PREFABRICATION IN DEFENCE HOUSING IN EASTERN SECTOR

A DISSERTATION
submitted in partial fulfilment
of the requirements for the award of the Degree
of
MASTER OF ARCHITECTURE

By

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CERTIFICATE

Certified that the Dissertation entitled "PREFABRICATION IN DEFENCE HOUSING IN EASTERN SECTOR", which is being submitted by Capt. BASHESHER NATH PANDEY in partial fulfilment for the award of the Degree of Master of Architecture in the Department of Architecture, University of Roorkee, Roorkee, India, is a bonafide record of the student's own work carried out by him under my supervision and guidance. The matter embodied in this Dissertation has not been submitted for the award of any other Degree or Diploma.

This is further to certify that he has worked for a period of 8 months from January 1973 to September 1973 for preparing this Dissertation at this University.

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INTRODUCTION

In order to solve the acute housing problem, particularly in the remote areas of hilly regions, where it is difficult to get adequate skilled labour, conventional building materials and transport heavy building components. It is proposed to undertake residential development schemes by adopting industrialised methods of production. These would not only solve the housing problem but also cater for good speed and economy which are essential requirements in mass housing project for the Defence.

Prefabricated structures are essentially built of machine made identical components, which need some ordered system of basic measurement. Their design among other things depends on the principle of modular concept which determines the basic dimension to be followed as a guide and control system relating not only to linear dimensions or the areas but also to space and volume.

It is obvious that the prefabrication system is dependent for its successful implementation on the manufacturing processes and construction equipments available for the purpose. In more technologically advanced countries, this is not a problem but for developing countries like ours, it can only be successful when industry is geared up to the production of components as required in terms of materials, module and construction methods which are dependent mostly on manual handling to avoid use of heavy machinery.

FACTORS AFFECTING SELECTION OF BUILDING SYSTEM

AVAILABILITY OF MATERIALS

This, in each case, is the most important single factor. The basic materials required and normally expected to be available are stone, sand, timber and water.

Sand and Stones

In many areas suitable stone is not available in sufficient quantities which can be used as aggregate in the RCC work. Similarly sand suitable for concreting or plastering is also not available in most of the places.

Timber

In remote locations, even forested areas sawn timber is generally not available except in very small quantities at a few places. As such use of timber as a principle building material for large housing projects in such areas is not found suitable unless production of reasonably seasoned sawn timber in adequate quantity is undertaken in advance through special measures. In certain areas like Ladakh and Himachal Pradesh timber is not at all available.

Water

Non-availability of water in sufficient quantity presents a problem only in certain areas. However pumping of water upto height of 500 ft or more is often necessary in hilly areas.

Availability of Labour

Non-availability of skilled and unskilled labour in adequate quantity in any area renders uneconomical, the adoption of types of construction which require lot of labour. Some of the hilly areas in this region are very thinly populated and practically no labour is available. In any case most of the civilian labour has to be brought in from other populated areas.

Life of Structures

Cost considerations dictate that the type of construction adopted should be the cheapest possible for the duration for which it is required. In determining the relative cost of construction for a specified period, the anticipated maintenance expenditure for that period has also to be taken into account. For the purpose of standardisation various usage periods are adopted e.g. upto one year, 1 to 2 years, 2o to 3 years or 3 to 5 years and finally the permanent construction. The type of construction traditionally adopted in Eastern region has been discussed in detail in one of the chapters.

Distance from Rail Head

The cost of transportation of building materials and fittings to the site of work will have an obviously important influence on the selection of building system. For example the cost of cement goes up by 100% if it has to be transported upto 150 km in hilly region and almost four times for another 150 km.

The cost of transportation per tonne km increases with increase in the total load involved. For remote areas, far away from rail heads and sources of supply of building materials, it is particularly important that type of construction adopted by such that the weight and to some extent the cubical content of the materials transported outside be kept to the minimum possible.

Climatic Conditions

This is another important factor which influence the type of construction at any location. Temperature and rainfall are the essential considerations. Climatic conditions and the state of transportation has been discussed in another chapter.

Time Available for Execution

To finish a project within the specified period also helps in deciding the type of construction.

whole project has been completed departmentally by one of the Project Engineers. Contracts have been awarded to the civil contractors for supply of transportation facilities of materials from rail head to the actual work site or laying of sewers etc.

WHY IT SHOULD BE ADOPTED IN DEFENCE CONSTRUCTIONS

This modern method of construction should be adopted in defence constructions since it is one of the largest construction agencies due to the following reasons:

i. To solve the large scale housing programmes and specially in the remote localities of hilly terrain.

ii. To complete the projects much faster and thus saving in time and cost.

iii. Due to the non-availability of skilled and unskilled labour and difficulty in getting contractors to work in remote areas.

iv. Availability of powerful transport and handling equipments with construction companies.

These factors strongly speak for adoption of prefabrication in defence construction programmes specially in areas where time is more important and there is no labour available.

We are in the process of buying or procuring some highly sophisticated mobile plants which could be transported to the work site, assembled and the components can be manufactured. One of the plant/machine is the one which is developed by the Building Research Station in U.K. and known as 'GOCON'. This machine produces large panels and with various adjustments we can have different sizes. Maximum size it can manufacture is the full room size panels. Also search is still on if there is better plant available in some other country which is mobile and easy to handle.

Thus it can be said that although traditional methods will continue to be practiced in the near future but gradual efforts are being made to reach the higher level of industrialisation in the Defence construction it being the largest construction agency in the country. We can set an example for others to solve most of our problems like the one of shortage of housing.

CHAPTER 1

STATUS OF TRANSPORTATION AND CLIMATIC CONDITIONS OF EASTERN SECTOR

The Eastern Command comprises of the following areas, which can be classified according to the regions as under:

West Bengal

Assam Valley

Eastern Himalayas

- a. Sikkim
- b. Bhutan
- c. Nefa (Arunachal)

Purvanchal

- a. Purvanchal North
  - i. Lohit Tirop region
  - ii. Nagaland
- b. Purvanchal South
  - i. Imphal Valley
  - ii. Manipur hills
- c. Mizo hills
- d. Tripura-Cacha Region
  - i. Tripura Plains
  - ii. Tripura hills
  - iii. Cachar Plain
  - iv. North Cachar hills

Meghalaya Mikir Region

West Bengal

The region experiences a hot and humid climate. The proximity to the Bay of Bengal on the South, the alignment of Himalayas on the North and that of Meghalaya in the North East determine largely the climatic character. Irrespective of the general vagaries and seasonal distributions of the elements such as temperature, rainfall and relative humidity are too uneven.

A fairly good transport net work with wide spatial variations has been developed in the region. Prior to the advent of the quicker and more assumed surface transport, the railways and the roads, the perennial streams like the Ganga and the Brahmputra served as the link between the Ports along Hoogly and the Eastern region.

Assam Valley

The climate of the Assam valley as well as that of the entire Assam is mainly controlled by the five factors which are as under.

i. Orogrophy

ii. The alternating pressure cells of North-West India and the Bay of Bengal.

iii. The predominance of Maritime tropical air mass.

iv. The periodic Western disturbances.

v. The local mountains and the valley winds.

