 0.099) MJ

Table 5.7: Energy Costs of Steel vis-à-vis that of RCC Work and Total Civil Work for Double Storeyed Dwelling Units

Project No.	Qty. of Steel (X 10^2 kg)	Energy Cost of Steel		
		(EEC# +TEC$) (in MJ)	% of (EEC_1+TEC_1)	% of the PEC
11	27.40	92162.64	**48.73**	**13.13**
12	40.28	129890.61	**45.69**	**16.81**
13	33.77	113588.77	**46.90**	**13.51**

\# EEV for steel = 3360.00 MJ/ 10^2 kg
Hence, EEC for steel = (qty. of steel x 3360.00) MJ
$ TEV for steel = 0.036 MJ/kg or 3.6 MJ/ 10^2 kg
Hence, TEC for steel = (qty. of steel x 3.6) MJ

Table 5.8: Comparative PEC Breakup

Unit Category	Average Share in PEC				
	Masonry Work	Concrete Work	RCC Work	Flooring	Finishing
Single Storeyed	56.25%	13.25%	23.25%	3.25%	4.00%
Double Storeyed	54.25%	7.50%	29.25%	4.00%	5.00%

contribution of masonry work to the PEC falls by an average of about 2% for double storeyed units vis-à-vis single storeyed units. There is a corresponding average fall of about 6% in the energy share of concrete work. But the energy share of RCC work rises on an average by about 6% of the PEC. An average rise of about 1% is also observed in the share of flooring and finishing respectively.

5.3.1. Analysis

The two main components of masonry work are:

i. masonry work in the foundation and plinth
ii. masonry work in the superstructure

Table 5.9 presents their individual energy contributions to the masonry work for single and double storeyed units. The comparative percentage shares are shown in Table 5.10, which shows that the total energy cost of masonry work in the foundation and the plinth decreases on an average by about 8% of the PEC for double storeyed units as compared to single storeyed units. This happens because masonry work in the foundation and the plinth is common for both storeys in the double storeyed units. Hence, there is no increase in its quantity unlike the other items, which increase with the additional construction work. This results in a fall in the energy contribution of masonry work, in the foundation and the plinth, to the PEC for double storeyed units.

The energy contribution of masonry work in the superstructure increases on an average by about 6% of the PEC for double storeyed units vis-à-vis single storeyed units. Thus, there is an average decrease of about 2% in the energy share of masonry work in the PEC for double storeyed units vis-à-vis single storeyed units. Similarly, nearly all the items of concrete work for double storeyed units are in the foundation and the plinth, viz., base concrete, Damp proof course (DPC) and plinth protection. The quantities of these items also do not increase with increase in the storeys of the projects, thus lowering the energy share of concrete work to the PEC in double storeyed units vis-à-vis single storeyed units.

Table 5.9: Breakup of the Energy Cost of Masonry Work for Single and Double Storeyed Units

Project No.		Energy Cost of Masonry Work (EEC_1 +TEC_1)		
		Breakup		Total
		Foundation and Plinth	Superstructure	
1	MJ	19111.64	43563.67	62675.31
	% PEC	**17.17**	**39.15**	**56.32**
2	MJ	33235.27	74847.12	108082.30
	% PEC	**18.57**	**41.83**	**60.40**
3	MJ	60506.62	81579.19	142103.81
	% PEC	**23.71**	**31.98**	**55.69**
4	MJ	45000.44	100795.71	145796.15
	% PEC	**17.37**	**38.92**	**56.29**
5	MJ	47693.40	117118.41	164811.81
	% PEC	**14.77**	**36.28**	**56.29**
6	MJ	82003.81	152296.67	234300.48
	% PEC	**21.83**	**40.53**	**62.36**
7	MJ	117733.08	228650.45	346383.53
	% PEC	**18.62**	**36.15**	**54.77**
8	MJ	108841.43	228446.95	337288.38
	% PEC	**17.63**	**30.71**	**54.65**
9	MJ	132968.18	239341.20	372309.38
	% PEC	**21.10**	**37.96**	**59.06**
10	MJ	121609.63	259958.15	381567.78
	% PEC	**16.84**	**36.00**	**52.84**
11	MJ	74006.76	319981.47	393988.23
	% PEC	**10.55**	**45.60**	**56.15**
12	MJ	75504.02	389431.02	464935.04
	% PEC	**8.49**	**43.78**	**52.27**
13	MJ	113693.89	338990.67	452684.56
	% PEC	**13.58**	**40.48**	**54.06**

Table 5.10: Comparative Energy Shares of the Components of Masonry Work in the PEC

Unit Category	Energy Share	Masonry Work in Foundation and Plinth	Masonry Work in Superstructure	Total Masonry Work
Single	Range	15-24%	31-42%	51-62%
	Average	19.0%	37.0%	56.0%
Double	Range	8.5-13.5%	40.5-45.5%	52-56%
	Average	11.0%	43.0%	54%

The quantities and hence, the energy shares of RCC work, flooring and finishing increase with the addition of another storey[1]. This reason, alongwith a fall in the net percentage energy share of masonry and concrete work, results in an increase in the share of RCC work, flooring and finishing in the PEC for double storeyed units vis-à-vis single storeyed units.

There is, therefore, an average rise of about 4% in the combined energy share of masonry and RCC work in the PEC for double storeyed units vis-à-vis single storeyed units and an average rise of about 1% in the share of flooring and finishing respectively.

5.4. ENERGY RATES

The energy rates of civil work for the double storeyed units have been obtained from their PEC estimates, similar to single storeyed units. These rates are presented in Table 5.11. Similarly, the individual shares of the sub-works to the energy rates are shown in Table 5.12. The PA energy rates are in the range of about 2625-2995 MJ/sqm and the corresponding FA energy rates are about 3155-3565 MJ/sqm.

5.4.1. Analysis

It is observed that the PA energy rates for the double storeyed units fall by upto 950-2255 MJ/sqm vis-à-vis the rates for single storeyed dwelling units. This is equivalent to a drop of about 26.5-43% in the PA energy rates. Similarly, the corresponding FA energy rates fall by upto 1260-2490 MJ/sqm, i.e., a drop of about 28.5-41%. Table 5.13, obtained from Table 4.10 and 5.12, presents the comparative range of energy shares of sub-works to the energy rates for single and double storeyed units.

[1] This increase is not proportionate to the increased area of construction.

Table 5.11: Energy Rates for Double Storeyed Dwelling Units

Project No.	PA (sqm)	FA (sqm)	PEC = $EEC_T + TEC_T$ (MJ)	PA Energy Rate (MJ/sqm)	FA Energy Rate (MJ/sqm)
11	237.00	208.50	710698.61	**2960.75**	**3365.46**
12	296.90	249.40	889502.30	**2995.97**	**3566.57**
13	318.87	265.26	837343.27	**2625.97**	**3156.69**

Table 5.12: Shares of Sub-works in Energy Rates for Double Storeyed Dwelling Units

Project No.	Share (MJ/sqm)						Total Energy Rate (MJ/sqm)
		Masonry Work	Concrete Work	RCC Work	Flooring	Finishing	
11	PA	1662.40	223.26	798.05	117.24	159.81	**2960.75**
	FA	1889.63	253.78	907.14	133.26	181.65	**3365.46**
12	PA	1565.97	197.32	957.51	123.76	151.41	**2995.97**
	FA	1864.21	234.90	1139.87	147.34	180.24	**3566.57**
13	PA	1419.65	233.41	759.59	100.97	112.35	**2625.97**
	FA	1706.57	280.58	913.11	121.38	135.05	**3156.69**

Table 5.13: Comparative Ranges of Shares of Sub-works in Energy Rates for Single and Double Storeyed Dwelling Units

Project Type	Range of Share (MJ/sqm)						
		Masonry Work	Concrete Work	RCC Work	Flooring	Finishing	Total
Single Storeyed	PA	1825-2875	365-715	705-1295	70-195	135-190	**3575-5250**
	FA	2255-3315	480-825	885-1490	85-230	160-220	**4415-6055**
Double Storeyed	PA	1420-1665	200-235	760-960	100-125	110-160	**2625-2995**
	FA	1705-1890	235-280	910-1140	120-150	135-180	**3155-3565**

It reveals that there is a fall in the contribution of every sub-work to the energy rates for double storeyed units compared to the corresponding rates for single storeyed units. The maximum slump is in masonry work, followed by concrete work. This is because of the reason discussed earlier, viz., the quantities of masonry and concrete work in foundation and plinth do not increase proportionately with the additional storey. On the other hand, the fall in the share of RCC work, flooring and finishing in the energy rates are not sharp.

5.5. PEC EQUATIONS

The data presented in Table 5.11 has been used to derive Equations for the preliminary estimation of the PEC for double storeyed dwellings units. The Equations are both linear and quadratic, as explained in Chapter 3. The corresponding trendlines are shown in Figs. 5.2– 5.5.

The Equations are as follows:

- **PEC = 1968.6 A + 249921** (refer Fig. 5.2) (5.2)
- **PEC = -67.29 A^2 + 39063.75 A – 4776552.35** (refer Fig. 5.3) (5.3)

  where A = Total PA of the unit

- **PEC = 2828 a + 127811** (refer Fig. 5.4) (5.4)
- **PEC = -138.84 a^2 + 68166.08 a – 7475293.06** (refer Fig. 5.5) (5.5)

  where a = Total FA of the unit

Moreover, Eqns. 3.2 and 3.4 have been modified by incorporating the TEC_T, to compute the PEC for double storeyed units. This has been done with the help of Eqn. 5.1, where TEC_T had been calculated as a fraction of the EEC_T.

$$PEC = 1.0242\ EEC_T \quad (5.1)$$

And $$EEC_T = 3008.00\ A + 21202.70 \quad (3.2)$$

- **PEC = 3080.79 A + 21715.81** (5.6)

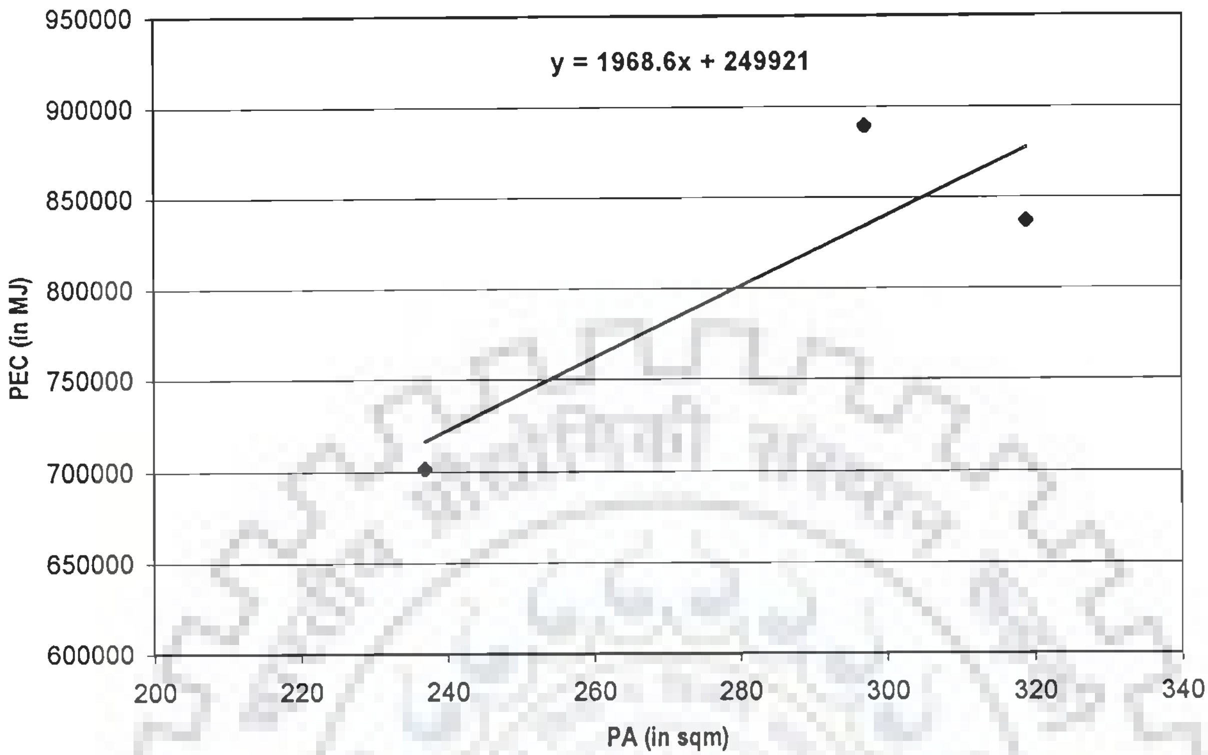

Fig. 5.2 : Linear Trend of PEC for Project Nos. 11 - 13 Using PA

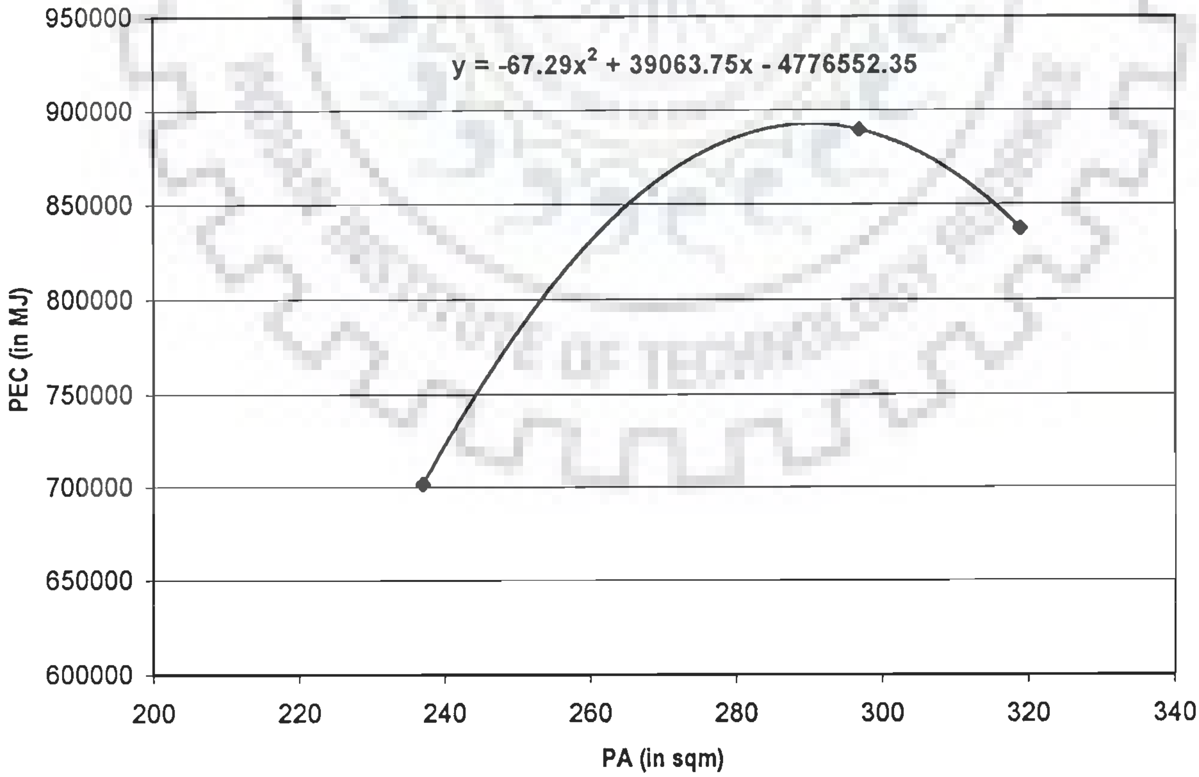

Fig. 5.3 : Quadratic Trend of PEC for Project Nos. 11 - 13 Using PA

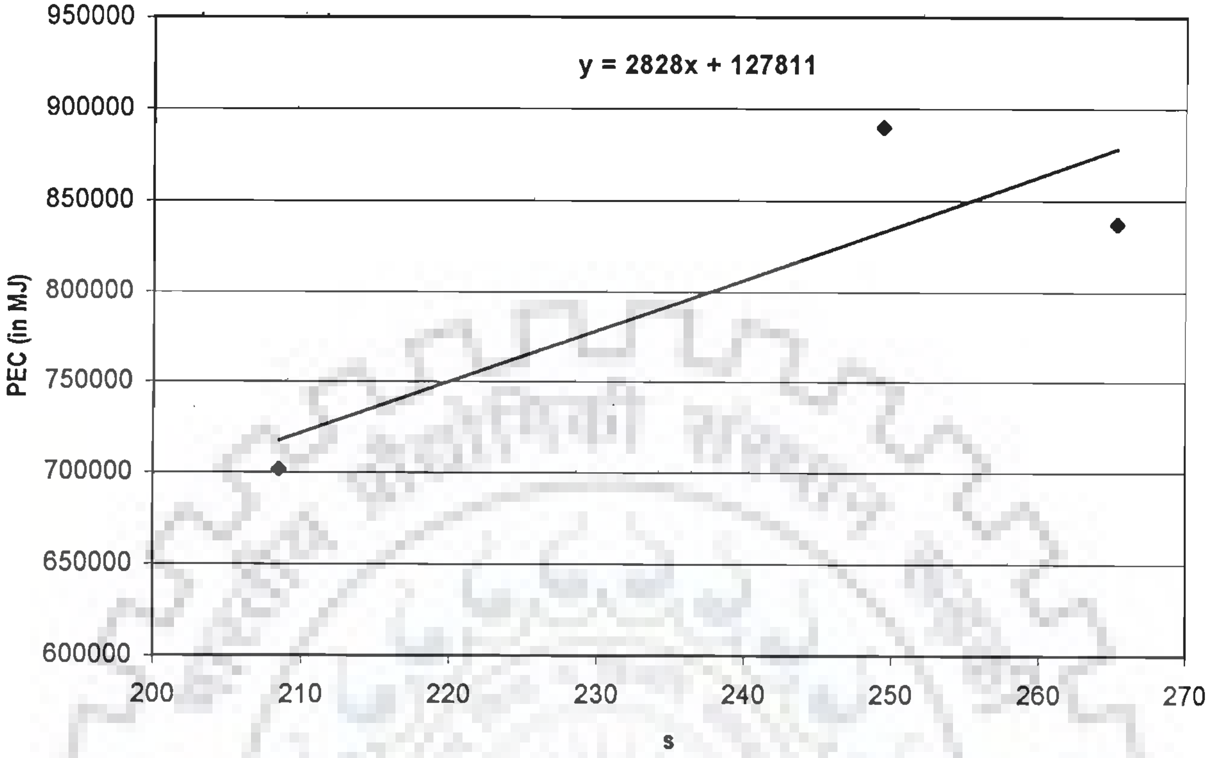

Fig. 5.4 : Linear Trend of PEC for Project Nos. 11 - 13 Using FA

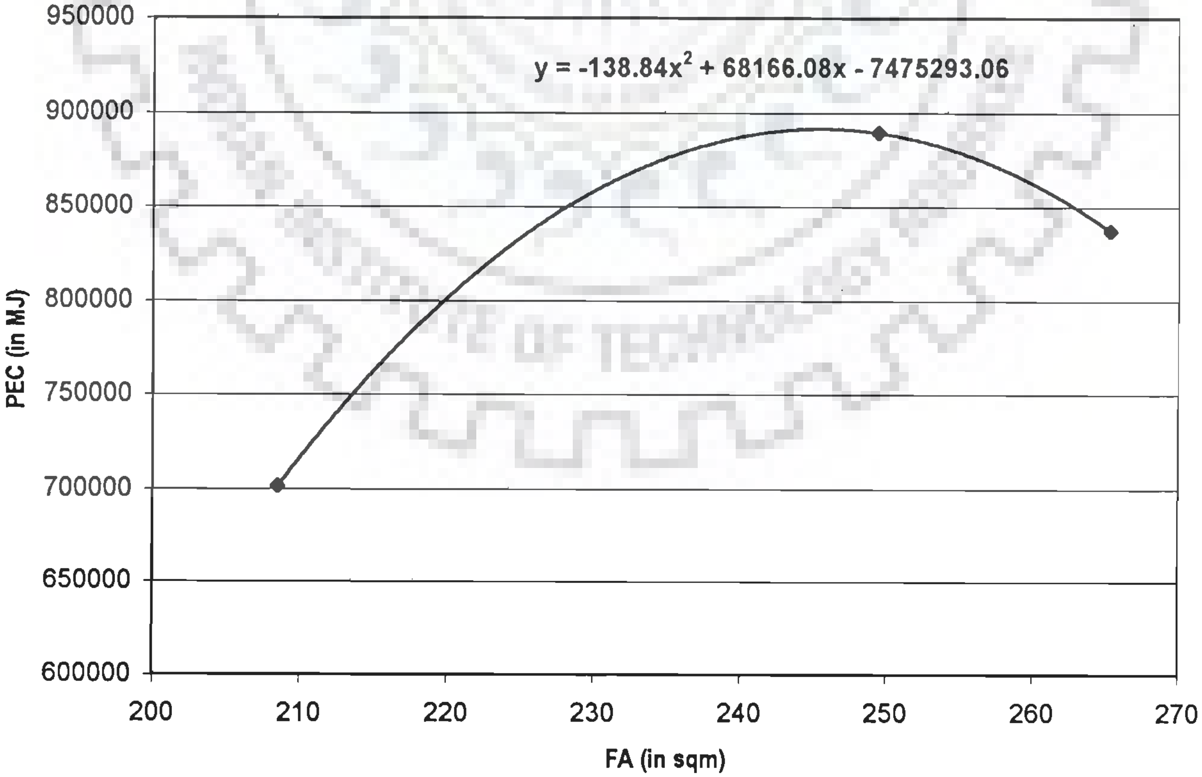

Fig. 5.5 : Quadratic Trend of PEC for Project Nos. 11 - 13 Using FA

Similarly, from Eqns. 5.1 and 3.4:

$$PEC = 1.0242\ (3261.18A)$$

▪ **PEC = 3340.10 A** (5.7)

Table 5.14 presents the PEC values computed from Eqns. 5.1-5.7, alongwith the PEC obtained from the detailed estimates. The percentage deviations of the computed values from the estimated PEC are also shown.

5.5.1. Analysis

It is clear that, due to the high deviations from the estimated value, Eqns. 5.6 and 5.7 are not suitable for estimating the PEC. Eqn. 5.1 gives a fairly close estimate, but it can only be used if the detailed EEC_T is available.

The linear Eqns. 5.2 and 5.4 show a much larger deviation than the quadratic Eqns. 5.3 and 5.5. In fact, the quadratic Equations give values, which are nearly as or even more accurate than those obtained from Eqn. 5.1. Therefore, Eqns. 5.3 and 5.5 are preferable, out of which, Eqn. 5.5 is the better option.

5.6. CONCLUDING REMARKS

The TEC_T again has very little impact on the PEC since it is only about 2.4% of the EEC_T for double storeyed units. The masonry and RCC work are again the major determiners of the PEC, having a combined share of about 83-84% in the PEC for double storeyed dwelling units. This also shows that there is a rise of about 4% (avg.) in their share in the PEC for double storeyed units as compared to single storeyed units.

The masonry work continues to be the single largest contributor to the PEC, accounting for nearly half of the PEC for double storeyed dwellings. This is because of the high EEV of traditional bricks, which alone have a share of about 46% (avg.) in the PEC.

Table 5.14: Estimated PEC from Equations vis-à-vis the Detailed Estimates for Double Storeyed Project Nos. 11-13

Project No.		Estimated PE C (in MJ) from								
		Detailed Estimate	Eqn. 5.1	Eqn. 5.2	Eqn. 5.3	Eqn. 5.4	Eqn. 5.5	Eqn. 5.6	Eqn. 5.7	Eqn. 5.8
11	PEC	701698.61	701400.10	713851.94	716479.20	701944.39	717449.00	701647.43	751863.04	791603.70
	% Deviation	-	-0.04	+1.73	+2.11	+0.04	+2.24	-0.01	+7.15	+12.81
12	PEC	889502.30	889691.26	914466.27	834398.34	889887.77	833114.20	889429.31	936402.36	991675.69
	% Deviation	-	+0.02	+2.81	-6.19	+0.04	-6.34	-0.01	+5.27	+11.49
13	PEC	837343.27	837394.64	801099.83	877648.48	837787.82	877966.28	837260.78	1004087.32	1065057.69
	% Deviation	-	+0.01	-4.33	+4.81	+0.05	+4.85	-0.01	+19.91	+27.19
Range of % Deviation		-	-0.04 to +0.02	-4.33 to +2.81	-6.19 to +4.81	+0.04 to +0.05	-6.34 to +4.85	-0.01	5.27 to +19.9	+11.49 to +27.19

Bricks and steel have a combined average share of 60% in the PEC, just as in case of single storeyed units. Therefore, the rise in the number of storeys does not effect the percentage contribution of bricks and steel.

There is a significant fall in the energy rates for double storeyed units vis-à-vis single storeyed units. The PA energy rates fall by upto 26.5-43%, whereas the FA energy rates are lower by about 28.5-41%. This slump can be primarily attributed to the fall in the energy share of masonry and concrete work. Thus, it is clear that double storeyed housing construction has significantly lower range of energy costs as compared to single storeyed development.

The preferable Equation for providing a preliminary estimate of the PEC for double storeyed units is:

- **PEC = -138.84 a² + 68166.08 a – 7475293.06**

The above conclusions have been arrived at within the constraints of the available data of the BOQ for double storeyed housing construction. But the results still hold true because, firstly, the trends obtained from the available data indicate that their energy rates will remain within the calculated range, i.e., there will be a symmetrical rise in the PEC of the double storeyed dwelling units with increasing PA and FA. Secondly, when the data for single and double storeyed units is considered together, it reveals similar trends, viz.:

- Masonry and RCC work are the major determiners of the PEC, with masonry work being the single largest contributor
- Bricks and steel have the same combined energy share in the PEC for both types of units

More data on BOQ of double storeyed housing construction will help to further substantiate the results.

CHAPTER 6

ESTIMATION OF ENERGY COSTS FOR FOUR STOREYED HOUSING PROJECTS

6.1. INTRODUCTION

Estimation of the energy costs of civil work for four storeyed housing projects are presented in this chapter. The energy rates, derived from the estimates, are also presented. Equations to provide a preliminary estimate of the PEC are discussed at the end of the chapter. A comparative analysis has also been done to obtain the most suitable equations for computing the preliminary estimate of PEC for a given four storeyed project.

Four storeyed dwellings in Northern India are generally not constructed as individual units, but as a group of units, i.e., as housing projects. Moreover, though both single and double storeyed units are nearly always in load bearing masonry construction, four storeyed units are built both in load bearing masonry as well as in RCC framed construction. Therefore, four storeyed housing projects in both types of structural systems have been considered.

Three projects were studied, having total PA[1] between 2045-16680 sqm and corresponding total FA[2] in the range of 1720-14010 sqm. They are listed in Table 6.1 as Project Nos. 14 to 16[3]. Project Nos. 14 and 16 were planned housing projects. The former had been designed and executed by a government organisation, whereas the latter by a private architectural firm. Project No. 15 was evolved for the present study by considering a development of fifteen four storeyed dwelling units. Project No. 14 was in RCC frame, whereas Nos. 15 and 16 were

[1] Sum of the PAs of all dwellings in a housing project

[2] Sum of the FAs of all dwellings in a housing project

[3] - Project No. 14 has 10 units; total number of dwellings = 36
- Project No. 15 has 15 units; total number of dwellings = 120
- Project No. 16 has 32 units; total number of dwellings = 187

in load bearing masonry construction. Their general specifications were similar to the ones listed in Table 4.2. The drawings of the projects are shown in Appendix-III (Fig.III.14 - III.16). Another fact, clear from the drawings, was that Project Nos. 14 and 16 had dwellings of different PA and FA, unlike in the previous categories of units. Only Project No. 15 had the same plan for all fifteen units.

Detailed estimates for the EEC and TEC for each project are presented in Appendix-III (Tables III.1.14 - III.1.16 and III.2.14 - III.2.16).

6.2. BREAKUP OF ENERGY COST

Tables 6.2 and 6.3 present the breakups of the EEC_T and TEC_T obtained from the detailed estimates. Table 6.4 and Fig. 6.1 present the total energy share of each sub-work in the PEC for individual projects. The ranges of the percentage shares of the sub-works in the EEC_T, TEC_T and PEC are shown in the Table 6.5.

6.2.1. Analysis

Here again, the breakups of the PEC are the same as the EEC_T breakup (refer Table 6.5), i.e., the TEC_T has a negligible impact in the final percentage breakup of the PEC. It is also observed that the TEC_T has an average value of 2.11% of the EEC_T (refer Table 6.3).

$$\therefore \quad PEC = EEC_T + TEC_T$$

$$\text{or} \quad \mathbf{PEC = 1.0211\ EEC_T} \tag{6.1}$$

It is also revealed that, unlike the single and double storeyed units, the energy share of RCC work is higher than for masonry work, except in Project No. 15. These are followed by finishing, flooring and concrete work in that order.

Table 6.1: List of Four Storeyed Housing Projects

Project No.	Description	Total PA (sqm)	Total FA (sqm)
14	Staff Housing Complex of Indian Oil Corporation at Panchkula, Haryana	2046.00	1719.00
15	A Group of Fifteen Units – Eight Dwellings per Unit	8907.00	7482.00
16	I.R.W.O. Housing, Rail Vihar, Sector 33, Noida	16680.00	14008.00

Table 6.2: Breakup of EEC_T for Four Storeyed Housing Projects

Project No.		Breakup of EEC_T (MJ)					EEC_T (MJ)
		Masonry Work (EEC_1)	Concrete Work (EEC_2)	RCC Work (EEC_3)	Flooring (EEC_4)	Finishing (EEC_5)	
14	EEC	1847217.73	173553.51	4217043.12	289913.34	209033.89	**6736761.59**
	%	**27.42**	**2.58**	**62.60**	**4.30**	**3.10**	**100.00**
15	EEC	13362679.22	897653.54	8570694.65	945541.12	1319790.67	**25096359.20**
	%	**53.25**	**3.58**	**34.15**	**3.76**	**5.26**	**100.00**
16	EEC	21604468.67	1576230.35	25152699.75	2104837.00	3038836.50	**53477072.27**
	%	**40.40**	**2.95**	**47.03**	**3.94**	**5.68**	**100.00**

Table 6.3: Breakup of TEC_T for Four Storeyed Housing Projects

Project No.		Breakup of TEC_T (MJ)					TEC_T (MJ)	TEC_T as % of EEC_T
		Masonry Work (TEC_1)	Concrete Work (TEC_2)	RCC Work (TEC_3)	Flooring (TEC_4)	Finishing (TEC_5)		
14	TEC	46004.20	9151.56	62370.00	7101.33	6603.12	**131230.21**	1.95
	%	**35.06**	**6.97**	**47.53**	**5.41**	**5.03**	100.00	
15	TEC	348295.68	35572.11	142290.00	22783.86	44442.01	**593383.66**	2.36
	%	**58.70**	**6.00**	**23.98**	**3.83**	**7.49**	**100.00**	
16	TEC	536705.47	76283.44	335790.00	60268.95	71507.50	**1080555.36**	2.02
	%	**49.67**	**7.06**	**31.07**	**5.58**	**6.62**	**100.00**	

Table 6.4: Breakup of PEC for Four Storeyed Housing Projects

Project No.		Break up of PEC (MJ)					Total PEC = $EEC_T + TEC_T$ (MJ)
		($EEC_1 + TEC_1$) for Masonry Work	($EEC_2 + TEC_2$) for Concrete Work	($EEC_3 + TEC_3$) for RCC Work	($EEC_4 + TEC_4$) for Flooring	($EEC_5 + TEC_5$) for Finishing	
14	EEC + TEC	1893221.93	182705.07	4279413.12	297014.67	215637.01	6867991.80
	%	**27.57**	**2.66**	**62.31**	**4.32**	**3.14**	**100.00**
15	EEC + TEC	13710974.90	933225.65	8712984.65	968324.98	1364232.68	**25689742.86**
	%	**53.37**	**3.63**	**33.92**	**3.77**	**5.31**	**100.00**
16	EEC + TEC	22141174.14	1652513.79	25488489.75	2165105.95	3110344.00	**54557627.63**
	%	**40.58**	**3.03**	**46.72**	**3.97**	**5.70**	**100.00**

Table 6.5: Percentage Shares of Sub-works in the EEC_T, TEC_T and PEC for Four Storeyed Housing Projects

Project Nos.	Breakup of the EEC_T				
	EEC_1	EEC_2	EEC_3	EEC_4	EEC_5
14-16	27 – 53%	2.5 – 3.5%	34.5 – 62.5%	3.5 – 4.5%	3 – 6%
	Breakup of the TEC_T				
	TEC_1	TEC_2	TEC_3	TEC_4	TEC_5
	35 - 59%	5.5 – 7%	24.5 – 47.5 %	3.5 – 5.5%	5 – 7.5%
	Breakup of the PEC				
	$EEC_1 + TEC_1$	$EEC_2 + TEC_2$	$EEC_3 + TEC_3$	$EEC_4 + TEC_4$	$EEC_5 + TEC_5$
	27 – 53%	2.5 – 3.5%	34.5 – 62.5%	3.5 – 4.5%	3 – 6%

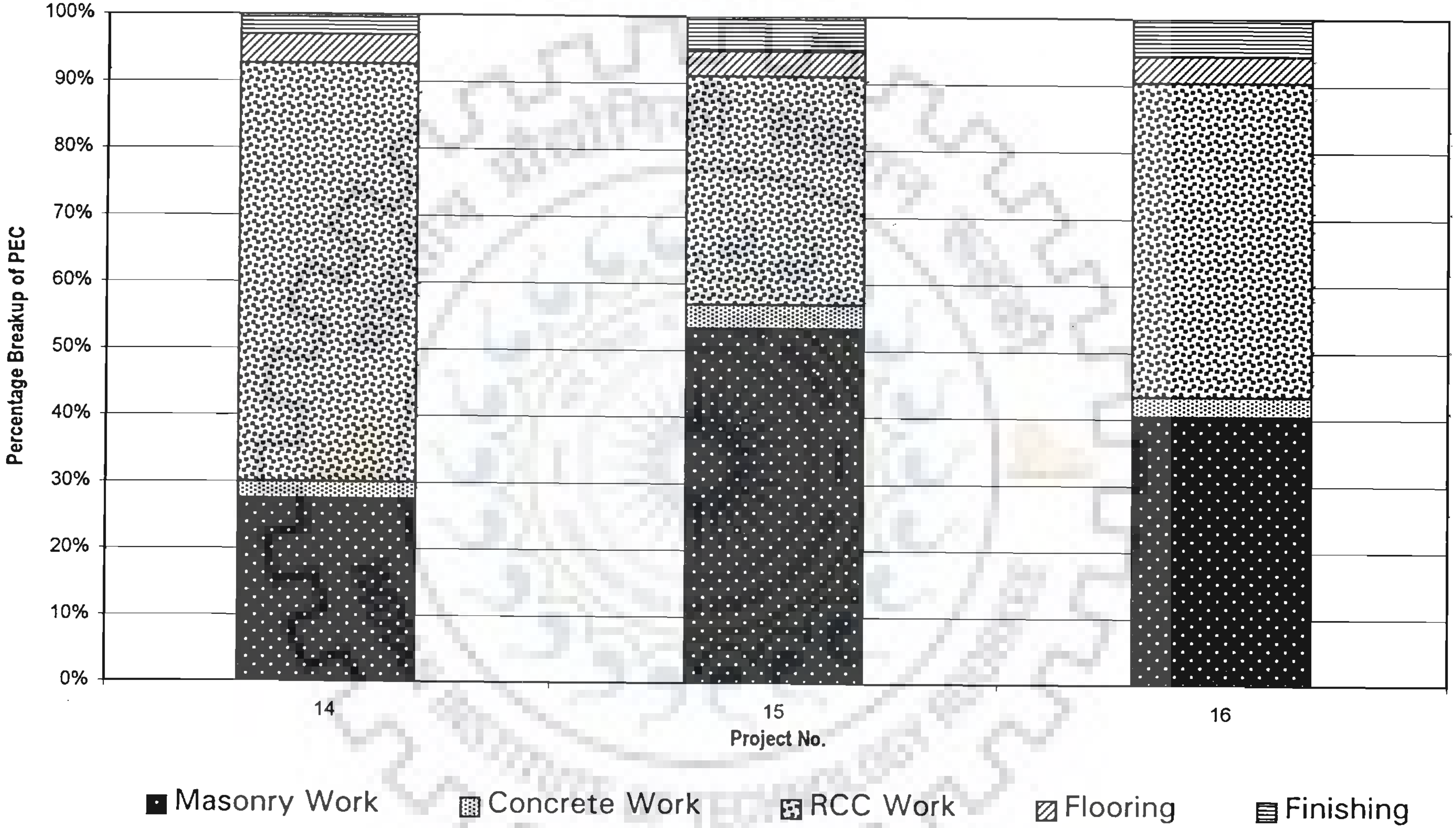

Fig. 6.1 : Breakup of PEC for Four Storeyed Housing Projects

It was not possible to compute average energy shares of the sub-works to the PEC as there are wide variations in the shares of masonry and RCC work. Moreover, each project had to be studied separately because of these variations.

6.2.1.1. Project No. 14

This project had units in RCC framed construction. Therefore, it has a higher quantity of RCC work, making it the highest energy contributor (62.31%) to the PEC. The second highest contributor is masonry work, having an energy share of 27.57%. In fact, the energy shares of masonry and RCC work are nearly interchanged vis-à-vis single and double storeyed units, as highlighted in Table 6.6.

Table 6.6: Comparative PEC Breakup

Unit Category		Average Share in the PEC of				
		Masonry Work	Concrete Work	RCC Work	Flooring	Finishing
Single Storeyed		56.25%	13.25%	23.25%	3.25%	4.00%
Double Storeyed		54.25%	7.50%	29.25%	4.00%	5.00%
Four Storeyed	14	27.57%	2.66%	62.31%	4.32%	3.14%
	15	53.37%	3.63%	33.92%	3.77%	5.31%
	16	40.58%	3.03%	46.72%	3.97%	5.70

Table 6.7 shows that, though bricks have about 82% of the energy share in masonry work (EEC_T+TEC_T) in this project, their share in the PEC falls to only about 23%, as against an average of 47.5% and 46% in the PEC for single and double storeyed units respectively. But the energy share of steel rises to about 33% of the PEC (Table 6.8) as against an average of 12% for single storeyed units and 14.5% for double storeyed units. Table 6.9 further clarifies the fall in the energy shares of the components of masonry work as compared to the single and double storeyed units (refer Table 5.9 and 5.10 also). The fall in the energy contribution of concrete work continues and there is a drop of about 5% vis-à-vis double storeyed units in this project (Table 6.6).

Table 6.7: Energy Costs of Bricks vis-à-vis that of Masonry Work and Total Civil Work for Four Storeyed Housing Projects

Project No.	Qty. of Bricks (nos.)	Energy Cost of Bricks		
		(EEC# +TEC$) (MJ)	% of (EEC_1+TEC_1)	% of the PEC
14	337849	1553767.55	**82.07**	**22.62**
15	2532013	11644727.79	**84.93**	**45.33**
16	3907490	17970546.51	**81.16**	**32.94**

EEV for bricks = 4.5 MJ/brick
Hence, EEC for bricks = (qty. of bricks x 4.5) MJ
$ TEV for one brick = wt. of brick x 0.036 MJ/kg
= 2.75 x 0.036 = 0.099 MJ
Hence, TEC for bricks = (qty. of bricks x 0.099) MJ

Table 6.8: Energy Costs of Steel vis-à-vis that of RCC Work and Total Civil Work for Four Storeyed Housing Projects

Project No.	Qty. of Steel (10^2 kg)	Energy Cost of Steel		
		(EEC# +TEC$) (in MJ)	% of (EEC_1+TEC_1)	% of the PEC
14	676.00	2273793.60	**53.13**	**33.11**
15	1208.40	4064574.24	**46.65**	**16.06**
16	4330.00	14564388.00	**57.14**	**26.70**

EEV for steel = 3360.00 MJ/ 10^2 kg
Hence, EEC for steel = (qty. of steel x 3360.00) MJ
$ TEV for steel = 0.036 MJ/kg or 3.6 MJ/ 10^2 kg
Hence, TEC for steel = (qty. of steel x 3.6) MJ

Table 6.9: Breakup of the Energy Cost of Masonry Work (EEC_1 + TEC_1) for Four Storeyed Housing Projects

Project No.		Energy Cost of Masonry Work (EEC_1 +TEC_1)		
		Breakup		Total
		Foundation and Plinth	Superstructure	
14	MJ	132832.63	1760389.30	1893221.93
	% PEC	1.93	25.63	27.57
15	MJ	1227440.85	12483534.05	13710974.90
	% PEC	4.78	48.59	53.37
16	MJ	3668659.64	18472514.50	22141174.14
	% PEC	6.72	33.86	40.58

This is so because concrete work does not increase in quantity in proportion to the increase in the number of storeys as discussed in Chapter 5. There is not much variation in the shares of flooring and finishing, as their quantities increase with the additional storeys.

6.2.1.2. Project No. 15

This project had dwelling units in load bearing masonry construction. Therefore, the energy contribution of masonry work is in the same range as for single and double storeyed units. In fact, the energy share of masonry work in foundation and plinth drops further (refer Table 6.9 and 5.9), but the rise in the energy share of masonry work in superstructure offsets the fall in foundation and plinth. Thus, there is no further decline in the PEC share of masonry work for this project. The energy contribution of bricks to the PEC is about 45%, similar to single and double storeyed units (Table 6.7). There is a percentage increase in the energy share of RCC work in the PEC similar to the rise observed from single to double storeyed units (Table 6.6). The energy contribution of steel to the PEC is about 16% (Table 6.8), comparable to that of single and double storeyed units. The energy shares of concrete work, flooring and finishing show a similar trend as for Project No. 14 (Table 6.6).

6.2.1.3. Project No. 16

Though the dwelling units in this project were also in load bearing masonry construction, the energy contribution of masonry work is limited to about 40.5% of the PEC, whereas RCC work is about 47% of the PEC (Table 6.6). Bricks and steel have energy shares of about 33% and 27% of the PEC respectively. (Table 6.7 and 6.8).

The energy shares of the both the components of masonry work are lower vis-à-vis the single and double storeyed projects (Table 6.9 and 5.9). Thus, it is inferred that significantly large four storeyed projects in load bearing construction will result in a decreasing energy share of masonry work, but an increasing share of RCC work. The energy contribution of concrete work, flooring and finishing show a similar trend as the two previous projects (Table 6.6).

Masonry and RCC work are again the major determiners of the PEC for all the projects, accounting for about 87-90% of the PEC. This means that the type of structural system in four storeyed construction does not effect the net contribution of these two major sub-works. This also shows that there is an average rise of about 8.5% in the combined energy share of masonry and RCC work vis-à-vis their share in single storeyed units and about 4.5% vis-à-vis their share in double storeyed units. Tables 6.7 and 6.8 also reveal that the combined energy share of bricks and steel for four storeyed projects is about 60% (avg.) in the PEC, similar to that for single and double storeyed units.

6.3. ENERGY RATES

Energy rates of the four storeyed projects have been obtained from their PEC estimates, as done in the previous chapters. The rates are presented in Table 6.10, whereas the Table 6.11 presents the individual shares of the sub-works in the energy rates. The PA energy rates are in the range of about 2885-3355 MJ/sqm and the FA energy rates are about 3435-3995 MJ/sqm.

6.3.1. Analysis

Table 6.12 presents the comparative ranges of the shares of sub-works in the energy rates for all units. The ranges of the total energy rates are also shown. It is seen that there is a substantial fall in the energy shares of masonry and concrete work for four storeyed projects vis-à-vis single and double storeyed units because the quantities of masonry and concrete work do not increase proportionately with the additional storeys, as discussed in Chapter 5. But there is a corresponding rise in the share of RCC work. The shares of flooring and finishing do not register any major changes.

Table 6.10: Energy Rates for Four Storeyed Housing Projects

Project No.	PA (sqm)	FA (sqm)	PEC = $EEC_T + TEC_T$ (MJ)	PA Energy Rate (MJ/sqm)	FA Energy Rate (MJ/sqm)
14	2046.00	1719.00	6867991.80	**3356.79**	**3995.34**
15	8907.00	7482.00	25689742.86	**2884.22**	**3433.54**
16	16680.00	14008.00	54557627.63	**3270.84**	**3894.75**

Table 6.11: Shares of Sub-works in Energy Rates for Four Storeyed Housing Projects

Project No.	Share of (MJ/sqm)						Total Energy Rate (MJ/sqm)
		Masonry Work	Concrete Work	RCC Work	Flooring	Finishing	
14	PA	925.33	89.30	2091.60	145.17	105.39	**3356.79**
	FA	1101.35	106.29	2489.48	172.78	125.44	**3995.34**
15	PA	1539.35	104.77	978.22	108.72	153.16	**2884.22**
	FA	1832.53	124.73	1164.53	129.42	182.33	**3433.54**
16	PA	1327.41	99.07	1528.09	129.80	186.47	**3270.84**
	FA	1580.61	117.97	1819.57	154.56	222.04	**3894.75**

Table 6.12: Comparative Ranges of Shares of Sub-works in Energy Rates for Single and Double Storeyed Dwelling Units and Four Storeyed Housing Projects

Project Type	Range of Share (MJ/sqm) of						
		Masonry Work	Concrete Work	RCC Work	Flooring	Finishing	Total
Single Storeyed	PA	1825-2875	365-715	705-1295	70-195	135-190	**3575-5250**
	FA	2255-3315	480-825	885-1490	85-230	160-220	**4415-6055**
Double Storeyed	PA	1420-1665	200-235	760-960	100-125	110-160	**2625-2995**
	FA	1705-1890	235-280	910-1140	120-150	135-180	**3155-3565**
Four Storeyed	PA	925-1540	90-105	980-2090	110-145	105-185	**2885-3355**
	FA	1100-1835	105-125	1165-2490	130-175	180-220	**3435-3995**

It is also seen that the PA energy rates for four storeyed projects are lower by about 690-1895 MJ/sqm (19-36%) as compared to the corresponding rates for single storeyed units, whereas the FA energy rates are lower by about 980-2060 MJ/sqm (22-34%), as seen in Table 6.12. But the PA energy rates of four storeyed projects are higher by about 260-360 MJ/sqm (10-12%) vis-à-vis the corresponding rates for double storeyed construction, whereas the FA energy rates are higher by about 280-430 MJ/sqm (9-12%).

Project No. 14 in RCC frame has the highest PA and FA energy rates in four storeyed construction. But they are also less than the corresponding energy rates for single storeyed load bearing masonry construction. Moreover, the variation in the energy rates for four storeyed projects is within about 550 MJ/sqm, which is considerably less than in single storeyed units, which are all in load bearing masonry construction. This proves that the structural system used in housing does not play a major role in determining the total energy needed in construction.

6.4. PEC EQUATIONS

The data presented in Table 6.10 has been used to derive Equations for the preliminary estimation of the PEC for four storeyed housing projects. The Equations are both linear and quadratic, as explained in Chapter 3. The corresponding trendlines are shown in Figs. 6.2-6.5. The Equations are as follows:

- $\mathbf{PEC = 3268.85\ A - 1070953.93}$ (refer Fig. 6.2) (6.2)
- $\mathbf{PEC = 0.07\ A^2 + 2016.86\ A + 2463861.16}$ (refer Fig. 6.3) (6.3)

  where A = Total PA of the project
- $\mathbf{PEC = 3892.59\ a - 1075947.42}$ (refer Fig. 6.4) (6.4)
- $\mathbf{PEC = 0.09\ a^2 + 2399.28\ a + 2465286.15}$ (refer Fig. 6.5) (6.5)

  where a = Total FA of the project

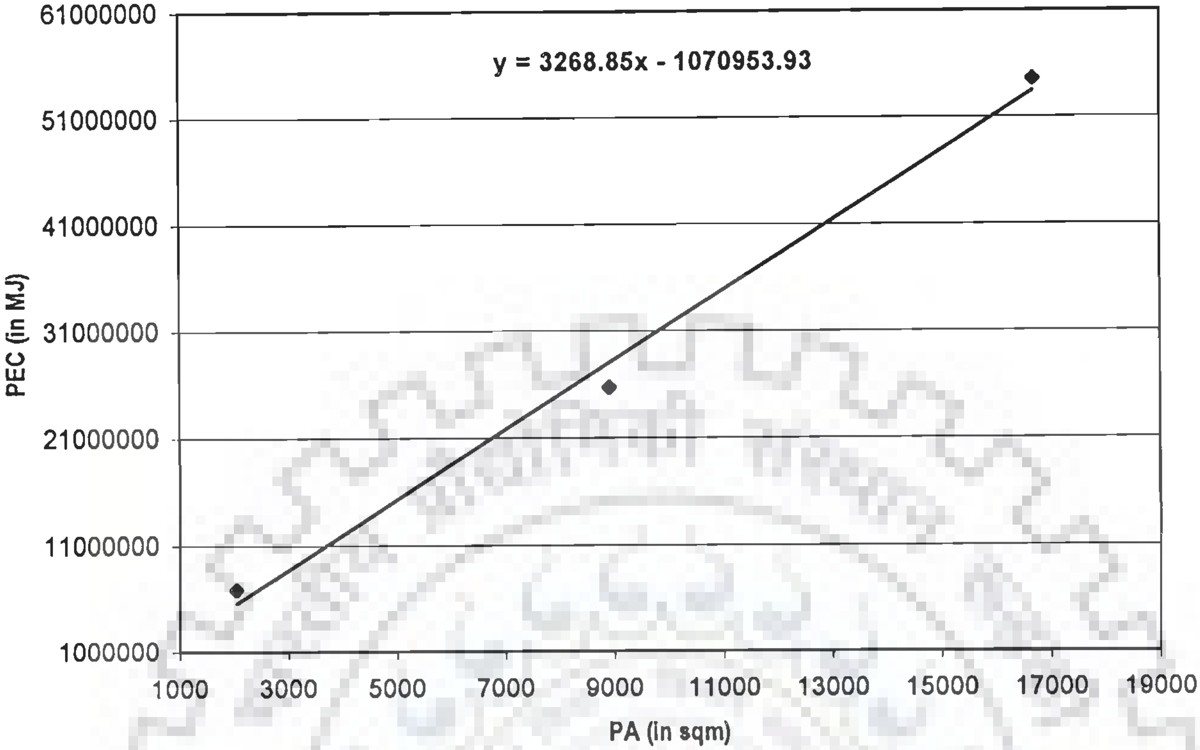

Fig. 6.2 : Linear Trend of PEC for Project Nos. 14-16 Using PA

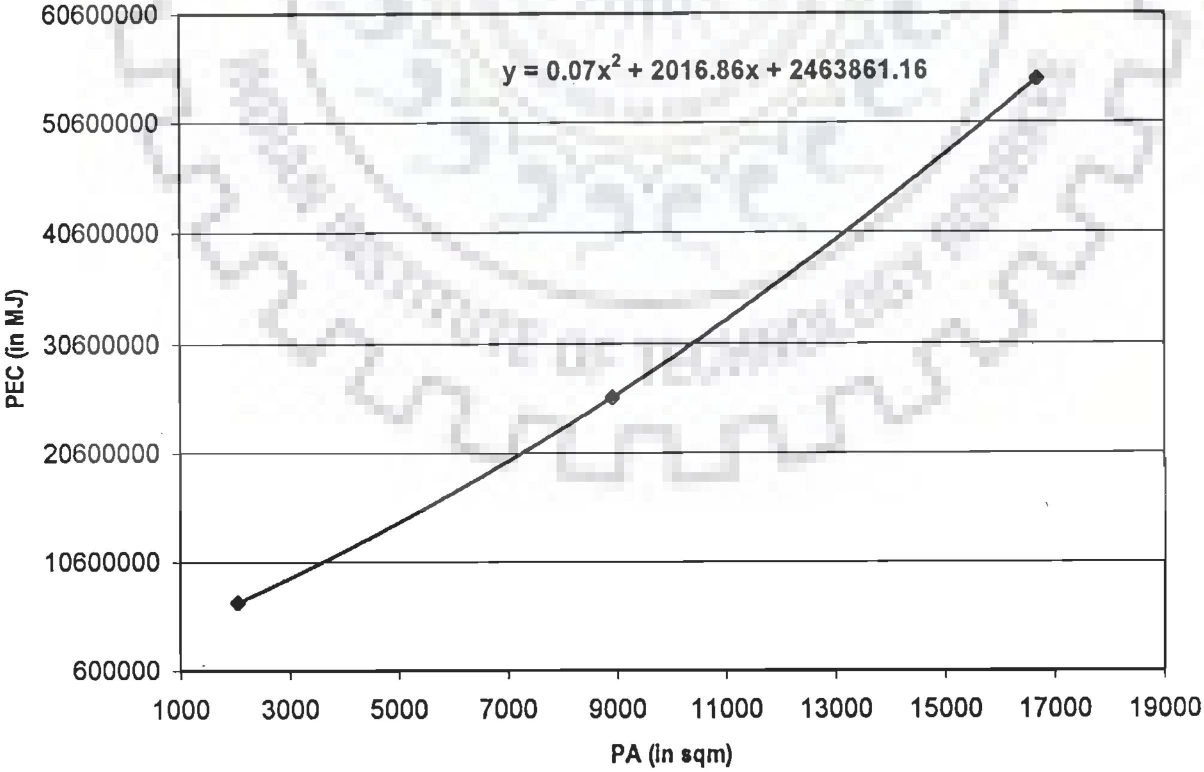

Fig. 6.3 : Quadratic Trend of PEC for Project Nos. 14-16 Using PA

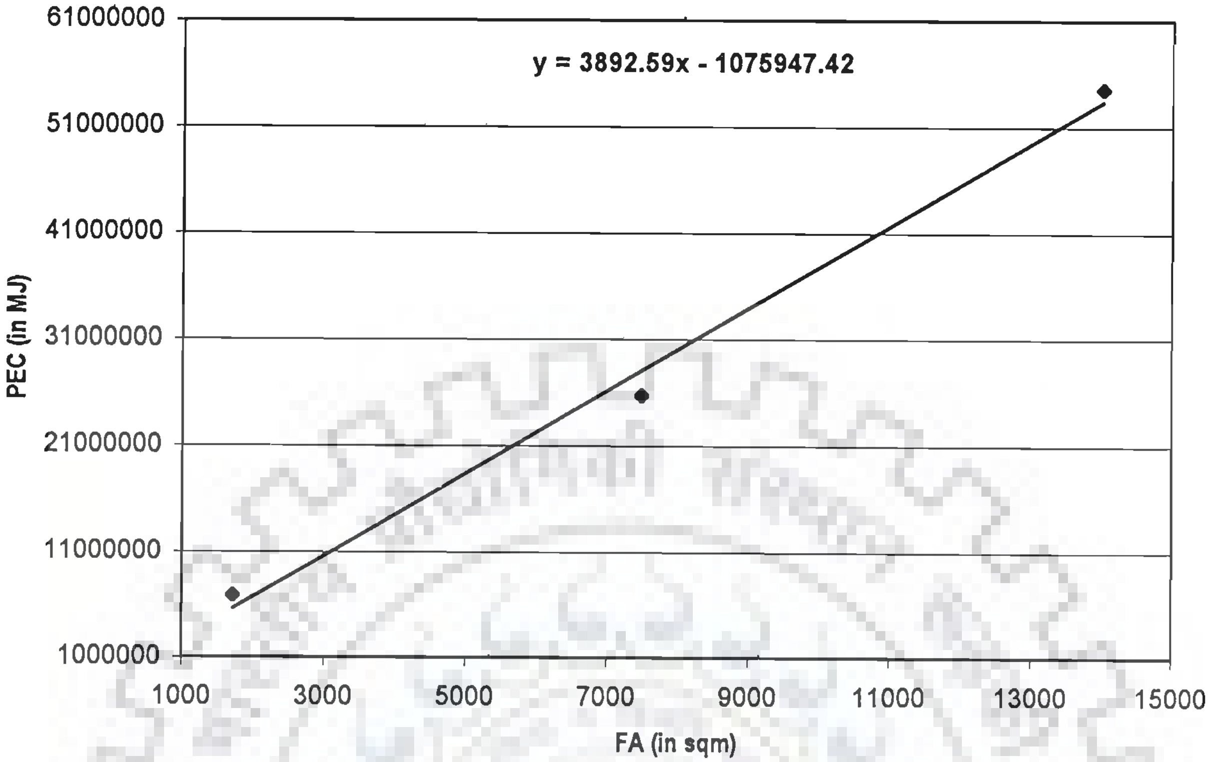

Fig. 6.4 : Linear Trend of PEC for Project Nos. 14-16 Using FA

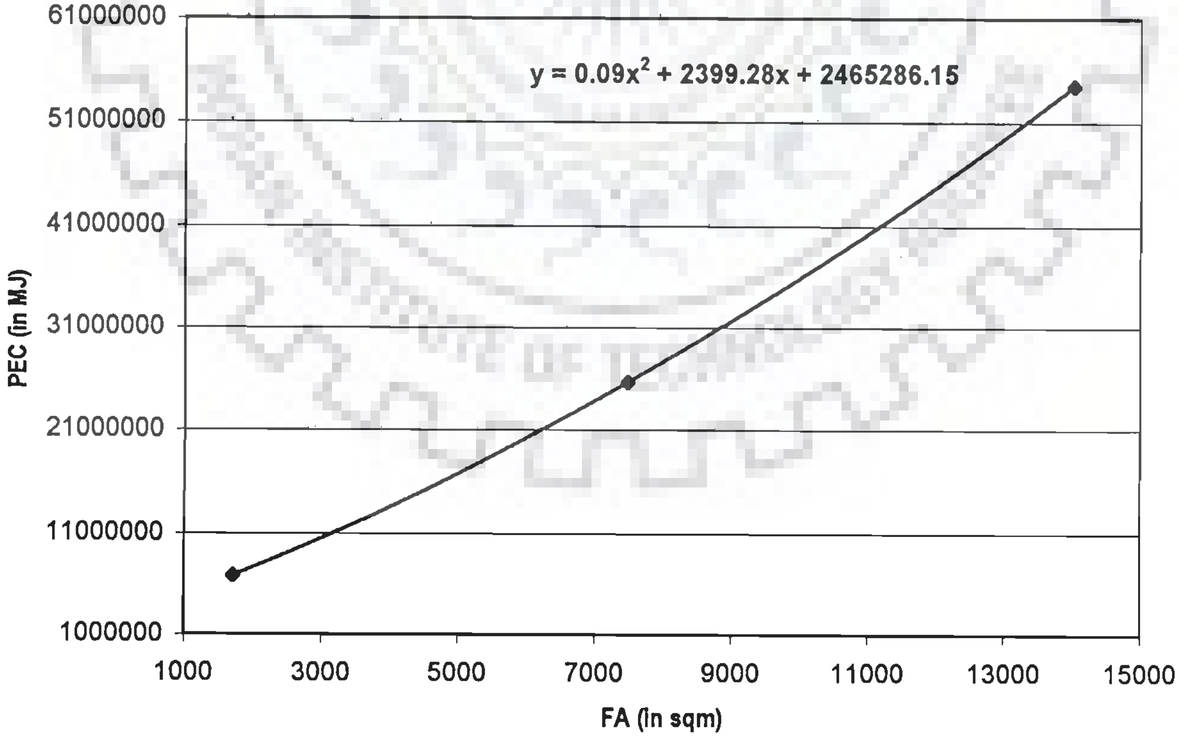

Fig. 6.5 : Quadratic Trend of PEC for Project Nos. 14-16 Using FA

Since Eqn. 3.3 (Chapter 3) is only applicable for PA from 30-100 sqm, it could not be applied here. Only Eqns. 3.5 and 3.6 have been considered. TEC_T has been again factored into both these equations. Eqn. 6.1 has been considered, where TEC_T had been added as a fraction of the EEC_T.

$$PEC = 1.0211\ EEC_T \qquad (6.1)$$

And $$EEC_T = 3059.84\ A \qquad (3.5)$$

$$\therefore \quad PEC = 1.0211\ (3059.84A)$$

- $$\mathbf{PEC = 3124.40\ A} \qquad (6.6)$$

The Eqn. 6.6 is only valid for four storeyed housing projects in load bearing construction. Similarly, for four storeyed projects in RCC framed construction, Eqn. 3.6 has been used. From Eqns. 3.6 and 6.1:

$$PEC = 1.0211\ (3333.18A)$$

- $$\mathbf{PEC = 3403.51A} \qquad (6.7)$$

Table 6.13 presents the PEC values computed from Eqns. 6.1-6.7, alongwith the estimated PEC for the four storeyed projects from the detailed estimates. The percentage deviations of the computed values from the estimated PEC are also shown.

6.4.1. Analysis

The deviations revealed that the nearest values to the estimated PEC are obtained from Eqn. 6.1. But this Equation can only be applied after the EEC_T estimate has been prepared. PEC computed from the linear Eqns. 6.2 and 6.4 give very large deviations. Therefore, they can be discarded. The quadratic Eqns. 6.3 and 6.5 give the closest values to the estimated PEC, but out of these two, Eqn. 6.5 is preferable.

Table 6.13: Estimated PEC from Equations vis-à-vis the Detailed Estimates for Project Nos. 14-16

Project No.		Estimated PEC (MJ) from							
		Detailed Estimate	Eqn. 6.1	Eqn. 6.2	Eqn. 6.3	Eqn. 6.4	Eqn. 6.5	Eqn. 6.6	Eqn. 6.7
14	PEC	6867991.80	6878907.26	5617113.17	6883384.84	5615414.79	6855594.96	-	6963581.46
	% Deviation	-	0.16	-18.21	0.22	-18.24	-0.18	-	1.39
15	PEC	25689742.86	25625892.38	28044693.02	25981458.61	28048410.96	25454928.27	27829030.80	-
	% Deviation	-	-0.25	9.17	1.14	9.18	-0.91	8.33	-
16	PEC	54557627.63	54605438.49	53453464.07	55580653.96	53451453.30	53734566.15	52114992.00	-
	% Deviation	-	0.09	-2.02	1.88	-2.03	-1.51	-4.48	-
Range of % Deviation		-	-0.25 to +0.16	-18.21 to +9.17	+0.22 to +1.88	-18.24 to +9.18	-1.51 to -0.18	-4.48 to +8.33	-

Eqn. 6.6 is applicable for load bearing construction, i.e., Project Nos. 15 and 16. This gives a maximum deviation of about +10%, which renders it unsuitable for preparing the preliminary PEC estimate. Eqn. 6.7 gives a deviation of only about +1.5%. But it can only be applied for RCC framed construction, i.e., Project No.14. More four storeyed projects in RCC frames will be needed to prove the validity of this equation.

Thus, Eqn. 6.5 is a suitable equation for estimating the PEC.

6.5. CONCLUDING REMARKS

The TEC_T again has very little impact on the PEC, being only about 2.1% of the EEC_T for the four storeyed projects. RCC work has the largest energy share in the PEC for Project No. 14, which is an RCC framed construction, whereas masonry work has the highest share for Project No. 15, which is in load bearing masonry. Though Project No. 16 is also in load bearing masonry, it is RCC work, which has the highest share in the PEC, closely followed by masonry work. This is due to the significant increase in the area of the project, which results in a decreasing share of masonry work, but an increasing share of RCC work. It is also evident that smaller four storeyed projects in load bearing construction (like No.15) have similar energy breakups of their sub-works as in single or double storeyed units.

Masonry and RCC work are the major determiners of the energy needed for four storeyed housing construction as they together account for nearly 87-90% of the PEC. Thus, there is an average rise of about 8.5% in the combined share of masonry and RCC work vis-à-vis their share in single storeyed units and about 4.5% vis-à-vis their share in double storeyed units.

The combined energy share of bricks and steel for four storeyed projects is about 60% (avg.) of the PEC, comparable to that for single and double storeyed units. This proves that the net energy share of bricks and steel in the PEC is nearly constant, irrespective of the type of housing or the structural system used.

The energy rates for four storeyed projects are lower by about 20-35% vis-à-vis the corresponding rates for single storeyed units, but are higher by about 10-12% as compared to the energy rates for double storeyed units. The range of the energy rates for four storeyed projects are also not large, despite having two different types of structural systems. This shows that the structural system used in housing is not the major determiner of the PEC .

The suitable Equation for providing a preliminary estimate of the PEC for four storeyed housing projects is:

- **PEC = $0.09\ a^2 + 2399.28\ a + 2465286.15$**

The above conclusions have been arrived at within the constraints of the available data of BOQ for four storeyed housing construction. But the results still hold true because, firstly, the trends obtained from the available data indicate that their energy rates will remain within the calculated range, i.e., there will be a symmetrical rise in the PEC of the four storeyed housing construction with increasing PA and FA. Secondly, when the data for single, double and four storeyed units is considered together, it reveals similar trends, viz.:

- Masonry and RCC work are the major determiners of the PEC, irrespective of the type of structural frame work used
- Bricks and steel have the same combined energy share in the PEC for all the three types of units

Availability of more data will help to further substantiate the above results of the PEC for four storeyed housing construction.

CHAPTER 7

ALTERNATIVES FOR MASONRY WORK

7.1. INTRODUCTION

The energy estimation of the sixteen projects reveals that masonry work is the single largest contributor to the PEC for nearly all the projects. Its share is about 50-60% in the PEC for single and double storeyed units and about 40-50% for four storeyed projects in load bearing construction. This share reduces to about 27% of the PEC in the four storeyed RCC framed construction. Therefore, masonry work has been selected to study the savings in its energy share that can be achieved by using alternatives because any such reduction will result in substantial savings in the PEC of a project.

7.2. ALTERNATIVES

The main cause for the high energy share of masonry work is primarily because of the high EEV of traditional burnt clay bricks, which generally account for 80-85% in the energy share of masonry work. Hence, it is imperative to find out energy efficient substitutes for bricks to reduce the energy cost of masonry work. Alongwith this, alternatives for the conventional 1:6 cement mortar (1 cement: 6 fine sand) need to be studied.

For this purpose, a total of eighty-nine combinations of masonry units and mortar mixes have been considered as alternatives for 1st class traditional brickwork in 1:6 cement mortar (1cement: 6 fine sand)[1].

[1] As the detailed estimates show, traditional brickwork in 1:6 cement mortar (1 cement: 6 fine sand) is the most common item of full brickwork in Northern India.

The chosen masonry units[1] and mortar mixes are:

Masonry Units

1. Traditional bricks (22.9cm x 11.4cm x 7.6cm)
2. Modular bricks (20cm x 10cm x 10cm)
3. Clay flyash bricks (20cm x 10cm x 10cm)
4. Sand lime bricks (20cm x 10cm x 10cm)
5. Hollow concrete blocks (40cm x 20cm x 10cm)
6. Hollow concrete blocks (40cm x 20cm x 20cm)
7. Aerated concrete blocks (40cm x 20cm x 20cm)
8. Solid concrete blocks (30cm x 20cm x 15cm)
9. Fal-G blocks (30cm x 20cm x 15cm)

Mortar Mixes

a. Lime mortar 1:1:1 (1 lime putty: 1 flyash: 1 fine sand)
b. Cement mortar 1:3 (1 cement: 3 fine sand)
c. Cement mortar 1:4 (1 cement: 4 fine sand)
d. Cement mortar 1:5 (1 cement: 5 fine sand)
e. Cement mortar 1:6 (1 cement: 6 fine sand)
f. Composite mortar 1:1:6 (1 cement: 1 lime putty: 6 fine sand)
g. Composite mortar 1:1:7 (1 cement: 1 lime putty: 7 fine sand)
h. Composite mortar 1:1:8 (1 cement: 1 lime putty: 8 fine sand)
i. Composite mortar 1:2:9 (1 cement: 2 lime putty: 9 fine sand)

The EER of the combinations are listed in Appendix-II (Schedule of Energy Rates). A similar selection of substitutes have also been considered as substitutes for half brick work in 1:3 or 1:4 cement mortar (1 cement: 3 or 4 coarse sand), with or without reinforcement. Their EER, alongwith the TER of all the alternate masonry works are also listed in Appendix-II.

7.3. ALTERNATE ENERGY RATES

Since full brickwork is the major component of masonry, variation in its energy rates have the maximum impact on the total energy cost of masonry work and consequently, on the PEC. Table 7.1 presents the variations in EER using alternatives to full brick work. They are listed as item 1a to 9j in the table. All the energy values are indexed to a standard value of 100 given to traditional brick work in 1:6 cement mortar (1f). The following observations are made from this data:

- For a given mortar mix, the energy rates are the highest for masonry work with traditional bricks, with an index range of 100-116.49 (1f -1c).

[1] Refer Appendix – I (Section B) for brief descriptions of these materials

Table 7.1: Comparative Embodied Energy Rates (EER) of Masonry Work Using Alternate Masonry Units and Mortar Mixes

Mortar Mix		EER (MJ/cum) of Masonry Work Using								
		Masonry Unit								
		Traditional Bricks (22.9 x 11.4 x 7.6)#	Modular Bricks (20 x 10 x 10)	Clay Flyash Bricks (20 x 10 x 10)	Sand Lime Blocks (20 x 10 x 10)	Hollow Concrete Blocks (40 x 20 x 10)	Hollow Concrete Blocks (40 x 20 x 20)	Aerated Concrete Blocks (40 x 20 x 20)	Solid Concrete Blocks (30x 20x15)	Fal-G Blocks (30x20x15)
		1	2	3	4	5	6	7	8	9
Lime mortar 1:1:1 (1 lime putty: 1 flyash:1 fine sand)	a	2712.13	2621.93	1560.30	1789.16	1800.00	1015.82	1047.32	1556.10	1276.10
		102.66	99.25	59.06	67.72	68.14	38.45	39.64	58.90	48.31
Lime mortar 1:1:1 (1 lime putty: 1 surkhi: 1 fine sand)	b	2885.44	2774.45	1712.78	1941.68	1959.45	1130.21	1161.71	1694.75	1414.80
		109.22	105.02	64.84	73.50	74.17	42.78	43.98	64.15	53.56
Cement mortar 1:3 (1 cement:3 fine sand)	c	3077.25	2943.24	1881.60	2110.50	2135.91	1256.81	1288.31	1848.20	1568.20
		116.49	111.41	71.23	79.89	80.85	47.57	48.77	69.96	59.36
Cement mortar 1:4 (1 cement: 4 fine sand)	d	2859.50	2751.62	1690.00	1918.85	1935.58	1113.10	1144.60	1674.00	1394.00
		108.24	104.16	63.97	72.64	73.27	42.13	43.33	63.37	52.77
Cement mortar 1:5 (1 cement: 5 fine sand)	e	2742.25	2648.44	1586.78	1815.67	1827.17	1035.71	1067.21	1580.20	1300.20
		103.80	100.25	60.07	68.73	69.17	39.21	40.40	59.82	49.22
Cement mortar 1:6 (1 cement: 6 fine sand)	f	2651.75	2560.00	1498.34	1727.23	1735.25	969.38	1001.00	1499.80	1219.80
		100.00	96.91	56.72	65.38	65.69	36.69	37.89	56.77	46.17
Cement lime mortar 1:1:6 (1 cement: 1 lime putty: 6 fine sand)	g	2825.38	2721.60	1660.00	1888.82	1904.20	1090.57	1122.07	1646.70	1366.70
		106.95	103.02	62.84	71.50	72.08	41.28	42.47	62.33	51.73
Cement lime mortar 1:1:7 (1 cement:1 lime putty: 7 fine sand	h	2749.13	2654.60	1592.83	1821.72	1834.04	1040.24	1071.74	1585.70	1305.70
		104.06	100.48	60.29	68.96	69.43	39.38	40.57	60.02	49.43
Cement lime mortar 1:1:8 (1 cement: 1 lime putty: 8 fine sand)	i	2677.75	2591.68	1530.00	1758.91	1768.37	993.14	1024.64	1528.60	1248.60
		101.36	98.10	57.92	66.58	66.94	37.59	38.79	57.86	47.26
Cement lime mortar 1:2:9 (1 cement: 2 lime putty: 9 fine sand)	j	2753.13	2658.00	1596.35	1825.24	1837.72	1043.00	1074.50	1588.90	1308.90
		104.22	100.62	60.43	69.09	69.56	39.48	40.67	60.15	49.55

All dimensions in cms

- They are least with hollow blocks (40cm x 20cm x 20cm), with a range of 36.69-47.57 (6f-6c).
- For a given masonry unit, the EER is the highest for masonry work in 1:3 cement mortar (1cement: 3 fine sand) with a range of 47.57-116.49 (6c-1c). It is the least for masonry in 1:6 cement mortar (1cement: 6 fine sand) having a range of 36.69-100 (6f-1f).
- The alternative having the maximum EER was traditional brick masonry in 1:3 cement mortar, having an index of 116.49 (1c), i.e., an EER which was about 17% greater than that of the original brickwork.
- Hollow block masonry (40 cm x 20 cm x 20 cm) in 1:6 cement mortar has the least EER with an index of 36.69 (6f). This means a saving of upto 63% of the EER of traditional brick work in 1:6 cement mortar.
- The descending order of the energy efficiency of masonry units and mortar mixes vis-à-vis their EER is as follows:

Masonry Units	Mortar Mixes
▪ Hollow concrete blocks (40cm x 20cm x 20cm)	▪ Cement mortar 1:6 (1 cement: 6 fine sand)
▪ Aerated concrete blocks (40cm x 20cm x 20cm)	▪ Composite mortar 1:1:8 (1 cement: 1 lime putty: 8 fine sand)
▪ Fal-G blocks (30cm x 20cm x 15cm)	▪ Lime mortar 1:1:1 (1 lime putty: 1 flyash: 1 fine sand)
▪ Solid concrete blocks (30cm x 20cm x 15cm)	▪ Cement mortar 1:5 (1 cement: 5 fine sand)
▪ Clay flyash bricks (20cm x 10cm x 10cm)	▪ Composite mortar 1:1:7 (1 cement: 1 lime putty: 7 fine sand)
▪ Sand lime bricks (20cm x 10cm x 10cm)	▪ Composite mortar 1:2:9 (1 cement: 2 lime putty: 9 fine sand)
▪ Hollow concrete blocks (40cm x 20cm x 10cm)	▪ Composite mortar 1:1:6 (1 cement: 1 lime putty: 6 fine sand)
▪ Modular bricks (20cm x 10cm x 10cm)	▪ Cement mortar 1:4 (1 cement: 4 fine sand)
▪ Traditional bricks (22.9cm x 11.4cm x 7.6cm)	▪ Cement mortar 1:3 (1 cement: 3 fine sand)

7.3.1. Analysis

The energy savings achieved in masonry work by using hollow blocks (40 cm x 20 cm x 20 cm) and aerated blocks vis-à-vis traditional bricks are because of the following factors:

- Size of blocks: Because these blocks are larger in size, only 63 numbers of each type of block are required per cum of masonry work as against 494 numbers of traditional bricks. Therefore, though the EEV of the blocks is higher than traditional bricks (Table 3.1), their contribution to the EER of masonry work is substantially less.

- Saving in mortar volume: The larger size of the blocks also reduce the number of mortar joints required per cum of masonry work. Therefore, the mortar requirement falls from 0.25 cum for traditional brick work to 0.165 cum for hollow and aerated concrete blocks (40 cm x 20 cm x 20 cm), resulting in a further reduction in the EER of masonry work.

Table 7.2 shows a sample breakup of materials and energy for the substitutes vis-à-vis traditional bricks. The reduction in the EER by using Fal-G blocks masonry is also less because of the same reasons (refer Table 7.2). The Fal-G blocks have the added advantage of a comparatively low EEV[1] because of the use of flyash[2] in their composition.

The clay flyash bricks have the same volume as traditional bricks. Moreover, masonry work using either of them requires nearly the same volume of mortar mix. But the EEV of a clay flyash brick is only 2.32 MJ as against 4.5 MJ for a traditional brick. This is again because of the presence of flyash, which can replace clay in traditional bricks by upto 40%. Flyash has a very small calorific content due to the unburnt carbon left behind in it as a residue. This carbon aids the firing of clay flyash bricks in the kiln, reducing the energy required in their firing and significantly reducing their EEV vis-à-vis traditional bricks. Therefore, the contribution of masonry units to the EER of masonry work is nearly halved by substituting traditional bricks with clay flyash bricks (refer Table 7.2).

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[1] Fal-G blocks have and EEV of 7.90 MJ/block compared to the same sized solid concrete blocks, which have an EEV of 10.40 MJ/block

[2] Flyash is a waste by-product of thermal power plants and hence has an EEV = 0.0 MJ

Table 7.2: Comparative Breakup of EER of Alternate Masonry Work vis-à-vis Traditional Brickwork

Item Code No.[1]	Description of Item of Work	Materials	Unit	Quantity	Energy Value (MJ/Unit)	Energy Value (MJ)	EER
2.2.11.	Masonry work with 1st class traditional bricks and 1: 6 cement mortar (1 cement: 6 fine sand) in foundation & plinth (Details for 1 cum)	1st class bricks Cement mortar 1:6	nos cum	494 0.25	4.50 1675.00	2223.00 418.75	**2641.75 MJ/cum**
2.3.6.	Masonry work with clay flyash bricks and 1: 6 cement mortar (1 cement: 6 fine sand) in foundation & plinth (Details for 1 cum)	1st class bricks Cement mortar 1:6	nos cum	487 0.22	2.32 1675.00	1129.84 368.50	**1498.34 MJ/cum**
2.3.57.	Masonry work with hollow concrete blocks (40cm x 20cm x 20cm) and 1:6 cement mortar (1 cement : 6 fine sand) in foundation and plinth (Details for 1 cum)	Hollow blocks (40cm x 20cm x 20cm) Cement mortar 1:6	nos cum	63 0.165	11.00 1675.00	693.00 276.38	**969.38 MJ/cum**
2.3.69.	Masonry work with aerated concrete blocks and 1:6 cement mortar (1 cement : 6 fine sand) in foundation and plinth (Details for 1 cum)	Aerated blocks Cement mortar 1:6	nos cum	63 0.165	11.50 1675.00	724.50 276.38	**1001.00 MJ/cum**
2.3.98.	Masonry work with Fal-G blocks and 1:6 cement mortar (1 cement : 6 fine sand) in foundation and plinth (Details for 1 cum)	Fal-G blocks Cement mortar 1:6	nos cum	112 0.20	7.90 1675.00	884.80 335.00	**1219.80 MJ/cum**

[1] Refer Appendix-II, 'Schedule of Energy Rates'

7.4. ESTIMATION OF ENERGY COSTS

A comparison of the EER of alternate masonry works does not show the actual savings in energy cost of a project, since masonry is only one of the components of civil work. Therefore, it is essential to estimate the PEC of a project using the substitutes to determine the net reduction. This has been done by applying the EER of the combinations to estimate the energy costs of the alternative masonry works (EEC_T and TEC_T) from the detailed energy estimates of all the projects. The new EEC_T and TEC_T values thus obtained have been totalled to obtain the resultant PEC for all the projects. For this purpose, the ninety combinations have been narrowed down to a select forty-five. These include all the nine masonry units (including the traditional bricks). But only five mortar mixes have been taken, which include 1:3 cement mortar, which has the highest range of EER and 1:6 cement mortar, which has the least range. The selected mortar mixes are a lime mortar mix using flyash (1: 1: 1), three cement mortar mixes (1:3, 1:5 and 1:6) and one composite cement lime mortar (1:1:6).

7.4.1. Estimation of EEC_1 and EEC_T

The EEC_I (EEC for masonry work) has been estimated for all the projects using the selected alternatives. The following assumptions have been made while doing these calculations:

1. For all the half brickwork, only bricks have been substituted with the alternate units and the remaining specification is the same as originally adopted for half brick masonry in all the projects. This has been done because half brick masonry work requires stronger mortar mixes similar to those used in the projects.
2. Half masonry work is not possible for hollow blocks (40cm x 20cm x 20cm) and aerated blocks since they are not manufactured with a dimension corresponding to half brick thickness, i.e., 11.4 cm (or 10 cm). Hence, the energy cost of half masonry with hollow blocks (40cm x 20cm x 10cm) have been applied for the half masonry work in the former units.

The EEC_1 values of the combinations have been then used to estimate the resultant EEC_T of the projects. The alternate EEC_1 values are presented in Tables IV.1.1-IV.1.16 (Appendix-IV) and the corresponding EEC_T values are shown in Tables IV.2.1 - IV.2.16 (Appendix-IV). The Chart 7.1 illustrates sample calculations of these energy values for Project No.4.

7.4.2. Estimation of TEC_1 and TEC_T

The alternative values of TEC_1 have been estimated for all the projects and the resultant TEC_T values have been obtained (refer Chart 7.1). The TEC_1 and the TEC_T have two sets of values for each project, one where the masonry work is in lime mortar1:1:1 (1 lime: 1 flyash: 1 fine sand) and the second where it is in cement (or composite) mortar. This is so because of the variation in the TER of masonry work in lime mortar vis-à-vis in cement mortar. The complete calculations are shown in Tables IV.3.3-IV.3.6 (Appendix-IV).

7.4.3. Estimation of PEC

The PEC values have been estimated by totalling the range of EEC_T and TEC_T for each project, as illustrated in Chart 7.1. All the alternate PEC values have been indexed to a value of 100, given to traditional brickwork in 1:6 cement mortar. The PEC calculations for all the projects are shown in Tables IV.4.1 – IV.4.16 (Appendix-IV).

7.4.3.1. Analysis

The average PEC indices of the alternative masonry combinations for the three types of dwelling projects are given in Tables 7.3-7.5. The maximum deviations from the standard value occur in single storeyed projects and the least in the four storeyed projects. This is because the proportion of masonry vis-à-vis the other sub-works is greater in the single storeyed projects as compared to the four storeyed projects, as seen in Chapter 6. Therefore, the effect of the change in the energy cost of masonry on the PEC is also greater in the former.

Table IV.1.4: Embodied Energy Costs of Masonry Work (EEC_1) in Project No. 4 Using Alternate Masonry Units and Mortar Mixes

			EEC_1 (in MJ) using								
No.	Mortar Mix Ratio		Traditional Bricks (22.9 cm X 11.4 cm X 7.6 cm)	Modular Bricks (20 cm X 10 cm X 10 cm)	Clay Flyash Bricks (20 cm X 10 cm X 10 cm)	Sand Lime Bricks (20 cm X 10 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 20 cm)	Aerated Concrete Blocks (40 cm X 20 cm X 20 cm)	Solid Concrete Blocks (30 cm X 20 cm X 15 cm)	Fal-G Blocks (30 cm X 20 cm X 15 cm)
1.	1:1:1 (1 Lime Putty: 1 Flyash : 1 Fine Sand)	Full Brick	137505.00	132931.85	79107.21	90710.41	91260.00	51502.07	53099.12	78894.27	64698.27
		Half Brick	8129.70	10448.34	6539.60	7382.31	6284.02	6284.02	6284.02	5504.21	4615.86
		EEC_1	145634.70	143380.19	85646.81	98092.72	97544.02	57786.09	59383.14	84398.48	69314.13
2.	1:3 (1 Cement : 3 Fine Sand)	Full Brick	156016.58	149222.27	95397.12	107002.35	108290.64	63720.27	65317.32	93703.74	79507.74
		Half Brick	8129.70	10448.34	6539.60	7382.31	6284.02	6284.02	6284.02	5504.21	4615.86
		EEC_1	164146.28	159670.61	101936.72	114384.66	114574.66	70004.29	71601.34	99207.95	84123.60

Table IV.2.4: EEC_1 and Resultant EEC_T for Project No. 4 Using Alternate Masonry Units and Mortar Mixes

			EEC_1 (in MJ) and EEC_T (in MJ) Using								
No.	Mortar Mix Ratio		Traditional Bricks (22.9 cm X 11.4 cm X 7.6 cm)	Modular Bricks (20 cm X 10 cm X 10 cm)	Clay Flyash Bricks (20 cm X 10 cm X 10 cm)	Sand Lime Bricks (20 cm X 10 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 20 cm)	Aerated Concrete Blocks (40 cm X 20 cm X 20 cm)	Solid Concrete Blocks (30 cm X 20 cm X 15 cm)	Fal-G Blocks (30 cm X 20 cm X 15 cm)
1.	1:1:1 (1 Lime Putty: 1 Flyash : 1 Fine Sand)	EEC_1	145634.70	143380.19	85646.81	98092.72	97544.02	57786.09	59383.14	84398.48	69314.13
		EEC_T	256128.33	253873.82	196140.44	208586.35	208037.65	168279.72	169876.77	194892.11	179807.76
2.	1:3 (1 Cement : 3 Fine Sand)	EEC_1	164146.28	159670.61	101936.72	114384.66	114574.66	70004.29	71601.34	99207.95	84123.60
		EEC_T	274639.91	270164.24	212430.35	224878.29	225068.29	180497.92	182094.97	209701.58	194617.23

Table IV.3.2: TEC_1 and Resultant TEC_T in Single Storeyed Dwellings Using Alternate Masonry Units and Cement Mortar

No.	Project		TEC_1 (in MJ) and TEC_T (in MJ) Using Cement Mortar and								
			Traditional Bricks (22.9 cm X 11.4 cm X 7.6 cm)	Modular Bricks (20 cm X 10 cm X 10 cm)	Clay Flyash Bricks (20 cm X 10 cm X 10 cm)	Sand Lime Bricks (20 cm X 10 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 20 cm)	Aerated Concrete Blocks (40 cm X 20 cm X 20 cm)	Solid Concrete Blocks (30 cm X 20 cm X 15 cm)	Fal-G Blocks (30 cm X 20 cm X 15 cm)
4.	4	TEC_1	3729.72	3729.72	2781.10	3729.72	3453.44	3221.07	3179.92	4724.20	4724.20
		TEC_T	6447.75	6447.75	5499.13	6447.75	6171.47	5939.10	5897.95	7442.23	7442.23

Table IV.4.4: PEC and its Index for Project No. 4 Using Alternate Masonry Units and Mortar Mixes

			PEC and its Index with Varying EEC_1 & TEC_1 Using								
No.	Mortar Mix Ratio		Traditional Bricks (22.9 cm X 11.4 cm X 7.6 cm)	Modular Bricks (20 cm X 10 cm X 10 cm)	Clay Flyash Bricks (20 cm X 10 cm X 10 cm)	Sand Lime Bricks (20 cm X 10 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 20 cm)	Aerated Concrete Blocks (40 cm X 20 cm X 20 cm)	Solid Concrete Blocks (30 cm X 20 cm X 15 cm)	Fal-G Blocks (30 cm X 20 cm X 15 cm)
1	1:1:1 (1 Lime Putty: 1 Flyash : 1Fine Sand)	PEC	262444.26	260189.75	201507.23	214902.28	214072.10	174119.31	175675.20	202214.51	187130.16
		INDEX	101.33	100.46	77.80	82.97	82.65	67.23	67.83	78.07	72.25
2.	1:3 (1 Cement : 3 Fine Sand)	PEC	281087.66	276612.00	217929.48	231326.04	231239.76	186437.02	187992.92	217143.81	202059.46
		INDEX	108.52	106.80	84.14	89.31	89.28	71.98	72.58	83.84	78.01

Chart 7.1: Sample Computations of EEC_1, EEC_T, TEC_1, TEC_T and Resultant PEC Using Alternate Masonry Works

The masonry work in 1:3 cement mortar has the highest range of PEC for all the projects, with indices of about 71.6-108.6 for single storeyed and 72.4-108.4 for double storeyed units. The corresponding range for four storeyed projects is 79.9-105.3.

The lowest PEC range is obtained for masonry in 1:6 cement mortar, with indices of 65.9-100.0 for single storeyed and 66.9-100.0 for double storeyed units. The range for four storeyed projects was 76.3-100.0. Table 7.6 shows the index ranges for the combination of all nine masonry units and five mortar mixes, when all the projects are considered together.

Traditional bricks give the highest range of PEC with all mortar mixes, whereas hollow concrete blocks (40 cm x 20 cm x 20 cm) give the least range, as seen earlier in the comparison of the EER values of the combinations. The suitable alternative combinations vis-à-vis the PEC are:

- Hollow concrete blocks (40cm x 20cm x 20cm) in 1:6 cement mortar or in 1:5 cement mortar or in 1:1:1 lime mortar
- Aerated concrete blocks(40cm x 20cm x 20cm) in 1:6 cement mortar or in 1:5 cement mortar or in 1:1:1 lime mortar

Masonry work in the above mentioned blocks give PEC savings of about 25-35% vis-à-vis traditional brickwork. Masonry work in building materials, which are manufactured using industrial by products, also give energy savings vis-à-vis traditional brick work. The suitable alternatives are as follows:

- Fal-G blocks in 1:6 cement mortar or in 1:5 cement mortar or in 1:1:1 lime mortar
- Clay flyash bricks in 1:6 cement mortar or in 1:5 cement mortar or in 1:1:1 lime mortar

These combinations give energy savings in the range of about 15-25% as compared to the traditional brickwork.