The weather of this valley is much different from that of West

Bengal region. The mountain and valley winds have their effect on moderating the temperature conditions. Prevalence of fog in the valley is a characteristic feature of weather during winter mornings. Fog occurs in most places and varying from 60 - 100 days . Thunder storms are very common features associated with the weather of Assam. Rainfall is very high and largely associated with storms in the premonsoon and monsoon periods.

Transport and communication system as a whole is not well developed. The entire North East India is linked with the rest of India only by narrow corridor between the Himalayas and Bangladesh, has to a great extent prevented the development of a quick and efficient transport system in the region. The growth of inland water transport is also checked by the inclusion of the lower part of the Brahamputra in Bangladesh. Within the region itself the development of roads and railways has been hindered by the existence of numerous rivers and streams which keep on shifting courses requiring frequent bridging and circuiting of tracks. However this region has a much more efficient system of transport and communication system than the surrounding hilly areas. The region has about 1718 km of Railways with about 100 km of broadgauge. Rest is all in metre gauge. The two main railway lines run longitudinally along both the banks of Brahamputra and connects most of the major urban centres on either side.

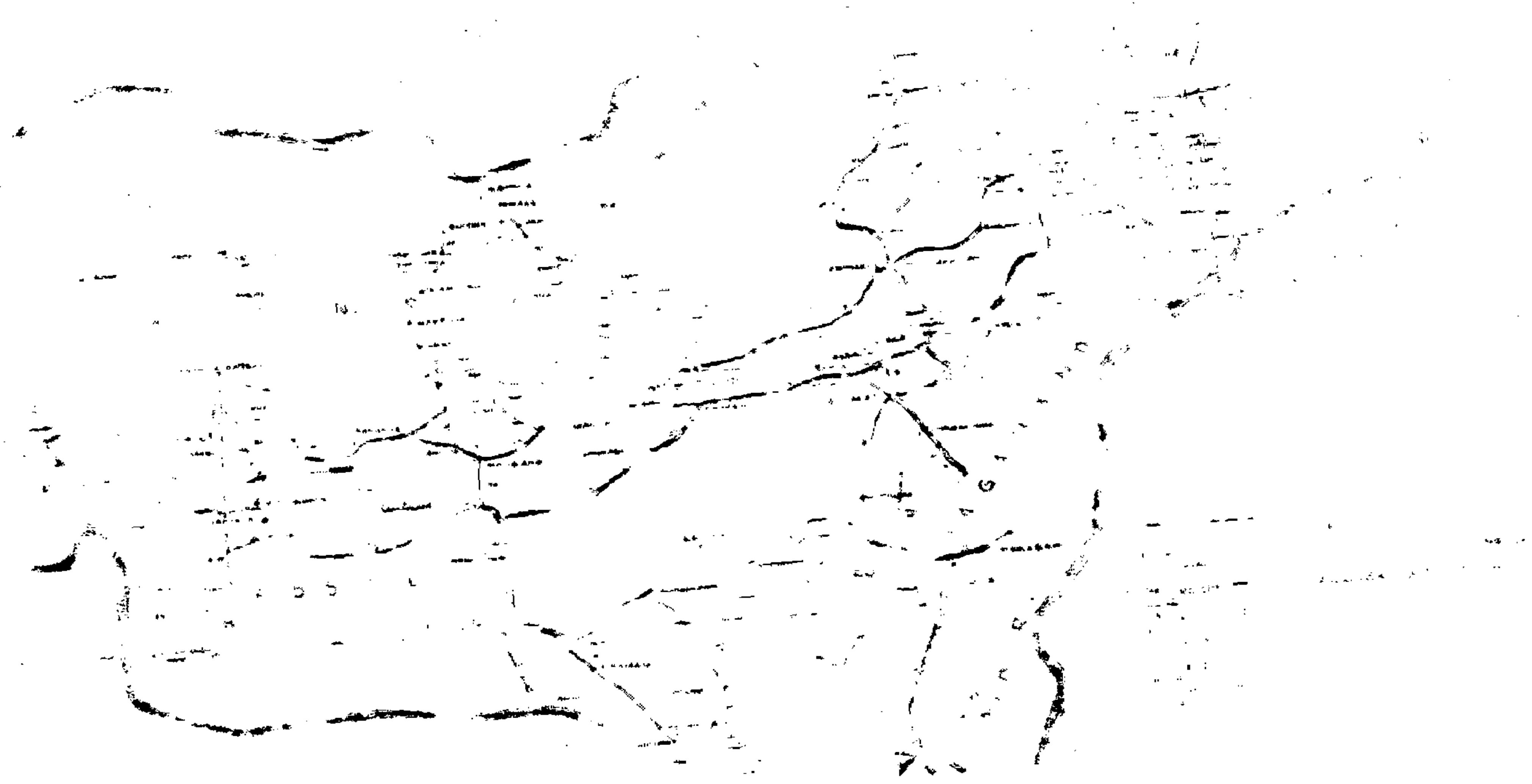
There are about 13155 km of roads including PWD, District and village roads with 1140 km of national highway and 714 km of state highways. The NH-37 is the most important communication link between Eastern region and whole of India. Further this roads and rail link is not dependeable during the rains owing to the heavy incidence of breaches due to the torrential hill streams.

Eastern Himalayas

Eastern Himalaya the most strategic area of our portion covers an area of approximately 1,22,802 km^2 comprising kingdom of Sikkim and Bhutan and Arunachal including Tirap and part of Lohit division lying south of Lohit river.

Owing to rapid changes in topographic and altitudinal aspects, the climatic conditions tend to change within short distances. There is contrast in temperature and rainfall between the sheltered valleys, foot hills and the mountain topo. The premonsoon showers begin towards the end of March, the monsoon proper lasting from May to the end of September.

Snowfall is experienced in most of the region at the height of 1500 m and above. The winters are cold and damp. The temperature varies from $0^{\circ}C$ to - $70^{\circ}C$. Summer season which starts from early May is short and moderate by frequent showers the temperature going upto $41^{\circ}C$.



COMMUNICATION MAP EAST. REGION

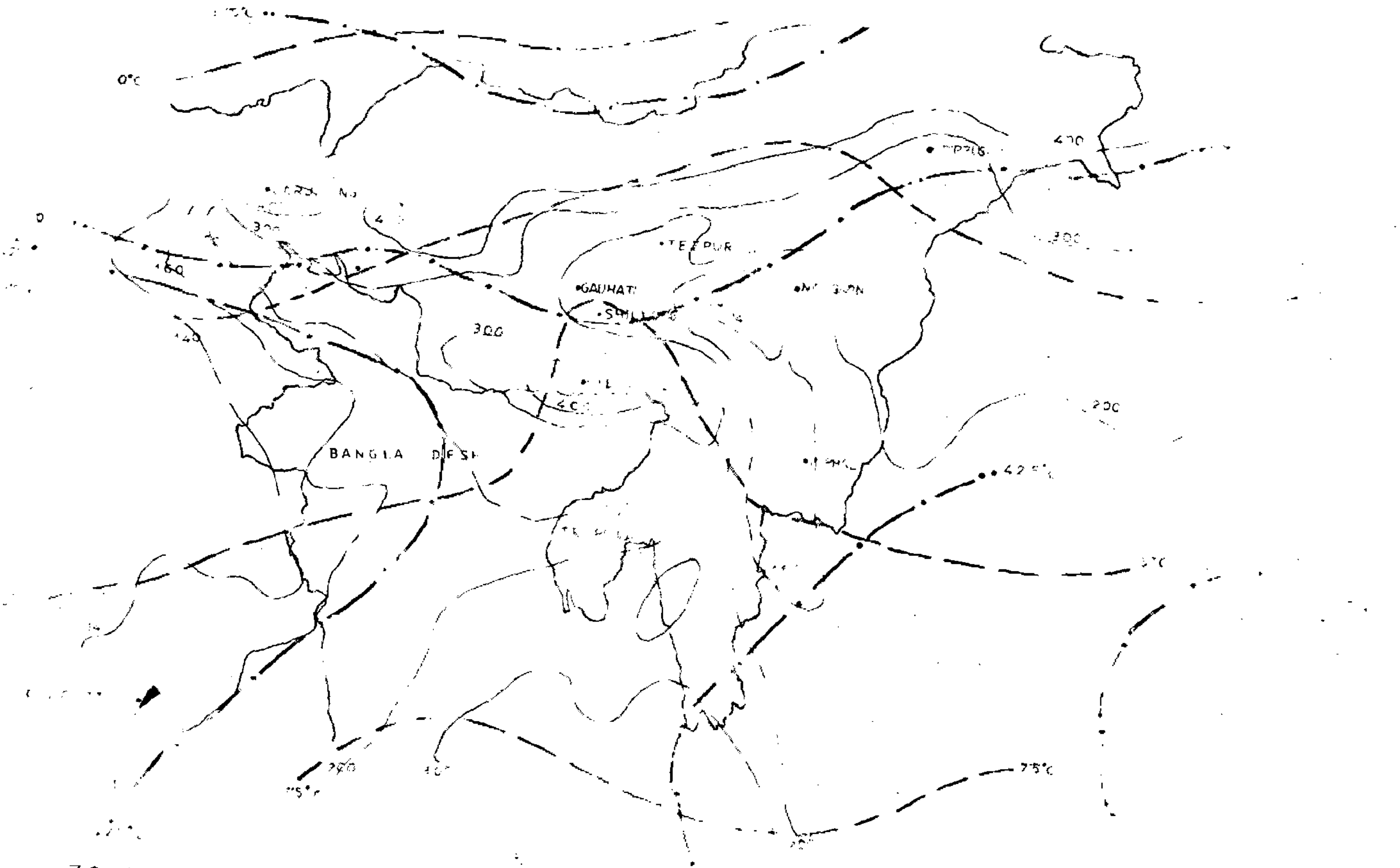
Lack of transportation and communication has been the major factor for the underdevelopment of the region. Special attention has been paid to the speedy development of the means of transport and communication in view of their importance from both administrative and strategic point of views. In the whole region only Darjeeling can be regarded as well connected and accessible.

In NEFA there are six transport cooperative societies which are operating goods cum passenger services in the various parts of the territory in addition to the defence transport. Limited road accessibility has led and the development of air transport for carriage of mail, cash, supplies etc. There are four air strips in NEFA out of which only two are suitable for Dakotas.

Purvanchal

The Purvanchal covering an area of about 94,800 km^2 with a population of over 4 millions. The region enjoys a typical monsoonal climate with variants ranging from tropical to temperate conditions. The rapid changes in topographic conditions results in climatic changes in short distances. The rainfall varies from a minimum of 100 cm to a maximum of 300 cm.

This area is found to be one of the most inaccessible tracts of the country, the links of various transport system is confined to a few areas, having some importance. Cachar and North Cachar are



ZONAL MAP SHOWING MIN MAX TEMP & RAINFALL

National Atlas of India (map computed)

the only districts having a rail communication. The NH-39 is the most important road which crosses the region running from TAMU and Goleghat in Assam. The highway interlinks the two important capital town Imphal and Kohima. Seeing the backwardness of the region with respect to its rail, road and water transport system, the work for important routes has already been undertaken by Border Roads and PWD.

Meghalaya

The Meghalaya Mikir Region consists of Garo, Khasi, Jaintia and Mikir hills. The region is about 400 km long with an average width of 40 km. covering about 35291 km^2.

The region is of strategic importance because it is surrounded by Bangladesh on West and South side.

The climate of this region differs from that of the Assam valley mainly due to its high relief which in general makes the climate very salubrious while that of the Brahamputra planes is comparatively much warmer in summer and cool in winter. However it is worthwhile to note that only the climate of the central part of the central and eastern Meghalaya (Khasi and Jaintia hills is conducive, whereas in the Western Meghalaya (Garo hills) except for the winter (November to February) it becomes opressive as a result of high temperature, heavy rainfall rendering the atmosphere exceedingly moderated by rainfall. The climate of the Mikir hills is uncomfortable except in winter and becomes opressive during monsoons leading to malarial conditions, which have been bringing unprecedented havoc wrought by blackwater fever to the people.

Lack of transport and communication facilities is the main limiting factor in the development of the region. The Central and Eastern Meghalaya only have some good roads, the most important being the Gauhati Shillong (NH-40), Shillong, Dawki and the Shillong Cherapunji roads. At present this region has 306 km of black topped road, 200 km of metalled road, 296 km of grovelled road, 238 km of earth road, 382 km of path, the total road being about 1,422 km. The Western Meghalaya has only 31 km of black topped road, 422 km of grovelled road, 62 km of earth road, 14 km of bridle path, the total road being 735 km. In the Eastern most Meghalaya NH-39 is the single most important road. A section of NF railway 77 km passes through this region which is of very much importance. Refer Table showing climatological data on the following page.

HOUSING SITUATION - EXISTING AND PROPOSED

Considering the vast population or the strength of the Army, it is not possible to provide the married accommodation to each and every one. But even then the policy is to provide married accommodation

*Computed from Climatological and Solar Data for Indi[illegible] pp. 39-52.

wherever it is possible and convenient. The statement* of Field Marshal Manekshaw in this connection is quoted here. "We must change with social changes, when I joined Army, the soldier never brought his family. He used to gohome on leave very occasionally. But today the men want to bring their families. The attitude is changing".

At present there is a little married accommodation available in Eastern sector. The various stations where married accommodation is either available or has been proposed in the near future are discussed below.

In first Corps area the Cantonments that have come up so far are Binajura where married accommodation has been provided and where area division of this Corps is located. In Siliguri also the construction for married accommodation has been started and the work is likely to be completed in a short time. Gauhati and Shillong are also having married accommodation since they are old Cantonments in this region. A new Cantonment has been constructed at a place called Misa South of Brahamputra on Gauhati Nawgaon road. Married accommodation for one brigade has been provided here. In Tejpur the married accommodation for 2nd Corps HQ is almost on the finishing stage and the families have started moving in. Misamori is also having married accommodation. This is the extension of Tejpur Cantonments. No married accommodation has been provided or planned for a division,

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***See Field-Marshal Manekshaw - Interview In Sainik Samachar, Jan. 1973**

can be done with much more speed and efficiency.