TABLE 7.3: PEC Index for Single Storeyed Dwelling Units Using Alternate Masonry Units and Mortar Mixes

			PEC Index with Varying EEC_1 & TEC_1 Using								
No.	Mortar Mix Ratio		Traditional Bricks (22.9 X 11.4 X 7.6)#	Modular Bricks (20 X 10 X 10)	Clay Flyash Bricks (20 X 10 X 10)	Sand Lime Bricks (20 X 10 X 10)	Hollow Concrete Blocks (40 X 20 X 10)	Hollow Concrete Blocks (40 X 20 X 20)	Aerated Concrete Blocks (40 X 20 X 20)	Solid Concrete Blocks (30 X 20 X 15)	Fal-G Blocks (30 X 20 X 15)
1.	1:1:1 (1 Lime Putty: 1 Flyash: 1 Fine Sand)	INDEX	101.33	99.87	77.67	82.74	82.55	67.09	67.70	78.04	72.32
2.	1:3 (1 Cement : 3 Fine Sand)	INDEX	108.61	106.28	83.82	88.94	89.03	71.55	72.15	83.60	77.82
3.	1:5 (1 Cement : 5 Fine Sand)	INDEX	101.98	100.44	77.98	83.11	82.92	67.17	67.78	78.25	72.51
4.	1:6 (1 Cement : 6 Fine Sand)	INDEX	100.00	98.69	76.24	81.36	81.10	65.86	66.64	76.71	70.92
5.	1:1:6 (1 Cement : 1 Lime Putty : 6 Fine Sand)	INDEX	103.62	101.89	79.44	84.56	84.45	67.99	68.86	79.61	73.83

TABLE 7.4: PEC Index for Double Storeyed Dwelling Units Using Alternate Masonry Units and Mortar Mixes

			PEC Index with Varying EEC_1 & TEC_1 Using								
No.	Mortar Mix Ratio		Traditional Bricks (22.9 X 11.4 X 7.6)	Modular Bricks (20 X 10 X 10)	Clay Flyash Bricks (20 X 10 X 10)	Sand Lime Bricks (20 X 10 X 10)	Hollow Concrete Blocks (40 X 20 X 10)	Hollow Concrete Blocks (40 X 20 X 20)	Aerated Concrete Blocks (40 X 20 X 20)	Solid Concrete Blocks (30 X 20 X 15)	Fal-G Blocks (30 X 20 X 15)
1.	1:1:1 (1 Lime Putty: 1 Flyash: 1 Fine Sand)	INDEX	101.29	99.69	78.12	83.05	82.95	67.73	68.31	78.57	73.00
2.	1:3 (1 Cement : 3 Fine Sand)	INDEX	108.39	105.95	84.38	89.31	89.49	72.41	73.01	84.26	78.70
3.	1:5 (1 Cement : 5 Fine Sand)	INDEX	101.92	100.25	78.69	83.61	83.53	68.14	68.74	79.08	73.51
4.	1:6 (1 Cement : 6 Fine Sand)	INDEX	100.00	98.54	76.98	81.90	81.75	66.86	67.45	77.53	71.96
5.	1:1:6 (1 Cement : 1 Lime Putty : 6 Fine Sand)	INDEX	103.52	101.67	80.10	85.03	85.02	69.20	69.80	80.37	74.80

#All dimensions in cms

TABLE 7.5: PEC Index for Four Storeyed Housing Projects Using Alternate Masonry Units and Mortar Mixes

No.	Mortar Mix Ratio		PEC Index with Varying EEC_1 & TEC_1 Using Traditional Bricks (22.9 X 11.4 X 7.6)	Modular Bricks (20 X 10 X 10)	Clay Flyash Bricks (20 X 10 X 10)	Sand Lime Bricks (20 X 10 X 10)	Hollow Concrete Blocks (40 X 20 X 10)	Hollow Concrete Blocks (40 X 20 X 20)	Aerated Concrete Blocks (40 X 20 X 20)	Solid Concrete Blocks (30 X 20 X 15)	Fal-G Blocks (30 X 20 X 15)
1.	1:1:1 (1 Lime Putty: 1 Flyash: 1 Fine Sand)	INDEX	100.70	100.13	84.27	87.89	86.79	76.87	77.26	83.57	79.45
2.	1:3 (1 Cement : 3 Fine Sand)	INDEX	105.33	104.09	88.47	91.93	91.03	79.93	80.31	87.28	83.24
3.	1:5 (1 Cement : 5 Fine Sand)	INDEX	101.11	100.37	84.75	88.22	87.14	77.15	77.06	83.49	79.87
4.	1:6 (1 Cement : 6 Fine Sand)	INDEX	100.00	99.26	83.64	87.11	85.98	76.31	76.70	82.89	78.86
5.	1:1:6 (1 Cement : 1 Lime Putty : 6 Fine Sand)	INDEX	102.15	101.30	85.67	89.11	88.11	77.84	78.22	84.74	80.71

TABLE 7.6: Comparative Ranges of PEC Indices for All Projects Using Alternate Masonry Units and Mortar Mixes

No.	Mortar Mix Ratio		PEC Index with Varying EEC_1 & TEC_1 Using Traditional Bricks (22.9 X 11.4 X 7.6)	Modular Bricks (20 X 10 X 10)	Clay Flyash Bricks (20 X 10 X 10)	Sand Lime Bricks (20 X 10 X 10)	Hollow Concrete Blocks (40 X 20 X 10)	Hollow Concrete Blocks (40 X 20 X 20)	Aerated Concrete Blocks (40 X 20 X 20)	Solid Concrete Blocks (30 X 20 X 15)	Fal-G Blocks (30 X 20 X 15)
1.	1:1:1 (1 Lime Putty: 1 Flyash: 1 Fine Sand)	INDEX	100.70-101.33	99.87 - 100.13	77.67 - 84.27	82.74 - 87.89	82.55 - 86.79	67.09 – 76.87	67.70 – 77.26	78.04 – 83.57	72.32 – 79.45
2.	1:3 (1 Cement : 3 Fine Sand)	INDEX	105.33 - 108.61	104.09 - 106.28	83.82 – 88.47	88.94 – 91.93	89.03 – 91.03	71.55 – 79.93	72.15 – 80.31	83.60-87.28	77.82 – 83.24
3.	1:5 (1 Cement : 5 Fine Sand)	INDEX	101.11 - 101.98	100.37 – 100.44	77.98 – 84.75	83.11 – 88.22	82.92 – 87.14	67.17 – 77.15	67.78 – 77.06	78.25 – 83.49	72.51 – 79.87
4.	1:6 (1 Cement : 6 Fine Sand)	INDEX	100.00	98.69 – 99.26	76.24 – 83.64	81.36 – 87.11	81.10 – 85.98	65.86 – 76.31	66.64 – 76.70	76.71 – 82.89	70.92 – 78.86
5.	1:1:6 (1 Cement : 1 Lime Putty : 6 Fine Sand)	INDEX	102.15 - 103.62	101.30 - 101.89	79.44 – 85.67	84.56 – 89.11	84.45 – 88.11	67.99 – 77.84	68.86 – 78.22	79.61 – 84.74	73.83 – 80.71

The cement mortar mixes most commonly used for masonry work in housing construction in Northern India are 1:5 and 1:6. The 1:1:1 lime mortar is normally not adopted because it sets slowly. Moreover, it is difficult to handle three types of materials. It is also difficult to obtain lime and flyash of consistently good quality for large-scale projects.

7.5. ENERGY RATES

All the four masonry units discussed above, viz., aerated and hollow concrete blocks (40 cm x 20 cm x 20 cm), clay flyash bricks and Fal-G blocks, give the least energy rates when used with 1:6 cement mortar. Table 7.7 presents the comparative PA and FA energy rates and their ranges for the projects using these alternatives for masonry work. The fall in the energy rates using alternatives vis-à-vis traditional brickwork are shown in Table 7.8.

7.5.1. Analysis

Figs. 7.1-7.4 further highlight the decreasing energy levels by using these combinations. The fall in the energy rates is steeper in single storeyed units, followed by double and four storeyed projects in that order. This is because the share of masonry work in the energy rates falls with an increase in the number of storeys[1]. Therefore, the change in its share has a lesser effect on the energy rates with the increasing number of storeys.

7.6. PEC EQUATIONS

The four masonry units in 1:6 cement mortar have been selected to obtain the mathematical Equations for estimating the PEC of housing construction using alternative masonry work. Both linear and quadratic Equations have been fitted in the available data, as done in Chapters 4-6.

[1] Energy share of masonry work falls because of the proportionate fall in the quantity of masonry work with the additional storeys as mentioned earlier in this chapter and in Chapters 5 and 6.

Table 7.7: Comparative Energy Rates for All Projects Using Alternate Masonry Works

Project No.			Energy Rates(MJ/sqm) with masonry work in 1:6 cement mortar and				
			Traditional Bricks	Clay Flyash Bricks	Hollow Concrete Blocks (40x20x20)	Aerated Concrete Blocks	Fal-G Blocks
Single Storeyed Projects	1	PA	3929.86	2982.04	2556.74	2591.44	2784.05
		FA	4707.85	3572.40	3062.90	3104.47	3335.20
	2	PA	3929.14	2912.70	2456.60	2483.59	2700.36
		FA	4922.50	3649.08	3077.68	3111.49	3383.07
	3	PA	4161.02	3168.50	2723.19	2749.54	2961.21
		FA	4843.47	3688.17	3169.82	3200.49	3446.87
	4	PA	3732.10	2860.20	2476.31	2476.43	2657.00
		FA	4712.66	3611.68	3126.93	3127.08	3355.09
	5	PA	3578.97	2814.74	2481.37	2500.95	2639.53
		FA	4414.37	3471.76	3060.58	3084.72	3255.64
	6	PA	4009.05	2938.37	2457.93	2486.36	2714.71
		FA	4776.61	3500.94	2928.52	2962.40	3234.45
	7	PA	5248.56	4052.73	3547.95	3577.39	3767.86
		FA	6052.82	4673.75	4091.62	4125.57	4345.23
	8	PA	4893.62	3775.82	3298.94	3326.82	3515.09
		FA	5896.37	4549.52	3974.92	4008.52	4235.37
	9	PA	3954.07	2976.11	2567.48	2591.33	2744.81
		FA	4753.36	3577.71	3086.48	3115.15	3299.65
	10	PA	4263.10	3323.31	2924.10	2947.41	3102.21
		FA	5028.44	3919.93	3449.05	3476.55	3659.14
	Range	PA	**3575-5250**	**2815-4055**	**2455-3550**	**2475-3580**	**2640-3770**
		FA	**4415-6055**	**3470-4675**	**2930-4090**	**2960-4125**	**3235-4345**
Double Storeyed Projects	11.	PA	2960.75	2257.17	1952.13	1952.26	2100.70
		FA	3365.46	2565.70	2218.97	2219.11	2387.84
	12.	PA	2995.97	2330.41	2038.38	2055.60	2185.57
		FA	3566.57	2774.26	2426.60	2447.11	2601.83
	13.	PA	2625.97	2019.60	1748.94	1764.86	1890.02
		FA	3156.69	2427.77	2102.40	2121.54	2272.00
	Range	PA	**2625-2995**	**2020-2330**	**1750-2040**	**1765-2055**	**1890-2185**
		FA	**3155-3565**	**2425-2775**	**2100-2425**	**2120-2450**	**2270-2600**
Four Storeyed Projects	14.	PA	3356.79	2994.20	2837.80	2845.91	2878.05
		FA	3995.34	3563.77	3377.63	3387.28	3425.54
	15.	PA	2884.22	2241.70	1946.97	1963.75	2088.03
		FA	3433.54	2668.65	2317.79	2337.76	2485.71
	16.	PA	3270.84	2747.40	2514.71	2525.89	2565.38
		FA	3894.75	3271.46	2994.38	3007.69	3054.72
	Range	PA	**2840-3355**	**2240-2995**	**1945-2840**	**1965-2845**	**2085-2880**
		FA	**3380-3995**	**2670-3565**	**2315-3380**	**2335-3390**	**2485-3425**

Table 7.8: Fall in Energy Rates Using Alternate Masonry Works vis-à-vis Traditional Brickwork

Project Type		Range of Fall in theEnergy Rates (MJ/sqm) with masonry work in 1:6 cement mortar and			
		Clay Flyash Bricks	Hollow Concrete Blocks (40 x 20 x 20)	Aerated Concrete Blocks	Fal-G Blocks
Single Storeyed	PA	760-1195	1120-1700	1100-1670	935-1480
	FA	945-1380	1485-1965	1455-1930	1180-1710
Double Storeyed	PA	605-665	875-955	860-940	735-810
	FA	730-790	1055-1140	1035-1115	885-965
Four Storeyed	PA	360-600	515-895	510-875	475-755
	FA	430-710	615-1065	605-1045	570-895

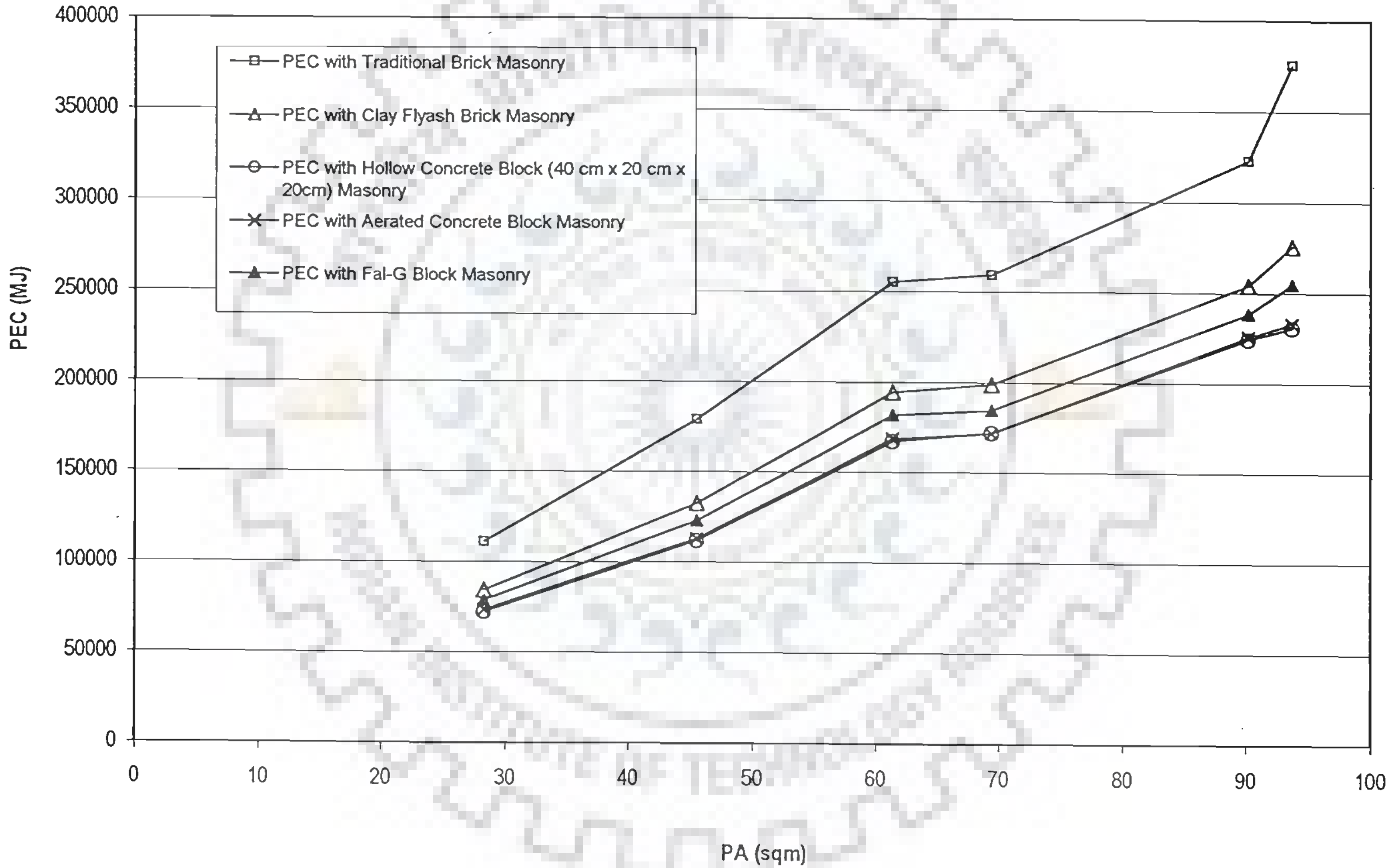

Fig. 7.1 : Comparative PEC Using Alternate Masonry Works for Project Nos. 1-6

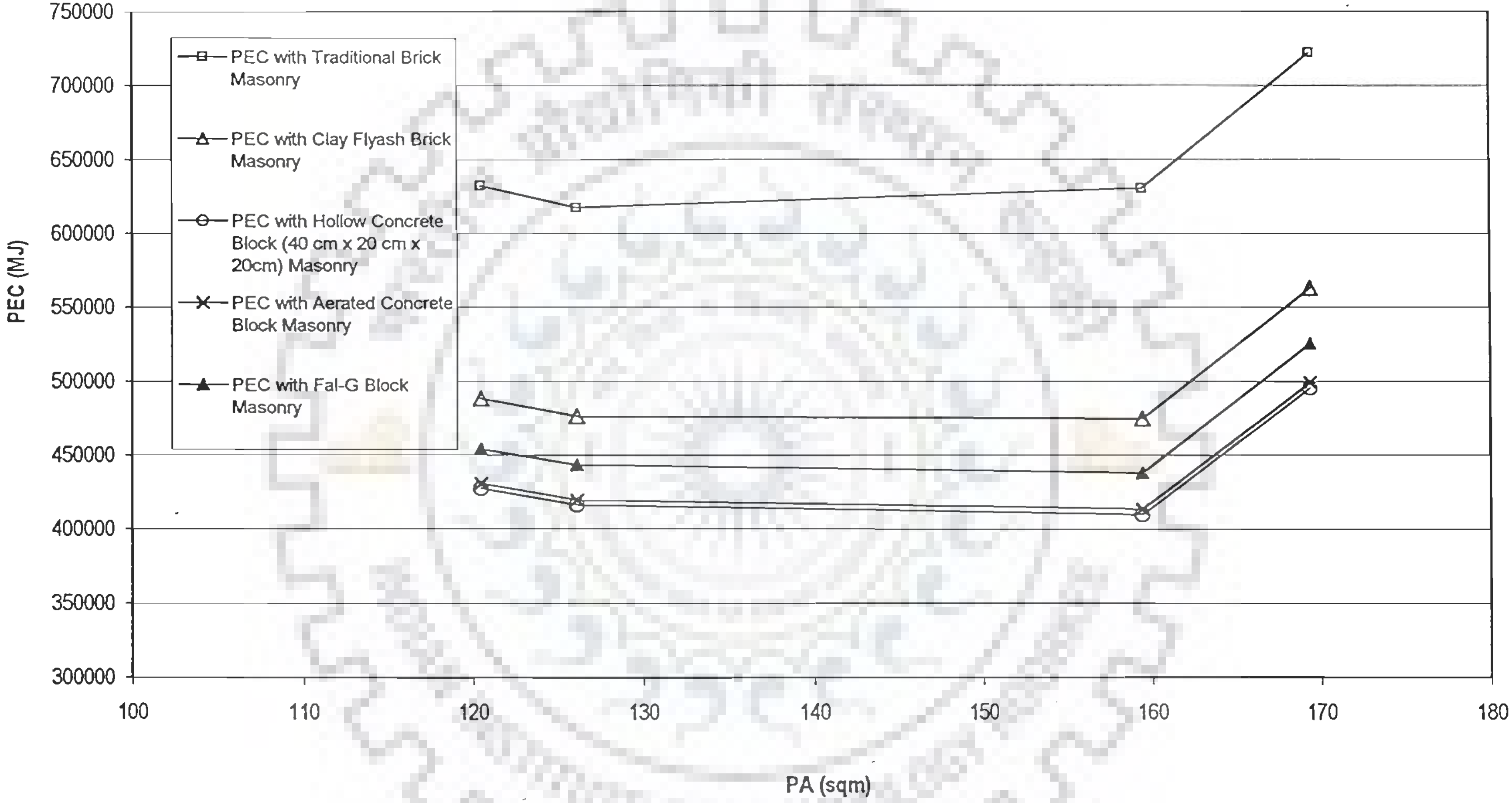

Fig. 7.2 : Comparative PEC Using Alternate Masonry Works for Project Nos. 7-10

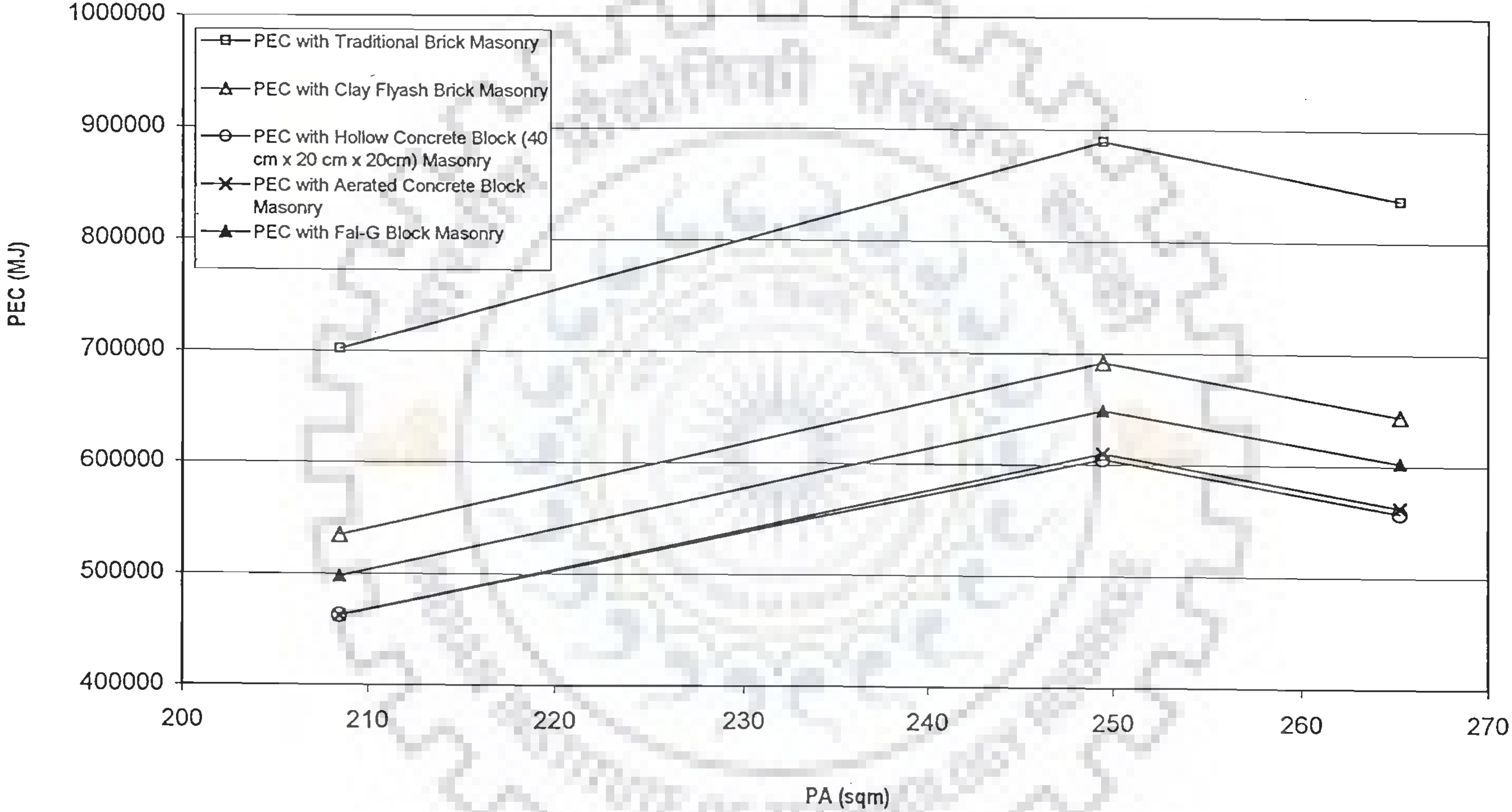

Fig. 7.3 : Comparative PEC Using Alternate Masonry Works for Project Nos. 11-13

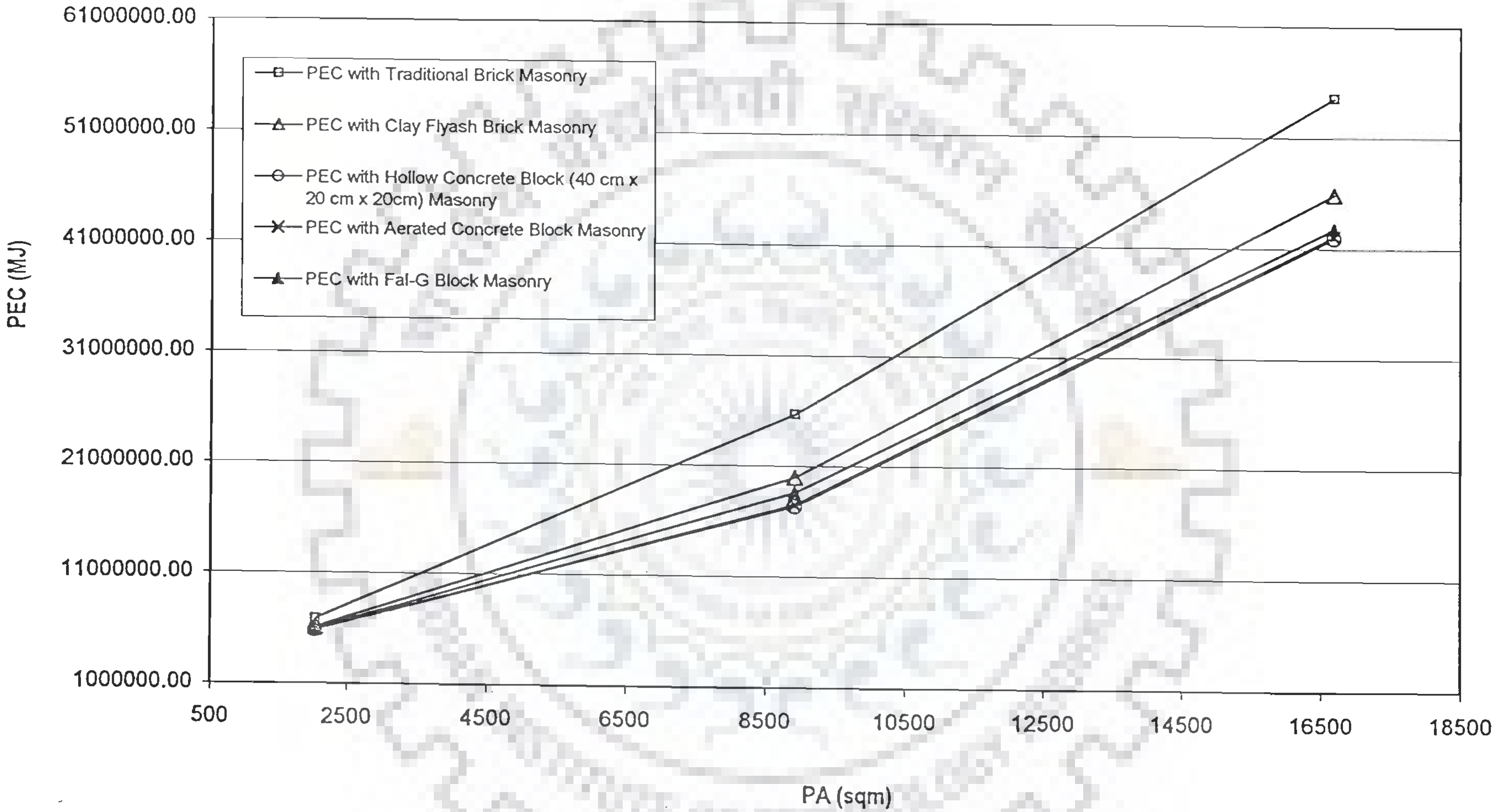

Fig. 7.4 : Comparative PEC Using Alternate Masonry Works for Project Nos. 14-16

The Equations are presented as follows:

Table No.	Equation Nos.	Description
7.9	7.1.1 – 7.1.16	For single storeyed projects (Nos. 1-6)
7.10	7.2.1 - 7.2.16	For single storeyed projects (Nos. 7-10)
7.11	7.3.1 - 7.3.16	For double storeyed projects (Nos. 11-13)
7.12	7.4.1 - 7.4.16	For four storeyed projects (Nos. 14-16)

Tables 7.13-7.20 present the PEC values computed from the Equations, alongwith the estimated PEC for the projects using alternatives[1]. The percentage deviations of the computed values from the estimated PEC are also shown. The range of deviations, as shown in the Tables, reveal that the PEC obtained from the linear Equations deviates significantly from the estimated values, whereas the quadratic Equations give fairly accurate results. The following Equations are found to be the most appropriate:

A. For **single storeyed projects** (Nos. 1-6) with masonry work in 1:6 cement mortar and FA of the project (a) upto 80 sqm:

1. Clay flyash bricks

$$\mathbf{PEC = -10.138\, a^2 + 4470\, a - 15646} \quad (7.1.4)$$

2. Hollow concrete blocks (40 cm x 20 cm x 20 cm)

$$\mathbf{PEC = -12.075\, a^2 + 4187.2\, a - 21369} \quad (7.1.8)$$

3. Aerated concrete blocks

$$\mathbf{PEC = -10.818\, a^2 + 4080.7\, a - 18345} \quad (7.1.12)$$

4. Fal-G blocks

$$\mathbf{PEC = -10.271\, a^2 + 4241.1\, a - 16180} \quad (7.1.16)$$

[1] The estimated PEC for the projects using the alternatives have been obtained from the detailed energy estimates. The PEC values are shown in Tables IV.4.1 - IV.4.16, Appendix-IV.

B. For **single storeyed projects** (Nos. 7-10) with masonry work in 1:6 cement mortar and FA of the project (a) more than 100 sqm and less than 145 sqm:

1. Clay flyash bricks

$$\mathbf{PEC = 214.23\ a^2 - 51101.32\ a + 3483414.51} \quad (7.2.4)$$

2. Hollow concrete blocks (40 cm x 20 cm x 20 cm)

$$\mathbf{PEC = 212.69\ a^2 - 50901.68\ a + 3418907.34} \quad (7.2.8)$$

3. Aerated concrete blocks

$$\mathbf{PEC = 212.79\ a^2 - 50915.36\ a + 3422795.29} \quad (7.2.12)$$

4. Fal-G blocks

$$\mathbf{PEC = 215.80\ a^2 - 51589.42\ a + 3483690.09} \quad (7.2.16)$$

C. For **double storeyed projects** (Nos. 11-13) with masonry work in 1:6 cement mortar and total PA of the project (A):

1. Clay flyash bricks

$$\mathbf{PEC = -58.64\ A^2 + 33928.45\ A - 4212307.22} \quad (7.3.2)$$

2. Hollow concrete blocks (40 cm x 20 cm x 20 cm)

$$\mathbf{PEC = -55.48\ A^2 + 32000.32\ A - 4005172.70} \quad (7.3.6)$$

3. Aerated concrete blocks

$$\mathbf{PEC = -116.41\ a^2 + 56912.84\ a - 6343102.45} \quad (7.3.12)$$

4. Fal-G blocks

$$\mathbf{PEC = -116.41\ a^2 + 56995.80\ a - 6325253.16} \quad (7.3.16)$$

D. For **four storeyed projects** (Nos. 14-16) with masonry work in 1:6 cement mortar and total PA of the project (A):

1. Clay flyash bricks

$$\mathbf{PEC = 0.09\ A^2 + 1037.13\ A + 3629540.56} \tag{7.4.2}$$

2. Hollow concrete blocks (40 cm x 20 cm x 20 cm)

$$\mathbf{PEC = 0.10\ A^2 + 570.64\ A + 4214116.65} \tag{7.4.6}$$

3. Aerated concrete blocks

$$\mathbf{PEC = 0.10\ A^2 + 600.93\ A + 4172914.96} \tag{7.4.10}$$

4. Fal-G blocks

$$\mathbf{PEC = 0.12\ a^2 + 1081.02\ a + 3669123.94} \tag{7.4.16}$$

where a = Total FA of the project

The PEC values obtained from the Equations for single storeyed projects deviated by a maximum of about ±1.5% from the estimated values. The exceptions are Eqns. 7.1.8 and 7.1.12, where the deviations are within ±2.5% (approx.). All these Equations are based on the FA of the single storeyed units.

The values from the Equations for double storeyed units deviated by a maximum of only about -0.03 to +0.01%. The Eqns. 7.2.12 to 7.2.16 for aerated and Fal-G blocks respectively are also based on the FA of the double storeyed units.

The deviations for the Equations for four storeyed projects are less than ±1%. The maximum deviation is about –1.0% for Fal-G blocks (Eqn. 7.4.16) and only this Equation is based on the FA of the four storeyed projects.

Table 7.9: Equations for Estimating PEC for Project Nos. 1-6 with Masonry Work in Alternative Masonry Units and 1:6 Cement Mortar

Masonry Work with		Equations from Plinth Area (A), Where $A \leq 95$ sqm		Equations from Floor Area (a), Where $a \leq 80$ sqm	
Clay Flyash Bricks	Eqn. No.	7.1.1	7.1.2	7.1.3	7.1.4
	Eqn.	PEC = 2820.2 A + 7250.6	PEC = -5.198 A^2 + 3469.8 A - 10230	PEC = 3420.1 a + 7785.5	PEC = -10.138 a^2 + 4470 a - 15646
Hollow Concrete Blocks (40 cm x 20 cm x 20 cm)	Eqn. No.	7.1.5	7.1.6	7.1.7	7.1.8
	Eqn.	PEC = 2427.8 A + 5681.2	PEC = -5.8168 A^2 + 3154.7 A - 13881	PEC = 2936.8 a + 6538.2	PEC = -12.075 a^2 + 4187.2 a - 21369
Aerated Concrete Blocks	Eqn. No.	7.1.9	7.1.10	7.1.11	7.1.12
	Eqn.	PEC = 2445.6 A + 5907.3	PEC = -5.0172 A^2 + 3072.6 A - 10965	PEC = 2960.4 a + 6657.9	PEC = -10.818 a^2 + 4080.7 a – 18345
Fal-G Blocks	Eqn. No.	7.1.13	7.1.14	7.1.15	7.1.16
	Eqn.	PEC = 2620.8 A + 7020.3	PEC = -5.1385 A^2 + 3262.9 A - 10260	PEC = 3177.5 a + 7558.2	PEC = -10.271 a^2 + 4241.1 a - 16180

Table 7.10: Equations for Estimating PEC for Project Nos. 7-10 with Masonry Work in Alternative Masonry Units and 1:6 Cement Mortar

Masonry Work with		Equations from Plinth Area (A), Where $120 \leq A \leq 170$ sqm		Equations from Floor Area (a), Where $100 \leq a \leq 145$ sqm	
Clay Flyash Bricks	Eqn. No.	7.2.1	7.2.2	7.2.3	7.2.4
	Eqn.	PEC = 1084.3 A + 344501	PEC = 164.79 A^2 - 46524.16 A + 3710648.33	PEC = 1439.3 a + 325839	PEC = 214.23 a^2 - 51101.32 a + 3483414.51
Hollow Concrete Blocks (40 cm x 20 cm x 20 cm)	Eqn. No.	7.2.5	7.2.6	7.2.7	7.2.8
	Eqn.	PEC = 940.2 A + 301800	PEC = 161.25 A^2 - 45645.28 A + 3595615.60	PEC = 1260.9 a + 284050	PEC = 212.69 a^2 - 50901.68 a + 3418907.34
Aerated Concrete Blocks	Eqn. No.	7.2.9	7.2.10	7.2.11	7.2.12
	Eqn.	PEC = 948.63 A + 304291	PEC = 161.46 A^2- 45695.25 A + 3602235.94	PEC = 1271.3 a + 286489	PEC = 212.79 a^2 - 50915.36 a + 3422795.29
Fal-G Blocks	Eqn. No.	7.2.13	7.2.14	7.2.15	7.2.16
	Eqn.	PEC = 1001.6 A + 321013	PEC = 163.20 A^2 - 46146.79 A + 3654631.17	PEC = 1336 a + 302988	PEC = 215.80 a^2- 51589.42 a + 3483690.09

Table 7.11: Equations for Estimating PEC for Project Nos. 11-13 with Masonry Work in Alternative Masonry Units and 1:6 Cement Mortar

Masonry Work with		Equations from Plinth Area (A)		Equations from Floor Area (a)	
Clay Flyash Bricks	Eqn. No.	7.3.1	7.3.2	7.3.3	7.3.4
	Eqn.	$PEC = 1603.6\ A + 167785$	$PEC = -58.64\ A^2 + 33928.45\ A - 4212307.22$	$PEC = 2302.5\ a + 68595$	$PEC = -120.83\ a^2 + 59164.81\ a - 6548225.45$
Hollow Concrete Blocks (40 cm x 20 cm x 20 cm)	Eqn. No.	7.3.5	7.3.6	7.3.7	7.3.8
	Eqn.	$PEC = 1417.8\ A + 138830$	$PEC = -55.48\ A^2 + 32000.32\ A - 4005172.70$	$PEC = 2034.6\ a + 51396$	$PEC = -114.18\ a^2 + 55766.69\ a - 6201172.13$
Aerated Concrete Blocks	Eqn. No.	7.3.9	7.3.10	7.3.11	7.3.12
	Eqn.	$PEC = 1484.3\ A + 123322$	$PEC = -56.54\ A^2 + 32649.81\ A - 4099671.50$	$PEC = 2130.6\ a + 31671$	$PEC = -116.41\ a^2 + 56912.84\ a - 6343102.45$
Fal-G Blocks	Eqn. No.	7.3.13	7.3.14	7.3.15	7.3.16
	Eqn.	$PEC = 1541.9\ A + 144844$	$PEC = -56.50\ A^2 + 32685.25\ A - 4075147.33$	$PEC = 2213.9\ a + 49477$	$PEC = -116.41\ a^2 + 56995.80\ a - 6325253.16$

Table 7.12: Equations for Estimating PEC for Project Nos. 14-16 with Masonry Work in Alternative Masonry Units and 1:6 Cement Mortar

Masonry Work with		Equations from Plinth Area (A)		Equations from Floor Area (a)	
Clay Flyash Bricks	Eqn. No.	7.4.1	7.4.2	7.4.3	7.4.4
	Eqn.	$PEC = 2726.43\ A - 1139925.81$	$PEC = 0.09\ A^2 + 1037.13\ A + 3629540.56$	$PEC = 3246.64\ a - 1143913.27$	$PEC = 0.13\ a^2 + 1232.95\ a + 3631348.46$
Hollow Concrete Blocks (40 cm x 20 cm x 20 cm)	Eqn. No.	7.4.5	7.4.6	7.4.7	7.4.8
	Eqn.	$PEC = 2484.87\ A - 1190407.04$	$PEC = 0.10\ A^2 + 570.64\ A + 4214116.65$	$PEC= 2958.98\ a - 1193938.18$	$PEC = 0.14\ a^2 + 677.60\ a + 4216124.06$
Aerated Concrete Blocks	Eqn. No.	7.4.9	7.4.10	7.4.11	7.4.12
	Eqn.	$PEC = 2496.32\ A - 1178448.24$	$PEC = 0.10\ A^2 + 600.93\ A + 4172914.96$	$PEC = 2972.62\ a - 1182003.27$	$PEC = 0.14\ a^2 + 713.65\ a + 4174905.08$
Fal-G Blocks	Eqn. No.	7.4.13	7.4.14	7.4.15	7.4.16
	Eqn.	$PEC = 2534.69\ A - 921267.23$	$PEC = 0.09\ A^2 + 909.43\ A + 3667390.60$	$PEC = 3018.31\ a - 924959.20$	$PEC = 0.12\ a^2 + 1081.02\ a + 3669123.94$

Table 7.13: Estimated PEC from Equations vis-à-vis the Detailed Estimates for Project Nos. 1-6

Project No.		Estimated PEC (MJ) with Masonry Work in Clay Flyash Bricks from					Estimated PEC (MJ) with Masonry Work in Hollow Concrete Blocks (40 cm x 20 cm x 20 cm) from				
		Detailed Estimate[#]	Eqn. 7.1.1	Eqn. 7.1.2	Eqn. 7.1.3	Eqn. 7.1.4	Detailed Estimate	Eqn. 7.1.5	Eqn. 7.1.6	Eqn. 7.1.7	Eqn. 7.1.8
1	PEC	84451.47	87118.66	83865.82	88636.66	84359.18	72406.87	74436.50	70794.90	75964.15	70868.30
	% Deviation	-	3.16	-0.69	4.96	-0.11	-	2.80	-2.23	4.91	-2.12
2	PEC	132644.23	135682.51	137004.60	132106.14	133442.93	111873.55	116243.21	117720.63	113290.88	114880.75
	% Deviation	-	2.29	3.29	-0.41	0.60	-	3.91	5.23	1.27	2.69
3	PEC	194292.64	180185.26	182992.92	187956.37	191698.80	166985.92	154553.90	157693.21	161248.82	165702.37
	% Deviation	-	-7.26	-5.82	-3.26	-1.34	-	-7.44	-5.56	-3.44	-0.77
4	PEC	201507.23	202972.48	205538.68	195754.20	199402.34	171856.03	174170.52	177039.38	167944.73	172285.75
	% Deviation	-	0.73	2.00	-2.86	-1.04	-	1.35	3.02	-2.28	0.25
5	PEC	257292.44	261632.64	260454.82	257897.41	257027.11	223819.90	224668.76	223347.22	221306.38	220263.87
	% Deviation		1.69	1.23	0.24	-0.10	-	0.38	-0.21	-1.12	-1.59
6	PEC	275384.03	271559.74	269303.34	276810.57	273236.38	230357.45	233214.62	230685.98	237546.89	233283.35
	% Deviation	-	-1.39	-2.21	0.52	-0.78	-	1.24	0.14	3.12	1.27
Range of % Deviation		-	-7.26 to +3.16	-5.82 to +3.29	-3.26 to +4.96	-1.34 to +0.60	-	-7.44 to +3.91	-5.56 to +3.02	-3.44 to +4.91	-2.12 to +2.69

[#] PEC values as shown in Tables IV.4.1-IV.4.16, Appendix-IV

Table 7.14: Estimated PEC from Equations vis-à-vis the Detailed Estimates for Project Nos. 1-6

Project No.		Estimated PEC (MJ) with Masonry Work in Aerated Concrete Blocks from					Estimated PEC (MJ) with Masonry Work in Fal-G Blocks from				
		Detailed Estimate	Eqn. 7.1.9	Eqn. 7.1.10	Eqn. 7.1.11	Eqn. 7.1.12	Detailed Estimate	Eqn. 7.1.13	Eqn. 7.1.14	Eqn. 7.1.15	Eqn. 7.1.16
1	PEC	73389.66	75166.69	72029.39	76641.76	72077.11	78844.18	81241.36	78024.14	82674.30	78339.66
	% Deviation	-	2.42	-1.85	4.43	-1.79	-	3.04	-1.04	4.86	-0.64
2	PEC	113102.74	117279.92	118559.72	114268.44	115694.38	122974.56	126371.53	127675.77	123060.33	124412.68
	% Deviation	-	3.69	4.82	1.03	2.29	-	2.76	3.82	0.07	1.17
3	PEC	168602.03	155871.49	158586.35	162611.77	166604.35	181581.22	167727.76	170499.54	174948.90	178737.25
	% Deviation	-	-7.55	-5.94	-3.55	-1.18	-	-7.63	-6.10	-3.65	-1.57
4	PEC	171864.32	175631.94	178114.35	169361.48	173253.40	184395.58	188903.82	191436.39	182193.60	185886.26
	% Deviation	-	2.19	3.64	-1.46	0.81	-	2.44	3.82	-1.19	0.81
5	PEC	225585.75	226500.42	225370.60	223151.95	222221.96	238085.18	243416.46	242246.54	239928.78	239042.37
	% Deviation	-	0.41	-0.10	-1.08	-1.49	-	2.24	1.75	0.77	0.40
6	PEC	233022.09	235108.93	232938.30	239522.96	235707.62	254422.16	252641.68	250405.29	257500.35	253874.19
	% Deviation	-	0.90	-0.04	2.79	1.15	-	-0.70	-1.58	1.21	-0.22
Range of % Deviation		-	-7.55 to +3.69	-5.94 to +4.82	-3.55 to +4.43	-1.79 to +2.29	-	-7.63 to +3.04	-6.10 to 3.82	-3.65 to +4.86	-1.57 to +1.17

Table 7.15: Estimated PEC from Equations vis-à-vis the Detailed Estimates for Project Nos. 7-10

Project No.		Estimated PEC (MJ) with Masonry Work in Clay Flyash Bricks from					Estimated PEC (MJ) with Masonry Work in Hollow Concrete Blocks (40 cm x 20 cm x 20 cm) from				
		Detailed Estimate	Eqn. 7.2.1	Eqn. 7.2.2	Eqn. 7.2.3	Eqn. 7.2.4	Detailed Estimate	Eqn. 7.2.5	Eqn. 7.2.6	Eqn. 7.2.7	Eqn. 7.2.8
7	PEC	488313.14	475148.31	497347.16	476217.06	482898.36	427492.56	415084.70	436817.53	415788.83	422438.83
	% Deviation	-	-2.70	1.85	-2.48	-1.11	-	-2.90	2.18	-2.74	-1.18
8	PEC	476243.75	481263.76	464163.37	476504.92	481639.76	416095.04	420387.43	403666.71	416041.01	421155.74
	% Deviation	-	1.05	-2.54	0.05	1.13	-	1.03	-2.99	-0.01	1.22
9	PEC	474511.15	517381.79	481981.57	516733.36	474305.72	409359.70	451705.49	417086.72	451283.17	409187.10
	% Deviation	-	9.03	1.57	8.90	-0.04	-	10.34	1.89	10.24	-0.04
10	PEC	562902.48	528159.73	558142.72	532522.48	562893.22	495283.81	461051.08	490413.56	465115.24	495298.07
	% Deviation	-	-6.17	-0.85	-5.40	0.00	-	-6.91	-0.98	-6.09	0.00
Range of % Deviation		-	-6.17 to +9.03	-2.54 to +1.85	-5.40 to +8.90	-1.11 to +1.13	-	-6.91 to –10.34	-2.99 to +2.18	-6.09 to +10.74	-1.18 to +1.22

Table 7.16: Estimated PEC from Equations vis-à-vis the Detailed Estimates for Project Nos. 7-10

Project No.		Estimated PEC (MJ) with Masonry Work in Aerated Concrete Blocks from					Estimated PEC (MJ) with Masonry Work in Fal-G Blocks from				
		Detailed Estimate	Eqn. 7.2.9	Eqn. 7.2.10	Eqn. 7.2.11	Eqn. 7.2.12	Detailed Estimate	Eqn. 7.2.13	Eqn. 7.2.14	Eqn. 7.2.15	Eqn. 7.2.16
7	PEC	431039.24	418591.43	440465.73	419314.42	425989.10	453989.49	441695.78	463715.95	442573.28	449315.48
	% Deviation	-	-2.89	2.19	-2.72	-1.17	-	-2.71	2.14	-2.51	-1.03
8	PEC	419611.81	423941.70	407325.18	419568.68	424707.46	443358.20	447344.81	430448.94	442840.48	448024.94
	% Deviation	-	1.03	-2.93	-0.01	1.21	-	0.90	-2.91	-0.12	1.05
9	PEC	413161.96	455540.57	421078.28	455101.52	413019.74	437632.42	480708.10	445712.71	480181.68	437462.02
	% Deviation	-	10.26	1.92	10.15	-0.03	-	9.84	1.85	9.72	-0.04
10	PEC	499233.14	464969.95	494594.79	469047.68	499283.67	525452.26	490664.01	520428.05	494837.60	525452.55
	% Deviation	-	-6.86	-0.93	-6.05	0.01	-	-6.62	-0.96	-5.83	0.00
Range of % Deviation		-	-6.86 to +10.26	-2.93 to +2.19	-6.05 to +10.15	-1.17 to +1.21	-	-6.62 to +9.84	-2.91 to +2.14	-5.83 to +9.72	-1.03 to +1.05

Table 7.17: Estimated PEC from Equations vis-à-vis the Detailed Estimates for Project Nos. 11-13

Project No.		Estimated PEC (MJ) with Masonry Work in Clay Flyash Bricks from					Estimated PEC (MJ) with Masonry Work in Hollow Concrete Blocks (40 cm x 20 cm x 20 cm) from				
		Detailed Estimate	Eqn. 7.3.1	Eqn. 7.3.2	Eqn. 7.3.3	Eqn. 7.3.4	Detailed Estimate	Eqn. 7.3.5	Eqn. 7.3.6	Eqn. 7.3.7	Eqn. 7.3.8
11	PEC	534949.30	547838.20	534985.27	548666.25	534885.47	462654.39	474848.60	462647.02	475610.10	462521.23
	% Deviation	-	2.41	0.01	2.56	-0.01	-	2.64	0.00	2.80	-0.03
12	PEC	691900.21	643893.84	691956.45	642838.50	691808.67	605193.55	559774.82	605181.95	558825.24	605003.25
	% Deviation	-	-6.94	0.01	-7.09	-0.01	-	-7.50	0.00	-7.66	-0.03
13	PEC	643990.39	679124.93	644055.20	679356.15	643886.76	557683.03	590923.89	557669.63	591094.00	557467.84
	% Deviation	-	5.46	0.01	5.49	-0.02	-	5.96	0.00	5.99	-0.04
Range of % Deviation		-	-6.94 to +5.46	+0.01	-7.09 to +5.49	-0.02 to -0.01	-	-7.50 to +5.96	±0.00	-7.66 to +5.99	-0.04 to -0.03

Table 7.18: Estimated PEC from Equations vis-à-vis the Detailed Estimates for Project Nos. 11-13

Project No.		Estimated PEC (MJ) with Masonry Work in Aerated Concrete Blocks from					Estimated PEC (MJ) with Masonry Work in Fal-G Blocks from				
		Detailed Estimate	Eqn. 7.3.9	Eqn. 7.3.10	Eqn. 7.3.11	Eqn. 7.3.12	Detailed Estimate	Eqn. 7.3.13	Eqn. 7.3.14	Eqn. 7.3.15	Eqn. 7.3.16
11	PEC	462684.72	475101.10	462538.21	475901.10	462620.07	497864.94	510274.30	497708.42	511075.15	497766.52
	% Deviation	-	2.68	-0.03	2.86	-0.01	-	2.49	-0.03	2.65	-0.02
12	PEC	610308.25	564010.67	610078.14	563042.64	610215.94	648896.30	602634.11	648650.43	601623.66	648755.45
	% Deviation	-	-7.59	-0.04	-7.74	-0.02	-	-7.13	-0.04	-7.29	-0.02
13	PEC	562760.43	596620.74	562494.95	596833.96	562656.07	602670.67	636509.65	602386.99	636736.11	602511.33
	% Deviation	-	6.02	-0.05	6.05	-0.02	-	5.61	-0.05	5.65	-0.03
Range of % Deviation		-	-7.59 to +6.02	-0.05 to -0.03	-7.74 to +6.05	-0.02 to -0.01	-	-7.13 to +5.61	-0.05 to -0.03	-7.29 to +5.65	-0.03 to -0.02

Table 7.19: Estimated PEC from Equations vis-à-vis the Detailed Estimates for Project Nos. 14-16

Project No.		Estimated PEC (MJ) with Masonry Work in Clay Flyash Bricks from					Estimated PEC (MJ) with Masonry Work in Hollow Concrete Blocks (40 cm x 20 cm x 20 cm) from				
		Detailed Estimate	Eqn. 7.4.1	Eqn. 7.4.2	Eqn. 7.4.3	Eqn. 7.4.4	Detailed Estimate	Eqn. 7.4.5	Eqn. 7.4.6	Eqn. 7.4.7	Eqn. 7.4.8
14	PEC	6126125.77	4438349.97	6128258.98	4437060.89	6134934.44	5806143.12	3893636.98	5800257.69	3892548.44	5794613.00
	% Deviation	-	-27.55	0.03	-27.57	0.14	-	-32.94	-0.10	-32.96	-0.20
15	PEC	19966832.34	23144386.20	20007375.88	23147447.21	20133722.48	17341691.56	20942330.05	17230272.03	20945150.18	17123172.62
	% Deviation	-	15.91	0.20	15.93	0.84	-	20.76	-0.64	20.78	-1.26
16	PEC	45826644.72	44336926.59	45968884.96	44335019.85	46411640.38	41945315.63	40257224.56	41554631.85	40255453.66	41179313.82
	% Deviation	-	-3.25	0.31	-3.25	1.28	-	-4.02	-0.93	-4.03	-1.83
Range of % Deviation		-	-27.55 to +15.91	+0.03 to +0.31	-27.57 to +15.93	+0.14 to +1.28	-	-32.94 to +20.76	-0.93 to -0.10	-32.96 to +20.78	-1.83 to -0.20

Table 7.20: Estimated PEC from Equations vis-à-vis the Detailed Estimates for Project Nos. 14-16

Project No.		Estimated PEC (MJ) with Masonry Work in Aerated Concrete Blocks from					Estimated PEC (MJ) with Masonry Work in Fal-G Blocks from				
		Detailed Estimate	Eqn. 7.4.9	Eqn. 7.4.10	Eqn. 7.4.11	Eqn. 7.4.12	Detailed Estimate	Eqn. 7.4.13	Eqn. 7.4.14	Eqn. 7.4.15	Eqn. 7.4.16
14	PEC	5822729.67	3929022.48	5821029.34	3927930.51	5815363.97	5888497.30	4264708.51	5904834.82	4263515.69	5881992.64
	% Deviation	-	-32.52	-0.03	-32.54	-0.13	-	-27.58	0.28	-27.60	-0.11
15	PEC	17491109.16	21056274.00	17458863.37	21059139.57	17351679.74	18598104.62	21655216.60	18907802.02	21658036.22	18474954.46
	% Deviation	-	20.38	-0.18	20.40	-0.80	-	16.44	1.67	16.45	-0.66
16	PEC	42131762.08	40460169.36	42018667.36	40458457.69	41643083.24	42790571.97	41357361.97	43876699.00	41355527.28	42358939.78
	% Deviation	-	-3.97	-0.27	-3.97	-1.16	-	-3.35	2.54	-3.35	-1.01
Range of % Deviation		-	-32.52 to +20.38	-0.27 to -0.03	-32.54 to +20.40	-1.16 to -0.13	-	-27.58 to +16.44	+0.28 to +2.54	-27.60 to +16.45	-1.01 to -0.11

7.7. CONCLUDING REMARKS

All the alternatives examined give at least some amount of energy reduction in any selected mortar mix vis-à-vis traditional bricks. Hollow (40 cm x 20 cm x 20 cm) and aerated concrete blocks in 1:6 cement mortar (1 cement: 6 fine sand) give the maximum savings of 25-35% of the PEC of traditional brickwork. These are followed by Fal-G blocks and clay flyash bricks, which give energy savings of about 15-25%.

Though clay flyash bricks and Fal-G blocks do not give as much energy savings as hollow or aerated blocks (40 cm x 20 cm x 20 cm), they give more energy savings vis-à-vis modular bricks, solid and hollow concrete blocks (40cm x 20cm x 10cm). They are also useful as they utilise flyash. Flyash also replaces clay by upto 40% in clay flyash bricks, thus reducing the consumption of clay.

Other masonry units provide energy savings, which range from as low as about 1.5% (using modular bricks) to as high as 23% (using solid concrete blocks). Thus, even modular bricks are a better option than traditional bricks.

The conventional 1:6 cement mortar has the least energy value for any given masonry unit, closely followed by 1:1:1 lime mortar and 1:5 cement mortar. The advantage of 1:1:1 lime mortar is that it utilises flyash. But it has a slower setting time and uses materials like lime and flyash, whose qualities cannot be consistently maintained.

Masonry work in hollow (40 cm x 20 cm x 20 cm) and aerated concrete blocks or Fal-G blocks and clay flyash bricks in 1:6 cement mortar (1 cement: 6 fine sand) have been further compared for their energy rates. It is found that the PA energy rates fall by about 500-1700 MJ/sqm by using hollow and aerated blocks in 1:6 cement mortar. The corresponding fall for Fal-G blocks and clay flyash bricks is about 475-1500 MJ/sqm and 350-1200 MJ/sqm respectively. The FA energy rates fall by about 600-1950 MJ/sqm with hollow and aerated blocks. The corresponding decrease is about 570-1700 MJ/sqm with Fal-G blocks and about

430-1400 MJ/sqm for clay flyash bricks.

Fairly accurate Equations have been proposed for estimating the PEC, using the above substitutes, with the largest deviation being only about ±2.5%.

The fall in the rates is steeper in single storeyed units, followed by double storeyed and four storeyed projects. This is because of the fall in the net share of masonry work in the PEC with the additional storeys.

CHAPTER 8

DISCUSSION OF RESULTS

8.1. INTRODUCTION

This Chapter presents several important conclusions that have been drawn from the 'Schedule of Energy Rates'. The projects have been re-analysed by bringing them on par with each other vis-à-vis their building elements. Inferences have also been drawn from the energy estimates of the case studies. Similarly, certain typical observations have been discussed concerning the alternatives to masonry work.

8.2. ENERGY RATES

The following observations are made from the 'Schedule of Energy Rates':

- Cement mortars have lower EER than composite (cement-lime) mortars. A typical comparison of mortars of similar strength is shown in Table 8.1. Moreover, masonry work in cement mortar also has lesser EER as compared to the equivalent work in composite mortar (refer Table 8.1).

- Cement mortars using flyash as a partial substitute for cement have lower EER than a cement mortar of similar strength. Comparison of 1:3 cement mortar (1 cement: 3 fine sand) and 1:1½:3 cement mortar (1 cement: 1½ flyash: 3 fine sand)[1] illustrates this fact. The determining factor is the quantity of cement used in the mix, which drops from 510.0 kg per cum of mortar in the former to 350.0 kg per cum in the latter.

[1] Item Code Nos. 1.14. and 1.27. in Appendix-II, 'Schedule of Energy Rates'.

Table 8.1: Comparative EER

Item Code No.[1]	Description of the Item of Work	Materials	Unit	Quantity	Energy Value (MJ/Unit)	Energy Value (MJ)	EER
1.17.	Cement mortar 1:6 (1cement: 6 fine sand) (Details for 1 cum)	Cement Fine sand	kg cum	250.00 1.07	6.70 0.00	1675.00 0.00	**1675.00 MJ/cum**
1.35.	Cement mortar 1:1:6 (1cement: 1lime putty: 6 fine sand) (Details for 1 cum)	Cement Lime putty Fine sand	kg cum cum	250.00 113.00 1.07	6.70 6.50 0.00	1675.00 734.50 0.00	**2409.50 MJ/cum**
2.2.3.	Masonry work with 1st class trad. bricks &1: 1:6 cement mortar (1 cement: 1 lime putty: 6 fine sand) in foundation & plinth (Details for 1 cum)	1st class bricks Cement mortar 1:1:6	Nos cum	494 0.25	4.50 2409.50	223.00 602.38	**2825.38 MJ/cum**
2.2.11.	Masonry work with 1st class trad. bricks & 1: 6 cement mortar (1 cement: 6 fine sand) in foundation & plinth (Details for 1 cum)	1st class bricks Cement mortar 1:6	nos cum	494 0.25	4.50 1675.00	223.00 418.75	**2641.75 MJ/cum**
2.1.11.	Masonry work with modular bricks & 1: 6 cement mortar (1 cement:6 fine sand) in foundation & plinth (Details for 1 cum)	Modular bricks Cement mortar 1:6	nos cum	487 0.22	4.50 1675.00	2191.50 368.50	**2560.00 MJ/cum**
2.2.31.	Half brickwork with 1st class trad. bricks & 1: 3 cement mortar (1 cement: 3 coarse sand) in foundation & plinth (Details for 10 sqm)	1st class bricks Cement mortar 1:6	nos cum	565 0.28	4.50 3417.00	2542.50 956.76	**3499.26 MJ/10sqm = 3069.52 MJ/cum**
2.1.27.	Half brickwork with modular bricks & 1: 3 cement mortar (1cement: 3 coarse sand) in foundation & plinth (Details for 10 sqm)	Modular bricks Cement mortar 1:6	nos cum	550 0.25	4.50 3417.00	2475.00 854.25	**3329.25 MJ/10sqm = 3329.25 MJ/cum**
3.7.(a)	Cement concrete 1:3:6 (1cement: 3 coarse sand: 6 graded stone agg. 40 mm nom. size) in foundation and plinth (Details for 1 cum)	Cement Coarse sand Stone agg. 40 mm Stone agg. 20 mm	kg cum cum cum	220.00 0.47 0.65 0.24	6.70 0.00 538.00 538.00	1474.00 0.00 349.70 129.12	**1952.82 MJ/cum**

[1] Refer Appendix-II, 'Schedule of Energy Rates'

Table 8.1 (contd.):

Item Code No.	Description of the Item of Work	Materials	Unit	Quantity	Energy Value (MJ/Unit)	Energy Value (MJ)	EER
3.19.(a)	Cement concrete 1:3:6 (1cement: 3 coarse sand: 6 stone agg. 20 mm nom. size) in foundation and plinth (Details for 1 cum)	Cement	kg	220.00	6.70	1474.00	1979.72 MJ/cum
		Coarse sand	cum	0.47	0.00	0.00	
		Stone agg. 20 mm	cum	0.70	538.00	376.60	
		Stone agg. 10 mm	cum	0.24	538.00	129.12	
3.9.(a)	Cement concrete 1:5:10 (1cement: 5 coarse sand: 10 stone agg. 40 mm nom. size) in foundation & plinth (Details for 1 cum)	Cement	kg	130.00	6.70	871.00	1349.82 MJ/cum
		Coarse sand	cum	0.47	0.00	0.00	
		Stone agg. 40 mm	cum	0.65	538.00	349.70	
		Stone agg. 20 mm	cum	0.24	538.00	129.12	
3.13.(a)	Cement concrete 1:5:10 (1cement: 5 coarse sand: 10 brick agg. 40 mm nom. size) in foundation and plinth (Details for 1cum)	Cement	kg	130.00	6.70	871.00	2860.15 MJ/cum
		Coarse sand	cum	0.47	0.00	0.00	
		Brick agg. 40 mm	cum	0.65	2235.00	1452.75	
		Brick agg. 20 mm	cum	0.24	2235.00	536.40	
5.12.(f)	40 mm thick marble chips flooring - under layer 34 mm thick cement concrete 1:2:4 (1 cement :2 coarse sand : 4 stone agg. 12.5 mm nom. size) & top layer 6 mm thick with marble chips of size 4-7 mm nom. size laid in cement marble powder mix [3:1 (3 cement :1 marble powder) by wt.] in 4:7 (4 cement marble powder mix: 7 marble chips) by volume – ordinary cement without any pigment (Details for 10 sqm)	Cement	kg	149.50	6.70	1001.65	1164.67 MJ/10sqm or 116.47 MJ/sqm
		Coarse sand	cum	0.151	0.00	0.00	
		Stone agg.12.5 mm	cum	0.227	538.00	122.13	
		Stone agg. 10 mm	cum	0.076	538.00	40.89	
		Marble chips	kg	87.20	0.00	0.00	
		Marble powder	cum	0.007	0.00	0.00	
5.28.(a)	Marble stone slab flooring over 20 mm (av.) thick base of lime mortar 1:1:1 (1 lime putty :1 surkhi :1 coarse sand) laid and jointed with gray cement slurry - Makrana white marble slab 25 mm thick (Details for 10 sqm)	Marble tiles	sqm	11.50	0.00	0.00	928.55 MJ/10sqm or 92.86 MJ/sqm
		Base mortar	cum	0.224	2649.75	593.55	
		Cement slurry @ 4.4 kg/sqm	kg	50.00	6.70	335.00	

Sand and flyash have no contribution in the EER, since their EEV is 0.0 MJ. But the analysis of rates for masonry in cement flyash mortars are not available. Hence, these mortars could not be considered as alternatives in the projects in the present study.

- Masonry construction in modular bricks has lower EER than in traditional bricks. This is because, though both have the same EEV, lesser number of modular bricks (487 nos.) are required per cum of work vis-à-vis traditional bricks (494 nos.)[1], as highlighted in Table 8.1. Moreover, modular brickwork requires less mortar volume (0.22 per cum of work) than traditional brickwork (0.25 cum), because of the slightly larger volume of modular bricks, alongwith their uniform shape and size. This results in savings of about 3.5-5% in the EER of masonry work by using modular bricks instead of traditional bricks (refer Table 8.1). This trend in EER is reversed for half brickwork, because of the variation in the thickness of a half brick wall in the two types of bricks (refer Table 8.1). The net savings in the PEC by replacing traditional bricks with modular bricks have been found to be upto 1.5%, as shown in Chapter 7.

- There is a slight increase of about 1 % in the EER of concrete work by decreasing the nominal size of the stone aggregates, because of the small increase in the quantity of the stone aggregates per cum by using a smaller size, as shown in Table 8.1.

  The EER of concrete work in brick aggregate is nearly twice the corresponding work in stone aggregate, because of the higher EEV of bricks vis-à-vis stone aggregates, as shown through the example in Table 8.1. The EER of concrete work with brick aggregate will be effectively lowered vis-à-vis concrete work in stone aggregate if it is known how much percentage of the brick aggregate can be obtained from wastes (as wastes are considered to have an EEV of 0.0 MJ).

  Therefore, it is profitable to use concrete in brick aggregate on sites where waste bricks are available in significant quantities. But it must be kept in mind that its application is

[1] Based on the CPWD 'Analysis of Rates'

limited to base concrete in foundation, base layer of floorings and terracing. If sufficient waste bricks are not available on site, then it is preferable to use concrete in stone ballast even for these applications because of the substantial energy savings.

8.3. ENERGY COSTS

As mentioned in the previous chapters, the combined energy share of masonry and RCC work is the major determiner of the PEC. The PEC share of these two sub-works is about 78-82% for single storeyed, 83-84% for double storeyed and about 87-90% for four storeyed housing construction. The share of these sub-works is shown in Table 8.2. The table reveals that the fall in the share of masonry with the increasing number of storeys is less than the rise in the share of RCC work. Therefore, the net share of masonry and RCC work in the energy costs will rise with an increase in the number of storeys.

Table 8.2: Percentage Shares of Sub-works in the PEC

Projects	Share in the PEC	
	Masonry Work	RCC Work
Single Storeyed	51-62%	18-30%
Double Storeyed	52–56%	27–32%
Four Storeyed	27–53%	34.5–62.5%

The previous chapters have also shown that double storeyed construction has the least energy rates (refer Table 6.13), because the share of all the sub-works in the energy rates of double storeyed units is less than their shares in single storeyed units, thus reducing the total rates of the former. Though the share of masonry and concrete is less in the four storeyed units than in double storeyed units, the decrease is offset by the large increase in the share of RCC work. The contributions of flooring and finishing in the rates are also slightly higher for the four storeyed units as compared to the double storeyed units. Thus, double storeyed dwellings have the lowest energy rates.

8.4. PEC EQUATIONS

The Equations for estimating the PEC of the three types of projects have been presented in the previous chapters. The sixteen projects have now been considered together to examine whether common linear and quadratic Equations can be applied to all of them. The common PEC Equations obtained are:

- **PEC= 3188.4 A – 15559** (8.1)

  where A = Total PA of the project

- **PEC = 0.0426 A^2 + 2539.5 A + 214620** (8.2)
- **PEC = 3796.4 a – 16449** (8.3)

  where a = Total FA of the project

- **PEC = 0.0606 a^2 + 3021.9a+ 214378** (8.4)

Table 8.3 shows the PEC calculated from the above Equations. Their percentage deviations from the PEC obtained from the detailed estimates are also shown in the Table. The range of deviations are so large that these Equations cannot be applied for estimating the PEC. Similarly, large deviations are also observed when only single and double storeyed or double and four storeyed projects are considered. Wright et. al. (1979) had also obtained an Equation for estimating the PEC, as mentioned earlier in Chapter 2. The Equation is:

- **Log PEC = 0.18 + 1.1 log a** (8.5)

The PEC computed from this Equation, alongwith their deviations from the original values, are also presented in Table 8.3. The ranges of deviations are again quite large. The main reason for this is that Wright et. al. had not considered load bearing masonry construction, which is the most common system adopted for housing construction in the North Indian plains. Their Equation was for estimating the PEC for dwellings in timber frames, steel frames and precast concrete, which are not used for housing in the Northern Indian plains and hence have not been considered in this study.

Table 8.3 : Estimated PEC from Equations vis-à-vis Detailed Estimates for Project Nos. 1-16

Project No.		Estimated PEC (MJ) from					
		Detailed Estimate	Eqn. 8.1	Eqn. 8.2	Eqn. 8.3	Eqn. 8.4	Eqn. 8.5
1	PEC	111293.55	74736.49	286572.81	73297.90	285849.58	49092.17
	% Deviation	-	-32.85	157.49	-34.14	156.84	-55.89
2	PEC	178932.90	129640.74	330357.18	121550.14	324304.14	78805.20
	% Deviation	-	-27.55	84.63	-32.07	81.24	-55.96
3	PEC	255253.74	179953.69	370502.32	183545.35	373739.87	118525.10
	% Deviation	-	-29.50	45.15	-28.09	46.42	-53.57
4	PEC	259007.81	205715.96	391066.48	192201.14	380644.67	124179.93
	% Deviation	-	-20.58	50.99	-25.79	46.96	-52.06
5	PEC	322822.83	272034.68	444029.50	261181.73	435693.64	170022.00
	% Deviation	-	-15.73	37.55	-19.09	34.96	-47.33
6	PEC	375728.38	283257.85	452996.11	282175.82	452455.61	184216.84
	% Deviation	-	-24.61	20.56	-24.90	20.42	-50.97
7	PEC	632398.78	368611.32	521222.81	380198.87	530767.63	251730.87
	% Deviation	-	-41.71	-17.58	-39.88	-16.07	-60.19
8	PEC	617232.11	386593.89	535604.85	380958.15	531374.54	252260.98
	% Deviation	-	-37.37	-13.22	-38.28	-13.91	-59.13
9	PEC	630437.55	492799.50	620600.82	487067.53	616238.59	327269.81
	% Deviation	-	-21.83	-1.56	-22.74	-2.25	-48.09
10	PEC	722083.67	524492.19	645982.69	528714.04	649572.47	357165.81
	% Deviation	-	-27.36	-10.54	-26.78	-10.04	-50.54
11	PEC	701698.61	740091.80	818874.30	775100.40	847078.57	538290.44
	%age Deviation	-	5.47	16.70	10.46	20.72	-23.29
12	PEC	889502.30	931076.96	972352.72	930373.16	971809.20	655520.22
	% Deviation	-	4.67	9.31	4.59	9.25	-26.30
13	PEC	837343.27	1001126.11	1028721.85	990584.06	1020231.18	701518.20
	% Deviation	-	19.56	22.86	18.30	21.84	-16.22
14	PEC	6867991.80	6507907.40	5588765.54	6509562.60	5588094.74	5480289.04
	% Deviation	-	-5.24	-18.63	-5.22	-18.64	-20.21
15	PEC	25689742.86	28383519.80	26213602.55	28388215.80	26216641.43	27632455.18
	% Deviation	-	10.49	2.04	10.50	2.05	7.56
+16	PEC	54557627.63	53166953.00	54425754.24	53163522.20	54436331.48	55082513.10
	% Deviation	-	-2.55	-0.24	-2.56	-0.22	0.96
Range of % Deviation		-	-41.71 to +19.56	-18.63 to +157.49	-39.88 to +18.30	-18.64 to +156.84	-60.19 to +7.56

The PEC values obtained from the detailed estimates are also graphically compared with the PEC obtained from the most suitable Equations listed in Chapters 4-6, the Equations derived from Singh and Sofat's data and the Equation given by Wright et. al. The graphs, presented in Figs. 8.1-8.4, clearly show that <u>the Equations derived in the present work are suitable for estimating the PEC.</u>

8.5. ALTERNATIVES TO MASONRY WORK

Savings in the PEC that are achieved by using alternative masonry works have already been presented in Chapter 7. Further saving is possible in the plastering work because the alternative masonry units give a fairly smooth external and internal wall surface due to their uniform shape and size.

The savings in the plaster work have been estimated for all the projects by assuming that the masonry work is executed in alternate masonry units and the plastering is done on only one face of the walls[1]. A 12 mm plaster in 1:6 cement mortar has been considered. The computations, shown in Table 8.4, reveal that there is a saving of about 1-2% in the PEC due to the reduction in plastering.

The preferred Equations for estimating the PEC of the three types of projects using the four alternatives, which give maximum energy savings vis-à-vis traditional brickwork, have already been presented in Chapter 7. Equations have now been derived by considering all the projects together. They are presented in Table 8.5.

The PEC estimated from these Equations are presented in Tables 8.6-8.9. These values were compared with the PEC of the projects obtained with each alternative combination. The deviations, as shown in these Tables, clearly show that these Equations are not suitable for estimating the PEC with alternative masonry works.

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[1] IS-2185 (Part 1-3) states that the true plane surfaces obtained by using concrete masonry units obviate the necessity of plaster for unimportant buildings situated in low rainfall areas; even when plaster is used, the quantity required for satisfactory coverage is significantly small.

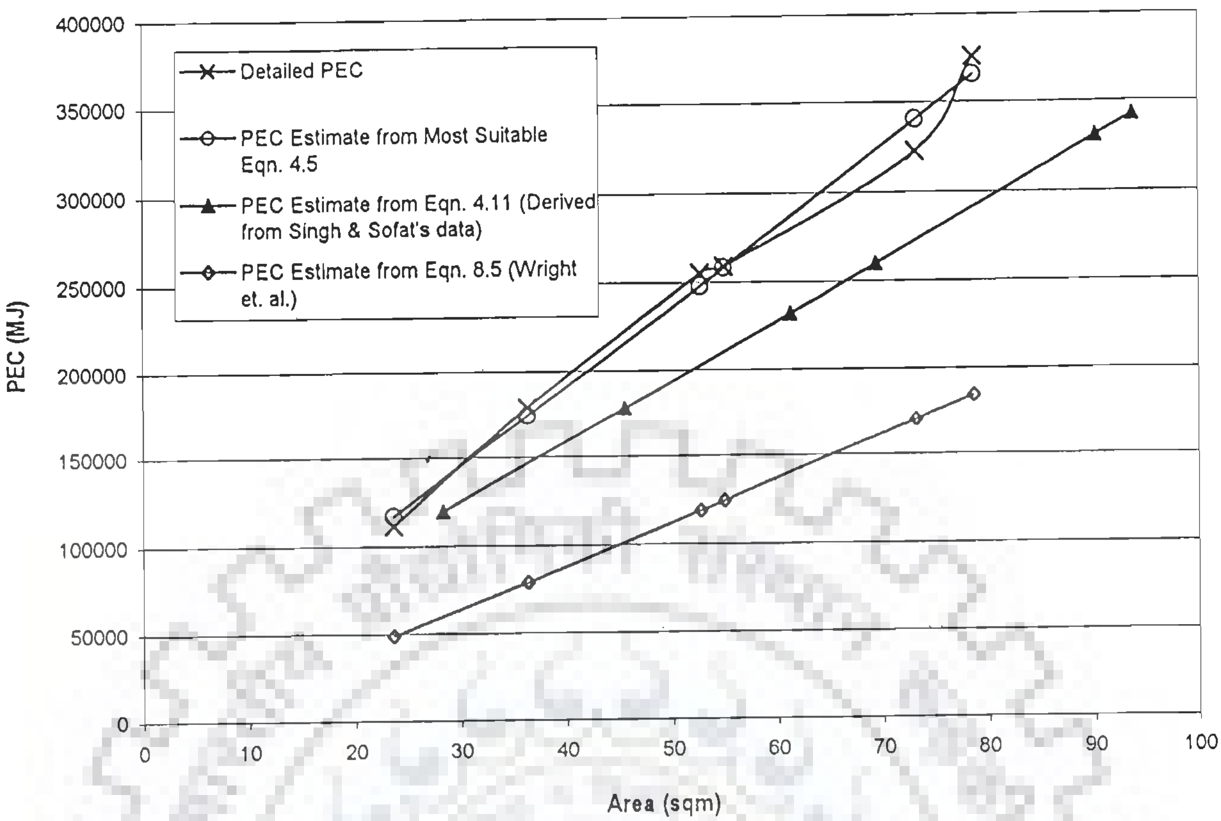

Fig. 8.1 : Comparative PEC from Various Data for Project Nos. 1-6

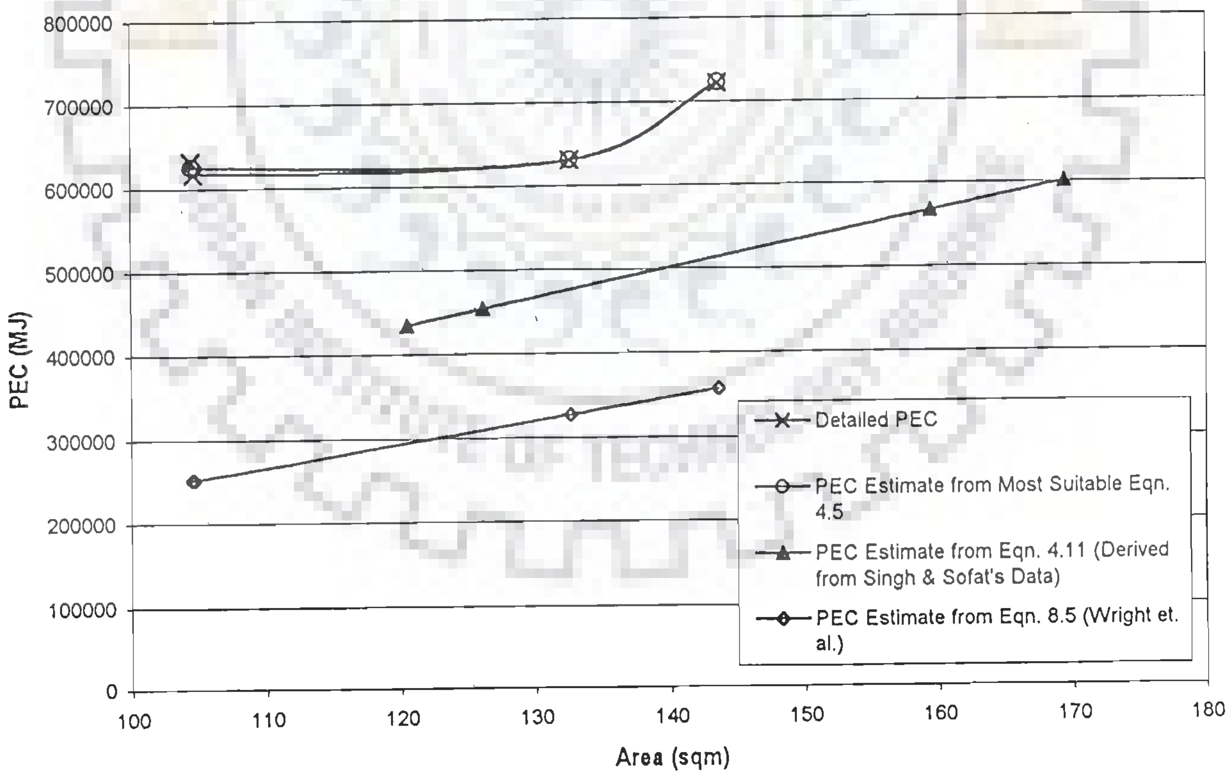

Fig. 8.2 : Comparative PEC from Various Data for Project Nos. 7-10

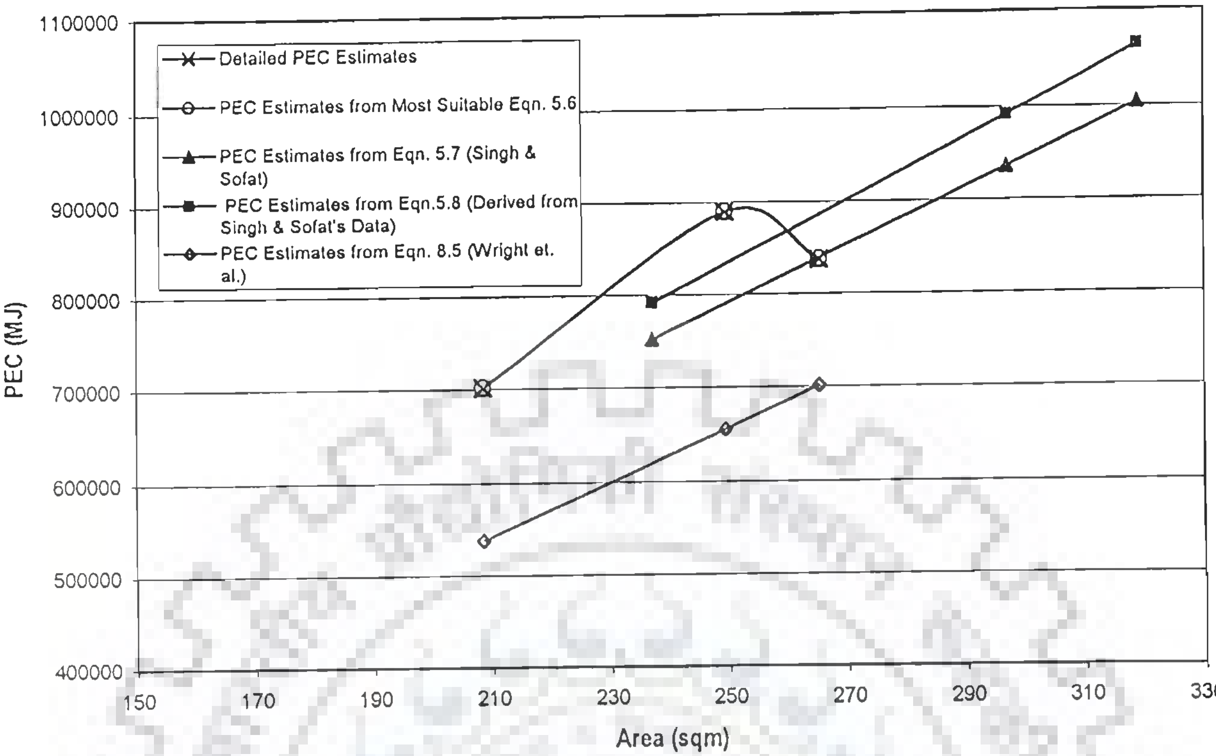

Fig. 8.3 : Comparative PEC from Various Data for Project Nos. 11-13

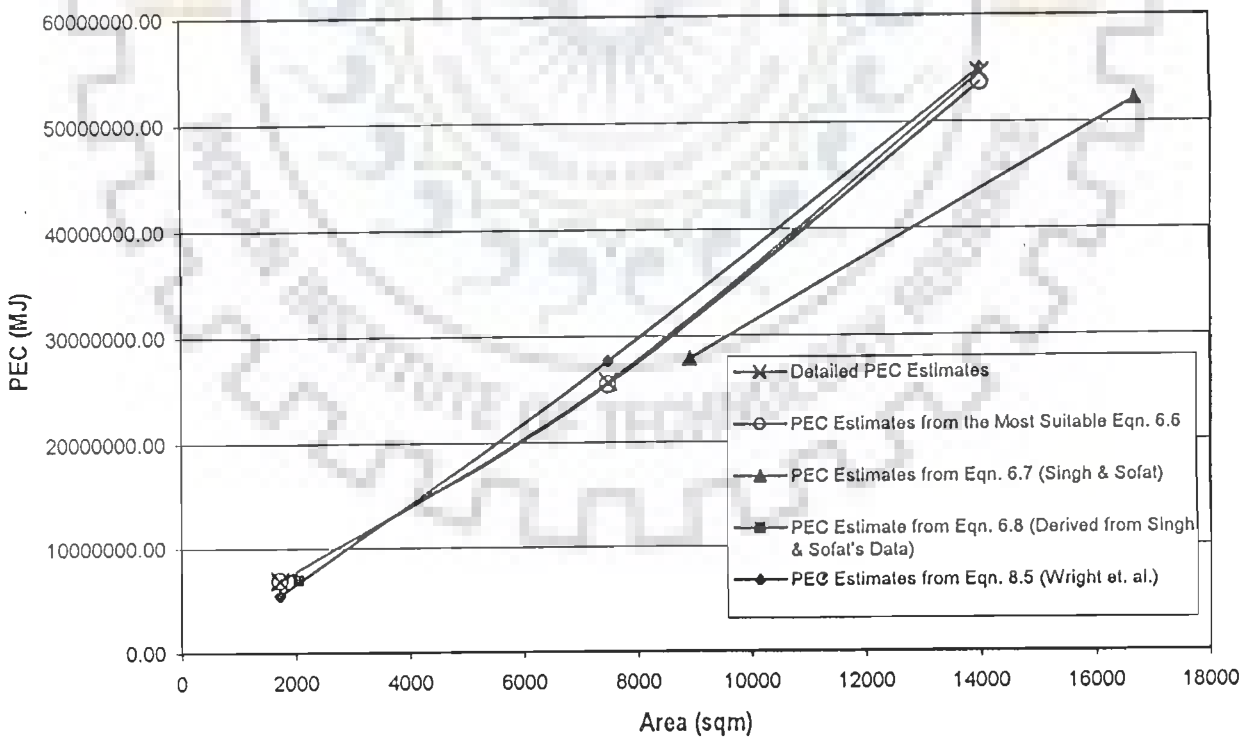

Fig. 8.4 : Comparative PEC from Various Data for Project Nos. 14-16

Table 8.4: Reduction in the PEC with Modified Plastering Work Using Clay Flyash Bricks

Project No.	PEC (MJ)	Reduction in PEC with Plastering	
		(MJ)	(%)
1	111293.55	1895.77	**1.70**
2	178932.90	3291.89	**1.84**
3	255153.74	3572.86	1.40
4	259007.81	4945.50	1.91
5	322822.83	6044.50	1.87
6	375728.38	6612.17	1.76
7	632398.78	10545.31	1.67
8	617232.11	9690.37	1.57
9	630437.55	10884.33	1.73
10	722083.67	12637.73	1.75
11	701698.61	15303.58	2.18
12	889502.30	18270.88	2.05
13	837343.27	15707.18	1.88
14	6867991.80	76131.67	1.11
15	25689742.86	555394.56	2.16
16	54557627.63	719236.50	1.32

Table 8.5: Equations for Estimating PEC for Project Nos. 1-16 with Masonry Work in Alternative Masonry Units and 1:6 Cement Mortar

Masonry Work with		Equations from PA (A)		Equations from FA (a)	
Clay Flyash Bricks	Eqn. No.	**8.10.1**	**8.10.2**	**8.10.3**	**8.10.4**
	Eqn.	$PEC = 2644 A - 58327$	$PEC = 0.0536 A^2 + 1827.4 A + 231323$	$PEC = 3148.2 a - 59050$	$PEC = 0.0761 a^2 + 2174.4 a + 231166$
Hollow Concrete Blocks (40 cm x 20 cm x 20 cm)	Eqn. No.	**8.11.1**	**8.11.2**	**8.11.3**	**8.11.4**
	Eqn.	$PEC = 2398.9 A - 62870$	$PEC = 0.0597 A^2 + 1490.2 A + 259475$	$PEC = 2856.4 a - 63517$	$PEC = 0.0847 a^2 + 1773 a + 259359$
Aerated Concrete Blocks	Eqn. No.	**8.12.1**	**8.12.2**	**8.12.3**	**8.12.4**
	Eqn.	$PEC= 2411.2 A - 61237$	$PEC = 0.0591 A^2 + 1511.2 A + 258000$	$PEC = 2870.9 a - 61887$	$PEC = 0.0839 a^2 + 1798 a + 257882$
Fal-G Blocks	Eqn. No.	**8.13.1**	**8.13.2**	**8.13.3**	**8.13.4**
	Eqn.	$PEC= 2467.9 A - 45797$	$PEC = 0.0497 A^2 + 1710.4 A + 222904$	$PEC = 2938.6 a - 46472$	$PEC = 0.0706 a^2 + 2035.2 a + 222755$

Table 8.6: Estimated PEC from Equations vis-à-vis the Detailed Estimates for Project Nos. 1-16 (Masonry Work in Clay Flyash Bricks)

Project No.		Estimated PEC (MJ) from				
		Detailed Estimate#	Eqn. 8.10.1	Eqn. 8.10.2	Eqn. 8.10.3	Eqn. 8.10.4
1	PEC	84451.47	16551.08	283117.96	15373.45	282611.34
	% Deviation	-	**-80.40**	**235.24**	**-81.80**	**234.64**
2	PEC	132644.23	62080.76	314653.96	55387.07	310305.99
	% Deviation	-	-53.20	137.22	-58.24	133.94
3	PEC	194292.64	103803.08	343580.71	106797.18	345924.58
	% Deviation	-	-46.57	76.84	-45.03	78.04
4	PEC	198498.20	125166.60	358402.72	113975.07	350900.89
	% Deviation	-	-36.94	80.56	-42.58	76.78
5	PEC	253889.96	180161.80	396590.57	171177.87	390586.85
	% Deviation	-	-29.04	56.21	-32.58	53.84
6	PEC	275384.03	189468.68	403057.72	188587.41	402675.16
	% Deviation	-	-31.20	46.36	-31.52	46.22
7	PEC	488313.14	260248.56	452284.58	269873.94	459178.02
	% Deviation	-	-46.70	-7.38	-44.73	-5.97
8	PEC	476243.75	275160.72	462665.67	270503.58	459616.09
	% Deviation	-	-42.22	-2.85	-43.20	-3.49
9	PEC	474511.15	363232.36	524046.23	358495.77	520895.33
	% Deviation	-	-23.45	10.44	-24.45	9.78
10	PEC	562902.48	389513.72	542385.77	393031.52	544979.10
	% Deviation	-	-30.80	-3.64	-30.18	-3.18
11	PEC	534949.30	568301.00	667427.46	597349.70	687836.64
	% Deviation	-	6.23	24.76	11.66	28.58
12	PEC	691900.21	726676.60	778602.88	726111.08	778194.81
	% Deviation	-	5.03	12.53	4.94	12.47
13	PEC	643990.39	784765.28	819475.98	776041.53	813301.96
	% Deviation	-	21.86	27.25	20.51	26.29
14	PEC	6126125.77	5351297.00	4194559.22	5352705.80	4193832.13
	% Deviation	-	-12.65	-31.53	-12.62	-31.54
15	PEC	19966832.34	23491781.00	20760311.99	23495782.40	20760129.46
	% Deviation	-	17.65	3.97	17.67	3.97
16	PEC	45826644.72	44043593.00	45625075.64	44040935.60	45622812.47
	% Deviation	-	-3.89	-0.44	-3.90	-0.44
Range of % Deviation		-	-80.40 to +21.86	-31.53 to +235.24	-81.80 to +20.51	-31.54 to +234.64

PEC obtained from detailed estimates using alternatives for masonry work

Table 8.7: Estimated PEC from Equations vis-à-vis the Detailed Estimates for Project Nos. 1-16 (Masonry Work in Hollow Concrete Blocks (40 cm x 20 cm x 20 cm))

Project No.		Estimated PEC (MJ) from				
		Detailed Estimate	Eqn. 8.11.1	Eqn. 8.11.2	Eqn. 8.11.3	Eqn. 8.11.4
1	PEC	72406.87	5066.85	301725.34	4008.30	301320.05
	% Deviation	-	**-93.00**	**316.71**	**-94.46**	**316.15**
2	PEC	111873.55	46375.91	327462.52	40313.14	323919.47
	% Deviation	-	-58.55	192.71	-63.97	189.54
3	PEC	166985.92	84230.55	351078.54	86958.15	352995.70
	% Deviation	-	-49.56	110.24	-47.92	111.39
4	PEC	171856.03	103613.66	363182.42	93470.74	357058.92
	% Deviation	-	-39.71	111.33	-45.61	107.77
5	PEC	223819.90	153510.78	394376.76	145371.53	389471.47
	% Deviation	-	-31.41	76.20	-35.05	74.01
6	PEC	427492.56	161954.91	399660.92	161167.42	399347.25
	% Deviation	-	-62.12	-6.51	-62.30	-6.58
7	PEC	427492.56	226173.46	439895.91	234919.67	445526.63
	% Deviation	-	-47.09	2.90	-45.05	4.22
8	PEC	416095.04	239703.26	448383.68	235490.95	445884.77
	% Deviation	-	-42.39	7.76	-43.40	7.16
9	PEC	409359.70	319610.62	498590.13	315327.33	496001.92
	% Deviation	-	-21.92	21.80	-22.97	21.17
10	PEC	495283.81	343455.68	513597.84	346662.04	515708.40
	% Deviation	-	-30.65	3.70	-30.01	4.12
11	PEC	462654.39	505669.30	616005.69	532042.40	632711.60
	% Deviation	-	9.30	33.15	15.00	36.76
12	PEC	605193.55	649363.41	707177.91	648869.16	706813.57
	% Deviation	-	7.30	16.85	7.22	16.79
13	PEC	557683.03	702067.24	740725.26	694171.66	735624.71
	% Deviation	-	**25.89**	32.82	24.47	31.91
14	PEC	5806143.12	4845279.40	3558335.33	4846634.60	3557431.20
	% Deviation	-	-16.55	**-38.71**	-16.53	-38.73
15	PEC	17341691.56	21304132.30	18268964.95	21308067.80	18266478.44
	% Deviation	-	22.85	5.35	22.87	5.33
16	PEC	41945315.63	39950782.00	41725888.28	39948934.20	41715721.22
	% Deviation	-	-4.76	-0.52	-4.76	-0.55
Range of % Deviation		-	-93.00 to +25.89	-38.71 to 316.71	-94.46 to +24.47	-38.73 to +316.15

Table 8.8: Estimated PEC from Equations vis-à-vis the Detailed Estimates for Project Nos. 1-16 (Masonry Work in Aerated Concrete Blocks)

Project No.		Estimated PEC (MJ) from				
		Detailed Estimate	Eqn. 8.12.1	Eqn. 8.12.2	Eqn. 8.12.3	Eqn. 8.12.4
1	PEC	73389.66	7048.18	300844.58	5981.08	300433.61
	% Deviation	-	**-90.40**	**309.93**	**-91.85**	**309.37**
2	PEC	113102.74	48569.05	326942.61	42470.22	323350.16
	% Deviation	-	**-57.06**	**189.07**	**-62.45**	**185.89**
3	PEC	168602.03	86617.78	350889.01	89352.01	352833.48
	% Deviation	-	**-48.63**	**108.12**	**-47.00**	**109.27**
4	PEC	171864.32	106100.28	363161.93	95897.66	356953.51
	% Deviation	-	**-38.27**	**111.31**	**-44.20**	**107.69**
5	PEC	225585.75	156253.24	394791.08	148061.92	389818.44
	% Deviation	-	**-30.73**	**75.01**	**-34.37**	**72.80**
6	PEC	431039.24	164740.66	400148.77	163937.99	399831.80
	% Deviation	-	**-61.78**	**-7.17**	**-61.97**	**-7.24**
7	PEC	431039.24	229288.49	440942.49	238064.63	446652.90
	% Deviation	-	**-46.81**	**2.30**	**-44.77**	**3.62**
8	PEC	419611.81	242887.66	449547.86	238638.81	447016.01
	% Deviation	-	**-42.12**	**7.13**	**-43.13**	**6.53**
9	PEC	413161.96	323204.73	500448.12	318880.47	497826.60
	% Deviation	-	**-21.77**	**21.13**	**-22.82**	**20.49**
10	PEC	499233.14	347172.06	515662.61	350374.24	517804.90
	% Deviation	-	**-30.46**	**3.29**	**-29.82**	**3.72**
11	PEC	462684.72	510217.40	619473.99	536695.65	636412.32
	% Deviation	-	**10.27**	**33.89**	**16.00**	**37.55**
12	% Deviation	610308.25	654648.28	711884.92	654115.46	711521.81
	% Deviation	-	**7.27**	**16.64**	**7.18**	**16.58**
13	PEC	562760.43	707622.34	745885.52	699647.93	740722.92
	% Deviation	-	**25.74**	**32.54**	**24.32**	**31.62**
14	PEC	5822729.67	4872078.20	3597314.66	4873190.10	3596565.23
	% Deviation	-	**-16.33**	**-38.22**	**-16.31**	**-38.23**
15	PEC	17491109.16	21415321.40	18406936.16	21418186.80	18407267.18
	% Deviation	-	**22.44**	**5.24**	**22.45**	**5.24**
16	PEC	42131762.08	40157579.00	41907759.84	40153680.20	41907464.97
	% Deviation	-	**-4.69**	**-0.53**	**-4.69**	**-0.53**
Range of % Deviation		-	**-90.40 to +25.74**	**-38.22 to +309.93**	**-91.85 to +24.32**	**-38.23 to +309.37**

Table 8.9: Estimated PEC from Equations vis-à-vis the Detailed Estimates for Project Nos. 1-16 (Masonry Work in Fal-G Blocks)

Project No.		Estimated PEC (MJ) from				
		Detailed Estimate	Eqn. 8.13.1	Eqn. 8.13.2	Eqn. 8.13.3	Eqn. 8.13.4
1	PEC	78844.18	24093.93	271382.39	22996.50	270906.58
	% Deviation	-	**-69.44**	**244.20**	**-70.83**	**243.60**
2	PEC	122974.56	66591.17	300898.69	60346.11	296827.81
	% Deviation	-	**-45.85**	**144.68**	**-50.93**	**141.37**
3	PEC	181581.22	105534.63	327972.61	108333.45	330165.26
	% Deviation	-	**-41.88**	**80.62**	**-40.34**	**81.83**
4	PEC	184395.58	125475.26	341845.13	115033.46	334822.85
	% Deviation	-	-31.95	85.39	-37.62	81.58
5	PEC	238085.18	176807.58	377586.44	168427.82	371966.74
	% Deviation	-	-25.74	58.59	-29.26	56.23
6	PEC	254422.16	185494.59	383639.22	184678.28	383280.66
	% Deviation	-	-27.09	50.79	-27.41	50.65
7	PEC	453989.49	251560.27	429711.63	260552.93	436163.37
	% Deviation	-	-44.59	-5.35	-42.61	-3.93
8	PEC	443358.20	265479.23	439427.42	261140.65	436573.36
	% Deviation	-	-40.12	-0.89	-41.10	-1.53
9	PEC	437632.42	347684.98	496873.61	343274.52	493925.48
	% Deviation	-	-20.55	13.54	-21.56	12.86
10	PEC	525452.26	372215.90	514037.42	375510.96	516465.56
	% Deviation	-	-29.16	-2.17	-28.54	-1.71
11	PEC	497864.94	539095.30	631060.40	566226.10	650163.34
	% Deviation	-	8.28	26.75	13.73	30.59
12	PEC	648896.30	686922.51	735102.80	686414.84	734725.23
	% Deviation	-	5.86	13.29	5.78	13.23
13	PEC	602670.67	741142.27	773352.65	733021.04	767579.77
	% Deviation	-	22.98	28.32	21.63	27.36
14	PEC	5888497.30	5003526.40	3930432.37	5004981.40	3929884.05
	% Deviation	-	-15.03	-33.25	-15.00	-33.26
15	PEC	18598104.62	21935788.30	19400368.86	21940133.20	19402332.27
	% Deviation	-	17.95	4.31	17.97	4.32
16	PEC	42790571.97	41118775.00	42580029.28	41117436.80	42585255.52
	% Deviation	-	-3.91	-0.49	-3.91	-0.48
Range of % Deviation		-	-69.44 to +22.98	-33.25 to +244.20	-70.83 to +21.63	-33.26 to +243.60

Similarly, large deviations are also observed when only single and double storeyed or double and four storeyed projects are considered. Therefore, the final Equations presented in Chapter 7 are most suitable for estimating the PEC of housing construction with the selected substitutes.

8.6. COMPARATIVE ANALYSIS OF PROJECTS WITH MODIFICATIONS

Another comparison has been considered by bringing all the projects at par with regard to the building elements. Therefore, boundary walls with open paved areas and stairwells have been added to single storeyed units (Nos. 1-6), which do not normally have these elements because of their low PA and FA. The material requirement per m for the boundary walls and the open paved areas have been estimated from the projects having these elements, leading to the estimation of the energy rates of these elements for each unit. Similarly, the energy rates of the stairwells have been quantified using the existing data from the projects, which had stairwells.

The double storeyed units (Nos 11-13) have also been studied by providing the units with boundary walls and open paved areas. The single storeyed Project Nos 7 – 10 and all the four storeyed housing projects already had these elements. The former energy rates of the single storeyed Project Nos. 1-6 and their new rates with the additional elements are presented in Table 8.10. The rates of Project Nos. 7-10 have not been shown as they remain unaltered because they already had these elements in their original design. Similarly, Table 8.11 presents the former and the modified rates for the double storeyed Project Nos. 11-13.

The following inferences have been drawn from these tables:

- There is a rise of about 1000-1605 MJ/sqm in the PA energy rates and 1190-1915 MJ/sqm in the FA energy rates of the single storeyed Project Nos. 1-6 because of the added building elements. This is equivalent to an increase of 25-41% in the energy rates of these dwelling units.

Table 8.10: Change in Energy Rates of Single Storeyed Project Nos. 1-6 with Boundary Walls, Open Paved Areas and Stairwells

Project No.		Energy Rates (MJ/sqm)	
1	Previous	PA Energy Rate	3929.86
		FA Energy Rate	4707.85
	Building Elements	PA Energy Rate	1603.59
		FA Energy Rate	1916.45
	Total	PA Energy Rate	5533.45
		FA Energy Rate	6624.30
	% Rise		41%
2	Previous	PA Energy Rate	3929.14
		FA Energy Rate	4922.50
	Building Elements	PA Energy Rate	1330.90
		FA Energy Rate	1640.86
	Total	PA Energy Rate	5260.04
		FA Energy Rate	6563.36
	% Rise		34%
3	Previous	PA Energy Rate	4161.02
		FA Energy Rate	4843.47
	Building Elements	PA Energy Rate	1192.95
		FA Energy Rate	1396.84
	Total	PA Energy Rate	5353.97
		FA Energy Rate	6240.31
	% Rise		29%
4	Previous	PA Energy Rate	3732.10
		FA Energy Rate	4712.66
	Building Elements	PA Energy Rate	1188.05
		FA Energy Rate	1475.63
	Total	PA Energy Rate	4920.15
		FA Energy Rate	6188.29
	% Rise		32%
5	Previous	PA Energy Rate	3578.97
		FA Energy Rate	4414.37
	Building Elements	PA Energy Rate	1015.91
		FA Energy Rate	1241.42
	Total	PA Energy Rate	4594.88
		FA Energy Rate	5655.79
	% Rise		28%
6	Previous	PA Energy Rate	4009.05
		FA Energy Rate	4776.61
	Building Elements	PA Energy Rate	998.49
		FA Energy Rate	1188.64
	Total	PA Energy Rate	5007.54
		FA Energy Rate	5965.25
	% Rise		25%

Table 8.11: Change in Energy Rates of Double Storeyed Project Nos. 11-13 with Boundary Walls and Open Paved Areas

Project No.		Energy Rates (MJ/sqm)	
11	Previous	PA Energy Rate	2960.75
		FA Energy Rate	3365.46
	Building Elements	PA Energy Rate	287.64
		FA Energy Rate	326.96
	Total	PA Energy Rate	3248.39
		FA Energy Rate	3692.42
	% Rise		10%
12	Previous	PA Energy Rate	2995.97
		FA Energy Rate	3566.57
	Building Elements	PA Energy Rate	266.64
		FA Energy Rate	317.43
	Total	PA Energy Rate	3262.61
		FA Energy Rate	3884.00
	% Rise		9%
13	Previous	PA Energy Rate	2625.97
		FA Energy Rate	3156.69
	Building Elements	PA Energy Rate	244.82
		FA Energy Rate	294.30
	Total	PA Energy Rate	2870.79
		FA Energy Rate	3450.99
	% Rise		9%

- The PA energy rates of double storeyed Project Nos. 11-13 rise by about 245-290 MJ/sqm and the FA energy rates by about 295-325 MJ/sqm because of the added building elements. This is equivalent to an increase of 9-10% in the energy rates of these units.

Table 8.12 presents the comparative energy rates of the single and double storeyed units after the modifications.

Table 8.12 : Comparative Ranges of Energy Rates of Single and Double Storeyed Units After Modifications

Projects	Range of Energy Rates (in MJ/sqm)	
Single Storeyed (1-6)	PA Energy Rate	4595-5535
	FA Energy Rate	5655-6625
Single Storeyed (7-10)	PA Energy Rate	3955-5250
	FA Energy Rate	4755-6055
Double Storeyed	PA Energy Rate	2870-3265
	FA Energy Rate	3450-3885

The following observations have been made:

- In single storeyed units, the range of PA and FA energy rates of Project Nos. 1-6 are now higher by 285-640 MJ/sqm (5-16%) and 570-900 MJ/sqm (9.5-19%) respectively compared to the corresponding values for Project Nos.7-10. Thus, when single storeyed units are compared at par with each other with regard to their building elements, the units with PA and FA less than 100 sqm generally have higher energy rates than those with PA and FA greater than 100 sqm.

- The energy rates for double storeyed units continue to be less than that for single storeyed units despite the addition of the boundary walls and open paved areas.

The Equations for estimating the PEC for the single storeyed Project Nos. 1-6 and double storeyed Project Nos. 11-13, after the modifications, have also been derived. The most suitable Equations are as follows:

PEC estimation based on FA of unit (a):

For Project Nos. 1-6:

$$\mathbf{PEC = -14.002\ a^2 + 6842.7\ a + 5514} \quad ; a \leq 80 \text{ sqm} \tag{8.10}$$

For Project Nos. 11-13:

$$\mathbf{PEC = -144.80\ a^2 + 71162.97\ a - 7772976.22} \tag{8.11}$$

Similarly, the Equations have also been derived to estimate the PEC for the modified projects using the most suitable substitutes for masonry work. The most preferred Equations are as follows:

A. For **single storeyed projects** (Nos. 1-6) with masonry work in 1:6 cement mortar and:

1. Clay flyash bricks

$$\mathbf{PEC = -18.099\ a^2 + 6093.7\ a - 12129} \tag{8.12.1}$$

2. Hollow concrete blocks (40 cm x 20 cm x 20 cm)

$$\mathbf{PEC = -18.387\ a^2 + 5576.1\ a - 14790} \tag{8.12.2}$$

3. Aerated concrete blocks

$$\mathbf{PEC = -17.146\ a^2 + 5472.7\ a - 11732} \tag{8.12.3}$$

4. Fal-G blocks

$$\mathbf{PEC = -16.448\ a^2 + 5602.7\ a - 9903.6} \tag{8.12.4}$$

B. For **double storeyed projects** (Nos. 11-13) with masonry work in 1:6 cement mortar and:

1. Clay flyash bricks

$$\mathbf{PEC = -60.81\ A^2 + 35226.04 - 4346182.27} \tag{8.13.1}$$

2. Hollow concrete blocks (40 cm x 20 cm x 20 cm)

$$\mathbf{PEC = -57.46\ A^2 + 33183.64 - 4127258.23} \tag{8.13.2}$$

3. Aerated concrete blocks

$$\mathbf{PEC = -120.56\ a^2 + 59000.15\ a - 6550436.11} \tag{8.13.3}$$

4. Fal-G blocks

$$PEC = -120.37\, a^2 + 58987.70\, a - 6523110.16 \qquad (8.13.4)$$

8.7. NEW LIGHT WEIGHT ALTERNATIVE BUILDING MATERIALS

Several new light weight building materials[1] have also been studied as substitutes for non-load bearing walls in traditional brick masonry work. They are:

- Poly Vinyl Chloride (PVC) Boards (2.5 cm thick)
- Cement Bonded (CB) Boards (4.0 cm thick)
- Ferrocement Panels (2.5 cm thick)
- Medium Density Fibre (MDF) Boards (1.9 cm thick)
- Ply Boards (1.9 cm thick)

Their EER and TER are listed in Table 8.13.

Table 8.13: EER and TER for New Alternative Building Materials

Building Material	Unit	EER (MJ)	TER (MJ)
PVC Boards	cum	237450.00	54.00
CB Boards	cum	8112.50	45.00
Ferrocement Panels	cum	6242.00	60.73
MDF Boards	cum	24842.00	27.72
Ply Boards	cum	16421.00	25.20

The wall panels obtained from these materials are thinner and are, therefore, comparatively much lighter vis-à-vis traditional brick work. They have been studied in the projects as substitutes for non-load bearing walls and some other walls, which can be replaced without disturbing the structural strength of the construction. But, because of their thinness, they have certain limitations, which are:

1. They cannot be used to replace any external walls

[1] Refer Appendix – I (Section B) for brief descriptions of these materials

2. They cannot replace walls of bathrooms and also have limitations as substitutes for kitchen walls due to the problems of dampness and privacy

Thus, they could not be used as a replacement for the brick masonry walls in Project Nos. 1 and 2. They have been used to substitute selected wall areas for Project Nos. 3 to 16. The total cubic content replaced in these projects has been listed in Table 8.14.

Table No. 8.14: Replaced Cubic Content of Brickwork in the Projects

Cubic Content (cum)	Project No.													
	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.
Full Brickwork	0.21	0.21	0.71	0.74	0.33	0.33	1.38	0.58	1.39	2.53	2.76	-	75.90	121.00
7.6 cm or Half Brickwork	-	0.30	0.17	-	0.23	0.23	-	0.28	0.56	-	-	25.28	-	11.11
Total	0.21	0.51	0.88	0.74	0.56	0.56	1.38	0.86	1.95	2.53	2.76	25.28	75.90	132.11

The PEC estimates have been computed using these substitutions and the resultant values have been compared with the PEC obtained with traditional brickwork. All the values have been indexed by giving traditional brickwork indexed values of 100.00. The comparative PEC and their indices are shown in Tables 8.15 and 8.16 respectively.

Table 8.15: Comparative PEC Using Light Weight Alternatives

Proj. No.	Traditional Brick	PVC	Cement Bonded Boards	Ferrocement	MDF Boards	Plyboards
3.	255253.70	298100.00	257004.00	255908.00	252474.00	257351.00
4.	259007.80	372501.00	263776.00	261028.00	261363.00	264509.00
5.	322822.80	521740.00	329767.00	326091.00	329958.00	332107.00
6.	375728.40	539987.00	383680.00	378386.00	378661.00	383420.00
7.	632398.80	748363.00	637038.00	634312.00	626220.00	638095.00
8.	617232.10	729692.00	620176.00	619145.00	611275.00	622928.00
9.	630437.60	938655.00	637934.00	635394.00	634285.00	641214.00
10.	722083.70	906043.00	726353.00	724770.00	717035.00	729105.00
11.	701698.60	1142584.00	712172.00	708583.00	716930.00	721527.00
12.	889502.30	1461413.00	901925.00	897269.00	911294.00	915874.00
13.	837343.30	1465679.00	852336.00	847257.00	864229.00	866187.00
14.	6867992.00	12655088.00	6733689.00	6687168.00	6939915.00	6891181.00
15.	25689743.00	46075970.00	29507539.00	29120030.00	29288556.00	29487474.00
16.	54557628.00	84898214.00	55458047.00	54793468.00	55677029.00	55828559.00

Table 8.16: Comparative PEC Indices Using Light Weight Alternatives

Proj. No.	Traditional Brick	PVC	Cement Bonded Boards	Ferrocement	MDF Boards	Plyboards
3.	100.00	116.79	100.69	100.27	98.91	100.82
4.	100.00	143.82	101.84	100.78	100.91	102.12
5.	100.00	161.62	102.15	101.01	102.21	102.88
6.	100.00	143.72	102.12	100.71	100.78	102.05
7.	100.00	118.34	100.73	100.30	99.02	100.90
8.	100.00	118.22	100.48	100.31	99.03	100.92
9.	100.00	148.89	101.19	100.79	100.61	101.71
10.	100.00	125.48	100.59	100.37	99.30	100.97
11.	100.00	162.83	101.49	100.98	102.17	102.83
12.	100.00	164.30	101.40	100.87	102.45	102.96
13.	100.00	175.04	101.79	101.18	103.21	103.44
14.	100.00	184.26	98.04	97.37	101.05	100.34
15.	100.00	179.36	114.86	113.35	114.01	114.78
16.	100.00	155.61	101.65	100.43	102.05	102.33

8.7.1. Analysis

The indices show that the highest rise in the PEC is seen when traditional brickwork is partially replaced with PVC. For the majority of the projects using the other substitutes, the PEC only varies about ±0-2% vis-à-vis the PEC with traditional brickwork. It is also evident that if more brickwork were to be replaced by these alternatives, the change in the PEC will be greater and will, in most cases, result in a rise rather than a fall in the PEC.

Thus, in energy terms, these alternatives do not provide a effective solution to traditional brickwork. Moreover, except for ferrocement, the other materials are highly susceptible to fire. Moreover, they are expensive and their thinness is a hindrance in fixing electrical conduit pipes and sanitary pipelines. As stated earlier, they also cannot be used for bathroom walls due to the possibility of dampness seeping through and the lack of privacy. But, since they show little change in the PEC of the projects (except for PVC), they can be suitable in a future scenario when bricks may not be sufficient to meet the growing demand, as mentioned in Chapter 1.

8.8. COMPARISON OF ENERGY RATES WITH INTERNATIONAL DATA

A comparison of the FA energy rates of single units of housing construction from various sources and the ones obtained from this study are presented in Table 8.17. The dwellings studied by the other authors had floor areas in the range of 95-150 sqm. They have not specified the number of storeys, except in S.No. 4 (Table 8.17), which was a single storeyed unit. It is seen that the energy rates obtained through the present study are comparable to the ones estimated by the previous authors.

Table 8.17: Comparative FA Energy Rates of Housing Construction from Various Sources

S.No.	Dwelling			
	Description	Author	Floor Area (in sqm)	FA Energy Rate (in MJ/sqm)
1.	Timber framed house – New Zealand, 1983	Baird & Chan	94.00	3800
2.	Standard mid-terrace house - U.K., 1976	Markus & Slesser	96.00	7000
3.	Three bedroomed semi-detached house - U.K., 1974	Brown & Stellon	100.00	3970
4.	Single storeyed house – Australia, 1978	Hill	144.00	3600
5.	One family house - U.S.A., 1976	Stein et.al.	-	8000
6.	Single storeyed house – India (Project Nos. 1-6)	Present study	23.00 - 79.00	4415 - 4925 5655-6625[Y]
7.	Single storeyed unit – India (Project Nos. 7-10)	Present study	105.00 - 145.00	4755- 6055
8.	Double storeyed unit - India (Project Nos. 11-13) (Floor areas of individual dwellings are in the range of 52.00-66.00 sqm)	Present study	208.00 – 265.00[#]	3155 - 3565 3450-3885[Y]
9.	Four storeyed project – India (Project Nos. 14-16) (Floor areas of individual dwellings are in the range of 33.00-111.00 sqm)	Present study	1719.00 – 14008.00[*]	3435 – 3995

[Y] FA energy rates with additional elements

[#] Total floor area of four dwellings per unit

[*] Total floor area of the housing project

8.9. CONCLUDING REMARKS

Cement mortars have lower EER than composite mortars. 1:6 cement mortar (1 cement : 6 fine sand) has the least EER of all the mortar mixes considered in this study.

The EER of masonry work in modular bricks is lower than masonry in traditional bricks, but this trend is reversed for half brickwork. The net savings in the PEC by replacing traditional bricks with modular bricks are upto 1.5%. Concrete work with smaller stone aggregates have slightly higher EER than concrete with larger aggregates. The EER of concrete using brick aggregate is about twice the EER of the corresponding concrete work using stone aggregate. Sufficient availability of waste bricks at a site effectively lowers the EER of concrete using brick aggregate, thus making it preferable to use on the site. Otherwise, concrete in stone ballast is the best option.

Double storeyed housing construction has the least range of primary energy rates of the housing types considered in the North Indian plains. The energy rates of housing construction obtained in the present study are comparable to the international rates.

Savings in the energy costs are possible through reduced plastering work by using alternatives to normal brick masonry work. Energy savings obtained are in the range of 1-2% of the actual PEC.

Use of new light weight building materials as substitutes for non-load bearing traditional masonry does not provide any significant benefits vis-à-vis the PEC of the projects. Moreover, their thinness limits their use in housing construction, as discussed earlier. They are also comparatively expensive (with the exception of ferrocement) and are, therefore, not a very viable solution to traditional brickwork, particularly in the context of low and middle income housing, which form the core of the housing requirement in India. But, since they can be suitable in a future scenario when bricks may not be sufficient to meet the growing requirement of housing construction.

The common Equations (including the data for single, double and four storeyed constructions) for estimating the PEC of the projects are found unsuitable. Therefore, the final Equations, which are listed in the previous Chapters, are preferred. New Equations are also derived for estimating the PEC of single and double storeyed units to which additional elements have been added. Similar modified Equations are also obtained for the PEC estimation of these projects using the substitutes, which give maximum energy savings vis-à-vis traditional brickwork.

The suitable Equations for providing a preliminary estimate of the PEC of housing construction of the types studied are listed in Table 8.18, whereas the best Equations using the substitutes to traditional brick masonry work are listed in Table 8.19.

Table 8.18: Suitable Equations for Estimating PEC for Housing

Type		PEC
Single Storeyed Units	Eqns.	$PEC = 4515.4\ a + 10107$ where $a^{\#} \leq 80$ sqm (excl. boundary wall, open paved area and stairwell) $PEC = -14.002\ a^2 + 6842.7\ a + 5514$ where $a \leq 80$ sqm $PEC = 209.80\ a^2 - 49572.91\ a + 3514665.22$ where 100 sqm $\leq a \leq$ 145 sqm
Double Storeyed Units	Eqns.	$PEC = -138.84\ a^2 + 68166.08\ a - 7475293.06$ (excl. boundary wall and open paved area) $PEC = -144.80\ a^2 + 71162.97\ a - 7772976.22$
Four Storeyed Projects	Eqns.	$PEC = 0.09\ a^2 + 2399.28\ a + 2465286.15$

a = Floor area (FA) of the project

CHAPTER 9

CONCLUSIONS AND RECOMMENDATIONS

The estimation of PEC for housing construction using the detailed building estimates has been found to be the most suitable approach as it can be readily understood and applied by the construction professionals, viz., architects, civil engineers, quantity surveyors and contractors. Moreover, the detailed estimate can provide the PEC for any dwelling. The energy rates of the items of civil work, viz., the EER and the TER, have been calculated and compiled as a 'Schedule of Energy Rates'. These rates are directly applicable for computing the PEC from the building estimates for a wide range of dwellings or projects[1].

The TEC_T has very little impact in determining the PEC, as it is only about 2-2.5% of the EEC_T for housing construction.

The combined contribution of masonry and RCC work to the PEC is found to be about 78-82% for single storeyed, 83-84% for double storeyed and about 87-90% for four storeyed projects. Therefore, masonry and RCC work are the main determiners of the PEC for housing construction.

Bricks and reinforcing steel, which are the main constituents of masonry and RCC work, have an average combined share of 60% in the PEC for all the projects. This proves that the net share of bricks and steel in the PEC is nearly constant, irrespective of the type of housing or the structural system used.

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[1] This is similar to the estimation of construction cost of civil work of a building using the construction rates of civil work, listed in the 'Schedule of Rates', for eg., DSR, 1997.

The individual share of masonry work alone is about 50-60% in the PEC for single and double storeyed projects and about 40-55% for four storeyed projects in load bearing construction. This share comes down to about 27% of the PEC in the four storeyed RCC framed construction.

Thus, masonry work is the single largest contributor to the PEC and construction cost in nearly all the projects. This is primarily because of the use of traditional burnt clay bricks, which account for upto 80-85% of the energy share of masonry work in the PEC.

Single storeyed units have the highest energy rates, followed by four storeyed projects, whose energy rates are lower by about 20-35%. Double storeyed units have the least energy rates, being about 27-42% less than for single storeyed and about 8-11% less than for four storeyed construction.

The range of the energy rates for the four storeyed projects is not large, despite having two different types of structural systems. This shows that the structural system used in housing is not the major determiner of the PEC or the construction cost.

Within single storeyed dwelling units, Project Nos. 7-10 (PA >120 sqm and FA >100 sqm) have energy rates, which are about 8-25% higher than those of Project Nos. 1-6 (PA ≤ 95 sqm and FA ≤ 80 sqm). The construction rates of the former are also higher than the latter by about 1-27%. This is primarily because of the additional elements of work in Project Nos. 7-10, viz., the boundary wall with the open paved area and the stairwell, which account for about 14-20% in the energy and construction rates of these projects.

Since single storeyed Project Nos. 1-6 did not have boundary walls, open paved areas and stairwells and the double storeyed Project Nos. 11-13 did not have boundary walls, these elements have been added to consider all the projects on par with each other. The modifications in Project Nos. 1-6 result in a rise of about 25-41% in their energy rates. This also means that these units (PA $\leq$ 95 sqm FA $\leq$ 80 sqm) now have energy rates, which are higher by about 5-20% than single storeyed Project Nos. 7-10 (PA >120 sqm and FA >100 sqm).

The addition of boundary walls also raises the energy rates of double storeyed units by about 9-10%. Moreover, the energy rates of double storeyed units continue to be the least despite the modifications.

The energy rates of housing construction obtained in the present study are comparable to the international rates.

Since masonry work is the single largest contributor to the PEC for nearly all the projects considered in this study, it has been selected for detailed study to examine the savings in its energy share that can be achieved by using alternatives because any such reduction will result in substantial savings in the PEC of a project. Since the main cause for the high-energy share of masonry work is primarily the high EEV of traditional burnt clay bricks, it is imperative to find out energy efficient substitutes for bricks to reduce the energy cost of masonry work. Alongwith this, alternatives for the conventional 1:6 cement mortar (1 cement: 6 fine sand) have also been studied.

All the alternative masonry units considered with any selected mortar mix give some amount of energy savings vis-à-vis the traditional brickwork. Hollow concrete blocks (40 cm x 20 cm x 20cm) and aerated concrete blocks give savings of about 25-35% in the PEC of the projects. These are followed by Fal-G blocks and clay flyash bricks, which give energy savings of about 15-25%. Other masonry units provide energy savings, which range from as low as about 1.5% (using modular bricks) to as high as 23% (using solid concrete blocks).

Present trends of housing construction also indicate that there is a clear shift towards concrete based products for walling in some parts of India. There has been a significant shift of about 11%, over the last decades[1], but this figure is expected to grow very rapidly, particularly in the large cities. This is especially true in areas where suitable clay for manufacturing traditional bricks are not available. In many of these areas concrete block are already replacing bricks. Another area they thrive are where the stone crushers exist in large numbers. Manufacture of concrete blocks can be ideally combined with the stone crusher, especially as they can utilise stone dust and chips (> 10 mm), which is otherwise a waste. Moreover, integrating concrete block production utilising stone dust is one way of immediately mitigating the effects of air pollution that this waste is creating.

Though clay flyash bricks and Fal-G blocks do not give as much energy savings as hollow or aerated blocks (40 cm x 20 cm x 20 cm), they are immensely useful as they utilise flyash, which is an ecological hazard. Moreover, flyash replaces clay by upto 40% in clay flyash bricks, thus reducing the consumption of clay. This helps in saving precious topsoil and hence prime agricultural land, as greater number of bricks (by upto 40%) can be produced from the same quantity of soil. Flyash also has a very small calorific content due to the unburnt carbon left behind in it as a residue. This carbon aids the firing of clay flyash bricks in the kiln, reducing the energy required in their firing and saving coal upto 3-5 tonnes per 100,000 bricks.

Amongst mortars, the conventional 1:6 cement mortar (1 cement: 6 fine sand) has the least EER, closely followed by 1:1:1 lime mortar (1 lime putty: 1 flyash: 1 fine sand) and 1:5 cement mortar (1 cement: 5 fine sand) in that order. Though 1:1:1 lime mortar is advantageous because it utilises flyash, it has a slower setting time and uses materials like lime and flyash, whose qualities cannot be consistently maintained.

The energy rates of the projects, computed by using masonry work in Hollow concrete blocks

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[1] DA/BMTPC, Energy in Building Materials – Final Report, 1995

(40cm x 20cm x 20cm), aerated concrete blocks, clay flyash bricks or Fal-G blocks, in 1:6 cement mortar, have also been compared with the actual energy rates with traditional brick masonry work. It is found that there is a drop of about 500-1950 MJ/sqm in the energy rates by using hollow and aerated blocks in 1:6 cement mortar. The corresponding fall for Fal-G blocks and clay flyash bricks is about 475-1700 MJ/sqm and 350-1400 MJ/sqm respectively. The fall in the rates is steeper in single storeyed units, followed by double storeyed and four storeyed housing construction. This is because of the fall in the net share of masonry work in the PEC with the additional storeys.

The true plane surfaces achieved by using alternative masonry units instead of traditional bricks also result in reducing the quantity of plastering needed for satisfactory coverage. This leads to savings of about 1-2% in the actual PEC of the projects.

The suitable Equations for providing a preliminary estimate of the PEC of housing construction of the types studied are listed in Table 8.18, whereas the preferred Equations for estimating the PEC using the suitable substitutes to traditional brick masonry work are listed in Table 8.19.

The partial replacement of brick masonry walls with new light-weight materials results in a change in the PEC of the projects by about ±0-2% in most of the cases. Thus, in energy terms, use of these alternatives do not result in a major change in the PEC of housing construction w.r.t. traditional brickwork. Moreover, except for ferrocement, the other materials are highly susceptible to fire. Moreover, they are expensive and their thinness is a hindrance in fixing electrical conduit pipes and sanitary pipelines. They also cannot be used for bathroom walls due to the possibility of dampness seeping through and the lack of privacy. But, since they show little change in the PEC of the projects (except for PVC), they can be suitable in a future scenario when bricks may not be sufficient to meet the growing demand, as mentioned in Chapter 1.

The broad recommendations from this study are as follows:

1. Double storeyed housing should be encouraged vis-à-vis the PEC of housing construction. But the effect of double storeyed housing on urban land use patterns and infrastructure also needs to be studied to arrive at a more comprehensive solution.
2. Traditional brick masonry work must be replaced by suitable alternatives obtained in this study in order to bring about a substantial reduction in the PEC of housing construction, which in turn will help in producing larger quantities of masonry units within the existing energy levels. Moreover, the use of materials like clay flyash bricks and Fal-G blocks will help in dealing with the ecological problem of flyash. Another major advantage will be the saving in top soil used in manufacturing traditional bricks. Concrete blocks will also prove to be a suitable replacement, particularly in areas where stone or stone aggregates are available in abundance.
3. It is imperative that the Government increases the awareness of architects and civil engineers to energy consumption in construction and the resultant ecological fallout.
4. Governmental policies need to be formulated to encourage the production and commercial application of alternative building materials.

Thus, the demand for more building materials will be met within the existing levels of energy consumption and within the contemporary methods of construction.

SCOPE FOR FUTURE RESEARCH

The present research has highlighted the sustainable impact of alternatives to masonry work. Further research has to be carried out to understand the technical characteristics of the alternatives vis-à-vis conventional materials, particularly with regard to structural safety[1] and

[1] Codes of the Bureau of Indian Standards (BIS), viz., IS-2185, Parts 1-3, have already specified the use of hollow, aerated and solid concrete blocks for both load bearing and non-load bearing construction.

thermal comfort. Their commercial viability also needs to be studied in detail. Studies are also needed to compute the PEC of housing construction using concrete blocks, where cement is partially substituted with flyash.

A similar approach can be adopted to seek substitutes for other sub-works of construction, particularly RCC work, which is the second major contributor to the PEC and construction cost. PEC of housing construction also needs to be studied vis-à-vis different types of foundations required for divergent types of soil.

The use of other industrial by-products as substitute building materials to conserve PEC can be studied, together with the use of recycled materials or demolition wastes. Further research is also needed in the use of light weight building materials.

Another important area of research is the development of a methodology for estimating the Secondary Energy Cost (SEC), which is the other component of the Construction Energy Cost (CEC). Together with this, the relationship between the CEC and the Operating Energy Cost (OEC) needs further investigation.

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APPENDIX-I

Methods for Estimating EEV of Building Materials and Description of Alternate Masonry Units

SECTION A

METHODS OF ANALYSIS FOR ESTIMATING EMBODIED ENERGY VALUES (EEV) OF BUILDING MATERIALS

The methods of analysis for estimating the EEV of building materials are as follows[1]:

1. Statistical Method
2. Input/Output Method
3. Process Analysis Method

1. Statistical Method

In this method, the EEV for a material is computed by dividing the energy input of an industry by its output. For example, in U.K., the brick industry consumed 68.4×10^9 MJ of energy in 1968 for the production of 7.5×10^9 bricks. This gave an EEV of 9.12 MJ per brick. But the disadvantage of the statistical method is that it gives an average EEV of the building material, irrespective of the quality of the raw material used or the process applied to manufacture it. For example, in brick production, the method can not distinguish between bricks made from highly carboniferous clays which provide some of their own firing energy and those which are made from low carbon clays which need a heavier fuel input to the kiln. It also cannot distinguish between the output of bricks from the more and less efficient brick manufacturing processes.

Though the Statistical Method has the above disadvantages, it provides a useful rough estimate of the EEV of building materials.

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[1] Source: Brown et. al., 1974.

2. **Input/Output Method**

This method is more elaborate than the Statistical Method. The interactions between the various sectors of industry are tabulated in matrix form so that the input of each industry to the other industry is available. It is possible by an alternate series of calculations to evaluate the direct and indirect energy inputs to each sector of industry. The disadvantage of this method of energy accounting is that there is a limited level of integration of industry and the fact that few industries produce a homogenous range of products.

3. **Process Analysis Method**

This method of estimation of the EEV deals with the actual process of manufacture itself. The energy inputs are quantified at each stage of production and summed to give the EEV of the finished material. Using this method, every stage of production can be analysed in detail. But this method also has several difficulties. Firstly, there has to be a thorough understanding of the manufacturing process, which is not an easy task as the required information about the process may not be available, particularly in some of the more complex industries. Moreover, it is impossible to assess how representative the process being analysed is to the whole of the industry concerned.

All the methods of analysis for accounting the EEV produce different results for the same material. Even using the same method of analysis can result in different EEV for the same material, because of the differing manufacturing processes used. However, given the time and effort, the Process Analysis Method is more likely to cover all the important variables thus invalidating the use of either of the other two methods.

SECTION B

ALTERNATE MASONRY UNITS

CLAY FLYASH BRICKS

Flyash can be utilised as an integral mix with brick making soils, yielding good quality building bricks. Bricks confirming in the range of grades 50 to 300 as prescribed in IS: 1077-1992[1] can be manufactured. These bricks can be used for all types of brick masonry and paving purposes. Strength of bricks in case of red and black soils is significantly increased with the addition of flyash while, in case of alluvial soils, brick strength is slightly improved. The bulk density of the clay flyash bricks is less than the traditional bricks, which provides better thermal insulation in the masonry walls and reduces the dead load on the brick masonry structure.

Clay flyash bricks are ecologically advantageous because they utilise an hazardous waste like flyash. Waste flyash upto 100-125 tonnes per 100,000 bricks in case of red and black soils and 30-40 tonnes per 100,000 bricks in case of alluvial soils can be utilised. They are also an economically and ecologially sound option as replacement of clay with flyash saves topsoil and hence, prime agricultural land. Flyash also reduces the energy required in the firing of bricks in the kiln, thus saving coal upto 3-5 tonnes per 10^5 bricks.

SAND LIME BRICKS

Calcium silicate bricks, generally known as sand lime bricks, are made from sand or silicious waste (like flyash, tailings from gold, copper, iron and zinc) and hydrated lime. Manufacture of these bricks is economically feasible where sand or silicious waste and lime are readily available and good quality clay is not found. These bricks consume about 30% less energy in

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[1] IS: 1077-1992, Common Burnt Clay Building Bricks

their production as compared to traditional bricks. Moreover, good quality sand lime bricks have been manufactured by using different raw materials at the Central Building Research Institute (CBRI) and they compare favourably with the traditional bricks.

CONCRETE BLOCKS

Cement based alternatives for masonry applications have become extremely popular in large areas of the country where block availability is adversely affected due to depleted clay resources and fuel shortages. In areas with black cotton soil, the switch over to concrete blocks is already highly advanced. This is aided by easy availability of crushed stone and cement. The concrete blocks can be designed to suit the needs of varying types of construction, ranging from load bearing walls to partition walls. The main categories of concrete blocks that exist are :

- Hollow load bearing concrete blocks
- Hollow non-load bearing concrete blocks
- Solid load bearing concrete blocks
- Aerated Concrete blocks

As per IS: 2185 (Part 1)[1] and IS: 2185 (Part 3)[2], hollow, solid and aerated concrete blocks are defined as follows:

- **Hollow Concrete Block**

  A block having one or more large holes of cavities, which either pass through the block (open cavity) or do not effectively pass through the block (closed cavity). The solid material in the block is between 50-75% of the total volume of the block calculated from the overall dimensions.

[1] BIS code IS: 2185 (Part I) – 1979, Indian Standard Specification for Concrete Masonry Units – Hollow and Solid Concrete Blocks
[2] BIS code IS: 2185 (Part 3) – 1984, Indian Standard Specification for Concrete Masonry Units – Autoclaved Cellular (Aerated) Concrete Blocks

- **Solid Concrete Block**

  A block, which has solid material not less than 75% of the total volume of the block, calculated from the overall dimensions.

- **Aerated Concrete Block**

  A block involving the use of aerated concrete, which is made by introducing air or other gases into a slurry composed of cement or lime and a siliceous filler so that when the mixture sets hard after autoclaving, a uniform cellular structure is obtained.

Concrete blocks are manufactured from varying mixes which consist mainly of cement, sand and coarse aggregates. Various combinations substituting flyash for sand are also possible. Flyash addition also reduces the cement requirement of blocks. The mix ratios have been found to be varying from 1 part cement to 15 part of the other additives to richer mixes in the ratio of 1:5.

The strength of the solid concrete blocks can vary from 80-150 kg/sqm. There is a drastic reduction in strength in the case of hollow blocks with typical strength of 35 kg/sqm. The sizes of the blocks are normally 30cm x 20cm x 15 cm for solid blocks and 40cm x 20cm x 10cm or 40cm x 20cm x 20cm for hollow blocks. The size for aerated blocks is 40cm x 20cm x 20cm.

Concrete blocks may be manufactured either manually or using a block making machine. The blocks made by the machine are far superior in strength and finish vis-à-vis the manually made blocks.

FAL-G BLOCKS

Fal-G blocks have gained widespread acceptance in the southern Indian state of Andhra Pradesh and are made of flyash, lime and gypsum. If the flyash is too fine, sand or cinder fines may have to be added. The blocks are made in the same manner as the concrete blocks and cured for 21 days. The compressive strength achieved is reported to be 70-110 kg/sqm.

ADVANTAGES OF ALTERNATIVE MASONRY UNITS

All the alternative masonry units have several advantages vis-à-vis traditional bricks:

- They are more appealing due to their accurate shapes, edges and corners.
- There is saving in mortar volume due to their uniform shapes and sizes. Moreover, the large size of the concrete blocks result in fewer joints, resulting in considerable saving in mortar and also increases the strength of the wall.
- The production of these alternative masonry units can be assured throughout the year and is not subject to the vagaries of weather.
- The large size of the concrete and Fal-G blocks also ensures rapid construction as more wall can be laid per man-hour than in the traditional brick construction.
- Alternatives like the hollow blocks, while providing adequate support as load bearing members, also ensure good insulation, thus reducing the net thermal gain.
- The true plane surfaces obtained by these alternatives reduce the requirement of plaster for satisfactory coverage.
- Alternative units like clay flyash bricks, with flyash as an additive, not only help in utilising a hazardous waste, but also help in saving precious top soil needed to make traditional bricks.
- All the alternatives have attractive appearance and are readily adaptable to any style of architecture. Bricks of different colours are also possible in clay flyash and sand lime bricks.

POLY VINYL CHLORIDE (PVC)

It is versatile thermoplastic material, which can used in the production of highly rigid products, such as pipes, doors, windows, roofing and walling elements.

CEMENT BONDED BOARDS (CBB)

These boards are made up of 62% cement and 28% wood. CBB panels have the strength and durability of cement and the easy workability of wood. They can be used for door shutters, floors, roofs, partitions and even prefabricated structures.

FERROCEMENT

It is a highly versatile form of reinforced concrete made of cement mortar and wire mesh reinforcement and possesses the unique qualities of strength and serviceability. The advantages of ferrocement construction are:

- Structures can be thin and light
- They can be easily pre-cast
- They are amenable to repairs in case of local damage
- Considerable savings in framework particularly of complex shapes
- High cost saving potentials

Since the construction techniques for ferrocement is simple, the workmen can be easily trained in using it on site. It can be an efficient prefabricated system for mass scale projects. Ferrocement can be used for roofing, understructure elements, doors, partitions and water tanks etc.

MEDIUM DENSITY FIBREBOARDS

MDF is manufactured by a dry process where the fibres are dried before they are formed into a mat for pressing. MDF is made stronger by adding synthetic resin binders. The physical properties of MDF approach those of solid wood.

PLYBOARDS

Plywood and plyboards are used for panels in furniture, doors, windows and partitions etc. They consist of sheets of veneers bonded by a synthetic resin glue, urea formaldehyde or phenol formaldehyde.

APPENDIX-II

Schedule of Energy Rates

EMBODIED ENERGY VALUES (EEV) OF BUILDING MATERIALS

S.No.	Building Material	Size (Dims in cms.)	Unit	Embodied Energy Value (EEV) in MJ/Unit
1.	Traditional Brick	22.9 x 11.4 x 7.6	brick	4.50
2.	Modular Brick	20 x 10 x 10	brick	4.50
3.	Brick Tile	22.9 x 11.4 x 3.81	tile	2.25
4.	Brick Tile	20 x 10 x 5	tile	2.25
5.	Brick Tile	22.9 x 11.4 x 3.18	tile	1.90
6.	Brick Tile	25 x 25 x 2.5	tile	3.50
7.	Clay Flyash Brick	20 x 10 x 10	brick	2.32
8.	Sand Lime Brick	20 x 10 x 10	brick	2.79
9.	Hollow Concrete Block	40 x 20. x 10	block	10.80
10.	Hollow Concrete Block	40 x 20 x 20	block	11.00
11.	Aerated Block	40 x 20 x 20	block	11.50
12.	Solid Concrete Block	30 x 20 x 15	block	10.40
13.	Fal-G. Block	30 x 20 x 15	block	7.90
14.	Cement	-	kg	6.70
15.	Steel	-	kg	32.00
16.	Lime	-	kg	6.50
17.	Surkhi[1]	-	cum	1459.50
18.	Coarse Aggregate	-	cum	538.00
19.	Flyash	-	cum	0.00
20.	Fine Sand	-	cum	0.00
21.	Coarse Sand	-	cum	0.00
22.	Cinder	-	cum	0.00
23.	Stone Dust	-	cum	0.00
24.	Marble Dust	-	cum	0.00
25.	Mud	-	cum	0.00
26.	Sheet Glass	-	sqm	276.96

[1] Surkhi is made from burnt clay bricks by finely grinding them

1. MORTAR WORK

Item Code No.	Description of Item of Work	Unit	Embodied Energy Rate (EER) in MJ/Unit
	Mortar Work with Lime Mortar		
1.1.	Lime mortar 1:1 (1 lime putty : 1 fine sand)	cum	2931.50
1.2.	Lime mortar 1:2 (1 lime putty : 2 fine sand)	cum	1956.50
1.3.	Lime mortar 1:3 (1 lime putty : 3 coarse sand)	cum	1462.50
1.4.	Lime mortar 1:2 (1 lime putty : 2 surkhi)	cum	3343.03
1.5.	Lime mortar 1:3 (1 lime putty : 3 surkhi)	cum	3021.25
1.6.	Lime mortar 1:2 (1 lime putty : 2 cinder)	cum	1956.50
1.7.	Lime mortar 1:2 (1 lime putty : 2 flyash)	cum	1956.50
1.8.	Lime mortar 1:1:1 (1 lime putty : 1 surkhi : 1 fine sand)	cum	2649.76
1.9.	Lime mortar 1:1:1 (1 lime putty : 1 surkhi : 1 coarse sand)	cum	2649.76
1.10.	Lime mortar 1:1:2 (1 lime putty : 1 surkhi : 2 coarse sand)	cum	1982.08
1.11.	Lime mortar 1:1:1 (1 lime putty : 1 flyash : 1 fine sand)	cum	1956.50
	Mortar Work with Cement Mortar		
1.12.	Cement mortar 1:1 (1 cement : 1 fine sand)	cum	6834.00
1.13.	Cement mortar 1:2 (1 cement : 2 fine sand)	cum	4556.00
1.14.	Cement mortar 1:3 (1 cement : 3 fine sand)	cum	3417.00
1.15.	Cement mortar 1:4 (1 cement : 4 fine sand)	cum	2546.00
1.16.	Cement mortar 1:5 (1 cement : 5 fine sand)	cum	2077.00
1.17.	Cement mortar 1:6 (1 cement : 6 fine sand)	cum	1675.00
1.18.	Cement mortar 1:2 (1 cement : 2 coarse sand)	cum	4556.00
1.19.	Cement mortar 1:3 (1 cement : 3 coarse sand)	cum	3417.00
1.20.	Cement mortar 1:4 (1 cement : 4 coarse sand)	cum	2546.00
1.21.	Cement mortar 1:5 (1 cement : 5 coarse sand)	cum	2077.00

Item Code No.	Description of Item of Work	Unit	Embodied Energy Rate (EER) in MJ/Unit
1.22.	Cement mortar 1:6 (1 cement : 6 coarse sand)	cum	1675.00
1.23.	Cement mortar 1: 2 (1 cement : 2 stone dust)	cum	4556.00
1.24.	Cement mortar 1: 2 (1 cement : 2 marble dust)	cum	4556.00
1.25.	Cement mortar 1: 5 (1 cement : 5 marble dust)	cum	2077.00
1.26.	Cement mortar 1:1:3 (1 cement : 1 marble dust : 3 stone dust)	cum	2345.00
1.27.	Cement mortar 1:1:3 (1 cement: 1 flyash: 3 fine sand)	cum	2345.00
1.28.	Cement mortar 1:2:4 (1 cement : 2 flyash : 4 fine sand)	cum	1809.00
1.29.	Cement mortar 1: 3.6: 6.5 (1cement: 3.6 flyash: 6.5 fine sand)	cum	1139.00
	Mortar Work with White Cement Mortar		
1.30.	White cement mortar 1:2 (1 white cement : 2 marble dust)	cum	4556.00
1.31.	White cement mortar 1:3 (1 white cement : 3 marble dust)	cum	3417.00
1.32.	White cement mortar 1:5 (1 white cement : 5 marble dust)	cum	2077.00
1.33.	White cement lime mortar ¼:1:1:1 (¼white cement : 1 lime putty : 1 stone dust : 1 marble dust)	cum	2885.50
	Mortar Work with Composite Mortar		
1.34.	Cement lime mortar 1:1:3 (1 cement: 1 lime putty: 3 fine sand)	cum	3923.50
1.35.	Cement lime mortar 1:1:6 (1 cement : 1 lime putty: 6 fine sand)	cum	2409.50
1.36.	Cement lime mortar 1:1:7 (1 cement: 1 lime putty: 7 fine sand)	cum	2104.50
1.37.	Cement lime mortar 1:1:8 (1 cement: 1 lime putty: 8 fine sand)	cum	1819.00
1.38.	Cement lime mortar 1:2:9 (1 cement: 2 lime putty: 9 fine sand)	cum	2120.50

Item Code No.	Description of Item of Work	Unit	Embodied Energy Rate (EER) in MJ/Unit
1.39.	Cement lime mortar 1:1:3 (1 cement: 1lime putty: 3 coarse sand)	cum	3923.50
1.40.	Cement lime mortar 1:1:6 (1cement: 1lime putty: 6 coarse sand)	cum	2409.50

2. MASONRY WORK

2.1. MASONRY WORK IN MODULAR BRICKS

Item Code No.	Description of Item of Work	Unit	Embodied Energy Rate (EER) in MJ/Unit
2.1.1.	1st class brick work in foundation and plinth in lime mortar 1:1:1 (1 lime putty : 1 flyash : 1 fine sand)	cum	2621.93
2.1.2.	1st class brick work in foundation and plinth in lime mortar 1:1:1 (1 lime putty : 1 surkhi : 1 fine sand)	cum	2774.45
2.1.3.	1st class brick work in foundation and plinth in cement lime mortar 1:1:6 (1 cement : 1 lime putty : 6 fine sand)	cum	2721.60
2.1.4.	1st class brick work in foundation and plinth in cement lime mortar 1:1:7 (1 cement : 1 lime putty : 7 fine sand)	cum	2654.50
2.1.5.	1st class brick work in foundation and plinth in cement lime mortar 1:1:8 (1 cement : 1 lime putty : 8 fine sand)	cum	2591.68
2.1.6.	1st class brick work in foundation and plinth in cement lime mortar 1:2:9 (1 cement : 2 lime putty : 9 fine sand)	cum	2658.00
2.1.7.	1st class brick work in foundation and plinth in cement lime mortar 1:1:6 (1cement :1lime putty : 6 coarse sand)	cum	2721.59
2.1.8.	1st class brick work in foundation and plinth in cement mortar 1:3 (1 cement : 3 fine sand)	cum	2943.24
2.1.9.	1st class brick work in foundation and plinth in cement mortar 1:4 (1 cement : 4 fine sand)	cum	2751.62
2.1.10.	1st class brick work in foundation and plinth in cement mortar 1:5 (1 cement : 5 fine sand)	cum	2648.44
2.1.11.	1st class brick work in foundation and plinth in cement mortar 1:6 (1 cement : 6 fine sand)	cum	2560.00
2.1.12.	1st class brick work in foundation and plinth in cement mortar 1:3 (1 cement : 3 coarse sand)	cum	2943.24
2.1.13.	1st class brick work in foundation and plinth in cement mortar 1:4 (1 cement : 4 coarse sand)	cum	2751.62
2.1.14.	1st class brick work in foundation and plinth in cement mortar 1:5 (1 cement : 5 coarse sand)	cum	2648.44
2.1.15.	1st class brick work in foundation and plinth in cement mortar 1:6 (1 cement : 6 coarse sand)	cum	2560.00

Item Code No.	Description of Item of Work	Unit	Embodied Energy Rate (EER) in MJ/Unit
2.1.16.	2nd class brick work in foundation and plinth in mud mortar	cum	2191.50
2.1.17.	Extra for brick work in superstructure above plinth lvl. upto 1st flr. lvl.	cum	0.00
2.1.18.	Extra for brick work in superstructure above 1st flr. lvl.	cum	0.00
2.1.19.	Extra for brick work in square and rectangular pillars	cum	0.00
2.1.20.	Extra for brick work in circular pillars	cum	639.00
2.1.21.	Extra for brick work curved on plan up to a mean radius not exceeding 6 m	cum	157.50
2.1.22.	1st class brick work in plain arches in superstructure in cement mortar 1:4 (1 cement : 4 coarse sand)	cum	2751.62
2.1.23.	2nd class brick work in plain arches in superstructure in cement mortar 1:4 (1 cement: 4 coarse sand)	cum	2751.62
2.1.24.	1st class brick work in gauged arches in superstructure in cement mortar 1:4 (1 cement : 4 coarse sand)	cum	3170.12
	Half Brick Masonry Work		
2.1.25.	Half brick masonry (1st class) in foundation and plinth in cement lime mortar 1:1:6 (1 cement: 1 lime putty: 6 fine sand)	cum	3077.38
2.1.26.	Half brick masonry (1st class) in foundation and plinth in cement lime mortar 1:1:6 (1 cement: 1lime putty: 6 coarse sand)	cum	3077.38
2.1.27.	Half brick masonry (1st class) in foundation and plinth in cement mortar 1:3 (1 cement: 3 coarse sand)	cum	3329.25
2.1.28.	Half brick masonry (1st class) in foundation and plinth in cement mortar 1:4 (1cement : 4 coarse sand)	cum	3111.50
2.1.29.	(a) Half brick masonry (1st class) in foundation and plinth in cement mortar 1:3 (1 cement : 3 coarse sand) with hoop iron 25 mm x 1.6 mm or equivalent reinforcement at every 3rd course, embedded in the cement mortar	cum	3636.45
	(b) Half brick masonry (1st class) in foundation and		

Item Code No.	Description of Item of Work	Unit	Embodied Energy Rate (EER) in MJ/Unit
	plinth in cement mortar 1:4 (1cement: 4 coarse sand) with 2 nos. 6mm & mild steel bar at every third course in superstructure above plinth lvl. upto 1st flr. lvl.	cum	3674.70
2.1.30.	Extra for half brick masonry in superstructure above plinth lvl. upto 1st flr. lvl.	cum	0.00
	Tile Brick Masonry Work		
2.1.31.	1st class tile brick masonry in foundation and plinth in lime mortar 1:1:1(1 lime putty :1 surkhi: 1 fine sand)	cum	2932.43
2.1.32.	1st class tile brick masonry in foundation and plinth in lime mortar 1:1:1 (1 lime putty : 1 flyash : 1 fine sand)	cum	2724.45
2.1.33.	1st class tile brick masonry in foundation and plinth in cement lime mortar 1:1:6 (1 cement :1 lime putty: 6 fine sand)	cum	2860.35
2.1.34.	1st class tile brick masonry in foundation and plinth in cement lime mortar 1:1:6 (1 cement : 1 lime putty: 6 coarse sand)	cum	2860.35
2.1.35.	1st class tile brick masonry in foundation and plinth in cement mortar 1:4 (1 cement : 4 fine sand)	cum	2901.30
2.1.36.	1st class tile brick masonry in foundation and plinth in cement mortar 1:6 (1 cement : 6 fine sand)	cum	2640.00
2.1.37.	1st class tile brick masonry in foundation and plinth in cement mortar 1:4 (1 cement : 4 coarse sand)	cum	2901.30
2.1.38.	1st class tile brick masonry in foundation and plinth in cement mortar 1:6 (1 cement : 6 coarse sand)	cum	2640.00
2.1.39.	Extra for tile brick masonry in superstructure above plinth lvl. upto 1st flr. lvl.	cum	0.00
2.1.40.	Extra for tile brick masonry in superstructure above 1st flr. lvl.	cum	0.00
2.1.41.	Extra for 1st class tile brick masonry in square or rectangular pillars	cum	0.00
2.1.42.	Extra for 1st class tile brick masonry curved on plan upto a mean radius not exceeding 6 m	cum	150.75
2.1.43.	1st class tile brick masonry in plain arch work in superstructure in cement mortar 1:4 (1 cement : 4 coarse sand)	cum	2901.30

Item Code No.	Description of Item of Work	Unit	Embodied Energy Rate (EER) in MJ/Unit
2.1.44.	1st class tile brick masonry in gauged arch work in superstructure in cement mortar 1:4 (1 cement : 4 coarse sand)	cum	2939.55
2.1.45.	Tile brick masonry 5 cm thick in superstructure in cement mortar 1:3 (1 cement : 3 coarse sand)	sqm	136.42
2.1.46.	Tile brick masonry 5 cm thick in superstructure in cement mortar 1:3 (1cement: 3 coarse sand) with hoop iron 25 mm x 1.6 mm or equivalent reinforcement at every 3rd course, embedded in the cement mortar	sqm	167.14
	<u>Miscellaneous Brick Masonry Work</u>		
2.1.47.	Honey comb brick work 10 cm thick with 1st class bricks in cement mortar 1:4 (1cement : 4 coarse sand)	sqm	181.61
2.1.48.	Extra for making tapered surface of brick masonry	sqm	84.67
2.1.49.	Jointing old brick work in metric system with new brick work in metric system	sqm	68.80
2.1.50.	Providing 10 cm thick 1st class brick drip course at junction of roofs and walls in cement mortar 1:4 (1cement : 4 sand)	m	27.52
2.1.51.	Providing 10 cm thick 1st class brick drip course at junctions of roofs and walls in cement mortar 1:6 (1cement : 6 sand)	m	25.60
2.1.52.	Providing 10 cm thick 2nd class brick drip course at junction of roofs and walls in cement mortar 1:6 (1 cement: 6 sand)	m	25.60
2.1.53.	Providing 10 cm thick 5 cm projected 1st class brick string course in cement mortar 1:4 (1 cement : 4 fine sand)	m	13.76
2.1.54.	Mouldings and cornices in brick work with cement plaster 1:4 (1 cement : 4 fine sand)	m per cm girth	1.26
2.1.55.	Providing brick band 10 cm thick and 5 cm projected from the wall face in 1st class brick work laid in cement mortar 1:4 (1cement : 4 fine sand)	m	13.76

2.2. MASONRY WORK IN TRADITIONAL BRICKS

Item Code No.	Description of Item of Work	Unit	Embodied Energy Rate (EER) in MJ/Unit
2.2.1..	1st class brick work in foundation and plinth in lime mortar 1:1:1 (1 lime putty : 1 flyash : 1 fine sand)	cum	2712.13
2.2.2.	1st class brick work in foundation and plinth in lime mortar 1:1:1 (1 lime putty : 1 surkhi : 1 fine sand)	cum	2885.44
2.2.3.	1st class brick work in foundation and plinth in cement lime mortar 1:1:6 (1 cement : 1 lime putty : 6 fine sand)	cum	2825.38
2.2.4..	1st class brick work in foundation and plinth in cement lime mortar 1:1:7 (1 cement : 1 lime putty : 7 fine sand)	cum	2749.13
2.2.5..	1st class brick work in foundation and plinth in cement lime mortar 1:1:8 (1 cement : 1 lime putty : 8 fine sand)	cum	2677.75
2.2.6..	1st class brick work in foundation and plinth in cement lime mortar 1:2:9 (1 cement : 2 lime putty : 9 fine sand)	cum	2753.13
2.2.7..7.	1st class brick work in foundation and plinth in cement lime mortar 1:1:6 (1 cement : 1lime putty : 6 coarse sand)	cum	2825.38
2.2.8..	1st class brick work in foundation and plinth in cement mortar 1:3 (1 cement : 3 fine sand)	cum	3077.25
2.2.9.9.	1st class brick work in foundation and plinth in cement mortar 1:4 (1 cement : 4 fine sand)	cum	2859.50
2.2.10.	1st class brick work in foundation and plinth in cement mortar 1:5 (1 cement : 5 fine sand)	cum	2742.25
2.2.11.	1st class brick work in foundation and plinth in cement mortar 1:6 (1 cement : 6 fine sand)	cum	2641.75
2.2.12.	1st class brick work in foundation and plinth in cement mortar 1:3 (1 cement : 3 coarse sand)	cum	3077.25
2.2.13.	1st class brick work in foundation and plinth in cement mortar 1:4 (1 cement : 4 coarse sand)	cum	2859.50
2.2.14.	1st class brick work in foundation and plinth in cement mortar 1:5 (1 cement : 5 coarse sand)	cum	2742.25
2.2.15.	1st class brick work in foundation and plinth in cement mortar 1:6 (1 cement : 6 coarse sand)	cum	2641.75

Item Code No.	Description of Item of Work	Unit	Embodied Energy Rate (EER) in MJ/Unit
2.2.16.	2nd class brick work in foundation and plinth in mud mortar	cum	2223.00
2.2.17.	Extra for brick work in superstructure above plinth lvl. upto 1st flr. lvl.	cum	0.00
2.2.18.	Extra for brick work in superstructure above 1st flr. lvl.	cum	0.00
2.2.19.	Extra for brick work in square and rectangular pillars	cum	0.00
2.2.20.	Extra for brick work in circular pillars	cum	634.50
2.2.21.	Extra for brick work curved on plan up to a mean radius not exceeding 6 m	cum	162.00
2.2.22.	1st class brick work in plain arches in superstructure in cement mortar 1:4 (1 cement : 4 coarse sand)	cum	2859.50
2.2.23.	2nd class brick work in plain arches in superstructure in cement mortar 1:4 (1 cement: 4 coarse sand)	cum	2859.50
2.2.24.	1st class brick work in gauged arches in superstructure in cement mortar 1:4 (1 cement : 4 coarse sand)	cum	3057.50
2.2.25.	1st class brick work 7.6 cm thick in cement mortar 1:3 (1cement : 3 coarse sand) in superstructure	sqm	2013.04
2.2.26.	1st class brick work 7.6 cm thick in cement mortar 1:3 (1cement : 3 coarse sand) with hoop iron 25 mm x 1.6 mm or equivalent reinforcement at every 3rd course, embedded in cement mortar in superstructure	sqm	2021.40
2.2.27.	2nd class brick work 7.6 cm thick in superstructure in cement mortar 1:3 (1cement : 3 coarse sand)	sqm	2013.04
2.2.28.	2nd class brick work 7.6 cm thick in superstructure in cement mortar 1:3 (1cement : 3 coarse sand) with hoop iron 25 mm x 1.6 mm or equivalent reinforcement at every 3rd course, embedded in the cement mortar	sqm	2021.40
	Half Brick Masonry Work		
2.2.29.	Half brick masonry (1st class) in foundation and plinth in cement lime mortar 1:1:6 (1 cement: 1 lime putty: 6 fine sand)	cum	2822.07
2.2.30.	Half brick masonry (1st class) in foundation and plinth in cement lime mortar 1:1:6 (1cement: 1lime putty: 6 coarse sand)	cum	2822.07

Item Code No.	Description of Item of Work	Unit	Embodied Energy Rate (EER) in MJ/Unit
2.2.31.	Half brick masonry (1st class) in foundation and plinth in cement mortar 1:3 (1 cement: 3 coarse sand)	cum	3069.52
2.2.32.	Half brick masonry (1st class) in foundation and plinth in cement mortar 1:4 (1 cement : 4 coarse sand)	cum	2855.61
2.2.33.	(a) Half brick masonry (1st class) in foundation and plinth in cement mortar 1:3 (1 cement : 3 coarse sand) with hoop iron 25 mm x 1.6 mm or equivalent reinforcement at every 3rd course, embedded in the cement mortar	cum	3339.00
	(b) Half brick masonry (1st class) in foundation and plinth in cement mortar 1:4 (1 cement: 4 coarse sand) with 2 nos. 6mm & mild steel bar at every third course in superstructure above plinth lvl. upto 1st flr. lvl.	cum	3349.63
2.2.34.	(a) Extra for half brick masonry in superstructure above plinth lvl. upto 1st flr. lvl.	cum	0.00
	(b) Extra for half brick masonry in superstructure above 1st flr. lvl.	cum	0.00
	Tile Brick Masonry Work		
2.2.35.	1st class tile brick masonry in foundation and plinth in lime mortar 1:1:1 (1 lime putty :1 surkhi: 1 fine sand)	cum	2808.15
2.2.36.	1st class tile brick masonry in foundation and plinth in lime mortar 1:1:1 (1 lime putty : 1 flyash : 1 fine sand)	cum	2530.85
2.2.37.	1st class tile brick masonry in foundation and plinth in cement lime mortar 1:1:6 (1 cement: 1 lime putty: 6 fine sand)	cum	2712.05
2.2.38.	1st class tile brick masonry in foundation and plinth in cement lime mortar 1:1:6 (1 cement : 1 lime putty: 6 coarse sand)	cum	2712.05
2.2.39.	1st class tile brick masonry in foundation and plinth in cement mortar 1:4 (1 cement : 4 fine sand)	cum	2766.65
2.2.40.	1st class tile brick masonry in foundation and plinth in cement mortar 1:6 (1 cement : 6 fine sand)	cum	2418.25
2.2.41.	1st class tile brick masonry in foundation and plinth in cement mortar 1:4 (1 cement : 4 coarse sand)	cum	2766.65
2.2.42.	1st class tile brick masonry in foundation and plinth in		

Item Code No.	Description of Item of Work	Unit	Embodied Energy Rate (EER) in MJ/Unit
	cement mortar 1:6 (1 cement : 6 coarse sand)	cum	2418.25
2.2.43.	Extra for tile brick masonry in superstructure above plinth lvl. upto 1st flr. lvl.	cum	0.00
2.2.44.	Extra for tile brick masonry in superstructure above 1st flr. lvl.	cum	0.00
2.2.45.	Extra for 1st class tile brick masonry in square or rectangular pillars	cum	0.00
2.2.46.	Extra for 1st class tile brick masonry curved on plan upto a mean radius not exceeding 6 m	cum	123.75
2.2.47.	1st class tile brick masonry in plain arch work in superstructure in cement mortar 1:4 (1 cement : 4 coarse sand)	cum	2766.65
2.2.48.	1st class tile brick masonry in gauged arch work in superstructure in cement mortar 1:4 (1 cement: 4 coarse sand)	cum	2798.15
2.2.49.	Tile brick masonry 3.175 cm thick in superstructure in cement mortar 1:3 (1 cement: 3 coarse sand)	sqm	122.85
2.2.50.	Tile brick masonry work 3.175 cm thick in superstructure in cement mortar 1:3 (1 cement: 3 coarse sand) with hoop iron from 25 mm x 1.6 mm or equivalent reinforcement at every 3rd course, embedded in the cement mortar	sqm	153.61
	<u>Miscellaneous Brick Masonry Work</u>		
2.2.51.	Honey comb brick work 3.175 cm thick with 1st class bricks in cement mortar 1:4 (1 cement : 4 coarse sand)	sqm	197.31
2.2.52.	Extra for making tapered surface of brick masonry	sqm	86.13
2.2.53.	Jointing old brick work in F.P.S. system with new brick work in F.P.S. system	sqm	82.00
2.2.54.	Providing 7.6 cm thick 1st class brick drip course at junction of roofs and walls in cement mortar 1:4 (1 cement: 4 fine sand)	m	24.88
2.2.55.	Providing 7.6 cm thick 1st class brick drip course at junctions of roofs and walls in cement mortar 1:6 (1 cement: 6 fine sand)	m	22.98
2.2.56.	Providing 10.0 cm thick 2nd class brick drip course at		

Item Code No.	Description of Item of Work	Unit	Embodied Energy Rate (EER) in MJ/Unit
	the junctions of roofs and walls in cement mortar 1:6 (1 cement: 6 fine sand)	m	22.98
2.2.57.	Providing 7.62 cm thick 5 cm projected 1st class brick string course in cement mortar 1:4 (1 cement : 4 fine sand)	m	12.30
2.2.58.	Mouldings and cornices in brick work with cement plaster 1:4 (1 cement : 4 fine sand)	m per cm girth	1.43
2.2.59.	Providing brick band 7.62 cm thick and 5.72 cm projected from the wall face, in 1st class brick work laid in cement mortar 1:4 (1 cement : 4 fine sand)	m	12.30

2.3. MASONRY WORK IN ALTERNATE MASONRY UNITS

Item Code No.	Description of Item of Work	Unit	Embodied Energy Rate (EER) in MJ/Unit
	MASONRY WORK IN CLAY FLYASH BRICKS (20 CM X 10 CM X 10 CM)		
2.3.1.	Brick masonry work in foundation and plinth in 1:1:1 lime mortar (1 lime putty: 1flyash:1 fine sand)	cum	1560.30
2.3.2.	Brick masonry work in foundation and plinth in 1:1:1 lime mortar (1 lime putty: 1surkhi: 1 fine sand)	cum	1712.78
2.3.3.	Brick masonry work in foundation and plinth in 1:3 cement mortar (1 cement: 3 fine sand)	cum	1881.60
2.3.4.	Brick masonry work in foundation and plinth in 1:4 cement mortar (1 cement: 4 fine sand)	cum	1690.00
2.3.5.	Brick masonry work in foundation and plinth in 1:5 cement mortar (1 cement: 5 fine sand)	cum	1586.78
2.3.6.	Brick masonry work in foundation and plinth in 1:6 cement mortar (1 cement: 6 fine sand)	cum	1498.34
2.3.7.	Brick masonry work in foundation and plinth in 1:6 cement mortar (1 cement: 6 coarse sand)	cum	1498.34
2.3.8.	Brick masonry work in foundation and plinth in 1:1:6 cement lime mortar (1 cement: 1 lime putty : 6 fine sand)	cum	1660.00
2.3.9.	Brick masonry work in foundation and plinth in 1:1:7 cement lime mortar (1 cement : 1 lime putty : 7 fine sand)	cum	1592.83
2.3.10.	Brick masonry work in foundation and plinth in 1:1:8 cement lime mortar (1 cement : 1 lime putty : 8 fine sand)	cum	1530.00
2.3.11.	Brick masonry work in foundation and plinth in 1:2:9 cement lime mortar (1 cement : 2 lime putty : 9 fine sand)	cum	1596.35
2.3.12.	Extra for brick masonry work in superstructure above plinth lvl. upto 1st flr. lvl.	cum	0.00
	Half Brick Masonry Work in Clay Flyash Bricks		
2.3.13.	Half brick masonry work in foundation and plinth in cement mortar 1:3 (1 cement: 3 coarse sand)	cum	2130.25

Item Code No.	Description of Item of Work	Unit	Embodied Energy Rate (EER) in MJ/Unit
2:3.14.	Half brick masonry work in foundation and plinth in cement mortar 1:4 (1 cement : 4 coarse sand)	cum	1912.50
2.3.15.	Half brick masonry work in foundation and plinth in cement lime mortar 1:1:6 (1 cement : 1 lime putty: 6 coarse sand)	cum	1878.38
2.3.16.	(a) Half brick masonry work in foundation and plinth in cement mortar 1:3 (1 cement : 3 coarse sand) with hoop iron 25 mm x 1.6 mm or equivalent reinforcement at every 3rd course, embedded in the cement mortar	cum	2437.45
	(b) Half brick masonry work in foundation and plinth in cement mortar 1:4 (1cement: 4 coarse sand) with 2 nos. 6mm & mild steel bar at every third course in superstructure above plinth level upto 1st flr. lvl.	cum	2475.70
2.3.17.	Extra for half brick. masonry work in superstructure above plinth lvl.	cum	0.00
	MASONRY WORK IN SAND LIME BRICKS (20 CM X 10 CM X 10 CM)		
2.3.18.	Brick masonry work in foundation and plinth in 1:1:1 lime mortar (1 lime putty: 1 flyash: 1 fine sand)	cum	1789.16
2.3.19.	Brick masonry work in foundation and plinth in 1:1:1 lime mortar (1 lime putty: 1surkhi:1 fine sand)	cum	1941.68
2.3.20.	Brick masonry work in foundation and plinth in 1:3 cement mortar (1 cement: 3 fine sand)	cum	2110.50
2.3.21.	Brick masonry work in foundation and plinth in 1:4 cement mortar (1 cement: 4 fine sand)	cum	1918.85
2.3.22.	Brick masonry work in foundation and plinth in 1:5 cement mortar (1 cement: 5 fine sand)	cum	1815.67
2.3.23.	Brick masonry work in foundation and plinth in 1:6 cement mortar (1 cement: 6 fine sand)	cum	1727.23
2.3.24.	Brick masonry work with sand lime bricks in foundation and plinth in 1:6 cement mortar (1 cement: 6 coarse sand)	cum	1727.23
2.3.25.	Brick masonry work with sand lime bricks in foundation and plinth in 1:1:6 cement lime mortar (1 cement: 1 lime putty : 6 fine sand)	cum	1888.82

Item Code No.	Description of Item of Work	Unit	Embodied Energy Rate (EER) in MJ/Unit
2.3.26.	Brick masonry work with sand lime bricks in foundation and plinth in 1:1:7 cement lime mortar (1 cement: 1 lime putty : 7 fine sand)	cum	1821.72
2.3.27.	Brick masonry work with sand lime bricks in foundation and plinth in 1:1:8 cement lime mortar (1 cement: 1 lime putty : 8 fine sand)	cum	1758.91
2.3.28.	Brick masonry work with sand lime bricks in foundation and plinth in 1:2:9 cement lime mortar (1 cement: 2 lime putty : 9 fine sand)	cum	1825.24
	<u>Half Brick Masonry Work in Sand Lime Bricks</u>		
2.3.29.	Extra for brick masonry work with sand lime bricks in superstructure above plinth level upto 1st flr. lvl.	cum	0.00
2.3.30.	Half brick masonry work in foundation and plinth in cement mortar 1:3 (1 cement: 3 coarse sand)	cum	2388.75
2.3.31.	Half brick masonry work in foundation and plinth in cement mortar 1:4 (1 cement : 4 coarse sand)	cum	2171.00
2.3.32.	Half brick masonry work in foundation and plinth in cement lime mortar 1:1:6 (1cement: 1lime putty: 6 coarse sand)	cum	2136.88
2.3.33.	(a) Half brick masonry work in foundation and plinth in cement mortar 1:3 (1 cement : 3 coarse sand) with hoop iron 25 mm x 1.6 mm or equivalent reinforcement at every 3rd course, embedded in the cement mortar	cum	2695.95
	(b) Half brick masonry work in foundation and plinth in cement mortar 1:4 (1cement: 4 coarse sand) with 2 nos. 6mm & mild steel bar at every third course in superstructure above plinth level upto 1st flr. lvl.	cum	2734.20
2.3.34.	Extra for half brick masonry work in superstructure above plinth lvl.	cum	0.00
	MASONRY WORK IN HOLLOW CONCRETE BLOCKS (40 CM X 20 CM X 10 CM)		
2.3.35.	Block masonry work in foundation and plinth in 1:1:1 lime mortar (1lime putty: 1flyash: 1fine sand)	cum	1800.00
2.3.36.	Block masonry work in foundation and plinth in 1:1:1 lime mortar (1 lime putty: 1surkhi: 1 fine sand)	cum	1959.45

Item Code No.	Description of Item of Work	Unit	Embodied Energy Rate (EER) in MJ/Unit
2.3.37.	Block masonry work in foundation and plinth in 1:3 cement mortar (1 cement: 3 fine sand)	cum	2135.91
2.3.38.	Block masonry work in foundation and plinth in 1:4 cement mortar (1 cement: 4 fine sand)	cum	1935.58
2.3.39.	Block masonry work in foundation and plinth in 1:5 cement mortar (1 cement: 5 fine sand)	cum	1827.17
2.3.40.	Block masonry work in foundation and plinth in 1:6 cement mortar (1 cement: 6 fine sand)	cum	1735.25
2.3.41.	Block masonry work in foundation and plinth in 1:6 cement mortar (1 cement: 6 coarse sand)	cum	1735.25
2.3.42.	Block masonry work in foundation and plinth in 1:1:6 cement lime mortar (1 cement: 1 lime putty:6 fine sand)	cum	1904.20
2.3.43.	Block masonry work in foundation and plinth in 1:1:7 cement lime mortar (1 cement: 1 lime putty:7 fine sand)	cum	1834.04
2.3.44.	Block masonry work in foundation and plinth in 1:1:8 cement lime mortar (1 cement: 1 lime putty:8 fine sand)	cum	1768.37
2.3.45.	Block masonry work in foundation and plinth in 1:2:9 cement lime mortar (1 cement: 2 lime putty: 9 fine sand)	cum	1837.72
2.3.46.	Extra for block masonry work in superstructure above plinth lvl.	cum	0.00
	<u>Half Block Masonry Work in Hollow Concrete Blocks (40 cm X 20 cm X 10 cm)</u>		
2.3.47.	Half block masonry work in foundation and plinth in cement mortar 1:3 (1 cement: 3 coarse sand)	cum	2036.94
2.3.48.	Half block masonry work in foundation and plinth in cement mortar 1:4 (1 cement : 4 coarse sand)	cum	1845.32
2.3.49.	Half block masonry work in foundation and plinth in cement lime mortar 1:1:6 (1cement: 1lime putty: 6 coarse sand)	cum	1815.29
2.3.50.	(a) Half block masonry work in foundation and plinth in cement mortar 1:3 (1 cement : 3 coarse sand) with hoop iron 25 mm x 1.6 mm or equivalent reinforcement at every 3rd course, embedded in the cement mortar	cum	2113.74

Item Code No.	Description of Item of Work	Unit	Embodied Energy Rate (EER) in MJ/Unit
	(b) Half block masonry work in foundation and plinth in cement mortar 1:4 (1cement: 4 coarse sand) with 2 nos. 6mm & mild steel bar at every third course in superstructure above plinth level upto 1st flr. lvl	cum	1986.12
2.3.51.	Extra for half block masonry work in superstructure above plinth lvl.	cum	0.00
	MASONRY WORK IN HOLLOW CONCRETE BLOCKS (40 CM X 20 CM X 20 CM)		
2.3.52.	Block masonry work in foundation and plinth in 1:1:1 lime mortar (1lime putty: 1flyash: 1fine sand)	cum	1015.82
2.3.53.	Block masonry work in foundation and plinth in 1:1:1 lime mortar (1lime putty: 1surkhi: 1fine sand)	cum	1130.21
2.3.54.	Block masonry work in foundation and plinth in 1:3 cement mortar (1 cement : 3 fine sand)	cum	1256.81
2.3.55.	Block masonry work in foundation and plinth in 1:4 cement mortar (1 cement : 4 fine sand)	cum	1113.10
2.3.56.	Block masonry work in foundation and plinth in 1:5 cement mortar (1 cement : 5 fine sand)	cum	1035.71
2.3.57.	Block masonry work in foundation and plinth in 1:6 cement mortar (1 cement : 6 fine sand)	cum	969.38
2.3.58.	Block masonry work in foundation and plinth in 1:6 cement mortar (1 cement : 6 coarse sand)	cum	969.38
2.3.59.	Block masonry work in foundation and plinth in 1:1:6 cement lime mortar (1 cement : 1 lime putty : 6 fine sand)	cum	1090.57
2.3.60.	Block masonry work in foundation and plinth in 1:1:7 cement lime mortar (1 cement : 1 lime putty : 7 fine sand)	cum	1040.24
2.3.61.	Block masonry work in foundation and plinth in 1:1:8 cement lime mortar (1 cement : 1 lime putty : 8 fine sand)	cum	993.14
2.3.62.	Block masonry work in foundation and plinth in 1:2:9 cement lime mortar (1 cement : 2 lime putty : 9 fine sand)	cum	1043.00
2.3.63.	Extra for block masonry work in superstructure above plinth lvl.	cum	0.00

Item Code No.	Description of Item of Work	Unit	Embodied Energy Rate (EER) in MJ/Unit
	MASONRY WORK IN AERATED CONCRETE BLOCKS (40 CM X 20 CM X 20 CM)		
2.3.64.	Block masonry work in foundation and plinth in 1:1:1 lime mortar (1 lime putty: 1flyash: 1 fine sand)	cum	1047.32
2.3.65.	Block masonry work in foundation and plinth in 1:1:1 cement mortar (1 lime putty: 1 surkhi: 1 fine sand)	cum	1161.71
2.3.66.	Block masonry work in foundation and plinth in 1:3 cement mortar (1 cement : 3 fine sand)	cum	1288.31
2.3.67.	Block masonry work in foundation and plinth in 1:4 cement mortar (1 cement : 4 fine sand)	cum	1144.60
2.3.68.	Block masonry work in foundation and plinth in 1:5 cement mortar (1 cement : 5 fine sand)	cum	1067.21
2.3.69.	Block masonry work in foundation and plinth in 1:6 cement mortar (1 cement : 6 fine sand)	cum	1001.00
2.3.70.	Block masonry work in foundation and plinth in 1:6 cement mortar (1 cement : 6 coarse sand)	cum	1001.00
2.3.71.	Block masonry work in foundation and plinth in 1:1:6 cement lime mortar (1 cement : 1 lime putty : 6 fine sand)	cum	1122.07
2.3.72.	Block masonry work in foundation and plinth in 1:1:7 cement lime mortar (1 cement : 1 lime putty : 7 fine sand)	cum	1071.74
2.3.73.	Block masonry work in foundation and plinth in 1:1:8 cement lime mortar (1 cement : 1 lime putty : 8 fine sand)	cum	1024.64
2.3.74.	Block masonry work in foundation and plinth in 1:2:9 cement lime mortar (1 cement : 2 lime putty : 9 fine sand)	cum	1074.50
2.3.75.	Extra for block masonry work in superstructure above plinth lvl.	cum	0.00
	MASONRY WORK IN SOLID CONCRETE BLOCKS (30 CM X 20 CM X 15 CM)		
2.3.76.	Block masonry work in foundation and plinth in 1:1:1 lime mortar (1lime putty : 1flyash: 1fine sand)	cum	1556.10
2.3.77.	Block masonry work in foundation and plinth in 1:1:1 lime mortar (1 lime putty: 1 surkhi: 1 fine sand)	cum	1694.75

Item Code No.	Description of Item of Work	Unit	Embodied Energy Rate (EER) in MJ/Unit
2.3.78.	Block masonry work in foundation and plinth in 1:3 cement mortar (1 cement : 3 fine sand)	cum	1848.20
2.3.79.	Block masonry work in foundation and plinth in 1:4 cement mortar (1 cement : 4 fine sand)	cum	1674.00
2.3.80.	Block masonry work in foundation and plinth in 1:5 cement mortar (1 cement : 5 fine sand)	cum	1580.20
2.3.81.	Block masonry work in foundation and plinth in 1:6 cement mortar (1 cement : 6 fine sand)	cum	1499.80
2.3.82.	Block masonry work in foundation and plinth in 1:6 cement mortar (1 cement : 6 coarse sand)	cum	1499.80
2.3.83.	Block masonry work in foundation and plinth in 1:1:6 cement lime mortar (1 cement : 1 lime putty : 6 fine sand)	cum	1646.70
2.3.84.	Block masonry work in foundation and plinth in 1:1:7 cement lime mortar (1 cement : 1 lime putty : 7 fine sand)	cum	1585.70
2.3.85.	Block masonry work in foundation and plinth in 1:1:8 cement lime mortar (1 cement : 1 lime putty : 8 fine sand)	cum	1528.60
2.3.86.	Block masonry work in foundation and plinth in 1:2:9 cement lime mortar (1 cement : 2 lime putty: 9 fine sand)	cum	1588.90
2.3.87.	Extra for block masonry work in superstructure above plinth lvl.	cum	0.00
	Half Block Masonry Work In Solid Concrete Blocks		
2.3.88.	Half block masonry work in foundation and plinth in cement mortar 1:3 (1 cement: 3 coarse sand)	cum	1782.83
2.3.89.	Half block masonry work in foundation and plinth in cement mortar 1:4 (1 cement : 4 coarse sand)	cum	1617.34
2.3.90.	Half block masonry work in foundation and plinth in cement lime mortar 1:1:6 (1 cement: 1 lime putty: 6 coarse sand)	cum	1591.41
2.3.91.	(a) Half block masonry work in foundation and plinth in cement mortar 1:3 (1 cement : 3 coarse sand)		

Item Code No.	Description of Item of Work	Unit	Embodied Energy Rate (EER) in MJ/Unit
	with hoop iron 25 mm x 1.6 mm or equivalent reinforcement at every 3rd course, embedded in the cement mortar	cum	1834.03
	(b) Half block masonry work in foundation and plinth in cement mortar 1:4 (1cement: 4 coarse sand) with 2 nos. 6mm & mild steel bar at every third course in superstructure above plinth lvl. upto 1st flr. lvl.	cum	711.10
2.3.92.	Extra for half block masonry work in superstructure above plinth lvl.	cum	0.00
	MASONRY WORK IN FAL-G BLOCKS (30 CM X 20 CM X 15 CM)		
2.3.93.	Block masonry work in foundation and plinth in 1:1:1 lime mortar (1 lime putty:1 flyash: 1 fine sand)	cum	1276.10
2.3.94.	Block masonry work in foundation and in 1:1:1 cement mortar (1 lime putty : 1surkhi : 1 fine sand)	cum	1414.80
2.3.95.	Block masonry work in foundation and plinth in 1:3 cement mortar (1 cement : 3 fine sand)	cum	1568.20
2.3.96.	Block masonry work in foundation and plinth in 1:4 cement mortar (1 cement : 4 fine sand)	cum	1394.00
2.3.97.	Block masonry work in foundation and plinth in 1:5 cement mortar (1 cement : 5 fine sand)	cum	1300.20
2.3.98.	Block masonry work in foundation and plinth in 1:6 cement mortar (1 cement : 6 fine sand)	cum	1219.80
2.3.99.	Block masonry work in foundation and plinth in 1:6 cement mortar (1 cement : 6 coarse sand)	cum	1219.80
2.3.100.	Block masonry work in foundation and plinth in 1:1:6 cement lime mortar (1 cement : 1 lime putty : 6 fine sand)	cum	1366.70
2.3.101.	Block masonry work in foundation and plinth in 1:1:7 cement lime mortar (1 cement : 1 lime putty : 7 fine sand)	cum	1305.70
2.3.102.	Block masonry work in foundation and plinth in 1:1:8 cement lime mortar (1 cement : 1 lime putty : 8 fine sand)	cum	1248.60
2.3.103.	Block masonry work in foundation & plinth in 1:2:9 cement mortar (1 cement : 2 lime putty : 9 fine sand)	cum	1308.90

Item Code No.	Description of Item of Work	Unit	Embodied Energy Rate (EER) in MJ/Unit
2.3.104.	Extra for block masonry work in superstructure above plinth lvl.	cum	0.00
	<u>Half Block Masonry Work in Fal-G Blocks</u>		
2.3.105.	Half block masonry work in foundation and plinth in cement mortar 1:3 (1 cement: 3 coarse sand)	cum	1510.33
2.3.106.	Half block masonry work in foundation and plinth in cement mortar 1:4 (1 cement : 4 coarse sand)	cum	1344.84
2.3.107.	Half block masonry work in foundation and plinth in cement lime mortar 1:1:6 (1cement: 1lime putty: 6 coarse sand)	cum	1318.91
2.3.108.	(a) Half block masonry work in foundation and plinth in cement mortar 1:3 (1 cement : 3 coarse sand) with hoop iron 25 mm x 1.6 mm or equivalent reinforcement at every 3rd course, embedded in the cement mortar	cum	1561.53
	(b) Half block masonry work in foundation and plinth in cement mortar 1:4 (1cement: 4 coarse sand) with 2 nos. 6mm & mild steel bar at every third course in superstructure above plinth lvl. upto 1st flr. lvl.	cum	1438.60
2.3.109.	Extra for half block masonry work in superstructure above plinth lvl.	cum	0.00

3. CONCRETE WORK

Item Code No.	Description of Item of Work	Unit	Embodied Energy Rate (EER) in MJ/Unit
3.1.	Providing & laying in foundation and plinth, lime concrete with graded stone agg. 40 mm nom. size and 40% lime mortar 1:1:1 (1lime putty: 1 flyash: 1 fine sand)	cum	1288.25
3.2.	Providing & laying in foundation and plinth, lime concrete with graded stone agg. 40 mm nom. size and 40% lime mortar 1:1:1 (1 lime putty: 1 surkhi : 1 fine sand)	cum	1565.62
3.3.	Providing & laying in foundation and plinth, lime concrete with graded brick agg. 40 mm nom. size and 40% lime mortar 1:1:1 (1 lime putty : 1 flyash : 1 fine sand)	cum	2883.50
3.4.	Providing & laying in foundation and plinth, lime concrete with graded brick agg. 40 mm nom. size and 40% lime mortar 1:1:1 (1 lime putty:1 surkhi: 1 fine sand)	cum	3160.80
3.5.	Providing & laying upon terrace upto 1st flr. lvl., lime concrete with graded brick agg. 25 mm nom. size and 50% lime mortar 1:2 (1 lime putty : 2 surkhi)	cum	3906.51
3.6.	Providing & laying cement concrete 1:2:4 (1 cement: 2 coarse sand: 4 graded stone agg. 40 mm nom. size)		
	(a) Foundation and plinth	cum	2601.30
	(b) Walls incl. attached buttresses, pilasters and their caps & bases and string courses etc. upto 2nd flr. lvl.	cum	2601.30
	(c) Independent piers, columns and pillars up to 2nd flr. lvl.	cum	2601.30
3.7.	Providing & laying cement concrete 1:3:6 (1 cement: 3 coarse sand : 6 graded stone agg. 40 mm nom.size)		
	(a) Foundation and plinth	cum	1952.82
	(b) Walls incl. attached buttresses, pilasters and their caps & bases and string courses etc. upto 2nd flr. lvl.	cum	1952.82
	(c) Independent piers, columns and pillars upto 2nd flr.lvl.	cum	1952.82
3.8.	Providing & laying cement concrete 1:4:8 (1 cement: 4 coarse sand : 8 graded stone agg. 40 mm nom. size)		
	(a) Foundation and plinth	cum	1617.82

Item Code No.	Description of Item of Work	Unit	Embodied Energy Rate (EER) in MJ/Unit
	(b) Walls incl. attached buttresses, pilasters and their caps & bases and string courses etc up to 2nd flr. lvl.	cum	1617.82
3.9.	Providing & laying cement concrete 1:5:10 (1 cement: 5 coarse sand : 10 graded stone agg. 40 mm nom. size)		
	(a) Foundation and plinth	cum	1349.82
	(b) Walls incl. attached buttresses, pilasters and their caps & bases and string courses etc. upto 2nd flr. lvl.	cum	1349.82
3.10.	Providing & laying cement concrete 1:3:6 (1 cement: 3 fine sand : 6 graded stone agg. 40 mm nom. size)		
	(a) Foundation and plinth	cum	1952.82
	(b) Walls incl. attached buttresses, pilasters and their caps & bases and string courses etc. upto 2nd flr. lvl.	cum	1952.82
	(c) Independent piers, columns and pillars up to 1st flr. lvl.	cum	1952.82
3.11.	Providing & laying cement concrete 1:4:8 (1 cement: 4 fine sand: 8 graded stone agg. 40 mm nom. size)		
	(a) Foundation and plinth	cum	1617.82
	(b) Walls incl. attached buttresses, pilasters and their caps & bases and string courses etc. upto 2nd flr. lvl.	cum	1617.82
3.12.	Providing & laying cement concrete 1:5:10 (1 cement : 5 fine sand: 10 graded stone agg. 40 mm nom. size)		
	(a) Foundation and plinth	cum	1349.82
	(b) Walls incl. attached buttresses, pilasters and their caps & bases and string courses etc. upto 2nd flr. lvl.	cum	1349.82
3.13.	Providing & laying cement concrete 1:5:10 (1 cement: 5 fine sand: 10 graded brick agg. 40 mm nom. size)		
	(a) Foundation and plinth	cum	2860.15
	(b) Walls incl. attached buttresses, pilasters and their caps & bases and string courses etc. upto 2nd flr. lvl.	cum	2860.15
3.14.	Providing & laying cement concrete 1:6:12 (1 cement : 6 fine sand: 12 graded stone agg. 40 mm nom. size)		
	(a) Foundation and plinth	cum	1215.82

Item Code No.	Description of Item of Work	Unit	Embodied Energy Rate (EER) in MJ/Unit
	(b) Walls incl. attached buttresses, pilasters and their caps & bases and string courses etc. upto 2nd flr. lvl.	cum	1215.82
3.15.	Providing & laying cement concrete 1:1:2 (1 cement : 1 coarse sand: 2 graded stone agg. 20 mm nom. size)		
	(a) Foundation and plinth	cum	4544.30
	(b) Walls incl. attached buttresses, pilasters and their caps & bases and string courses etc. upto 2nd flr. lvl.	cum	4544.30
	(c) Independent piers, columns and pillars upto 2nd flr. lvl.	cum	4544.30
3.16.	Providing & laying cement concrete 1:1½ :3 (1 cement: 1½ coarse sand: 3 graded stone agg. 20 mm nom. size)		
	(a) Foundation and Plinth	cum	3137.30
	(b) Walls incl. attached buttresses, pilasters and their caps & bases and string courses etc. upto 2nd flr. lvl.	cum	3137.30
	(c) Independent piers, columns and pillars upto 2nd flr. lvl.	cum	3137.30
3.17.	Providing & laying cement concrete 1½:2:4 (1½ cement: 2 coarse sand: 4 graded stone agg. 20 mm nom. size)		
	(a) Foundation and plinth	cum	3008.68
	(b) Walls incl. attached buttresses, pilasters and their caps & bases and string courses etc. upto 2nd flr. lvl.	cum	3008.68
	(c) Independent piers, columns & pillars upto 2nd flr.lvl.	cum	3008.68
3.18.	Providing & laying cement concrete 1:2:4 (1 cement: 2 coarse sand : 4 graded stone agg. 20 mm nom. size)		
	(a) Foundation and plinth	cum	2622.82
	(b) Walls incl. attached buttresses, pilasters and their caps & bases and string courses etc. upto 2nd flr. lvl.	cum	2622.82
	(c) Independent piers, columns & pillars upto 2ndflr. lvl.	cum	2622.82
3.19.	Providing & laying cement concrete 1:3:6 (1 cement: 3 coarse sand : 6 graded stone agg. 20 mm nom. size)		
	(a) Foundation and Plinth	cum	1979.72

Item Code No.	Description of Item of Work	Unit	Embodied Energy Rate (EER) in MJ/Unit
	(b) Walls incl. attached buttresses, pilasters and their caps & bases and string courses etc. upto 2nd flr. lvl.	cum	1979.72
	(c) Independent piers, column & pillars upto 2nd flr. lvl.	cum	1979.72
3.20.	Providing & laying up to 2nd flr. lvl. cement concrete 1:2:4 (1 cement : 2 coarse sand : 4 graded stone agg. 20 mm nom. size) incl. smooth finishing to exposed surfaces with cement mortar 1:3 (1 cement : 3 fine sand)		
	(a) Kerbs, steps and the like	cum	2827.82
	(b) String courses, copings, bed plates, anchor blocks, plain window sills and the like	cum	3032.67
	(c) Small lintels not exceeding 1.5m clear span, over sailings, copings and the like requiring form work to suspended portions	cum	3005.37
	(d) Mouldings as in cornices, window sills etc. exceeding 15cm in girth	cum	3032.67
	(e) Mouldings as in cornices, window sills etc. not exceeding 15 cm in girth	cum	3032.67
3.21.	Providing & laying up to 2nd flr.lvl. cement concrete 1:3:6 (1 cement : 3 coarse sand : 6 graded stone agg. 20 mm. nom. size) incl. smooth finishing to exposed surfaces with cement mortar 1:3 (1 cement: 3 fine sand)		
	(a) Kerbs, steps and the like	cum	2184.72
	(b) String courses, copings, bed plates, anchor blocks, plain window sills and the like	cum	2389.67
	(c) Small lintels not exceeding 1.5m span, over sailings, copings and the like requiring form work to suspended portions	cum	2362.40
	(d) Mouldings as in cornices, window sills etc. exceeding 15cm in girth	cum	2389.67
	(e) Mouldings as in cornices, window sills etc. not exceeding 15 cm in girth	cum	2389.67
3.22.	Providing & fixing up to 2nd flr.lvl., precast cement concrete 1:2:4 (1 cement : 2 coarse sand : 4 graded stone agg. 20 mm. nom. size) set in position with cement mortar 1:2 (1 cement : 2 coarse sand) & finished smooth with 6 mm thick cement plaster 1:3 (1 cement: 3 fine sand) on exposed surfaces		

Item Code No.	Description of Item of Work	Unit	Embodied Energy Rate (EER) in MJ/Unit
	(a) Kerbs, steps and the like	cum	2909.82
	(b) String courses, copings, bed plates, anchor blocks, plain window sills and the like	cum	3032.67
	(c) Small lintels not exceeding 1.5 m clear span over sailings, copings, shelves and the like requiring form work to suspended portions	cum	2896.11
3.23.	Providing & laying in foundation mud concrete with graded stone agg. 40 mm nom. size and 40% mud mortar	cum	371.22
3.24.	Providing & laying in foundation mud concrete with graded brick agg. 40 mm nom. size and 40% mud mortar	cum	1899.75
3.25.	Extra for concrete by using 12.5 mm nom. size stone agg. instead of 20 mm nom. size stone agg.	cum	0.00
3.26.	Extra for all concrete work above 1st flr. lvl.	cum	0.00
3.27.	Providing & laying damp proof course (DPC) 25 mm thick with cement concrete 1:2:4 (1 cement : 2 coarse sand : 4 stone agg. 10 mm nom. size)	sqm	65.57
3.28.	Providing & laying DPC 38 mm thick with cement concrete 1:2:4 (1 cement : 2 coarse sand : 4 stone agg. 12.5 mm nom. size)	sqm	99.67
3.29.	Providing & laying DPC 40 mm thick with cement concrete 1:2:4 (1 cement: 2 coarse sand: 4 graded stone agg. 12.5 mm. nom. size)	sqm	104.91
3.30.	Providing & laying DPC 50 mm thick with cement concrete 1:2:4 (1 cement : 2 coarse sand : 4 graded stone agg. 20 mm. nom. size)	sqm	131.14
3.31.	Making plinth protection 50 mm thick of cement concrete 1:3:6 (1 cement: 3 coarse sand: 6 graded stone agg. 20 mm nom. size) over 75 mm bed of dry grick ballast 40 mm nom. size, well rammed, consolidated and grouted with fine sand include. finishing the top smooth	sqm	266.61

4. REINFORCED CEMENT CONCRETE

Item Code No.	Description of Item of Work	Unit	Embodied Energy Rate (EER) in MJ/Unit
4.1.	Reinforced cement concrete (RCC) work 1:2:4 (1 cement: 2 coarse sand: 4 graded stone agg. 20 mm nom. size) in suspended floors, roofs, landings, shelves and their supports and balconies upto 2nd flr. lvl. excl. reinforcement but incl. finishing and plastering the ceiling with cement mortar 1:3 (1 cement: 3 fine sand) of thickness not exceeding 6 mm to have a smooth and even surface	cum	2836.10
4.2.	RCC work 1:2:4 (1 cement: 2 coarse sand: 4 graded stone agg. 20 mm nom. size) excl. reinforcement but incl. finishing and plastering the exposed surface with cement mortar 1:3 (1 cement: 3 fine sand) of thickness not exceeding 6 mm to give a smooth and even surface		
	(a) Foundations, footings, bases of columns etc. and mass concrete	cum	2663.90
	(b) Walls (any thickness) incl.. attached pilasters, buttresses, plinth and string courses etc. up to 2nd flr. lvl.	cum	2760.67
	(c) Lintels, beams, girders, bressummers and cantilevers upto 2nd flr. lvl.	cum	2827.74
	(d) Columns, pillars, posts and struts upto 2nd flr. lvl.	cum	2827.74
	(e) Staircases (except spiral staircase) excl. landing but incl. preparing of the top surface and finishing nosing upto 2nd flr. lvl.	cum	2900.28
	(f) Spiral staircase incl. landings etc upto 2nd flr. lvl.	cum	3131.25
	(g) Arches upto 2nd flr. lvl.	cum	2700.92
	(h) Domes, vaults and shell roofs upto 1st flr. lvl.	cum	2950.91
	(i) Chimneys and shafts upto 1st flr. lvl.	cum	2760.67
	(j) Wall steining	cum	2760.67
	(k) Vertical and horizontal fins individually forming boxes, louvers and projected bands upto 2nd flr.lvl.	cum	3647.82
4.3.	RCC work 1:1½:3 (1 cement: 1½ coarse sand: 3 graded stone agg. 20 mm nom. size) excl. reinforcement but incl. finishing and plastering		

Item Code No.	Description of Item of Work	Unit	Embodied Energy Rate (EER) in MJ/Unit
	the exposed surface with cement mortar 1:3 (1 cement: 3 fine sand) of thickness not exceeding 6 mm to give a smooth and even surface		
	(a) Foundations, footings, bases of columns etc. and mass concrete	cum	3178.38
	(b) Walls (any thickness) incl. attached pilasters, buttresses, plinth and string courses etc. upto 1st flr. lvl.	cum	3275.15
	(c) Lintels, beams, girders, bressummers and cantilevers upto 1st flr. lvl.	cum	3342.22
	(d) Columns, pillars, posts and struts upto 1st flr. lvl.	cum	3342.22
4.4.	RCC work 1:1:2 (1 cement: 1 coarse sand: 2 graded stone agg. 20 mm nom. size) excl. reinforcement but incl. finishing and plastering the exposed surface with cement mortar 1:3 (1 cement : 3 fine sand) of thickness not exceeding 6 mm to give a smooth and even surface		
	(a) Foundations, footings, bases of columns etc. and mass concrete	cum	4585.38
	(b) Walls incl. attached pilasters, buttresses and string courses etc. upto 1st flr. lvl.	cum	4682.15
	(c) Lintels, beams, girders, bressummers and cantilevers upto 1st flr. lvl.	cum	4700.02
	(d) Columns, pillars, posts and struts upto 1st flr. lvl.	cum	4749.22
4.5.	RCC work 1:2:4 (1 cement: 2 coarse sand: 4 graded stone agg. 20 mm nom. size) in sunshades not exceeding 15 cm in thickness upto 1st flr. lvl. excl. reinforcement but incl. finishing and plastering the exposed surface with cement mortar 1:3 (1 cement : 3 fine sand) of thickness not exceeding 6mm. to give a smooth and even surface	cum	3114.82
4.6.	RCC 1:2:4 (1 cement: 2 coarse sand: 4 graded stone agg. 20 mm nom. size) in sunshades exceeding 15 cm. in thickness upto 1st flr. lvl. excl. reinforcement but incl. finishing and plastering the exposed surfaced with cement mortar 1 :3 (1 cement : 3 fine sand) of thickness not exceeding 6 mm to give a smooth and even surface	cum	2882.92
4.7.	Providing and fixing upto 1st flr. lvl., precast RCC 1 : 2 : 4 (1 cement : 2 coarse sand : 4 graded stone agg.		