The labour which is from the GREF has been trained and is being used as skilled labour. For carriage the pioneer cogs have been working and being utilised as unskilled labour.

TYPES OF CONSTRUCTION

Adoption of traditional types of construction in full is rarely possible in remote areas, due to the reasons already discussed. However, partial use in varying degrees is usually made of these types of construction. A brief description of specifications and approximate plinth area rates for these are given in the Table on the next page. These rates are in the plains. Additional expenditure for transportation to forward areas has to be added. The cost goes up by 100% and more during transportation depending upon the distances.

COMPOSITION - EASTERN COMMAND

The Eastern Command got its command Headquarters at Fort William Calcutta, commanded by Lt. Gen. known as GOC in C's also as Army Commander. Under his command are two Corps. Each of them is commanded by Lt. Gen. who is known as Corps Commander. The Headquarters of these Corps are at Siliguri and Tejpur.

Each Corps is having three Mountain Divisions under its command. These divisions are all employed along the Northern and

Table 4
(Refer page 21)

Table

Sl No.	Type of construction and brief specifications	Period for which suitable yrs.	Approx. plinth rate per sft. Rs.	Remarks
1.	Bachas, Bamboo and Ballie posts, bamboo trusses, purlins and framework terza walling, thatch roofing, chattii doors and windows, earth floor.	1	3.00	
2.	Timber trusses and frame-work timber/steal purlins, brick work upto sill level and tarza walling above sill level AC/CGI sheet roofing, wooden doors and windows, RCC floor.	2 to 3	11.00	Specification conforming partly to serial 1 and partly to sr. 2 are also used.
3.	Assam Type: As for serial 2 above but with Ekra walling above sill level.	3 to 5	14.00 16.00	In local practice used for longer periods.
4.	As for serial 2 above but with chicken wire lath, plaster walling above sill level.	3 to 5	13.00 to 15.00	
5.	Normal permanent construction	Perma-nent	20.00 to 25.60	

Northern Eastern borders.

In addition to these two Corps there are two independent Mountain Divisions. In addition to these there are also other rescue troops which are affiliated to command, corps as well as Divisions.

*Information supplied by Chief Engineer, North Assam Zone during personal discussion.

Now each of the Division got again three Brigades under its command. Further each of these three Brigades got three Battalions under its command.

To find out the approx. total strength we will calculate from the Division strength. To give exact strength is not possible because of its tactical importance. But what we can quote is the strength which is known to all and is not a secret.

From the composition of the command we find out that there are total eight Mountain Division in it. The strength and composition of one Mountain Division is as under:

i.	Officers	544
ii.	JCOs	434
iii.	ORs	14,793
iv.	NCSE	858
	Total:	16,629

Therefore the strength of eight Mountain Division becomes 1,33,032 persons. In addition to this there is service population which is authorised at the rate of 10-12%. Therefore the total population of Eastern Command can be taken as 1,45,000 approx. This strength is not always present because about 20% strength is either on courses, temporary duties or leave. Therefore effective strength during peace can be assumed as 1,20,000. The composition of command has been shown and attached as Appendix F.

CHAPTER 2

BUILDING MATERIALS - LOCALLY AVAILABLE IN URBAN AND RURAL AREAS

*In this chapter we will discuss the locally available building materials used for the building construction as far as the housing material pattern in the Eastern region is concerned. Later on, various methods of construction have been discussed and illustrated with the help of photographs.

Materials of Wall

Grass, leaves, reeds or bamboos are the materials most commonly used for walls of houses in the region because out of the 4,40,460 sample houses, 3,74,849 houses have used only these materials. The other materials also used for walls in Assam and other areas are burnt bricks for 12,764 sample houses, timber for 11,264, mud for 11,983, Unburnt bricks for 1,071, corrugated iron sheets for 4,943, stones for 547, cement concrete for 10,395 and other materials for 12,644 sample houses. There are no mud walls in Eastern region of the type that are found in Uttar Pradesh or other parts of India. The frame of a wall is generally either of bamboo or ekra (which is a kind of small bamboo and/or reed). This frame is covered either with lime plaster (which is a mixture of lime and sand) or with mud. When it is plastered

*See Report, Census of India, Assam
Figures quoted in this Chapter have been taken from the same source.

with mud some times it is also called as Mud Walls. There are many houses which have mixed materials for walls such as half brick and half lime plaster, half corrugated iron sheets and half thatch etc. and such mixtures have been classified as 'other materials'. In the towns of Assam most commonly used materials for walls are EKRA walls plastered with lime plaster. In the rural areas, the most used materials are bamboo, reeds and grass with or without plaster of any kind.

In the three towns which have a population of over 50,000, Gauhati has a total of 4,121, Shillong has 3,084 and Dibrugarh has 1,975 sample houses. In Gauhati 544 houses out of every 1000 houses are in reeds or bamboo as materials for their walls. In Dibrugarh town 707 houses out of 1000 houses use the same materials as Gauhati, whereas in Shillong, 610 houses out of every 1000 houses use such materials. However as already stated above the so called walls made of reeds or bamboo really mean ekra walls with or without lime plaster or mud plaster. Whereas in Shillong there are no houses without plaster probably because of the extreme cold in winter. In Gauhati the next material used for walls is cement concrete in as much as 171 houses out of every 1000 houses use this material. Next in order of importance for materials of walls in Gauhati are mud, burnt bricks, timber and corrugated iron sheets. In respect of Dibrugarh town, the other wall materials in order of importance are burnt bricks, cement concrete, timber corrugated iron sheets and mud. In Shillong other materials in order of importance are timber corrugated iron sheets, mud, cement concrete unburnt bricks and stones. As already commented above, the socalled mud walls in these three towns also are really ekra walls plastered with mud. From the above statement,it is clear and it appears that usage of timber and corrugated iron sheets as wall materials is common in Shillong, the use of cement concrete is greatest in Gauhati and the use of burnt bricks is greater in Dibrugarh.

It need not perhaps be over-emphasised that the locally available materials mostly determine the nature of the walls of houses. In Shillong, a small type of bamboo locally known as 'Kdait' or 'Ekra' is available in large quantity and so far the majority of houses in Shillong have this type of Ekra as the main material for walls of houses. This Ekra is about 4 ft to 8 ft long and is very tough and long lasting especially when it is fully mature. If cut during the proper time and properly dried it will last more than a life time. This type of ekra is available only in the high lands, in portion of United Khasi and Jaintia hills district. With this 'Ekra' as frame the walls of houses in Shillong are mostly plastered with a mixture of lime and sand to which another coating of lime is added together with three or four coats of white washing. In the houses of very poor people, the same 'Ekra' is used as frame but instead of the lime plaster mud mixed with cowdung is used as plaster. In the case of Gauhati, Dibrugarh and other towns of Assam, the frame of the walls is generally made of split bamboo to which lime or mud plaster is used. Bamboo is available in great quantities in the plains of Assam and that is the reason why it is mainly used as the main material for walls. What is true of the towns in the plains of Assam is also true of all the villages in the plains of Assam with the only difference that in the rural areas, mud mixed with cowdung is mostly used as plastering material, wherever plaster is used in the rural areas of the plains because the climate is not hot and so they can do without plaster. In the interior of the hills districts of Meghalaya bamboo is also used as a material for walls because of its local availability.