Item Code No.	Description of Item of Work	Unit	Embodied Energy Rate (EER) in MJ/Unit
	20 mm nom. size) excl. reinforcement but incl. finishing and plastering with cement plaster 1: 3 (1 cement: 3 fine sand) of thickness not exceeding 6 mm on exposed surface to give a smooth and even surface		
	(a) Kerbs, steps and the like	cum	2909.82
	(b) String courses, coping, bed plates, anchor blocks, plain window sills and the like	cum	3032.67
	(c) Small lintels not exceeding 1.5 m clear span over sailings, copings and the like	cum	2896.11
4.8.	Providing and laying up to 1st flr. lvl. RCC 1 : 2 : 4 (1 cement: 2 coarse sand : 4 graded stone agg. 20 mm nom. size) excl. reinforcement but incl. finishing and plastering with cement mortar 1:3 (1cement: 3 fine sand) of thickness not exceeding 6 mm on exposed surface to give a smooth and even surface		
	(a) Kerbs, steps and the like	cum	2827.82
	(b) String courses, copings, bed plates, anchor blocks, plain window sills and the like	cum	3032.67
	(c) Small lintels not exceeding 1.5 m clear span over sailings, copings and the like	cum	3005.37
	(d) Mouldings as in cornices, window sills etc. exceeding 15 cm. in girth	cum	3032.67
	(e) Mouldings as in cornices, window sills etc. not exceeding 15 cm. in girth	cum	3032.67
4.9.	Providing RCC cave board 25 mm. thick and 15 cm. to 30 cm. wide in 1:2:4 mix (1 cement : 2 coarse sand: 4 stone agg. 10 mm nom. size) upto 1st flr. lvl. excl. reinforcement but incl. finishing and plastering with cement mortar 1:3 (1 cement : 3 fine sand) of thickness not exceeding 6 mm on exposed surface to give a smooth and even surface	cum	4684.88
4.10.	Encasing rolled steel sections in beams and columns with cement concrete 1:2:4 (1 cement: 2 coarse sand: 4 stone agg. 12.5 mm nom. size) excl. reinforcement but incl. finishing and plastering with cement mortar 1:3 (1cement: 3 fine sand) of thickness not exceeding 6mm on the exposed surface to give a smooth and even surface up to 1st flr. lvl.	cum	2860.24
4.11.	Encasing rolled steel sections in grillage with cement		

Item Code No.	Description of Item of Work	Unit	Embodied Energy Rate (EER) in MJ/Unit
	lvl.concrete 1:2:4 (1 cement: 2 coarse sand: 4 stone agg. 12.5 mm nom. size) upto 1st flr	cum	2622.82
4.12.	Extra for all RCC work above 1st flr. lvl. excl. reinforcement	cum	0.00
4.13.	Mild steel reinforcement for RCC work incl. bending, binding and placing in position complete	q	3360.00
4.14.	Hard drawn steel wire fabric for RCC work	q	3360.00
4.15.	Extra for rendering smooth the top of suspended floors, landings and staircases (treads and risers) with cement mortar 1:2 (1 cement : 2 coarse sand) incl. a floating coat of neat cement and protecting the surface with a layer of 7.5 cm of earth laid over 15 mm of fine sand in case of suspended floors	sqm	27.94
4.16.	Applying cement slurry on RCC slabs or cement concrete work using 2.75 kg/sqm for receiving cement concrete floor	sqm	18.43
4.17.	Deduct for omitting in RCC work smooth finishing of the exposed surface with cement mortar 1:3 (1 cement: 3 fine sand)	sqm	246.02

5. FLOORING

Item Code No.	Description of Item of Work	Unit	Embodied Energy Rate (EER) in MJ/Unit
	Brick Flooring		
5.1.	1st class brick flooring in cement mortar 1:4 (1 cement: 4 fine sand)	sqm	298.83
5.2.	1st class brick flooring in cement mortar 1:6 (1 cement: 6 coarse sand)	sqm	273.58
5.3.	2nd class dry brick flooring incl. filling joints with fine sand	sqm	243.00
	Cement Concrete Flooring and Skirting		
5.4.	25 mm. cement concrete flooring 1:2:4 (1 cement: 2 coarse sand: 4 graded stone agg. 12.5 mm nom. size) finished with a floating coat of neat cement	sqm	80.28
5.5.	Cement concrete flooring 1:2:4 (1cement : 2 coarse sand : 4 graded stone agg. 20 mm nom. size) finished with a floating coat of neat cement		
	(a) 40 mm thick	sqm	119.65
	(b) 50 mm thick	sqm	145.88
	(c) 75 mm thick	sqm	211.48
5.6.	A. 40 mm thick red oxide flooring - under layer of 30 mm. thick cement concrete 1:2:4 (1 cement: 2 coarse sand: 4 graded stone agg. 12.5 mm nom. size) and top layer of 10 mm thick plaster 1:3 (1 cement : 3 coarse sand) of cement red oxide mix (using 3.5 kg of red oxide of iron per 50 kg of cement), finished with a floating coat of neat cement red oxide mix of the same proportion	sqm	149.03
	B. Add or deduct for using more or less than 3.5 kg of red oxide of iron per 50 kg of cement in 40 mm thick red oxide flooring	sqm	55.61
5.7.	Cement concrete pavement (25 mm. to 50 mm. thick) with 1:2:4 (1cement: 2 coarse sand: 4 graded stone agg. 20 mm. nom. size) incl. finishing complete	cum	2836.10
5.8.	52 mm. thick cement concrete flooring with metallic concrete hardner topping - under layer of 40 mm thick cement concrete 1:2:4 (1 cement: 2 coarse sand:4 graded stone agg. 20 mm nom. size) and top layer of 12 mm thick of metallic cement hardener consisting of		

Item Code No.	Description of Item of Work	Unit	Embodied Energy Rate (EER) in MJ/Unit
	mix 1:2 (1cement: 2 stone agg. 6mm nom size) by vol. with which metallic hardening compound of approved quality is mixed in ratio 4:1 (4 cement: 1 metallic floor hardening compound of approved quality) by wt. incl. finishing complete	sqm	166.71
5.9.	62 mm. thick cement concrete flooring with metallic concrete hardener topping – under layer of 50 mm thick cement concrete 1:2:4 (1 cement: 2 coarse sand: 4 graded stone agg. 20 mm nom. size) and top layer of 12 mm thick metallic concrete hardener consisting of mix 1:2 (1 cement: 2 stone agg. 6 mm nom. size) by vol. with which metallic hardening compound of approved quality is mixed in the ratio 4:1 (4 cement: 1 metallic floor hardening compound of approved quality) by wt. incl. Finishing complete	sqm	192.94
5.10.	Cement plaster skirting (up to 30 cm height) with cement mortar 1:3 (1 cement: 3 coarse sand) finished with a floating coat of neat cement, incl. rounding of junctions with floor		
	(a) 18 mm thick	sqm	87.00
	(b) 21 mm thick	sqm	97.25
5.11.	Red oxide plaster skirting (up to 30 cm height) with top layer of 6 mm thick plaster of cement mix using 3.5 kg of red oxide of iron per 50 kg of cement in mortar 1:3 (1cement: 3 coarse sand) finished with a floating coat of cement red oxide mix of same proportion		
	(a) 18 mm thick with under layer 12 mm thick cement plaster 1:3 (1 cement: 3 coarse sand)	sqm	80.51
	(b) 21 mm thick with under layer 12 mm thick cement plaster 1:3 (1 cement: 3 coarse sand)	sqm	90.57
	(c) Add or deduct for using more or less than 3.5 kg of red oxide of iron per 50 kg of cement in 18 mm thick or 21 mm thick red oxide plaster skirting	sqm	31.50
	<u>Terrazzo Flooring</u>		
5.12.	40 mm thick marble chips flooring rubbed and polished to granolithic finish - under layer 34 mm thick cement concrete 1:2:4 (1 cement: 2 coarse sand: 4 graded stone agg. 12.5 mm nom. size) and top layer 6mm thick with white or black or white and black marble chips of size from 1 mm to 4 mm nom. size		

Item Code No.	Description of Item of Work	Unit	Embodied Energy Rate (EER) in MJ/Unit
	laid in cement marble powder mix [3:1 (3 cement: 1 marble powder) by wt.] in proportion of 4:7 (4 cement marble powder mix: 7 marble chips) by volume		
	(a) Dark shade pigment with ordinary cement	sqm	116.47
	(b) Light shade pigment with white cement	sqm	116.47
	(c) Medium shade pigment with approx. 50% white cement and 50% ordinary cement	sqm	116.47
	(d) White cement without any pigment	sqm	116.47
	(e) Light shade pigment with ordinary cement	sqm	116.47
	(f) Ordinary cement without any pigment	sqm	116.47
5.13.	40 mm thick marble chips flooring rubbed and polished to granolithic finish - under layer 31 mm thick cement concrete 1:2:4 (1 cement :2 coarse sand : 4 graded stone agg. 12.5 mm nom. size) and top layer 9 mm thick with white or black or white and black marble chips of size 4-7 mm nom. size laid in cement marble powder mix [3:1 (3 cement :1 marble powder) by wt.] in proportion of 4:7 (4 cement marble powder mix: 7 marble chips) by volume		
	(a) Dark shade pigment with ordinary cement	sqm	117.36
	(b) Light shade pigment with white cement	sqm	117.36
	(c) Medium shade pigment with approx. 50% white cement and 50% ordinary cement	sqm	117.36
	(d) White cement without any pigment	sqm	117.36
	(e) Light shade pigment with ordinary cement	sqm	117.36
	(f) Ordinary cement without any pigment	sqm	117.36
5.14.	35 mm thick marble chips flooring rubbed and polished to granolithic finish - under layer 23 mm thick cement concrete 1:2:4 (1 cement: 2 coarse sand: 4 graded stone agg. 12.5 mm nom. size) and top layer 12 mm thick with white or black or white and black marble chips of size from 7 mm-10 mm nom. size, laid in cement marble powder mix [3:1 (3 cement: 1 marble powder) by wt.] in proportion of 2:3 (2 cement marble powder mix: 3 marble chips) by volume		
	(a) Dark shade pigment with ordinary cement	sqm	127.82
	(b) Light shade pigment with white cement	sqm	127.82
	(c) Medium shade pigment with approx. 50% white cement and 50% ordinary cement	sqm	127.82

Item Code No.	Description of Item of Work	Unit	Embodied Energy Rate (EER) in MJ/Unit
	(d) White cement without any pigment	sqm	127.82
	(e) Light shade pigment with ordinary cement	sqm	127.82
	(f) Ordinary cement without any pigment	sqm	127.82
5.15.	Marble chips skirting (up to 30 cm height) rubbed and polished to granolithic finish - top layer 6mm thick with white or black or white and black marble chips from smallest to 4 mm nom. size, laid in cement marble powder mix [3:1 (3 cement : 1 marble powder) by wt.] in proportion of 4:7 (1cement marble powder mix: 7 marble chips) by volume		
	A. 18 mm thick with under layer 12 mm thick cement plaster 1:3 (1cement :3 coarse sand)		
	(a) Dark shade pigment with ordinary cement	sqm	86.60
	(b) Light shade pigment with white cement	sqm	86.60
	(c) Medium shade pigment with approx. 50% white cement and 50% ordinary cement	sqm	86.60
	(d) White cement without any pigment	sqm	86.60
	(e) Light shade pigment with ordinary cement	sqm	86.60
	(f) Ordinary cement without any pigment	sqm	86.60
	B. 21 mm thick with under layer 15 mm thick cement plaster 1:3 (1 cement: 3 coarse sand)		
	(a) Dark shade pigment with ordinary cement	sqm	85.90
	(b) Light shade pigment with white cement	sqm	85.90
	(c) Medium shade pigment with approx. 50% white cement and 50% ordinary cement	sqm	85.90
	(d) White cement without any pigment	sqm	85.90
	(e) Light shade pigment with ordinary cement	sqm	85.90
	(f) Ordinary cement without any pigment	sqm	85.90
5.16.	Extra for providing and fixing aluminium strips 40 mm wide and 1.6 mm thick in joints of terrazzo floors	m	26.65

Item Code No.	Description of Item of Work	Unit	Embodied Energy Rate (EER) in MJ/Unit
5.17.	Extra for providing and fixing glass strips in joints of Terrazzo floors		
	(a) 40 mm wide and 4 mm thick	m	11.79
	(b) 40 mm wide and 6 mm thick	m	11.79
	(c) 35 mm wide and 4 mm thick	m	10.32
5.18.	Special surface finishing to treads, risers and the ends ofconcrete strips and the like	sqm	14.74
5.19.	Providing and laying cushioning layer on RCC slabs, consisting of 40 mm thick lime concrete using brick agg. of 20 mm nom. size and 50% mortar comprising of 1: 2 (1lime putty: 2 surkhi)	sqm	156.26
	<u>Terrazzo Tile Flooring</u>		
5.20.	Precast terrazzo tiles 20 mm thick with white or black or white and black marble chips of sizes upto 6 mm, laid in floors, treads of steps and landings on 25 mm thick bed of lime mortar 1:1:1 (1lime putty: 1surkhi: 1 coarse sand) painted with neat cement slurry mixed with pigment to match the shade of the tiles		
	(a) Light shade pigment using white cement	sqm	255.50
	(b) Medium shade pigment using approx. 50% white cement and 50% ordinary cement	sqm	226.02
	(c) Dark shade pigment using ordinary cement	sqm	226.02
5.21.	Precast terrazzo tiles 20 mm thick white or black or white and black marble chips of sizes upto 6 mm, laid in floors, treads of steps and landing on 25 mm thick bed of lime mortar 1:2 (1 lime putty: 2 surkhi) jointed with neat cement skirting mixed with pigment to match the shade of the tiles, incl. rubbing and polishing complete with precast tiles		
	(a) Light shade pigment using white cement	sqm	273.18
	(b) Medium shade pigment using approx. 50% white cement and 50% ordinary cement	sqm	243.70
	(c) Dark shade pigment using ordinary cement	sqm	243.70
5.22.	Extra if terrazzo tiles are laid in treads of steps not exceeding 30 cm in width	sqm	0.00

Item Code No.	Description of Item of Work	Unit	Embodied Energy Rate (EER) in MJ/Unit
5.23.	Precast terrazzo tiles 20 mm thick with marble chips of sizes upto 6 mm in skirting and risers of steps not exceeding 30 cm in height on 12 mm thick cement plaster 1:3 (1 cement: 3 coarse sand) jointed with neat cement skirting		
	(a) Light shade pigment using white cement	sqm	192.92
	(b) Medium shade pigment using approx. 50% white cement and 50% ordinary cement	sqm	192.92
	(c) Dark shade pigment using ordinary cement	sqm	192.92
5.24.	Precast terrazzo tiles 20 mm thick with marble chips of sizes 6 mm fixed on walls on 12 mm cement plaster 1:3 (1 cement : 3 coarse sand) jointed with neat cement slurry		
	(a) Light shade pigment using white cement	sqm	192.92
	(b) Medium shade pigment using approx. 50% white cement and 50% ordinary cement	sqm	192.92
	(c) Dark shade pigment using ordinary cement	sqm	192.92
5.25.	Extra if cut tiles other than half tiles are used in risers of steps, skirting and dado	sqm	0.00
5.26.	Chequered terrazzo tiles 22 mm thick with marble chips of size upto 16 mm in floors on 25 mm thick bed of lime mortar 1:1:1 (1 lime putty: 1 surkhi: 1coarse sand), jointed with neat cement slurry mixed with pigment to match the shade of tiles		
	(a) Light shade pigment using white cement	sqm	265.46
	(b) Medium shade pigment using approx. 50% white cement and 50% ordinary cement	sqm	236.00
	(c) Dark shade pigment using ordinary cement	sqm	236.00
5.27.	Chequered terrazzo tiles 22 mm thick with marble chips of sizes upto 6 mm in floors on 25 mm thick bed of lime mortar 1:2 (1 lime putty : 2 coarse sand), jointed with neat cement slurry mixed with pigment to match the shade of the tile		
	(a) Light shade pigment using white cement	sqm	314.07
	(b) Medium shade pigment using approx. 50% white cement and 50% ordinary cement	sqm	284.61
	(c) Dark shade pigment using ordinary cement	sqm	284.61

Item Code No.	Description of Item of Work	Unit	Embodied Energy Rate (EER) in MJ/Unit
	<u>Marble Stone Slab Flooring</u>		
5.28.	Marble stone slab flooring over 20 mm (av.) thick base of lime mortar 1:1:1 (1 lime putty :1 surkhi :1 coarse sand) laid and jointed with gray cement slurry		
	(a) Makrana white marble slab 25 mm thick	sqm	92.86
	(b) Makrana white marble slab 30 mm thick	sqm	93.66
	(c) Makrana white marble slab 40 mm thick	sqm	95.27
	(d) Makrana pink marble slab 25mm thick	sqm	92.86
	(e) Makrana pink marble slab 30 mm thick	sqm	93.66
	(f) Makrana pink marble slab 40 mm thick	sqm	95.27
	(g) Chittor black marble slab 25 mm thick	sqm	92.86
	(h) Chittor black marble slab 30 mm thick	sqm	93.66
	(i) Chittor black marble slab 40 mm thick	sqm	95.27
	(j) Bhanslana black marble slab 25 mm thick	sqm	92.86
	(k) Bhanslana black marble slab 30 mm thick	sqm	93.66
	(l) Bhanslana black marble slab 40 mm thick	sqm	95.27
	(m) Jaisalmer yellow marble slab 25 mm thick	sqm	92.86
	(n) Jaisalmer yellow marble slab 30 mm thick	sqm	93.66
	(o) Jaisalmer yellow marble slab 40 mm thick	sqm	95.27
	(p) Baroda green marble slab 25 mm thick	sqm	92.86
	(q) Baroda green marble slab 30 mm thick	sqm	93.66
	(r) Baroda green marble slab 40 mm thick	sqm	95.27
5.29.	Marble stone slab flooring over 20 mm (av.) thick base of cement mortar 1:4 (1 cement: 4 coarse sand) laid and jointed with gray cement slurry		
	(a) Makrana white marble slab 25 mm thick	sqm	90.53
	(b) Makrana white marble slab 30 mm thick	sqm	91.33
	(c) Makrana white marble slab 40 mm thick	sqm	92.94
	(d) Makrana pink marble slab 25 mm thick	sqm	90.53

Item Code No.	Description of Item of Work	Unit	Embodied Energy Rate (EER) in MJ/Unit
	(e) Makrana pink marble slab 30 mm thick	sqm	91.33
	(f) Makrana pink marble slab 40 mm thick	sqm	92.94
	(g) Chittor black marble slab 26 mm thick	sqm	90.53
	(h) Chittor black marble slab 30 mm thick	sqm	91.33
	(i) Chittor black marble slab 40 mm thick	sqm	92.94
	(j) Bhanslana black marble slab 25 mm. thick	sqm	90.53
	(k) Bhanslana black marble slab 30 mm thick	sqm	91.33
	(l) Bhanslana black marble slab 40 mm thick	sqm	92.94
	(m) Jaisalmer Yellow marble slab 25 mm thick	sqm	90.53
	(n) Jaisalmer Yellow marble slab 30 mm thick	sqm	91.33
	(o) Jaisalmer Yellow marble slab 40 mm thick	sqm	92.94
	(p) Baroda green marble slab 25 mm thick	sqm	90.53
	(q) Baroda green marble slab 30 mm thick	sqm	91.33
	(r) Baroda green marble slab 40 mm thick	sqm	92.94
5.30.	Marble tiles in risers of steps, skirting, dado, walls and pillars laid on 12 mm (av.) thick base of cement mortar 1:3 (1 cement : 3 coarse sand) and jointed with gray cement slurry		
	(a) Makrana white marble 25 mm thick	sqm	82.71
	(b) Makrana pink marble 25 mm thick	sqm	82.71
	(c) Chittor black marble 25 mm thick	sqm	82.71
	(d) Jaisalmar yellow marble 25 mm thick	sqm	82.71
	(e) Baroda green marble 25 mm thick	sqm	82.71
5.31.	Extra for nosing in marble stone for treads	sqm	0.00
5.32.	Extra for marble stone flooring in treads of steps, not exceeding 30 cm in width	sqm	0.00
	<u>Kota Stone Flooring</u>		
5.33.	Kota stone slab flooring over 20 mm (av.) thick base of line mortar 1:1:1 (1 lime putty: 1 surkhi: 1 coarse sand),		

Item Code No.	Description of Item of Work	Unit	Embodied Energy Rate (EER) in MJ/Unit
	laid over and jointed with grey cement slurry mixed with pigment to match the shade of the slab		
	(a) 25 mm thick	sqm	102.24
	(b) 30 mm thick	sqm	104.92
	(c) 40 mm thick	sqm	110.30
5.34.	Kota stone slab flooring over 20 mm (av.) thick base of cement mortar 1:4 (1 cement: 4 coarse sand), laid over and jointed with gray cement slurry mixed with pigment to match the shade of the slab		
	(a) 25 mm thick	sqm	99.91
	(b) 30 mm thick	sqm	102.60
	(c) 40 mm thick	sqm	108.00
5.35.	Kota stone slab 25 mm thick in risers of steps, skirting, dados and pillars laid in 18 mm (av.) thick base of cement mortar 1:3 (1 cement: 3 coarse sand) and jointed with grey cement slurry mixed with pigment to match the shade of the slabs	sqm	92.10
	Sand Stone Flooring		
5.36.	49 mm thick rough chisel dressed stone flooring over 20 mm (av.) thick base of cement mortar 1:5 (1 cement: 5 coarse sand) with joints finished flush		
	(a) Red sand stone	sqm	51.93
	(b) White sand stone	sqm	51.93
5.37.	40 mm thick rough chisel dressed stone flooring over 20 mm av. thick base of cement mortar 1:5 (1 cement: 5 coarse sand) incl. pointing with cement mortar 1:2 (1 cement: 2 stone dust) with an admixture of pigment to match the shade of stone		
	(a) Red sand stone	sqm	62.40
	(b) White sand stone	sqm	62.40
5.38.	40 mm thick rough chisel dressed stone flooring over 20 mm (av.) thick base of lime mortar 1:1:1 (1 lime putty: 1 surkhi: 1 coarse sand) with joints finished flush		
	(a) Red sand stone	sqm	66.24
	(b) White sand stone	sqm	66.24

Item Code No.	Description of Item of Work	Unit	Embodied Energy Rate (EER) in MJ/Unit
5.39.	40 mm thick rough chiseled dressed stone flooring over 20 mm (av.) thick base of lime mortar 1:1:1 (1 lime putty: 1surkhi: 1 coarse sand) incl. pointing with cement mortar 1:2 (1 cement :2 stone dust) with an admixture of pigment to match the shade of stone		
	(a) Red sand stone	sqm	76.72
	(b) White sand stone	sqm	76.72
5.40.	40 mm thick fine dressed stone flooring over 20 mm (av.) thick base of cement mortar 1:5 (1cement: 5 coarse sand) with joints finished flush		
	(a) Red sand stone	sqm	51.93
	(b) White sand stone	sqm	51.93
5.41.	40 mm thick fine dressed stone flooring over 20 mm (av.) thick base of cement mortar 1:5 (1 cement: 5 coarse sand) incl. pointing with cement mortar 1:2 (1 cement: 2 stone dust) with an admixture of pigment to match the shade of stone.		
	(a) Red sand stone	sqm	62.40
	(b) White sand stone	sqm	62.40
5.42.	40 mm thick fine dressed stone flooring over 20 mm (av.) thick base of lime mortar 1:1:1 (1 line putty: 1 surkhi: 1 coarse sand) with joints finished flush		
	(a) Red sand stone	sqm	66.24
	(b) White sand stone	sqm	66.24
5.43.	40 mm thick fine dressed stone flooring over 20 mm (av.) thick base of line mortar 1:1:1 (1 line putty: 1 surkhi : 1 coarse sand) incl. pointing with cement mortar 1:2 (1 cement: 2 stone dust) with an admixture of pigment to match the shade of stone		
	(a) Red sand stone	sqm	76.72
	(b) White sand stone	sqm	76.72
5.44.	40 mm thick fine dressed and rubbed stone flooring over 20 mm (av.) thick base of cement mortar 1:5 (1 cement: 5 coarse sand) with joints 3 mm thick and sides buttered with cement mortar 1:2 (1 cement: 2 stone dust) admixed with pigment to match the shade		

Item Code No.	Description of Item of Work	Unit	Embodied Energy Rate (EER) in MJ/Unit
	of stone and pointed with the same mortar		
	(a) Red sand stone	sqm	62.40
	(b) White sand stone	sqm	62.40
5.45.	40 mm thick fine dressed and rubbed stone flooring over 20 mm (av.) thickness of lime mortar, 1:1:1 (1 lime putty: 1surkhi: 1coarse sand) with joints 3 mm thick and sides buttered with cement mortar 1:2 (1 cement: 2 stone dust) admixed with pigment to match the shade of stone and pointed with the same mortar		
	(a) Red sand stone	sqm	76.72
	(b) White sand stone	sqm	76.72
5.46.	40 mm thick fine dressed and rubbed stone flooring over 20 mm (av.) thick base of cement mortar 1:5 (1 cement: 5 coarse sand) with joint 5 mm thick finished flush		
	(a) Red sand stone	sqm	51.93
	(b) White sand stone	sqm	51.93
5.47.	40 mm thick fine dressed and rubbed stone flooring over 20 mm (av.) thick base of cement mortar 1:5 (1 cement: 5 coarse sand) with joints 5 mm thick incl. pointing with cement mortar 1:2 (1 cement: 2 stone dust) with an admixture of pigment to match the shade of stone		
	(a) Red sand stone	sqm	62.40
	(b) White sand stone	sqm	62.40
5.48.	40 mm thick fine dressed and rubbed stone flooring over 20 mm (av.) thick base of lime mortar 1:1:1 (1 lime putty: 1 surkhi: 1 coarse sand) with joints 5 mm thick incl. pointing with cement mortar 1:2 (1 cement: 2 stone dust) with an admixture of pigment to match the shade of stone		
	(a) Red sand stone	sqm	76.72
	(b) White sand stone	sqm	76.72
5.49.	Extra for nosing in steps and treads of Kota stone slab	sqm	0.00
5.50.	Extra for Kota stone flooring in steps and treads not exceeding 30 cm in width	sqm	0.00

Item Code No.	Description of Item of Work	Unit	Embodied Energy Rate (EER) in MJ/Unit
5.51.	Extra for nosing in steps and treads of red or white rough dressed sand stone	sqm	0.00
5.52.	Extra for red or white rough dressed sand stone flooring in steps and treads not exceeding 30 cm in width	sqm	0.00
5.53.	Extra for nosing in steps and treads of red or white fine dressed sand stone	sqm	0.00
5.54.	Extra for red or white fine dressed sand stone flooring in steps and treads not exceeding 30 cm in width	sqm	0.00
5.55.	Extra for nosing in steps and treads of red or white fine dressed and rubbed sand stone	sqm	0.00
5.56.	Extra for red or white fine dressed and rubbed sandstone flooring in steps and treads not exceeding 30 cm in width	sqm	0.00
	Miscellaneous		
5.57.	Providing and laying 25 mm thick burnt clay tiles 250 mm x 250 mm x 25 mm of approved quality over roofs with 1 cm side joints grouted with cement mortar 1:3 (1 cement: 3 fine sand) over 15 mm thick bed of cement mortar 1:3 (1 cement: 3 fine sand) and finished neatly	sqm	125.75

6. FINISHING

6.1. PLASTERING

Item Code No.	Description of Item of Work	Unit	Embodied Energy Rate (EER) in MJ/Unit
	Plastering with Lime Plaster		
6.1.1.	12 mm lime plaster 1:1:1 (1 lime putty: 1 surkhi: 1 fine sand)	sqm	38.16
6.1.2.	15 mm lime plaster 1:1:1 (1 lime putty : 1 surkhi : 1 fine sand) on the rough side of a single or half brick wall	sqm	45.58
6.1.3.	18 mm lime plaster 1:1:1 (1 lime putty : 1 surkhi: 1 fine sand) in 2 coats - under layer 12 mm and top layer 6 mm thick	sqm	57.24
6.1.4.	Lime punning with lime mortar 1:1 (1 lime putty : 1 fine sand)	sqm	8.80
	Plastering with Cement Plaster (in Fine Sand)		
6.1.5.	10 mm cement plaster 1:3 (1 cement : 3 fine sand)	sqm	41.00
6.1.6.	12 mm cement plaster 1:3 (1 cement : 3 fine sand)	sqm	49.21
6.1.7.	12 mm cement plaster 1:4 (1 cement: 4 fine sand)	sqm	36.67
6.1.8.	12 mm cement plaster 1:5 (1 cement : 5 fine sand)	sqm	29.91
6.1.9.	12 mm cement plaster 1:6 (1 cement : 6 fine sand)	sqm	24.12
6.1.10.	15 mm cement plaster 1:3 (1 cement : 3 fine sand) on the rough side of a single or half brick wall	sqm	58.77
6.1.11.	15 mm cement plaster 1:4 (1 cement : 4 fine sand) on the rough side of a single or half brick wall	sqm	43.80
6.1.12.	15 mm cement plaster 1:5 (1 cement : 5 fine sand) on the rough side of a single or half brick wall	sqm	35.72
6.1.13.	15 mm cement plaster 1:6 (1 cement : 6 fine sand) on the rough side of a single or half brick wall	sqm	28.81
6.1.14.	20 mm cement plaster 1:3 (1 cement : 3 fine sand)	sqm	76.54
6.1.15.	20 mm cement plaster 1:4 (1 cement : 4 fine sand)	sqm	57.03
6.1.16.	20 mm cement plaster 1:5 (1 cement : 5 fine sand)	sqm	46.53
6.1.17.	20 mm cement plaster 1:6 (1 cement : 6 fine sand)	sqm	37.52

Item Code No.	Description of Item of Work	Unit	Embodied Energy Rate (EER) in MJ/Unit
6.1.18.	6 mm cement plaster to ceiling 1:3 (1 cement : 3 fine sand)	sqm	24.60
6.1.19.	6 mm cement plaster to ceiling 1:4 (1 cement : 4 fine sand)	sqm	18.33
6.1.20.	6 mm cement plaster to ceiling 1:6 (1 cement : 6 fine sand)	sqm	12.06
6.1.21.	Neat cement punning	sqm	14.74
6.1.22.	12 mm cement plaster 1:3 (1 cement : 3 fine sand), finished with a floating coat of neat cement	sqm	63.95
6.1.23.	12 mm cement plaster 1:4 (1 cement : 4 fine sand), finished with a floating coat of neat cement	sqm	51.41
6.1.24.	15 mm cement plaster 1:3 (1 cement : 3 fine sand) on the rough side of a single or half brick wall, finished with a floating coat of neat cement	sqm	73.51
6.1.25.	15 mm cement plaster 1:4 (1 cement : 4 fine sand) on the rough side of a single or half brick wall, finished with a floating coat of neat cement	sqm	58.54
6.1.26.	20 mm cement plaster 1:3 (1 cement : 3 fine sand), finished with a floating coat of neat cement	sqm	91.28
6.1.27.	20 mm cement plaster 1:4 (1 cement : 4 fine sand), finished with a floating coat of neat cement	sqm	71.77
6.1.28.	6 mm cement plaster 1:3 (1 cement : 3 fine sand), finished with a floating coat of neat cement & a thick coat of lime wash on top of wall when dry, for bearing of R.C.C. slabs & beams	sqm	39.34
	<u>Plastering with Cement Plaster (in Coarse Sand)</u>		
6.1.29.	12 mm cement plaster 1:3 (1 cement : 3 coarse sand)	sqm	49.21
6.1.30.	12 mm cement plaster 1:4 (1 cement : 4 coarse sand)	sqm	36.67
6.1.31.	12 mm cement plaster 1:5 (1 cement : 5 coarse sand)	sqm	29.91
6.1.32.	12 mm cement plaster 1:6 (1 cement : 6 coarse sand)	sqm	24.12
6.1.33.	15 mm cement plaster 1:3 (1 cement : 3 coarse sand) on the rough side of a single or half brick wall	sqm	58.77
6.1.34.	15 mm cement plaster 1:4 (1 cement : 4 coarse sand) on the rough side of a single or half brick wall	sqm	43.80

Item Code No.	Description of Item of Work	Unit	Embodied Energy Rate (EER) in MJ/Unit
6.1.35.	15 mm cement plaster 1:5 (1 cement : 5 coarse sand) on the rough side of a single or half brick wall	sqm	28.81
6.1.36.	15 mm cement plaster 1:6 (1 cement : 6 coarse sand) on the rough side of a single or half brick wall	sqm	28.81
6.1.37.	20 mm cement plaster 1:2 (1 cement : 2 coarse sand)	sqm	102.05
6.1.38.	20 mm cement plaster 1:3 (1 cement : 3 coarse sand)	sqm	76.54
6.1.39.	20 mm cement plaster 1:4 (1 cement : 4 coarse sand)	sqm	57.03
6.1.40.	20 mm cement plaster 1:5 (1 cement : 5 coarse sand)	sqm	46.53
6.1.41.	20 mm cement plaster 1:6 (1 cement : 6 coarse sand)	sqm	37.52
6.1.42.	12 mm cement plaster 1:3 (1 cement : 3 coarse sand), finished with a floating coat of neat cement	sqm	63.95
6.1.43.	15 mm cement plaster 1:3 (1 cement : 3 coarse sand), finished with a floating coat of neat cement	sqm	73.51
6.1.44.	18 mm cement plaster in 2 coats - under layer 12 mm cement plaster 1:5 (1 cement : 5 coarse sand), finished with a top layer of 6 mm thick cement plaster 1:6 (1 cement : 6 fine sand)	sqm	41.97
6.1.45.	18 mm cement plaster in 2 coats - under layer 12 mm cement plaster 1:5 (1 cement : 5 coarse sand) & top layer 6 mm thick cement plaster 1:3 (1 cement: 3 coarse sand), finished rough with sponge	sqm	54.51
	Plastering with Cement Lime Plaster		
6.1.46.	12 mm cement lime plaster 1:1:6 (1 cement : 1 lime putty: 6 fine sand)	sqm	34.70
6.1.47.	12 mm cement lime plaster 1:1:7 (1 cement : 1 lime putty : 7 fine sand)	sqm	30.31
6.1.48.	12 mm cement lime plaster 1:1:8 (1 cement : 1 lime putty : 8 fine sand)	sqm	26.20
6.1.49.	12 mm cement lime plaster 1:2:9 (1 cement : 2 lime putty.: 9 fine sand)	sqm	30.54
6.1.50.	15 mm cement lime plaster 1:1:6 (1 cement : 1 lime putty : 6 fine sand)	sqm	41.44
6.1.51.	15 mm cement lime plaster 1:1:7 (1 cement : 1 lime putty : 7 fine sand) on the rough side of single or half brick wall	sqm	36.20

Item Code No.	Description of Item of Work	Unit	Embodied Energy Rate (EER) in MJ/Unit
6.1.52.	15 mm cement lime plaster 1:1:8 (1 cement : 1 lime putty : 8 fine sand) on the rough side of single or half brick wall	sqm	31.30
6.1.53.	15 mm cement lime plaster 1:2:9 (1 cement : 2 lime putty : 9 fine sand) on the rough side of single or half brick wall	sqm	36.47
6.1.54.	18 mm cement lime plaster in 2 coats - under layer 12 mm cement plaster 1:5 (1 cement : 5 coarse sand), finished with 6 mm cement lime plaster 1:1:6 (1cement: 1 lime putty: 6 fine sand)	sqm	47.26
6.1.55.	18 mm cement lime plaster in 2 coats - under layer 12 mm cement plaster 1:5 (1cement:5 coarse sand) finished with 6 mm cement lime plaster 1:1:7 (1cement: 1lime putty: 7 fine sand)	sqm	45.06
6.1.56.	18 mm cement lime plaster in 2 coats - under layer 12 mm cement plaster 1:5 (1 cement : 5 coarse sand), finished with 6 mm cement lime plaster 1:1:8 (1cement: 1 lime putty: 8 fine sand)	sqm	43.00
	Plastering with Lime Surkhi Plaster		
6.1.57.	12 mm lime surkhi plaster 1:2 (1 lime putty: 2 surkhi)	sqm	48.14
6.1.58.	15 mm lime surkhi plaster 1:2 (1 lime putty: 2 surkhi) on the rough side of single or half brick wall	sqm	57.50
6.1.59.	18 mm lime surkhi plaster 1:2 (1 lime putty: 2 surkhi) in 2 coats, under layer 12 mm & top layer 6 mm	sqm	67.20
	Miscellaneous Items		
6.1.60.	12 mm cement plaster 1:2 (1 cement : 2 stone dust)	sqm	65.61
6.1.61.	15 mm cement plaster 1:2 (1 cement : 2 stone dust) on the rough side of single or half brick wall	sqm	78.36
6.1.62.	20 mm cement plaster 1:2 (1 cement: 2 stone dust)	sqm	102.05
6.1.63.	Extra for providing & mixing water proofing materials		
	(a) 12 mm cement plaster 1:3 (1 cement : 3 sand)	sqm	49.51
	(b) 12 mm cement plaster 1:4 (1 cement : 4 sand)	sqm	37.04
	(c) 15 mm cement plaster 1:3 (1 cement : 3 sand)	sqm	59.22
	(d) 15 mm cement plaster 1:4 (1 cement : 4 sand)	sqm	44.25

Item Code No.	Description of Item of Work	Unit	Embodied Energy Rate (EER) in MJ/Unit
	(e) 20 mm cement plaster 1:3 (1 cement : 3 sand)	sqm	77.00
	(f) 20 mm cement plaster 1:4 (1 cement: 4 sand)	sqm	57.62
6.1.64.	18 mm plastering with terrazzo finish, rubbed and polished complete - under layer 12 mm thick cement plaster 1:3 (1 cement : 3 coarse sand) & top layer 6 mm thick white, black, or white & black marble chips of 3 mm and down size, laid in cement marble powder mix [3:1 (3 cement: 1 marble powder) by wt.] in proportion of 4:7 (4 cement marble powder mix : 7 marble chips) by volume	sqm	49.21
6.1.65.	Extra if white cement is used instead of ordinary cement in top layer of 18 mm plastering with terrazzo finish	sqm	28.81
6.1.66.	12 mm thick plain cement mortar band 10 cm thick, in cement mortar 1:4 (1 cement: 4 fine sand)		
	(a) Flush band	m	3.56
	(b) Sunk band	m	3.56
	(c) Raised band	m	3.56
6.1.67.	18 mm thick plain cement mortar band 10 cm thick, in cement mortar 1:4 (1cement: 4 fine sand)		
	(a) Flush band	m	5.10
	(b) Sunk band	m	5.10
	(c) Raised band	m	5.10
6.1.68.	12 mm thick cement mortar band in cement mortar 1:4 (1 cement : 4 fine sand)	m	3.56
6.1.69.	18 mm thick moulded cement mortar band in cement mortar 1:4 (1 cement : 4 fine sand)	m	5.10
6.1.70.	18 mm thick moulded cement mortar band 10 cm thick, in 2 coats - under layer 12 mm thick with cement mortar 1:5 (1 cement : 5 coarse sand) & top layer, 6 mm thick with cement mortar 1:4 (1 cement : 4 fine sand)	m	4.70
6.1.71.	18 mm thick artificial red stone plaster consisting of 12 mm thick under coat of cement plaster 1:4 (1 cement: 4 coarse sand) with 6 mm thick finishing coat of cement mortar 1:1:3 (1 cement : 1 marble dust : 3 stone dust) mixed with red oxide to match the shade		

Item Code No.	Description of Item of Work	Unit	Embodied Energy Rate (EER) in MJ/Unit
	of red stone	sqm	63.46
6.1.72.	18 mm thick lime plaster of marble shade consisting of 12 mm thick undercoat of cement plaster 1:4 (1 cement: 4 coarse sand), 6 mm thick middle coat of Makrana lime paste, fine marble particles & stone dust in ratio of 2:1:1 (2 Makrana lime paste : 1 fine marble particles : 1 stone dust) and brushed and polished with Makrana lime paste & mishri incl. polishing & glazing complete	sqm	70.46

6.2. POINTING

Item Code No.	Description of Item of Work	Unit	Embodied Energy Rate (EER) in MJ/Unit
6.2.1.	Pointing on brick work with cement mortar 1:3 (1 cement: 3 fine sand)		
	(a) Flush pointing	sqm	10.25
	(b) Ruled pointing	sqm	10.25
	(c) Cut or weather struck pointing	sqm	10.25
	(d) Raised or cut pointing	sqm	15.72
6.2.2.	Pointing on brick work with a mixture of white cement, lime, marble dust & stone dust in proportion of ¼:1:1:1 (¼ white cement: 1 lime: 1 marble dust: 1 stone dust)		
	(a) Flush pointing	sqm	5.61
	(b) Ruled pointing	sqm	5.61
	(c) Cut or weather struck pointing	sqm	5.61
6.2.3.	Pointing on brick work with lime surkhi mortar 1:2 (1 lime putty : 2 surkhi)		
	(a) Flush pointing	sqm	10.03
	(b) Ruled pointing	sqm	10.03
	(c) Cut or weather struck pointing	sqm	10.03
6.2.4.	Pointing on brick work with cement lime mortar 1:1:3 (1cement : 1 lime putty : 3 fine sand) with an admixture of red oxide to match the shade of brick work		

Item Code No.	Description of Item of Work	Unit	Embodied Energy Rate (EER) in MJ/Unit
	(a) Flush pointing	sqm	11.77
	(b) Ruled pointing	sqm	11.77
	(c) Cut or weather struck pointing	sqm	11.77
6.2.5.	Pointing on brick flooring with cement mortar 1:2 (1 cement : 2 fine sand)		
	(a) Flush pointing	sqm	9.11
	(b) Ruled pointing	sqm	9.11
6.2.6.	Pointing on brick flooring with cement mortar 1:4 (1 cement : 4 fine sand)		
	(a) Flush pointing	sqm	5.09
	(b) Ruled pointing	sqm	5.09
6.2.7.	Pointing on brick flooring with cement mortar 1:6 (1 cement : 6 fine sand)		
	(a) Flush pointing	sqm	3.35
	(b) Ruled pointing	sqm	3.35
6.2.8.	Pointing on tile brick work with cement mortar 1:3 (1 cement: 3 fine sand)		
	(a) Flush pointing	sqm	15.72
	(b) Ruled pointing	sqm	15.72
	(c) Cut or weather struck pointing	sqm	15.72
6.2.9.	Pointing on tile brick work with a mixture of white cement, lime, marble dust & stone dust in proportion of ¼ :1:1:1 (¼ white cement : 1 lime putty : 1 marble dust: 1 stone dust)		
	(a) Flush pointing	sqm	8.60
	(b) Ruled pointing	sqm	8.60
	(c) Cut or weather struck pointing	sqm	8.60
6.2.10.	Pointing on tile brick work with lime mortar 1:2 (1 lime putty: 2 surkhi)		
	(a) Flush pointing	sqm	15.38

Item Code No.	Description of Item of Work	Unit	Embodied Energy Rate (EER) in MJ/Unit
	(b) Ruled pointing	sqm	15.38
	(c) Cut or weather struck pointing	sqm	15.38
6.2.11.	Pointing on tile brick work with cement lime mortar 1:1:3 (1 cement: 1 lime putty: 3 fine sand) with an admixture of red oxide to match the shade of tile brick work.		
	(a) Flush pointing	sqm	18.05
	(b) Ruled pointing	sqm	18.05
	(c) Cut or weather struck pointing	sqm	18.05
6.2.12.	Pointing on stone work with cement mortar 1:3 (1 cement: 3 fine sand)		
	(a) Flush pointing	sqm	7.86
	(b) Ruled pointing	sqm	7.86
	(c) Raised & cut pointing	sqm	12.99
6.2.13..	Raised & cut pointing on stone work with white cement mortar 1:3 (1 white cement: 3 marble dust)	sqm	12.99
6.2.14.	Raised & cut pointing on stone work with white cement lime mortar ¼:1:1:1 (¼ white cement: 1 marble dust: 1 stone dust: 1lime putty)	sqm	7.10
6.2.15.	Pointing on white stone slab pavement with white cement lime mortar ¼:1:1:1 (¼ white cement: 1 marble dust: 1 stone dust: 1 lime putty)		
	(a) Flush pointing	sqm	2.80
	(b) Ruled pointing	sqm	2.80
6.2.16.	Pointing on stone slab ceiling with cement mortar 1:2 (1 cement : 2 fine sand)		
	(a) Flush pointing	sqm	6.83
	(b) Ruled pointing	sqm	6.83

6.3. WHITE WASHING

Item Code No.	Description of Item of Work	Unit	Embodied Energy Rate (EER) in MJ/Unit
6.3.1.	White washing with lime on new work (three or more coats) to give an even shade	sqm	1.95
6.3.2.	White washing with lime on old work to give an even shade		
	(a) One coat	sqm	0.65
	(b) Two or more coats	sqm	1.30
6.3.3.	Colour washing such as green, blue or buff on new work. (two or more coats) incl. a base coat of white washing with lime to give an even shade	sqm	1.95
6.3.4.	Colour washing such as green, blue or buff with lime on old work to give an even shade		
	(a) One coat	sqm	0.65
	(b) Two or more coats	sqm	1.30
6.3.5.	Colour washing such as green, blue or buff on new work (two or more coats) incl. a base coat of white washing with whiting to give an even shade	sqm	1.95
6.3.6.	Hiramchi colour wash on new work (two or more coats) to give an even shade	sqm	1.30
6.3.7.	Hiramchi colour wash on old work (one coat) to give an even shade	sqm	0.65

7. TRANSPORT ENERGY RATE

S.No.	Item of Work	Unit	Unit Weight in Kg/Unit	Transport Energy Rate[1] (TER) in MJ /Unit
7.1.	MASONRY WORK			
	7.1.1. Masonry Work with Traditional or Modular Bricks			
	(a) in cement mortar	cum	1920.00	69.12
	(b) in lime mortar	cum	1850.00	66.59
	(c) in tapered surface of brick masonry	sqm	61.00	2.20
	7.1.2. Masonry Work with Clay Flyash Bricks			
	(a) in cement mortar	cum	1431.60	51.54
	(b) in lime mortar	cum	1361.20	49.00
	7.1.3. Masonry Work with Sand Lime Bricks			
	(a) in cement mortar	cum	1920.00	69.12
	(b) in lime mortar	cum	1850.00	66.59
	7.1.4. Masonry Work with Hollow Concrete Blocks (40 cm x 20 cm x 10 cm)			
	(a) in cement mortar	cum	1778.00	64.00
	(b) in lime mortar	cum	1704.80	61.37
	7.1.5. Masonry Work with Hollow Concrete Blocks (40 cm x 20 cm x 20 cm)			
	(a) in cement mortar	cum	1654.00	59.54
	(b) in lime mortar	cum	1601.00	57.63

[1] TER are obtained by multiplying the TEV value of the building materials (0.036 MJ/kg) with their unit weights

S.No.	Item of Work	Unit	Unit Weight in Kg/Unit	Transport Energy Rate (TER) in MJ/Unit
	7.1.6. Masonry Work with Aerated Concrete Blocks (40 cm x 20 cm x 20 cm)			
	(a) in cement mortar	cum	1632.00	58.75
	(b) in lime mortar	cum	1579.00	56.84
	7.1.7. Masonry Work with Solid Concrete Blocks (30 cm x 20 cm x 15 cm)			
	(a) in cement mortar	cum	2432.00	87.55
	(b) in lime mortar	cum	2368.00	85.25
	7.1.8. Masonry Work with Fal-G Blocks (30 cm x 20 cm x 15 cm)			
	(a) in cement mortar	cum	2432.00	87.55
	(b) in lime mortar	cum	2368.00	85.25
7.2.	CONCRETE WORK			
	7.2.1. Concrete Work with Stone Aggregate	cum	2240.00	80.64
	7.2.2. Concrete Work with Brick Aggregate	cum	1840.00	66.24
	7.2.3. DPC			
	(a) 25 mm thick	sqm	56.00	2.02
	(b) 40 mm thick	sqm	90.00	3.24
	7.2.4. Plinth Protection (50 mm thick)	sqm	92.00	3.31
7.3.	RCC WORK	cum	2500.00	90.00
7.4.	FLOORING			
	7.4.1. Cement Concrete Flooring			
	(a) 25 mm thick	sqm	56.00	2.02
	(b) 40 mm thick	sqm	90.00	3.24

S.No.	Item of Work	Unit	Unit Weight in Kg/Unit	Transport Energy Rate (TER) in MJ/Unit
	7.4.2. Terrazzo Flooring			
	(a) 10 mm thick	sqm	24.00	0.86
	(b) 25 mm thick	sqm	60.00	2.16
	(c) 40 mm thick	sqm	96.00	3.46
	7.4.3. Cement Plaster Skirting			
	(a) 18 mm thick	sqm	37.50	1.35
	(b) 21 mm thick	sqm	43.50	1.57
	7.4.4. Terrazzo Finish in Skirting			
	(a) 18 mm thick	sqm	43.00	1.55
	(b) 21 mm thick	sqm	50.00	1.80
	7.4.5. Glass Strips			
	(a) 4 mm thick, 35 mm wide	m	0.35	0.01
	(b) 4 mm thick, 40 mm wide	m	0.40	0.01
	(c) 6 mm thick, 35 mm wide	m	0.53	0.02
	(d) 6 mm thick, 40 mm wide	m	0.60	0.02
	7.4.6. Marble Stone Slab Flooring			
	(a) 25 mm thick Makarana white marble slab over 20 mm thick layer of cement mortar 1:4	sqm	110.00	3.96
	(b) 30 mm thick Bhanslana marble slab over 20 mm thick layer of cement mortar 1:4	sqm	123.00	4.43
	7.4.7. Kota Stone Slab Flooring			
	(a) 25 mm thick stone slab over 20 mm thick layer of cement mortar 1:4	sqm	98.00	3.53

S.No.	Item of Work	Unit	Unit Weight in Kg/Unit	Transport Energy Rate (TER) in MJ/Unit
	(a) 25 mm thick stone slab over 12 mm thick layer of cement mortar 1:3	sqm	81.00	2.92
	(b) 30 mm thick stone slab over 20 mm thick layer of cement mortar 1:4	sqm	109.00	3.92
	7.4.8. Roofing with Burnt Clay Tiles (25 mm thick)	sqm	79.00	2.84
7.5.	FINISHING			
	7.5.1. Plastering			
	(a) 6 mm thick	sqm	12.50	0.45
	(b) 10 mm thick	sqm	21.00	0.76
	(c) 12 mm thick	sqm	25.00	0.90
	(d) 15 mm thick	sqm	31.00	1.12
	(e) 18 mm thick	sqm	37.50	1.35
	(f) 20 mm thick	sqm	41.50	1.49
	7.5.2. Pointing			
	(a) Struck or weathered pointing	sqm	6.24	0.22
	7.5.3. White washing	sqm	0.30	0.01

APPENDIX-III

Plans for All Projects and the Detailed Estimates of Their Energy Costs

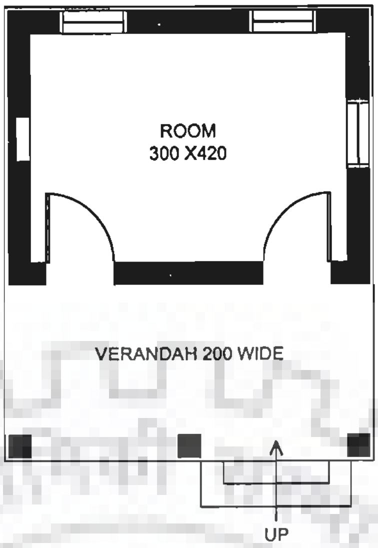

Fig. III.1 - Plan of Project No. 1
(Plinth Area = 28.32 sqm; Floor Area = 23.64 sqm)

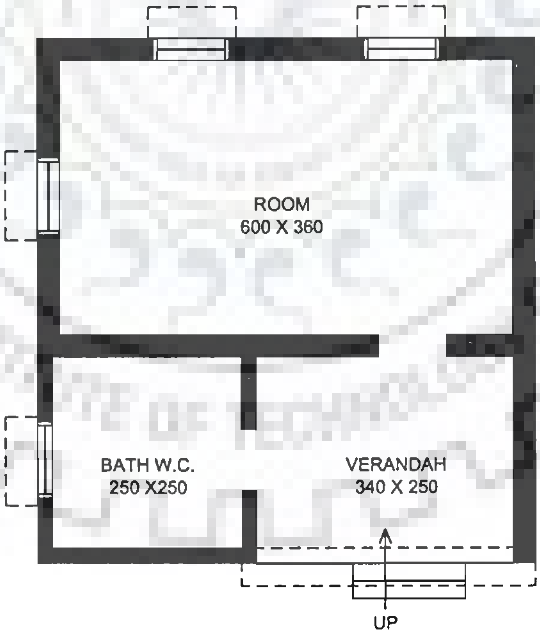

Fig. III.2 - Plan of Project No. 2
(Plinth Area = 45.54 sqm; Floor Area = 36.35 sqm)

Note : (a) Scale of drawing 1:100 (b) All dimensions in cm

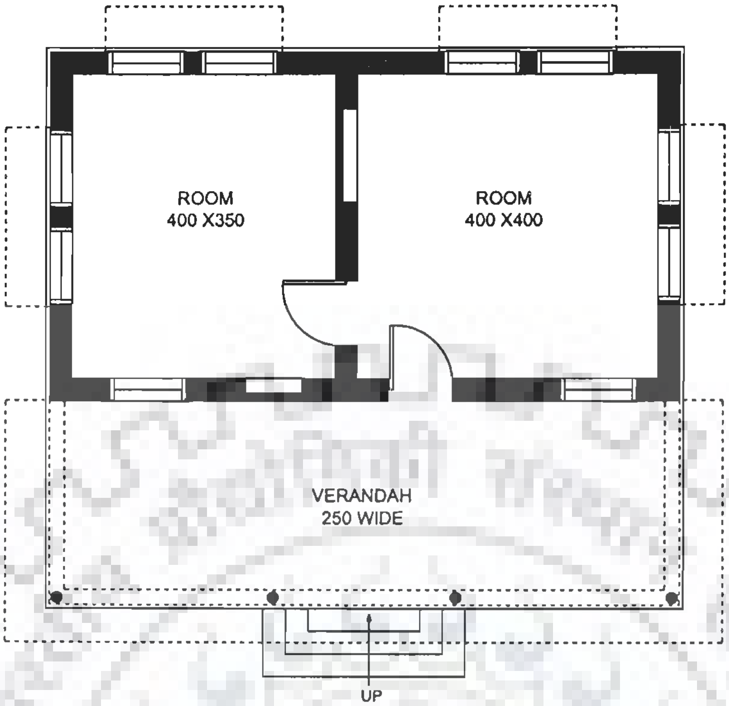

Fig. III.3 - Plan of Project No. 3
(Plinth Area = 61.32 sqm; Floor Area = 52.68 sqm)

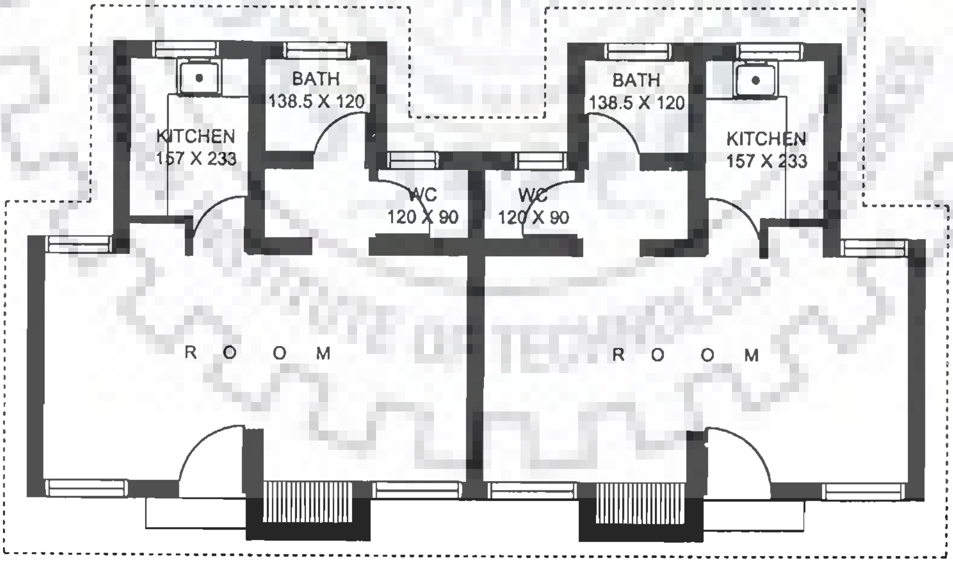

Fig. III.4 - Plan of Project No. 4
(Plinth Area = 69.40 sqm; Floor Area = 54.96 sqm)

Note : (a) Scale of drawing 1:100 (b) All dimensions in cm

Fig. III.5 - Plan of Project No. 5
(Plinth Area = 90.20 sqm; Floor Area = 73.13 sqm)

Note : (a) Scale of drawing 1:100 (b) All dimensions in cm

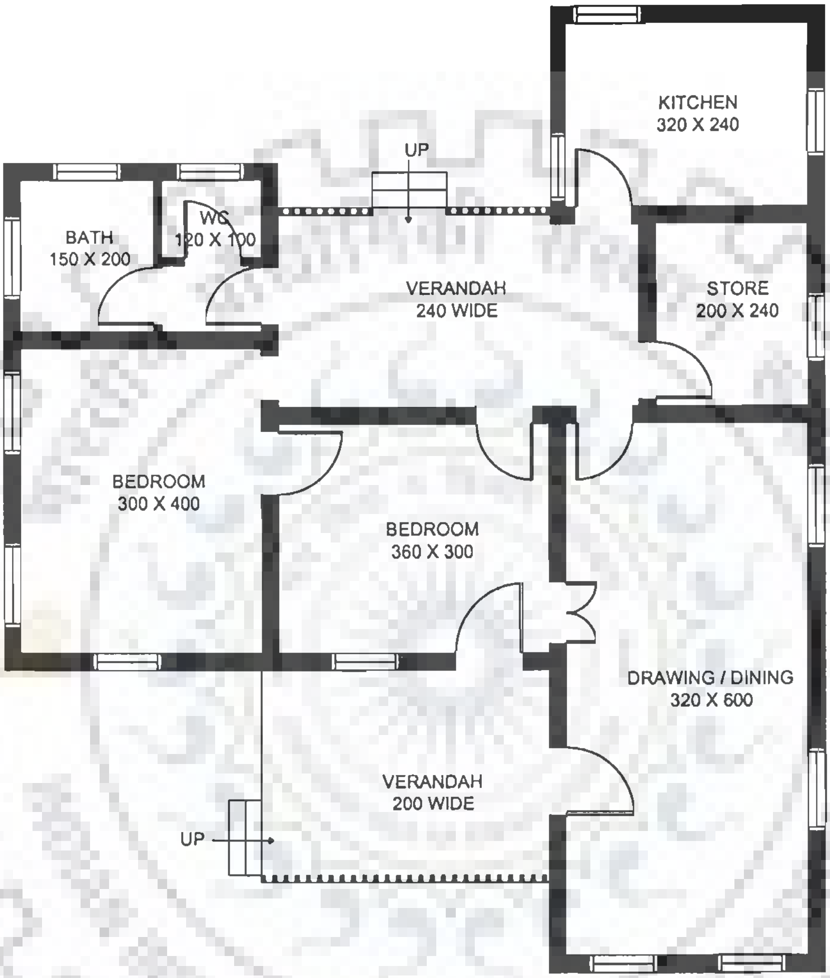

Fig. III.6 - Plan of Project No. 6
(Plinth Area = 93.72 sqm; Floor Area = 78.66 sqm)

Note : (a) Scale of drawing 1:100 (b) All dimensions in cm

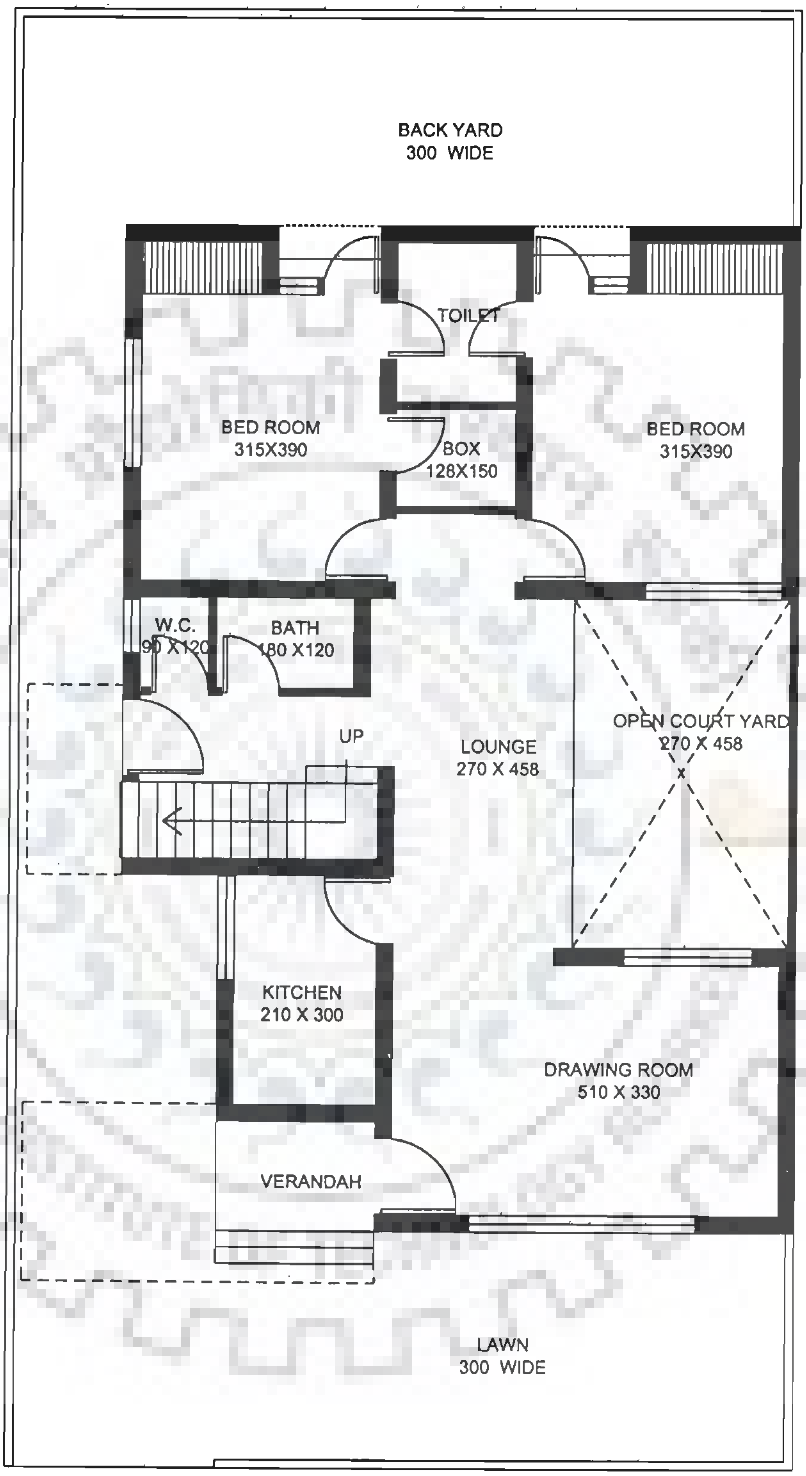

Fig. III.7(a) - Ground Floor Plan of Project No. 7
(Plinth Area = 120.49 sqm; Floor Area = 104.48 sqm)

Note : (a) Scale of drawing 1:100 (b) All dimensions in cm

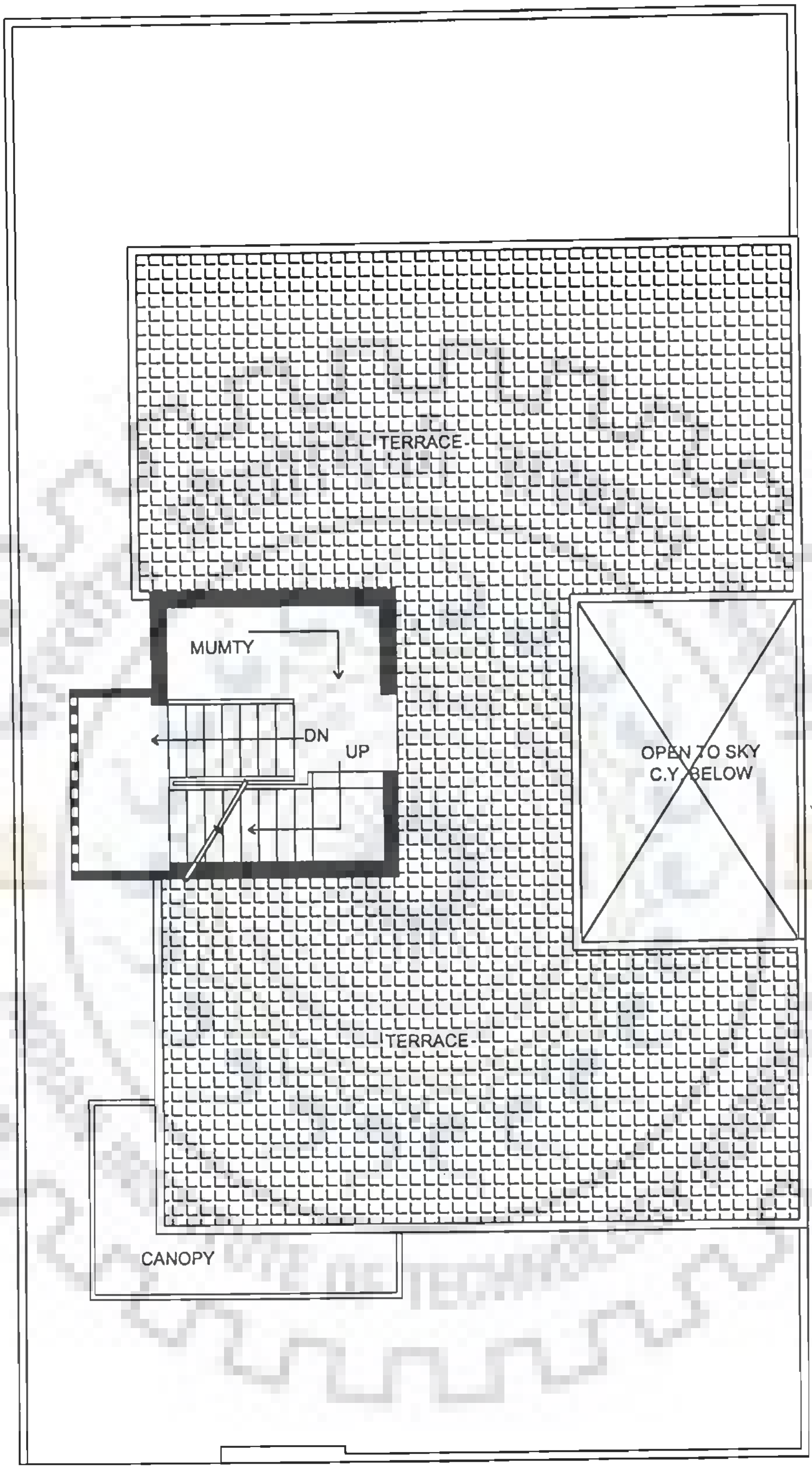

Fig. III.7(b) - Terrace Plan of Project No. 7

Note : (a) Scale of drawing 1:100 (b) All dimensions in cm

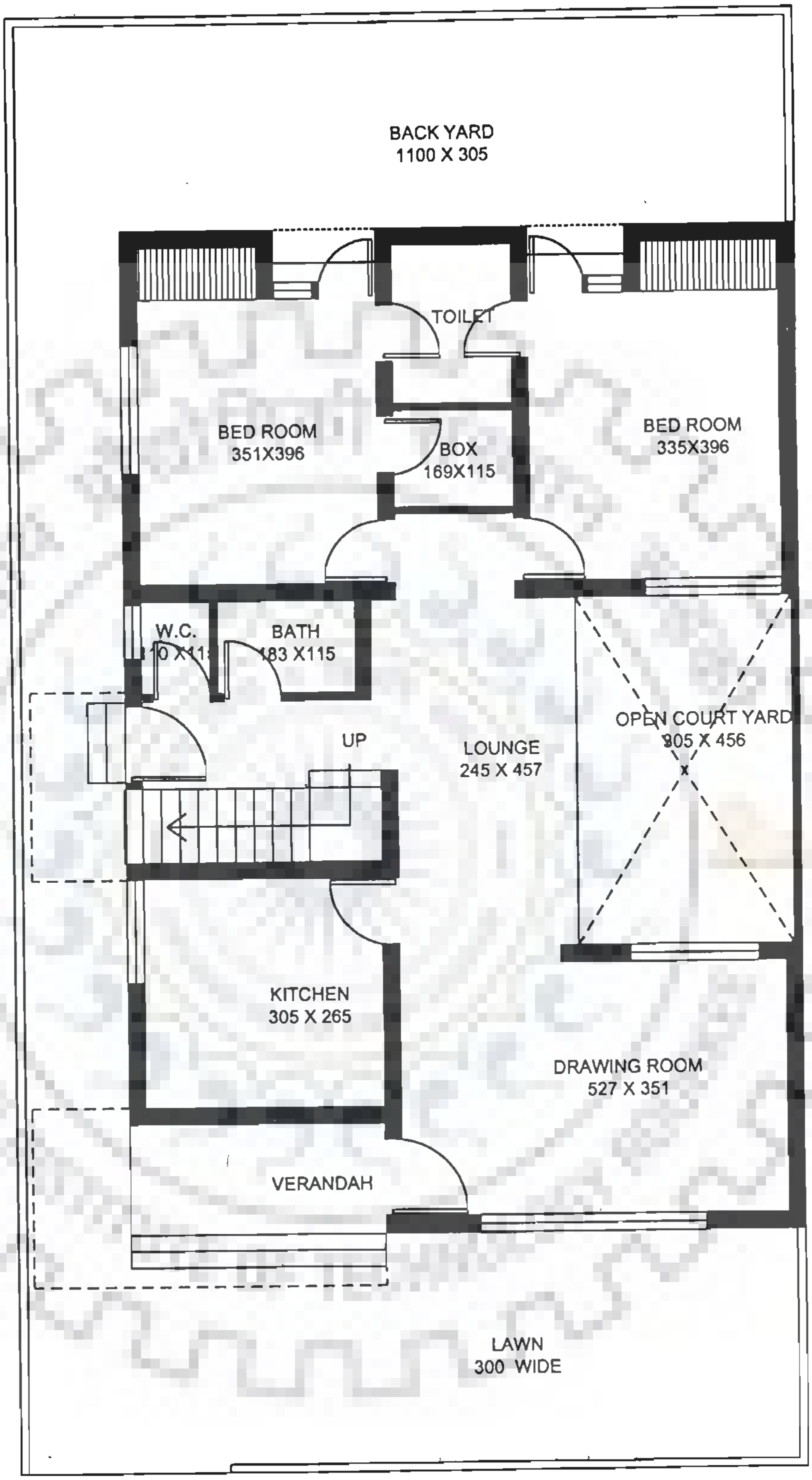

Fig. III.8(a) - Ground Floor Plan of Project No. 8
(Plinth Area = 126.13 sqm; Floor Area = 104.68 sqm)

Note : (a) Scale of drawing 1:100 (b) All dimensions in cm

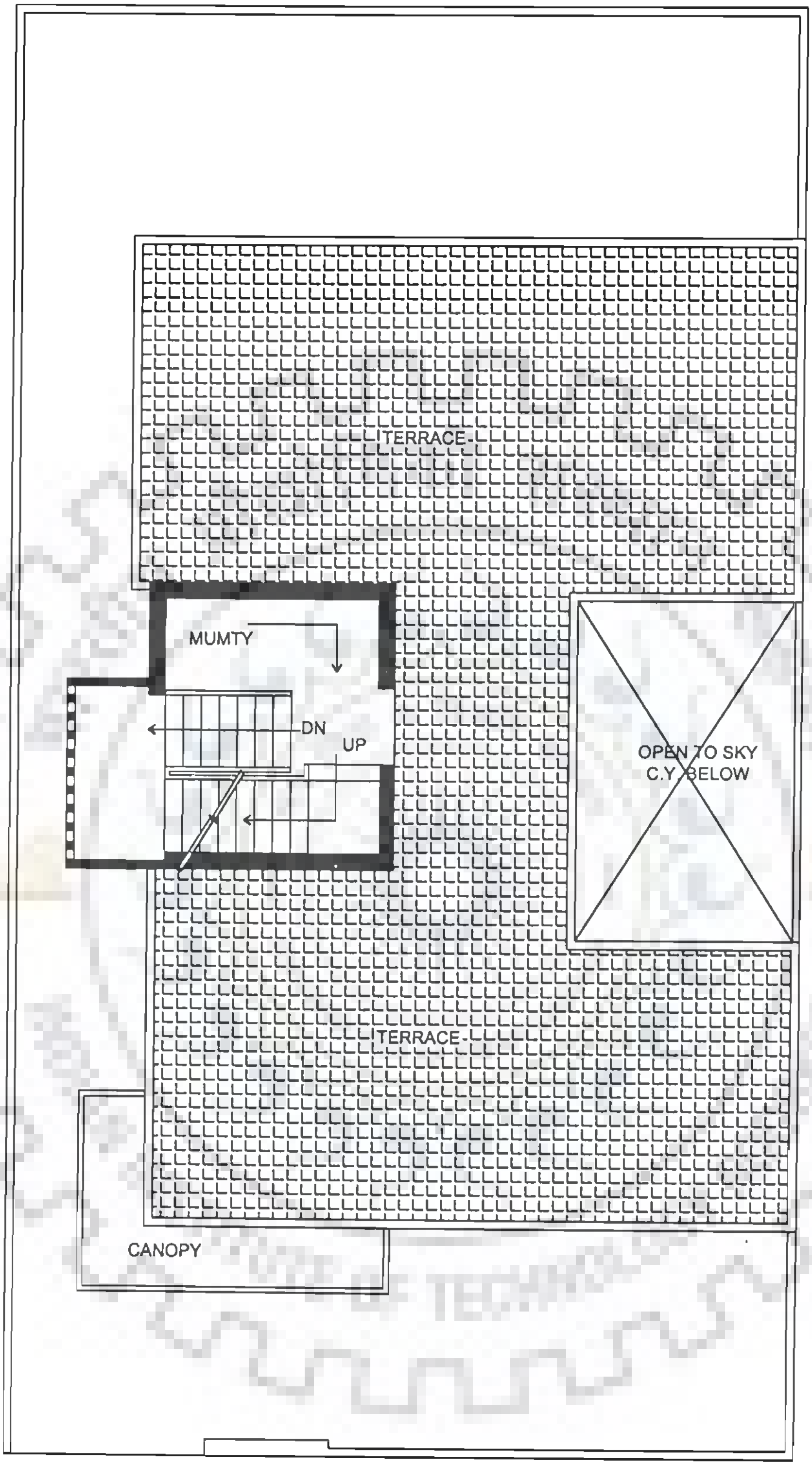

Fig. III.8(b) - Terrace Plan of Project No. 8

Note : (a) Scale of drawing 1:100 (b) All dimensions in cm

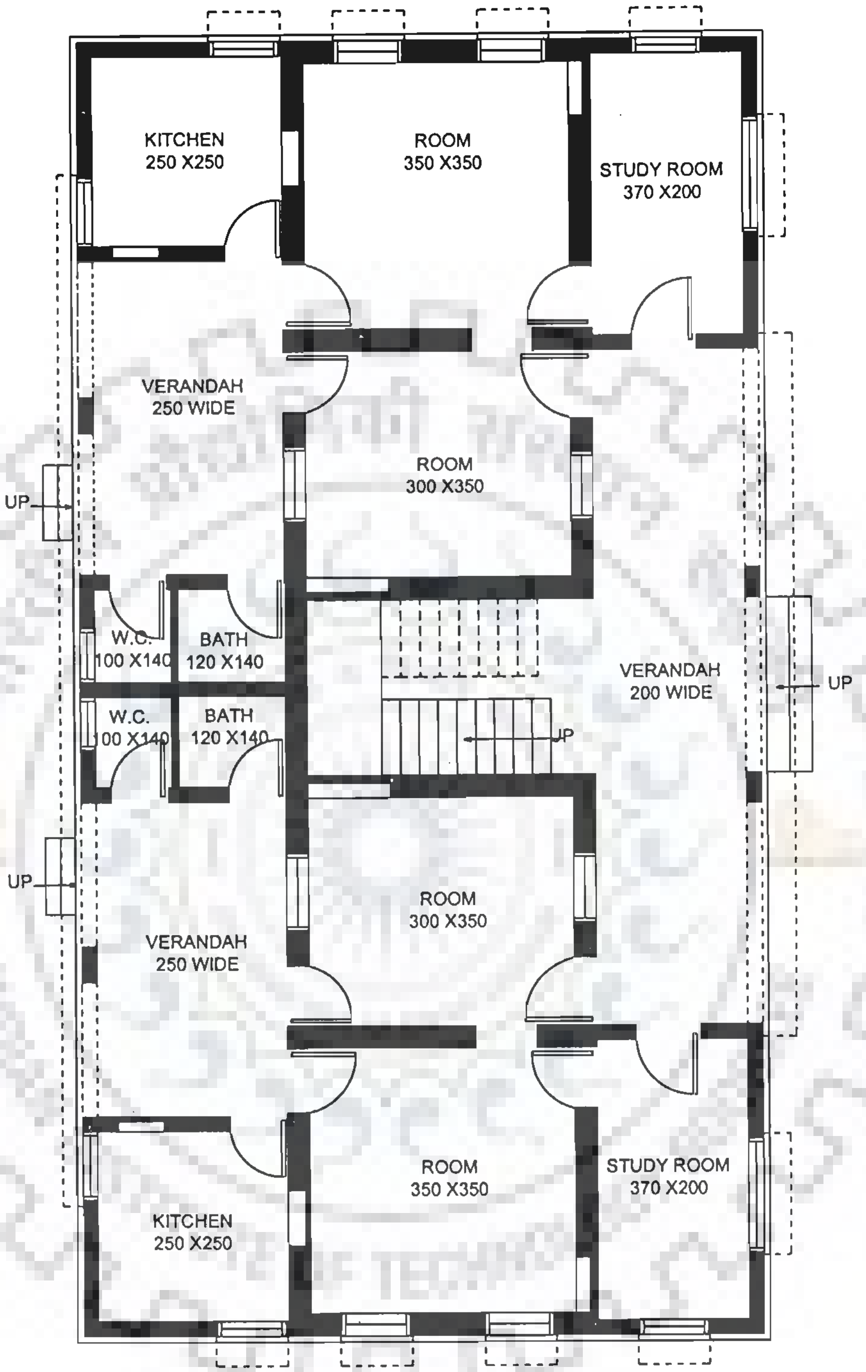

Fig. III.9 - Plan of Project No. 9
(Total Plinth Area = 159.44 sqm; Total Floor Area = 132.63 sqm)