In the United Khasi and Jaintia hills timber is also used in great quantities even in the interior because pine trees are available in great quantities and they can easily be cut into planks and the cost is also comparatively cheap. In the towns in the plains of Assam, bricks are available locally and so many well-to-do people now-a-days use bricks as material for walls. The materials that are not locally available are corrugated iron sheets and cement. These are imported from the factories outside Assam.

The climate and rainfall of a place are great factors in determining the materials of walls. In the United Khasi and Jaintia rural Assam, people use thatch or grass as a roofing material. The main reason for this usage is because thatch and grass are the most easily available roofing materials in the rural areas of Assam. Corrugated iron sheets and Asbestos cement sheets are used by well-to-do persons in the rural Assam because these materials give sufficient protection from the heavy rainfall of Assam and they are also not easily combustible. The other materials mentioned are a mixture of thatch and some other materials like kerosene oil tins, bamboo etc. and as they cannot be classified under any of the previous headings, they have been summed up as other materials.

In the urban areas the distribution of 1000 census houses by roofing material is as follows.

Grass, leaves, reeds, thatch, wood or bamboo - 373 tiles, slate 16, corrugated iron or other metal sheets 561, Asbestos cement sheet 15, brick and lime 12. Concrete and stone slabs 5 and all other materials 18. It is thus seen that in the urban areas, corrugated iron sheets are mostly used as roofing materials while the proportion of materials other than thatch or bamboo is also comparatively much higher. The reason for this is the same as mentioned earlier. Many municipalities do not also allow the use of thatch or other combustible materials for new houses for roofing purposes. However, the proportion of thatch roofing is also very big. But that is mostly in small urban areas in the interiors. There is however, one glaring point in respect of the usage of corrugated iron sheets. In the urban areas of United Khasi and Jaintia hills district as many as 896 houses of every 1000 houses use only corrugated iron sheets. In the United Mihir and North Cachar hills 809 out of every 1000 houses use corrugated iron sheets for roofing materials. Even in rural areas of these areas use the greatest amount of CGI sheets in as much as 388 houses out of every 1000 houses. The rainfall is heaviest in this district and also the people appear to be comparatively better off than those of other hills areas of Assam and so CGI sheets are used in great quantities here.

As far as the three main towns of this region is concerned, which are having population of over 50,000, Shillong has 927 houses out of every 1000 using CGI sheets as roofing material whereas Dibrugarh has only 661 and Gauhati only 444 such houses. The main reason is that in Shillong no new houses are allowed to be built of thatçh or any other combustible materials. In Gauhati 483 houses out of every 1000 still use thatch, bamboo or other combustible materials whereas in Dibrugarh only 314 houses out of every 1000 use such materials and in Shillong only 54 out of every 1000 houses use these materials. The use of Asbestos cement sheets is also greatest in Shilong but the use of brick and lime is greatest in Gauhati followed by Dibrugarh.

CGI sheets and Asbestos cement sheets are materials imported from Calcutta or other places where these materials are manufactured.

All the other roofing materials are available locally. CGI sheets are the most favoured roofing materials and much more houses would have had these materials for their roofing had it not been for their non-availability. The obvious reason is because corrugated iron sheets give the best protection from rain roofs of houses are almost entirely of the sloping type and not flat (photographs attached). The reason is obvious that flat roofed houses cannot drain away the rain water quickly and will therefore cause leakages. Sloping roofs have a definite advantage in speedily draining away rain water.

Thatch or sawn grass is a kind of grass that is mostly used as roofing materials. This grass is tough and long (about 3 ft to 6 ft) and is very suitable as a roofing material. That is why in many areas including the tea gardens, certain patches of land are left only for the growth of this type of grass. It is not only plentiful but it grows quite naturally in many places. However as more and more land is put under cultivation the availability of this type of grass is gradually dimishing. It has also become very costly and has to be replaced every three or four years and so people would much prefer the use of CGI sheets if it is available.

For walling material as already been discussed that in highland portions of Khasi and Jaintia hills district, Ekra or 'Kdait' is the best material. This type of small bamboo grows quite naturally in the highland valleys but many people also grow it in their gardens. It is also very beautiful and therefore many bungalows grow it for the sake of beautifying their gardens and also for the purpose of supporting the tendrils of many creeping flowers. In the rural areas whether in the plains or hills bamboo almost grows wild. In the plains, however, it used to be planted around each homestead. Bamboo which is thus plentifully available can easily be used as walling materials. Some skilled workers can also split bamboo in such a way and by weaving it into a 'Torza', the bamboo can also be used as roofing materials which is leak proof. Many temporary Railway quarters have such bamboo 'Torza' as their roofs.

Table on the next page shows the availability of the building materials and their use in construction both in urban and rural areas. This table has been prepared with the help of data given in the Census Report of Assam.

Type of Houses - Description and Illustration*

"Various house types found in the region are illustrated mostly in the shape of photographs and line drawings. Each photograph or line drawing has a caption immediately below it. These captions are generally self explanatory but for the sake of greater elucidation short explanations are given below about each illustration.

Figure 1 shows a bird's eye view of the various types of houses which are generally found in the region. These houses have

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*See Report, Census of India, Assam Material and Pictures, illustrated are quoted from the same source.

Table 5

(Refer to page 32)

LOCALLY AVAILABLE BUILDING MATERIALS AND THEIR USE

Sl No.	Building Materials	Walls				Roofs			
		Urban Areas		Rural Areas		Urban Areas		Rural Areas	
		%used	whe-ther in use	%used	whe-ther in use	%used	whe-ther in use	%used	whe-ther in use
1.	Grass		yes)	)	yes	)	yes	)	yes
2.	Leaves/ Thatch	61.0	yes)	85.0)	yes	37.3)	yes	84.7)	yes
3.	Reeds & Bamboos		yes)	)	yes	)	yes	)	yes
4.	Burnt bricks	6.1	yes	4.0	yes	1.2	yes	0.1	yes
5.	CGI/ other metal sheets		yes	1.5	yes	56.1	yes	10.0	yes
6.	Asbestos sheets					1.5	yes	1.0	yes
7.	Cement concrete	16.5	yes	2.0	yes	0.5	yes	0.1	yes
8.	Tiles							1.0	yes
9.	Slate/ stone		yes	0.25	yes			1.0	yes
10.	Timber	8.2	yes	2.5	yes				
11.	Mud		yes	3.0	yes				
12.	Other materials	৪·২	yes	1·75	yes	3.4	yes	2·1	yes

Note: i. In Shillong area the use of timber and CGI sheets is the greatest
ii. In Gauhati area the use of cement concrete is the greatest
iii. In Dibrugarh area the use of burnt bricks is the greatest

*Computed from Report, Census of India, Assam.