Note : (a) Scale of drawing 1:100 (b) All dimensions in cm

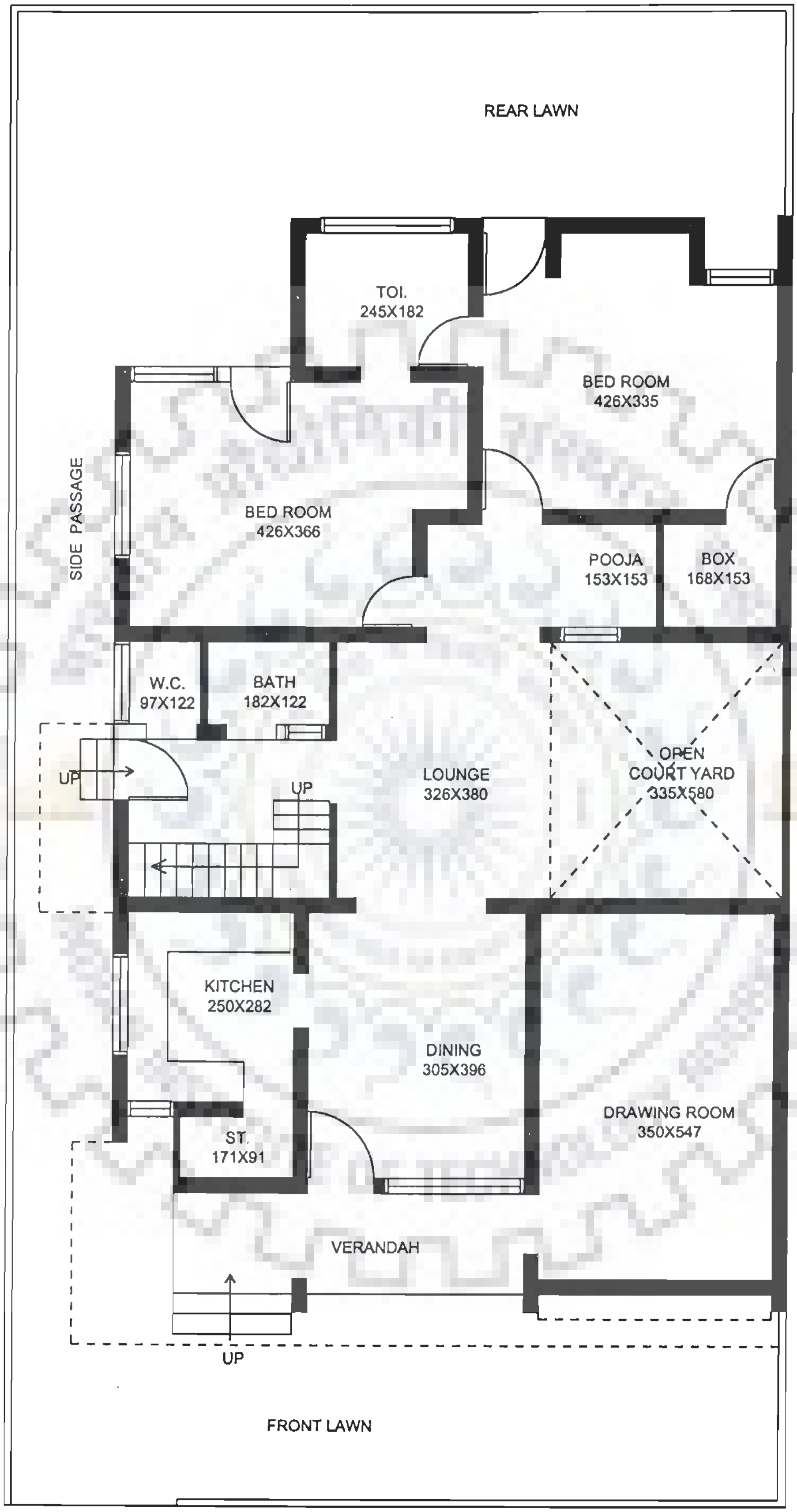

Fig. III.10(a) - Ground Floor Plan of Project No. 10
(Plinth Area = 169.38 sqm; Floor Area = 143.60 sqm)

Note : (a) Scale of drawing 1:100 (b) All dimensions in cm

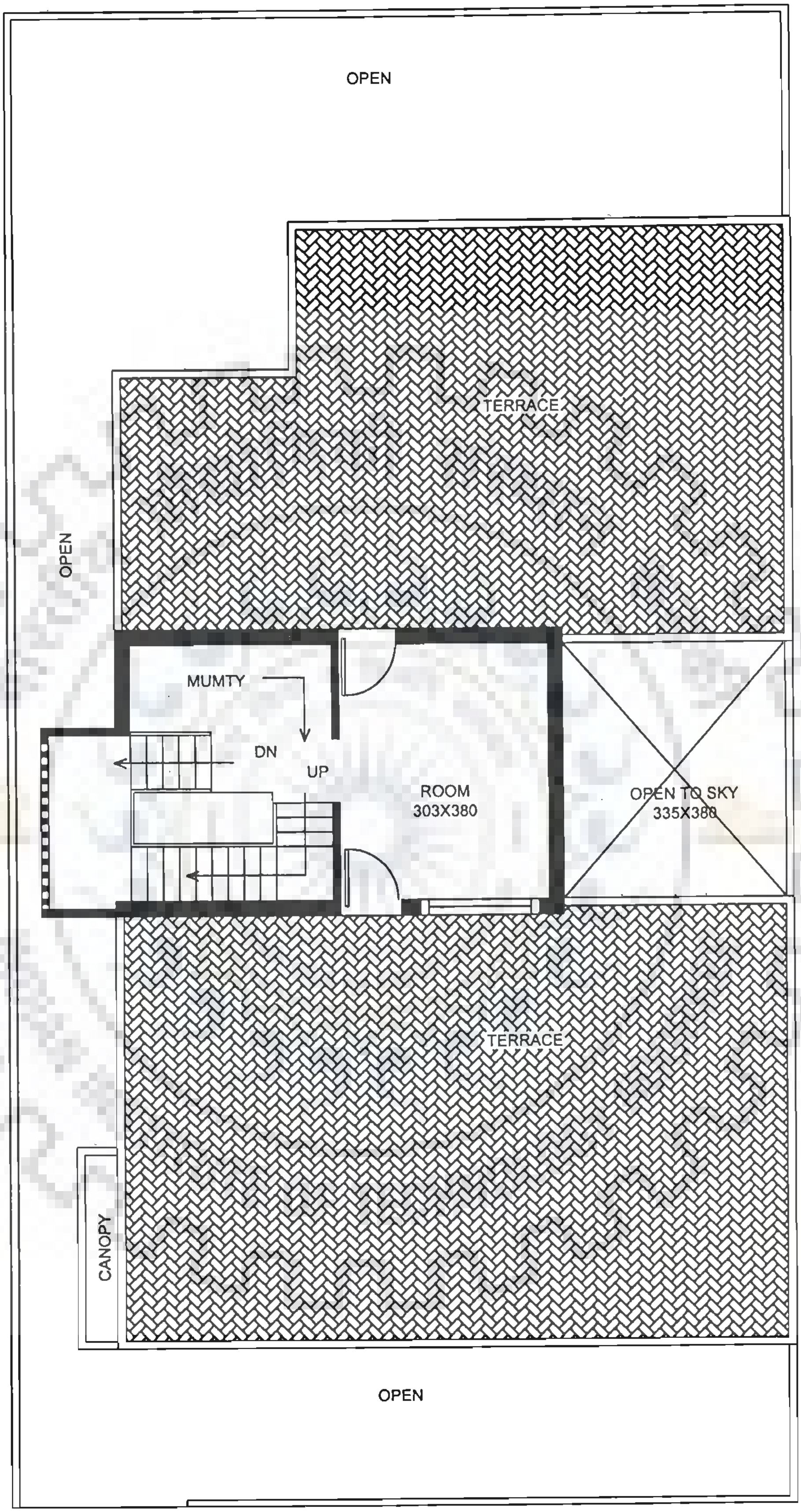

Fig. III.10(b) - Terrace Plan of Project No. 10

Note : (a) Scale of drawing 1:100 (b) All dimensions in cm

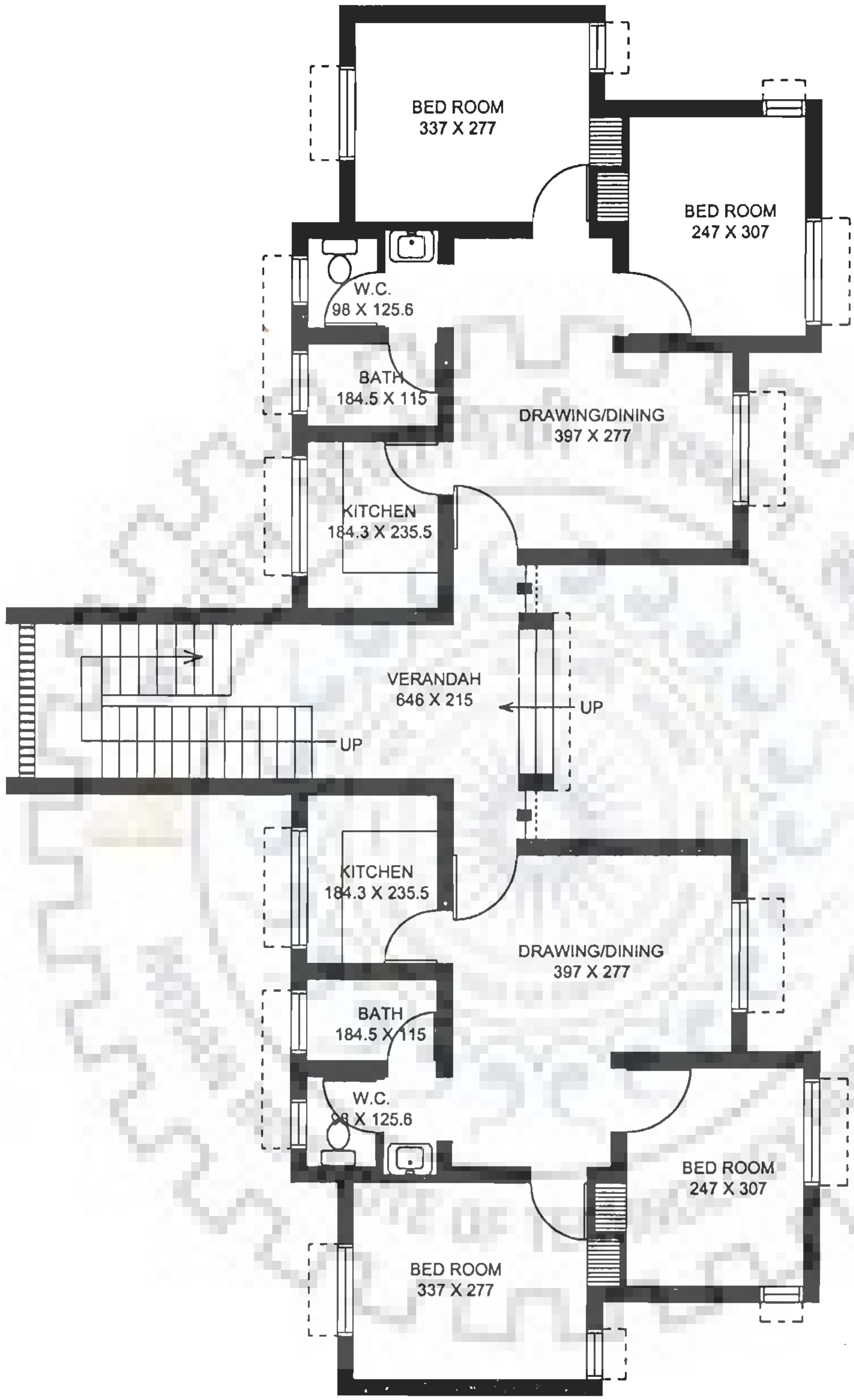

Fig. III.11(a) - Ground Floor Plan of Project No. 11
(Total Plinth Area = 237.00 sqm; Total Floor Area = 208.50 sqm)

Note : (a) Scale of drawing 1:100 (b) All dimensions in cm

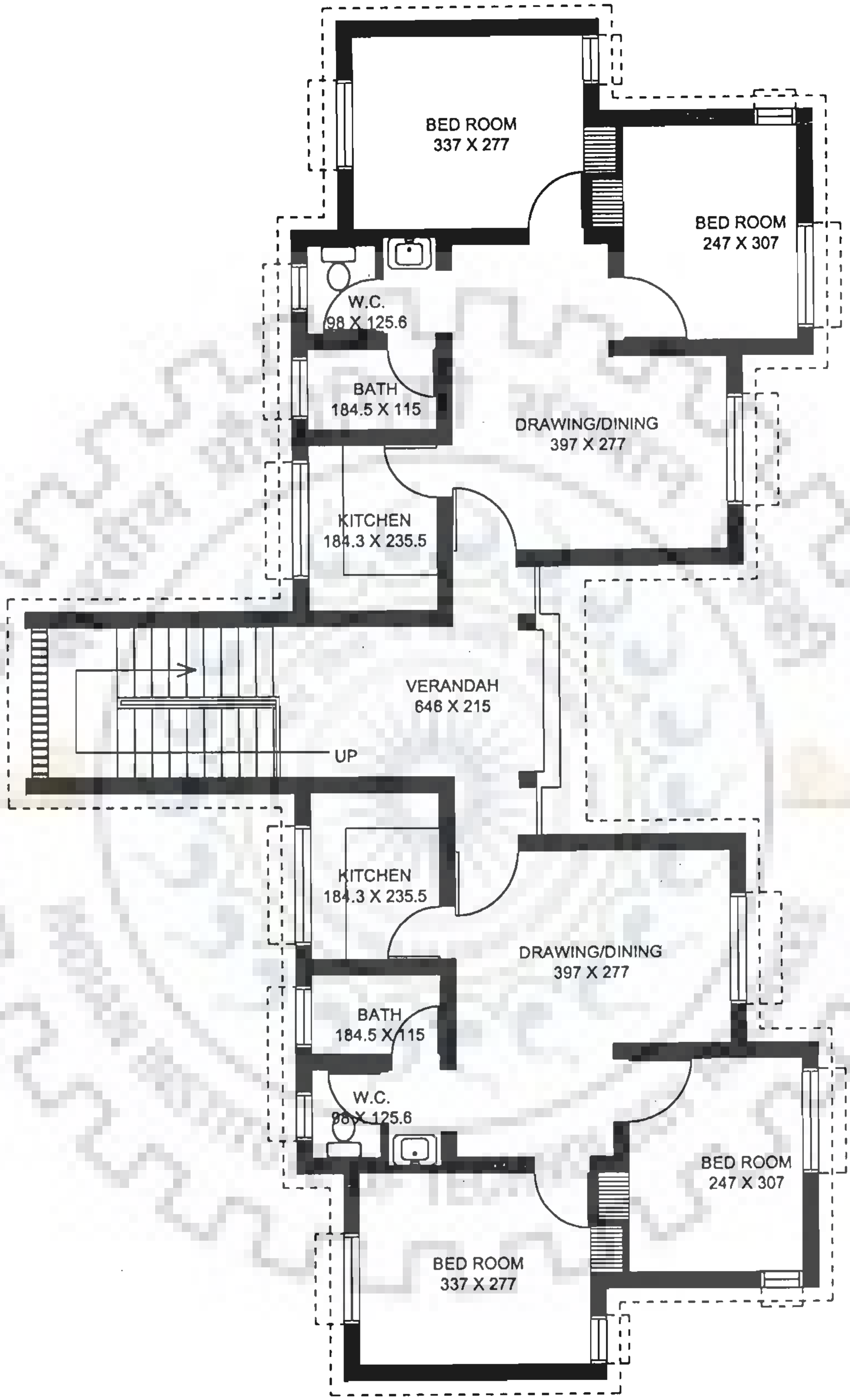

Fig. III.11(b) - First Floor Plan of Project No. 11

Note : (a) Scale of drawing 1:100 (b) All dimensions in cm

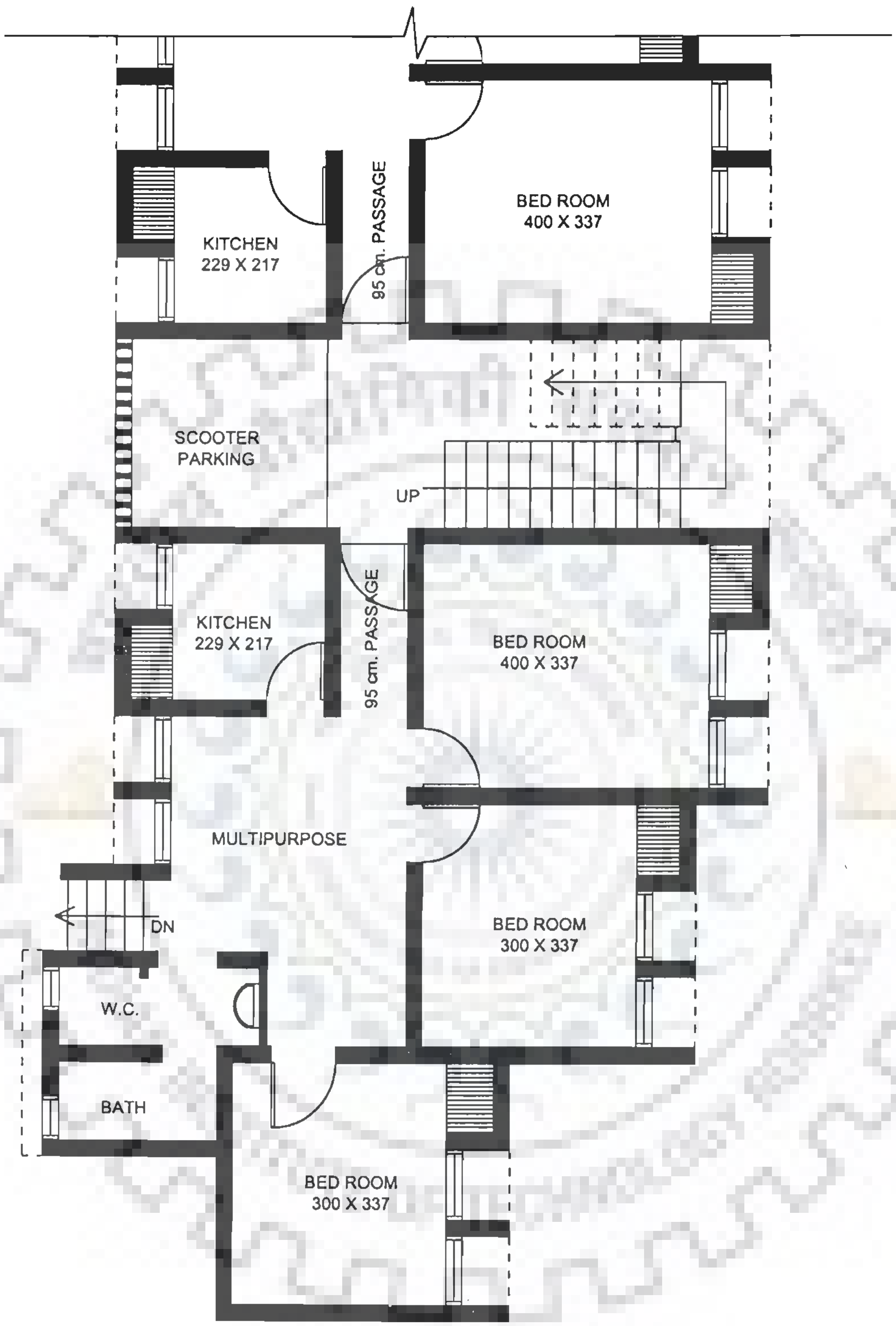

Fig. III.12(a) - Ground Floor Plan of Project No. 12
(Total Plinth Area = 296.90 sqm; Floor Area = 249.40 sqm)

Note : (a) Scale of drawing 1:100 (b) All dimensions in cm

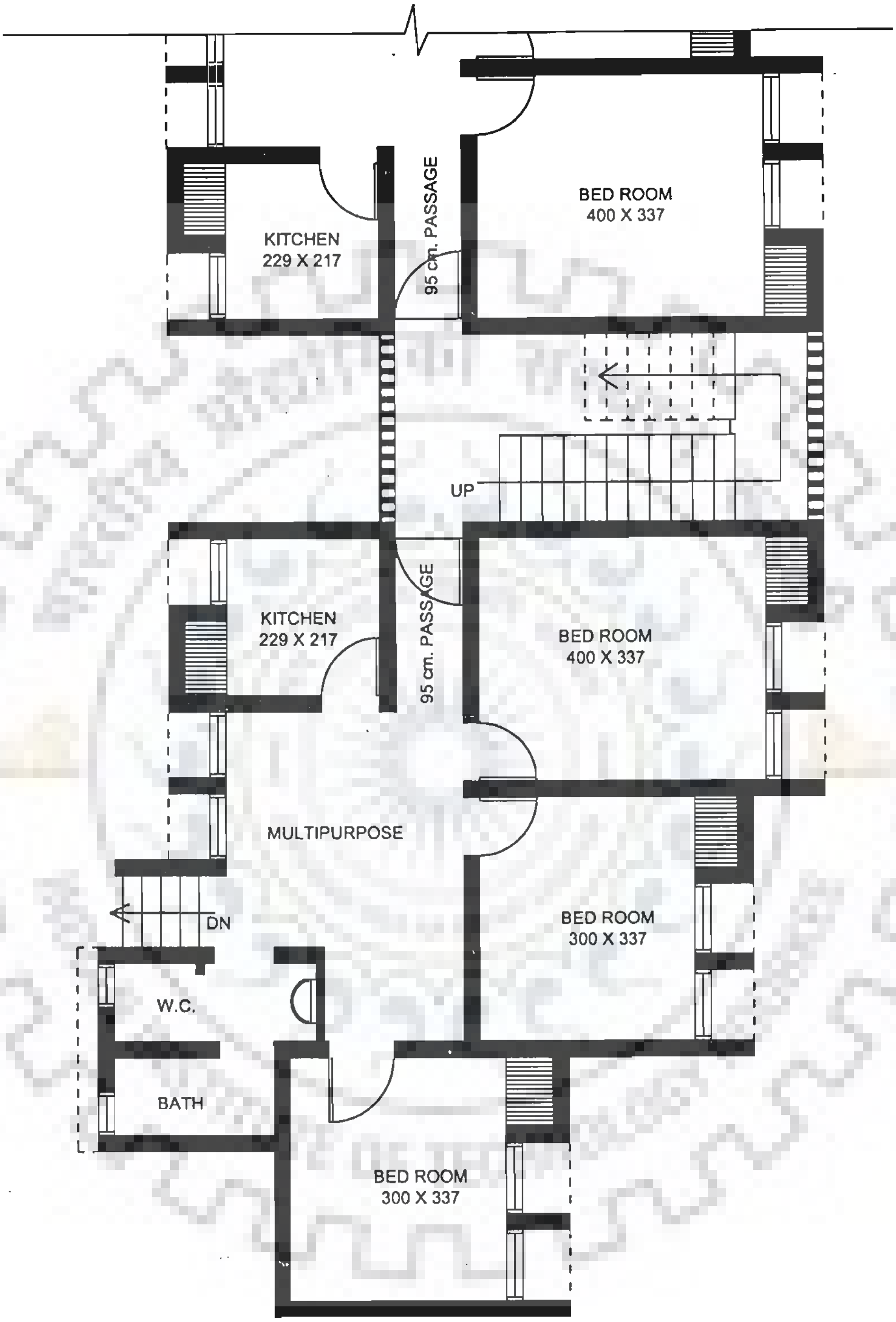

Fig. III.12(b) - First FloorPlan of Project No. 12

Note : (a) Scale of drawing 1:100 (b) All dimensions in cm

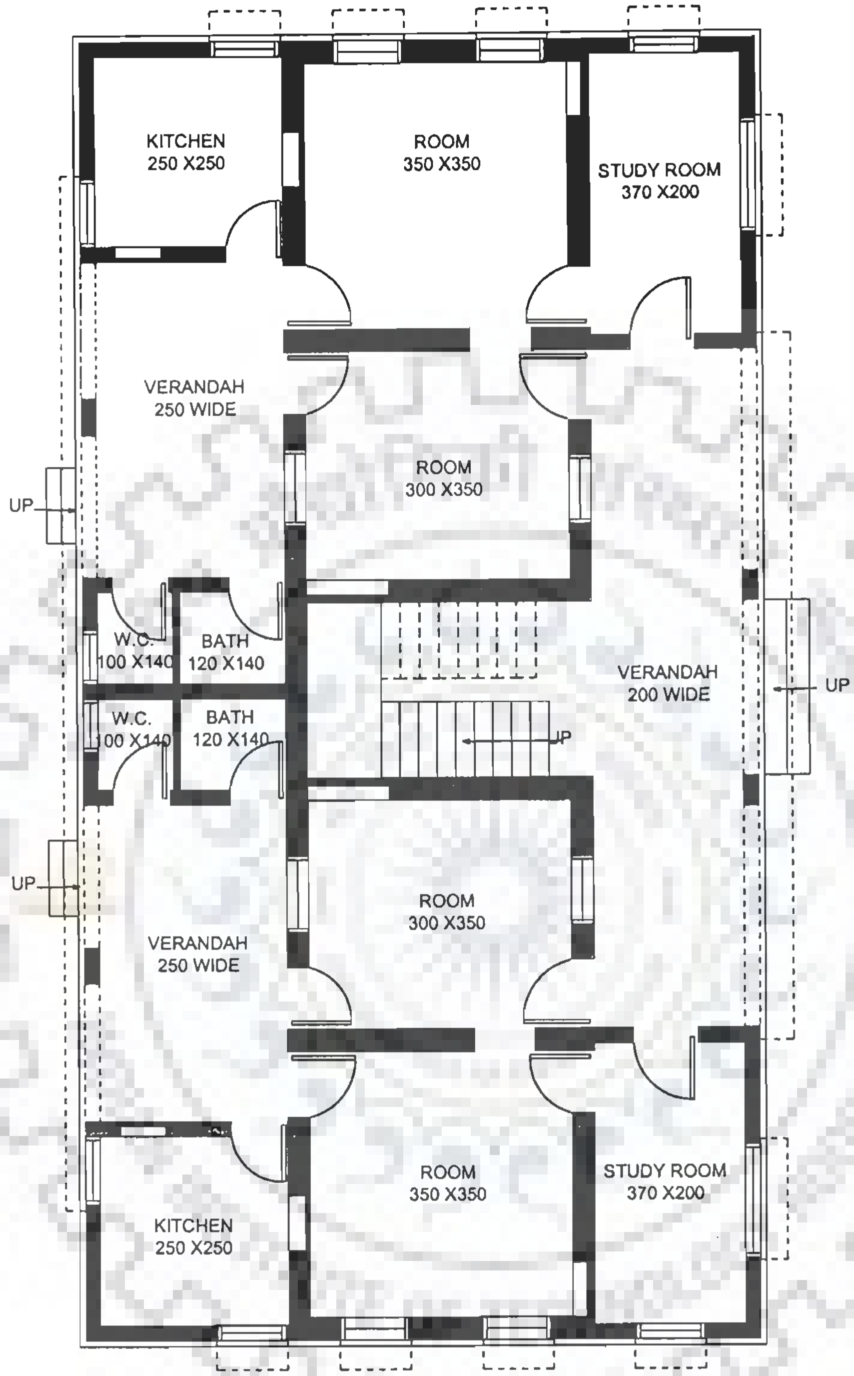

Fig. III.13(a) - Ground Floor Plan of Project No. 13
(Total Plinth Area = 318.87 sqm; Total Floor Area = 265.26 sqm)

Note : (a) Scale of drawing 1:100 (b) All dimensions in cm

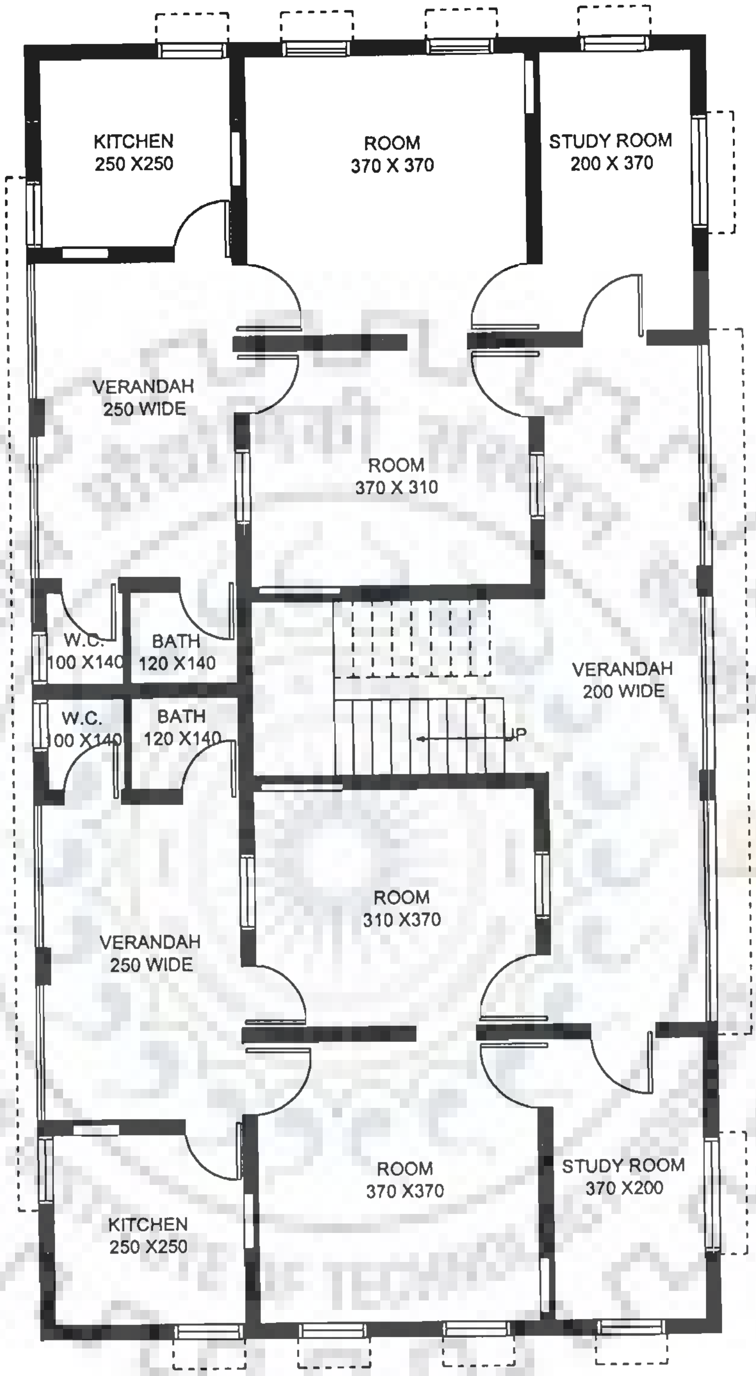

Fig. III.13(b) - First Floor Plan of Project No. 13

Note : (a) Scale of drawing 1:100 (b) All dimension in cm

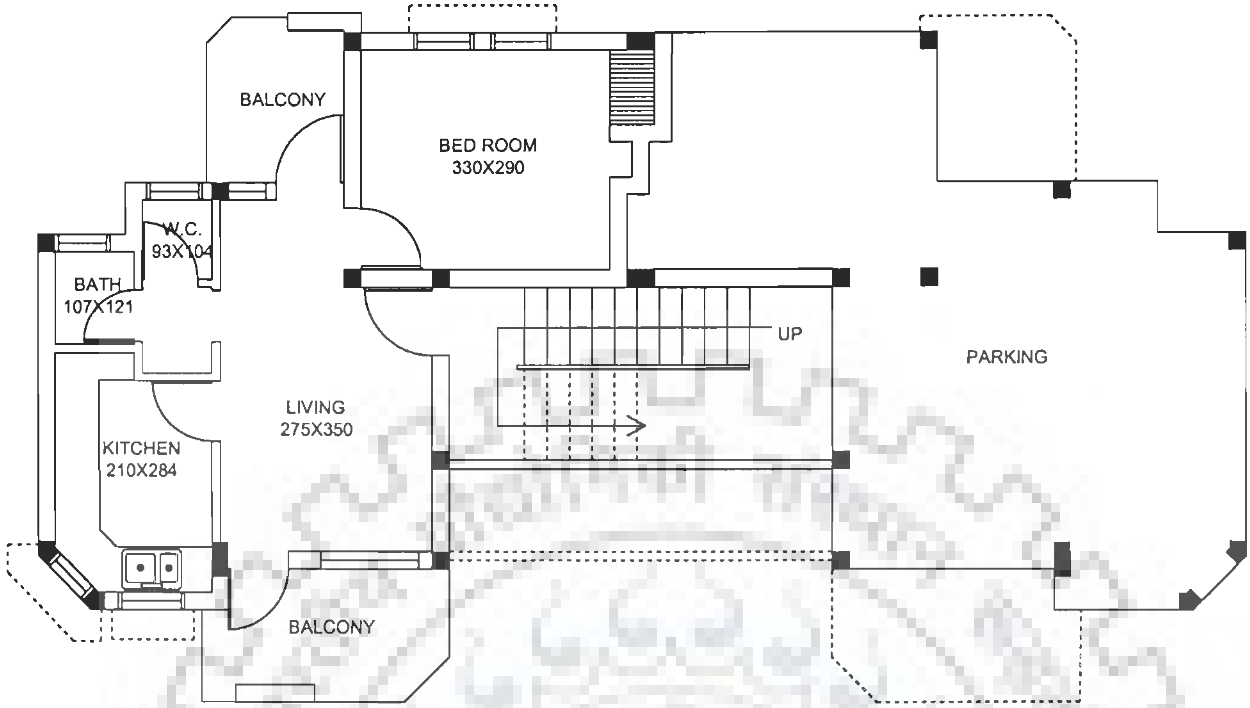

Fig. III.14(a) - Ground Floor Plan of Type A-A, Project No. 14
(Plinth Area of One Dwelling = 39.18 sqm; Floor Area of One Dwelling= 32.91 sqm)

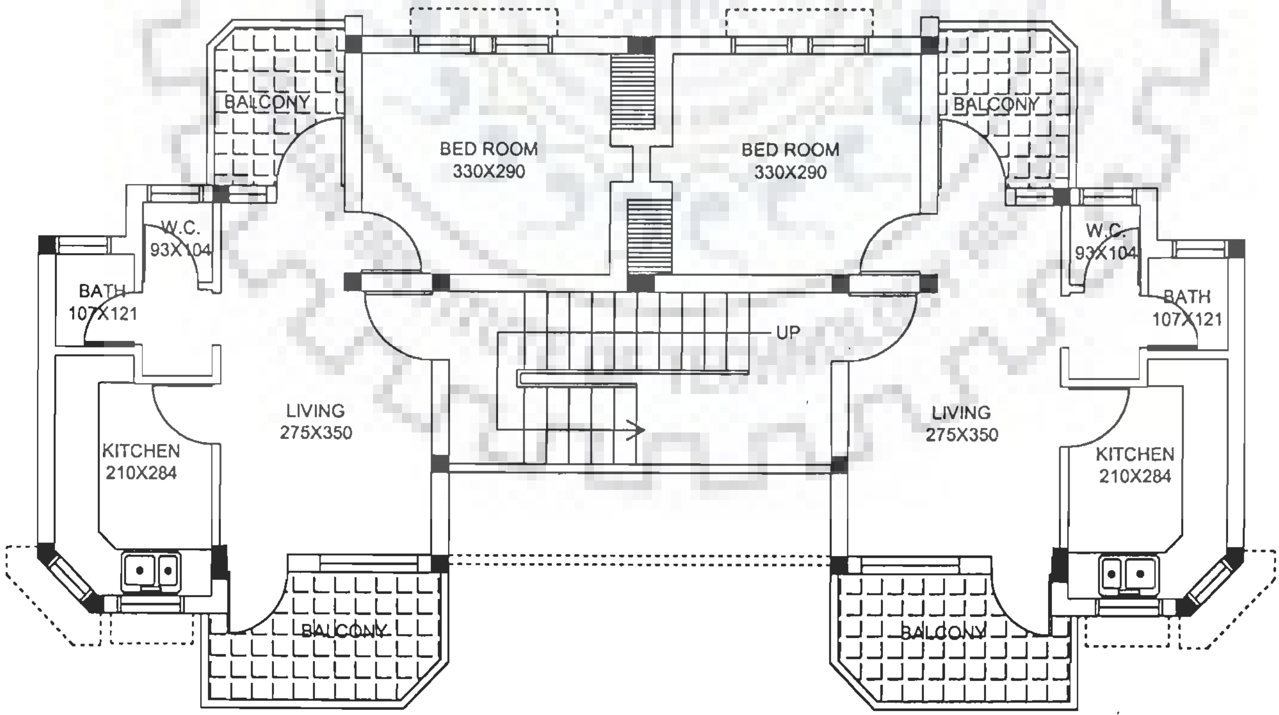

Fig. III.14(b) - Typical Floor Plan of Type A-A, Project No. 14

Note : (a) Scale of drawing 1:100 (b) All dimensions in cm

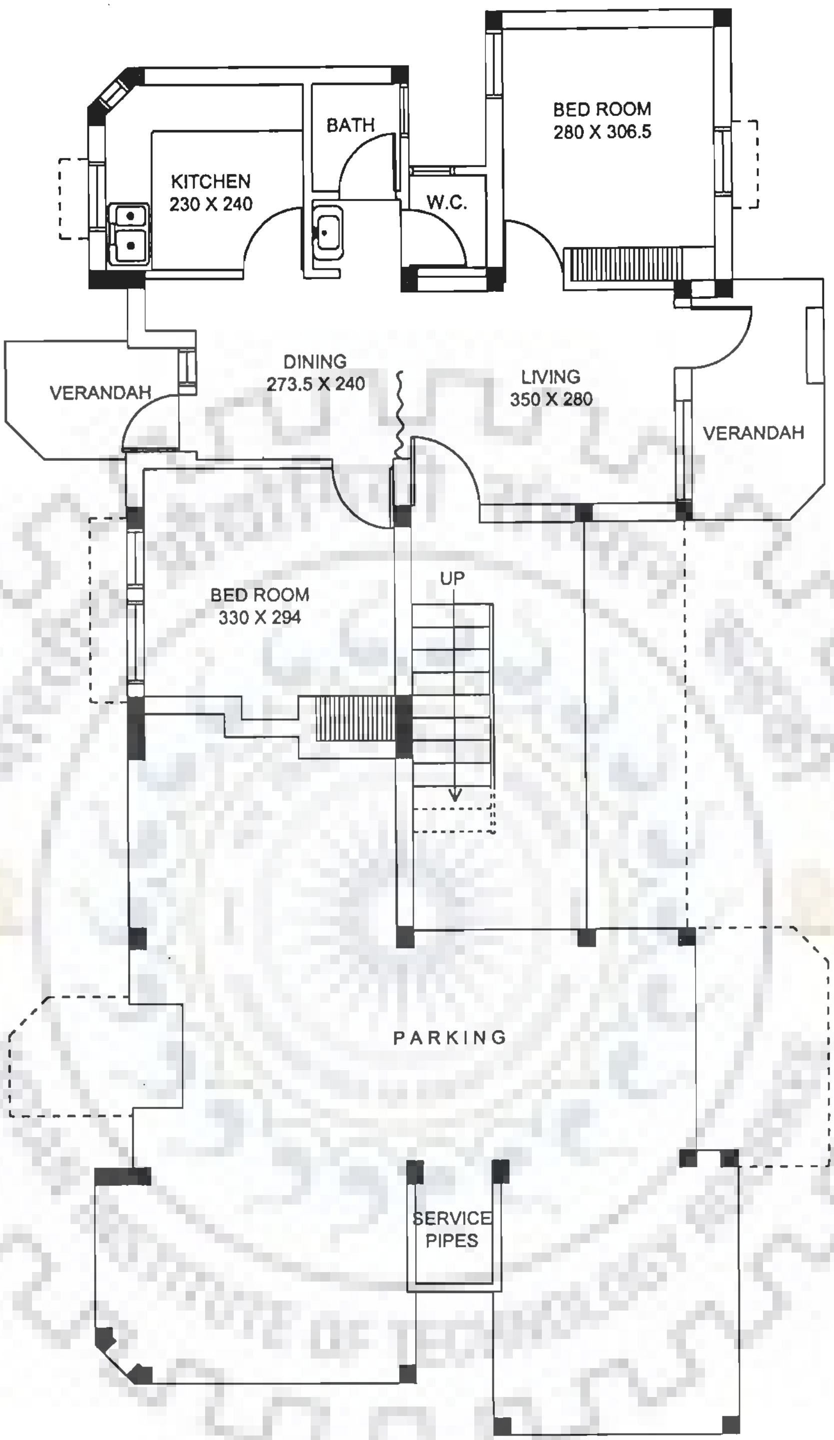

Fig. III.14(c) - Ground Floor Plan of Type B-B, Project No. 14
(Plinth Area of One Dwelling = 57.69 sqm; Floor Area of One Dwelling= 48.46 sqm)

Note : (a) Scale of drawing 1:100 (b) All dimensions in cm

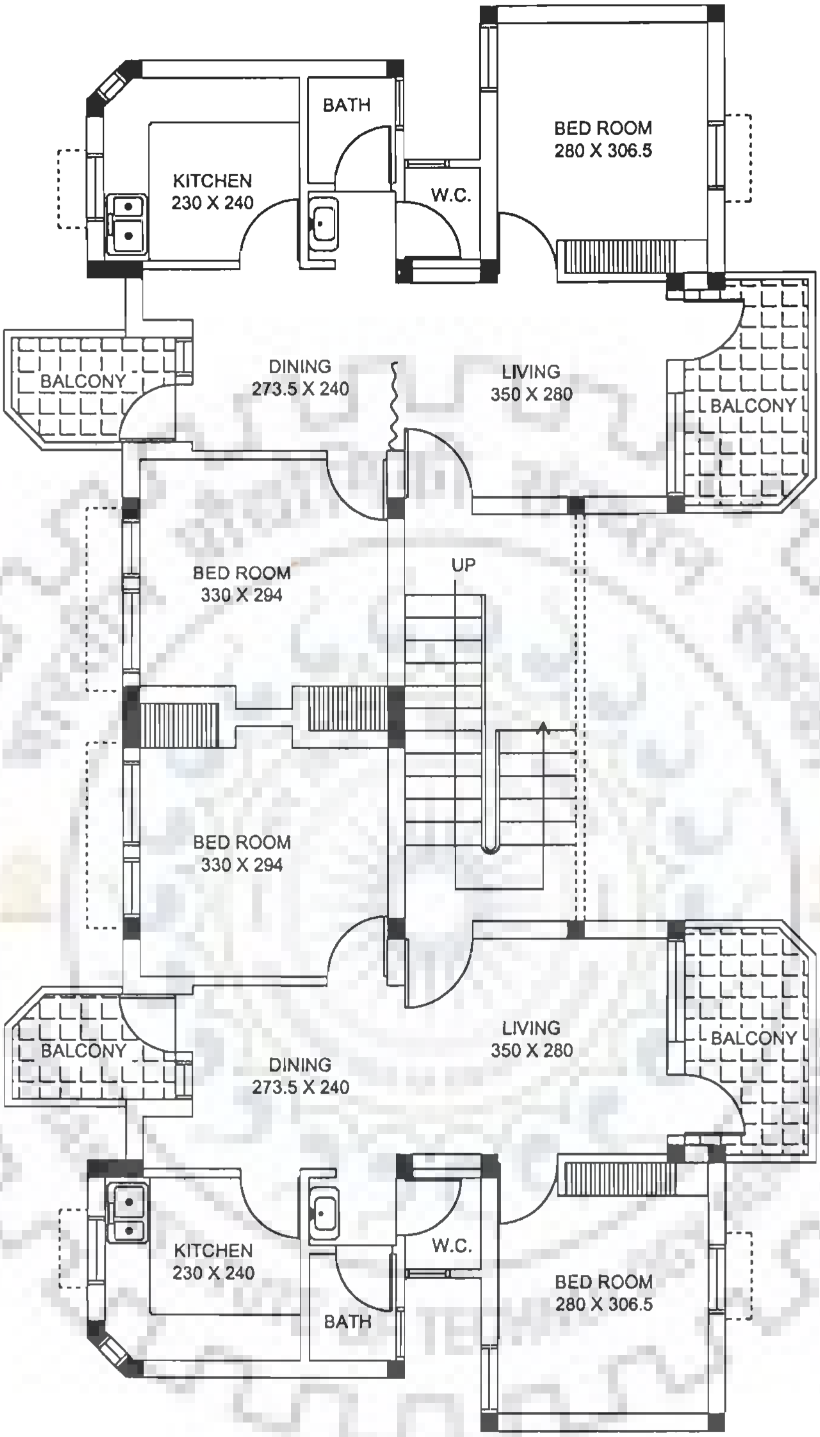

Fig. III.14(d) - Typical Floor Plan of Type B-B, Project No. 14

Note : (a) Scale of drawing 1:100 (b) All dimensions in cm

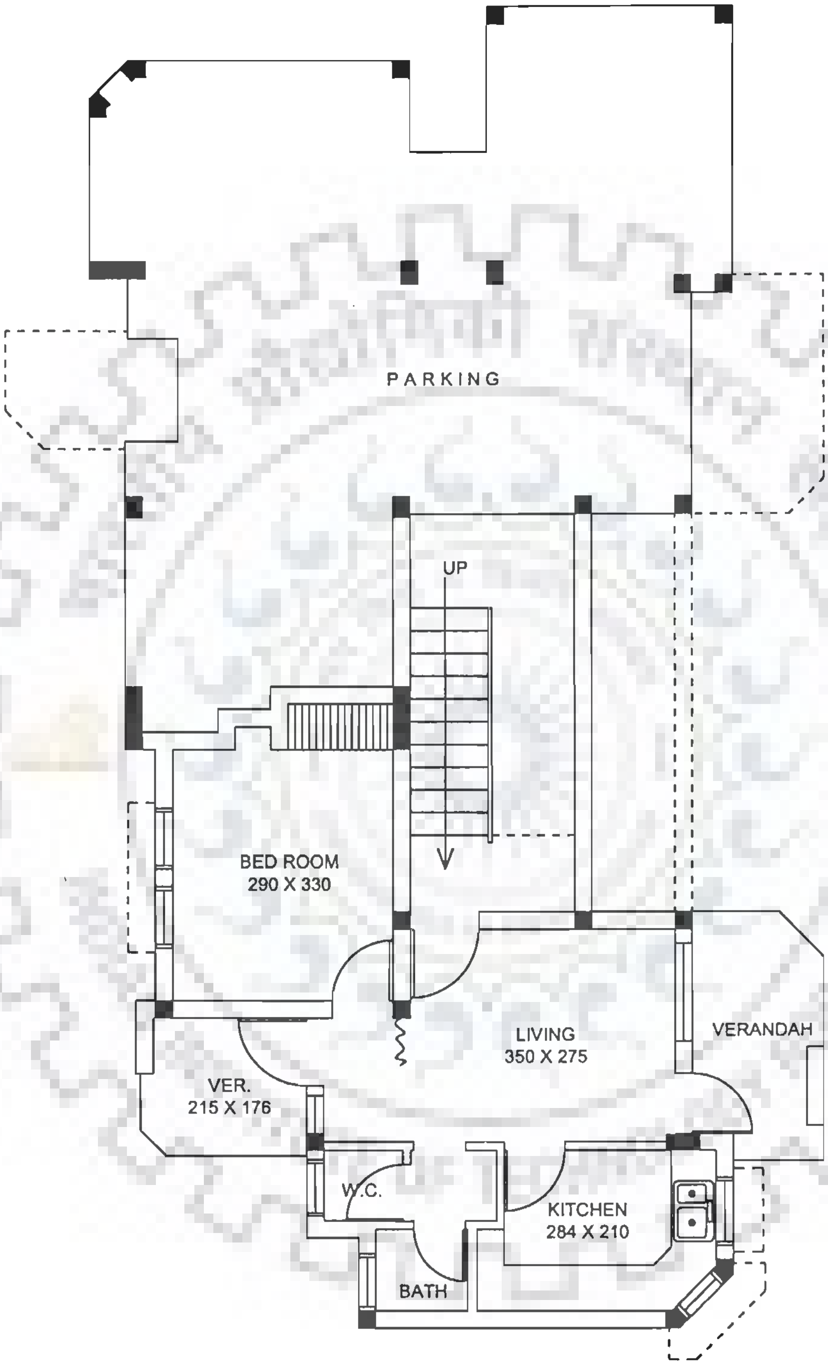

Fig. III.14(e) - Ground Floor Plan of Type A-B, Project No. 14

Note : (a) Scale of drawing 1:100 (b) All dimensions in cm

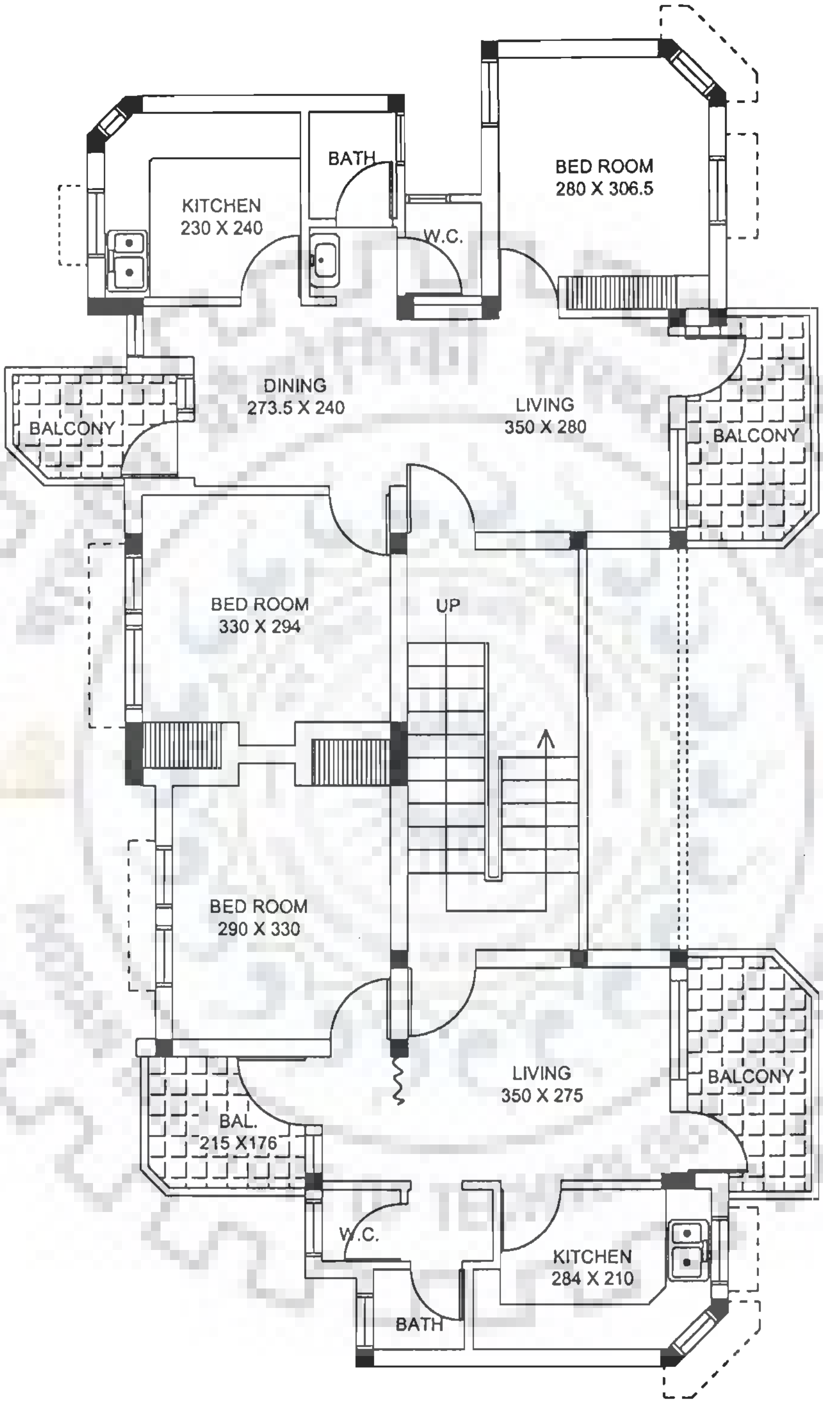

Fig. III.14(f) - Typical Floor Plan of Type A-B, Project No. 14

(Total Plinth Area of the Project = 2046.00 sqm; Total Floor Area of the Project = 1719.00 sqm)

Note : (a) Scale of drawing 1:100 (b) All dimensions in cm

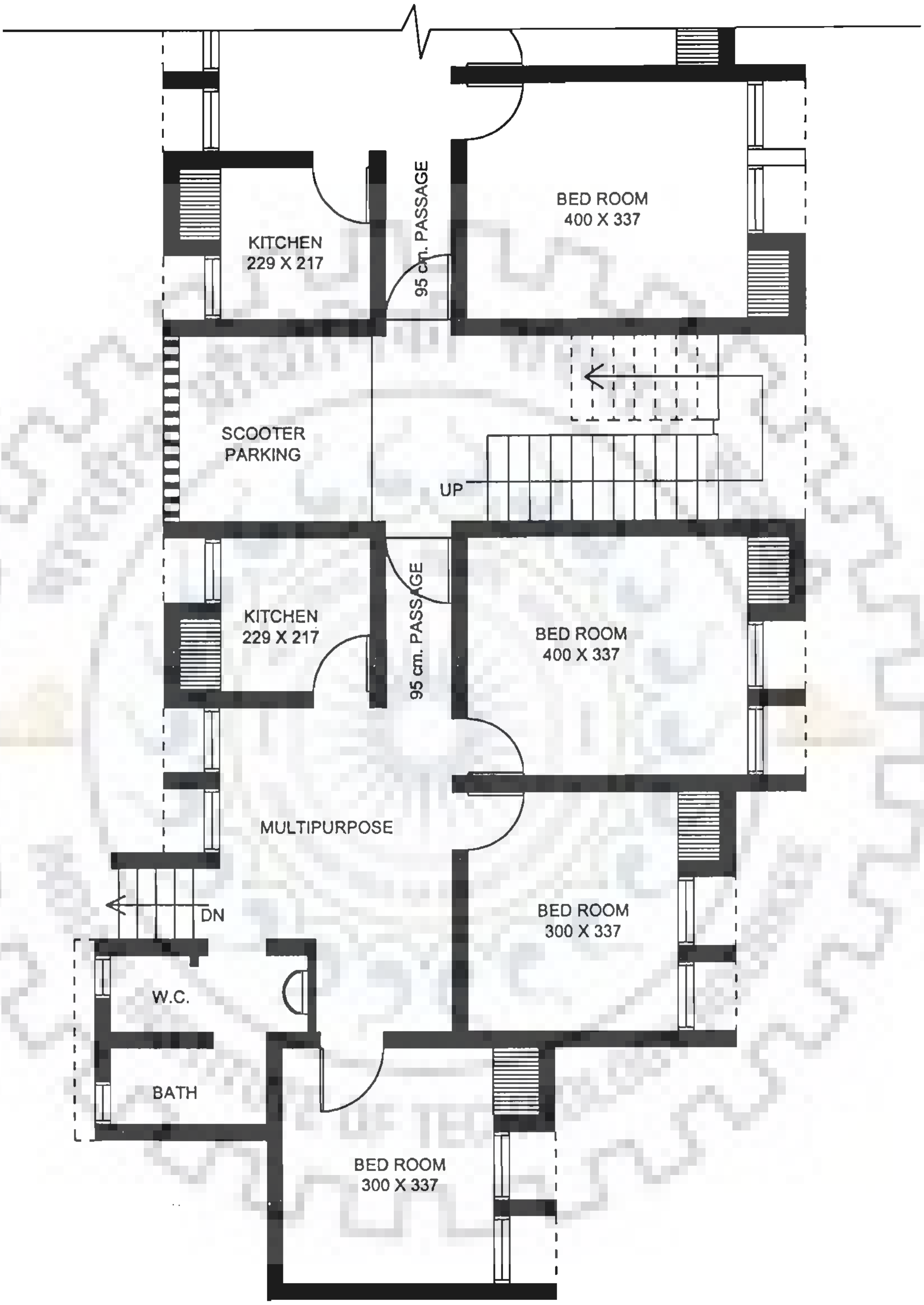

Fig. III.15(a) - Ground Floor Plan of Project No. 15 (One Unit)

Note : (a) Scale of drawing 1:100 (b) All dimensions in cm

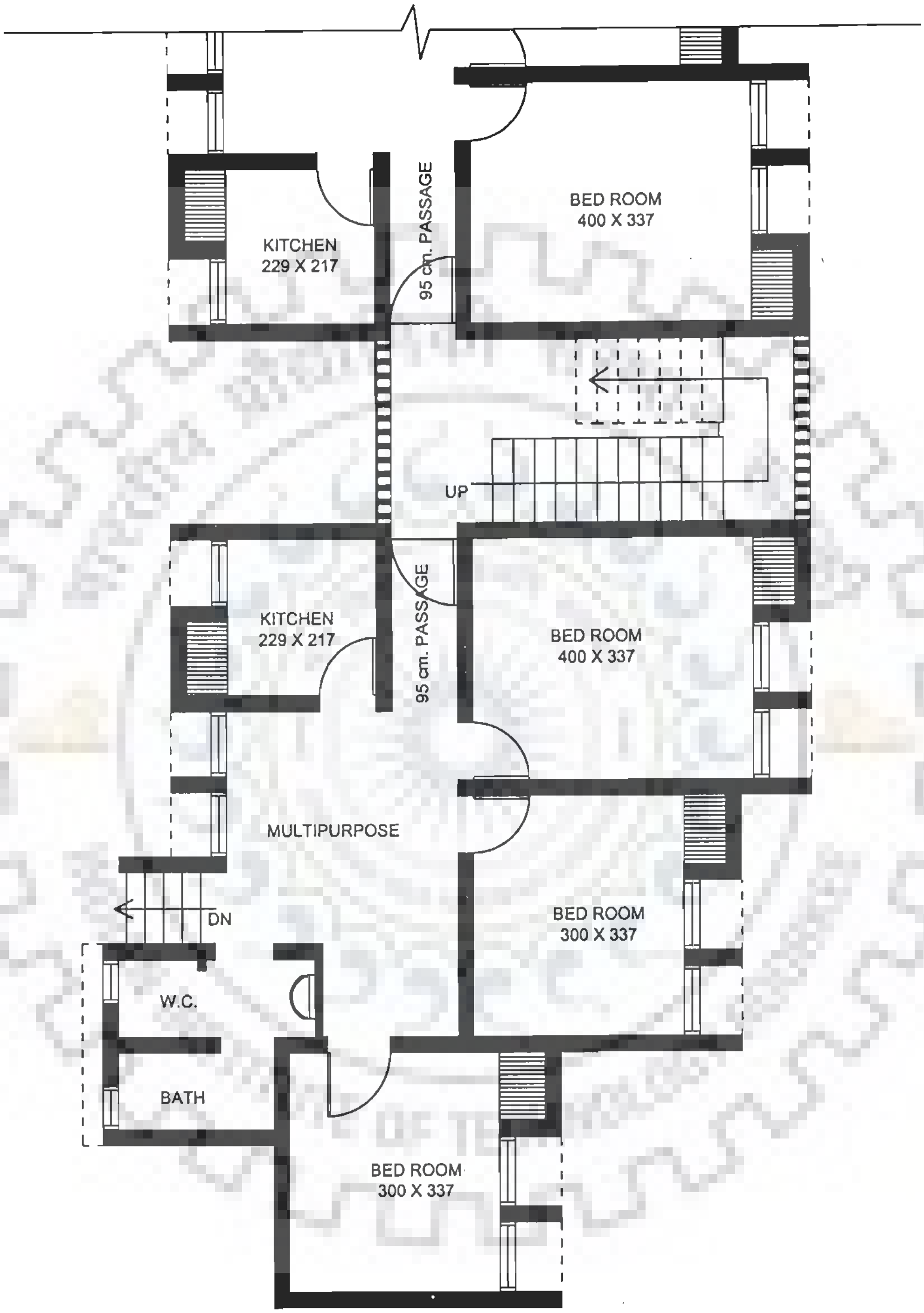

Fig. III.15(b) - First Floor Plan of Project No. 15 (One Unit)

(Total Plinth Area of Project = 8907.00 sqm; Total Floor Area of Project = 7482.00 sqm)

Note : (a) Scale of drawing 1:100 (b) All dimensions in cm

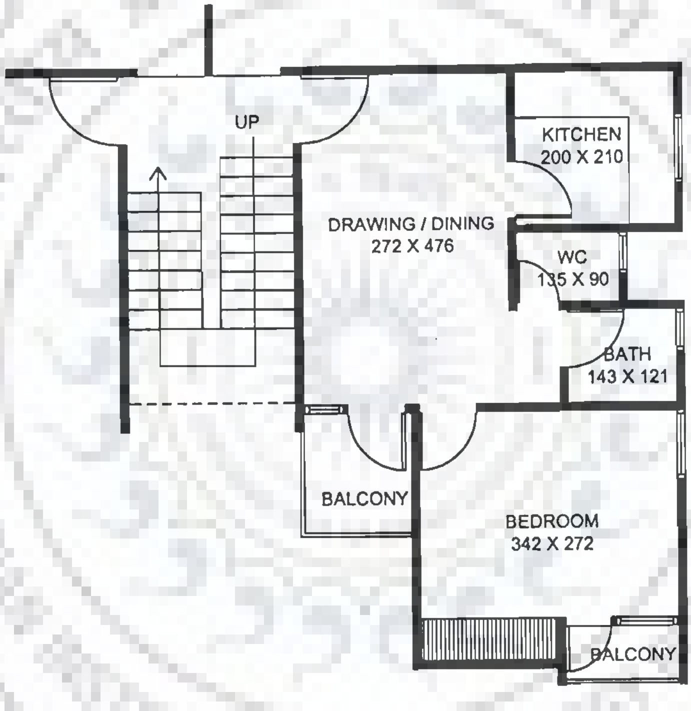

Fig. III.16(a) - Typical Floor Plan of Type I, Project No. 16
(Plinth Area of One Dwelling = 47.30 sqm; Floor Area of One Dwelling = 39.70 sqm)

Note : (a) Scale of drawing 1:100 (b) All dimensions in cm

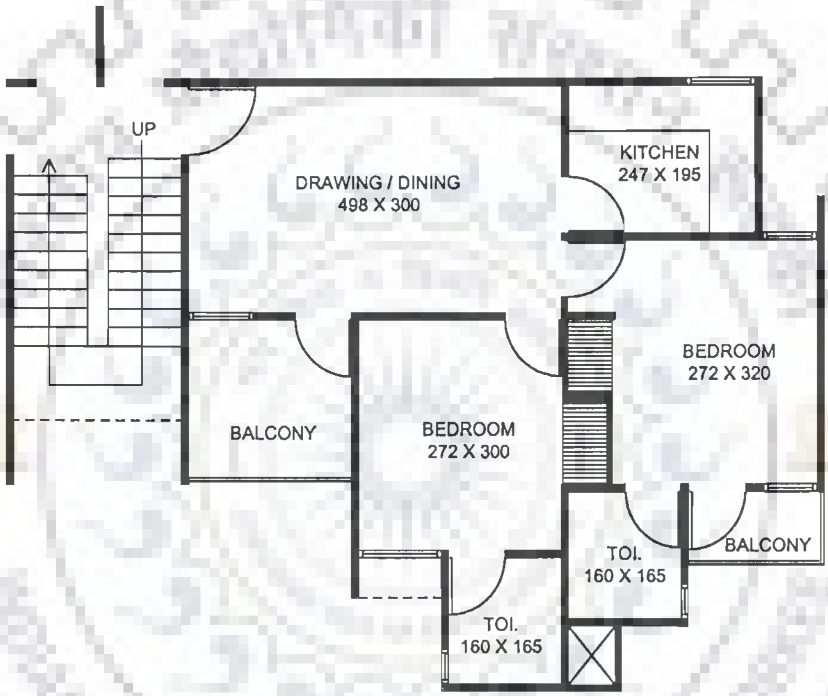

Fig. III.16(b) - Typical Floor Plan of Type II, Project No. 16
(Plinth Area of One Dwelling = 66.00 sqm; Floor Area of One Dwelling = 55.40 sqm)

Note : (a) Scale of drawing 1:100 (b) All dimensions in cm

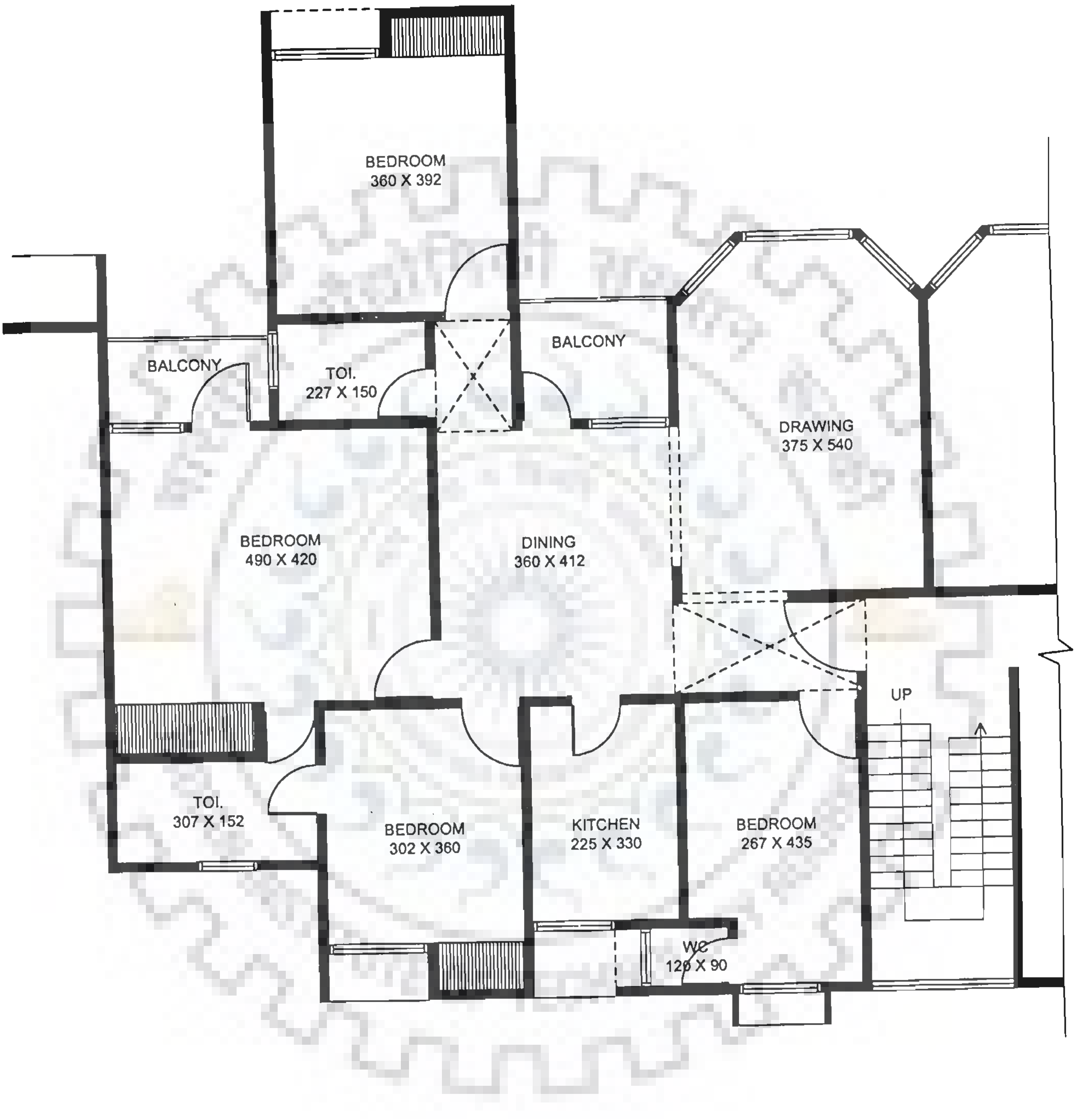

Fig. III.16(c) - Typical Floor Plan of Type IV, Project No. 16
(Plinth Area of One Dwelling = 132.25 sqm; Floor Area of One Dwelling = 111.10 sqm)

(Total Plinth Area of the Project = 16680.00 sqm; Total Floor Area of the Project = 14008.00 sqm)

Note : (a) Scale of drawing 1:100 (b) All dimensions in cm

Table III.1.1: EEC_T[1] Estimate for Project No. 1 - Dwelling Unit with One Room and a Front Verandah
(Plinth Area = 28.32 sqm; Floor Area = 23.64 sqm)

S.No.	Item of Work	Unit	Quantity	EER [2] in MJ/Unit	EEC [3] in MJ	Schedule of EER Item Code No.
	MASONRY WORK					
1.	1st class brick work in foundation and plinth in cement mortar 1:6 (1 cement: 6 fine sand)	cum	7.05	2641.75	18624.34	2.2.11.
2.	1st class brick work in superstructure in cement mortar 1:6 (1 cement: 6 fine sand)	cum	16.07	2641.75	42452.92	2.2.11. + 2.2.17.
	EEC for Masonry Work (EEC_1)				**61077.26**	
	CONCRETE WORK					
3.	Cement concrete in foundation in the proportion 1:5:10 (1 cement: 5 coarse sand: 10 graded stone agg. 40 mm nom. size)	cum	4.56	1349.82	6155.18	3.12.(a)
4.	Concrete in roof terracing with 25 mm gauge brick ballast, white lime and surkhi in the proportion of 100:18:36	cum	1.96	3906.51	7656.76	3.5.
5.	25 mm damp proof course DPC with cement concrete 1:2:4 (1 cement: 2 coarse sand: 4 stone agg. 10 mm nom. size)	sqm	5.92	65.57	388.17	3.27.
	EEC for Concrete Work (EEC_2)				**14200.11**	

[1] EEC_T – Total Embodied Energy Cost of a project
[2] EER - Embodied Energy Rate of an item of work
[3] EEC – Embodied Energy Cost of an item of work or sub-work

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
6.	RCC WORK RCC work 1:2:4 (1 cement : 2 coarse sand: 4 graded stone agg. 20 mm nom. size) excl. reinforcement but incl. finishing and plastering the exposed surface with cement mortar 1:3 (1 cement: 3 fine sand) of thickness not exceeding 6 mm to give a smooth and even surface					
	(a) Roof slab	cum	4.13	2836.10	11713.09	4.1.
	(b) Lintels	cum	0.79	2827.74	2233.92	4.2.(c)
7.	Precast RCC slab 1:2:4 (1 cement: 2 coarse sand: 4 graded stone agg. 20 mm nom. size) in shelves excl. reinforcement but incl. finishing and plastering the exposed surface with cement plaster 1:3 (1 cement: 3 fine sand) of thickness not exceeding 6 mm on an exposed surface to give a smooth and even surface	cum	0.032	3032.67	97.05	4.7.(b)
8.	Mild steel reinforcement for RCC work	q	3.89	3360.00	13070.40	4.13.
				EEC for RCC Work (EEC_3)	**27114.46**	
9.	FLOORING 25 mm cement concrete flooring 1:2:4 (1 cement: 2 coarse sand: 4 graded stone agg. 12.5 mm nom. size) finished with a floating coat of neat cement	sqm	24.37	80.28	1956.42	5.4.
				EEC for Flooring (EEC_4)	**1956.42**	

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
	FINISHING					
10.	12 mm plastering in walls 1:6 (1 cement: 6 fine sand)	sqm	151.54	24.12	3655.15	6.1.9.
11.	20 mm cement plaster in steps with cement mortar 1:3 (1 cement : 3 coarse sand), finished with neat cement	sqm	2.37	91.28	216.33	6.1.26.
12.	White washing (3 coats) - inside	sqm	93.47	1.95	182.27	6.3.1.
13.	Colour washing (one coat) over one coat of white washing - outside	sqm	77.09	1.95	150.33	6.3.3.
	EEC for Finishing (EEC_5)				**4204.08**	
	$EEC_T = EEC_1 + EEC_2 + EEC_3 + EEC_4 + EEC_5$				**108552.33 MJ**	

Table III.1.2: EEC_T Estimate for Project No. 2 - Dwelling Unit with One Room, a Bathroom and a Front Verandah (Plinth Area = 45.54 sqm; Floor Area = 36.35 sqm)

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
	MASONRY WORK					
1.	1st class brick work in foundation and plinth in 1:6 (1 cement: 6 coarse sand)	cum	12.26	2641.75	32387.86	2.2.11.
2.	1st class brick work in superstructure in 1:6 (1 cement: 6 coarse sand)	cum	27.61	2641.75	72938.72	2.2.11 + 2.2.17.
	EEC for Masonry Work (EEC_1)				**105326.58**	
	CONCRETE WORK					
3.	Providing and laying cement concrete 1:4:8 (1 cement: 4 coarse sand: 8 graded stone agg. 40 mm nom. size) in foundation	cum	6.78	1617.82	10968.82	3.8.(a)
4.	Concrete in roof terracing with 25 mm gauge brick ballast, white lime and surkhi in the proportion of 100:18:36	cum	3.71	3906.51	14493.15	3.5.
5.	25 mm DPC 1:2:4 (1 cement : 2 coarse sand : 4 graded stone agg. 20 mm nom. size)	sqm	8.72	65.57	571.77	3.27.
	EEC for Concrete Work (EEC_2)				**26033.74**	

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
6.	RCC WORK RCC work with 1:2:4 (1 cement : 2 coarse sand : 4 graded stone agg. 20 mm nom. size) excl. reinforcement but incl. finishing and plastering the exposed surface with cement mortar 1:3 (1 cement: 3 fine sand) of thickness not exceeding 6 mm to give a smooth and even surface					
	(a) Roof slab	cum	5.21	2836.10	14776.08	4.1.
	(a) Lintels	cum	0.34	2827.74	961.43	4.2.(c)
	(b) Sunshades not exceeding 15 cm in thickness	cum	0.21	3114.82	654.11	4.5.
7.	Mild steel reinforcement in RCC work incl. bending	q	4.52	3360.00	15187.20	4.13.
				EEC for RCC Work (EEC_3)	**31578.82**	
8.	FLOORING 40 mm thick cement concrete flooring 1:2:4 (1 cement: 2 coarse sand: 4 graded stone agg. 20 mm nom. size), finished with a floating coat of neat cement	sqm	36.35	119.65	4349.28	5.5.(a)
9.	25 mm thick cement concrete flooring in sills with 1:2:4 (1 cement: 2 coarse sand: 4 graded stone agg. 20 mm nom. size), finished with a floating coat of neat cement	sqm	1.22	80.28	97.94	5.4.
				EEC for Flooring (EEC_4)	**4447.2**	

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
	FINISHING					
10.	12 mm thick plastering in walls with cement mortar 1:6 (1 cement: 6 fine sand)	sqm	263.14	24.12	6346.94	6.1.9.
11.	20 mm cement plastering in steps with cement mortar 1:3 (1 cement: 3 fine sand), finished with a floating coat of neat cement	sqm	1.85	91.28	168.87	6.1.26.
12.	White washing (3 coats) - inside	sqm	163.89	1.95	319.59	6.3.1.
13.	Colour washing (2 coats) over 1 coat of white washing on outside walls	sqm	135.39	1.95	264.01	6.3.3.
	EEC for Finishing (EEC_5)				**7099.41**	
	$EEC_T = EEC_1 + EEC_2 + EEC_3 + EEC_4 + EEC_5$				**174485.77 MJ**	

Table III.1.3: EEC_T Estimate for Project No. 3 - Dwelling Unit with Two Rooms and a Front Verandah
(Plinth Area = 61.32 sqm; Floor Area = 52.68 sqm)

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
	MASONRY WORK					
1.	1st class brick work in foundation and plinth in cement mortar 1:6 (1 cement: 6 fine sand)	cum	22.32	2641.75	58963.86	2.2.11.
2.	1st class brick work in superstructure in cement mortar 1:6 (1 cement: 6 fine sand)	cum	30.10	2641.75	79516.68	2.2.11. + 2.2.17.
	EEC for Masonry Work (EEC_1)				**138480.54**	
	CONCRETE WORK					
3.	Providing and laying cement concrete 1:4:8 (1 cement: 4 coarse sand: 8 graded stone agg. 40 mm nom. size) in foundation	cum	10.74	1617.82	17375.39	3.8.(a)
4.	Concrete in roof terracing with 25 mm gauge brick ballast, white lime and surkhi in the proportion of 100:18:36	cum	5.36	3906.51	20938.89	3.5.
5.	40 mm DPC 1:2:4 (1 cement: 2 coarse sand: 4 stone agg. 20 mm nom. size)	sqm	10.52	104.91	1103.65	3.29.
	EEC for Concrete Work (EEC_2)				**39417.93**	
	RCC WORK					
6.	RCC work 1:2:4 (1 cement: 2 coarse sand: 4 graded stone agg.					

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
	20 mm nom. size) excl. reinforcement but incl. finishing & plastering the exposed surface with cement mortar 1:3 (1 cement: 3 fine sand) of thickness not exceeding 6 mm to give a smooth and even surface					
	(a) Slab	cum	8.38	2836.10	23766.52	4.1.
	(b) Lintels	cum	1.79	2827.74	5061.65	4.2.(c)
7.	RCC work with 1:1½ :3 (1 cement: 1½ coarse sand: 3 graded stone agg. 20 mm nom. size) in verandah columns excl. reinforcement but incl. finishing and plastering the exposed surface with cement mortar 1:3 (1 cement: 3 fine sand) of thickness not exceeding 6 mm to give a smooth and even surface	cum	0.19	3342.22	635.02	4.3.(d)
8.	Mild steel reinforcement in RCC work incl. bending	q	8.10	3360.00	27216.00	4.13.
		EEC for RCC Work (EEC$_3$)			**56679.19**	
	FLOORING					
9.	40 mm thick cement concrete flooring 1:2:4 (1cement: 2 coarse sand: 4 graded stone agg. 20 mm nom. size) finished with a floating coat of neat cement	sqm	50.00	119.65	5982.50	5.5.(a)
10.	25 mm thick cement concrete flooring in sills with 1:2:4 (1 cement: 2 coarse sand : 4 graded stone agg. 20 mm nom. size) finished with a floating coat of neat cement	sqm	4.02	80.28	322.73	5.4.

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
	EEC for Flooring (EEC_4)				**6305.23**	
	FINISHING					
11.	12 mm thick plastering in walls with cement mortar 1:6 (1 cement: 6 fine sand)	sqm	285.60	24.12	6888.67	6.1.9.
12.	20 mm cement plaster in steps with cement mortar 1:3 (1 cement: 3 fine sand), finished with a floating coat of neat cement	sqm	4.59	91.28	418.98	6.1.26.
13.	White washing (3 coats) - inside	sqm	203.64	1.95	397.10	6.3.3.
14.	Colour washing (2 coats over) 1 coat of white washing - outside	sqm	171.58	1.95	334.58	6.3.3.
	EEC for Finishing (EEC_5)				**8039.33**	
	$EEC_T = EEC_1 + EEC_2 + EEC_3 + EEC_4 + EEC_5$				**248922.22 MJ**	

Table III.1.4: EEC_T Estimate for Project No. 4 - Staff Residence, Navodaya Vidyalaya - a Block of Two Units (Plinth Area = 69.40 sqm; Floor Area = 54.96 sqm)

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
	MASONRY WORK					
1.	1st class brick work in foundation and plinth in cement mortar 1:6 (1 cement : 6 coarse sand)	cum	16.60	2641.75	43853.05	2.2.15.
2.	1st class brick work in superstructure above plinth upto 1st flr. lvl. in cement mortar 1:6 (1 cement : 6 coarse sand)	cum	34.10	2641.75	90083.68	2.2.15.+2.2.17.
3.	1st class brick work 7.6 cm thick in supe structure upto 1st flr. lvl. in cement mortar 1:3 (1 cement : 3 coarse sand)	cum	1.40	2013.04	2818.26	2.2.25.+ 2.2.17.
4.	Half brick masonry (1st class) in superstructure upto 1st flr. lvl. in cement mortar 1:4 (1 cement : 4 coarse sand)	cum	1.86	2855.61	5311.44	2.2.32.+ 2.2.34.(a)
	EEC for Masonry Work (EEC_1)				**142066.43**	
	CONCRETE WORK					
5.	Providing and laying cement concrete 1:5:10 (1 cement: 5 coarse sand: 10 graded stone agg. 40 mm nom. size) in footings	cum	7.40	1349.82	9988.67	3.9.(a)
6.	Providing and laying cement concrete 1:5:10 (1 cement: 5 fine sand: 10 graded stone agg. 40 mm nom. size) in walls (any thickness) incl. plinth upto 1st flr. lvl.	cum	4.10	1349.82	5534.26	3.12.(b)

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
7.	Providing and laying DPC 40 mm thick with cement concrete 1:2:4 (1 cement : 2 coarse sand : 4 graded stone agg. 12.5 mm nom. size)	sqm	13.30	104.91	1395.30	3.29.
8.	Making plinth protection 50 mm thick of cement concrete 1:3:6 (1 cement : 3 coarse sand : 6 graded stone agg. 20 mm nom. size) over 75 mm bed of dry brick ballast 40 mm nom. size, well rammed, consolidated and grouted with fine sand incl. finishing the top smooth	sqm	33.20	266.61	8851.45	3.31.
	EEC for Concrete Work (EEC_2)				**25769.68**	
	RCC WORK					
9.	RCC work with 1:2:4 (1 cement : 2 coarse sand : 4 graded stone agg. 20 mm nom. size) excl. reinforcement but incl. finishing and plastering the exposed surface with cement mortar 1:3 (1cement: 3 fine sand) of thickness not exceeding 6 mm to give a smooth and even surface					
	(a) In roofs upto 1^{st} flr. lvl.	cum	8.10	2836.10	22972.41	4.1.
	(b) In shelves upto 1^{st} flr. lvl.	cum	0.60	2836.10	1701.66	4.1.
	(c) In chajjas, facias and gutters upto 1^{st} flr. lvl.	cum	0.60	3114.82	1868.90	4.5.
	(d) In lintels upto 1^{st} flr. lvl.	cum	1.40	2827.74	3958.84	4.2.(c)
	(e) In plain window sills and the like upto 1^{st} flr.lvl.	cum	0.70	3032.67	2122.87	4.8.(b)

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
10.	Reinforcement for RCC work including bending, binding and placing in position					
	(a) Mild steel and medium tensile steel bars	q	1.15	3360.00	3864.00	4.13.
	(b) Cold twisted bars	q	8.40	3360.00	28224.00	4.13.
			EEC for RCC Work (EEC_3)		**64712.68**	
	FLOORING					
11.	40 mm thick cement concrete flooring 1:2:4 (1 cement : 2 coarse sand: 4 graded stone agg. 20 mm nom. size) finished with a floating coat of neat cement incl. cement slurry, rounding off edges and strips etc.	sqm	49.00	119.65	5862.85	5.5.(a)
	18 mm thick cement plaster skirting (upto 30 cm height) with cement mortar 1:3 (1 cement : 3 coarse sand) finished with a floating coat of neat cement incl. rounding of junctions with floors where required	sqm	9.00	87.00	783.00	5.10.(a)
12.	40 mm thick marble chips flooring, rubbed and polished to granolithic finish - under layer 31 mm thick cement concrete 1:2:4 (1 cement : 2 coarse sand : 4 graded stone agg. 12.5 mm nom. size) and top layer 9 mm thick with white, black, chocolate, grey, yellow or Baroda green marble chips of sizes from 4 mm to 7 mm nom. size laid in cement marble powder mix [3:1 (3 cement : 1 marble powder) by wt.] in proportion of 4:7 (4 cement marble powder mix : 7 marble					

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
	chips) by vol. incl. cement slurry etc., complete using dark shade pigment with ordinary cement	sqm	9.00	117.36	1056.24	5.13.(a)
13.	Providing and fixing glass strips in joints of terrazzo/cement concrete floors - 40 mm wide and 6 mm thick	m	18.00	11.79	212.22	5.17.(b)
			EEC for Flooring (EEC$_4$)		**7914.31**	
14.	FINISHING 12 mm cement plaster of mix 1:6 (1 cement : 6 fine sand)	sqm	180.00	24.12	4341.60	6.1.9.
15.	15 mm cement plaster of mix 1:6 (1 cement : 6 fine sand) on the rough side of single or half brick wall	sqm	180.00	28.81	5185.80	6.1.13.
16.	6 mm cement plaster of mix 1:3 (1 cement : 3 fine sand) finished with a floating coat of neat cement and thick coat of lime wash on top of walls when dry, for bearing of RCC slabs and beams	sqm	14.00	39.34	550.76	6.1.28.
17.	18 mm plastering with terrazzo finish for dado, rubbed and polished complete - under layer 12 mm thick cement plaster 1:3 (1 cement: 3 coarse sand) and top layer 6 mm thick white, black, chocolate, grey, yellow or Baroda green marble chips of 3 mm and down size, laid in cement marble powder mix [3:1 (3 cement : 1 marble powder) by wt.] in proportion of 4:7 (4 cement marble powder mix : 7 marble chips) by volume	sqm	22.40	49.21	1102.30	6.1.64.

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
18.	White washing with lime on new work (three or more coats) to give an even shade	sqm	235.00	1.95	458.25	6.3.1.
19.	Colour washing such as green, blue or buff on new work (two or more coats) with a base coat of white washing with lime to give an even shade	sqm	235.00	1.95	458.25	6.3.3.
				EEC for Finishing (EEC_5)	**12096.96**	
				$EEC_T = EEC_1 + EEC_2 + EEC_3 + EEC_4 + EEC_5$	**252560.06 MJ**	

Table III.1.5: EEC_T Estimate for Project No. 5 - Principal's Residence , Navodaya Vidyalaya
(Plinth Area = 90.20 sqm; Floor Area = 73.13 sqm)

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
	MASONRY WORK					
1.	1st class brick work in foundation and plinth in cement mortar 1:6 (1 cement: 6 coarse sand)	cum	17.00	2641.75	44909.75	2.2.15.
2.	1st class brick work in super structure above plinth upto 1st flr. lvl. in cement mortar 1:6 (1 cement : 6 coarse sand)	cum	40.30	2641.75	106462.53	2.2.15.+ 2.2.17.
3.	1st class brick work 7.6 cm thick in superstructure upto 1st flr. lvl. in cement mortar 1:3 (1 cement : 3 coarse sand)	cum	0.90	2013.04	1811.74	2.2.25.+ 2.2.17.
4.	Half brick masonry (1st class) in foundation & plinth in cement mortar 1:4 (1 cement : 4 coarse sand)	cum	0.55	2855.61	1570.59	2.2.32.
5.	Half brick masonry (1st class) in superstructure upto 1st flr. lvl. in cement mortar 1:4 (1 cement : 4 coarse sand)	cum	2.05	2855.61	5854.00	2.2.32.+ 2.2.34.(a)
	EEC for Masonry Work (EEC_1)				**160608.61**	
	CONCRETE WORK					
6.	Providing and laying cement concrete 1:5:10 (1 cement: 5 coarse sand: 10 graded stone agg. 40 mm nom. size) in footings and bases for columns	cum	8.00	1349.82	10798.56	3.12.(a)

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
7.	Providing and laying cement concrete 1:5:10 (1 cement: 5 fine sand: 10 graded stone agg. 40mm nom. size) in walls (any thickness) upto 1^{st} flr. lvl.	cum	7.30	1349.82	9853.69	3.12.(b)
8.	Providing and laying upto 1^{st} flr. lvl. cement concrete 1:2:4 (1 cement: 2 coarse sand : 4 graded stone agg. 20 mm nom. size) in parapets, plain window sills and the like	cum	0.10	3032.67	303.27	3.20.(b)
9.	Providing and laying DPC 40 mm thick with cement concrete 1:2:4 (1 cement : 2 coarse sand : 4 graded stone agg. 12.5 mm nom. size)	sqm	14.40	104.91	1510.70	3.29.
10.	Making plinth protection 50 mm thick of cement concrete 1:3:6 (1 cement: 3 coarse sand: 6 graded stone agg. 20 mm nom. size) over 75 mm bed of dry brick ballast 40 mm nom. size well rammed and consolidated and grouted with fine sand incl. finishing the top smooth	sqm	34.60	266.61	9224.71	3.31.
	EEC for Concrete Work (EEC_2)				**31690.93**	
11.	<u>RCC WORK</u> RCC work with 1:2:4 (1 cement : 2 coarse sand: 4 graded stone agg. 20 mm nom. size) excl. reinforcement but incl. finishing and plastering the exposed surface with cement mortar 1:3 (1cement: 3 fine sand) of thickness not exceeding 6 mm to give a smooth and even surface					

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
	(a) In roofs upto 1^{st} flr. lvl.	cum	11.30	2836.10	32047.93	4.1.
	(b) In shelves upto 1^{st} flr. lvl.	cum	1.00	2836.10	2836.10	4.1.
	(c) In chajjas, facias and gutters upto 1^{st} flr. lvl.	cum	0.60	3114.82	1868.90	4.5.
	(d) In lintels upto 1^{st} flr. lvl.	cum	1.70	2827.74	4807.16	4.2.(c)
	(e) In columns, posts and struts upto 1^{st} flr. lvl.	cum	0.10	2827.74	282.77	4.2.(d)
	(f) In plain window sills and the like upto 1^{st} flr. lvl.	cum	0.80	3032.67	2426.14	4.8.(b)
12.	Reinforcement for RCC work incl. bending, binding and placing in position complete					
	(a) Mild steel and medium tensile steel bars	q	1.00	3360.00	3360.00	4.13.
	(b) Cold twisted bars	q	13.75	3360.00	46200.00	4.13.
				EEC for RCC Work (EEC_3)	**93829.00**	
13.	FLOORING 40 mm thick cement concrete flooring 1:2:4 (1 cement: 2 coarse sand: 4 graded stone agg. 20 mm nom. size) finished with a floating coat of neat cement incl. cement slurry, rounding off edges and strips etc.	sqm	68.00	119.65	8136.20	5.5.(a)

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
14.	18 mm thick cement plaster skirting (upto 30 cm height) with cement mortar 1:3 (1 cement: 3 coarse sand), finished with a floating coat of neat cement incl. rounding of junctions with floors	sqm	11.00	87.00	957.00	5.10.(a)
15.	40 mm thick marble chips flooring, rubbed and polished to granolithic finish – under layer 31 mm thick cement concrete 1:2:4 (1 cement: 2 coarse sand: 4 graded stone agg. 12.5 mm nom. size) and top layer 9 mm thick with white, black, chocolate, grey, yellow or Baroda green marble chips of sizes from 4 mm to 7 mm nom. size laid in cement marble powder mix [3:1 (3 cement : 1 marble powder) by wt.] in proportion of 4:7 (4 cement marble powder mix: 7 marble chips) by vol. incl. cement slurry etc. complete, using dark shade pigment with ordinary cement	sqm	9.00	117.36	1056.24	5.13.(a)
16.	Providing and fixing glass strips in joints of terrazzo/cement concrete floors - 40 mm wide and 6 mm thick	m	18.00	11.79	212.22	5.17.(b)
17.	Providing and laying 25 mm thick burnt clay tiles 250 mm x 250 mm x 25 mm over roof with 1cm side joints, grouted with cement mortar 1:3 (1 cement: 3 fine sand) over 15 mm thick bed of cement mortar 1:3 (1 cement: 3 fine sand) and finished neat	sqm	32.00	125.75	4024.00	5.57.
				EEC for Flooring (EEC_4)	**14385.66**	
18.	FINISHING 12 mm cement plaster of mix 1:6 (1 cement : 6 fine sand)	sqm	220.00	24.12	5306.40	6.1.9.