"become known as "Assam type' of houses. The basic features of these Assam types of houses are that they have a masonry plinth on which wooden frames are built. The frames of the walls are of 'Ekra' which are plastered with a mortar of lime and sand and then white washed. The roofs are generally of corrugated GI sheets or Asbestos cement sheets in the urban areas and of thatch or of the above materials in the rural areas. This area is in seismic region with plenty of rainfall, The houses must therefore be light but durable. The Assam type of houses can withstand earthquakes better. CGI sheets are better for roofing because they give the best protection from the heavy rainfall.

The captions to figures 2, 3 and 5 speak for themselves. The original Khasi houses are oval shaped, low, thatch-roofed and dark. Most of such houses have disappeared in Khasi and Jaintia Hills. Fig. 4 shows a modernised oval shaped Khasi house with walls of stones roof of CGI sheets and with windows and a chimney to let out smoke. This house is in Cherapunji where plenty of coal is found and is used in the chimney.

Figure 6 shows a Bodo house in the Brahamputra valley, while Fig. 9 shows a granary which can be found in almost every house in the plains. The granary used to be built on stout stilts of wood and planted in such a way that rats cannot go to destroy the paddy. The walls are either of wood or of Ekra plastered with mud with practically no window. In the top portion of the front part there is a door through which people can get in to store or take out the paddy. Namghars or prayer houses can be found in every village in the Brahramputra valley. Simple types are of wooden post with bamboo walls and thatch roof but fig. 8 shows a modernised Namghar. The shape of all types of Namghars are however similar irrespective of the materials of which they are constructed. Fig. 7 shows a Garo house in the hills. Garo houses are generally built on stilts with bamboo floors. In the hilly areas, one part of the house may be on the level of ground but the other part may be high up above the ground due to the terrain. The Garos, the Mikirs and Mizos used to keep cattle, goats, fowls, etc. beneath the plinth. Fig. 21 shows a Garo housing colony. Some Garos and Mikirs who live in the plains may have mud plinths like other houses in the plains.

Fig. 10 shows a typical Hmar house whilefig. 11 shows a Jaintia house which can generally be found in the rural areas of the Jaintia hills. Fig. 13 shows a house whose walls are of planks and the roof is of the tiles. Houses with roofs of tiles were not formerly found in Assam but recently many houses in lower Assam in particular, have roofs of this material. The advantage of tiles is that they can be manufactured locally out of the clay and can withstand sun and rain with good effect.

Fig. 14, 15, 16 and 17 show houses which can be built out of timber or bamboo which are found locally. Fig. 14 shows a housing colony in the Railway quarters at Pandu. Fig. 17 shows a close up of 'Torza' skilfully woven to make it water proof for the purpose of roofing. Fig. 16 shows a roof frame made out of wood and bamboos ready for being used with 'Torza' while Fig. 15 shows a finished house with these materials. The roofs made of 'Torzas' have steep inclines of about 60 degrees so as to make them leakproof. Fig. 18 shows a typical house with a roof made of kerosine oil tins while Fig. 19 shows a 'Torza' house with half of its walls made of bricks to withstand heavy rainfall.

Fig. 22 shows a modern concrete building which can be found in Assam as well as any where in India. While fig. 23 shows one of three or four modern flour mills built in Assam. Fig. 24 shows the Lagislative Assembly building in Shillong, the roof of which is made entirely of galvanised plain sheets. In this type of roofing, plank is first used for roofing and on top of the planks, plain galvanised sheets are put ending in rolled up lines to prevent leaking. The dome-shaped library of this building has concrete rafters with tiles for roofing. Fig. 25 shows a house with walls of bricks.

The captions of Fig. 26 and 27 are the typical Assames house, one for poor man and the other for middle class man. Fig. 28 presents a Mikir house found in the plains of Assam with mud plinth. A distinctive feature of this house is that there is a loin room in front of the house.

Fig. 29 shows the type of quarters made for the tea gardens labourers by the management in Assam. Fig. 30 is a sketch of a typical Miri house which is built on stout wooden stilts and is generally of great length, anything from about 80 ft and as much as 250 ft. These houses are generally of one room but with different entrances where members of the joint family can have entrance or exit. It may be noted that the front part has a verandah with a wooden staircase near which is generally seen a flail for husking rice.

Fig. 31 and fig. 34 captions speak for themselves and are self explanatory. Fig. 35 is a sketch of a typical Mizo house, while fig. 36 shows a typical house of immigrants from East Bengal (Now Bangladesh)."