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
19.	15 mm cement plaster on the rough side of single or half brick wall of mix 1:6 (1 cement : 6 fine sand)	sqm	220.00	28.81	6338.20	6.1.13.
20.	6 mm cement plaster of mix 1:3 (1 cement : 3 fine sand), finished with a floating coat of neat cement and thick coat of lime wash on top of walls when dry, for bearing of RCC slabs and beams	sqm	19.00	39.34	747.46	6.1.28.
21.	18 mm plastering with terrazzo finish for dado rubbed and polished complete – under layer 12 mm thick cement plaster 1:3 (1 cement : 3 coarse sand) and top layer 6 mm thick white, black, chocolate, grey, yellow or Baroda green marble chips of 3 mm and down size, laid in cement marble powder mix [3:1 (3 cement : 1 marble powder) by wt.] in proportion of 4:7 (4 cement marble powder mix: 7 marble chips) by volume	sqm	20.00	49.21	984.20	6.1.64.
22.	White washing with lime on new work (three or more coats) to give an even shade	sqm	285.00	1.95	555.75	6.3.1.
23.	Colour washing such as green, blue or buff on new work (two or more coats) with a base coat of white washing with lime to give an even shade	sqm	285.00	1.95	555.75	6.3.3.
	EEC for Finishing (EEC_5)				**14487.76**	
	$EEC_T = EEC_1 + EEC_2 + EEC_3 + EEC_4 + EEC_5$				**315001.96 MJ**	

Table III.1.6: EEC_T Estimate for Project No. 6 - Dwelling Unit with Three Rooms (Plinth Area = 93.72 sqm; Floor Area = 78.66 sqm)

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
	MASONRY WORK					
1.	1^{st} class brick work in foundation and plinth in cement mortar 1:6 (1 cement: 6 fine sand)	cum	30.25	2641.75	79912.93	2.2.11
2.	1^{st} class brick work in superstructure in cement mortar 1:6 (1 cement: 6 fine sand)	cum	56.18	2641.75	148413.51	2.2.11. + 2.2.17.
				EER for Masonry Work (EEC_1)	**228326.44**	
	CONCRETE WORK					
3.	Providing and laying cement concrete 1:6:12 (1 cement: 6 fine sand: 12 graded stone agg. 40 mm nom. size) in foundation	cum	13.88	1215.82	16875.58	3.14.(a)
4.	Concrete in roof terracing with 25 mm gauge brick ballast, white lime and surkhi in the proportion of 100:18:36	cum	6.38	3906.51	24923.53	3.5.
5.	Providing and laying DPC 25 mm thick with cement concrete 1:2:4 (1 cement : 2 coarse sand : 4 stone agg. 10 mm nom. size)	sqm	23.38	65.57	1533.03	3.27.
				EEC for Concrete Work (EEC_2)	**43332.14**	
	RCC WORK					
6.	RCC work 1:2:4 (1 cement : 2 coarse sand : 4 graded stone agg. 40 mm nom. size) excl. reinforcement but incl. finishing and plastering the exposed surface with cement mortar 1:3					

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
	(1 cement :3 fine sand) of thickness not exceeding 6 mm to give a smooth and even surface					
	(a) Roof slab	cum	11.31	2836.10	32076.29	4.1.
	(b) Lintels	cum	1.13	2827.74	3195.35	4.2.(c)
	(c) Sunshades	cum	0.53	3114.82	1650.85	4.5.
7.	Mild steel reinforcement incl. bending in RCC	q	10.18	3360.00	34204.80	4.13.
			EEC for RCC Work (EEC_3)		**71127.29**	
	FLOORING					
8.	40 mm thick marble chips flooring rubbed and polished to granolithic finish - under layer 34 mm thick cement concrete 1:2:4 (1 cement : 2 coarse sand : 4 graded stone agg. 12.5 mm nominal size) and top layer 6 mm thick with white or black or white and white and black marble chips of 4 mm nominal size laid in cement marble powder mix [3:1 (3 cement : 1 marble powder by wt.] in proportion of 4:7 (4 cement : 7 marble powder mix : 7 marble chips) by vol. - light shade pigment with ordinary cement	sqm	83.36	116.47	9708.94	5.12.(e)
			EEC for Flooring (EEC_4)		**9708.94**	
	FINISHING					
9.	12 mm cement plastering in walls with 1:6 cement mortar (1 cement : 6 fine sand)	sqm	528.55	24.12	12748.63	6.1.9.

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
10.	White washing with lime on new work (3 or more coats) to give an even shade	sqm	505.28	1.95	985.30	6.3.1.
	EEC for Finishing (EEC_5)				**13733.93**	
	$EEC_T = EEC_1 + EEC_2 + EEC_3 + EEC_4 + EEC_5$				**366228.74 MJ**	

Table III.1.7: EEC_T Estimate for Project No. 7 - Residence of O.N.Vidyarathi at II Phase Development, BHEL Yojna, Ranipur, Hardwar (Plinth Area = 120.49 sqm; Floor Area = 104.48 sqm)

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
	MASONRY WORK					
1.	1st class brick work in foundation and plinth in cement mortar 1:6 (1 cement: 6 fine sand)	cum	43.43	2641.75	114731.20	2.2.11.
2.	(a) 1st class brick work in superstructure in 1:6 cement mortar (1 cement: 6 fine sand)	cum	71.61	2641.75	189175.72	2.2.11. + 2.2.17.
	(b) 1st class brick work in superstructure in walls of half brick thickness in 1:3 cement mortar (1cement: 3 coarse sand)	cum	11.00	3069.52	33764.72	2.2.31. + 2.2.34.(a)
	EEC for Masonry Work (EEC_1)				**337671.64**	
	CONCRETE WORK					
3.	Cement concrete in foundation in the proportion 1:6:12 (1cement: 6 fine sand: 12 graded stone agg. 40 mm nom. size)	cum	33.56	1215.82	40802.92	3.14. (a)
4.	Concrete in roof terracing with 25 mm gauge brick ballast, white lime and surkhi in the proportion of 100:18:36	cum	9.10	3906.51	35549.24	3.5.
5.	40 mm thick DPC 1:2:4 (1cement: 2 coarse sand: 4 stone ballast 6 mm gauge)	sqm	18.52	104.91	1942.93	3.29.

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
6.	Cement concrete 1:2:4 (1 cement: 2 coarse sand: 4 approved stone ballast 20 mm nom. size)	cum	1.61	2622.82	4222.74	3.18.
	EEC for Concrete Work (EEC_2)				**82517.83**	
	RCC WORK					
7.	RCC work 1:2:4 (1cement: 2 coarse sand: 4 graded stone ballast 6 mm to 19 mm gauge) excl. reinforcement but incl. finishing and plastering the exposed surface with cement mortar 1:3 (1 cement: 3 fine sand) of thickness not exceeding 6 mm to give a smooth and even surface					
	(a) Lintels of doors and windows, sills, shelves, sunshades, louvers, sun breakers etc.	cum	2.56	2827.74	7239.01	4.2.(c)
	(b) T-beams and slab roof incl. L-beams, staircase, spiral staircase and RCC columns	cum	18.92	3131.25	59243.25	4.2.(f)
8.	(a) Mild steel or iron work of small sizes and sections such as holding down bolts, hold fasts, tie rods, gratings etc., wrought to required form	q	1.52	3360.00	5107.20	4.13.
	(b) Tor steel in plain work such as reinforced concrete, wrought to required shape	q	0.00	3360.00	0.00	4.13.
	(c) Same as item 8 (b) but in mild steel	q	24.50	3360.00	82320.00	4.13.
	EEC for RCC Work (EEC_3)				**153909.46**	

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
	FLOORING					
9.	40 mm thick plain cement concrete floor 1:2:4 (1 cement: 2 coarse sand: 4 graded stone ballast 20 mm nom. size) with 3 mm floating coat of cement and marble dust in the ratio of 5:1	sqm	76.91	119.65	9202.28	5.5.(a)
10.	21 mm thick cement plaster in dado or skirting with cement mortar 1:3 (1 cement: 3 coarse sand) laid in panels, finished with 3 mm floating coat of cement and marble dust in the ratio of 5:1	sqm	2.77	97.25	269.38	5.10.(b)
11.	40 mm thick granolithic marble flooring - under layer 34 mm thick cement concrete 1:2:4 (1cement: 2 coarse sand: 4 approved stone ballast 20 mm nom. size) laid in panels incl. borders, designing, bonds and patterns and top layer 6 mm thick with black or white or grey or mixed marble chips of approved quality, laid in cement marble powder mix in the proportion of 1:2	sqm	75.69	116.47	8815.61	5.12.(a)
12.	Providing and fixing glass strips of 4 mm thickness in joints of floors and skirting at the time of laying floors, flush with flr. lvl. up to 35 mm depth	m	230.00	10.32	2373.60	5.17.(c)
				EEC for Flooring (EEC_4)	**20660.87**	
	FINISHING					
13.	12 mm thick plaster with cement mortar in proportion of 1:6 (1 cement: 6 fine sand)	sqm	842.95	24.12	20331.95	6.1.9.

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
14.	Struck cement pointing with cement mortar 1:2 (1cement: 2 fine sand), with colouring materials to match the colour of brick work	sqm	0.00	9.11	0.00	6.2.5.
15.	White washing three coats	sqm	962.58	1.95	1877.03	6.3.1.
	EEC for Finishing (EEC_5)				22208.98	
	$EEC_T = EEC_1 + EEC_2 + EEC_3 + EEC_4 + EEC_5$				**616968.78 MJ**	

Table III.1.8: EEC_T Estimate for Project No. 8 - Residence for Shri R.K. Bansal at Plot No. K-112, II Phase Development, BHEL Yojna, Ranipur, Hardwar (Plinth Area = 126.13 sqm; Floor Area = 104.68 sqm)

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
	MASONRY WORK					
1.	1st class brick work in foundation and plinth in cement mortar 1:6 (1 cement: 6 fine sand)	cum	40.15	2641.75	106066.26	2.2.11.
2.	(a) 1st class brick work in superstructure in 1:6 cement mortar (1 cement: 6 fine sand)	cum	73.92	2641.75	195278.16	2.2.11. + 2.2.17.
	(b) 1st class brick work in superstructure in walls of half brick thickness in 1:3 cement mortar (1cement: 3 coarse sand)	cum	8.94	3069.52	27441.51	2.2.31. + 2.2.34.(a)
				EEC for Masonry Work (EEC_1)	**328785.93**	
	CONCRETE WORK					
3.	Cement concrete in foundation in the proportion 1:6:12 (1 cement: 6 fine sand: 12 graded stone agg. 40 mm nom. size)	cum	34.18	1215.82	41556.73	3.14. (a)
4.	Concrete in roof terracing with 25 mm gauge brick ballast, white lime and surkhi in the proportion of 100:18:36	cum	8.60	3906.51	33596.00	3.5.
5.	40 mm thick DPC 1:2:4 (1cement: 2 coarse sand: 4 stone ballast 6 mm gauge)	sqm	18.15	104.91	1904.12	3.29.

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
6.	Cement concrete 1:2:4 (1cement: 2 coarse sand: 4 approved stone ballast 20 mm nom. size)	cum	1.88	2622.82	4930.90	3.18.
	EEC for Concrete Work (EEC_2)				**81987.75**	
	RCC WORK					
7.	RCC work 1:2:4 (1cement: 2 coarse sand: 4 graded stone ballast 6 mm to 19mm gauge) excl. reinforcement but incl. finishing and plastering the exposed surface with cement mortar 1:3 (1 cement : 3 fine sand) of thickness not exceeding 6 mm to give a smooth and even surface					
	(a) Lintels of doors and windows, sills, shelves, sunshades, louvers, sun breakers etc.	cum	3.48	2827.74	9840.53	4.2.(c)
	(b) T-beams and slab roof incl. L-beams, staircase, spiral staircase and RCC columns	cum	17.16	3131.25	53732.25	4.2.(f)
8.	(a) Mild steel or iron work of small sizes and sections such as holding down bolts, hold fasts, tie rods, grating etc. wrought to required form	q	1.95	3360.00	6552.00	4.13.
	(b) Tor steel in plain work such as reinforced concrete or reinforced brick work wrought to required shape	q	0.00	3360.00	0.00	4.13.
	(c) Same as item 8 (b) but in mild steel	q	22.93	3360.00	77044.80	4.13.

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
			EEC for RCC Work (EEC_3)		**147169.58**	
9.	FLOORING 40 mm thick plain cement concrete floor 1:2:4 (1 cement: 2 coarse sand: 4 graded stone ballast 20 mm nom. size) with 3 mm floating coat of cement and marble dust in the ratio of 5:1	sqm	85.23	119.65	10197.77	5.5.(a)
10.	21 mm thick cement plaster in dado or skirting with cement mortar 1:3 (1 cement: 3 coarse sand), laid in panels finished with 3 mm floating coat of cement and marble dust in the ratio of 5:1	sqm	2.50	97.25	243.13	5.10.(b)
11.	40 mm thick granolithic marble flooring - under layer 34 mm thick cement concrete 1:2:4 (1cement: 2 coarse sand: 4 approved stone ballast 20mm nom. size) laid in panels incl. borders, designing, bonds and patterns and top layer 6 mm thick with black or white or grey or mixed marble chips of approved quality, laid in cement marble powder mix in the proportion of 1:2	sqm	93.56	116.47	10896.93	5.12.(a)
12.	Providing and fixing glass strips of 4 mm thickness in joints of floors and skirting at the time of laying floors, flush with flr. lvl. upto 35 mm depth	m	225.00	10.32	2322.00	5.17.(c)
			EEC for Flooring (EEC_4)		**23659.83**	
13.	FINISHING 12 mm thick plaster with cement mortar in proportion of 1:6 (1 cement: 6 fine sand)	sqm	774.61	24.12	18683.59	6.1.9.

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
14.	Struck cement pointing with cement mortar 1:2 (1cement: 2 fine sand), with colouring materials to match the colour of brick work	sqm	0.00	9.11	0.00	6.2.5.
15.	White washing - three coats	sqm	890.73	1.95	1736.92	6.3.1.
	EEC for Finishing (EEC_5)				**20420.51**	
	$EEC_T = EEC_1 + EEC_2 + EEC_3 + EEC_4 + EEC_5$				**602023.60 MJ**	

Table III.1.9: EEC_T Estimate for Project No. 9 - Single Storeyed Residence
(Plinth Area = 159.44 sqm; Floor Area = 132.63 sqm)

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
	MASONRY WORK					
1.	1st class brick work in foundation and plinth in cement mortar 1:6 (1 cement: 6 coarse sand)	cum	49.05	2641.75	129577.84	2.2.15.
2.	1st class brick work in superstructure above plinth in cement mortar 1:6 (1 cement: 6 coarse sand)	cum	74.28	2641.75	196229.19	2.2.15. + 2.2.17.
3.	Half brick masonry (1st class) in boundary wall above plinth in cement mortar 1:4 (1 cement: 4 coarse sand)	cum	11.81	2855.61	33724.75	2.2.32. + 2.2.34.
4.	Half brick masonry (1st class) in superstructure in cement mortar 1:3 (1 cement: 3 coarse sand) with hoop iron 25 mm x 1.6 mm at every 3rd course, embedded in the cement mortar	cum	0.82	3339.00	2737.98	2.2.33.(a) + 2.2.34.(a)
5.	Providing brick band 7.62 cm thick and 5.72 cm projected from the wall face in 1st class brick work laid in cement mortar 1:4 (1 cement: 4 fine sand)	m	52.20	12.30	642.06	2.2.59.
				EEC for Masonry Work (EEC_1)	**362911.82**	
	CONCRETE WORK					
6.	Providing and laying cement concrete 1:6:12 (1 cement: 6 fine sand: 12 graded stone agg. 40 mm nom. size) in foundation	cum	27.29	1215.82	33179.73	3.14.(a)

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
7.	Concrete in roof terracing with 25 mm gauge brick ballast, white lime and surkhi in the proportion of 100:18:36	cum	11.36	3906.51	44377.95	3.5.
8.	25 mm DPC with cement concrete 1:2:4 (1 cement : 2 coarse sand: 4 stone agg. 10 mm nom. size)	sqm	28.97	65.57	1899.56	3.27.
9.	Providing and laying cement concrete 1:2:4 (1 cement: 2 fine sand: 4 graded stone agg. 20 mm nom. size) in steps	cum	0.385	2827.82	1088.71	3.20.(a)
				EEC for Concrete Work (EEC_2)	**80545.95**	
	RCC WORK					
10.	RCC work 1:2:4 (1 cement : 2 coarse sand : 4 graded stone agg. 40 mm nom. size) excl. reinforcement, but incl. finishing and plastering the exposed surface with cement mortar 1:3 (1 cement: 3 fine sand) of thickness not exceeding 6 mm to give a smooth and even surface					
	(a) Slabs	cum	18.23	2836.10	51702.10	4.1.
	(b) Lintels	cum	2.35	2827.74	6645.19	4.2.(c)
	(c) Sunshades	cum	0.91	3114.82	2834.49	4.5.
	(d) Slabs of shelves	cum	0.264	2836.10	748.73	4.1.
	(e) Staircase	cum	0.92	2900.28	2668.26	4.2.(e)

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
11.	Mild steel reinforcement bars incl. bending in RCC work	q	17.80	3360.00	59808.00	4.13.
				EEC for RCC Work (EEC_3)	**124406.77**	
	FLOORING					
12.	Cement concrete flooring 1:2:4 (1 cement: 2 coarse sand: 4 graded stone agg. 12.5 mm nom. size) finished with a floating coat of neat cement - 25 mm thick	sqm	221.25	80.28	17761.95	5.4.
13.	Cement plaster skirting (upto 30 cm height) with cement mortar 1:3 (1 cement: 3 coarse sand) finished with a floating coat of neat cement, incl. rounding of junctions with the floor - 18 mm thick	sqm	34.29	87.00	2983.23	5.10.(a)
14.	Dado 18 mm thick cement mortar 1:3 (1 cement: 3 coarse sand), finished with a floating coat of neat cement.	sqm	22.45	87.00	1953.15	5.10.(a)
				EEC for Flooring (EEC_4)	**22698.33**	
	FINISHING					
15.	12 mm plastering with cement mortar 1:6 (1 cement: 6 fine sand)	sqm	870.05	24.12	20985.61	6.1.9.
16.	20 mm plastering in steps with cement mortar 1:3 (1 cement: 3 fine sand), finished with a floating coat of neat cement)	sqm	13.96	91.28	1274.27	6.1.26.
17.	White washing (3 coats) - inside	sqm	734.59	1.95	1432.45	6.3.1.

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
18.	Colour washing (2 coats) over one coat of white washing - outside	sqm	187.10	1.95	364.85	6.3.3.
	EEC for Finishing (EEC_5)				**24057.18**	
	$EEC_T = EEC_1 + EEC_2 + EEC_3 + EEC_4 + EEC_5$				**614620.05 MJ**	

Table III.1.9(a): EEC Estimate of Boundary Wall and Open Paved Area for Project No. 9

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
	MASONRY WORK					
1.	1st class brick work in foundation and plinth in cement mortar 1:6 (1 cement: 6 coarse sand)	cum	7.11	2641.75	18782.84	2.2.15.
2.	Half brick masonry (1st class) in boundary wall above plinth in cement mortar 1:4 (1 cement: 4 coarse sand)	cum	11.81	2855.61	33724.75	2.2.32. + 2.2.34.
				EEC for Masonry Work	**52507.59**	
	CONCRETE WORK					
3.	Providing and laying cement concrete 1:6:12 (1 cement: 6 fine sand: 12 graded stone agg. 40 mm nom. size) in foundation	cum	7.93	1215.82	9641.45	3.14.(a)
				EEC for Concrete Work	**9641.45**	
	FLOORING					
4.	Cement concrete flooring 1:2:4 (1 cement: 2 coarse sand: 4 graded stone agg. 12.5 mm nom. size) finished with a floating coat of neat cement - 25 mm thick	sqm	83.25	80.28	6683.31	5.4.
				EEC for Flooring	**6683.31**	

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
	FINISHING					
5.	12 mm plastering with cement mortar 1:6 (1 cement: 6 fine sand)	sqm	147.50	24.12	3557.70	6.1.9.
6.	White washing (3 coats) – inside and outside	sqm	138.78	1.95	270.62	6.3.1.
	EEC for Finishing				**3828.32**	
	Total EEC of Boundary Wall and Open Paved Area				**72660.67 MJ**	

Table III.1.9(b): EEC Estimate of Stairwell for Project No. 9

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
	MASONRY WORK					
1.	1st class brick work in stairwell above plinth in cement mortar 1:6 (1 cement: 6 coarse sand):					
	(a) Ground flr. lvl.	cum	0.22	2641.75	581.19	2.2.15. + 2.2.17.
	(b) Mumty[4] room	cum	5.07	2641.75	13393.67	2.2.15. + 2.2.17.
				EEC for Masonry Work	**13974.86**	
	CONCRETE WORK					
2.	Providing and laying cement concrete 1:6:12 (1 cement: 6 fine sand: 12 graded stone agg. 40 mm nom. size) in foundation for staircase	cum	0.64	1215.82	778.12	3.14.(a)
3.	Concrete in mumty roof terracing with 25 mm gauge brick ballast, white lime and surkhi in the proportion of 100:18:36	cum	2.26	3906.51	8828.71	3.5.
4.	Providing and laying cement concrete 1:2:4 (1 cement: 2 fine sand: 4 graded stone agg. 20 mm nom. size) in steps	cum	0.385	2827.82	1088.71	3.20.(a)
				EEC for Concrete Work	**10695.54**	

[4] Mumty is a vernacular word for the upper covered portion of the stairwell leading to the terrace

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
	RCC WORK					
5.	RCC work 1:2:4 (1 cement : 2 coarse sand : 4 graded stone agg. 40 mm nom. size) excl. reinforcement, but incl. finishing and plastering the exposed surface with cement mortar 1:3 (1 cement: 3 fine sand) of thickness not exceeding 6 mm to give a smooth and even surface					
	(a) Slabs of landings	cum	2.673	2836.10	7580.89	4.1.
	(b) Lintels	cum	0.114	2827.74	322.36	4.2.(c)
	(c) Staircase flight	cum	0.92	2900.28	2668.26	4.2.(e)
6.	Mild steel reinforcement bars (excl. steps) incl. bending in RCC work	q	2.90	3360.00	9744.00	4.13.
				EEC for RCC Work	**20315.51**	
	FLOORING					
7.	Cement concrete flooring 1:2:4 (1 cement: 2 coarse sand: 4 graded stone agg. 12.5 mm nom. size) finished with a floating coat of neat cement - 25 mm thick					
	(a) Ground flr. lvl.	sqm	8.05	80.28	646.25	5.4.
	(b) Staircase landings	sqm	3.11	80.28	249.67	5.4.
				EEC for Flooring	**895.92**	

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
	FINISHING					
8.	12 mm plastering with cement mortar 1:6 (1 cement: 6 fine sand)	sqm	83.02	24.12	2002.44	6.1.9.
9.	20 mm plastering in steps with cement mortar 1:3 (1 cement: 3 fine sand), finished with a floating coat of neat cement)	sqm	7.48	91.28	682.77	6.1.26.
10.	White washing (3 coats) - inside	sqm	53.28	1.95	103.90	6.3.1.
11.	Colour washing (2 coats) over one coat of white washing - outside	sqm	29.74	1.95	58.00	6.3.3.
	EEC for Finishing				**2847.11**	
	Total EEC of Stairwell				**48728.94 MJ**	

Table III.1.10: EEC_T Estimate for Project No. 10 - Residence of Y.P. Sharma at Plot No. J-25, II Phase Development, BHEL Yojna, Ranipur, Hardwar (Plinth Area = 169.38 sqm; Floor Area = 143.60 sqm)

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
	MASONRY WORK					
1.	1st class brick work in foundation and plinth in cement mortar 1:6 (1cement: 6 fine sand)	cum	44.86	2641.75	118508.91	2.2.11.
2.	(a) 1st class brick work in superstructure in 1:6 cement mortar (1cement: 6fine sand)	cum	83.24	2641.75	219899.27	2.2.11. + 2.2.17.
	(b) 1st class brick work in superstructure in walls of half brick thickness in 1:3 cement mortar (1cement: 3 coarse sand)	cum	10.93	3042.83	33258.13	2.2.31. + 2.2..34.(a)
	EEC for Masonry Work (EEC_1)				**371666.31**	
	CONCRETE WORK					
3.	Cement concrete in foundation in the proportion 1:6:12 (1cement: 6 fine sand: 12 graded stone agg. 40 mm nom. size)	cum	37.26	1215.82	45301.45	3.14. (a)
4.	40 mm thick DPC 1:2:4 (1cement: 2 coarse sand: 4 stone ballast 6 mm gauge) incl. waterproofing materials	sqm	21.03	104.91	2206.26	3.29.
5.	Cement concrete 1:2:4 (1cement: 2 coarse sand: 4 stone ballast 20 mm nom. size)	cum	1.71	2622.82	4485.02	3.18.
6.	Concrete in roof terracing with 25 mm gauge brick ballast, white lime and surkhi in the proportion of 100:18:36	cum	13.21	3906.51	51605.00	3.5.

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
	EEC for Concrete Work (EEC_2)				**103597.73**	
	RCC WORK					
7.	RCC work 1:2:4 (1cement: 2 coarse sand: 4 graded stone ballast 6 mm to 19 mm gauge) excl. reinforcement but incl. finishing and plastering the exposed surface with cement mortar 1:3 (1 cement : 3 fine sand) of thickness not exceeding 6 mm to give a smooth and even surface					
	(a) Lintels of doors and windows, sills, shelves, sunshades, louvers, sun breakers etc.	cum	2.96	2827.74	8370.11	4.2.(c)
	(b) T-beams and slab roof incl. L-beams and staircase	cum	21.10	3131.25	66069.38	4.2.(f)
8.	(a) Mild steel or iron work of small sizes and sections such as holding down bolts, hold fasts, tie rods, grating etc. wrought to required form	q	1.78	3360.00	5980.80	4.13.
	(b) For Tor steel in plain work such as reinforced concrete wrought to required shape	q	0.00	3360.00	0.00	4.13.
	(c) Same as item 8 (b) but in mild steel	q	27.13	3360.00	91156.80	4.13.
	EEC for RCC Work (EEC_3)				**171577.09**	

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
	FLOORING					
9.	40 mm thick plain cement concrete floor 1:2:4 (1 cement: 2 coarse sand: 4 graded stone ballast 20 mm nom. size) with 3 mm floating coat of cement and marble dust in ratio of 5:1	sqm	83.94	119.65	10043.42	5.5.(a)
10.	21 mm thick cement plaster in dado or skirting with cement mortar 1:3 (1 cement: 3 coarse sand), laid in panels finished with 3 mm floating coat of cement and marble dust in the ratio of 5:1	sqm	3.51	97.25	341.35	5.10.(b)
11.	40 mm thick granolithic marble flooring – under layer 34 mm thick cement concrete 1:2:4 (1cement: 2 coarse sand: 4 approved stone ballast 20mm nom. size) laid in panels incl. borders, designing, bonds and patterns and top layer 6 mm thick with black or white or grey or mixed marble chips of approved quality passing 3 mm but retained on 1.5 mesh screen, laid in cement marble powder mix in the proportion of 1:2	sqm	132.14	116.47	15390.35	5.12.(a)
12.	21 mm thick granolithic marble dado – under layer 15 mm thick 1:3 (1cement: 3 coarse sand) and top layer 6 mm thick with black or white or grey or mixed marble chips passing 3mm but retained on 15 mm mesh screen, in proportion of 1:2	sqm	30.09	85.90	2584.73	5.15.B. (a)
13.	Providing and fixing glass strips of 4 mm thickness in joints of floors and skirting at the time of laying floors, flush with flr. lvl. upto 35 mm depth	m	260.00	10.32	2683.20	5.17.(c)
	EEC for Flooring (EEC_4)				**31043.05**	

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
	FINISHING					
14.	12 mm thick plaster with cement mortar in proportion of 1:6 (1cement: 6 fine sand)	sqm	1010.21	24.12	24366.27	6.1.9.
15.	Struck cement pointing with cement mortar 1:2 (1 cement: 2 fine sand), with colouring materials to match the colour of brick work	sqm	0.00	9.11	0.00	6.2.5.
16.	White washing (three coats)	sqm	1010.21	1.95	1969.91	6.3.1.
	EEC for Finishing (EEC_5)				**26336.18**	
	$EEC_T = EEC_1 + EEC_2 + EEC_3 + EEC_4 + EEC_5$				**704512.08 MJ**	

Table III.1.11: EEC_T Estimate for Project No. 11 - Staff Residence at Navodaya Vidyalaya - a Unit of Four Dwellings
(Total Plinth Area = 237.00 sqm; Total Floor Area = 208.50 sqm)

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
	MASONRY WORK					
1.	1^{st} class brick work in foundation and plinth in cement mortar 1:6 (1 cement: 6 coarse sand)	cum	27.30	2641.75	72119.78	2.2.15.
2.	1^{st} class brick work in superstructure above plinth in cement mortar 1:6 (1 cement: 6 coarse sand).					
	(a) Upto 1^{st} flr. lvl.	cum	55.70	2641.75	147145.47	2.2.15.+ 2.2.17.+ 2.2.18.
	(b) From 1^{st} flr. lvl. to 2^{nd} flr. lvl.	cum	55.00	2641.75	145296.25	2.2.15.+ 2.2.17.+ 2.2.18.
3.	Half brick masonry (1^{st} class) in superstructure in cement mortar 1:4 (1 cement : 4 coarse sand)					
	(a) Upto 1^{st} flr. lvl.	cum	3.08	2855.61	8795.28	2.2.32.+ 2.2.34.(a) + 2.2.34.(b)
	(b) From 1^{st} flr. lvl. to 2^{nd} flr. lvl.	cum	3.72	2855.61	10622.87	2.2.32.+ 2.2.34.(a)
			EEC for Masonry Work (EEC_1)		**383979.65**	
	CONCRETE WORK					
4.	Providing and laying lime concrete on terrace/sunken floor with					

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
	graded brick agg. 25mm nom. size and 50% mortar comprising of 1 lime putty: 2 surkhi					
	(a) Upto 1st flr. lvl.	cum	4.10	3906.51	16016.70	3.5. + 3.26.
	(b) From 1st flr. lvl. to 2nd flr. lvl.	cum	0.00	3906.51	0.00	3.5. + 3.26.
5.	Providing and laying cement concrete in footings and bases for columns with 1:5:10 (1 cement: 5 coarse sand: 10 graded stone agg. 40 mm nom. size)	cum	12.40	1349.82	16737.77	3.12.(a)
6.	Providing and laying cement concrete in retaining walls, return walls, walls (any thickness) incl. attached pilasters, buttresses, plinth, string courses, fillets etc. upto 2nd flr. lvl. 1:5:10 (1 cement: 5 fine sand: 10 graded stone agg. 40 mm nom. size)	cum	7.00	1349.82	9448.74	3.12.(b) + 3.26.
7.	Providing and laying 40 mm thick DPC 1:2:4 (1 cement: 2 coarse sand: 4 graded stone agg. 12.5 mm nom. size)	sqm	20.40	104.91	2140.16	3.29.
8.	Making plinth protection 50 mm thick of cement concrete 1:3:6 (1 cement: 3 coarse sand : 6 graded stone agg. 20 mm nom. size) over 75 mm bed of dry brick ballast 40 mm nom. size, well rammed, consolidated and grouted with fine sand incl. finishing the top smooth	sqm	24.70	266.61	6585.27	3.31.
				EEC for Concrete Work (EEC$_2$)	**50928.64**	

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
	RCC WORK					
9.	RCC work with 1:2:4 (1 cement : 2 coarse sand : 4 graded stone agg. 20 mm nom. size) in roofs, landings and balconies excl. reinforcement but incl. finishing and plastering the exposed surface with cement mortar 1:3 (1cement : 3 fine sand) of thickness not exceeding 6 mm to give a smooth and even surface					
	(a) Upto 1st flr. lvl.	cum	9.50	2836.10	26942.95	4.1.
	(b) From 1st flr. lvl. to 2nd flr. lvl.	cum	12.30	2836.10	34884.03	4.1. + 4.12.
10.	RCC work with 1:2:4 (1 cement: 2 coarse sand: 4 graded stone agg. 20 mm nom. size) in shelves excl. reinforcement but incl. finishing and plastering the exposed surface with cement mortar 1:3 (1cement: 3 fine sand) of thickness not exceeding 6 mm to give a smooth and even surface					
	(a) Upto 1st flr. lvl.	cum	0.50	2836.10	1418.05	4.1.
	(b) From 1st flr. lvl. to 2nd flr. lvl.	cum	0.50	2836.10	1418.05	4.1. + 4.12.
11.	RCC work with 1:2:4 (1 cement: 2 coarse sand: 4 graded stone agg. 20 mm nom. size) in chajjas, facias and gutters excl. reinforcement but incl. finishing and plastering the exposed surface with cement mortar 1:3 (1cement: 3 fine sand) of thickness not exceeding 6 mm to give a smooth and even surface					

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
	(a) Upto 1st flr. lvl.	cum	0.80	3114.82	2491.86	4.5. + 4.12.
	(b) From 1st flr. lvl. to 2nd flr. lvl.	cum	0.40	3114.82	1245.93	4.5. + 4.12.
12.	RCC work with 1:2:4 (1 cement: 2 coarse sand: 4 graded stone agg. 20 mm nom. size) in lintels, beams, plinth beams and bressumers excl. reinforcement but incl. finishing and plastering the exposed surface with cement mortar 1:3 (1cement : 3 fine sand) of thickness not exceeding 6 mm to give a smooth and even surface					
	(a) Upto 1st flr. lvl.	cum	2.80	2827.74	7917.67	4.2.(c)
	(b) From 1st flr. lvl. to 2nd flr. lvl.	cum	2.60	2827.74	7352.12	4.2.(c)
13.	RCC work with 1:2:4 (1 cement: 2 coarse sand: 4 graded stone agg. 20 mm nom. size) in staircases (excl. landings) except spiral staircases excl. reinforcement but incl. finishing and plastering the exposed surface with cement mortar 1:3 (1cement : 3 fine sand) of thickness not exceeding 6 mm to give a smooth and even surface and preparing of the top surface and nosing					
	(a) Upto 1st flr. lvl.	cum	1.30	2900.28	3770.36	4.2.(e)
	(b) From 1st flr. lvl. to 2nd flr. lvl.	cum	0.00	2900.28	0.00	4.2.(e) + 4.12.
14.	Providing and laying RCC with 1:2:4 (1 cement: 2 coarse sand: 4 graded stone agg. 20 mm nom. size.) in string courses, bands,					

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
	copings, bed plates, anchor blocks, plain window sills and the like excl. reinforcement but incl. finishing and plastering the exposed surface with cement mortar 1:3 (1cement : 3 fine sand) of thickness not exceeding 6 mm to give a smooth and even surface and preparing of the top surface and nosing					
	(a) Upto 1st flr. lvl.	cum	1.10	3032.67	3335.94	4.8.(b) + 4.12.
	(b) From 1st flr. lvl. to 2nd flr. lvl.	cum	1.10	3032.67	3335.94	4.8.(b) + 4.12.
15.	Reinforcement for RCC work					
	(a) Mild steel and medium tensile steel bars	q	6.00	3360.00	20160.00	4.13.
	(b) Cold twisted bars	q	21.40	3360.00	71904.00	4.13.
			EEC for RCC Work (EEC_3)		**186176.90**	
	FLOORING					
16.	40 mm thick cement concrete flooring 1:2:4 (1 cement : 2 coarse sand: 4 graded stone aggregate 20 mm nom. size) finished with a floating coat of neat cement incl. cement slurry, rounding off edges and strips etc. but excl. the nosing of steps	sqm	176.00	119.65	21508.40	5.5.(a)
17.	18 mm thick cement plaster skirting (up to 30 cm height) with cement mortar 1:3 (1 cement: 3 coarse sand), finished with a floating coat of neat cement incl. rounding of junctions with floors	sqm	33.20	87.00	2888.40	5.10.(a)

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
18.	40 mm thick marble chips flooring, rubbed and polished to granolithic finish – under layer 31 mm thick cement concrete 1:2:4 (1 cement : 2 coarse sand : 4 graded stone agg. 12.5 mm nom. size) and top layer 9 mm thick with white, black, chocolate, grey, yellow or Baroda green marble chips of sizes from 4 mm to 7 mm nom. size laid in cement marble powder mix [3:1 (3 cement : 1 marble powder) by wt.] in proportion of 4:7 (4 cement marble powder mix: 7 marble chips) by vol. incl. cement slurry etc., complete using dark shade pigment with ordinary cement	sqm	19.20	117.36	2253.31	5.13.(a)
19.	Providing and fixing glass strips in joints of terrazzo/cement concrete floors - 40 mm wide and 6 mm thick	m	38.40	11.79	452.74	5.17.(b)
	EEC for Flooring (EEC_4)				**27102.85**	
	<u>FINISHING</u>					
20.	12 mm cement plaster of mix 1:6 (1 cement : 6 fine sand)	sqm	557.00	24.12	13434.84	6.1.9.
21.	15 mm cement plaster on the rough side of single or half brick wall of mix 1:6 (1 cement : 6 fine sand)	sqm	557.00	28.81	16047.17	6.1.13.
22.	6 mm cement plaster of mix 1:3 (1 cement : 3 fine sand) finished with a floating coat of neat cement and thick coat of lime wash on top of walls when dry, for bearing of RCC slabs and beams	sqm	50.00	39.34	1967.00	6.1.28.

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
23.	18 mm plastering with terrazzo finish for dado, rubbed and polished complete – under layer 12 mm thick cement plaster 1:3 (1 cement : 3 coarse sand) and top layer 6 mm thick white, black, chocolate, grey, yellow or Baroda green marble chips of 3 mm and down size laid in cement marble powder mix [3:1 (3 cement : 1 marble powder) by wt.] in proportion of 4:7 (4 cement marble powder mix : 7 marble chips) by volume	sqm	47.30	49.21	2327.63	6.1.64.
24.	White washing with lime on new work (three or more coats) to give an even shade	sqm	734.00	1.95	1431.30	6.3.1.
25.	Colour washing such as green, blue or buff on new work (two or more coats) with a base of white washing with lime to give an even shade	sqm	734.00	1.95	1431.30	6.3.3.
	EEC for Finishing (EEC_5)				**36639.24**	
	$EEC_T = EEC_1 + EEC_2 + EEC_3 + EEC_4 + EEC_5$				**684827.28 MJ**	

Table III.1.12: EEC$_T$ Estimate for Project No. 12 - Staff Residence at Navodaya Vidyalaya - a Unit of Four Dwellings (Total Plinth Area = 296.90 sqm; Total Floor Area = 249.40 sqm)

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
	MASONRY WORK					
1.	1^{st} class brick work in foundation and plinth in cement mortar 1:6 (1cement: 6 coase sand)	cum	27.0	2641.75	71327.25	2.2.15.
2.	1^{st} class brick work in superstructure above plinth in cement mortar 1:6 (1 cement: 6 coarse sand)					
	(a) Upto 1^{st} flr. lvl.	cum	61.70	2641.75	162996.00	2.2.15. + 2.2.17. + 2.2.18.
	(b) From 1^{st} flr. lvl. to 2^{nd} flr. lvl.	cum	77.20	2641.75	203943.10	2.2.15. + 2.2.18.
3.	Half brick masonry (1^{st} class) in foundation and plinth in cement mortar 1:4 (1 cement: 4 coarse sand)	cum	0.79	2855.61	2255.93	2.2.32.
4.	Half brick masonry (1^{st} class) in superstructure in cement mortar 1:4 (1cement: 4 coarse sand)					
	(a) Upto 1^{st} flr. lvl.	cum	2.11	2855.61	6025.34	2.2.32.+ 2.2..34(a)+ 2.2.34(b)
	(b) From 1^{st} flr. lvl. to 2^{nd} flr. lvl.	cum	2.30	2855.61	6567.90	2.2.32.+ 2.2.34(b)
				EEC for Masonry Work (EEC$_1$)	**453115.52**	

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
5.	CONCRETE WORK Providing and laying lime concrete on terrace/gutters/sunken floors upto 2nd flr. lvl. with graded brick agg. 25 mm nom. size and 50% lime mortar (1 lime putty: 2 surkhi)	cum	3.2	3906.51	12500.83	3.5.
6.	Providing and laying cement concrete 1:5:10 (1 cement: 5 coarse sand: 10 graded stone agg. 40 mm nom. size) in footings and bases for columns	cum	11.9	1349.82	16062.86	3.9. (a)
7.	Providing and laying cement concrete 1:5:10 (1 cement: 5 fine sand: 10 graded stone agg. 40 mm nom. size) in walls (any thickness) incl. plinth etc. upto 2nd flr. lvl.	cum	9.1	1349.82	12283.36	3.12.(b) + 3.26.
8.	Providing and laying DPC 40 mm thick with cement concrete 1:2:4 (1 cement : 2 coarse sand : 4 graded stone agg. 12.5 mm nom. size)	sqm	24.1	104.91	2528.33	3.29.
9.	Making plinth protection 50 mm thick of cement concrete 1:3:6 (1 cement : 3 coarse sand : 6 graded stone agg. 20 mm nom. size) over 75 mm bed of dry brick ballast 40 mm nom. size, well rammed, consolidated and grouted with fine sand incl. finishing the top smooth	sqm	49.00	266.61	13063.89	3.31.
			EEC for Concrete Work (EEC_2)		56439.27	
10.	RCC WORK RCC work with 1:2:4 (1 cement: 2 coarse sand: 4 graded stone agg.					

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
	20 mm nom. size) in rafts, bases of columns etc excl. reinforcement but incl. finishing and plastering the exposed surface with cement mortar 1:3 (1 cement: 3 fine sand) of thickness not exceeding 6mm to give a smooth and even surface	cum	0.30	2663.90	799.17	4.2.(a)
11.	RCC work with 1:2:4 (1 cement : 2 coarse sand : 4 graded stone agg. 20 mm nom. size) in roofs, landings and balconies excl. reinforcement but incl. finishing and plastering the exposed surface with cement mortar 1:3 (1 cement: 3 fine sand) of thickness not exceeding 6 mm to give a smooth and even surface					
	(a) Upto 1st flr. lvl.	cum	17.20	2836.10	48780.92	4.1.
	(b) From 1st flr. lvl. to 2nd flr. lvl.	cum	20.80	2836.10	58990.88	4.1. + 4.12.
12.	RCC work with 1:2:4 (1 cement : 2 coarse sand : 4 graded stone agg. 20 mm nom. size) in shelves excl. reinforcement but incl. finishing and plastering the exposed surface with cement mortar 1:3 (1 cement: 3 fine sand) of thickness not exceeding 6 mm to give a smooth and even surface					
	(a) Upto 1st flr. lvl.	cum	1.4	2836.10	3970.54	4.1.
	(b) From 1st flr. lvl. to 2nd flr. lvl.	cum	1.4	2836.10	3970.54	4.1. + 4.12.
13.	RCC work with 1:2:4 (1 cement : 2 coarse sand:4 graded stone agg. 20 mm nom. size) in lintels, beams, plinth beams and bressumers					

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
	excl. reinforcement but incl. finishing and plastering the exposed surface with cement mortar 1:3 (1cement: 3 fine sand) of thickness not exceeding 6 mm to give a smooth and even surface					
	(a) Upto 1st flr. lvl.	cum	2.10	2827.74	5938.25	4.2.(c)
	(b) From 1st flr. lvl. to 2nd flr. lvl.	cum	2.20	2827.74	6221.03	4.2.(c) + 4.12.
	(c) From 2nd flr. lvl. to 3rd flr. lvl.	cum	0.00	2827.74	0.00	4.2.(c) + 4.12.
14.	RCC work with 1:2:4 (1cement: 2 coarse sand: 4 graded stone agg. 20mm nom. size) in columns, pillars, piers, abutments, posts and struts excl. reinforcement but incl. finishing and plastering the exposes surface with cement mortar 1:3 (1 cement : 3 fine sand) of thickness not exceeding 6 mm to give a smooth and even surface					
	(a) Upto 1st flr. lvl.	cum	0.00	2827.74	0.00	4.2.(d)
	(b) From 1st flr. lvl. to 2nd flr. lvl.	cum	0.00	2827.74	0.00	4.2.(d) + 4.12.
	(c) From 2nd flr. lvl. to 3rd flr. lvl.	cum	0.00	2827.74	0.00	4.2.(d) + 4.12.
15.	RCC work with 1:2:4 (1 cement: 2 coarse sand: 4 graded stone agg. 20 mm nom. size) in stair-cases (excl. landings) except spiral staircase excl. reinforcement but incl. finishing and plastering the exposed surface with cement mortar 1:3 (1 cement: 3 fine sand)					

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
	of thickness not exceeding 6 mm to give a smooth and even surface, preparing of the top surface, finishing and nosing					
	(a) Upto 1st flr. lvl.	cum	1.20	2900.28	3480.34	4.2.(e)
	(b) From 1st flr. lvl. to 2nd flr. lvl.	cum	0.00	2900.28	0.00	4.2.(e) + 4.12.
16.	RCC work with 1:2:4 (1 cement: 2 coarse sand: 4 graded stone agg. 20 mm nom. size) in chajjas, facias and gutters excl. reinforcement but incl. finishing and plastering the exposed surface with cement mortar 1:3 (1cement: 3 fine sand) of thickness not exceeding 6 mm to give a smooth and even surface					
	(a) Upto 1st flr. lvl.	cum	0.90	3114.82	2803.34	4.5. + 4.12.
	(b) From 1st flr. lvl. to 2nd flr. lvl.	cum	0.40	3114.82	1245.93	4.5. + 4.12.
	(c) From 2nd flr. lvl. to 3rd flr. lvl.	cum	0.00	3114.82	0.00	4.5. + 4.12.
17.	Providing and laying RCC with 1:2:4 (1 cement: 2 coarse sand: 4 graded stone agg. 20 mm nom. size) in string courses, bands, copings, bed plates, anchor blocks, plain window sills and the like excl. reinforcement but incl. finishing and plastering the exposed surface with cement mortar 1:3 (1cement: 3 fine sand) of thickness not exceeding 6 mm to give a smooth and even surface					
	(a) Upto 1st flr. lvl.	cum	1.30	3032.67	3942.47	4.8.(b)+4.12.

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
	(b) From 1st flr. lvl. to 2nd flr. lvl.	cum	1.40	3032.67	4245.74	4.8.(b)+4.12
	(c) From 2nd flr. lvl. to 3rd flr. lvl.	cum	0.00	3032.67	0.00	4.8.(b)+4.12.
18.	Reinforcement for RCC work					
	(a) Mild steel and medium tensile steel bars	q	5.31	3360.00	17841.60	4.13.
	(b) Cold twisted bars	q	34.97	3360.00	117499.20	4.13.
			EEC for RCC Work (EEC$_3$)		**279729.95**	
	<u>FLOORING</u>					
19.	25 mm thick cement concrete flooring 1:2:4 (1 cement: 2 coarse sand: 4 graded stone agg. 12.5 mm nom. size) finished with a floating coat of neat cement incl. cement slurry, rounding off edges and strips etc	sqm	230.00	80.28	18464.40	5.4.
20.	18 mm thick cement plaster skirting (upto 30 cm height) with cement mortar 1:3 (1 cement : 3 coarse sand) finished with a floating coat of neat cement incl. rounding of junctions with floors	sqm	24.00	87.00	2088.00	5.10.(a)
21.	40 mm thick marble chips flooring, rubbed and polished to granolithic finish – under layer 31 mm thick cement concrete 1:2:4 (1 cement : 2 coarse sand : 4 graded stone agg. 12.5 mm nom. size)					

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
	and top layer 9 mm thick with white, black, chocolate, grey, yellow or Baroda green marble chips of sizes from 4 mm to 7 mm nom. size, laid in cement marble powder mix [3:1 (3 cement : 1 marble powder) by wt.] in proportion of 4:7 (4 cement marble powder mix : 7 marble chips by volume incl. cement slurry etc. complete, using dark shade pigment with ordinary cement	sqm	20.00	117.36	2347.20	5.13.(a)
22.	Providing and fixing glass strips in joints of terrazzo/cement concrete floors – 40 mm wide and 6 mm thick	m	40.00	11.79	471.60	5.17.(b)
23.	Providing and laying 25 mm thick burnt clay tiles 250 mm x 250 mm x 25 mm of approved quality over roofs with 1 cm side joints grouted with CM 1:3 (1 cement: 3 fine sand) over 15 mm thick bed of cement mortar 1:3 (1 cement: 3 fine sand) and finished neatly	sqm	99.60	125.75	12524.70	5.57
				EEC for Flooring (EEC_4)	**35895.90**	
	FINISHING					
24.	12 mm cement plaster 1:6 with cement mortar (1 cement: 6 fine sand)	sqm	665.00	24.12	16039.80	6.1.9.
25.	15 mm cement plaster on the rough side of single or half brick wall of mix 1:6 (1 cement : 6 fine sand)	sqm	665.00	28.81	19158.65	6.1.13.
26.	6 mm cement plaster of mix 1:3 (1 cement: 3 fine sand) finished with a floating coat of neat cement and thick coat of lime wash on top of walls when dry for bearing of RCC slabs and beams	sqm	64.20	39.34	2525.63	6.1.28.

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
27.	18 mm plastering with terrazzo finish for dado rubbed and polished complete – under layer 12 mm thick cement plaster 1:3 (1 cement: 3 coarse sand) and top layer 6 mm thick white, black, chocolate, grey, yellow or Baroda green marble chips of 3 mm and down size, laid in cement marble powder mix [3:1 (3 cement : 1 marble powder) by weight] in proportion of 4:7 (4 cement marble powder mix: 7 marble chips) by volume	sqm	47.80	49.21	2352.24	6.1.64.
28.	White washing with lime on new work (three or more coats) to give an even shade	sqm	875.00	1.95	1706.25	6.3.1.
29.	Colour washing such as green, blue or buff on new work (two or more coats) with a base coat of white washing with lime to give an even shade	sqm	875.00	1.95	1706.25	6.3.3.
	EEC for Finishing (EEC_5)				**43488.82**	
	$EEC_T = EEC_1 + EEC_2 + EEC_3 + EEC_4 + EEC_5$				**868669.46 MJ**	

Table III.1.13: EEC_T Estimate for Project No. 13 – a Double Storeyed Residence; a Unit of Four Dwellings (Total Plinth Area = 318.87 sqm; Total Floor Area = 265.26 sqm)

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
	MASONRY WORK					
1.	1st class brick work in foundation and plinth in cement mortar 1:6 (1 cement: 6 coarse sand)	cum	41.94	2641.75	110795.00	2.2.15.
2.	1st class brick work in superstructure above plinth in cement mortar 1:6 (1 cement: 6 coarse sand)	cum	122.75	2641.75	324274.81	2.2.15. + 2.2..17.
3.	Half brick masonry (1st class) in superstructure in cement mortar 1:3 (1 cement: 3 coarse sand) with hoop iron 25 mm x 1.6 mm at every 3rd course, embedded in the cement mortar	cum	1.64	3339.00	5475.96	2.2.33.(a) + 2.2.34.(a)
4.	Providing brick band 7.62 cm thick and 5.72 cm projected from wall face in 1st class brick work laid in cement mortar 1:4 (1 cement: 4 fine sand)	m	52.20	12.30	642.06	2.2.59.
	EEC for Masonry Work (EEC_1)				**441187.83**	
	CONCRETE WORK					
5.	Providing and laying cement concrete 1:6:12 (1 cement: 6 fine sand: 12 graded stone agg. 40 mm nom. size) in foundation	cum	19.36	1215.82	23538.27	3.14.(a)
6.	Concrete in roof terracing with 25 mm gauge brick ballast, white lime and surkhi in the proportion of 100:18:36	cum	11.36	3906.51	44377.95	3.5.

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
7.	25 mm DPC with cement concrete 1:2:4 (1 cement : 2 coarse sand: 4 stone agg. 10 mm nom. size)	sqm	28.97	65.57	1899.56	3.27.
8.	Providing and laying cement concrete 1:2:4 (1 cement: 2 fine sand: 4 graded stone agg. 20 mm nom. size) in steps	cum	0.77	2827.82	2177.42	3.20.(A)
	EEC for Concrete Work (EEC_2)				**71993.20**	
9.	RCC WORK RCC work 1:2:4 (1 cement : 2 coarse sand : 4 graded stone agg. 40 mm nom. size) excl. reinforcement, but incl. finishing of plastering the exposed surface with cement mortar 1:3 (1 cement: 3 fine sand) of thickness not exceeding 6 mm to give a smooth and even surface					
	(a) Slabs	cum	34.57	2836.10	98043.98	4.1.
	(b) Lintels	cum	4.25	2827.74	12017.90	4.2.(c)
	(c) Sunshades	cum	1.82	3114.82	5668.97	4.5.
	(d) Slabs of shelves	cum	0.53	2836.10	1503.13	4.1.
	(e) Staircase	cum	2.61	2900.28	7569.73	4.2.(e)
10.	Mild steel reinforcement bars incl. bending in RCC work	q	33.77	3360.00	113467.20	4.13.

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
				EEC for RCC Work (EEC_3)	**238270.91**	
	FLOORING					
11.	Cement concrete flooring 1:2:4 (1 cement: 2 coarse sand: 4 graded stone agg. 12.5 mm nom. size) finished with a floating coat of neat cement - 25 mm thick	sqm	268.81	80.28	21580.07	5.4.
12.	Cement plaster skirting (upto 30 cm height) with cement mortar 1:3 (1 cement: 3 coarse sand) finished with a floating coat of neat cement, incl. rounding of junctions with the floor - 18 mm thick	sqm	69.12	87.00	6013.44	5.10.(a)
13.	Dado 18 mm thick cement mortar 1:3 (1 cement: 3 coarse sand), finished with a floating coat of neat cement.	sqm	44.90	87.00	3906.30	5.10.(a)
				EEC for Flooring (EEC_4)	**31499.81**	
	FINISHING					
14.	12 mm plastering with cement mortar 1:6 (1 cement: 6 fine sand)	sqm	1255.57	24.12	30284.35	6.1.9.
15.	20 mm plastering in steps with cement mortar 1:3 (1 cement: 3 fine sand), finished with a floating coat of neat cement)	sqm	13.96	91.28	1274.27	6.1.26.
16.	White washing (3 coats) - inside	sqm	1190.35	1.95	2321.18	6.3.1.

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
17.	Colour washing (2 coats) over one coat of white washing - outside	sqm	398.44	1.95	776.96	6.3.3.
				EEC for Finishing (EEC_5)	**34656.76**	
				$EEC_T = EEC_1 + EEC_2 + EEC_3 + EEC_4 + EEC_5$	**817608.51 MJ**	

Table III.1.14: EEC_T Estimate for Project No.14 -- Staff Housing Complex of Indian Oil Corporation at Panchkula, Haryana (Total Plinth Area = 2046.00 sqm; Total Floor Area = 1719.00 sqm)

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
	<u>MASONRY WORK</u>					
1.	Providing and laying 1st class brick work in foundation and plinth in 1:6 cement mortar (1 cement : 6 fine sand)	cum	49.00	2641.75	129445.75	2.2.15.
2.	Providing and laying 1st class brick work in superstructure above plinth in cement mortar 1:6 (1 cement : 6 fine sand) for all flr. lvls.	cum	107.00	2641.75	282667.25	2.2.15.+ 2.2.17.+ 2.2.18.
3.	Providing and laying 1st class brick work on external facade in superstructure above and below plinth in cement mortar 1:6 (1 cement: 6 fine sand) for all flr. lvls., incl. making horizontal grooves 10 mm wide, 12 mm deep complete in all respects	cum	382.00	2641.75	1009148.50	2.2.15.+ 2.2.17. + 2.2.18.
4.	Providing and laying half brick masonry (1st class) in superstructure in cement mortar 1:3 cement mortar (1 cement: 3 coarse sand) for all flr. lvls. incl. hoop iron 25 mm x 1.6 mm flat on every 4th course embedded in cement mortar of 25 mm thickness	cum	127.57	3339.00	425956.23	2.2.33.(a) + 2.2.34.(a) + 2.2.34.(b)
	EEC for Masonry Work (EEC_1)				**1847217.73**	
	<u>CONCRETE WORK</u>					
5.	Providing and laying cement concrete in foundations, footings and bases for columns and under plinth					
	(a) 1:4:8 (1 cement: 4 coarse sand: 8 graded stone agg. 40 mm nom. size)	cum	69.00	1617.82	111629.58	3.8.(a)

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
	(b) 1:5:10 (1 cement: 5 coarse sand: 10 graded stone agg. 40 mm nom. size)	cum	43.00	1349.82	58042.26	3.12.(a)
6.	Providing and laying DPC 40 mm thick with cement concrete 1:2:4 (1 cement : 2 coarse sand : 4 graded stone agg. 12.5 mm nom. size)	sqm	37.00	104.91	3881.67	3.29.
	EEC for Concrete Work (EEC_2)				**173553.51**	
7.	RCC WORK Providing and laying RCC in 1:2:4 (1 cement: 2 coarse sand: 4 graded stone agg. 20 mm nom. size) in rafts footings, bases of columns etc. and mass concrete excl. reinforcement but incl. finishing and plastering the exposed surface with cement mortar 1:3 (1cement : 3 fine sand) of thickness not exceeding 6 mm to give a smooth and even surface	cum	119.00	2663.90	317004.10	4.2.(a)
8.	Providing and laying RCC work in 1:2:4 (1 cement: 2 coarse sand: 4 graded stone agg. 20 mm nom. size) work in suspended floors, roofs, landings and balconies/projections up to all flr. lvls. excl. reinforcement but incl. finishing and plastering the exposed surface with cement mortar 1:3 (1cement : 3 fine sand) of thickness not exceeding 6 mm to give a smooth and even surface	cum	265.00	2836.10	751566.50	4.1. + 4.12.
9.	Providing and laying RCC work in 1:2:4 (1 cement: 2 coarse sand: 4 graded stone agg. 20 mm nom. size) in columns, pillars, piers, abutments, posts and struts from top of footings to all flr. lvls. excl. reinforcement but incl. finishing and plastering the exposed surface with cement mortar 1:3 (1cement : 3 fine sand) of thickness not exceeding 6 mm to give a smooth and even surface	cum	122.00	2827.74	344984.28	4.2.(d)+ 4.12.

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
10.	Providing and laying RCC work in 1:2:4 (1 cement: 2 coarse sand: 4 graded stone agg. 20 mm nom. size) in shelves upto all flr. lvls excl. reinforcement but incl. finishing and plastering the exposed surface with cement mortar 1:3 (1cement : 3 fine sand) of thickness not exceeding 6 mm to give a smooth and even surface	cum	11.00	2836.10	31197.10	4.1. + 4.12.
11.	Providing and laying RCC work in 1:2:4 (1 cement: 2 coarse sand: 4 graded stone agg. 20 mm nom. size) in chajjas, facias upto all flr. lvls. excl. reinforcement but incl. finishing and plastering the exposed surface with cement mortar 1:3 (1cement : 3 fine sand) of thickness not exceeding 6 mm to give a smooth and even surface	cum	5.00	3114.82	15574.10	4.5. + 4.12.
12.	Providing and laying RCC work in 1:2:4 (1 cement: 2 coarse sand: 4 graded stone agg. 20 mm nom. size) in lintels, beams, plinth beams and bressumers upto all flr. lvls. excl. reinforcement but incl. finishing and plastering the exposed surface with cement mortar 1:3 (1cement: 3 fine sand) of thickness not exceeding 6 mm to give a smooth and even surface	cum	146.00	2827.74	412850.04	4.2.(c)+ 4.12.
13.	Providing and laying RCC work in 1:2:4 (1 cement: 2 coarse sand: 4 graded stone agg. 20 mm nom. size) in staircases (excl. landings) except spiral staircases excl. reinforcement but incl. finishing and plastering the exposed surface with cement mortar 1:3 (1cement : 3 fine sand) of thickness not exceeding 6 mm to give a smooth and even surface and preparing of the top surface and nosing upto all flr. lvls	cum	25.00	2900.28	72507.00	4.2.(e) + 4.12.
14.	Providing and laying reinforcement for RCC work incl. binding wire, etc.	q	676.00	3360.00	2271360.00	4.13.

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
			EEC for RCC Work (EEC_3)		4217043.12	
	FLOORING					
15.	Providing and laying 40 mm thick cement concrete flooring with 1:2:4 mix (1 cement: 2 coarse sand: 4 graded stone agg. 20 mm nom. size) finished with a floating coat of neat cement on top incl. cement slurry, rounding off edges and glass strips, in joints etc. complete in all respects	sqm	99.00	119.65	11845.35	5.5.(a)
16.	Providing and laying 21 mm thick cement plaster in dado or skirting (up to 2.1m height) with 1:3 cement mortar (1 cement: 3 coarse sand) laid in panels, finished with floating coat of neat cement incl. rounding of junctions with the floor	sqm	23.00	97.25	2236.75	5.10.(b)
17.	Providing and laying 40 mm thick marble chips flooring, rubbing and wax polishing to granolithic finish – under layer 30 mm thick cement concrete 1:2:4 (1 cement: 2 coarse sand: 4 graded stone agg. 12.5 mm nom. size) and top layer 10 mm thick with white and/or coloured marble chips, laid in cement marble powder mix [3:1 (3 cement: 1 marble powder) by wt.] in proportion of 4:7 (4 cement marble powder mix: 7 marble chips) by vol. incl. cement slurry in base etc. complete in all respects					
	(a) With ordinary cement	sqm	997.00	117.36	117007.92	5.13.(a)
	(b) With white cement and light shade pigment	sqm	374.00	117.36	43892.64	5.13.(b)
18.	Providing and laying 20 mm thick marble chips skirting and dado					

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
	(up to 2.1 m height), rubbing and wax polishing to granolithic finish – top layer 6mm thick with white or coloured marble chips of sizes from smallest to 4 mm nom. size laid in cement marble powder mix [3:1 (3 cement: 1 marble powder) by wt.] in proportion of 4:7 (4 cement marble powder mix: 7 marble chips) by vol., incl. rounding of junctions with the floor					
	(a) With white cement and light shade pigment	sqm	60.00	85.90	5154.00	5.15.B.(b)
	(b) With ordinary cement	sqm	572.00	85.90	49134.80	5.15.B.(a)
19.	Providing and laying 25 mm thick polished Kota stone slab flooring over 20 mm thick (av.) thick cement mortar 1:4 (1 cement: 4 coarse sand) laid in base and jointed with grey cement slurry mixed with pigment to match the shade of the slab	sqm	36.00	99.91	3596.76	5.34.(a)
20.	Providing and laying 25 mm thick polished Kota stone slab, same as above, but in single pieces for staircase risers and treads and steps in 12 mm base of cement mortar 1:3 (1 cement : 3 coarse sand)	sqm	192.00	92.10	17683.20	5.35.
21.	Providing and laying Kota stone slab, same as above, but in skirting	sqm	50.00	92.10	4605.00	5.35.
22.	Providing and fixing glass strips in joints of terrazzo floors, 40 mm wide and 4 mm thick	m	2948.00	11.79	34756.92	5.17.(a)
	EEC for Flooring (EEC_4)				**289913.34**	
	FINISHING					
23.	Providing 6 mm thick cement plaster 1:3 (1 cement : 3 coarse sand)					

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
	finished with a floating coat of neat cement and a coat of lime wash on top of walls when dry, for bearing the R.C.C. slabs and beam	sqm	288.00	39.34	11329.92	6.1.28.
24.	Providing 12 mm thick cement plaster 1:3 (1 cement : 3 fine sand : 3 coarse sand) on even surface of wall	sqm	2378.00	24.12	57357.36	6.1.32.
25.	Providing 20 mm thick cement plaster 1:3:3 (1 cement : 3 fine sand : 3 coarse sand) on the rough side of wall	sqm	2378.00	37.52	89222.56	6.1.41.
26.	White washing with lime on new work (3 or more) coats with approved quality of lime to give an even shade	sqm	9644.00	1.95	18805.80	6.3.1.
27.	Struck or weathered pointing on exposed brick work with cement mortar 1:3 (1 cement : 3 fine sand)	sqm	3153.00	10.25	32318.25	6.2.1.(c)
	EEC for Finishing (EEC_5)				**209033.89**	
	$EEC_T = EEC_1 + EEC_2 + EEC_3 + EEC_4 + EEC_5$				**6736761.59 MJ**	

TABLE III.1.15: EEC_T Estimate for Project No.15 - a Group of Fifteen Units (Eight Dwellings per Unit)
(Total Plinth Area = 8907.00 sqm; Total Floor Area = 7482.00 sqm)

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
	MASONRY WORK					
1.	1st class brick work in foundation and plinth in cement mortar 1:6 (1cement: 6 coase sand)	cum	440.00	2641.75	1162370.00	2.2.15.
2.	1st class brick work in superstructure above plinth in cement mortar 1:6 (1 cement: 6 coarse sand)					
	(a) Upto 1st flr. lvl.	cum	932.50	2641.75	2463431.87	2.2.15. + 2.2.17. + 2.2.18.
	(b) From 1st flr. lvl. to 2nd flr. lvl.	cum	1158.00	2641.75	3059146.50	2.2.15. + 2.2.18.
	(c) From 2nd flr. lvl. to 3rd flr. lvl.	cum	1158.00	2641.75	3059146.50	-DO-
	(d) From 3rd flr. lvl. to 4th flr. lvl.	cum	1158.00	2641.75	3059146.50	-DO-
3.	Half brick masonry (1st class) in foundation and plinth in cement mortar 1:4 (1 cement: 4 coarse sand)	cum	11.85	2855.61	33838.98	2.2.32.
4.	Half brick masonry (1st class) in superstructure in cement mortar 1:4 (1cement: 4 coarse sand)					
	(a) Upto 1st flr. lvl.	cum	31.65	2855.61	90380.06	2.2.32.+ 2.2..34(a)+ 2.2.34(b)
	(b) From 1st flr. lvl. to 2nd flr. lvl.	cum	34.50	2855.61	98518.55	2.2.32.+ 2.2.34(b)
	(c) From 2nd flr. lvl. to 3rd flr. lvl.	cum	34.50	2855.61	98518.55	-DO-
	(d) From 3rd flr. lvl. to 4th flr. lvl.	cum	34.50	2855.61	98518.55	-DO-

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
5.	Half brick masonry (1st class) in superstructure in cement mortar 1:3 (1cement: 3 coarse sand)	cum	45.50	3069.52	139663.16	2.2.31 + 2.2.34. (a)
	EEC for Masonry Work (EEC_1)				**13362679.22**	
6.	CONCRETE WORK Providing and laying lime concrete on terrace/gutters/sunken floors upto 2nd flr. lvl. with graded brick agg. 25 mm nom. size and 50% lime mortar (1 lime putty: 2 surkhi)	cum	48.00	3906.51	187512.48	3.5.
7.	Providing and laying cement concrete 1:5:10 (1 cement: 5 coarse sand: 10 graded stone agg. 40 mm nom. size) in footings and bases for columns	cum	178.50	1349.82	240942.87	3.9. (a)
8.	Providing and laying cement concrete 1:6:12 (1 cement: 6 coarse sand: 12 graded stone agg. 40 mm nom. size) in foundation	cum	42.00	1215.82	51064.44	3.14.(a)
9.	Providing and laying cement concrete 1:5:10 (1 cement: 5 fine sand: 10 graded stone agg. 40 mm nom. size) in walls (any thickness) incl. plinth etc. upto 2nd flr. lvl.	cum	136.50	1349.82	184250.43	3.12.(b) + 3.26.
10.	Providing and laying DPC 40 mm thick with cement concrete 1:2:4 (1 cement : 2 coarse sand : 4 graded stone agg. 12.5 mm nom. size)	sqm	361.50	104.91	37924.97	3.29.
11.	Making plinth protection 50 mm thick of cement concrete 1:3:6 (1 cement : 3 coarse sand : 6 graded stone agg. 20 mm nom. size) over 75 mm bed of dry brick ballast 40 mm nom. size, well rammed, consolidated and grouted with fine sand incl. finishing the top smooth	sqm	735.00	266.61	195958.35	3.31.

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
	EEC for Concrete Work (EEC_2)				**897653.54**	
	<u>RCC WORK</u>					
12.	RCC work with 1:2:4 (1 cement: 2 coarse sand: 4 graded stone agg.20 mm nom. size) in rafts, bases of columns etc. excl. reinforcement but incl. finishing and plastering the exposed surface with cement mortar 1:3 (1 cement: 3 fine sand) of thickness not exceeding 6 mm to give a smooth and even surface	cum	4.50	2663.90	11987.55	4.2.(a)
13.	RCC work with 1:2:4 (1 cement : 2 coarse sand : 4 graded stone agg. 20 mm nom. size) in roofs, landings and balconies excl. reinforcement but incl. finishing and plastering the exposed surface with cement mortar 1:3 (1 cement: 3 fine sand) of thickness not exceeding 6 mm to give a smooth and even surface					
	(a) Upto 1st flr. lvl.	cum	258.00	2836.10	731713.80	4.1.
	(b) From 1st flr. lvl. to 2nd flr. lvl.	cum	312.00	2836.10	884863.20	4.1.+ 4.12.
	(c) From 2nd flr. lvl. to 3rd flr. lvl.	cum	312.00	2836.10	884863.20	4.1.+ 4.12.
	(d) From 3rd flr. lvl. to 4th flr. lvl.	cum	312.00	2836.10	884863.20	4.1. + 4.12.
14.	RCC work with 1:2:4 (1 cement : 2 coarse sand : 4 graded stone agg. 20 mm nom. size) in shelves excl. reinforcement but incl. finishing and plastering the exposed surface with cement mortar 1:3 (1 cement: 3 fine sand) of thickness not exceeding 6 mm to give a smooth and even surface					
	(a) Upto 1st flr. lvl.	cum	21.00	2836.10	59558.10	4.1.

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
	(b) From 1st flr. lvl. to 2nd flr. lvl.	cum	21.00	2836.10	59558.10	4.1.
	(c) From 2nd flr. lvl. to 3rd flr. lvl.	cum	21.00	2836.10	59558.10	4.1.+ 4.12.
	(d) From 3rd flr. lvl. to 4th flr. lvl.	cum	21.00	2836.10	59558.10	4.1. + 4.12.
15.	RCC work with 1:2:4 (1 cement : 2 coarse sand:4 graded stone agg. 20mm nom. size) in lintels, beams, plinth beams and bressumers excl. reinforcement but incl. finishing and plastering the exposed surface with cement mortar 1:3 (1cement: 3 fine sand) of thickness not exceeding 6 mm to give a smooth and even surface					
	(a) Upto 1st flr. lvl.	cum	31.50	2827.74	89073.81	4.2.(c)
	(b) From 1st flr. lvl. to 2nd flr. lvl.	cum	33.00	2827.74	93315.42	4.2.(c) + 4.12.
	(c) From 2nd flr. lvl. to 3rd flr. lvl.	cum	33.00	2827.74	93315.42	4.2.(c) + 4.12.
	(d) From 3rd flr. lvl. to 4th flr. lvl.	cum	33.00	2827.74	93315.42	4.2.(c) + 4.12.
16.	RCC work with 1:2:4 (1 cement: 2 coarse sand: 4 graded stone agg. 20 mm nom. size) in staircases (excl. landings) except spiral staircases excl. reinforcement but incl. finishing and plastering the exposed surface with cement mortar 1:3 (1cement:3 fine sand) of thickness not exceeding 6 mm to give a smooth and even surface, preparing of the top surface and nosing					
	(a) Upto 1st flr. lvl.	cum	18.00	2900.28	52205.04	4.2.(e)
	(b) From 1st flr. lvl. to 2nd flr. lvl.	cum	18.00	2900.28	52205.04	4.2.(e) + 4.12.
	(c) From 2nd flr. lvl. to 3rd flr. lvl.	cum	18.00	2900.28	52205.04	4.2.(e) + 4.12.

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
17.	RCC work with 1:2:4 (1 cement: 2 coarse sand: 4 graded stone agg. 20 mm nom. size) in chajjas, facias and gutters excl. reinforcement but incl. finishing and plastering the exposed surface with cement mortar 1:3 (1cement: 3 fine sand) of thickness not exceeding 6 mm to give a smooth and even surface					
	(a) Upto 1^{st} flr. lvl.	cum	13.50	3114.82	42050.07	4.5. + 4.12.
	(b) From 1^{st} flr. lvl. to 2^{nd} flr. lvl.	cum	6.00	3114.82	18688.92	4.5. + 4.12.
	(c) From 2^{nd} flr. lvl. to 3^{rd} flr. lvl.	cum	6.00	3114.82	18688.92	4.5.+ 4.12.
	(d) From 3^{rd} flr. lvl. to 4^{th} flr. lvl.	cum	6.00	3114.82	18688.92	4.5. + 4.12.
18.	Providing and laying RCC with 1:2:4 (1 cement: 2 coarse sand: 4 graded stone agg. 20 mm nom. size) in string courses, bands, copings, bed plates, anchor blocks, plain window sills and the like excl. reinforcement but incl. finishing and plastering the exposed surface with cement mortar 1:3 (1cement : 3 fine sand) of thickness not exceeding 6 mm to give a smooth and even surface					
	(a) Upto 1^{st} flr. lvl.	cum	19.50	3032.67	59137.07	4.8.(b)+4.12.
	(b) From 1^{st} flr. lvl. to 2^{nd} flr. lvl.	cum	21.00	3032.67	63686.07	4.8.(b)+4.12
	(c) From 2^{nd} flr. lvl. to 3^{rd} flr. lvl.	cum	21.00	3032.67	63686.07	4.8.(b)+4.12.
	(d) From 3^{rd} flr. lvl. to 4^{th} flr. lvl.	cum	21.00	3032.67	63686.07	4.8.(b)+4.12.

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
19.	Reinforcement for RCC work					
	(a) Mild steel and medium tensile steel bars	q	159.30	3360.00	535248.00	4.13.
	(b) Cold twisted bars	q	1049.10	3360.00	3524976.00	4.13.
				EEC for RCC Work (EEC_3)	**8570694.65**	
	FLOORING					
20.	25 mm thick cement concrete flooring 1:2:4 (1 cement : 2 coarse sand: 4 graded stone agg. 12.5 mm nom. size) finished with a floating coat of neat cement incl. cement slurry, rounding off edges and strips etc.	sqm	6900.00	80.28	553932.00	5.4.
21.	40 mm thick cement concrete flooring 1:2:4 (1 cement : 2 coarse sand: 4 graded stone agg. 20 mm nom. size) finished with a floating coat of neat cement incl. cement slurry, rounding off edges and strips etc.	sqm	472.50	119.65	56534.62	5.5.(a)
22.	18 mm thick cement plaster skirting (upto 30 cm height) with cement mortar 1:3 (1 cement : 3 coarse sand) finished with a floating coat of neat cement incl. rounding of junctions with floors	sqm	720.00	87.00	62640.00	5.10.(a)
23.	40 mm thick marble chips flooring, rubbed and polished to granolithic finish – under layer 31 mm thick cement concrete 1:2:4 (1 cement : 2 coarse sand : 4 graded stone agg. 12.5 mm nom. size) and top layer 9 mm thick with white, black, chocolate, grey, yellow or Baroda green marble chips of sizes from 4 mm to 7 mm nom. size, laid in cement marble powder mix [3:1 (3 cement : 1 marble powder) by wt.] in proportion of 4:7 (4 cement marble powder mix : 7 marble					

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
	chips by volume incl. cement slurry etc. complete, using dark shade pigment with ordinary cement	sqm	600.00	117.36	70416.00	5.13.(a)
24.	Providing and fixing glass strips in joints of terrazzo/cement concrete floors – 40 mm wide and 6 mm thick	m	1200.00	11.79	14148.00	5.17.(b)
25.	Providing and laying 25 mm thick burnt clay tiles 250 mm x 250 mm x 25 mm of approved quality over roofs with 1 cm side joints grouted with CM 1:3 (1 cement : 3 fine sand) over 15 mm thick bed of cement mortar1:3 (1 cement : 3 fine sand) and finished neat	sqm	1494.00	125.75	187870.50	5.57.
				EEC for Flooring (EEC_4)	**945541.12**	
	FINISHING					
26.	12 mm cement plaster 1:6 with cement mortar (1 cement: 6 fine sand)	sqm	20531.00	24.12	495207.72	6.1.9.
27.	15 mm cement plaster on the rough side of single or half brick wall of mix 1:6 (1 cement : 6 fine sand)	sqm	19950.00	28.81	574759.50	6.1.13.
28.	6 mm cement plaster of mix 1:3 (1 cement: 3 fine sand) finished with a floating coat of neat cement and thick coat of lime wash on top of walls when dry, for bearing of RCC slabs and beams	sqm	1926.00	39.34	75768.84	6.1.28.
29.	18 mm plastering with terrazzo finish for dados, rubbed and polished complete – under layer 12 mm thick cement plaster 1:3 (1 cement: 3 coarse sand) and top layer 6 mm thick white, black, chocolate, grey, yellow or Baroda green marble chips of 3 mm and down size, laid in cement marble powder mix [3:1 (3 cement : 1 marble powder) by weight] in proportion of 4:7 (4 cement marble powder mix: 7 marble chips) by volume	sqm	1434.00	49.21	70567.14	6.1.64.

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
30.	White washing with lime on new work (three or more coats) to give an even shade	sqm	26820.50	1.95	52299.97	6.3.1.
31.	Colour washing such as green, blue or buff on new work (two or more coats) with a base coat of white washing with lime to give an even shade	sqm	26250.00	1.95	51187.50	6.3.3.
	EEC for Finishing (EEC_5)				**1319790.67**	
	$EEC_T = EEC_1 + EEC_2 + EEC_3 + EEC_4 + EEC_5$				**25096359.20 MJ**	

Table III.1.16: EEC_T Estimate for Project No.16 - I.R.W.O.* Housing, Rail Vihar, Sector 33, Noida
(Total Plinth Area = 16680.00 sqm; Total Floor Area = 14008.00 sqm)

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
	MASONRY WORK					
1.	1st class brick work in foundation and plinth in cement mortar 1:6 (1 cement : 6 coarse sand)	cum	1250.00	2641.75	3302187.50	2.2.15.
2.	(a) 1st class brick work in superstructure above plinth in cement mortar 1:4 (1 cement: 4 coarse sand) up to 1st flr. lvl.	cum	1060.00	2859.50	3031070.00	2.2.13.+ 2.2.17.+2.2.18.
	(b) Same as above but for 1st flr. to 2nd flr. lvl. with cement mortar 1:6 (1 cement: 6 coarse sand)	cum	1060.00	2641.75	2800255.00	2.2.15. + 2.2.18.
	(c) Same as above but for 2nd flr. to 3rd flr. lvl. with cement mortar 1:6 (1 cement: 6 coarse sand)	cum	1060.00	2641.75	2800255.00	2.2.15. + 2.2.18.
	(d) Same as above but for 3rd flr. to 4th flr. lvl. with cement mortar 1:6 (1 cement: 6 coarse sand)	cum	1060.00	2641.75	2800255.00	2.2.15. + 2.2.18.
	(e) Same as above but for 4th flr. to 5th flr. lvl. with cement mortar 1:6 (1 cement: 6 coarse sand)	cum	560.00	2641.75	1479380.00	2.2.15. + 2.2.18.
3.	Extra for brick work curved on plan up to a mean radius not exceeding 6 m	cum	95.00	162.00	15390.00	2.2.21.
4.	Half brick masonry (1st class) in foundation and plinth in cement mortar 1:4 (1 cement: 4 coarse sand)	cum	95.76	2855.61	273453.21	2.2.32.

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
5.	Half brick masonry (1st class) in superstructure from plinth in cement mortar 1:4 (1 cement: 4 coarse sand) incl. 2 nos. 6 mm ⌀ mild steel bars at every third course					
	(a) Upto 1st flr. lvl.	cum	376.20	3349.63	1260130.81	2.2.33.(b) + 2.2.34.(a) + 2.2.34.(b)
	(b) Same as above but for 1st flr. to 2nd flr. lvl.	cum	376.20	3349.63	1260130.81	2.2.33.(b) + 2.2.34.(b)
	(c) Same as above but for 2nd flr. to 3rd flr. lvl.	cum	376.20	3349.63	1260130.81	-DO-
	(d) Same as above but for 3rd flr. to 4th flr. lvl.	cum	376.20	3349.63	1260130.81	-DO-
	(e) Same as above but for 4th flr. to 5th flr. lvl.	cum	14.82	3349.63	49641.52	-DO-
6.	Extra for making tapered surface of brick masonry for steps	sqm	140.00	86.13	12058.20	2.2.52.
				EEC for Masonry Work (EEC$_1$)	**21604468.67**	
	CONCRETE WORK					
7.	Providing and laying cement concrete 1:5:10 (1 cement: 5 fine sand: 10 graded stone agg. 40 mm nom. size) in walls (any thickness) incl. plinth etc. upto 2nd flr. lvl.	cum	855.28	1349.82	1154474.05	3.12.(b) + 3.26.
8.	Providing and laying DPC 40 mm thick with cement concrete 1:2:4 (1 cement : 2 coarse sand : 4 graded stone agg. 12.5 mm nom. size)	sqm	1072.24	104.91	112488.70	3.29.
9.	Making plinth protection 50 mm thick of cement concrete 1:3:6					

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
	(1 cement: 3 coarse sand: 6 graded stone agg. 20 mm nom. size) over 75 mm bed of dry brick ballast 40 mm nom. size, well rammed and consolidated and grouted with fine sand incl. finishing the top smooth	sqm	1160.00	266.61	309267.60	3.31.
				EEC for Concrete Work (EEC_2)	**1576230.35**	
	RCC WORK					
10.	RCC work with 1:2:4 (1 cement: 2 coarse sand: 4 graded stone agg. 20 mm nom. size) in slabs & beams of rafts, footings, bases of columns etc. and mass concrete excl. reinforcement but incl. finishing and plastering the exposed surface with cement mortar 1:3 (1cement: 3 fine sand) of thickness not exceeding 6 mm to give a smooth and even surface	cum	375.00	2663.90	998962.50	4.2.(a)
11.	RCC work with 1:2:4 (1 cement: 2 coarse sand: 4 graded stone agg. 20 mm nom. size) in walls (any thickness) incl. attached pilasters, buttresses, plinth and string courses, fillets etc. excl. reinforcement but incl. finishing and plastering the exposed surface with cement mortar 1:3 (1 cement: 3 fine sand) of thickness not exceeding 6 mm to give a smooth and even surface					
	(a) Upto 1^{st} flr. lvl.	cum	2.00	2760.67	5521.34	4.2.(b)
	(b) 1^{st} flr. to 2^{nd} flr. lvl.	cum	2.00	2760.67	5521.34	4.2.(b) + 4.12.
	(c) 2^{nd} flr. to 3^{rd} flr. lvl.	cum	2.00	2760.67	5521.34	4.2.(b)+ 4.12.

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
	(d) 3rd flr. to 4th flr. lvl.	cum	2.00	2760.67	5521.34	4.2.(b) + 4.12.
	(e) 4th flr. to 5th flr. lvl.	cum	5.00	2760.67	13803.35	4.2.(b) + 4.12.
12.	RCC work with 1:2:4 (1 cement: 2 coarse sand: 4 graded stone agg. 20 mm nom. size) in suspended floors, roofs, landings and balconies excl. reinforcement but incl. finishing and plastering the exposed surface with cement mortar 1:3 (1 cement: 3 fine sand) of thickness not exceeding 6 mm to give a smooth and even surface					
	(a) Upto 1st flr. lvl.	cum	422.00	2836.10	1196834.20	4.1.
	(b) 1st flr. to 2nd flr. lvl.	cum	422.00	2836.10	1196834.20	4.1. + 4.12.
	(c) 2nd flr. to 3rd flr. lvl.	cum	422.00	2836.10	1196834.20	4.1. + 4.12.
	(d) 3rd flr. to 4th flr. lvl.	cum	422.00	2836.10	1196834.20	4.1. + 4.12.
	(e) 4th flr. to 5th flr. lvl.	cum	35.00	2836.10	99263.50	4.1. + 4.12.
13.	RCC work with 1:2:4 (1 cement: 2 coarse sand: 4 graded stone agg. 20 mm nom. size) in shelves excl. reinforcement but incl. finishing and plastering the exposed surface with cement mortar 1:3 (1 cement: 3 fine sand) of thickness not exceeding 6 mm to give a smooth and even surface					
	(a) Upto 1st flr. lvl.	cum	35.00	2836.10	99263.50	4.1.
	(b) 1st flr. to 2nd flr. lvl.	cum	35.00	2836.10	99263.50	4.1. + 4.12.
	(c) 2nd flr. to 3rd flr. lvl.	cum	35.00	2836.10	99263.50	4.1. + 4.12.
	(d) 3rd flr. to 4th flr. lvl.	cum	35.00	2836.10	99263.50	4.1. + 4.12.

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
14.	RCC work with 1:2:4 (1 cement : 2 coarse sand : 4 graded stone agg. 20 mm nom. size) in chajjas excl. reinforcement but incl. finishing and plastering the exposed surface with cement mortar 1:3 (1 cement: 3 fine sand) of thickness not exceeding 6 mm to give a smooth and even surface					
	(a) Upto 1st flr. lvl.	cum	20.00	3114.82	62296.40	4.5. + 4.12.
	(b) 1st flr. to 2nd flr. lvl.	cum	20.00	3114.82	62296.40	4.5. + 4.12.
	(c) 2nd flr. to 3rd flr. lvl.	cum	20.00	3114.82	62296.40	4.5. + 4.12.
	(d) 3rd flr. to 4th flr. lvl.	cum	20.00	3114.82	62296.40	4.5. + 4.12.
15.	RCC work with 1:2:4 (1 cement: 2 coarse sand: 4 graded stone agg. 20 mm nom. size) in lintels, beams, plinth beams and bressumers excl. reinforcement but incl. finishing and plastering the exposed surface with cement mortar 1:3 (1 cement: 3 fine sand) of thickness not exceeding 6 mm to give a smooth and even surface					
	(a) Upto 1st flr. lvl.	cum	200.00	2827.74	565548.00	4.2.(c)
	(b) 1st flr. to 2nd flr. lvl.	cum	200.00	2827.74	565548.00	4.2.(c) + 4.12.
	(c) 2nd flr. to 3rd flr. lvl.	cum	200.00	2827.74	565548.00	4.2.(c) + 4.12.
	(d) 3rd flr. to 4th flr. lvl.	cum	200.00	2827.74	565548.00	4.2.(c) + 4.12.
	(e) 4th flr. to 5th flr. lvl.	cum	20.00	2827.74	56554.80	4.2.(c) + 4.12.

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
16.	RCC work with 1:2:4 (1 cement: 2 coarse sand: 4 graded stone agg. 20mm nom. size) in columns, pillars, piers, abutments, posts & struts excl. reinforcement but incl. finishing and plastering the exposed surface with cement mortar 1:3 (1 cement: 3 fine sand) of thickness not exceeding 6 mm to give a smooth and even surface					
	(a) Upto 1^{st} flr. lvl.	cum	85.00	2827.74	240357.90	4.2.(d)
	(b) 1^{st} flr. to 2^{nd} flr. lvl.	cum	62.00	2827.74	175319.88	4.2.(d) + 4.12.
	(c) 2^{nd} flr. to 3^{rd} flr. lvl.	cum	62.00	2827.74	175319.88	4.2.(d) + 4.12.
	(d) 3^{rd} flr. to 4^{th} flr. lvl.	cum	62.00	2827.74	175319.88	4.2.(d) + 4.12.
	(e) 4^{th} flr. to 5^{th} flr. lvl.	cum	5.00	2827.74	14138.70	4.2.(d) + 4.12.
17.	RCC work with 1:2:4 (1 cement: 2 coarse sand: 4 graded stone agg. 20 mm nom. size) in staircases (excl. landings) except spiral staircases excl. reinforcement but incl. finishing and plastering the exposed surface with cement mortar 1:3 (1 cement: 3 fine sand) of thickness not exceeding 6 mm to give a smooth and even surface, preparing of the top surface and nosing					
	(a) Upto 1^{st} flr. lvl.	cum	18.00	2900.28	52205.04	4.2.(e)
	(b) 1^{st} flr. to 2^{nd} flr. lvl.	cum	18.00	2900.28	52205.04	4.2.(e) + 4.12.
	(c) 2^{nd} flr. to 3^{rd} flr. lvl.	cum	18.00	2900.28	52205.04	4.2.(e) + 4.12.
	(d) 3^{rd} flr. to 4^{th} flr. lvl.	cum	18.00	2900.28	52205.04	4.2.(e) + 4.12.

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
18.	RCC work with 1:2:4 (1 cement: 2 coarse sand: 4 graded stone agg. 20 mm nom. size) in vertical and horizontal fins individually or forming box louvers and facias excl. reinforcement but incl. finishing and plastering the exposed surface with cement mortar 1:3 (1cement: 3 fine sand) of thickness not exceeding 6 mm to give a smooth and even surface					
	(a) Upto 1st flr. lvl.	cum	10.00	3647.82	36478.20	4.2.(k)
	(b) 1st flr. to 2nd flr. lvl.	cum	10.00	3647.82	36478.20	4.2.(k) + 4.12.
	(c) 2nd flr. to 3rd flr. lvl.	cum	10.00	3647.82	36478.20	4.2.(k) + 4.12.
	(d) 3rd flr. to 4th flr. lvl.	cum	10.00	3647.82	36478.20	4.2.(k) + 4.12.
19.	Providing and laying RCC with 1:2:4 (1 cement: 2 coarse sand: 4 graded stone agg. 20 mm nom. size) in string courses, bands, copings, bed plates, anchor blocks, plain window sills and the like excl. reinforcement but incl. finishing and plastering the exposed surface with cement mortar 1:3 (1 cement: 3 fine sand) of thickness not exceeding 6 mm to give a smooth and even surface					
	(a) Upto 1st flr. lvl.	cum	48.00	3032.67	145568.16	4.8.(b) + 4.12.
	(b) 1st flr. to 2nd flr. lvl.	cum	48.00	3032.67	145568.16	4.8.(b) + 4.12.
	(c) 2nd flr. to 3rd flr. lvl.	cum	48.00	3032.67	145568.16	4.8.(b) + 4.12.
	(d) 3rd flr. to 4th flr. lvl.	cum	48.00	3032.67	145568.16	4.8.(b) + 4.12.

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
20.	Reinforcement for RCC work incl. straightening of bars, bending, binding and placing in position complete					
	(a) Mild steel and medium tensile steel bars	q	80.00	3360.00	268800.00	4.13.
	(b) Cold twisted bars	q	4250.00	3360.00	14280000.00	4.13.
				EEC for RCC Work (EEC_3)	**25152699.75**	
	<u>FLOORING</u>					
21.	40 mm thick cement concrete flooring 1:2:4 (1 cement: 2 coarse sand: 4 graded stone agg. 20 mm nom. size.), finished with a floating coat of neat cement slurry incl. rounding off edges and strips etc. but excl. the nosing of steps etc. complete	sqm	740.00	119.65	88541.00	5.5.(a)
22.	Cement plaster skirting (upto 30 cm height) with cement mortar 1:3 (1 cement: 3 coarse sand), finished with a floating coat of neat cement incl. rounding of junctions with floor where required -18 mm thick	sqm	165.00	87.00	14355.00	5.10.(a)
23.	40 mm thick marble chips flooring rubbed and polished to granolithic finish – under layer 34 mm thick cement concrete 1:2:4 (1 cement: 2 coarse sand : 4 graded stone agg. 12.5 mm nom. size) and top layer 6 mm thick with white, black, chocolate grey, yellow or Baroda green marble chips of sizes from 1 mm to 4 mm nom. size, laid in cement marble powder mix [3.1 (3 cement : 1 marble powder) by wt.] in proportion of 4:7 (4 cement: marble powder mix: 7 marble chips) by vol. incl. cement slurry etc. complete					

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
	(a) Using ordinary cement without any pigment	sqm	8000.00	116.47	931760.00	5.12.(f)
	(b) Using white cement without any pigment	sqm	4070.00	116.47	474032.90	5.12.(d)
24.	Marble chips skirting (up to 30 cm height) 18 mm thick rubbed and polished to granolithic finish – top layer 6 mm thick with white, black, chocolate grey, yellow or Baroda green marble chips of sizes from smallest to 4 mm nom. size laid in cement marble powder mix [3:1 (3 cement: 1 marble powder) by wt.] in proportion of 4:7 (4 cement marble powder mix: 7 marble chips) by vol., 18mm thick with under layer 12 mm thick in cement plaster 1:3 (1 cement: 3 coarse sand)					
	(a) Using ordinary cement without any pigment	sqm	1200.00	86.60	103920.00	5.15.A.(f)
	(b) Using white cement without any pigment	sqm	400.00	86.60	34640.00	5.15.A.(d)
25.	Providing and fixing glass strips in joints of terrazzo/cement concrete floors 40 mm wide and 4 mm thick	m	12200.00	11.79	143838.00	5.17.(a)
26.	Polished white Makrana marble kitchen counter top 25 mm thick over 20 mm av. thick base of cement mortar 1:4 (1 cement: 4 coarse sand) laid & jointed with white/coloured cement slurry	sqm	550.00	90.53	49791.50	5.29.(a)
27.	Kota stone slab flooring 30 mm thick, over 20 mm thick (av.) base laid over & jointed with grey cement slurry mixed with pigment to match the shade of the slab incl. rubbing & polishing complete - 30 mm thick in 1:4 (1 cement: 4 coarse sand) mortar	sqm	1200.00	104.92	125904.00	5.33.(b)

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
28.	Kota stone slabs 25 mm thick in risers of steps, skirting, dado and pillars laid on 12 mm (av.) thick cement mortar 1:3 (1 cement: 3 coarse sand) and jointed with grey cement slurry mixed with pigment to match shade of slabs, incl. rubbing and polishing complete	sqm	190.00	92.10	17499.00	5.35.
29.	Providing and laying 30 mm thick machine cut Bhanslana marble stone tiles of first quality, on flooring and skirting, over 20 mm thick base of cement mortar 1:4 (1 cement: 4 coarse sand), jointed with cement slurry	sqm	1320.00	91.33	120555.60	5.29.(k)
				EEC for Flooring (EEC_4)	**2104837.00**	
	FINISHING					
30.	12 mm cement plaster of mix 1:6 (1 cement: 6 fine sand)	sqm	23400.00	24.12	564408.00	6.1.9.
31.	15 mm cement plaster of mix 1:6 (1 cement: 6 fine sand) on rough side of single or half brick wall	sqm	28500.00	28.81	821085.00	6.1.13.
32.	Rough cast plaster with a mixture of sand and gravel or crushed stone from 2.36 mm to 6 mm nom. size dashed over and incl. the fresh plaster in two layers – under layer 12 mm cement plaster 1:4 (1 cement : 4 coarse sand) and top layer 10 mm cement plaster 1:3 (1 cement: 3 fine sand) and providing grooves	sqm	17900.00	77.67	1390293.00	6.1.5.+ 6.1.30.
33.	18 mm cement plaster in sunken areas of toilet/kitchens, in two coats – under layer 12mm thick cement plaster 1:5 (1 cement : 5 coarse sand) finished with a top layer 6 mm thick cement plaster 1:6 (1 cement: 6 fine sand)	sqm	3150.00	41.97	132205.50	6.1.20. + 6.1.31.

S.No.	Item of Work	Unit	Quantity	EER in MJ/Unit	EEC in MJ	Schedule of EER Item Code No.
34.	Color washing such as green, blue or buff on new work (two or more coats), with a base coat of white washing with lime to give an even shade	sqm	51900.00	1.95	101205.00	6.3.3.
35.	White washing with lime new work (three or more coats) to give an even shade	sqm	15200.00	1.95	29640.00	6.3.1.
				EEC for Finishing (EEC_5)	**3038836.50**	
				$EEC_T = EEC_1 + EEC_2 + EEC_3 + EEC_4 + EEC_5$	**53477069.35 MJ**	

Table III.2.1: TEC_T[1] Estimate for Project No. 1

S.No.	Item of Work	Unit	Quantity	TER[2] in MJ/Unit	TEC[3] in MJ	Schedule of TER Item Code No.
1.	Brick Masonry Work	cum	23.12	69.12	1598.05	7.1.1.(a)
				TEC for Masonry Work (TEC_1)	**1598.05**	
2.	Concrete Work					
	(a) Concrete work	cum	4.56	80.64	367.72	7.2.1.
	– with stone agg.	cum	1.96	66.24	129.83	7.2.2.
	– with brick agg.	sqm	5.92	2.02	11.96	7.2.3.(a)
	(b) DPC (25 mm thick)					
				TEC for Concrete Work (TEC_2)	**509.51**	
3.	RCC Work	cum	4.92	90.00	442.80	7.3.
				TEC for RCC Work (TEC_3)	**442.80**	
4.	Flooring					
	(a) Cement concrete flooring - 25 mm thick	sqm	24.37	2.02	49.23	7.4.1.(a)

[1] TEC_T – Total Transport Energy Cost for a project
[2] TER – Transport Energy Rate for an item of work
[3] TEC - Transport Energy Cost for an item of work or sub-work

S.No.	Item of Work	Unit	Quantity	TER in MJ/Unit	TEC in MJ	Schedule of TER Item Code No.
	TEC for Flooring (TEC_4)				**49.23**	
5.	Finishing					
	(a) Plastering					
	– 12 mm thick	sqm	151.54	0.90	136.39	7.5.1.(c)
	– 20 mm thick	sqm	2.37	1.49	3.53	7.5.1.(f)
	(b) White washing and colour washing	sqm	170.56	0.01	1.71	7.5.3.
	TEC for Finishing (TEC_5)				**141.63**	
	$TEC_T = TEC_1 + TEC_2 + TEC_3 + TEC_4 + TEC_5$				**2741.22 MJ**	

Table III.2.2: TEC_T Estimate for Project No. 2

S.No.	Item of Work	Unit	Quantity	TER in MJ/Unit	TEC in MJ	Schedule of TER Item Code No.
1.	Brick Masonry Work	cum	39.87	69.12	2755.81	7.1.1.(a)
				TEC for Masonry Work (TEC_1)	**2755.81**	
2.	Concrete Work					
	(a) Concrete work					
	– with stone agg.	cum	6.78	80.64	546.74	7.2.1.
	– with brick agg.	cum	3.71	66.24	245.75	7.2.2.
	(b) DPC (25 mm thick)	sqm	8.72	2.02	17.61	7.2.3.(a)
				TEC for Concrete Work (TEC_2)	**810.10**	
3.	RCC Work	cum	5.76	90.00	518.40	7.3.
				TEC for RCC Work (TEC_3)	**518.40**	
4.	Flooring					
	(a) Cement concrete flooring - 25 mm thick	sqm	1.22	2.02	2.46	7.4.1.(a)
	(b) Cement concrete flooring - 40 mm thick	sqm	36.35	3.24	117.77	7.4.1.(b)
				TEC for Flooring (TEC_4)	**120.23**	

S.No.	Item of Work	Unit	Quantity	TER in MJ/Unit	TEC in MJ	Schedule of TER Item Code No.
5.	Finishing					
	(a) Plastering					
	– 12 mm thick	sqm	263.14	0.90	236.83	7.5.1.(c)
	– 20 mm thick	sqm	1.85	1.49	2.76	7.5.1.(f)
	(b) White washing and colour washing	sqm	299.28	0.01	3.00	7.5.3.
	TEC for Finishing (TEC_5)				**242.59**	
	$TEC_T = TEC_1 + TEC_2 + TEC_3 + TEC_4 + TEC_5$				**4447.13 MJ**	

Table III.2.3: TEC_T Estimate for Project No. 3

S.No.	Item of Work	Unit	Quantity	TER in MJ/Unit	TEC in MJ	Schedule of TER Item Code No.
1.	Brick Masonry Work	cum	52.42	69.12	3623.27	7.1.1.(a)
	TEC for Masonry Work (TEC_1)				**3623.27**	
2.	Concrete Work					
	(a) Concrete work					
	– with stone agg.	cum	10.74	80.64	866.07	7.2.1.
	– with brick agg.	cum	5.36	66.24	355.05	7.2.2.
	(b) DPC (40 mm thick)	sqm	10.52	3.24	34.08	7.2.3.(b)
	TEC for Concrete Work (TEC_2)				**1255.20**	
3.	RCC Work	cum	10.17	90.00	915.30	7.3.
	TEC for RCC Work (TEC_3)				**915.30**	
4.	Flooring					
	(a) Cement concrete flooring - 25 mm thick	sqm	4.02	2.02	8.12	7.4.1.(a)
	(b) Cement concrete flooring - 40 mm thick	sqm	50.00	3.24	162.00	7.4.1.(b)
	TEC for Flooring (TEC_4)				**170.12**	

S.No.	Item of Work	Unit	Quantity	TER in MJ/Unit	TEC in MJ	Schedule of TER Item Code No.
5.	Finishing					
	(a) Plastering					
	– 12 mm thick	sqm	285.60	0.90	257.04	7.5.1.(c)
	– 20 mm thick	sqm	4.59	1.49	6.84	7.5.1.(f)
	(b) White washing and colour washing	sqm	375.22	0.01	3.75	7.5.3.
	TEC for Finishing (TEC_5)				267.63	
6.	$TEC_T = TEC_1 + TEC_2 + TEC_3 + TEC_4 + TEC_5$				**6231.52 MJ**	

Table III.2.4: TEC_T Estimate for Project No. 4

S.No.	Item of Work	Unit	Quantity	TER in MJ/Unit	TEC in MJ	Schedule of TER Item Code No.
1.	Brick Masonry Work	cum	53.96	69.12	3729.72	7.1.1.(a)
				TEC for Masonry Work (TEC_1)	**3729.72**	
2.	Concrete Work					
	(a) Concrete work	cum	11.50	80.64	927.36	7.2.1.
	(b) DPC (40 mm thick)	sqm	13.30	3.24	43.09	7.2.3.(b)
	(c) Plinth protection (50 mm thick)	sqm	33.20	3.31	109.89	7.2.4.
				TEC for Concrete Work (TEC_2)	**1080.34**	
3.	RCC Work	cum	11.40	90.00	1026.00	7.3.
				TEC for RCC Work (TEC_3)	**1026.00**	
4.	Flooring					
	(a) Cement concrete flooring - 40 mm thick	sqm	49.00	3.24	158.76	7.4.1.(b)
	(b) Terrazzo flooring - 40 mm thick	sqm	9.00	3.46	31.10	7.4.2.(c)
	(c) Cement plaster skirting - 18 mm thick	sqm	9.00	1.35	12.15	7.4.3.(a)
	(d) Glass strips - 6 mm thick, 40 mm wide	m	18.00	0.02	0.36	7.4.5.(d)
				TEC for Flooring (TEC_4)	**202.37**	

S.No.	Item of Work	Unit	Quantity	TER in MJ/Unit	TEC in MJ	Schedule of TER Item Code No.
5.	Finishing					
	(a) Plastering					
	– 6 mm thick	sqm	14.00	0.45	6.30	7.5.1.(a)
	– 12 mm thick	sqm	180.00	0.90	162.00	7.5.1.(c)
	– 15 mm thick	sqm	180.00	1.12	201.60	7.5.1.(d)
	– 18 mm terrazzo finish	sqm	22.40	1.55	34.72	7.4.4.(a)
	(b) White washing and colour washing	sqm	470.00	0.01	4.70	7.5.3.
	TEC for Fiishing (TEC_5)				**409.32**	
	$TEC_T = TEC_1 + TEC_2 + TEC_3 + TEC_4 + TEC_5$				**6447.75 MJ**	

Table III.2.5: TEC_T Estimate for Project No.5

S.No.	Item of Work	Unit	Quantity	TER in MJ/Unit	TEC in MJ	Schedule of TER Item Code No.
1.	Brick Masonry Work	cum	60.80	69.12	4202.50	7.1.1.(a)
	TEC for Masonry Work (TEC_1)				**4202.50**	
2.	Concrete Work					
	(a) Concrete work	cum	15.40	80.64	1214.86	7.2.1.
	(b) DPC (40 mm thick)	sqm	14.40	3.24	46.66	7.2.3.(b)
	(c) Plinth protection (50 mm thick)	sqm	34.60	3.31	114.53	7.2.4.
	TEC for Concrete Work (TEC_2)				**1376.05**	
3.	RCC Work	cum	15.50	90.00	1395.00	7.3.
	TEC for RCC Work (TEC_3)				**1395.00**	
4.	Flooring					
	(a) Cement concrete flooring - 40 mm thick	sqm	68.00	3.24	220.32	7.4.1.(b)
	(b) Terrazzo flooring - 40 mm thick	sqm	9.00	3.46	31.14	7.4.2.(c)
	(c) Cement plaster skirting - 18 mm thick	sqm	11.00	1.35	14.85	7.4.3.(a)
	(d) Glass strips - 6 mm thick, 40 mm wide	m	18.00	0.02	0.36	7.4.5.(d)
	(e) Roofing tiles - 25 mm thick	sqm	32.00	2.84	91.00	7.4.8.

S.No.	Item of Work	Unit	Quantity	TER in MJ/Unit	TEC in MJ	Schedule of TER Item Code No.
	TEC for Flooring (TEC_4)				**357.67**	
5.	Finishing					
	(a) Plastering					
	– 6 mm thick	sqm	19.00	0.45	8.55	7.5.1.(a)
	– 12 mm thick	sqm	220.00	0.90	198.00	7.5.1.(c)
	– 15 mm thick	sqm	220.00	1.12	246.40	7.5.1.(d)
	– Terrazzo finish - 18 mm thick	sqm	20.00	1.55	31.00	7.4.4.
	(b) White washing and colour washing	sqm	570.00	0.01	5.70	7.5.3.
	TEC for Finishing (TEC_5)				**489.65**	
	$TEC_T = TEC_1 + TEC_2 + TEC_3 + TEC_4 + TEC_5$				**7820.87 MJ**	

Table III.2.6: TEC_T Estimate for Project No. 6

S.No.	Item of Work	Unit	Quantity	TER in MJ/Unit	TEC in MJ	Schedule of TER Item Code No.
1.	Brick Masonry Work	cum	86.43	69.12	5974.04	7.1.1.(a)
	TEC for Masonry Work (TEC_1)				**5974.04**	
2.	Concrete Work					
	(a) Concrete work					
	– with stone agg.	cum	13.88	80.64	1119.28	7.2.1.
	– with brick agg.	cum	6.38	66.24	422.61	7.2.2.
	(b) DPC (25 mm thick)	sqm	23.38	2.02	47.23	7.2.3.(a)
	TEC for Concrete Work (TEC_2)				**1589.12**	
3.	RCC Work	cum	12.97	90.00	1167.30	7.3.
	TEC for RCC Work (TEC_3)				**1167.30**	
4.	Flooring					
	(a) Terrazzo flooring - 40 mm thick	sqm	83.36	3.46	288.43	7.4.2.(c)
	TEC for Flooring (TEC_4)				**288.43**	

S.No.	Item of Work	Unit	Quantity	TER in MJ/Unit	TEC in MJ	Schedule of TER Item Code No.
5.	Finishing					
	(a) Plastering					
	– 12 mm thick	sqm	528.55	0.90	475.70	7.5.1.(c)
	(b) White washing and colour washing	sqm	505.28	0.01	5.05	7.5.3.
	TEC for Finishing (TEC_5)				**480.75**	
	$TEC_T = TEC_1 + TEC_2 + TEC_3 + TEC_4 + TEC_5$				**9499.64 MJ**	

Table III.2.7: TEC_T Estimate for Project No. 7

S.No.	Item of Work	Unit	Quantity	TER in MJ/Unit	TEC in MJ	Schedule of TER Item Code No.
1.	Brick Masonry Work	cum	126.04	69.12	8711.89	7.1.1.(a)
	TEC for Masonry Work (TEC_1)				**8711.89**	
2.	Concrete Work					
	(a) Concrete work					
	– with stone agg.	cum	35.17	80.64	2836.11	7.2.1.
	– with brick agg.	cum	9.10	66.24	602.78	7.2.2.
	(b) DPC (40 mm thick)	sqm	18.52	3.24	60.00	7.2.3.(b)
	TEC for Concrete Work (TEC_2)				**3498.89**	
3.	RCC Work	cum	21.48	90.00	1933.20	7.3.
	TEC for RCC Work (TEC_3)				**1933.20**	
4.	Flooring					
	(a) Cement concrete flooring - 40 mm thick	sqm	76.91	3.24	249.19	7.4.1.(b)
	(b) Terrazzo flooring - 40 mm thick	sqm	75.69	3.46	261.89	7.4.2.(b)
	(c) Cement plaster skirting - 21 mm thick	sqm	2.77	1.57	4.35	7.4.3.(b)
	(d) Glass strips - 4 mm thick, 35 mm wide	m	230.00	0.01	2.30	7.4.5.(a)

S.No.	Item of Work	Unit	Quantity	TER in MJ/Unit	TEC in MJ	Schedule of TER Item Code No.
	TEC for Flooring (TEC_4)				517.73	
5.	Finishing					
	(a) Plastering					
	– 12 mm thick	sqm	842.95	0.90	699.09	7.5.1.(c)
	(b) White washing and colour washing	sqm	962.58	0.01	8.96	7.5.3.
	TEC for Finishing (TEC_5)				768.29	
	$TEC_T = TEC_1 + TEC_2 + TEC_3 + TEC_4 + TEC_5$				15430.00 MJ	

Table III.2.8: TEC_T Estimate for Project No. 8

S.No.	Item of Work	Unit	Quantity	TER in MJ/Unit	TEC in MJ	Schedule of TER Item Code No.
1.	Brick Masonry Work	cum	123.01	69.12	8502.45	7.1.1.(a)
	TEC for Masonry Work (TEC_1)				**8502.45**	
2.	Concrete Work					
	(a) Concrete work					
	– with stone agg.	cum	36.96	80.64	2907.88	7.2.1.
	– with brick agg.	cum	8.60	66.24	569.66	7.2.2.
	(b) DPC (40 mm thick)	sqm	18.15	3.24	58.81	7.2.3.(b)
	TEC for Concrete Work (TEC_2)				**3536.35**	
3.	RCC Work	cum	20.64	90.00	1857.60	7.3.
	TEC for RCC Work (TEC_3)				**1857.60**	
4.	Flooring					
	(a) Cement concrete flooring - 40 mm thick	sqm	85.23	3.24	276.15	7.4.1.(b)
	(b) Terrazzo flooring - 40 mm thick	sqm	93.56	3.46	323.72	7.4.2.(c)
	(c) Cement plaster skirting - 21 mm thick	sqm	2.50	1.57	3.93	7.4.3.(b)
	(d) Glass strips - 4mm thick, 35 mm wide	m	225.00	0.01	2.25	7.4.5.(a)

S.No.	Item of Work	Unit	Quantity	TER in MJ/Unit	TEC in MJ	Schedule of TER Item Code No.
	TEC for Flooring (TEC_4)				**606.05**	
5.	Finishing					
	(a) Plastering					
	– 12 mm thick	sqm	774.61	0.90	697.15	7.5.1.(c)
	(b) White washing and colour washing	sqm	890.73	0.01	8.91	7.5.3.
	TEC for Finishing (TEC_5)				706.06	
	$TEC_T = TEC_1 + TEC_2 + TEC_3 + TEC_4 + TEC_5$				**15208.51 MJ**	

Table III.2.9: TEC_T Estimate for Project No. 9

S.No.	Item of Work	Unit	Quantity	TER in MJ/Unit	TEC in MJ	Schedule of TER Item Code No.
1.	Brick Masonry Work	cum	135.96	69.12	9397.56	7.1.1.(a)
	TEC for Masonry Work (TEC_1)				**9397.56**	
2.	Concrete Work					
	(a) Concrete work					
	– with stone agg.	cum	27.68	80.64	2232.12	7.2.1.
	– with brick agg.	cum	11.36	66.24	752.4	7.2.2.
	(b) DPC (25 mm thick)	sqm	28.97	2.02	58.52	7.2.3.(a)
	TEC for Concrete Work (TEC_2)				**3043.04**	
3.	RCC Work	cum	22.67	90.00	2040.30	7.3.
	TEC for RCC Work (TEC_3)				**2040.30**	
4.	Flooring					
	(a) Cement concrete flooring - 25 mm thick	sqm	221.25	2.02	446.93	7.4.1.(a)
	(b) Cement plaster skirting - 18 mm thick	sqm	56.47	1.35	76.60	7.4.3.(a)
	TEC for Flooring (TEC_4)				**523.53**	

S.No.	Item of Work	Unit	Quantity	TER in MJ/Unit	TEC in MJ	Schedule of TER Item Code No.
5.	Finishing					
	(a) Plastering					
	– 12 mm thick	sqm	870.05	0.90	783.05	7.5.1.(c)
	– 20 mm thick	sqm	13.96	1.49	20.80	7.5.1.(f)
	(b) White washing and colour washing	sqm	921.69	0.01	9.22	7.5.3.
	TEC for Finishing (TEC_5)				**813.07**	
	$TEC_T = TEC_1 + TEC_2 + TEC_3 + TEC_4 + TEC_5$				**15817.50 MJ**	

Table III.2.9 (a): TEC_T Estimate of Boundary Wall and Open Paved Area for Project No. 9

S.No.	Item of Work	Unit	Quantity	TER in MJ/Unit	TEC in MJ	Schedule of TER Item Code No.
1.	Brick Masonry Work	cum	18.92	69.12	1307.75	7.1.1.(a)
				TEC for Masonry Work	**1307.75**	
2.	Concrete Work					
	(a) Concrete work with stone agg.	cum	7.93	80.64	639.48	7.2.1.
				TEC for Concrete Work	**639.48**	
3.	Flooring					
	(a) Cement concrete flooring - 25 mm thick	sqm	83.25	2.02	168.17	7.4.1.(a)
				TEC for Flooring	**168.17**	
4.	Finishing					
	(a) Plastering					
	– 12 mm thick	sqm	147.50	0.90	132.75	7.5.1.(c)
	(b) White washing inside and outside	sqm	13.96	0.01	1.39	7.5.1.(f)
				TEC for Finishing (TEC_5)	**134.14**	
	Total TEC of Boundary Wall and Open Paved Area				**2249.54 MJ**	

Table III.2.9 (b): TEC_T Estimate of Stairwell for Project No. 9

S.No.	Item of Work	Unit	Quantity	TER in MJ/Unit	TEC in MJ	Schedule of TER Item Code No.
1.	Brick Masonry Work	cum	5.29	69.12	365.64	7.1.1.(a)
				TEC for Masonry Work	**365.64**	
2.	Concrete Work					
	– Concrete work with stone agg.	cum	3.29	80.64	265.30	7.2.1.
				TEC for Concrete Work	**265.30**	
3.	RCC Work	cum	3.71	90.00	333.90	7.3.
				TEC for RCC Work	**333.90**	
4.	Flooring					
	Cement concrete flooring - 25 mm thick	sqm	11.16	2.02	22.54	7.4.1.(a)
				TEC for Flooring	**22.54**	
5.	Finishing					
	(c) Plastering					
	– 12 mm thick	sqm	83.02	0.90	74.72	7.5.1.(c)
	– 20 mm thick	sqm	7.48	1.49	11.15	7.5.1.(f)
	(d) White washing and colour washing	sqm	83.02	0.01	0.83	7.5.3.
				TEC for Finishing	**86.70**	
				Total TEC of Stairwell	**1074.08 MJ**	

Table III.2.10: TEC_T Estimate for Project No. 10

S.No.	Item of Work	Unit	Quantity	TER in MJ/Unit	TEC in MJ	Schedule of TER Item Code No.
1.	Brick Masonry Work	cum	139.03	69.12	9609.75	7.1.1.(a)
				TEC for Masonry Work (TEC_1)	**9609.75**	
2.	Concrete Work					
	(a) Concrete work					
	– with stone agg.	cum	38.97	80.64	3142.54	7.2.1.
	– with brick agg.	cum	13.21	66.24	875.03	7.2.2.
	(b) DPC (40 mm thick)	sqm	21.03	3.24	68.14	7.2.3.(b)
				TEC for Concrete Work (TEC_2)	**4085.71**	
3.	RCC Work	cum	24.06	90.00	2165.40	7.3.
				TEC for RCC Work (TEC_3)	**2165.40**	
4.	Flooring					
	(a) Cement concrete flooring - 40 mm thick	sqm	83.94	3.24	271.97	7.4.1.(b)
	(b) Terrazzo flooring - 40 mm thick	sqm	132.14	3.46	457.20	7.4.2.(b)
	(c) Cement plaster skirting - 21 mm thick	sqm	3.51	1.57	5.51	7.4.3.(b)
	(d) Terrazzo finished skirting - 21 mm thick	sqm	30.09	1.80	54.16	7.4.4.(b)
	(e) Glass strips - 4mm thick, 35 mm wide	m	260.00	0.01	2.60	7.4.5.(a)

S.No.	Item of Work	Unit	Quantity	TER in MJ/Unit	TEC in MJ	Schedule of TER Item Code No.
	TEC for Flooring (TEC_4)				**791.44**	
5.	Finishing					
	(a) Plastering					
	– 12 mm thick	sqm	1010.21	0.90	909.19	7.5.1.(c)
	(b) White washing and colour washing	sqm	1010.21	0.01	10.10	7.5.3.
	TEC for Finishing (TEC_5)				**919.29**	
	$TEC_T = TEC_1 + TEC_2 + TEC_3 + TEC_4 + TEC_5$				**17571.59 MJ**	

Table III.2.11: TEC_T Estimate for Project No. 11

S.No.	Item of Work	Unit	Quantity	TER in MJ/Unit	TEC in MJ	Schedule of TER Item Code No.
1.	Brick Masonry Work	cum	144.80	69.12	10008.58	7.1.1.(a)
	TEC for Masonry Work (TEC_1)				**10008.58**	
2.	Concrete Work					
	(a) Concrete Work					
	– with stone agg.	cum	19.40	80.64	1564.42	7.2.1
	– with brick agg.	cum	4.10	66.24	271.58	7.2.2.
	(b) DPC (40 mm thick)	sqm	20.40	3.24	66.10	7.2.3.(b)
	(c) Plinth protection (50 mm thick)	sqm	24.70	3.31	81.76	7.2.4.
	TEC for Concrete Work (TEC_2)				**1983.86**	
3.	RCC Work	cum	32.90	90.00	2961.00	7.3.
	TEC for RCC (TEC_3)				**2961.00**	
4.	Flooring					
	(a) Cement concrete flooring - 40 mm thick	sqm	176.00	3.24	570.24	7.4.1.(b)
	(b) Terrazzo flooring - 40 mm thick	sqm	19.20	3.46	66.43	7.4.2.(c)

S.No.	Item of Work	Unit	Quantity	TER in MJ/Unit	TEC in MJ	Schedule of TER Item Code No.
	(c) Cement plaster skirting - 18 mm thick	sqm	33.20	1.35	44.82	7.4.3.(a)
	(d) Glass strips - 6 mm thick, 40 mm wide	m	38.40	0.02	0.77	7.4.5.(d)
	TEC for Flooring (TEC_4)				**682.26**	
5.	Finishing					
	(a) Plastering					
	– 6 mm thick	sqm	50.00	0.45	22.50	7.5.1.(a)
	– 12 mm thick	sqm	557.00	0.90	501.30	7.5.1.(c)
	– 15 mm thick	sqm	557.00	1.12	623.84	7.5.1.(d)
	– Terrazzo finish - 18 mm thick	sqm	47.30	1.55	73.31	7.4.4.(a)
	(b) White washing and colour washing	sqm	1468.00	0.01	14.68	7.5.3.
	TEC for Finishing (TEC_5)				1235.63	
	$TEC_T = TEC_1 + TEC_2 + TEC_3 + TEC_4 + TEC_5$				**16871.33 MJ**	

Table III.2.12: TEC_T Estimate for Project No. 12

S.No.	Item of Work	Unit	Quantity	TER in MJ/Unit	TEC in MJ	Schedule of TER Item Code No.
1.	Brick Masonry Work	cum	171.00	69.12	11819.52	7.1.1.(a)
	TEC for Masonry Work (TEC_1)				**11819.52**	
2.	Concrete Work					
	(a) Concrete work					
	– with stone agg.	cum	21.00	80.64	1693.44	7.2.1
	– with brick agg.	cum	3.20	66.24	211.97	7.2.2.
	(b) DPC (40 mm thick)	sqm	24.10	3.24	78.08	7.2.3.(b)
	(c) Plinth protection (50 mm thick)	sqm	49.00	3.31	162.19	7.2.4.
	TEC for Concrete Work (TEC_2)				**2145.68**	
3.	RCC Work	cum	50.60	90.00	4554.00	7.3.
	TEC for RCC Work (TEC_3)				**4554.00**	
4.	Flooring					
	(a) Cement concrete flooring - 25 mm thick	sqm	230.00	2.02	464.60	7.4.1.(a)
	(b) Terrazzo flooring - 40 mm thick	Sqm	20.00	3.46	69.20	7.4.2.(c)

S.No.	Item of Work	Unit	Quantity	TER in MJ/Unit	TEC in MJ	Schedule of TER Item Code No.
	(c) Cement plaster skirting - 18 mm thick	sqm	24.00	1.35	32.40	7.4.3.(a)
	(d) Glass strips - 6 mm thick, 40 mm wide	m	40.00	0.02	0.80	7.4.5.(d)
	(e) Roofing tiles - 25 mm thick	sqm	99.60	2.84	282.86	7.4.8.
5.				**TEC for Flooring (TEC_4)**	**849.86**	
6.	Finishing					
	(a) Plastering					
	– 6 mm thick	sqm	64.20	0.45	28.89	7.5.1.(a)
	– 12 mm thick	sqm	665.00	0.90	598.50	7.5.1.(c)
	– 15 mm thick	sqm	665.00	1.12	744.80	7.5.1.(d)
	– Terrazzo finish - 18 mm thick	sqm	47.80	1.55	74.09	7.4.4.(a)
	(b) White washing and colour washing	sqm	1750.00	0.01	17.50	7.5.3.
				TEC for Finishing (TEC_5)	1463.78	
				$TEC_T = TEC_1 + TEC_2 + TEC_3 + TEC_4 + TEC_5$	**20832.84 MJ**	

Table III.2.13: TEC_T Estimate Project No.13

S.No.	Item of Work	Unit	Quantity	TER in MJ/Unit	TEC in MJ	Schedule of TER Item Code No.
1.	Brick Masonry Work	cum	166.33	69.12	11496.73	7.1.1.(a)
	TEC for Masonry Work(TEC_1)				**11496.73**	
2.	Concrete Work					
	(a) Concrete work					
	– with stone agg.	cum	20.13	80.64	1623.28	7.2.1.
	– with brick agg.	cum	11.36	66.24	752.40	7.2.2.
	(b) DPC (40 mm thick)	sqm	28.97	2.02	58.52	7.2.3.(a)
	TEC for Concrete Work (TEC_2)				**2434.20**	
3.	RCC Work	cum	43.78	90.00	3940.20	7.3.
	TEC for RCC Work (TEC_4)				**3940.20**	
4.	Flooring					
	(a) Cement concrete flooring - 25 mm thick	sqm	268.81	2.02	543.00	7.4.1.(a)
	(b) Cement plaster skirting - 18 mm thick	sqm	114.02	1.35	153.93	7.4.3.(a)
	TEC for Flooring (TEC_4)				**696.93**	

S.No.	Item of Work	Unit	Quantity	TER in MJ/Unit	TEC in MJ	Schedule of TER Item Code No.
5.	Finishing					
	(a) Plastering					
	– 12 mm thick	sqm	1255.57	0.90	1130.01	7.5.1.(c)
	– 20 mm thick	sqm	13.96	1.49	20.80	7.5.1.(f)
	(b) White washing and colour washing	sqm	1588.79	0.01	15.89	7.5.3.
	TEC for Finishing (TEC_5)				**1166.70**	
	$TEC_T = TEC_1 + TEC_2 + TEC_3 + TEC_4 + TEC_5$				**19734.76 MJ**	

Table III.2.14: TEC_T Estimate for Project No. 14

S.No.	Item of Work	Unit	Quantity	TER in MJ/Unit	TEC in MJ	Schedule of TER Item Code No.
1.	Brick Masonry Work	cum	665.57	69.12	46004.20	7.1.1.(a)
	TEC for Masonry Work (TEC_1)				**46004.20**	
2.	Concrete Work					
	(a) Concrete work with stone agg.	cum	112.00	80.64	9031.68	7.2.1.
	(b) DPC (40 mm thick)	sqm	37.00	3.24	119.88	7.2.3.(b)
	TEC for Concrete Work (TEC_2)				**9151.56**	
3.	RCC Work	cum	693.00	90.00	62370.00	7.3.
4.	Flooring					
	(a) Cement concrete flooring - 40 mm thick	sqm	99.00	3.24	320.76	7.4.1.(b)
	(b) Terrazzo flooring - 40 mm thick	sqm	1371.00	3.46	4743.66	7.4.2.(c)
	(c) Cement plaster skirting - 21 mm thick	sqm	23.00	1.57	36.11	7.4.3.(b)
	(d) Terrazzo skirting - 21 mm thick	sqm	632.00	1.80	1137.60	7.4.4.(b)

S.No.	Item of Work	Unit	Quantity	TER in MJ/Unit	TEC in MJ	Schedule of TER Item Code No.
	(e) Glass strips - 4 mm thick, 40 mm wide	sqm	2948.00	0.01	29.48	7.4.5.(b)
	(f) Kota stone slab flooring - 25 mm thick, over 20 mm thick base	m	36.00	3.53	127.08	7.4.7.(a)
	(g) Kota stone slabs - 25 mm thick, over 12 mm thick base	sqm	242.00	2.92	706.64	7.4.7.(b)
				TEC for Flooring (TEC_4)	**7101.33**	
5.	Finishing					
	(a) Plastering					
	– 6 mm thick	sqm	288.00	0.45	129.60	7.5.1.(a)
	– 12 mm thick	sqm	2378.00	0.90	2140.20	7.5.1.(c)
	– 20 mm thick	sqm	2378.00	1.49	3543.22	7.5.1.(f)
	(b) Pointing	sqm	3153.00	0.22	693.66	7.5.2.(a)
	(c) White washing and colour washing	sqm	9644.00	0.01	96.44	7.5.3.
				TEC for Finishing (TEC_5)	**6603.12**	
				$TEC_T = TEC_1 + TEC_2 + TEC_3 + TEC_4 + TEC_5$	**131230.21 MJ**	

Table III.2.15: TEC_T Estimate for Project No. 15

S.No.	Item of Work	Unit	Quantity	TER in MJ/Unit	TEC in MJ	Schedule of TER Item Code No.
1.	Brick Masonry Work	cum	5039.00	69.12	348295.68	7.1.1.(a)
	TEC for Masonry Work (TEC_1)				**348295.68**	
2.	Concrete Work					
	(a) Concrete work					
	– with stone agg.	cum	357.00	80.64	28788.48	7.2.1
	– with brick agg.	cum	48.00	66.24	3179.52	7.2.2.
	(b) DPC (40 mm thick)	sqm	361.50	3.24	1171.26	7.2.3.(b)
	(c) Plinth protection (50 mm thick)	sqm	735.00	3.31	2432.85	7.2.4.
	TEC for Concrete Work(TEC_2)				**35572.11**	
3.	RCC Work	cum	1581.00	90.00	142290.00	7.3.
	TEC for RCC Work (TEC_3)				**142290.00**	
4.	Flooring					
	(a) Cement concrete flooring - 25 mm thick	sqm	6900.00	2.02	13938.00	7.4.1.(a)
	(b) Cement concrete flooring – 40 mm thick	sqm	472.50	3.24	1530.90	7.4.1.(b)
	(c) Terrazzo flooring - 40 mm thick	sqm	600.00	3.46	2076.00	7.4.2.(b)
	(d) Cement plaster skirting - 18 mm thick	sqm	720.00	1.35	972.00	7.4.3.(a)

S.No.	Item of Work	Unit	Quantity	TER in MJ/Unit	TEC in MJ	Schedule of TER Item Code No.
	(d) Glass strips - 6 mm thick, 40 mm wide	sqm	1200.00	0.02	24.00	7.4.5.(d)
	(e) Roofing tiles - 25 mm thick	sqm	1494.00	2.84	4242.96	7.4.8.
	TEC for Flooring (TEC_4)				**22783.86**	
5.	Finishing					
	(a) Plastering					
	– 6 mm thick	sqm	1926.00	0.45	866.70	7.5.1.(a)
	– 12 mm thick	sqm	20531.00	0.90	18477.90	7.5.1.(c)
	– 15 mm thick	sqm	19950.00	1.12	22344.00	7.5.1.(d)
	– Terrazzo finish - 18 mm thick	sqm	1434.00	1.55	2222.70	7.4.4.(a)
	(b) White washing and colour washing	sqm	53070.50	0.01	530.71	7.5.3.
	TEC for Finishing (TEC_5)				**44442.01**	
	$TEC_T = TEC_1 + TEC_2 + TEC_3 + TEC_4 + TEC_5$				**593383.66 MJ**	

Table III.2.16: TEC_T Estimate for Project No. 16

S.No.	Item of Work	Unit	Quantity	TER in MJ/Unit	TEC in MJ	Schedule of TER Item Code No.
1.	(a) Brick Masonry Work	cum	7760.38	69.12	536397.47	7.1.1.
	(b) Tapered surface of brick masonry	sqm	140.00	2.20	308.00	7.1.2.
				TEC for Masonry Work (TEC_1)	**536705.47**	
2.	Concrete Work					
	(a) Concrete work with stone agg.	cum	855.28	80.64	68969.78	7.2.1.
	(b) DPC (40 mm thick)	sqm	1072.24	3.24	3474.06	7.2.3.(b)
	(c) Plinth protection (50 mm thick)	sqm	1160.00	3.31	3839.60	7.2.4.
				TEC for Concrete Work (TEC_2)	**76283.44**	
3.	RCC Work	cum	3731.00	90.00	335790.00	7.3.
				TEC for RCC Work (TEC_3)	**335790.00**	
4.	Flooring					
	(a) Cement concrete flooring - 40 mm thick	sqm	740.00	3.24	2397.60	7.4.1.(b)
	(b) Terrazzo flooring - 40 mm thick	sqm	12070.00	3.46	41762.20	7.4.2.(c)
	(c) Cement plaster skirting - 18 mm thick	sqm	165.00	1.35	222.75	7.4.3.(a)

S.No.	Item of Work	Unit	Quantity	TER in MJ/Unit	TEC in MJ	Schedule of TER Item Code No.
	(d) Terrazzo skirting - 18 mm thick	sqm	1600.00	1.55	2480.00	7.4.4.(a)
	(e) Glass strips - 4 mm thick, 40 mm wide	m	12200.00	0.01	122.00	7.4.5.(b)
	(f) Kota stone slab flooring - 30 mm thick, over 20 mm thick base	sqm	1200.00	3.92	4704.00	7.4.7.(c)
	(g) Kota stone slabs - 25 mm thick, over 12 mm thick base	sqm	190.00	2.92	554.80	7.4.7.(b)
	(h) White Makrana marble - 25 mm thick, over 20 mm thick base	sqm	550.00	3.96	2178.00	7.4.6.(a)
	(i) Bhanslana marble - 30 mm thick, over 20 mm thick base	sqm	1320.00	4.43	5847.60	7.4.6.(b)
	TEC for Flooring (TEC_4)				**60268.95**	
5.	Finishing					
	(a) Plastering					
	– 10 mm thick	sqm	17900.00	0.76	13604.00	7.5.1.(b)
	– 12 mm thick	sqm	23400.00	0.90	21060.00	7.5.1.(c)
	– 15 mm thick	sqm	28500.00	1.12	31920.00	7.5.1.(d)
	– 18 mm thick	sqm	3150.00	1.35	4252.50	7.5.1.(e)
	(b) White washing and colour washing	sqm	67100.00	0.01	671.00	7.5.3.
	TEC for Finishing (TEC_5)				**71507.50**	
	$TEC_T = TEC_1 + TEC_2 + TEC_3 + TEC_4 + TEC_5$				**1080555.36 MJ**	

3.	RCC Work	cum	12.91	2500.00	32275.00	1161.90
4.	Flooring					
	(a) Cement concrete flooring 25 mm thick	sqm	32.03	56.00	1793.68	64.57
5.	Finishing					
	▪ Plastering					
	(a) 12 mm thick	sqm	168.86	25.00	4221.50	151.97
	(b) 15 mm thick	sqm	1.40	31.00	43.40	1.56
	▪ White washing and colour washing	sqm	252.55	0.30	75.77	2.73
	(TOTAL TRANSPORT ENERGY COST) TEC_T					**3162.45 MJ**

APPENDIX-IV

Estimates of Energy Cost for All Projects Using Alternative Masonry Works

Table IV.1.1: Embodied Energy Costs of Masonry Work (EEC_1) in Project No. 1 Using Alternate Masonry Units and Mortar Mixes

			EEC_1 (in MJ) Using								
No.	Mortar Mix Ratio		Traditional Bricks (22.9 cm X 11.4 cm X 7.6 cm)	Modular Bricks (20 cm X 10 cm X 10 cm)	Clay Flyash Bricks (20 cm X 10 cm X 10 cm)	Sand Lime Bricks (20 cm X 10 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 20 cm)	Aerated Concrete Blocks (40 cm X 20 cm X 20 cm)	Solid Concrete Blocks (30 cm X 20 cm X 15 cm)	Fal-G Blocks (30 cm X 20 cm X 15 cm)
1.	1:1:1 (1 Lime Putty: 1 Flyash : 1 Fine Sand)	Full Brick	62704.45	60619.02	36074.14	41365.38	41616.00	23485.76	24214.04	35977.03	29503.43
		Half Brick	-	-	-	-	-	-	-	-	-
		EEC_1	**62704.45**	**60619.02**	**36074.14**	**41365.38**	**41616.00**	**23485.76**	**24214.04**	**35977.03**	**29503.43**
2.	1:3 (1 Cement : 3 Fine Sand)	Full Brick	71146.02	68047.71	43502.60	48794.76	49382.24	29057.45	29785.73	42730.38	36256.78
		Half Brick	-	-	-	-	-	-	-	-	-
		EEC_1	**71146.02**	**68047.71**	**43502.60**	**48794.76**	**49382.24**	**29057.45**	**29785.73**	**42730.38**	**36256.78**
3.	1:5 (1 Cement : 5 Fine Sand)	Full Brick	63400.82	61231.93	36686.35	41978.29	42244.17	23945.62	24673.90	36534.22	30060.62
		Half Brick	-	-	-	-	-	-	-	-	-
		EEC_1	**63400.82**	**61231.93**	**36686.35**	**41978.29**	**42244.17**	**23945.62**	**24673.90**	**36534.22**	**30060.62**
4.	1:6 (1 Cement : 6 Fine Sand)	Full Brick	61077.26	59187.20	34641.62	39933.56	40118.98	22412.07	23143.12	34675.38	28201.78
		Half Brick	-	-	-	-	-	-	-	-	-
		EEC_1	**61077.26**	**59187.20**	**34641.62**	**39933.56**	**40118.98**	**22412.07**	**23143.12**	**34675.38**	**28201.78**
5.	1:1:6 (1 Cement : 1 Lime Putty : 6 Fine Sand)	Full Brick	65322.79	62923.40	38379.20	43669.52	44025.10	25213.98	25942.26	38071.70	31598.10
		Half Brick	-	-	-	-	-	-	-	-	-
		EEC_1	**65322.79**	**62923.40**	**38379.20**	**43669.52**	**44025.10**	**25213.98**	**25942.26**	**38071.70**	**31598.10**

Table IV.1.2: Embodied Energy Costs of Masonry Work (EEC$_1$) in Project No. 2 Using Alternate Masonry Units and Mortar Mixes

			EEC$_1$ (in MJ) Using								
No.	Mortar Mix Ratio		Traditional Bricks (22.9 cm X 11.4 cm X 7.6 cm)	Modular Bricks (20 cm X 10 cm X 10 cm)	Clay Flyash Bricks (20 cm X 10 cm X 10 cm)	Sand Lime Bricks (20 cm X 10 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 20 cm)	Aerated Concrete Blocks (40 cm X 20 cm X 20 cm)	Solid Concrete Blocks (30 cm X 20 cm X 15 cm)	Fal-G Blocks (30 cm X 20 cm X 15 cm)
1.	1:1:1 (1 Lime Putty: 1 Flyash : 1 Fine Sand)	Full Brick	108132.62	104536.35	62209.16	71333.81	71766.00	40500.74	41756.65	62041.71	50878.11
		Half Brick	-	-	-	-	-	-	-	-	-
		EEC$_1$	**108132.62**	**104536.35**	**62209.16**	**71333.81**	**71766.00**	**40500.74**	**41756.65**	**62041.71**	**50878.11**
2.	1:3 (1 Cement : 3 Fine Sand)	Full Brick	122689.96	117346.98	75019.40	84145.64	85158.73	50109.01	51364.92	73687.73	62524.13
		Half Brick	-	-	-	-	-	-	-	-	-
		EEC$_1$	**122689.96**	**117346.98**	**75019.40**	**84145.64**	**85158.73**	**50109.01**	**51364.92**	**73687.73**	**62524.13**
3.	1:5 (1 Cement : 5 Fine Sand)	Full Brick	109333.51	105593.30	63264.92	72390.76	72849.27	41293.76	42549.66	63002.57	51838.97
		Half Brick	-	-	-	-	-	-	-	-	-
		EEC$_1$	**109333.51**	**105593.30**	**63264.92**	**72390.76**	**72849.27**	**41293.76**	**42549.66**	**63002.57**	**51838.97**
4.	1:6 (1 Cement : 6 Fine Sand)	Full Brick	105326.58	102067.20	59738.82	68864.66	69184.42	38649.18	39909.87	59797.03	48633.43
		Half Brick	-	-	-	-	-	-	-	-	-
		EEC$_1$	**105326.58**	**102067.20**	**59738.82**	**68864.66**	**69184.42**	**38649.18**	**39909.87**	**59797.03**	**48633.43**
5.	1:1:6 (1 Cement : 1 Lime Putty : 6 Fine Sand)	Full Brick	112647.90	108510.20	66184.20	75307.25	75920.45	43481.03	44736.93	65653.93	54490.33
		Half Brick	-	-	-	-	-	-	-	-	-
		EEC$_1$	**112647.90**	**108510.20**	**66184.20**	**75307.25**	**75920.45**	**43481.03**	**44736.93**	**65653.93**	**54490.33**

Table IV.1.3: Embodied Energy Costs of Masonry Work (EEC_1) in Project No. 3 Using Alternate Masonry Units and Mortar Mixes

No.	Mortar Mix Ratio		EEC_1 (in MJ) Using: Traditional Bricks (22.9 cm X 11.4 cm X 7.6 cm)	Modular Bricks (20 cm X 10 cm X 10 cm)	Clay Flyash Bricks (20 cm X 10 cm X 10 cm)	Sand Lime Bricks (20 cm X 10 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 20 cm)	Aerated Concrete Blocks (40 cm X 20 cm X 20 cm)	Solid Concrete Blocks (30 cm X 20 cm X 15 cm)	Fal-G Blocks (30 cm X 20 cm X 15 cm)
1.	1:1:1 (1 Lime Putty: 1 Flyash : 1 Fine Sand)	Full Brick	142169.85	137441.57	81790.93	93787.77	94356.00	53249.28	54900.51	81570.76	66893.16
		Half Brick	-	-	-	-	-	-	-	-	-
		EEC_1	**142169.85**	**137441.57**	**81790.93**	**93787.77**	**94356.00**	**53249.28**	**54900.51**	**81570.76**	**66893.16**
2.	1:3 (1 Cement : 3 Fine Sand)	Full Brick	161309.45	154284.64	98633.47	110632.41	111964.40	65881.98	67533.21	96882.64	82205.04
		Half Brick	-	-	-	-	-	-	-	-	-
		EEC_1	**161309.45**	**154284.64**	**98633.47**	**110632.41**	**111964.40**	**65881.98**	**67533.21**	**96882.64**	**82205.04**
3.	1:5 (1 Cement : 5 Fine Sand)	Full Brick	143748.75	138831.22	83179.01	95177.42	95780.25	54291.92	55943.15	82834.08	68156.48
		Half Brick	-	-	-	-	-	-	-	-	-
		EEC_1	**143748.75**	**138831.22**	**83179.01**	**95177.42**	**95780.25**	**54291.92**	**55943.15**	**82834.08**	**68156.48**
4.	1:6 (1 Cement : 6 Fine Sand)	Full Brick	138480.54	134195.20	78542.98	90541.40	90961.81	50814.90	52472.42	78619.52	63941.92
		Half Brick	-	-	-	-	-	-	-	-	-
		EEC_1	**138480.54**	**134195.20**	**78542.98**	**90541.40**	**90961.81**	**50814.90**	**52472.42**	**78619.52**	**63941.92**
5.	1:1:6 (1 Cement : 1 Lime Putty : 6 Fine Sand)	Full Brick	148106.42	142666.27	87017.20	99011.94	99818.16	57167.68	58818.91	86320.01	71642.41
		Half Brick	-	-	-	-	-	-	-	-	-
		EEC_1	**148106.42**	**142666.27**	**87017.20**	**99011.94**	**99818.16**	**57167.68**	**58818.91**	**86320.01**	**71642.41**

Table IV.1.4: Embodied Energy Costs of Masonry Work (EEC_1) in Project No. 4 Using Alternate Masonry Units and Mortar Mixes

No.	Mortar Mix Ratio		EEC_1 (in MJ) Using								
			Traditional Bricks (22.9 cm X 11.4 cm X 7.6 cm)	Modular Bricks (20 cm X 10 cm X 10 cm)	Clay Flyash Bricks (20 cm X 10 cm X 10 cm)	Sand Lime Bricks (20 cm X 10 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 20 cm)	Aerated Concrete Blocks (40 cm X 20 cm X 20 cm)	Solid Concrete Blocks (30 cm X 20 cm X 15 cm)	Fal-G Blocks (30 cm X 20 cm X 15 cm)
1.	1:1:1 (1 Lme Putty: 1 Flyash : 1 Fine Sand)	Full Brick	137505.00	132931.85	79107.21	90710.41	91260.00	51502.07	53099.12	78894.27	64698.27
		Half Brick	8129.70	10448.34	6539.60	7382.31	6284.02	6284.02	6284.02	5504.21	4615.86
		EEC_1	**145634.70**	**143380.19**	**85646.81**	**98092.72**	**97544.02**	**57786.09**	**59383.14**	**84398.48**	**69314.13**
2.	1:3 (1 Cement : 3 Fine Sand)	Full Brick	156016.58	149222.27	95397.12	107002.35	108290.64	63720.27	65317.32	93703.74	79507.74
		Half Brick	8129.70	10448.34	6539.60	7382.31	6284.02	6284.02	6284.02	5504.21	4615.86
		EEC_1	**164146.28**	**159670.61**	**101936.72**	**114384.66**	**114574.66**	**70004.29**	**71601.34**	**99207.95**	**84123.60**
3.	1:5 (1 Cement : 5 Fine Sand)	Full Brick	139032.08	134275.91	80449.75	92054.47	92637.52	52510.50	54107.55	80116.14	65920.14
		Half Brick	8129.70	10448.34	6539.60	7382.31	6284.02	6284.02	6284.02	5504.21	4615.86
		EEC_1	**147161.78**	**144724.25**	**86989.35**	**99436.78**	**98921.54**	**58794.52**	**60391.57**	**85620.35**	**70536.00**
4.	1:6 (1 Cement : 6 Fine Sand)	Full Brick	133936.73	129792.00	75965.84	87570.56	87977.18	49147.57	50750.70	76039.86	61843.86
		Half Brick	8129.70	10448.34	6539.60	7382.31	6284.02	6284.02	6284.02	5504.21	4615.86
		EEC_1	**142066.43**	**140240.34**	**82505.44**	**94952.87**	**94261.20**	**55431.59**	**57034.72**	**81544.07**	**66459.72**
5.	1:1:6 (1 Cement : 1 Lme Putty : 6 Flne Sand)	Full Brick	143246.77	137985.12	84162.00	95763.17	96542.94	55291.90	56888.95	83487.70	69291.70
		Half Brick	8129.70	10448.34	6539.60	7382.31	6284.02	6284.02	6284.02	5504.21	4615.86
		EEC_1	**151376.47**	**148433.46**	**90701.00**	**103145.48**	**102826.96**	**61575.92**	**63172.97**	**88991.91**	**73907.56**

Table IV.1.5. : Embodied Energy Costs of Masonry Work (EEC_1) in Project No. 5 Using Alternate Masonry Units and Mortar Mixes

			EEC_1 (in MJ) using								
No.	Mortar Mix Ratio		Traditional Bricks (22.9 cm X 11.4 cm X 7.6 cm)	Modular Bricks (20 cm X 10 cm X 10 cm)	Clay Flyash Bricks (20 cm X 10 cm X 10 cm)	Sand Lime Bricks (20 cm X 10 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 20 cm)	Aerated Concrete Blocks (40 cm X 20 cm X 20 cm)	Solid Concrete Blocks (30 cm X 20 cm X 15 cm)	Fal-G Blocks (30 cm X 20 cm X 15 cm)
1.	1:1:1 (1 Lime Putty: 1 Flyash : 1 Fine Sand)	Full Brick	155405.05	150236.59	89405.19	102518.87	103140.00	58206.49	60011.44	89164.53	73120.53
		Half Brick	9236.33	11086.23	6889.73	7794.48	6631.08	6631.08	6631.08	5809.62	4855.88
		EEC_1	**164641.38**	**161322.82**	**96294.92**	**110313.35**	**109771.08**	**64837.57**	**66642.52**	**94974.15**	**77976.41**
2.	1:3 (1 Cement : 3 Fine Sand)	Full Brick	176326.43	168647.65	107815.68	120931.65	122387.64	72015.21	73820.16	105901.86	89857.86
		Half Brick	9236.33	11086.23	6889.73	7794.48	6631.08	6631.08	6631.08	5809.62	4855.88
		EEC_1	**185562.76**	**179733.88**	**114705.41**	**128726.13**	**129018.72**	**78646.29**	**80451.24**	**111711.48**	**94713.74**
3.	1:5 (1 Cement : 5 Fine Sand)	Full Brick	157130.93	151755.61	90922.50	104037.89	104696.84	59346.18	61151.13	90545.46	74501.46
		Half Brick	9236.33	11086.23	6889.73	7794.48	6631.08	6631.08	6631.08	5809.62	4855.88
		EEC_1	**166367.26**	**162841.84**	**97812.23**	**111832.37**	**111327.92**	**65977.26**	**67782.21**	**96355.08**	**79357.34**
4.	1:6 (1 Cement : 6 Fine Sand)	Full Brick	151372.28	146688.00	85854.88	98970.28	99429.83	55545.47	57357.30	85938.54	69894.54
		Half Brick	9236.33	11086.23	6889.73	7794.48	6631.08	6631.08	6631.08	5809.62	4855.88
		EEC_1	**160608.61**	**157774.23**	**92744.61**	**106764.76**	**106060.91**	**62176.55**	**63988.38**	**91748.16**	**74750.42**
5.	1:1:6 (1 Cement : 1 Lime Putty : 6 Fine Sand)	Full Brick	161894.27	155947.68	95118.00	108229.39	109110.66	62489.66	64294.61	94355.91	78311.91
		Half Brick	9236.33	11086.23	6889.73	7794.48	6631.08	6631.08	6631.08	5809.62	4855.88
		EEC_1	**171130.60**	**167033.91**	**102007.73**	**116023.87**	**115741.74**	**69120.74**	**70925.69**	**100165.53**	**83167.79**

Table IV.1.6: Embodied Energy Costs of Masonry Work (EEC$_1$) in Project No. 6 Using Alternate Masonry Units and Mortar Mixes

			EEC$_1$ (in MJ) using								
No.	Mortar Mix Ratio		Traditional Bricks (22.9 cm X 11.4 cm X 7.6 cm)	Modular Bricks (20 cm X 10 cm X 10 cm)	Clay Flyash Bricks (20 cm X 10 cm X 10 cm)	Sand Lime Bricks (20 cm X 10 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 20 cm)	Aerated Concrete Blocks (40 cm X 20 cm X 20 cm)	Solid Concrete Blocks (30 cm X 20 cm X 15 cm)	Fal-G Blocks (30 cm X 20 cm X 15 cm)
1.	1:1:1 (1 Lime Putty: 1 Flyash : 1 Fine Sand)	Full Brick	234409.40	226613.41	134856.73	154637.10	155574.00	87797.32	90519.87	134493.72	110293.32
		Half Brick	-	-	-	-	-	-	-	-	-
		EEC$_1$	**234409.40**	**226613.41**	**134856.73**	**154637.10**	**155574.00**	**87797.32**	**90519.87**	**134493.72**	**110293.32**
2.	1:3 (1 Cement : 3 Fine Sand)	Full Brick	265966.72	254384.23	162626.70	182410.52	184606.70	108626.09	111348.63	159739.93	135539.53
		Half Brick	-	-	-	-	-	-	-	-	-
		EEC$_1$	**265966.72**	**254384.23**	**162626.70**	**182410.52**	**184606.70**	**108626.09**	**111348.63**	**159739.93**	**135539.53**
3.	1:5 (1 Cement : 5 Fine Sand)	Full Brick	237012.67	228904.67	137145.40	156928.36	157922.30	89516.42	92238.96	136576.69	112376.29
		Half Brick	-	-	-	-	-	-	-	-	-
		EEC$_1$	**237012.67**	**228904.67**	**137145.40**	**156928.36**	**157922.30**	**89516.42**	**92238.96**	**136576.69**	**112376.29**
4.	1:6 (1 Cement : 6 Fine Sand)	Full Brick	228326.44	221260.80	129501.53	149284.49	149977.66	83783.51	86516.43	129627.71	105427.31
		Half Brick	-	-	-	-	-	-	-	-	-
		EEC$_1$	**228326.44**	**221260.80**	**129501.53**	**149284.49**	**149977.66**	**83783.51**	**86516.43**	**129627.71**	**105427.31**
5.	1:1:6 (1 Cement : 1 Lime Putty : 6 Fine Sand)	Full Brick	244197.60	235227.89	143473.80	163250.71	164580.00	94257.97	96980.51	142324.28	118123.88
		Half Brick	-	-	-	-	-	-	-	-	-
		EEC$_1$	**244197.60**	**235227.89**	**143473.80**	**163250.71**	**164580.00**	**94257.97**	**96980.51**	**142324.28**	**118123.88**

Table IV.1.7: Embodied Energy Costs of Masonry Work (EEC_1) in Project No. 7 Using Alternate Masonry Units and Mortar Mixes

			EEC_1 (in MJ) using								
No.	Mortar Mix Ratio		Traditional Bricks (22.9 cm X 11.4 cm X 7.6 cm)	Modular Bricks (20 cm X 10 cm X 10 cm)	Clay Flyash Bricks (20 cm X 10 cm X 10 cm)	Sand Lime Bricks (20 cm X 10 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 20 cm)	Aerated Concrete Blocks (40 cm X 20 cm X 20 cm)	Solid Concrete Blocks (30 cm X 20 cm X 15 cm)	Fal-G Blocks (30 cm X 20 cm X 15 cm)
1.	1:1:1 (1 Lime Putty: 1 Flyash : 1 Fine Sand)	Full Brick	312003.44	301626.83	179496.91	205824.97	207072.00	116859.93	120483.70	179013.74	146802.54
		Half Brick	33764.72	36621.75	23432.75	26276.25	22406.34	22406.34	22406.34	19611.13	16613.63
		EEC_1	**345768.16**	**338248.58**	**202929.66**	**232101.22**	**229478.34**	**139266.27**	**142890.04**	**198624.87**	**163416.17**
2.	1:3 (1 Cement : 3 Fine Sand)	Full Brick	354006.84	338590.33	216459.26	242791.92	245715.09	144583.42	148207.18	212616.93	180405.73
		Half Brick	33764.72	36621.75	23432.75	26276.25	22406.34	22406.34	22406.34	19611.13	16613.63
		EEC_1	**387771.56**	**375212.08**	**239892.01**	**269068.17**	**268121.43**	**166989.76**	**170613.52**	**232228.06**	**197019.36**
3.	1:5 (1 Cement : 5 Fine Sand)	Full Brick	315468.44	304676.54	182543.17	208874.68	210197.64	119148.08	122771.84	181786.21	149575.00
		Half Brick	33764.72	36621.75	23432.75	26276.25	22406.34	22406.34	22406.34	19611.13	16613.63
		EEC_1	**349233.16**	**341298.29**	**205975.92**	**235150.93**	**232603.98**	**141554.42**	**145178.18**	**201397.34**	**166188.63**
4.	1:6 (1 Cement : 6 Fine Sand)	Full Brick	303906.92	294502.40	172369.03	198700.54	199623.16	111517.48	115155.04	172537.00	140325.80
		Half Brick	33764.72	36621.75	23432.75	26276.25	22406.34	22406.34	22406.34	19611.13	16613.63
		EEC_1	**337671.64**	**331124.15**	**195801.78**	**224976.79**	**222029.50**	**133923.82**	**137561.38**	**192148.13**	**156939.43**
5.	1:1:6 (1 Cement : 1 Lime Putty : 6 Fine Sand)	Full Brick	325031.72	313092.86	190966.40	217289.85	219059.17	125459.17	129082.93	189436.37	157225.17
		Half Brick	33764.72	36621.75	23432.75	26276.25	22406.34	22406.34	22406.34	19611.13	16613.63
		EEC_1	**358796.44**	**349714.61**	**214399.15**	**243566.10**	**241465.51**	**147865.51**	**151489.27**	**209047.50**	**173838.80**

Table IV.1.8: Embodied Energy Costs of Masonry Work (EEC_1) in Project No. 8 Using Alternate Masonry Units and Mortar Mixes

			EEC_1 (in MJ) using								
No.	Mortar Mix Ratio		Traditional Bricks (22.9 cm X 11.4 cm X 7.6 cm)	Modular Bricks (20 cm X 10 cm X 10 cm)	Clay Flyash Bricks (20 cm X 10 cm X 10 cm)	Sand Lime Bricks (20 cm X 10 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 20 cm)	Aerated Concrete Blocks (40 cm X 20 cm X 20 cm)	Solid Concrete Blocks (30 cm X 20 cm X 15 cm)	Fal-G Blocks (30 cm X 20 cm X 15 cm)
1.	1:1:1 (1 Lime Putty: 1 Flyash : 1 Fine Sand)	Full Brick	309372.67	299083.56	177983.42	204089.48	205326.00	115874.59	119467.79	177504.33	145564.73
		Half Brick	27441.51	29763.50	19044.44	21355.43	18210.24	18210.24	18210.24	15938.50	13502.35
		EEC_1	**336814.18**	**328847.06**	**197027.86**	**225444.91**	**223536.24**	**134084.83**	**137678.03**	**193442.83**	**159067.08**
2.	1:3 (1 Cement : 3 Fine Sand)	Full Brick	351021.91	335735.39	214634.11	240744.74	243643.25	143364.32	146957.52	210824.17	178884.57
		Half Brick	27441.51	29763.50	19044.44	21355.43	18210.24	18210.24	18210.24	15938.50	13502.35
		EEC_1	**378463.42**	**365498.89**	**233678.55**	**262100.17**	**261853.49**	**161574.56**	**165167.76**	**226762.67**	**192386.92**
3.	1:5 (1 Cement : 5 Fine Sand)	Full Brick	312808.46	302107.55	181004.00	207113.48	208425.28	118143.44	121736.64	180253.41	148313.81
		Half Brick	27441.51	29763.50	19044.44	21355.43	18210.24	18210.24	18210.24	15938.50	13502.35
		EEC_1	**340249.97**	**331871.05**	**200048.44**	**228468.91**	**226635.52**	**136353.68**	**139946.88**	**196191.91**	**161816.16**
4.	1:6 (1 Cement : 6 Fine Sand)	Full Brick	301344.42	292019.20	170915.64	197025.13	197939.97	110577.18	114184.07	171082.19	139142.59
		Half Brick	27441.51	29763.50	19044.44	21355.43	18210.24	18210.24	18210.24	15938.50	13502.35
		EEC_1	**328785.93**	**321782.70**	**189960.08**	**218380.56**	**216150.21**	**128787.42**	**132394.31**	**187020.69**	**152644.94**
5.	1:1:6 (1 Cement : 1 Lime Putty : 6 Fine Sand)	Full Brick	322291.10	310452.91	189356.20	215457.70	217212.10	124401.32	127994.52	187839.07	155899.47
		Half Brick	27441.51	29763.50	19044.44	21355.43	18210.24	18210.24	18210.24	15938.50	13502.35
		EEC_1	**349732.61**	**340216.41**	**208400.64**	**236813.13**	**235422.34**	**142611.56**	**146204.76**	**203777.57**	**169401.82**

Table IV.1.9: Embodied Energy Costs of Masonry Work (EEC_1) in Project No. 9 Using Alternate Masonry Units and Mortar Mixes

			EEC_1 (in MJ) using								
No.	Mortar Mix Ratio		Traditional Bricks (22.9 cm X 11.4 cm X 7.6 cm)	Modular Bricks (20 cm X 10 cm X 10 cm)	Clay Flyash Bricks (20 cm X 10 cm X 10 cm)	Sand Lime Bricks (20 cm X 10 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 20 cm)	Aerated Concrete Blocks (40 cm X 20 cm X 20 cm)	Solid Concrete Blocks (30 cm X 20 cm X 15 cm)	Fal-G Blocks (30 cm X 20 cm X 15 cm)
1.	1:1:1 (1 Lime Putty: 1 Flyash : 1 Fine Sand)	Full Brick	334487.00	323362.63	192431.80	220657.10	221994.00	125281.08	129165.98	191913.81	157381.41
		Half Brick	36462.73	39728.70	24585.33	27850.19	23526.50	23526.50	23526.50	20604.70	17163.02
		EEC_1	**370949.73**	**363091.33**	**217017.13**	**248507.29**	**245520.50**	**148807.58**	**152692.48**	**212518.51**	**174544.43**
2.	1:3 (1 Cement : 3 Fine Sand)	Full Brick	379517.24	362989.79	232057.73	260287.97	263421.78	155002.38	158887.27	227938.51	193406.11
		Half Brick	36462.73	39728.70	24585.33	27850.19	23526.50	23526.50	23526.50	20604.70	17163.02
		EEC_1	**415979.97**	**402718.49**	**256643.06**	**288138.16**	**286948.28**	**178528.88**	**182413.77**	**248543.21**	**210569.13**
3.	1:5 (1 Cement : 5 Fine Sand)	Full Brick	338201.70	326632.11	195697.58	223926.58	225344.88	127734.11	131619.01	194886.07	160353.67
		Half Brick	36462.73	39728.70	24585.33	27850.19	23526.50	23526.50	23526.50	20604.70	17163.02
		EEC_1	**374664.43**	**366360.81**	**220282.91**	**251776.77**	**248871.38**	**151260.61**	**155145.51**	**215490.77**	**177516.69**
4.	1:6 (1 Cement : 6 Fine Sand)	Full Brick	326449.09	315724.80	184790.27	231019.28	214008.38	119553.64	123453.33	184970.33	150437.93
		Half Brick	36462.73	39728.70	24585.33	27850.19	23526.50	23526.50	23526.50	20604.70	17163.02
		EEC_1	**362911.82**	**355453.50**	**209375.60**	**240869.47**	**237534.88**	**143080.14**	**146979.83**	**205575.03**	**167600.95**
5.	1:1:6 (1 Cement : 1 Lime Putty : 6 Fine Sand)	Full Brick	348454.11	335654.93	204727.80	232948.17	234845.00	134500.00	138384.90	203087.51	168555.11
		Half Brick	36462.73	39728.70	24585.33	27850.19	23526.50	23526.50	23526.50	20604.70	17163.02
		EEC_1	**384916.84**	**375383.63**	**229313.13**	**260798.36**	**258371.50**	**158026.50**	**161911.40**	**223692.21**	**185718.13**

Table IV.1.10: Embodied Energy Costs of Masonry Work (EEC$_1$) in Project No. 10 Using Alternate Masonry Units and Mortar Mixes

No.	Mortar Mix Ratio		EEC$_1$ (in MJ) using: Traditional Bricks (22.9 cm X 11.4 cm X 7.6 cm)	Modular Bricks (20 cm X 10 cm X 10 cm)	Clay Flyash Bricks (20 cm X 10 cm X 10 cm)	Sand Lime Bricks (20 cm X 10 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 20 cm)	Aerated Concrete Blocks (40 cm X 20 cm X 20 cm)	Solid Concrete Blocks (30 cm X 20 cm X 15 cm)	Fal-G Blocks (30 cm X 20 cm X 15 cm)
1.	1:1:1 (1 Lime Putty: 1 Flyash : 1 Fine Sand)	Full Brick	347423.85	335869.23	199874.43	229191.40	230580.00	130126.54	134161.70	199336.41	163468.41
		Half Brick	33549.85	36388.70	23283.63	26109.04	22263.75	22263.75	22263.75	19486.33	16507.91
		EEC$_1$	**380973.70**	**372257.93**	**223158.06**	**255300.44**	**252843.75**	**152390.29**	**156425.45**	**218822.74**	**179976.32**
2.	1:3 (1 Cement : 3 Fine Sand)	Full Brick	394195.73	377029.04	241032.96	270355.05	273610.07	160997.36	165032.51	236754.42	200886.42
		Half Brick	33549.85	36388.70	23283.63	26109.04	22263.75	22263.75	22263.75	19486.33	16507.91
		EEC$_1$	**427745.58**	**413417.74**	**264316.59**	**296464.10**	**295873.82**	**183261.11**	**187296.26**	**256240.75**	**217394.33**
3.	1:5 (1 Cement : 5 Fine Sand)	Full Brick	351282.22	339265.16	203266.52	232587.33	234060.48	132674.45	136709.60	202423.62	166555.62
		Half Brick	33549.85	36388.70	23283.63	26109.04	22263.75	22263.75	22263.75	19486.33	16507.91
		EEC$_1$	**384832.07**	**375653.86**	**226550.15**	**258696.37**	**256324.23**	**154938.20**	**158973.35**	**221909.95**	**183063.53**
4.	1:6 (1 Cement : 6 Fine Sand)	Full Brick	338408.18	327936.00	191937.35	221258.16	222285.53	124177.58	128228.10	192124.38	156256.38
		Half Brick	33549.85	36388.70	23283.63	26109.04	22263.75	22263.75	22263.75	19486.33	16507.91
		EEC$_1$	**371958.03**	**364324.70**	**215220.98**	**247367.20**	**244549.28**	**146441.33**	**150491.85**	**211610.71**	**172764.29**
5.	1:1:6 (1 Cement : 1 Lime Putty : 6 Fine Sand)	Full Brick	361931.18	348636.96	212646.00	241957.84	243928.02	139702.02	143737.17	210942.27	175074.27
		Half Brick	33549.85	36388.70	23283.63	26109.04	22263.75	22263.75	22263.75	19486.33	16507.91
		EEC$_1$	**395481.03**	**385025.66**	**235929.63**	**268066.88**	**266191.77**	**161965.77**	**166000.92**	**230428.60**	**191582.18**

Table IV.1.11: Embodied Energy Costs of Masonry Work (EEC_1) in Project No. 11 Using Alternate Masonry Units and Mortar Mixes

No.	Mortar Mix Ratio		EEC_1 (in MJ) using: Traditional Bricks (22.9 cm X 11.4 cm X 7.6 cm)	Modular Bricks (20 cm X 10 cm X 10 cm)	Clay Flyash Bricks (20 cm X 10 cm X 10 cm)	Sand Lime Bricks (20 cm X 10 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 20 cm)	Aerated Concrete Blocks (40 cm X 20 cm X 20 cm)	Solid Concrete Blocks (30 cm X 20 cm X 15 cm)	Fal-G Blocks (30 cm X 20 cm X 15 cm)
1.	1:1:1 (1 Lime Putty: 1 Flyash : 1 Fine Sand)	Full Brick	374273.94	361826.34	215321.40	246904.08	248400.00	140183.16	144530.16	214741.80	176101.80
		Half Brick	19418.50	21158.20	13005.00	14762.80	12548.18	12548.18	12548.18	10997.91	9144.91
		EEC_1	**393692.44**	**382984.54**	**228326.40**	**261666.88**	**260948.18**	**152731.34**	**157078.34**	**225739.71**	**185246.71**
2.	1:3 (1 Cement : 3 Fine Sand)	Full Brick	424660.50	406167.12	259660.80	291249.00	294755.58	173439.78	177786.78	255051.60	216411.60
		Half Brick	19418.15	21158.20	13005.00	14762.80	12548.18	12548.18	12548.18	10997.91	9144.91
		EEC_1	**444078.65**	**427325.32**	**272665.80**	**306011.80**	**307303.76**	**185987.96**	**190334.96**	**266049.51**	**225556.51**
3.	1:5 (1 Cement : 5 Fine Sand)	Full Brick	378430.50	365484.72	218975.64	250562.46	252149.46	142927.98	147274.98	218067.60	179427.60
		Half Brick	19418.15	21158.20	13005.00	14762.80	12548.18	12548.18	12548.18	10997.91	9144.91
		EEC_1	**397848.65**	**386642.92**	**231980.64**	**265325.26**	**264697.64**	**155476.16**	**159823.16**	**229065.51**	**188572.51**
4.	1:6 (1 Cement : 6 Fine Sand)	Full Brick	364561.50	353280.00	206770.92	238357.74	239464.50	133774.44	138138.00	206972.40	168332.40
		Half Brick	19418.15	21158.20	13005.00	14762.80	12548.18	12548.18	12548.18	10997.91	9144.91
		EEC_1	**383979.65**	**374438.20**	**219775.92**	**253120.54**	**252012.68**	**146322.62**	**150686.18**	**217970.31**	**177477.31**
5.	1:1:6 (1 Cement : 1 Lime Putty : 6 Fine Sand)	Full Brick	389902.44	375580.80	229080.00	260657.16	262779.60	150498.66	154845.66	227244.60	188604.60
		Half Brick	19418.15	21158.20	13005.00	14762.80	12548.18	12548.18	12548.18	10997.91	9144.91
		EEC_1	**409320.59**	**396739.00**	**242085.00**	**275419.96**	**275327.78**	**163046.84**	**167393.84**	**238242.51**	**197749.51**

Table IV.1.12: Embodied Energy Costs of Masonry Work (EEC_1) in Project No. 12 Using Alternate Masonry Units and Mortar Mixes

			EEC₁ (in MJ) using								
No.	Mortar Mix Ratio		Traditional Bricks (22.9 cm X 11.4 cm X 7.6 cm)	Modular Bricks (20 cm X 10 cm X 10 cm)	Clay Flyash Bricks (20 cm X 10 cm X 10 cm)	Sand Lime Bricks (20 cm X 10 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 20 cm)	Aerated Concrete Blocks (40 cm X 20 cm X 20 cm)	Solid Concrete Blocks (30 cm X 20 cm X 15 cm)	Fal-G Blocks (30 cm X 20 cm X 15 cm)
1.	1:1:1 (1 Lime Putty: 1 Flyash : 1 Fine Sand)	Full Brick	449942.37	434978.19	258853.77	296821.64	298620.00	168524.54	173750.39	258157.00	211705.00
		Half Brick	14849.17	16179.80	9945.00	11289.20	9595.66	9595.66	9595.66	8410.17	6993.17
		EEC₁	**464791.54**	**451158.00**	**268798.77**	**308110.84**	**308215.66**	**178120.20**	**183346.05**	**266567.17**	**218698.17**
2.	1:3 (1 Cement : 3 Fine Sand)	Full Brick	510515.78	488283.52	312157.44	350131.95	354347.47	208504.78	213730.63	306616.38	260164.38
		Half Brick	14849.17	16179.80	9945.00	11289.20	9595.66	9595.66	9595.66	8410.17	6993.17
		EEC₁	**525364.95**	**504463.32**	**322102.44**	**361421.15**	**363943.13**	**218100.44**	**223326.29**	**315026.55**	**267157.55**
3.	1:5 (1 Cement : 5 Fine Sand)	Full Brick	454939.28	439376.20	263246.80	301219.65	303127.50	171824.29	177050.14	262155.18	215703.18
		Half Brick	14849.17	16179.80	9945.00	11289.20	9595.66	9595.66	9595.66	8410.17	6993.17
		EEC₁	**469788.45**	**455556.00**	**273191.80**	**312508.85**	**312723.16**	**181419.95**	**186645.80**	**270565.35**	**222696.35**
4.	1:6 (1 Cement : 6 Fine Sand)	Full Brick	438266.35	424704.00	248574.61	286547.46	287877.98	160820.14	166065.90	248816.82	202364.82
		Half Brick	14849.17	16179.80	9945.00	11289.20	9595.66	9595.66	9595.66	8410.17	6993.17
		EEC₁	**453115.52**	**440883.80**	**258519.61**	**297836.66**	**297473.64**	**170415.80**	**175661.56**	**257226.99**	**209357.99**
5.	1:1:6 (1 Cement : 1 Lime Putty : 6 Fine Sand)	Full Brick	468730.54	451513.44	275394.00	313355.24	315906.78	180925.56	186151.41	273187.53	226735.53
		Half Brick	14849.17	16179.80	9945.00	11289.20	9595.66	9595.66	9595.66	8410.17	6993.17
		EEC₁	**483579.71**	**467693.24**	**285339.00**	**324644.44**	**325502.44**	**190521.22**	**195747.07**	**281597.70**	**233728.70**

Table IV.1.13: Embodied Energy Costs of Masonry Work (EEC_1) in Project No. 13 Using Alternate Masonry Units and Mortar Mixes

			EEC_1 (in MJ) using								
No.	Mortar Mix Ratio		Traditional Bricks (22.9 cm X 11.4 cm X 7.6 cm)	Modular Bricks (20 cm X 10 cm X 10 cm)	Clay Flyash Bricks (20 cm X 10 cm X 10 cm)	Sand Lime Bricks (20 cm X 10 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 20 cm)	Aerated Concrete Blocks (40 cm X 20 cm X 20 cm)	Solid Concrete Blocks (30 cm X 20 cm X 15 cm)	Fal-G Blocks (30 cm X 20 cm X 15 cm)
1.	1:1:1 (1 Lime Putty: 1 Flyash : 1 Fine Sand)	Full Brick	446660.69	431805.65	256965.81	294656.76	296442.00	167295.40	172483.13	256274.11	210160.91
		Half Brick	5475.96	5963.78	3997.42	4421.36	3466.53	3466.53	3466.53	3007.76	2560.91
		EEC_1	**452136.65**	**437769.43**	**260963.23**	**299078.12**	**299908.53**	**170761.93**	**175949.66**	**259281.87**	**212721.82**
2.	1:3 (1 Cement : 3 Fine Sand)	Full Brick	506792.30	484722.20	309880.70	347578.25	351763.02	206984.04	212171.77	304380.06	258266.86
		Half Brick	5475.96	5963.78	3997.42	4421.36	3466.53	3466.53	3466.53	3007.76	2560.91
		EEC_1	**512268.26**	**490685.98**	**313878.12**	**351999.61**	**355229.55**	**210450.57**	**215638.30**	**307387.82**	**260827.77**
3.	1:5 (1 Cement : 5 Fine Sand)	Full Brick	451621.15	436171.58	261326.80	299022.70	300916.63	170571.08	175758.81	260243.14	214129.94
		Half Brick	5475.96	5963.78	3997.42	4421.36	3466.53	3466.53	3466.53	3007.76	2560.91
		EEC_1	**457097.11**	**442135.36**	**265324.22**	**303444.06**	**304383.16**	**174037.61**	**179225.34**	**263250.90**	**216690.85**
4.	1:6 (1 Cement : 6 Fine Sand)	Full Brick	435711.87	421606.40	246761.61	284457.51	285778.32	159647.19	164854.69	247002.06	200888.86
		Half Brick	5475.96	5963.78	3997.42	4421.36	3466.53	3466.53	3466.53	3007.76	2560.91
		EEC_1	**441187.83**	**427570.18**	**250759.03**	**288878.87**	**289244.85**	**163113.72**	**168321.22**	**250009.82**	**203449.77**
5.	1:1:6 (1 Cement : 1 Lime Putty : 6 Fine Sand)	Full Brick	465311.83	448220.30	273385.40	311069.77	313602.70	179605.97	184793.71	271195.02	225081.82
		Half Brick	5475.96	5963.78	3997.42	4421.36	3466.53	3466.53	3466.53	3007.76	2560.91
		EEC_1	**470787.79**	**454184.08**	**277382.82**	**315491.13**	**317069.23**	**183072.50**	**188260.24**	**274202.78**	**227642.73**

Table IV.1.14: Embodied Energy Costs of Masonry Work (EEC$_1$) in Project No. 14 Using Alternate Masonry Units and Mortar Mixes

			EEC$_1$ (in MJ) Using								
No.	Mortar Mix Ratio		Traditional Bricks (22.9 cm X 11.4 cm X 7.6 cm)	Modular Bricks (20 cm X 10 cm X 10 cm)	Clay Flyash Bricks (20 cm X 10 cm X 10 cm)	Sand Lime Bricks (20 cm X 10 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 20 cm)	Aerated Concrete Blocks (40 cm X 20 cm X 20 cm)	Solid Concrete Blocks (30 cm X 20 cm X 15 cm)	Fal-G Blocks (30 cm X 20 cm X 15 cm)
1.	1:1:1 (1 Lime Putty: 1 Flyash : 1 Fine Sand)	Full Brick	1459125.94	1410598.34	839441.40	962568.08	968400.00	546511.16	563458.16	837181.80	686541.80
		Half Brick	425956.23	463901.93	310945.50	343922.34	269649.81	269649.81	269649.81	233967.21	199204.38
		EEC$_1$	**1885082.17**	**1874500.27**	**1150386.90**	**1306490.42**	**1238049.81**	**816160.97**	**833107.97**	**1071149.01**	**885746.18**
2.	1:3 (1 Cement : 3 Fine Sand)	Full Brick	1655560.50	1583463.12	1012300.80	1135449.00	1149119.58	676163.78	693110.78	994331.60	843691.60
		Half Brick	425956.23	463901.93	310945.50	343922.34	269649.81	269649.81	269649.81	233967.21	199204.38
		EEC$_1$	**2081516.73**	**2047365.05**	**1323246.30**	**1479371.34**	**1418769.39**	**945813.59**	**962760.59**	**1228298.81**	**1042895.98**
3.	1:5 (1 Cement : 5 Fine Sand)	Full Brick	1475330.50	1424860.72	853687.64	976830.46	983017.46	557211.98	574158.98	850147.60	699507.60
		Half Brick	425956.23	463901.93	310945.50	343922.34	269649.81	269649.81	269649.81	233967.21	199204.38
		EEC$_1$	**1901286.73**	**1888762.65**	**1164633.14**	**1320752.80**	**1252667.27**	**826861.79**	**843808.79**	**1084114.81**	**898711.98**
4.	1:6 (1 Cement : 6 Fine Sand)	Full Brick	1421261.50	1377280.00	806106.92	929249.74	933564.50	521526.44	538538.00	806892.40	656252.40
		Half Brick	425956.23	463901.93	310945.50	343922.34	269649.81	269649.81	269649.81	233967.21	199204.38
		EEC$_1$	**1847217.73**	**1841181.93**	**1117052.42**	**1273172.08**	**1203214.31**	**791176.25**	**808187.81**	**1040859.61**	**855456.78**
5.	1:1:6 (1 Cement : 1 Lime Putty : 6 Fine Sand)	Full Brick	1520054.44	1464220.80	893080.00	1016185.16	1024459.60	586726.66	603673.66	885924.60	735284.60
		Half Brick	425956.23	463901.93	310945.50	343922.34	269649.81	269649.81	269649.81	233967.21	199204.38
		EEC$_1$	**1946010.67**	**1928122.73**	**1204025.50**	**1360107.50**	**1294109.41**	**856376.47**	**873323.47**	**1119891.81**	**934488.98**

Table IV.1.15: Embodied Energy Costs of Masonry Work (EEC_1) in Project No. 15 Using Alternate Masonry Units and Mortar Mixes

No.	Mortar Mix Ratio		EEC_1 (in MJ) Using: Traditional Bricks (22.9 cm X 11.4 cm X 7.6 cm)	Modular Bricks (20 cm X 10 cm X 10 cm)	Clay Flyash Bricks (20 cm X 10 cm X 10 cm)	Sand Lime Bricks (20 cm X 10 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 20 cm)	Aerated Concrete Blocks (40 cm X 20 cm X 20 cm)	Solid Concrete Blocks (30 cm X 20 cm X 15 cm)	Fal-G Blocks (30 cm X 20 cm X 15 cm)
1.	1:1:1 (1 Lime Putty: 1 Flyash : 1 Fine Sand)	Full Brick	13144338.05	12707183.75	7561993.95	8671163.94	8723700.00	4923171.63	5075836.38	7541638.65	6184618.65
		Half Brick	559437.83	608871.38	378063.88	427825.13	363942.81	363942.81	363942.81	318867.75	266411.50
		EEC_1	**13703775.88**	**13316055.12**	**7940057.83**	**9098989.07**	**9087642.81**	**5287114.44**	**5439779.19**	**7860506.40**	**6451030.15**
2.	1:3 (1 Cement : 3 Fine Sand)	Full Brick	14912353.50	14262941.04	9118233.60	10227483.00	10350619.86	6090501.26	6243150.26	8956377.20	7599497.20
		Half Brick	559437.83	608871.38	378063.88	427825.13	363942.81	363942.81	363942.81	318867.75	266411.50
		EEC_1	**15471791.33**	**14871812.42**	**9496297.48**	**10655308.13**	**10714562.67**	**6454444.07**	**6607093.07**	**9275244.95**	**7865908.70**
3.	1:5 (1 Cement : 5 Fine Sand)	Full Brick	13290314.63	12835664.46	7690329.27	8799644.66	8855379.41	5019568.52	5172233.27	7658439.30	6301419.30
		Half Brick	559437.83	608871.38	378063.88	427825.13	363942.81	363942.81	363942.81	318867.75	266411.50
		EEC_1	**13849752.46**	**13444535.84**	**8068393.15**	**9227469.78**	**9219322.22**	**5383511.33**	**5536176.08**	**7977307.05**	**6567830.80**
4.	1:6 (1 Cement : 6 Fine Sand)	Full Brick	12803241.38	12407040.00	7261704.81	8371020.20	8409889.13	4698100.17	4851346.50	7268780.70	5911760.70
		Half Brick	559437.83	608871.38	378063.88	427825.13	363942.81	363942.81	363942.81	318867.75	266411.50
		EEC_1	**13362679.21**	**13015911.38**	**7639768.69**	**8798845.32**	**8773831.94**	**5062042.98**	**5215289.31**	**7587648.45**	**6178172.20**
5.	1:1:6 (1 Cement : 1 Lime Putty : 6 Fine Sand)	Full Brick	13693204.17	13190234.40	8045190.00	9125087.13	9228705.30	5285447.51	5438112.26	7980731.55	6623711.55
		Half Brick	559437.83	608871.38	378063.88	427825.13	363942.81	363942.81	363942.81	318867.75	266411.50
		EEC_1	**14252642.00**	**13799105.78**	**8423253.88**	**9552912.26**	**9592648.11**	**5649390.32**	**5802055.07**	**8299599.30**	**6890123.05**

Table IV.1.16: Embodied Energy Costs of Masonry Work (EEC_1) in Project No. 16 Using Alternate Masonry Units and Mortar Mixes

			EEC_1 (in MJ) Using								
No.	Mortar Mix Ratio		Traditional Bricks (22.9 cm X 11.4 cm X 7.6 cm)	Modular Bricks (20 cm X 10 cm X 10 cm)	Clay Flyash Bricks (20 cm X 10 cm X 10 cm)	Sand Lime Bricks (20 cm X 10 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 20 cm)	Aerated Concrete Blocks (40 cm X 20 cm X 20 cm)	Solid Concrete Blocks (30 cm X 20 cm X 15 cm)	Fal-G Blocks (30 cm X 20 cm X 15 cm)
1.	1:1:1 (1 Lime Putty: 1 Flyash : 1 Fine Sand)	Full Brick	16408386.50	15862676.50	9439815.00	10824418.00	10890000.00	6145711.00	6336286.00	9414405.00	7720405.00
		Half Brick	5363617.97	5882104.85	3945264.23	4362839.96	3194855.52	3194855.52	3194855.52	2755098.26	2314907.21
		EEC_1	**21772004.47**	**21744781.35**	**13385079.23**	**15187257.96**	**14084855.52**	**9340566.52**	**9531141.52**	**12169503.26**	**10035312.21**
2.	1:3 (1 Cement : 3 Fine Sand)	Full Brick	18617362.50	17806602.00	11383680.00	12768525.00	12922255.50	7603700.50	7794275.50	11181610.00	9487610.00
		Half Brick	5363617.97	5882104.85	3945264.23	4362839.96	3194855.52	3194855.52	3194855.52	2755098.26	2314907.21
		EEC_1	**23980980.47**	**23688706.85**	**15328944.23**	**17131364.96**	**16117111.02**	**10798556.02**	**10989131.02**	**13936708.26**	**11802517.21**
3.	1:5 (1 Cement : 5 Fine Sand)	Full Brick	16590612.50	16023062.00	9600019.00	10984803.50	11054378.50	6266045.50	6456620.50	9560210.00	7866210.00
		Half Brick	5363617.97	5882104.85	3945264.23	4362839.96	3194855.52	3194855.52	3194855.52	2755098.26	2314907.21
		EEC_1	**21954230.47**	**21905166.85**	**13545283.23**	**15347643.46**	**14249234.02**	**9460901.02**	**9651476.02**	**12315308.26**	**10181117.21**
4.	1:6 (1 Cement : 6 Fine Sand)	Full Brick	16240850.70	15488000.00	9064957.00	10449741.50	1049262.50	5864749.00	6056050.00	9073790.00	7379790.00
		Half Brick	5363617.97	5882104.85	3945264.23	4362839.96	3194855.52	3194855.52	3194855.52	2755098.26	2314907.21
		EEC_1	**21604468.67**	**21370104.85**	**13010221.23**	**14812581.46**	**13693118.02**	**9059604.52**	**9250905.52**	**11828888.26**	**9694697.21**
5.	1:1:6 (1 Cement : 1 Lime Putty : 6 Fine Sand)	Full Brick	17093549.00	16465680.00	10043000.00	11427361.00	1152041.00	6597948.50	6788523.50	9962535.00	8268535.00
		Half Brick	5363617.97	5882104.85	3945264.23	4362839.96	3194855.52	3194855.52	3194855.52	2755098.26	2314907.21
		EEC_1	**22457166.97**	**22347784.85**	**13988264.23**	**15790200.96**	**14715265.52**	**9792804.02**	**9983379.02**	**12717633.26**	**10583442.21**

Table IV.2.1: EEC_1[1] and Resultant EEC_T[2] for Project No. 1 Using Alternate Masonry Units and Mortar Mixes