Fig. 1. A view of Assam type houses in Shillong

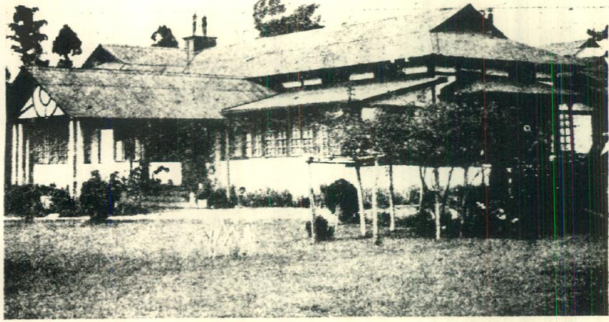


Fig. 2. A modern Bungalow type of houses in Assam

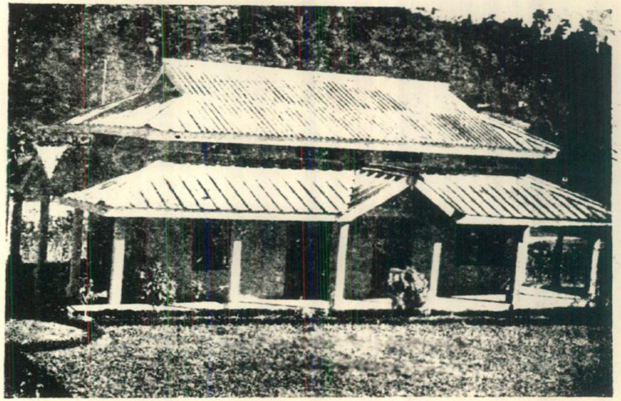


Fig. 3. A house with asbestos sheets roofing

Fig. 4. An oval-shaped Khasi House

Fig. 5. A middle class house

Fig. 6. A Bodo house

Fig. 7. A Garo house in the plains

Fig. 8. A modernised Namghar

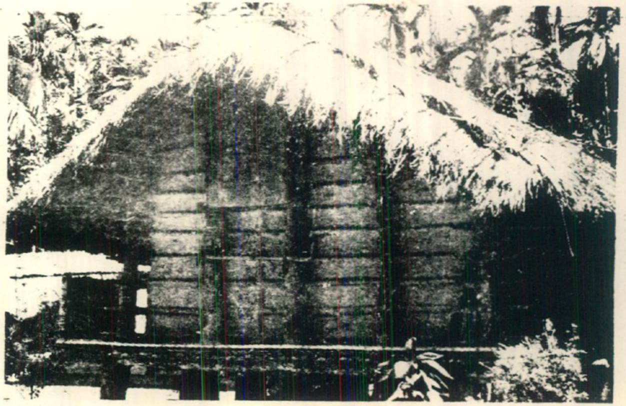


Fig. 9. A granary

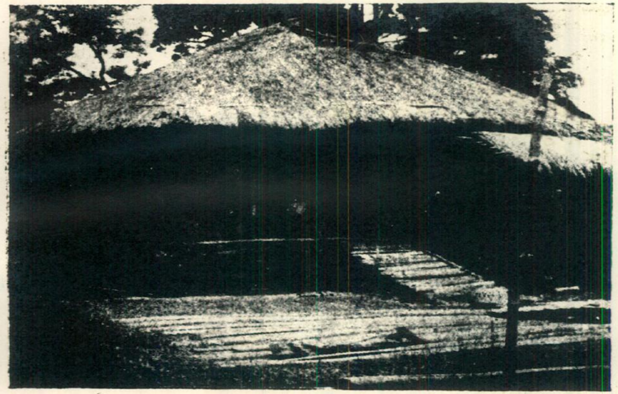


Fig. 10. A Hmar house

Fig. 11. A Jaintia House with kercsene oil tins roofing

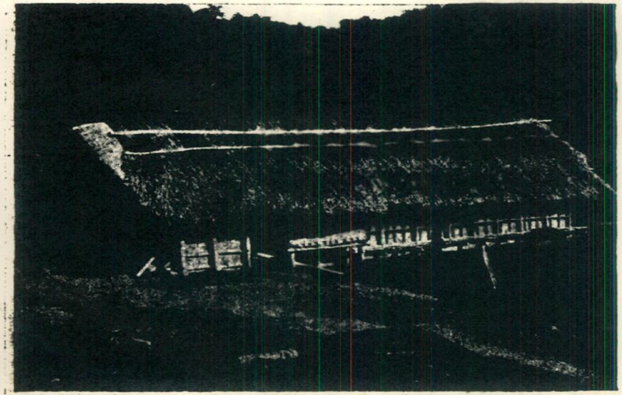


Fig. 12. A Garo House in the Hills

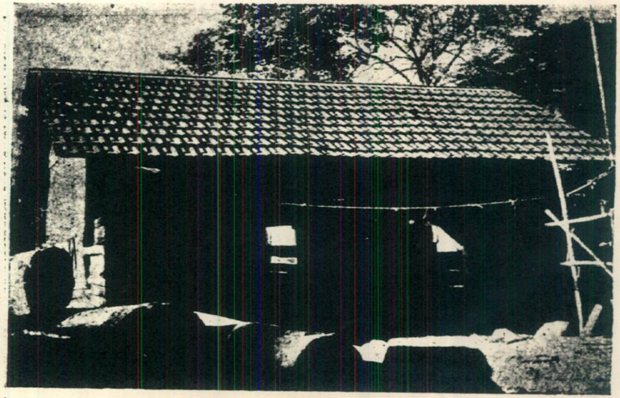


Fig. 13. A house with roof of tiles

Fig. 14. A housing colony with bamboo materials

Fig. 15. A house with bamboo torza roof

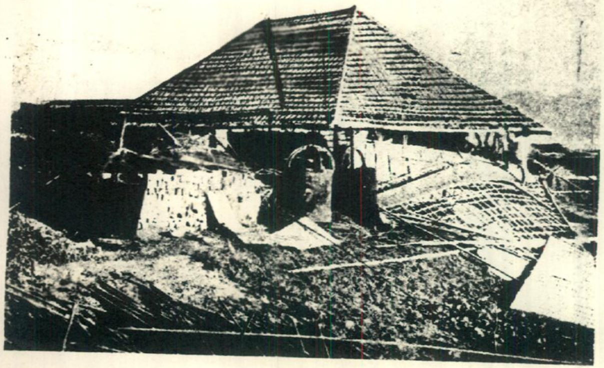


Fig. 16. A frame of a bamboo house

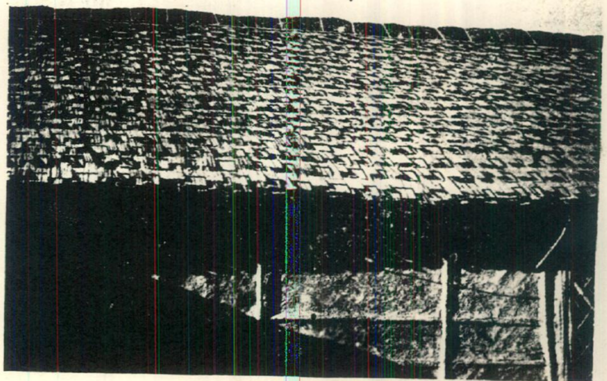


Fig. 17. A close up of a bamboo torza roof