			EEC_1 (in MJ) and EEC_T (in MJ) Using								
No.	Mortar Mix Ratio		Traditional Bricks (22.9 cm X 11.4 cm X 7.6 cm)	Modular Bricks (20 cm X 10 cm X 10 cm)	Clay Flyash Bricks (20 cm X 10 cm X 10 cm)	Sand Lime Bricks (20 cm X 10 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 20 cm)	Aerated Concrete Blocks (40 cm X 20 cm X 20 cm)	Solid Concrete Blocks (30 cm X 20 cm X 15 cm)	Fal-G Blocks (30 cm X 20 cm X 15 cm)
1.	1:1:1 (1 Lime Putty: 1 Flyash : 1 Fine Sand)	EEC_1	62704.45	60619.20	36074.14	41365.38	41616.00	23485.76	24214.04	35977.03	29503.43
		EEC_T	**110179.52**	**108094.27**	**83549.21**	**88840.45**	**89091.07**	**70960.83**	**71689.11**	**83452.10**	**76978.50**
2.	1:3 (1 Cement : 3 Fine Sand)	EEC_1	71146.02	68047.71	43502.60	48794.76	49382.24	29057.45	29785.73	42730.38	36256.78
		EEC_T	**118621.10**	**115522.78**	**90977.67**	**96269.83**	**96857.31**	**76532.52**	**77260.80**	**90205.45**	**83731.85**
3.	1:5 (1 Cement : 5 Fine Sand)	EEC_1	63400.82	61231.93	36686.35	41978.29	42244.17	23945.62	24673.90	36534.22	30060.62
		EEC_T	**110875.89**	**108707.00**	**84161.42**	**89453.36**	**89719.24**	**71420.70**	**72148.97**	**84009.30**	**77535.70**
4.	1:6 (1 Cement : 6 Fine Sand)	EEC_1	61077.26	59187.20	34641.62	39933.56	40118.98	22412.07	23143.12	34675.38	28201.78
		EEC_T	**108552.33**	**106662.27**	**82116.70**	**87408.63**	**87594.05**	**69887.14**	**70888.19**	**82150.45**	**75676.85**
5.	1:1:6 (1 Cement : 1 Lime Putty : 6 Fine Sand)	EEC_1	65322.79	62923.40	38379.20	43669.52	44025.10	25213.98	25942.26	38071.70	31598.10
		EEC_T	**112797.86**	**110398.47**	**85854.27**	**91144.60**	**91500.17**	**72689.05**	**73417.33**	**85546.77**	**79073.17**

[1] EEC_1 – Embodied Energy Cost of Masonry Work; alternative EEC_1 values obtained from Tables IV.1.1 – IV.1.16

[2] EEC_T – Total Embodied Energy Cost of Civil Work

Table IV.2.2: EEC_1 and Resultant EEC_T for Project No. 2 Using Alternate Masonry Units and Mortar Mixes

			EEC_1 (in MJ) and EEC_T (in MJ) Using								
No.	Mortar Mix Ratio		Traditional Bricks (22.9 cm X 11.4 cm X 7.6 cm)	Modular Bricks (20 cm X 10 cm X 10 cm)	Clay Flyash Bricks (20 cm X 10 cm X 10 cm)	Sand Lime Bricks (20 cm X 10 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 20 cm)	Aerated Concrete Blocks (40 cm X 20 cm X 20 cm)	Solid Concrete Blocks (30 cm X 20 cm X 15 cm)	Fal-G Blocks (30 cm X 20 cm X 15 cm)
1.	1:1:1 (1 Lime Putty: 1 Flyash : 1 Fine Sand)	EEC_1	108132.62	104536.35	62209.10	71333.81	71766.00	40500.74	41756.65	62041.71	50878.11
		EEC_T	**177291.81**	**173695.54**	**131368.30**	**140493.00**	**140925.20**	**109659.93**	**110915.84**	**131200.90**	**120037.30**
2.	1:3 (1 Cement : 3 Fine Sand)	EEC_1	122689.96	117346.98	75019.40	84145.64	85158.73	50109.01	51364.92	73687.73	62524.13
		EEC_T	**191849.15**	**186506.17**	**144178.60**	**153304.83**	**154317.92**	**119268.20**	**120524.11**	**142846.92**	**131683.32**
3.	1:5 (1 Cement : 5 Fine Sand)	EEC_1	109333.51	105593.30	63264.92	72390.76	72849.27	41293.76	42549.66	63002.57	51838.97
		EEC_T	**178492.70**	**174752.50**	**132424.11**	**141549.95**	**142008.46**	**110452.95**	**111708.85**	**131261.76**	**120998.16**
4.	1:6 (1 Cement : 6 Fine Sand)	EEC_1	105326.58	102067.20	59738.82	68864.66	69184.42	38649.18	39909.87	59797.03	48633.43
		EEC_T	**174485.77**	**171226.40**	**128898.01**	**138023.85**	**138343.61**	**107808.37**	**109069.06**	**128956.22**	**117792.62**
5.	1:1:6 (1 Cement : 1 Lime Putty : 6 Fine Sand)	EEC_1	112647.90	108510.20	66184.20	75307.25	75920.45	43481.03	44736.93	65653.93	54490.33
		EEC_T	**181807.10**	**177669.40**	**135343.40**	**144466.44**	**145079.64**	**112640.22**	**113896.12**	**134813.12**	**123649.52**

Table IV.2.3: EEC_1 and Resultant EEC_T for Project No. 3 Using Alternate Masonry Units and Mortar Mixes

EEC_1 (in MJ) and EEC_T (in MJ) Using											
No.	Mortar Mix Ratio		Traditional Bricks (22.9 cm X 11.4 cm X 7.6 cm)	Modular Bricks (20 cm X 10 cm X 10 cm)	Clay Flyash Bricks (20 cm X 10 cm X 10 cm)	Sand Lime Bricks (20 cm X 10 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 20 cm)	Aerated Concrete Blocks (40 cm X 20 cm X 20 cm)	Solid Concrete Blocks (30 cm X 20 cm X 15 cm)	Fal-G Blocks (30 cm X 20 cm X 15 cm)
1.	1:1:1 (1 Lime Putty: 1 Flyash : 1 Fine Sand)	EEC_1	142169.85	137441.57	81790.93	93787.77	94356.00	53249.28	54900.51	81570.76	66893.16
		EEC_T	**252611.53**	**247883.25**	**192232.61**	**204229.45**	**204797.68**	**163690.96**	**165342.20**	**192012.44**	**177334.84**
2.	1:3 (1 Cement : 3 Fine Sand)	EEC_1	161309.45	154284.64	98633.47	110632.41	111964.40	65881.90	67533.21	96882.64	82205.04
		EEC_T	**271751.13**	**264726.32**	**209075.15**	**221074.10**	**222406.08**	**176323.58**	**177974.90**	**207324.32**	**192646.72**
3.	1:5 (1 Cement : 5 Fine Sand)	EEC_1	143748.75	138831.22	83179.01	95177.42	95780.25	54291.92	55943.15	82834.08	68156.48
		EEC_T	**254190.43**	**249272.90**	**193620.69**	**205619.10**	**206221.93**	**164733.60**	**166384.83**	**193275.76**	**178598.16**
4.	1:6 (1 Cement : 6 Fine Sand)	EEC_1	138480.54	134195.20	78542.98	90541.40	90961.80	50814.90	52472.42	78619.52	63941.92
		EEC_T	**248922.22**	**244636.88**	**188984.66**	**200983.08**	**201403.49**	**161256.58**	**162914.10**	**189061.20**	**174383.60**
5.	1:1:6 (1 Cement : 1 Lime Putty : 6 Fine Sand)	EEC_1	148106.42	142666.27	87017.20	99011.94	99818.16	57167.68	58818.91	86320.01	71642.41
		EEC_T	**258548.10**	**253107.95**	**197548.88**	**209453.62**	**210259.84**	**167609.36**	**169260.60**	**196761.70**	**182084.10**

Table IV.2.4: EEC_1 and Resultant EEC_T for Project No. 4 Using Alternate Masonry Units and Mortar Mixes

			EEC_1 (in MJ) and EEC_T (in MJ) Using								
No.	Mortar Mix Ratio		Traditional Bricks (22.9 cm X 11.4 cm X 7.6 cm)	Modular Bricks (20 cm X 10 cm X 10 cm)	Clay Flyash Bricks (20 cm X 10 cm X 10 cm)	Sand Lime Bricks (20 cm X 10 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 20 cm)	Aerated Concrete Blocks (40 cm X 20 cm X 20 cm)	Solid Concrete Blocks (30 cm X 20 cm X 15 cm)	Fal-G Blocks (30 cm X 20 cm X 15 cm)
1.	1:1:1 (1 Lime Putty: 1 Flyash : 1 Fine Sand)	EEC_1	145634.70	143380.19	85646.81	98092.72	97544.02	57786.09	59383.14	84398.48	69314.13
		EEC_T	**256128.33**	**253873.82**	**196140.44**	**208586.35**	**208037.65**	**168279.72**	**169876.77**	**194892.11**	**179807.76**
2.	1:3 (1 Cement : 3 Fine Sand)	EEC_1	164146.28	159670.61	101936.72	114384.66	114574.66	70004.29	71601.34	99207.95	84123.60
		EEC_T	**274639.91**	**270164.24**	**212430.35**	**224878.29**	**225068.29**	**180497.92**	**182094.97**	**209701.58**	**194617.23**
3.	1:5 (1 Cement : 5 Fine Sand)	EEC_1	147161.78	144724.25	86989.35	99436.78	98921.54	58794.52	60391.57	85620.35	70536.00
		EEC_T	**257655.41**	**255217.88**	**197482.98**	**209930.41**	**209415.17**	**169288.15**	**170885.20**	**196113.98**	**181029.63**
4.	1:6 (1 Cement : 6 Fine Sand)	EEC_1	142066.43	140240.34	82505.44	94952.87	94261.20	55431.59	57034.72	81544.07	66459.72
		EEC_T	**252560.06**	**250733.97**	**192999.07**	**205446.50**	**204754.83**	**165925.22**	**167528.35**	**192037.70**	**176953.35**
5.	1:1:6 (1 Cement : 1 Lime Putty : 6 Fine Sand)	EEC_1	151376.47	148433.46	90701.00	103145.48	102826.96	61575.92	63172.97	88991.91	73907.56
		EEC_T	**261870.10**	**258927.09**	**201194.63**	**213639.11**	**213320.59**	**172069.55**	**173666.60**	**199485.54**	**184401.19**

Table IV.2.5: EEC_1 and Resultant EEC_T for Project No. 5 Using Alternate Masonry Units and Mortar Mixes

			EEC_1 (in MJ) and EEC_T (in MJ) Using								
No.	Mortar Mix Ratio		Traditional Bricks (22.9 cm X 11.4 cm X 7.6 cm)	Modular Bricks (20 cm X 10 cm X 10 cm)	Clay Flyash Bricks (20 cm X 10 cm X 10 cm)	Sand Lime Bricks (20 cm X 10 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 20 cm)	Aerated Concrete Blocks (40 cm X 20 cm X 20 cm)	Solid Concrete Blocks (30 cm X 20 cm X 15 cm)	Fal-G Blocks (30 cm X 20 cm X 15 cm)
1.	1:1:1 (1 Lime Putty: 1 Flyash : 1 Fine Sand)	EEC_1	164641.38	161322.82	96294.92	110313.35	109771.08	64837.57	66642.52	94974.15	77976.41
		EEC_T	**319035.03**	**315716.17**	**250688.27**	**264706.70**	**264164.43**	**219230.92**	**221035.87**	**249367.50**	**232369.76**
2.	1:3 (1 Cement : 3 Fine Sand)	EEC_1	185562.76	179733.88	114705.41	128726.13	129018.72	78646.29	80451.24	111711.48	94713.74
		EEC_T	**339956.11**	**334127.23**	**269098.76**	**283119.48**	**283412.07**	**233039.64**	**234844.60**	**266104.83**	**249107.10**
3.	1:5 (1 Cement : 5 Fine Sand)	EEC_1	166367.26	162841.84	97812.23	111832.37	111327.92	65977.26	67782.21	96355.08	79357.34
		EEC_T	**320760.61**	**317235.20**	**252205.58**	**266225.72**	**265721.27**	**220370.61**	**222175.56**	**250748.43**	**233750.70**
4.	1:6 (1 Cement : 6 Fine Sand)	EEC_1	160608.61	157774.23	92744.61	106764.76	106060.91	62176.55	63988.38	91748.16	74750.42
		EEC_T	**315001.96**	**312167.58**	**247137.96**	**261158.11**	**260454.26**	**216569.90**	**218381.73**	**246141.51**	**229143.77**
5.	1:1:6 (1 Cement : 1 Lime Putty : 6 Fine Sand)	EEC_1	171130.60	167033.91	102007.73	116023.87	115741.74	69120.74	70925.69	100165.53	83167.79
		EEC_T	**325523.95**	**321427.26**	**256401.08**	**270417.22**	**270135.10**	**223514.10**	**225319.04**	**254558.88**	**237561.14**

Table IV.2.6: EEC_1 and Resultant EEC_T for Project No. 6 Using Alternate Masonry Units and Mortar Mixes

			EEC_1 (in MJ) and EEC_T (in MJ) Using								
No.	Mortar Mix Ratio		Traditional Bricks (22.9 cm X 11.4 cm X 7.6 cm)	Modular Bricks (20 cm X 10 cm X 10 cm)	Clay Flyash Bricks (20 cm X 10 cm X 10 cm)	Sand Lime Bricks (20 cm X 10 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 20 cm)	Aerated Concrete Blocks (40 cm X 20 cm X 20 cm)	Solid Concrete Blocks (30 cm X 20 cm X 15 cm)	Fal-G Blocks (30 cm X 20 cm X 15 cm)
1.	1:1:1 (1 Lime Putty: 1 Flyash : 1 Fine Sand)	EEC_1	234409.40	226613.41	134856.73	154637.10	155574.00	87797.32	90519.87	134493.72	110293.32
		EEC_T	**372311.70**	**364515.71**	**272759.03**	**292539.40**	**293476.30**	**225699.62**	**228422.17**	**272396.02**	**248195.62**
2.	1:3 (1 Cement : 3 Fine Sand)	EEC_1	265966.72	254384.23	162626.70	182410.52	184606.70	108626.09	111348.63	159739.93	135539.53
		EEC_T	**403869.02**	**392286.53**	**300529.00**	**320312.82**	**322509.00**	**246528.40**	**249250.93**	**297642.23**	**273441.83**
3.	1:5 (1 Cement : 5 Fine Sand)	EEC_1	237012.67	228904.67	137145.40	156928.36	157922.30	89516.42	92238.96	136576.69	112376.29
		EEC_T	**374914.97**	**366806.97**	**275047.70**	**294830.66**	**295824.60**	**227418.72**	**230141.26**	**274479.00**	**250278.60**
4.	1:6 (1 Cement : 6 Fine Sand)	EEC_1	228326.44	221260.80	129501.53	149284.49	149977.66	83783.51	86516.43	129627.71	105427.31
		EEC_T	**366228.74**	**359163.10**	**267403.83**	**287186.80**	**287879.96**	**221685.81**	**224418.73**	**267530.01**	**243329.61**
5.	1:1:6 (1 Cement : 1 Lime Putty : 6 Fine Sand)	EEC_1	244197.60	235227.89	143473.80	163250.71	164580.00	94257.97	96980.51	142324.28	118123.88
		EEC_T	**382099.90**	**373130.20**	**281376.10**	**301153.01**	**302482.30**	**232160.27**	**234882.81**	**280226.58**	**256026.18**

Table IV.2.7: EEC_1 and Resultant EEC_T for Project No. 7 Using Alternate Masonry Units and Mortar Mixes

EEC₁ (in MJ) and EECT (in MJ) Using											
No.	Mortar Mix Ratio		Traditional Bricks (22.9 cm X 11.4 cm X 7.6 cm)	Modular Bricks (20 cm X 10 cm X 10 cm)	Clay Flyash Bricks (20 cm X 10 cm X 10 cm)	Sand Lime Bricks (20 cm X 10 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 20 cm)	Aerated Concrete Blocks (40 cm X 20 cm X 20 cm)	Solid Concrete Blocks (30 cm X 20 cm X 15 cm)	Fal-G Blocks (30 cm X 20 cm X 15 cm)
1.	1:1:1 (1 Lime Putty: 1 Flyash : 1 Fine Sand)	EEC_1	345768.16	338248.58	202929.66	232101.22	229478.34	139266.27	142890.04	198624.87	163416.17
		EEC_T	625065.30	617545.72	482226.80	511398.36	508775.48	418563.41	422187.18	477922.01	442713.31
2.	1:3 (1 Cement : 3 Fine Sand)	EEC_1	387771.56	375212.08	239892.01	269068.17	268121.43	166989.76	170613.52	232228.06	197019.36
		EEC_T	667068.70	654509.22	519189.15	548365.31	547418.57	446286.90	449910.66	511525.20	476316.50
3.	1:5 (1 Cement : 5 Fine Sand)	EEC_1	349233.16	341298.29	205975.92	235150.93	232603.98	141554.42	145178.18	201397.34	166188.63
		EEC_T	628530.30	620595.43	485273.06	514448.07	511901.12	420851.56	424475.32	480694.48	445485.77
4.	1:6 (1 Cement : 6 Fine Sand)	EEC_1	337671.64	331124.15	195801.78	224976.79	222029.50	133923.82	137561.38	192148.13	156939.43
		EEC_T	616968.78	610421.29	475098.92	504273.93	501326.64	413220.96	416858.52	471445.27	436236.57
5.	1:1:6 (1 Cement : 1 Lime Putty : 6 Fine Sand)	EEC_1	358796.44	349714.61	214399.15	243566.10	241465.51	147865.51	151489.27	209047.50	173838.80
		EEC_T	638093.58	629011.75	493696.29	522863.24	520762.65	427162.65	430786.41	488344.64	453135.94

Table IV.2.8: EEC_1 and Resultant EEC_T for Project No. 8 Using Alternate Masonry Units and Mortar Mixes

No.	Mortar Mix Ratio		EEC_1 (in MJ) and EEC_T (in MJ) Using								
			Traditional Bricks (22.9 cm X 11.4 cm X 7.6 cm)	Modular Bricks (20 cm X 10 cm X 10 cm)	Clay Flyash Bricks (20 cm X 10 cm X 10 cm)	Sand Lime Bricks (20 cm X 10 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 20 cm)	Aerated Concrete Blocks (40 cm X 20 cm X 20 cm)	Solid Concrete Blocks (30 cm X 20 cm X 15 cm)	Fal-G Blocks (30 cm X 20 cm X 15 cm)
1.	1:1:1 (1 Lime Putty: 1 Flyash : 1 Fine Sand)	EEC_1	336814.18	328847.06	197027.86	225444.91	223536.24	134084.83	137678.03	193442.83	159067.08
		EEC_T	**610051.85**	**602084.73**	**470265.53**	**498682.58**	**496773.91**	**407322.50**	**410915.70**	**466680.50**	**432304.75**
2.	1:3 (1 Cement : 3 Fine Sand)	EEC_1	378463.42	365498.89	233678.55	262100.17	261853.49	161574.56	165167.76	226762.67	192386.92
		EEC_T	**651701.09**	**638736.56**	**506916.22**	**535337.84**	**535091.16**	**434812.23**	**438405.43**	**500000.34**	**465624.59**
3.	1:5 (1 Cement : 5 Fine Sand)	EEC_1	340249.97	331871.05	200048.44	228468.91	226635.52	136353.68	139946.88	196191.91	161816.16
		EEC_T	**613487.64**	**605108.72**	**473286.11**	**501706.58**	**499873.19**	**409591.35**	**413184.55**	**469429.58**	**435053.83**
4.	1:6 (1 Cement : 6 Fine Sand)	EEC_1	328785.93	321782.70	189960.08	218380.56	216150.21	128787.42	132394.31	187020.69	152644.94
		EEC_T	**602023.60**	**595020.37**	**463197.75**	**491618.23**	**489387.88**	**402025.09**	**405631.98**	**460258.36**	**425882.61**
5.	1:1:6 (1 Cement : 1 Lime Putty : 6 Fine Sand)	EEC_1	349732.61	340216.41	208400.64	236813.13	235422.34	142611.56	146204.76	203777.57	169401.82
		EEC_T	**622970.28**	**613454.08**	**481638.31**	**510050.80**	**508660.01**	**415849.23**	**419442.43**	**477015.24**	**442639.49**

Table IV.2.9: EEC$_1$ and Resultant EEC$_T$ for Project No. 9 Using Alternate Masonry Units and Mortar Mixes

			EEC$_1$ (in MJ) and EEC$_T$ (in MJ) Using								
No.	Mortar Mix Ratio		Traditional Bricks (22.9 cm X 11.4 cm X 7.6 cm)	Modular Bricks (20 cm X 10 cm X 10 cm)	Clay Flyash Bricks (20 cm X 10 cm X 10 cm)	Sand Lime Bricks (20 cm X 10 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 20 cm)	Aerated Concrete Blocks (40 cm X 20 cm X 20 cm)	Solid Concrete Blocks (30 cm X 20 cm X 15 cm)	Fal-G Blocks (30 cm X 20 cm X 15 cm)
1.	1:1:1 (1 Lime Putty: 1 Flyash : 1 Fine Sand)	EEC$_1$	370949.73	363091.33	217017.13	248507.29	245520.50	148807.58	152692.48	212518.51	174544.43
		EEC$_T$	**622657.96**	**614799.56**	**468725.36**	**500215.52**	**497228.73**	**400515.81**	**404400.71**	**464226.74**	**426252.66**
2.	1:3 (1 Cement : 3 Fine Sand)	EEC$_1$	415979.47	402718.49	256643.06	288138.16	286948.28	178528.88	182413.77	248543.21	210569.13
		EEC$_T$	**667687.70**	**654426.72**	**508351.29**	**539846.39**	**538656.51**	**430237.11**	**434122.00**	**500251.44**	**462277.36**
3.	1:5 (1 Cement : 5 Fine Sand)	EEC$_1$	374664.43	366360.81	220282.91	251776.77	248871.38	151260.61	155145.51	215490.77	177516.69
		EEC$_T$	**626372.66**	**618069.04**	**471991.14**	**503485.00**	**500579.61**	**402968.84**	**406853.74**	**467199.00**	**429224.92**
4.	1:6 (1 Cement : 6 Fine Sand)	EEC$_1$	362911.82	355453.50	209375.60	240869.47	237534.88	143080.14	146979.83	205575.03	167600.95
		EEC$_T$	**614620.05**	**607161.73**	**461083.83**	**492577.70**	**489243.11**	**394788.37**	**398688.06**	**457283.26**	**419309.18**
5.	1:1:6 (1 Cement : 1 Lime Putty : 6 Fine Sand)	EEC$_1$	384916.84	375383.63	229313.13	260798.36	258371.50	158026.50	161911.40	223692.21	185718.13
		EEC$_T$	**636625.07**	**627091.86**	**481021.36**	**512506.59**	**510079.73**	**409734.73**	**413619.36**	**475400.44**	**437426.36**

Table IV.2.10: EEC_1 and Resultant EEC_T for Project No. 10 Using Alternate Masonry Units and Mortar Mixes

			EEC_1 (in MJ) and EEC_T (in MJ) Using								
No.	Mortar Mix Ratio		Traditional Bricks (22.9 cm X 11.4 cm X 7.6 cm)	Modular Bricks (20 cm X 10 cm X 10 cm)	Clay Flyash Bricks (20 cm X 10 cm X 10 cm)	Sand Lime Bricks (20 cm X 10 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 20 cm)	Aerated Concrete Blocks (40 cm X 20 cm X 20 cm)	Solid Concrete Blocks (30 cm X 20 cm X 15 cm)	Fal-G Blocks (30 cm X 20 cm X 15 cm)
1.	1:1:1 (1 Lime Putty: 1 Flyash : 1 Fine Sand)	EEC_1	380973.70	372257.93	223158.06	255300.44	252843.75	152390.29	156425.45	218822.74	179976.32
		EEC_T	713527.75	704811.98	555712.11	587854.49	585397.80	484944.34	488979.50	**551376.79**	**512530.37**
2.	1:3 (1 Cement : 3 Fine Sand)	EEC_1	427745.58	413417.74	264316.59	296464.10	295873.82	183261.11	187296.26	256240.75	217394.33
		EEC_T	760299.63	745971.79	596870.64	629018.15	628427.87	515815.16	519850.31	**588794.80**	**549948.38**
3.	1:5 (1 Cement : 5 Fine Sand)	EEC_1	384832.07	375653.86	226550.15	258696.37	256324.23	154938.20	158973.35	221909.95	183063.53
		EEC_T	717386.12	708207.91	559104.20	591250.42	588878.28	487492.25	491527.40	**554464.00**	**515617.58**
4.	1:6 (1 Cement : 6 Fine Sand)	EEC_1	371958.03	364324.70	215220.98	247367.20	244549.28	146441.33	150491.85	211610.71	172764.29
		EEC_T	704512.08	696878.75	547775.03	579921.25	577103.33	478995.38	483045.90	**544164.76**	**505318.34**
5.	1:1:6 (1 Cement : 1 Lime Putty : 6 Fine Sand)	EEC_1	395481.03	385025.66	235929.63	268066.88	266191.77	161965.77	166000.92	230428.60	191582.18
		EEC_T	728035.08	717579.71	568483.68	600620.93	598745.82	494519.82	498554.97	**562982.65**	**524136.23**

Table IV.2.11: EEC$_1$ and Resultant EEC$_T$ for Project No. 11 Using Alternate Masonry Units and Mortar Mixes

			EEC$_1$ (in MJ) and EEC$_T$ (in MJ) Using								
No.	Mortar Mix Ratio		Traditional Bricks (22.9 cm X 11.4 cm X 7.6 cm)	Modular Bricks (20 cm X 10 cm X 10 cm)	Clay Flyash Bricks (20 cm X 10 cm X 10 cm)	Sand Lime Bricks (20 cm X 10 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 20 cm)	Aerated Concrete Blocks (40 cm X 20 cm X 20 cm)	Solid Concrete Blocks (30 cm X 20 cm X 15 cm)	Fal-G Blocks (30 cm X 20 cm X 15 cm)
1.	1:1:1 (1 Lime Putty: 1 Flyash : 1 Fine Sand)	EEC$_1$	393692.44	382984.54	228326.40	261666.88	260948.18	152731.34	157078.34	225739.71	185246.71
		EEC$_T$	**694540.07**	**683832.17**	**529174.03**	**562514.51**	**561795.81**	**453578.97**	**457925.97**	**526587.34**	**486094.34**
2.	1:3 (1 Cement : 3 Fine Sand)	EEC$_1$	444078.65	427325.32	272665.80	306011.80	307303.76	185987.96	190334.96	266049.51	225556.51
		EEC$_T$	**744926.28**	**728172.95**	**573513.43**	**606859.43**	**608151.40**	**486835.60**	**491182.60**	**566897.14**	**526404.14**
3.	1:5 (1 Cement : 5 Fine Sand)	EEC$_1$	397848.65	386642.92	231980.64	265325.26	264697.64	155476.16	159823.16	229065.51	188572.51
		EEC$_T$	**698696.28**	**687490.55**	**532828.27**	**566172.90**	**565545.27**	**456323.80**	**460670.80**	**529913.14**	**489420.14**
4.	1:6 (1 Cement : 6 Fine Sand)	EEC$_1$	383979.65	374438.20	219775.92	253120.54	252012.68	146322.62	150686.18	217970.31	177477.31
		EEC$_T$	**684827.28**	**675285.83**	**520623.55**	**553968.17**	**552860.31**	**447170.25**	**451533.81**	**518817.94**	**478324.94**
5.	1:1:6 (1 Cement : 1 Lime Putty : 6 Fine Sand)	EEC$_1$	409320.59	396739.00	242085.00	275419.96	275327.78	163046.84	167393.84	238242.51	197749.51
		EEC$_T$	**710168.22**	**697586.63**	**542932.63**	**576267.60**	**576175.41**	**463894.47**	**468241.47**	**539090.14**	**498597.14**

Table IV.2.12: EEC$_1$ and Resultant EEC$_T$ for Project No. 12 Using Alternate Masonry Units and Mortar Mixes

			EEC$_1$ (in MJ) and EEC$_T$ (in MJ) Using								
No.	Mortar Mix Ratio		Traditional Bricks (22.9 cm X 11.4 cm X 7.6 cm)	Modular Bricks (20 cm X 10 cm X 10 cm)	Clay Flyash Bricks (20 cm X 10 cm X 10 cm)	Sand Lime Bricks (20 cm X 10 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 20 cm)	Aerated Concrete Blocks (40 cm X 20 cm X 20 cm)	Solid Concrete Blocks (30 cm X 20 cm X 15 cm)	Fal-G Blocks (30 cm X 20 cm X 15 cm)
1.	1:1:1 (1 Lime Putty: 1 Flyash : 1 Fine Sand)	EEC$_1$	464791.54	451158.00	268798.77	308110.84	308215.66	178120.20	183346.05	266567.17	218698.17
		EEC$_T$	880345.48	866711.94	684352.71	723664.78	723769.60	593674.14	598900.00	682121.11	634252.11
2.	1:3 (1 Cement : 3 Fine Sand)	EEC$_1$	525364.95	504463.32	322102.44	361421.15	363943.13	218100.44	223326.29	315026.55	267157.55
		EEC$_T$	940918.89	920017.26	737656.38	776975.09	779497.07	633654.38	638880.23	730580.49	682711.49
3.	1:5 (1 Cement : 5 Fine Sand)	EEC$_1$	469788.45	455556.00	273191.80	312508.85	312723.16	181419.95	186645.80	270565.35	222696.35
		EEC$_T$	885342.39	871109.94	688745.74	728062.79	728277.10	596973.89	602199.74	686119.29	638250.29
4.	1:6 (1 Cement : 6 Fine Sand)	EEC$_1$	453115.52	440883.80	258519.61	297836.66	297473.64	170415.80	175661.56	257226.99	209357.99
		EEC$_T$	868669.46	856437.74	674073.55	713390.60	713027.58	585969.74	591215.50	672780.93	624911.93
5.	1:1:6 (1 Cement : 1 Lime Putty : 6 Fine Sand)	EEC$_1$	483579.71	467693.24	285339.00	324644.44	325502.44	190521.22	195747.07	281597.70	233728.70
		EEC$_T$	899133.65	883247.18	700892.94	740198.38	741056.38	606075.16	611301.01	697151.64	649282.64

Table IV.2.13: EEC_1 and Resultant EEC_T for Project No. 13 Using Alternate Masonry Units and Mortar Mixes

			EEC₁ (in MJ) and EECT (in MJ) Using								
No.	Mortar Mix Ratio		Traditional Bricks (22.9 cm X 11.4 cm X 7.6 cm)	Modular Bricks (20 cm X 10 cm X 10 cm)	Clay Flyash Bricks (20 cm X 10 cm X 10 cm)	Sand Lime Bricks (20 cm X 10 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 20 cm)	Aerated Concrete Blocks (40 cm X 20 cm X 20 cm)	Solid Concrete Blocks (30 cm X 20 cm X 15 cm)	Fal-G Blocks (30 cm X 20 cm X 15 cm)
1.	1:1:1 (1 Lime Putty: 1 Flyash : 1 Fine Sand)	EEC_1	452136.65	437769.43	260963.23	299078.12	299908.53	170761.93	175949.66	259281.87	212721.82
		EEC_T	**828557.33**	**814190.11**	**637383.91**	**675498.80**	**676329.21**	**547182.61**	**552370.34**	**635702.55**	**589142.50**
2.	1:3 (1 Cement : 3 Fine Sand)	EEC_1	512268.26	490685.98	313878.12	351999.61	355229.55	210450.57	215638.30	307387.82	260827.77
		EEC_T	**888688.94**	**867106.66**	**690298.80**	**728420.30**	**731650.23**	**586871.25**	**592058.98**	**683808.50**	**637248.45**
3.	1:5 (1 Cement : 5 Fine Sand)	EEC_1	457097.11	442135.36	265324.22	303444.06	304383.16	174037.61	179225.34	263250.90	216690.85
		EEC_T	**833517.80**	**818556.04**	**641744.90**	**679864.74**	**680803.84**	**550458.30**	**555646.02**	**639671.58**	**593111.53**
4.	1:6 (1 Cement : 6 Fine Sand)	EEC_1	441187.83	427570.18	250759.03	288878.87	289244.85	163113.72	168321.22	250009.82	203449.77
		EEC_T	**817608.51**	**803990.86**	**627179.71**	**665299.55**	**665665.53**	**539534.40**	**544741.90**	**626430.50**	**579870.45**
5.	1:1:6 (1 Cement : 1 Lime Putty : 6 Fine Sand)	EEC_1	470787.79	454184.08	277382.82	315491.13	317069.23	183072.50	188260.24	274202.78	227642.73
		EEC_T	**847208.47**	**830604.76**	**653803.50**	**691911.81**	**693489.91**	**559493.18**	**564680.92**	**650623.46**	**604063.41**

Table IV.2.14: EEC$_I$ and Resultant EEC$_T$ for Project No. 14 Using Alternate Masonry Units and Mortar Mixes

			EEC$_I$ (in MJ) and EEC$_T$ (in MJ) Using								
No.	Mortar Mix Ratio		Traditional Bricks (22.9 cm X 11.4 cm X 7.6 cm)	Modular Bricks (20 cm X 10 cm X 10 cm)	Clay Flyash Bricks (20 cm X 10 cm X 10 cm)	Sand Lime Bricks (20 cm X 10 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 20 cm)	Aerated Concrete Blocks (40 cm X 20 cm X 20 cm)	Solid Concrete Blocks (30 cm X 20 cm X 15 cm)	Fal-G Blocks (30 cm X 20 cm X 15 cm)
1.	1:1:1 (1 Lime Putty: 1 Flyash : 1 Fine Sand)	EEC$_I$	1885082.17	1874500.27	1150386.90	1306490.42	1238049.81	816160.97	833107.97	1071149.01	885746.18
		EEC$_T$	**6774626.03**	**6764044.13**	**6039930.76**	**6196034.28**	**6127593.67**	**5705704.83**	**5722651.83**	**5960692.87**	**5775290.04**
2.	1:3 (1 Cement : 3 Fine Sand)	EEC$_I$	2081516.73	2047365.05	1323246.30	1479371.34	1418769.39	945813.59	962760.59	1228298.81	1042895.98
		EEC$_T$	**6971060.60**	**6936908.91**	**6212790.16**	**6368915.20**	**6308313.25**	**5835357.45**	**5852304.45**	**6117842.67**	**5932439.84**
3.	1:5 (1 Cement : 5 Fine Sand)	EEC$_I$	1901286.73	1888762.65	1164633.14	1320752.80	1252667.27	826861.79	843808.79	1084114.81	898711.98
		EEC$_T$	**6790830.60**	**6778306.51**	**6054177.00**	**6210296.66**	**6142211.13**	**5716405.65**	**5733352.65**	**5973658.67**	**5788255.84**
4.	1:6 (1 Cement : 6 Fine Sand)	EEC$_I$	1847217.73	1841181.93	1117052.42	1273172.08	1203214.31	791176.25	808187.81	1040859.61	855456.78
		EEC$_T$	**6736761.59**	**6730725.79**	**6006596.28**	**6162715.94**	**6092758.17**	**5680720.11**	**5697731.67**	**5930403.47**	**5745000.64**
5.	1:1:6 (1 Cement : 1 Lime Putty : 6 Fine Sand)	EEC$_I$	1946010.67	1928122.73	1204025.50	1360107.50	1294109.41	856376.47	873323.47	1119891.81	934488.98
		EEC$_T$	**6835554.53**	**6817666.60**	**6093569.36**	**6249651.36**	**6183653.27**	**5745920.33**	**5762867.33**	**6009435.67**	**5824032.84**

Table IV.2.15: EEC_1 and Resultant EEC_T for Project No. 15 Using Alternate Masonry Units and Mortar Mixes

No.	Mortar Mix Ratio		Traditional Bricks (22.9 cm X 11.4 cm X 7.6 cm)	Modular Bricks (20 cm X 10 cm X 10 cm)	Clay Flyash Bricks (20 cm X 10 cm X 10 cm)	Sand Lime Bricks (20 cm X 10 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 20 cm)	Aerated Concrete Blocks (40 cm X 20 cm X 20 cm)	Solid Concrete Blocks (30 cm X 20 cm X 15 cm)	Fal-G Blocks (30 cm X 20 cm X 15 cm)
			EEC_1 (in MJ) and EEC_T (in MJ) Using								
1.	1:1:1 (1 Lime Putty: 1 Flyash : 1 Fine Sand)	EEC_1	13703775.88	13316055.12	7940057.83	9098989.07	9087642.81	5287114.44	5439779.19	7860506.40	6451030.15
		EEC_T	**25437455.87**	**25049735.11**	**19673737.82**	**20832669.06**	**20821322.80**	**17020794.43**	**17173459.18**	**19594186.39**	**18184710.14**
2.	1:3 (1 Cement : 3 Fine Sand)	EEC_1	15471791.33	14871812.42	9496297.48	10655308.13	10714562.67	6454444.07	6607093.07	9275244.95	7865908.70
		EEC_T	**27205471.32**	**26605492.41**	**21229977.47**	**22388988.12**	**22448242.66**	**18188124.06**	**18340773.06**	**21008924.94**	**19599588.69**
3.	1:5 (1 Cement : 5 Fine Sand)	EEC_1	13849752.46	13444535.84	8068393.15	9227469.78	9219322.22	5383511.33	5172233.27	7658439.30	6567830.80
		EEC_T	**25583432.45**	**25178215.83**	**19802073.14**	**20961149.77**	**20953002.21**	**17117191.32**	**16905913.26**	**19392119.29**	**18301510.79**
4.	1:6 (1 Cement : 6 Fine Sand)	EEC_1	13362679.21	13015911.38	7639768.69	8798845.32	8773831.94	5062042.98	5215289.31	7587648.45	6178172.20
		EEC_T	**25096359.20**	**24749591.37**	**19373448.68**	**20532525.31**	**20507511.93**	**16795722.97**	**16948969.30**	**19321328.44**	**17911852.19**
5.	1:1:6 (1 Cement : 1 Lime Putty : 6 Fine Sand)	EEC_1	14252642.00	13799105.78	8423253.88	9552912.26	9592648.11	5649390.32	5802055.07	8299599.30	6890123.05
		EEC_T	**25986321.99**	**25532785.77**	**20156933.87**	**21286592.25**	**21326328.10**	**17383070.31**	**17535735.06**	**20033279.29**	**18623803.04**

Table IV.2.16: EEC$_1$ and Resultant EEC$_T$ for Project No. 16 Using Alternate Masonry Units and Mortar Mixes

No.	Mortar Mix Ratio		EEC$_1$ (in MJ) and EEC$_T$ (in MJ) Using								
			Traditional Bricks (22.9 cm X 11.4 cm X 7.6 cm)	Modular Bricks (20 cm X 10 cm X 10 cm)	Clay Flyash Bricks (20 cm X 10 cm X 10 cm)	Sand Lime Bricks (20 cm X 10 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 20 cm)	Aerated Concrete Blocks (40 cm X 20 cm X 20 cm)	Solid Concrete Blocks (30 cm X 20 cm X 15 cm)	Fal-G Blocks (30 cm X 20 cm X 15 cm)
1.	1:1:1 (1 Lime Putty: 1 Flyash : 1 Fine Sand)	EEC$_1$	21772004.47	21744781.35	13385079.23	15187257.96	14084855.52	9340566.52	9531141.52	12169503.26	10035312.21
		EEC$_T$	**53644608.07**	**53617384.95**	**45257682.83**	**47059861.56**	**45957459.12**	**41213170.12**	**41403745.12**	**44042106.86**	**41907915.81**
2.	1:3 (1 Cement : 3 Fine Sand)	EEC$_1$	23980980.47	23688706.85	15328944.23	17131364.96	16117111.02	10798556.02	10989131.02	13936708.26	11802517.21
		EEC$_T$	**55853584.07**	**55561310.45**	**47201547.83**	**49003968.56**	**47989714.62**	**42671159.62**	**42861734.62**	**45809311.86**	**43675120.81**
3.	1:5 (1 Cement : 5 Fine Sand)	EEC$_1$	21954230.47	21905166.85	13545283.23	15347643.46	14249234.02	9460901.02	9651476.02	12315308.26	10181117.21
		EEC$_T$	**53826834.07**	**53777770.45**	**45417886.83**	**47220247.06**	**46121837.62**	**41333504.62**	**41524079.62**	**44187911.86**	**42053720.81**
4.	1:6 (1 Cement : 6 Fine Sand)	EEC$_1$	21604468.67	21370104.85	13010221.23	14812581.46	13693118.02	9059604.52	9250905.52	11828888.26	9694697.21
		EEC$_T$	**53477072.27**	**53242708.45**	**44882824.83**	**46685185.06**	**45565721.62**	**40932208.12**	**41123509.12**	**43701491.86**	**41567300.81**
5.	1:1:6 (1 Cement : 1 Lime Putty : 6 Fine Sand)	EEC$_1$	22457166.97	22347784.85	13988264.23	15790200.96	14715265.52	9792804.02	9983379.02	12717633.26	10583442.21
		EEC$_T$	**54329770.57**	**54220388.45**	**45860867.83**	**47662804.56**	**46587869.12**	**41665407.62**	**41855982.62**	**44590236.86**	**42456045.81**

Table IV.3.1: TEC_1[1] and Resultant TEC_T[2] in Single Storeyed Dwellings Using Alternate Masonry Units and Lime Mortar

No.	Project		TEC₁ (in MJ) and TECT (in MJ) Using Lime Mortar and								
			Traditional Bricks (22.9 cm X 11.4 cm X 7.6 cm)	Modular Bricks (20 cm X 10 cm X 10 cm)	Clay Flyash Bricks (20 cm X 10 cm X 10 cm)	Sand Lime Bricks (20 cm X 10 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 20 cm)	Aerated Concrete Blocks (40 cm X 20 cm X 20 cm)	Solid Concrete Blocks (30 cm X 20 cm X 15 cm)	Fal-G Blocks (30 cm X 20 cm X 15 cm)
1.	1	TEC_1	1539.56	1539.56	1132.88	1539.56	1418.87	1332.41	1314.14	1970.98	1970.98
		TEC_T	**2682.73**	**2682.73**	**2276.05**	**2682.73**	**2562.04**	**2475.58**	**2457.31**	**3114.15**	**3114.15**
2.	2	TEC_1	2654.94	2654.94	1953.63	2654.94	2446.82	2297.71	2266.21	3398.92	3398.92
		TEC_T	**4346.26**	**4346.26**	**3644.95**	**4346.26**	**4138.14**	**3989.03**	**3957.53**	**5090.24**	**5090.24**
3.	3	TEC_1	3490.65	3490.65	2568.58	3490.65	3217.01	3020.96	2979.55	4468.81	4468.81
		TEC_T	**6098.90**	**6098.90**	**5176.83**	**6098.90**	**5825.26**	**5629.21**	**5587.80**	**7077.06**	**7077.06**
4.	4	TEC_1	3597.90	3597.90	2648.76	3597.90	3316.42	3121.56	3080.40	4604.37	4604.37
		TEC_T	**6315.93**	**6315.93**	**5366.79**	**6315.93**	**6034.45**	**5839.59**	**5798.43**	**7322.40**	**7322.40**
5.	5	TEC_1	4055.25	4055.25	2985.80	4055.25	3738.13	3520.47	3474.49	5189.18	5189.18
		TEC_T	**7673.62**	**7673.62**	**6604.17**	**7673.62**	**7356.50**	**7138.84**	**7092.86**	**8807.55**	**8807.55**
6.	6	TEC_1	5755.37	5755.37	4235.07	5755.37	5304.21	4980.96	4912.68	7368.16	7368.16
		TEC_T	**9280.97**	**9280.97**	**7760.67**	**9280.97**	**8829.81**	**8506.56**	**8438.28**	**10893.76**	**10893.76**
7.	7	TEC_1	8420.83	8420.83	6203.90	8420.83	7764.00	7333.76	7242.87	10770.21	10770.21
		TEC_T	**15138.95**	**15138.95**	**12922.02**	**15138.95**	**14482.12**	**14051.88**	**13960.99**	**17488.33**	**17488.33**
8.	8	TEC_1	8213.85	8213.85	6050.20	8213.85	7572.64	7146.01	7055.90	10507.16	10507.16
		TEC_T	**14919.91**	**14919.91**	**12756.26**	**14919.91**	**14278.70**	**13852.07**	**13761.96**	**17213.22**	**17213.22**
9.	9	TEC_1	9085.53	9085.53	6694.12	9085.53	8377.08	7915.83	7818.40	11619.64	11619.64
		TEC_T	**15505.47**	**15505.47**	**13114.06**	**15505.47**	**14797.02**	**14335.77**	**14238.34**	**18039.58**	**18039.58**
10.	10	TEC_1	9285.66	9285.66	6840.23	9285.66	8561.02	8081.92	7980.72	11877.45	11877.45
		TEC_T	**17247.50**	**17247.50**	**14802.07**	**17247.50**	**16522.86**	**16043.76**	**15942.56**	**19839.29**	**19839.29**

[1] TEC_1 – Transport Energy Cost for Masonry Work
[2] TEC_T – Total Transport Energy Cost

Table IV.3.2: TEC$_1$ and Resultant TEC$_T$ in Single Storeyed Dwellings Using Alternate Masonry Units and Cement Mortar

No.	Project		TEC$_1$ (in MJ) and TEC$_T$ (in MJ) Using Cement Mortar and								
			Traditional Bricks (22.9 cm X 11.4 cm X 7.6 cm)	Modular Bricks (20 cm X 10 cm X 10 cm)	Clay Flyash Bricks (20 cm X 10 cm X 10 cm)	Sand Lime Bricks (20 cm X 10 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 20 cm)	Aerated Concrete Blocks (40 cm X 20 cm X 20 cm)	Solid Concrete Blocks (30 cm X 20 cm X 15 cm)	Fal-G Blocks (30 cm X 20 cm X 15 cm)
1.	1	TEC$_1$	1598.05	1598.05	1191.60	1598.05	1479.68	1376.56	1358.30	2024.16	2024.16
		TEC$_T$	**2741.22**	**2741.22**	**2334.77**	**2741.22**	**2622.85**	**2519.73**	**2501.47**	**3167.33**	**3167.33**
2.	2	TEC$_1$	2755.81	2755.81	2054.90	2755.81	2551.68	2373.86	2342.36	3490.62	3490.62
		TEC$_T$	**4447.13**	**4447.13**	**3746.22**	**4447.13**	**4243.00**	**4065.18**	**4033.68**	**5181.94**	**5181.94**
3.	3	TEC$_1$	3623.27	3623.27	2701.73	3623.27	3354.88	3121.09	3079.68	4589.37	4589.37
		TEC$_T$	**6231.52**	**6231.52**	**5309.98**	**6231.52**	**5963.13**	**5729.34**	**5687.93**	**7197.62**	**7197.62**
4.	4	TEC$_1$	3729.72	3729.72	2781.10	3729.72	3453.44	3221.07	3179.92	4724.20	4724.20
		TEC$_T$	**6447.75**	**6447.75**	**5499.13**	**6447.75**	**6171.47**	**5939.10**	**5897.95**	**7442.23**	**7442.23**
5.	5	TEC$_1$	4202.50	4202.50	3133.63	4202.50	3891.20	3631.63	3585.65	5323.04	5323.04
		TEC$_T$	**7820.87**	**7820.87**	**6752.00**	**7820.87**	**7509.57**	**7250.00**	**7204.02**	**8941.41**	**8941.41**
6.	6	TEC$_1$	5974.04	5974.04	4454.60	5974.64	5531.52	5146.04	5077.76	7566.95	7566.95
		TEC$_T$	**9499.64**	**9499.64**	**7980.20**	**9499.64**	**9057.12**	**8671.64**	**8603.36**	**11092.55**	**11092.55**
7.	7	TEC$_1$	8711.88	8711.88	6496.10	8711.88	8066.56	7553.48	7462.60	11034.80	11034.80
		TEC$_T$	**15430.00**	**15430.00**	**13214.22**	**15430.00**	**14784.68**	**14271.60**	**14180.72**	**17752.92**	**17752.92**
8.	8	TEC$_1$	8502.45	8502.45	6339.94	8502.45	7872.64	7363.89	7273.77	10769.53	10769.53
		TEC$_T$	**15208.51**	**15208.51**	**13046.00**	**15208.51**	**14578.70**	**14069.95**	**13979.83**	**17475.59**	**17475.59**
9.	9	TEC$_1$	9397.56	9397.56	7007.38	9397.56	8701.44	8151.39	8053.96	11903.30	11903.30
		TEC$_T$	**15817.50**	**15817.50**	**13427.32**	**15817.50**	**15121.38**	**14571.33**	**14473.90**	**18323.24**	**18323.24**
10.	10	TEC$_1$	9609.75	9609.75	7165.61	9609.75	8897.92	8326.59	8225.40	12172.08	12172.08
		TEC$_T$	**17571.59**	**17571.59**	**15127.45**	**17571.59**	**16859.76**	**16288.43**	**16187.24**	**20133.92**	**20133.92**

Table IV.3.3: TEC$_1$ and Resultant TEC$_T$ for Double Storeyed Dwellings Using Alternate Masonry Units and Lime Mortar

No.	Project		TEC$_1$ (in MJ) and TEC$_T$ (in MJ) Using Lime Mortar and								
			Traditional Bricks (22.9 cm X 11.4 cm X 7.6 cm)	Modular Bricks (20 cm X 10 cm X 10 cm)	Clay Flyash Bricks (20 cm X 10 cm X 10 cm)	Sand Lime Bricks (20 cm X 10 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 20 cm)	Aerated Concrete Blocks (40 cm X 20 cm X 20 cm)	Solid Concrete Blocks (30 cm X 20 cm X 15 cm)	Fal-G Blocks (30 cm X 20 cm X 15 cm)
1.	11	TEC$_1$	9659.44	9659.44	7112.47	9659.44	8904.26	8388.14	8279.12	12359.84	12359.84
		TEC$_T$	**16522.19**	**16522.19**	**13975.22**	**16522.19**	**15767.01**	**15250.89**	**15141.87**	**19222.59**	**19222.59**
2.	12	TEC$_1$	11406.71	11406.71	8397.11	11406.71	10514.08	10101.09	9762.56	14598.24	14598.24
		TEC$_T$	**20420.03**	**20420.03**	**17410.43**	**20420.03**	**19527.40**	**19114.41**	**18775.88**	**23611.56**	**23611.56**
3.	13	TEC$_1$	11080.06	11080.06	8154.34	11080.06	10211.99	9596.04	9465.94	14183.40	14183.40
		TEC$_T$	**19318.09**	**19318.09**	**16392.37**	**19318.09**	**18450.02**	**17834.07**	**17703.97**	**22421.43**	**22421.43**

Table IV.3.4: TEC$_1$ and Resultant TEC$_T$ for Double Storeyed Dwellings Using Alternate Masonry Units and Cement Mortar

No.	Project		TEC$_1$ (in MJ) and TEC$_T$ (in MJ) Using Cement Mortar and								
			Traditional Bricks (22.9 cm X 11.4 cm X 7.6 cm)	Modular Bricks (20 cm X 10 cm X 10 cm)	Clay Flyash Bricks (20 cm X 10 cm X 10 cm)	Sand Lime Bricks (20 cm X 10 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 20 cm)	Aerated Concrete Blocks (40 cm X 20 cm X 20 cm)	Solid Concrete Blocks (30 cm X 20 cm X 15 cm)	Fal-G Blocks (30 cm X 20 cm X 15 cm)
1.	11	TEC$_1$	10008.58	10008.58	7462.99	10008.58	9267.20	8651.72	8542.70	12677.24	12677.24
		TEC$_T$	**16871.33**	**16871.33**	**14325.74**	**16871.33**	**16129.95**	**15514.47**	**15405.45**	**19540.00**	**19540.00**
2.	12	TEC$_1$	11826.43	11826.43	8818.49	11826.43	10950.40	10210.49	10079.43	14979.81	14979.81
		TEC$_T$	**20839.75**	**20839.75**	**17831.81**	**20839.75**	**19963.72**	**19223.81**	**19092.75**	**23993.13**	**23993.13**
3.	13	TEC$_1$	11496.73	11496.73	8572.65	11496.73	10645.12	9910.60	9780.50	14562.19	14562.19
		TEC$_T$	**19734.76**	**19734.76**	**16810.68**	**19734.76**	**18883.15**	**18148.63**	**18018.53**	**22800.22**	**22800.22**

Table IV.3.5: TEC$_1$ and Resultant TEC$_T$ in Four Storeyed Housing Using Alternate Masonry Units and Lime Mortar

No.	Project		TEC$_1$ (in MJ) and TEC$_T$ (in MJ) Using Lime Mortar and								
			Traditional Bricks (22.9 cm X 11.4 cm X 7.6 cm)	Modular Bricks (20 cm X 10 cm X 10 cm)	Clay Flyash Bricks (20 cm X 10 cm X 10 cm)	Sand Lime Bricks (20 cm X 10 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 20 cm)	Aerated Concrete Blocks (40 cm X 20 cm X 20 cm)	Solid Concrete Blocks (30 cm X 20 cm X 15 cm)	Fal-G Blocks (30 cm X 20 cm X 15 cm)
1.	14	TEC$_1$	44643.06	44643.06	32936.96	44643.06	41181.54	39169.42	38744.40	57033.25	57033.25
		TEC$_T$	**129869.07**	**129869.07**	**118162.97**	**129869.07**	**126407.55**	**124395.43**	**123970.41**	**142259.26**	**142259.26**
2.	15	TEC$_1$	336034.04	336034.04	247399.95	336034.04	309749.71	291623.80	287795.06	430017.50	430017.50
		TEC$_T$	**581122.02**	**581122.02**	**492487.93**	**581122.02**	**554837.69**	**536711.78**	**532883.04**	**675105.48**	**675105.48**
3.	16	TEC$_1$	520850.62	520850.62	384361.69	520850.62	480502.97	457520.67	452666.12	665287.77	523861.25
		TEC$_T$	**1064700.51**	**1064700.51**	**928211.58**	**1064700.51**	**1024352.86**	**1001370.56**	**996516.01**	**1209137.66**	**1067711.14**

Table IV.3.6: TEC$_1$ and Resultant TEC$_T$ in Four Storeyed Housing Using Alternate Masonry Units and Cement Mortar

No.	Project		TEC$_1$ (in MJ) and TEC$_T$ (in MJ) Using Cement Mortar and								
			Traditional Bricks (22.9 cm X 11.4 cm X 7.6 cm)	Modular Bricks (20 cm X 10 cm X 10 cm)	Clay Flyash Bricks (20 cm X 10 cm X 10 cm)	Sand Lime Bricks (20 cm X 10 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 20 cm)	Aerated Concrete Blocks (40 cm X 20 cm X 20 cm)	Solid Concrete Blocks (30 cm X 20 cm X 15 cm)	Fal-G Blocks (30 cm X 20 cm X 15 cm)
1.	14	TEC$_1$	46004.20	46004.20	34303.48	46004.20	42596.48	40197.00	39771.98	58270.65	58270.65
		TEC$_T$	**131230.21**	**131230.21**	**119529.49**	**131230.21**	**127822.49**	**125423.01**	**124997.99**	**143496.66**	**143496.66**
2.	15	TEC$_1$	348295.68	259710.06	348295.68	322496	300880.61	300880.61	297051.875	441164.45	441164.45
		TEC$_T$	**593383.66**	**504798.04**	**593383.66**	**567583.98**	**545968.59**	**545968.59**	**542139.855**	**686252.43**	**686252.43**
3.	16	TEC$_1$	536705.47	536705.47	399969.99	536705.47	496664.32	469257.62	464403.07	679421.27	679421.27
		TEC$_T$	**1080555.36**	**1080555.36**	**943819.88**	**1080555.36**	**1040514.21**	**1013107.51**	**1008252.96**	**1223271.16**	**1223271.16**

Table IV.4.1: PEC[1] and Its Index for Project No. 1 Using Alternate Masonry Units and Mortar Mixes

			PEC and Its Index with Varying EEC_1 & TEC_1 Using								
No.	Mortar Mix Ratio		Traditional Bricks (22.9 cm X 11.4 cm X 7.6 cm)	Modular Bricks (20 cm X 10 cm X 10 cm)	Clay Flyash Bricks (20 cm X 10 cm X 10 cm)	Sand Lime Bricks (20 cm X 10 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 20 cm)	Aerated Concrete Blocks (40 cm X 20 cm X 20 cm)	Solid Concrete Blocks (30 cm X 20 cm X 15 cm)	Fal-G Blocks (30 cm X 20 cm X 15 cm)
1.	1:1:1 (1 Lime Putty: 1 Flyash : 1 Fine Sand)	PEC	112862.25	110777.00	85825.26	91523.18	91653.11	73436.41	74146.42	86566.25	80092.65
		INDEX	**101.41**	**99.54**	**77.12**	**82.24**	**82.35**	**65.98**	**66.62**	**77.78**	**71.97**
2.	1:3 (1 Cement : 3 Fine Sand)	PEC	121362.32	118264.00	93312.44	99011.05	99480.16	79052.25	79762.27	93372.78	86899.18
		INDEX	**109.05**	**106.26**	**83.84**	**88.96**	**89.39**	**71.03**	**71.67**	**83.90**	**78.08**
3.	1:5 (1 Cement : 5 Fine Sand)	PEC	113617.11	111448.22	86496.20	92194.58	92342.10	73940.43	74650.44	87176.63	80703.03
		INDEX	**102.09**	**100.14**	**77.72**	**82.84**	**82.97**	**66.44**	**67.08**	**78.33**	**72.51**
4.	1:6 (1 Cement : 6 Fine Sand)	PEC	111293.55	109403.50	84451.47	90149.85	90216.90	72406.87	73389.66	85317.78	78844.18
		INDEX	**100.00**	**98.30**	**75.88**	**81.00**	**81.06**	**65.06**	**65.94**	**76.66**	**70.84**
5.	1:1:6 (1 Cement : 1 Lime Putty : 6 Fine Sand)	PEC	115539.08	113139.70	88189.04	93885.82	94123.02	75208.78	75918.80	88714.10	82240.50
		INDEX	**103.81**	**101.66**	**79.24**	**84.36**	**84.57**	**67.58**	**68.21**	**79.71**	**73.90**

[1] PEC – Primary Energy Cost

Table IV.4.2: PEC and Its Index for Project No. 2 Using Alternate Masonry Units and Mortar Mixes

			PEC and Its Index with Varying EEC_1 & TEC_1 Using								
No.	Mortar Mix Ratio		Traditional Bricks (22.9 cm X 11.4 cm X 7.6 cm)	Modular Bricks (20 cm X 10 cm X 10 cm)	Clay Flyash Bricks (20 cm X 10 cm X 10 cm)	Sand Lime Bricks (20 cm X 10 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 20 cm)	Aerated Concrete Blocks (40 cm X 20 cm X 20 cm)	Solid Concrete Blocks (30 cm X 20 cm X 15 cm)	Fal-G Blocks (30 cm X 20 cm X 15 cm)
1.	1:1:1 (1 Lime Putty: 1 Flyash : 1 Fine Sand)	PEC	181638.07	178041.80	135013.30	144839.26	145063.34	113648.96	114873.37	136291.14	125127.54
		INDEX	101.51	99.50	75.45	80.95	81.07	63.51	64.20	76.17	69.93
2.	1:3 (1 Cement : 3 Fine Sand)	PEC	196296.28	190953.30	147924.82	157751.96	158560.92	123333.38	124557.80	148028.86	136865.26
		INDEX	109.70	106.72	82.67	88.16	88.61	68.93	69.61	82.73	76.49
3.	1:5 (1 Cement : 5 Fine Sand)	PEC	182939.83	179199.63	136170.33	145997.08	146251.46	114518.13	115742.53	136443.70	126180.10
		INDEX	102.24	100.15	76.10	81.59	81.74	64.00	64.68	76.25	70.52
4.	1:6 (1 Cement : 6 Fine Sand)	PEC	178932.90	175673.53	132644.23	142470.98	142586.61	111873.55	113102.74	134138.16	122974.56
		INDEX	100.00	98.18	74.13	79.62	79.69	62.52	63.21	74.97	68.73
5.	1:1:6 (1 Cement : 1 Lime Putty : 6 Fine Sand)	PEC	186254.23	182116.53	139089.62	148913.57	149322.64	116705.40	117929.80	139995.06	128831.46
		INDEX	104.09	101.78	77.73	83.22	83.45	65.22	65.91	78.24	72.00

Table IV.4.3: PEC and Its Index for Project No. 3 Using Alternate Masonry Units and Mortar Mixes

No.	Mortar Mix Ratio		PEC and Its Index with Varying EEC_1 & TEC_1 Using: Traditional Bricks (22.9 cm X 11.4 cm X 7.6 cm)	Modular Bricks (20 cm X 10 cm X 10 cm)	Clay Flyash Bricks (20 cm X 10 cm X 10 cm)	Sand Lime Bricks (20 cm X 10 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 20 cm)	Aerated Concrete Blocks (40 cm X 20 cm X 20 cm)	Solid Concrete Blocks (30 cm X 20 cm X 15 cm)	Fal-G Blocks (30 cm X 20 cm X 15 cm)
1.	1:1:1 (1 Lime Putty: 1 Flyash : 1 Fine Sand)	PEC	258710.43	253982.15	197409.44	210328.35	210622.94	169320.17	170930.00	199089.50	184411.90
		INDEX	101.39	99.54	77.37	82.43	82.55	66.36	67.00	78.03	72.27
2.	1:3 (1 Cement : 3 Fine Sand)	PEC	277982.65	270957.84	214385.13	227305.62	228369.21	182052.92	183662.83	214521.94	199844.34
		INDEX	108.95	106.19	84.02	89. 08	89.50	71.35	71.98	84.08	78.32
3.	1:5 (1 Cement : 5 Fine Sand)	PEC	260421.95	255504.42	198930.67	211850.62	212185.06	170462.94	172072.76	200473.38	185795.78
		INDEX	102.06	100.14	77.97	83.03	83.16	66.81	67.44	78.57	72.82
4.	1:6 (1 Cement : 6 Fine Sand)	PEC	255153.74	250868.40	194292.64	207214.60	207366.62	166985.92	168602.03	196258.82	181581.22
		INDEX	100.00	98.32	76.15	81.21	81.27	65.45	66.08	76.92	71.17
5.	1:1:6 (1 Cement : 1 Lime Putty : 6 Fine Sand)	PEC	264779.62	259339.47	202858.86	215685.14	216222.97	173338.70	174948.53	203959.32	189281.72
		INDEX	103.77	101.64	79.50	84.53	84.74	67.94	68.57	79.94	74.18

Table IV.4.4: PEC and Its Index for Project No. 4 Using Alternate Masonry Units and Mortar Mixes

PEC and Its Index with Varying EEC_1 & TEC_1 Using											
No.	Mortar Mix Ratio		Traditional Bricks (22.9 cm X 11.4 cm X 7.6 cm)	Modular Bricks (20 cm X 10 cm X 10 cm)	Clay Flyash Bricks (20 cm X 10 cm X 10 cm)	Sand Lime Bricks (20 cm X 10 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 20 cm)	Aerated Concrete Blocks (40 cm X 20 cm X 20 cm)	Solid Concrete Blocks (30 cm X 20 cm X 15 cm)	Fal-G Blocks (30 cm X 20 cm X 15 cm)
1.	1:1:1 (1 Lime Putty: 1 Flyash : 1 Fine Sand)	PEC	262444.26	260189.75	201507.23	214902.28	214072.10	174119.31	175675.20	202214.51	187130.16
		INDEX	101.33	100.46	77.80	82.97	82.65	67.23	67.83	78.07	72.25
2.	1:3 (1 Cement : 3 Fine Sand)	PEC	281087.66	276612.00	217929.48	231326.04	231239.76	186437.02	187992.92	217143.81	202059.46
		INDEX	108.52	106.80	84.14	89.31	89.28	71.98	72.58	83.84	78.01
3.	1:5 (1 Cement : 5 Fine Sand)	PEC	264103.16	261665.63	202982.11	216378.16	215586.64	175227.25	176783.15	203556.21	188471.86
		INDEX	101.97	101.03	78.37	83.54	83.24	67.65	68.25	78.59	72.77
4.	1:6 (1 Cement : 6 Fine Sand)	PEC	259007.81	257181.72	198498.20	211894.25	210926.30	171864.32	173426.30	199479.93	184395.58
		INDEX	100.00	99.29	76.64	81.81	81.44	66.35	66.96	77.02	71.19
5.	1:1:6 (1 Cement : 1 Lime Putty : 6 Fine Sand)	PEC	268317.85	265374.84	206693.76	220086.86	219492.06	178008.65	179564.55	206927.77	191843.42
		INDEX	103.59	102.46	79.80	84.97	84.74	68.73	69.33	79.89	74.07

Table IV.4.5: PEC and Its Index for Project No. 5 Using Alternate Masonry Units and Mortar Mixes

PEC and Its Index with Varying EEC_1 & TEC_1 Using											
No.	Mortar Mix Ratio		Traditional Bricks (22.9 cm X 11.4 cm X 7.6 cm)	Modular Bricks (20 cm X 10 cm X 10 cm)	Clay Flyash Bricks (20 cm X 10 cm X 10 cm)	Sand Lime Bricks (20 cm X 10 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 20 cm)	Aerated Concrete Blocks (40 cm X 20 cm X 20 cm)	Solid Concrete Blocks (30 cm X 20 cm X 15 cm)	Fal-G Blocks (30 cm X 20 cm X 15 cm)
1.	1:1:1 (1 Lime Putty: 1 Flyash : 1 Fine Sand)	PEC	326708.65	323389.79	257292.44	272380.32	271620.93	226369.76	228128.73	258175.05	241177.31
		INDEX	101.20	100.18	79.70	84.37	84.14	70.12	70.67	79.97	74.71
2.	1:3 (1 Cement : 3 Fine Sand)	PEC	347776.98	341948.10	275850.76	290940.35	290921.64	240289.64	242048.62	275046.24	258048.51
		INDEX	107.73	105.92	85.45	90.12	90.12	74.43	74.98	85.20	79.94
3.	1:5 (1 Cement : 5 Fine Sand)	PEC	328581.48	325056.07	258957.58	274046.59	273230.84	227620.61	229379.58	259689.84	242692.11
		INDEX	101.78	100.69	80.22	84.89	84.64	70.51	71.05	80.44	75.18
4.	1:6 (1 Cement : 6 Fine Sand)	PEC	322822.83	319988.45	253889.96	268978.98	267963.83	223819.90	225585.75	255082.92	238085.18
		INDEX	100.00	99.12	78.65	83.32	83.01	69.33	69.88	79.02	73.75
5.	1:1:6 (1 Cement : 1 Lime Putty : 6 Fine Sand)	PEC	333344.82	329248.13	263153.08	278238.09	277644.67	230764.10	232523.06	263500.29	246502.55
		INDEX	103.26	101.99	81.52	86.19	86.01	71.48	72.03	81.62	76.36

Table IV.4.6: PEC and Its Index for Project No. 6 Using Alternate Masonry Units and Mortar Mixes

			PEC and Its Index with Varying EEC_1 & TEC_1 Using								
No.	Mortar Mix Ratio		Traditional Bricks (22.9 cm X 11.4 cm X 7.6 cm)	Modular Bricks (20 cm X 10 cm X 10 cm)	Clay Flyash Bricks (20 cm X 10 cm X 10 cm)	Sand Lime Bricks (20 cm X 10 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 20 cm)	Aerated Concrete Blocks (40 cm X 20 cm X 20 cm)	Solid Concrete Blocks (30 cm X 20 cm X 15 cm)	Fal-G Blocks (30 cm X 20 cm X 15 cm)
1.	1:1:1 (1 Lime Putty: 1 Flyash : 1 Fine Sand)	PEC	381592.67	373796.68	280519.70	301820.37	302306.11	234206.18	236860.45	283289.78	259089.38
		INDEX	**101.56**	**99.49**	**74.66**	**80.33**	**80.46**	**62.33**	**63.04**	**75.40**	**68.96**
2.	1:3 (1 Cement : 3 Fine Sand)	PEC	413368.66	410786.17	308509.20	329812.46	331566.12	255200.04	257854.29	308734.78	284534.38
		INDEX	**110.02**	**106.94**	**82.11**	**87.78**	**88.25**	**67.92**	**68.63**	**82.17**	**75.73**
3.	1:5 (1 Cement : 5 Fine Sand)	PEC	384414.61	376306.61	283027.90	304330.30	304881.72	236090.36	238744.62	285571.55	261371.15
		INDEX	**102.31**	**100.15**	**75.33**	**81.00**	**81.14**	**62.84**	**63.54**	**76.00**	**69.56**
4.	1:6 (1 Cement : 6 Fine Sand)	PEC	375728.38	368662.74	275384.03	296686.44	296937.08	230357.45	233022.09	278622.56	254422.16
		INDEX	**100.00**	**98.12**	**73.29**	**78.96**	**79.03**	**61.31**	**63.54**	**74.16**	**67.71**
5.	1:1:6 (1 Cement : 1 Lime Putty : 6 Fine Sand)	PEC	391599.54	382629.84	289356.30	310652.65	311539.42	230831.91	243486.17	291319.13	267118.73
		INDEX	**104.22**	**101.84**	**77.01**	**82.68**	**82.92**	**61.44**	**64.80**	**77.53**	**71.09**

Table IV.4.7: PEC and Its Index for Project No. 7 Using Alternate Masonry Units and Mortar Mixes

No.	Mortar Mix Ratio		PEC and Its Index with Varying EEC_1 & TEC_1 Using: Traditional Bricks (22.9 cm X 11.4 cm X 7.6 cm)	Modular Bricks (20 cm X 10 cm X 10 cm)	Clay Flyash Bricks (20 cm X 10 cm X 10 cm)	Sand Lime Bricks (20 cm X 10 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 20 cm)	Aerated Concrete Blocks (40 cm X 20 cm X 20 cm)	Solid Concrete Blocks (30 cm X 20 cm X 15 cm)	Fal-G Blocks (30 cm X 20 cm X 15 cm)
1.	1:1:1 (1 Lime Putty: 1 Flyash : 1 Fine Sand)	PEC	640204.25	632684.67	495148.82	526537.31	523257.60	432615.29	436148.17	495410.34	460201.64
		INDEX	101.23	100.05	78.30	83.26	82.74	68.41	68.97	78.34	72.77
2.	1:3 (1 Cement : 3 Fine Sand)	PEC	682498.70	669939.22	532403.37	563795.31	562203.25	460558.50	464091.38	529278.12	494069.42
		INDEX	107.92	105.94	84.19	89.15	88.90	72.83	73.39	83.69	78.13
3.	1:5 (1 Cement : 5 Fine Sand)	PEC	643960.30	636025.43	498487.28	529878.07	526685.80	435123.16	438656.04	498447.40	463238.69
		INDEX	101.83	100.57	78.82	83.79	83.28	68.81	69.36	78.82	73.25
4.	1:6 (1 Cement : 6 Fine Sand)	PEC	632398.78	625851.29	488313.14	519703.93	516111.32	427492.56	431039.24	489198.19	453989.49
		INDEX	100.00	98.96	77.22	82.18	81.61	67.60	68.16	77.36	71.79
5.	1:1:6 (1 Cement : 1 Lime Putty : 6 Fine Sand)	PEC	653523.58	644441.75	506910.51	538293.24	535547.33	441434.25	444967.13	506097.56	470888.86
		INDEX	103.34	101.90	80.16	85.12	84.69	69.80	70.36	80.03	74.46

Table IV.4.8: PEC and Its Index for Project No. 8 Using Alternate Masonry Units and Mortar Mixes

			PEC and Its Index with Varying EEC_1 & TEC_1 Using								
No.	Mortar Mix Ratio		Traditional Bricks (22.9 cm X 11.4 cm X 7.6 cm)	Modular Bricks (20 cm X 10 cm X 10 cm)	Clay Flyash Bricks (20 cm X 10 cm X 10 cm)	Sand Lime Bricks (20 cm X 10 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 20 cm)	Aerated Concrete Blocks (40 cm X 20 cm X 20 cm)	Solid Concrete Blocks (30 cm X 20 cm X 15 cm)	Fal-G Blocks (30 cm X 20 cm X 15 cm)
1.	1:1:1 (1 Lime Putty: 1 Flyash : 1 Fine Sand)	PEC	624971.76	617004.64	483021.79	513602.49	511052.61	421174.57	424677.66	483893.72	449517.97
		INDEX	**101.25**	**99.96**	**78.26**	**83.21**	**82.80**	**68.24**	**68.80**	**78.40**	**72.83**
2.	1:3 (1 Cement : 3 Fine Sand)	PEC	666909.60	653945.07	519962.22	550546.35	549669.86	448882.18	452385.26	517475.93	483100.18
		INDEX	**108.05**	**105.95**	**84.24**	**89.20**	**89.05**	**72.73**	**73.29**	**83.84**	**78.27**
3.	1:5 (1 Cement : 5 Fine Sand)	PEC	628696.15	620317.23	486332.11	516915.09	514451.89	423661.30	427164.38	486905.17	452529.42
		INDEX	**101.86**	**100.50**	**78.79**	**83.75**	**83.35**	**68.64**	**69.21**	**78.89**	**73.32**
4.	1:6 (1 Cement : 6 Fine Sand)	PEC	617232.11	610228.88	476243.75	506826.74	503966.58	416095.04	419611.81	477733.95	443358.20
		INDEX	**100.00**	**98.87**	**77.16**	**82.11**	**81.65**	**67.41**	**67.98**	**77.40**	**71.83**
5.	1:1:6 (1 Cement : 1 Lime Putty : 6 Fine Sand)	PEC	638178.79	628662.59	494684.31	525259.31	523238.71	429919.18	433422.26	494490.83	460115.08
		INDEX	**103.39**	**101.85**	**80.15**	**85.10**	**84.77**	**69.65**	**70.22**	**80.11**	**74.54**

Table IV.4.9: PEC and Its Index for Project No. 9 Using Alternate Masonry Units and Mortar Mixes

			PEC and Its Index with Varying EEC_1 & TEC_1 Using								
No.	Mortar Mix Ratio		Traditional Bricks (22.9 cm X 11.4 cm X 7.6 cm)	Modular Bricks (20 cm X 10 cm X 10 cm)	Clay Flyash Bricks (20 cm X 10 cm X 10 cm)	Sand Lime Bricks (20 cm X 10 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 20 cm)	Aerated Concrete Blocks (40 cm X 20 cm X 20 cm)	Solid Concrete Blocks (30 cm X 20 cm X 15 cm)	Fal-G Blocks (30 cm X 20 cm X 15 cm)
1.	1:1:1 (1 Lime Putty: 1 Flyash : 1 Fine Sand)	PEC	730775.25	722059.48	570514.18	605101.99	601920.66	500988.10	504922.06	571216.08	532369.66
		INDEX	101.20	100.00	79.01	83.80	83.36	69.38	69.93	79.11	73.73
2.	1:3 (1 Cement : 3 Fine Sand)	PEC	683505.20	670244.22	521778.61	555663.89	552777.89	444808.44	448595.90	518574.68	480600.60
		INDEX	108.42	106.31	82.76	88.14	87.84	70.56	71.16	82.26	76.23
3.	1:5 (1 Cement : 5 Fine Sand)	PEC	642190.16	633886.54	485418.46	519302.50	515701.00	417540.17	421327.64	485522.24	447548.16
		INDEX	101.86	100.55	77.00	82.37	81.80	66.23	66.83	77.01	71.00
4.	1:6 (1 Cement : 6 Fine Sand)	PEC	630437.55	622979.23	474511.15	508395.20	504364.50	409359.70	413161.96	475606.50	437632.42
		INDEX	100.00	98.82	75.27	80.64	80.00	64.93	65.54	75.44	69.42
5.	1:1:6 (1 Cement : 1 Lime Putty : 6 Fine Sand)	PEC	652442.57	642909.36	494448.68	528324.09	525201.11	424306.06	428093.26	493723.68	455749.60
		INDEX	103.49	101.98	78.43	83.80	83.31	67.30	67.90	78.31	72.30

Table IV.4.10: PEC and Its Index for Project No. 10 Using Alternate Masonry Units and Mortar Mixes

			PEC and Its Index with Varying EEC_1 & TEC_1 Using								
No.	Mortar Mix Ratio		Traditional Bricks (22.9 cm X 11.4 cm X 7.6 cm)	Modular Bricks (20 cm X 10 cm X 10 cm)	Clay Flyash Bricks (20 cm X 10 cm X 10 cm)	Sand Lime Bricks (20 cm X 10 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 20 cm)	Aerated Concrete Blocks (40 cm X 20 cm X 20 cm)	Solid Concrete Blocks (30 cm X 20 cm X 15 cm)	Fal-G Blocks (30 cm X 20 cm X 15 cm)
1.	1:1:1 (1 Lime Putty: 1 Flyash : 1 Fine Sand)	PEC	730775.25	722059.48	570514.18	605101.99	601920.66	500988.10	504922.06	571216.08	532369.66
		INDEX	101.20	100.00	79.01	83.80	83.36	69.38	69.93	79.11	73.73
2.	1:3 (1 Cement : 3 Fine Sand)	PEC	777871.22	763543.38	611998.09	646589.74	645287.63	532103.59	536037.55	608928.72	570082.30
		INDEX	107.73	105.74	84.75	89.54	89.36	73.69	74.23	84.33	78.95
3.	1:5 (1 Cement : 5 Fine Sand)	PEC	734957.71	725779.50	574231.65	608822.01	605738.04	503780.68	507714.64	574597.92	535751.50
		INDEX	101.78	100.51	79.52	84.31	83.89	69.77	70.31	79.57	74.20
4.	1:6 (1 Cement : 6 Fine Sand)	PEC	722083.67	714450.34	562902.48	597492.84	593963.09	495283.81	499233.14	564298.68	525452.26
		INDEX	100.00	98.94	77.96	82.75	82.26	68.59	69.14	78.15	72.77
5.	1:1:6 (1 Cement : 1 Lime Putty : 6 Fine Sand)	PEC	745606.67	735151.30	583611.13	618192.52	615605.58	510808.25	514742.21	583116.57	544270.15
		INDEX	103.26	101.81	80.82	85.61	85.25	70.74	71.29	80.75	75.37

Table IV.4.11: PEC and Its Index for Project No. 11 Using Alternate Masonry Units and Mortar Mixes

			PEC and Its Index with Varying EEC_1 & TEC_1 Using								
No.	Mortar Mix Ratio		Traditional Bricks (22.9 cm X 11.4 cm X 7.6 cm)	Modular Bricks (20 cm X 10 cm X 10 cm)	Clay Flyash Bricks (20 cm X 10 cm X 10 cm)	Sand Lime Bricks (20 cm X 10 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 20 cm)	Aerated Concrete Blocks (40 cm X 20 cm X 20 cm)	Solid Concrete Blocks (30 cm X 20 cm X 15 cm)	Fal-G Blocks (30 cm X 20 cm X 15 cm)
1.	1:1:1 (1 Lime Putty: 1 Flyash : 1 Fine Sand)	PEC	711062.26	700354.36	543149.25	579036.70	577562.82	468829.86	473067.84	545809.93	505316.93
		INDEX	101.33	99.81	77.40	82.52	82.31	66.81	67.42	77.78	72.01
2.	1:3 (1 Cement : 3 Fine Sand)	PEC	761797.61	745044.28	587839.18	623730.76	624281.35	502350.07	506588.05	586437.14	545944.14
		INDEX	108.56	106.18	83.77	88.89	88.97	71.59	72.19	83.57	77.80
3.	1:5 (1 Cement : 5 Fine Sand)	PEC	715567.61	704361.88	547154.02	583044.23	581675.22	471838.27	476076.25	549453.14	508960.14
		INDEX	101.98	100.38	77.98	83.09	82.90	67.24	67.85	78.30	72.53
4.	1:6 (1 Cement : 6 Fine Sand)	PEC	701698.61	692157.16	534949.30	570839.50	568990.26	462684.72	466939.26	538357.94	497864.94
		INDEX	100.00	98.64	76.24	81.35	81.09	65.94	66.54	76.72	70.95
5.	1:1:6 (1 Cement : 1 Lime Putty : 6 Fine Sand)	PEC	727039.55	714457.96	557258.38	593138.93	592305.36	479408.94	483646.92	558630.14	518137.14
		INDEX	103.61	101.82	79.42	84.53	84.41	68.32	68.93	79.61	73.84

Table IV.4.12: PEC and Its Index for Project No. 12 Using Alternate Masonry Units and Mortar Mixes

			PEC and Its Index with Varying EEC_1 & TEC_1 Using								
No.	Mortar Mix Ratio		Traditional Bricks (22.9 cm X 11.4 cm X 7.6 cm)	Modular Bricks (20 cm X 10 cm X 10 cm)	Clay Flyash Bricks (20 cm X 10 cm X 10 cm)	Sand Lime Bricks (20 cm X 10 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 20 cm)	Aerated Concrete Blocks (40 cm X 20 cm X 20 cm)	Solid Concrete Blocks (30 cm X 20 cm X 15 cm)	Fal-G Blocks (30 cm X 20 cm X 15 cm)
1.	1:1:1 (1 Lime Putty: 1 Flyash : 1 Fine Sand)	PEC	900765.51	887131.97	701763.14	744084.81	743297.00	612788.55	617675.88	705732.67	657863.67
		INDEX	101.27	99.73	78.89	83.65	83.56	68.89	69.44	79.34	73.96
2.	1:3 (1 Cement : 3 Fine Sand)	PEC	961751.73	940850.10	755483.04	797807.93	799454.39	652878.19	657972.98	754564.86	706695.86
		INDEX	108.12	105.77	84.93	89.69	89.88	73.40	73.97	84.83	79.46
3.	1:5 (1 Cement : 5 Fine Sand)	PEC	906175.23	891942.78	706572.40	748895.63	748234.42	616197.70	621292.49	710103.66	662234.66
		INDEX	101.87	100.27	79.43	84.19	84.12	69.27	69.85	79.83	74.45
4.	1:6 (1 Cement : 6 Fine Sand)	PEC	889502.30	877270.58	691900.21	734223.44	732984.90	605193.55	610308.25	696765.30	648896.30
		INDEX	100.00	98.62	77.79	82.54	82.40	68.04	68.61	78.33	72.95
5.	1:1:6 (1 Cement : 1 Lime Putty : 6 Fine Sand)	PEC	919966.50	904080.02	718719.60	761031.22	761013.70	625298.97	630393.76	721136.01	673267.01
		INDEX	103.42	101.64	80.80	85.56	85.56	70.30	70.87	81.07	75.69

Table IV.4.13: PEC and Its Index for Project No. 13 Using Alternate Masonry Units and Mortar Mixes

			PEC and Its Index with Varying EEC_1 & TEC_1 Using								
No.	Mortar Mix Ratio		Traditional Bricks (22.9 cm X 11.4 cm X 7.6 cm)	Modular Bricks (20 cm X 10 cm X 10 cm)	Clay Flyash Bricks (20 cm X 10 cm X 10 cm)	Sand Lime Bricks (20 cm X 10 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 20 cm)	Aerated Concrete Blocks (40 cm X 20 cm X 20 cm)	**Solid Concrete Blocks (30 cm X 20 cm X 15 cm)**	**Fal-G Blocks (30 cm X 20 cm X 15 cm)**
1.	1:1:1 (1 Lime Putty: 1 Flyash : 1 Fine Sand)	PEC	847875.42	833508.20	653776.28	694816.89	694779.23	565016.68	570074.31	658123.98	611563.93
		INDEX	**101.26**	**99.54**	**78.08**	**82.98**	**82.97**	**67.48**	**68.08**	**78.60**	**73.04**
2.	1:3 (1 Cement : 3 Fine Sand)	PEC	908423.70	886841.42	707109.48	748155.06	750533.38	605019.88	610077.51	706608.72	660048.67
		INDEX	**108.49**	**105.91**	**84.45**	**89.35**	**89.63**	**72.25**	**72.86**	**84.39**	**78.83**
3.	1:5 (1 Cement : 5 Fine Sand)	PEC	853252.56	838290.80	658555.58	699599.50	699687.00	568606.93	573664.55	662471.80	615911.75
		INDEX	**101.90**	**100.11**	**78.65**	**83.55**	**83.56**	**67.91**	**68.51**	**79.12**	**73.56**
4.	1:6 (1 Cement : 6 Fine Sand)	PEC	837343.27	823725.62	643990.39	685034.31	684548.68	557683.03	562760.43	649230.72	602670.67
		INDEX	**100.00**	**98.37**	**76.91**	**81.81**	**81.75**	**66.60**	**67.21**	**77.53**	**71.97**
5.	1:1:6 (1 Cement : 1 Lime Putty : 6 Fine Sand)	PEC	866943.23	850339.52	670614.18	711646.57	712373.06	577641.81	582699.45	673423.68	626863.63
		INDEX	**103.53**	**101.55**	**80.09**	**85.00**	**85.08**	**68.99**	**69.59**	**80.42**	**74.86**

Table IV.4.14: PEC and Its Index for Project No. 14 Using Alternate Masonry Units and Mortar Mixes

			PEC and Its Index with Varying EEC_1 & TEC_1 Using								
No.	Mortar Mix Ratio		Traditional Bricks (22.9 cm X 11.4 cm X 7.6 cm)	Modular Bricks (20 cm X 10 cm X 10 cm)	Clay Flyash Bricks (20 cm X 10 cm X 10 cm)	Sand Lime Bricks (20 cm X 10 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 20 cm)	Aerated Concrete Blocks (40 cm X 20 cm X 20 cm)	Solid Concrete Blocks (30 cm X 20 cm X 15 cm)	Fal-G Blocks (30 cm X 20 cm X 15 cm)
1.	1:1:1 (1 Lime Putty: 1 Flyash : 1 Fine Sand)	PEC	6904495.10	6893913.20	6158093.73	6325903.35	6254001.22	5830100.26	5846622.24	6102952.13	5917549.30
		INDEX	100.53	100.38	89.66	92.11	91.06	84.89	85.13	88.86	86.16
2.	1:3 (1 Cement : 3 Fine Sand)	PEC	7102290.81	7068139.12	6332319.65	6500145.41	6436135.74	5960780.46	5977302.45	6261339.33	6075936.50
		INDEX	103.41	102.91	92.20	94.64	93.71	86.79	87.03	91.17	88.47
3.	1:5 (1 Cement : 5 Fine Sand)	PEC	6922060.81	6909536.72	6173706.00	6341526.87	6270033.62	5841828.66	5858350.65	6117155.33	5931752.50
		INDEX	100.79	100.60	89.89	92.33	91.29	85.06	85.30	89.07	86.37
4.	1:6 (1 Cement : 6 Fine Sand)	PEC	6867991.80	6861956.00	6126125.77	6293946.15	6220580.66	5806143.12	5822729.67	6073900.13	5888497.30
		INDEX	100.00	99.91	89.20	91.64	90.57	84.54	84.78	88.44	85.74
5.	1:1:6 (1 Cement : 1 Lime Putty : 6 Fine Sand)	PEC	6966784.74	6948896.81	6213098.85	6380881.57	6311475.76	5871343.34	5887865.33	6152932.33	5967529.50
		INDEX	101.44	101.18	90.46	92.91	91.90	85.49	85.73	89.59	86.89

Table IV.4.15: PEC and Its Index for Project No. 15 Using Alternate Masonry Units and Mortar Mixes

PEC and Its Index with Varying EEC_1 & TEC_1 Using											
No.	Mortar Mix Ratio		Traditional Bricks (22.9 cm X 11.4 cm X 7.6 cm)	Modular Bricks (20 cm X 10 cm X 10 cm)	Clay Flyash Bricks (20 cm X 10 cm X 10 cm)	Sand Lime Bricks (20 cm X 10 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 20 cm)	Aerated Concrete Blocks (40 cm X 20 cm X 20 cm)	Solid Concrete Blocks (30 cm X 20 cm X 15 cm)	Fal-G Blocks (30 cm X 20 cm X 15 cm)
1.	1:1:1 (1 Lime Putty: 1 Flyash : 1 Fine Sand)	PEC	26018577.88	25630857.13	20166225.75	21413791.07	21376160.49	17557506.21	17706342.22	20269291.87	18859815.62
		INDEX	101.28	99.77	78.50	83.36	83.21	68.34	68.92	78.90	73.41
2.	1:3 (1 Cement : 3 Fine Sand)	PEC	27798854.98	27110290.45	21823361.13	22956572.10	22994211.25	18734092.65	18882912.92	21695177.37	20285841.12
		INDEX	108.21	105.53	84.95	89.36	89.51	72.92	73.50	84.45	78.96
3.	1:5 (1 Cement : 5 Fine Sand)	PEC	26176816.11	25683013.87	20395456.80	21528733.75	21498970.80	17663159.91	17448053.11	20078371.72	18987763.22
		INDEX	101.90	99.97	79.39	83.80	83.69	68.76	67.92	78.16	73.91
4.	1:6 (1 Cement : 6 Fine Sand)	PEC	25689742.86	25254389.41	19966832.34	21100109.29	21053480.52	17341691.56	17491109.16	20007580.87	18598104.62
		INDEX	100.00	98.31	77.72	82.13	81.95	67.50	68.09	77.88	72.40
5.	1:1:6 (1 Cement : 1 Lime Putty : 6 Fine Sand)	PEC	26579705.65	26037583.81	20750317.53	21854176.23	21872296.69	17929038.90	18077874.91	20719531.72	19310055.47
		INDEX	103.46	101.35	80.77	85.07	85.14	69.79	70.37	80.65	75.17

Table IV.4.16: PEC and Its Index for Project No. 16 Using Alternate Masonry Units and Mortar Mixes

			PEC and Its Index with Varying EEC_1 & TEC_1 Using								
No.	Mortar Mix Ratio		Traditional Bricks (22.9 cm X 11.4 cm X 7.6 cm)	Modular Bricks (20 cm X 10 cm X 10 cm)	Clay Flyash Bricks (20 cm X 10 cm X 10 cm)	Sand Lime Bricks (20 cm X 10 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 10 cm)	Hollow Concrete Blocks (40 cm X 20 cm X 20 cm)	Aerated Concrete Blocks (40 cm X 20 cm X 20 cm)	Solid Concrete Blocks (30 cm X 20 cm X 15 cm)	Fal-G Blocks (30 cm X 20 cm X 15 cm)
1.	1:1:1 (1 Lime Putty: 1 Flyash : 1 Fine Sand)	PEC	54709308.58	54682085.46	46185894.41	48124562.07	46981811.98	42214540.68	42400261.13	45251244.52	42975626.95
		INDEX	100.28	100.23	84.66	88.21	86.11	77.38	77.72	82.94	78.77
2.	1:3 (1 Cement : 3 Fine Sand)	PEC	56934139.43	56641865.81	48145367.72	50084523.92	49030228.83	43684267.13	43869987.58	47032583.02	44898391.97
		INDEX	104.36	103.82	88.25	91.80	89.87	80.07	80.41	86.21	82.30
3.	1:5 (1 Cement : 5 Fine Sand)	PEC	54907389.43	54858325.81	46361706.72	48300802.42	47162351.83	42346612.13	42532332.58	45411183.02	43276991.97
		INDEX	100.64	100.55	84.98	88.53	86.45	77.62	77.96	83.24	79.32
4.	1:6 (1 Cement : 6 Fine Sand)	PEC	54557627.63	54323263.81	45826644.72	47765740.42	46606235.83	41945315.63	42131762.08	44924763.02	42790571.97
		INDEX	100.00	99.57	84.00	87.55	85.43	76.88	77.22	82.34	78.43
5.	1:1:6 (1 Cement : 1 Lime Putty : 6 Fine Sand)	PEC	55410325.93	55300943.81	46804687.72	48743359.92	47628383.33	42678515.13	42864235.58	45813508.02	43679316.97
		INDEX	101.56	101.36	85.79	89.34	87.30	78.23	78.57	83.97	80.06