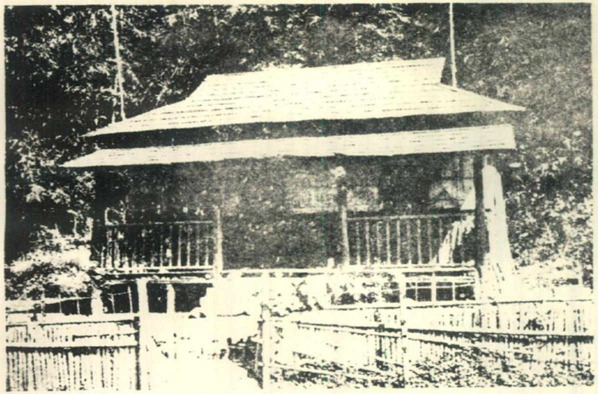


Fig. 18. A typical house with tin roof

Fig. 19. A house half-walled with bricks

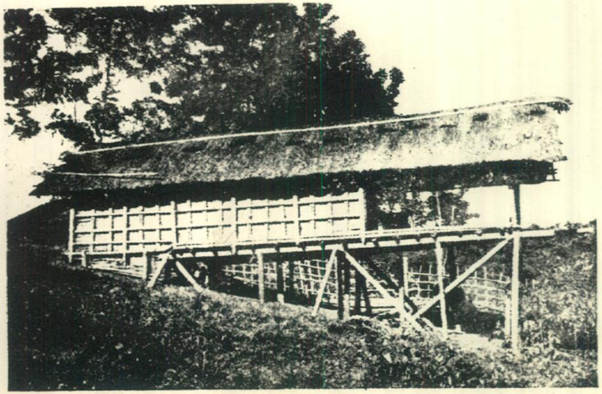


Fig. 20. A Mikir house in the hills

Fig. 21. A Garo housing colony

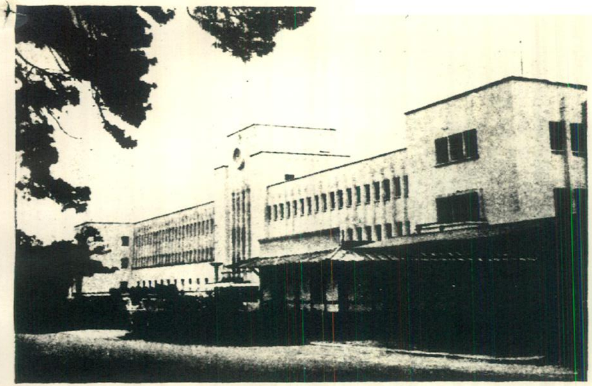


Fig. 22. A modern concrete building

Fig. 23. A modern flour mill

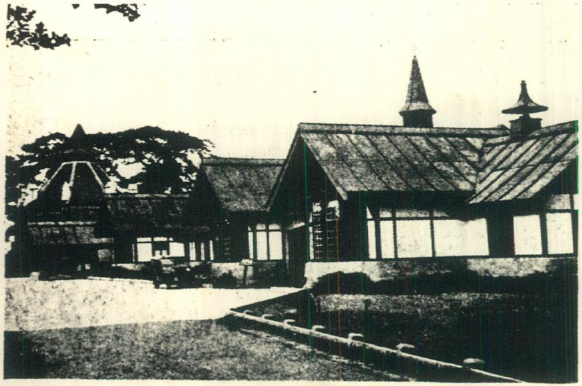


Fig. 24. A building with galvanised plain sheets roofing

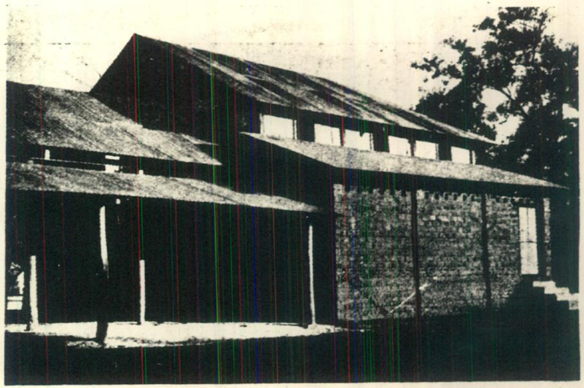


Fig. 25. A house with walls of bricks

Fig. 26. A typical Assamese house in village

Fig. 27. A middle class Assamese house

Fig. 28. A plains Mikir House with loin loom

Fig. 29. Tea garden houses for labour

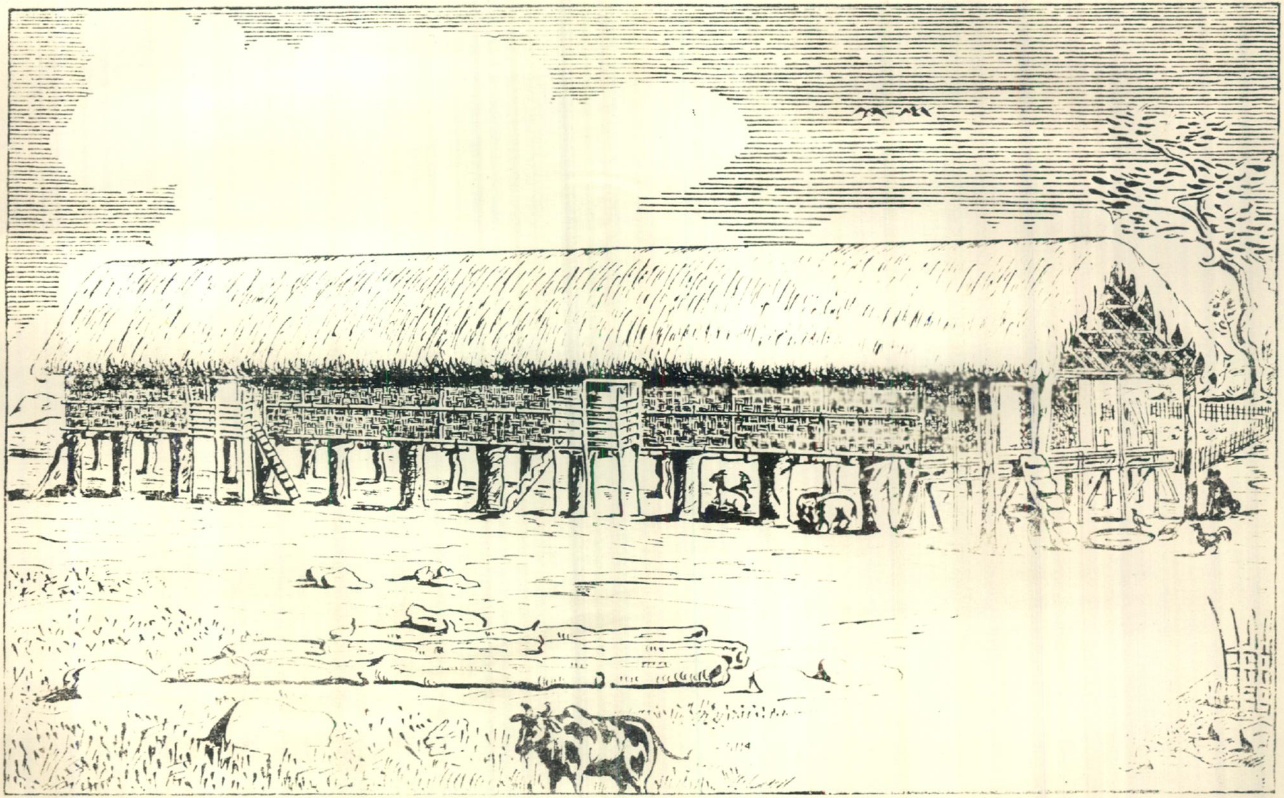


Fig. 20. A typical [illegible] house

Fig. 31. An Angami Naga house

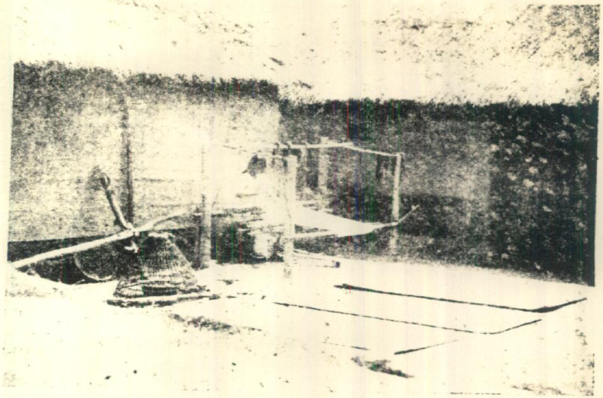


Fig. 32. Another typical Assamese house with handloom

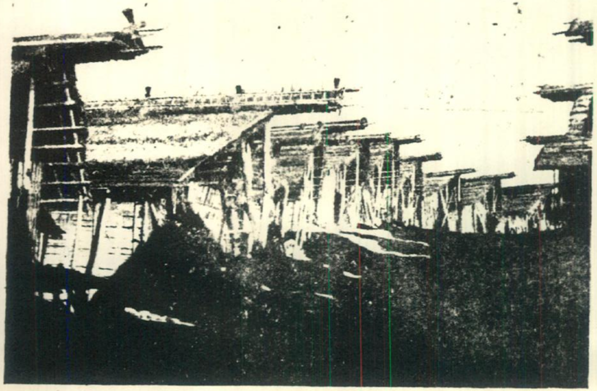


Fig. 33. An Ao Naga house

Fig. 34. Ex-tea Garden labour house

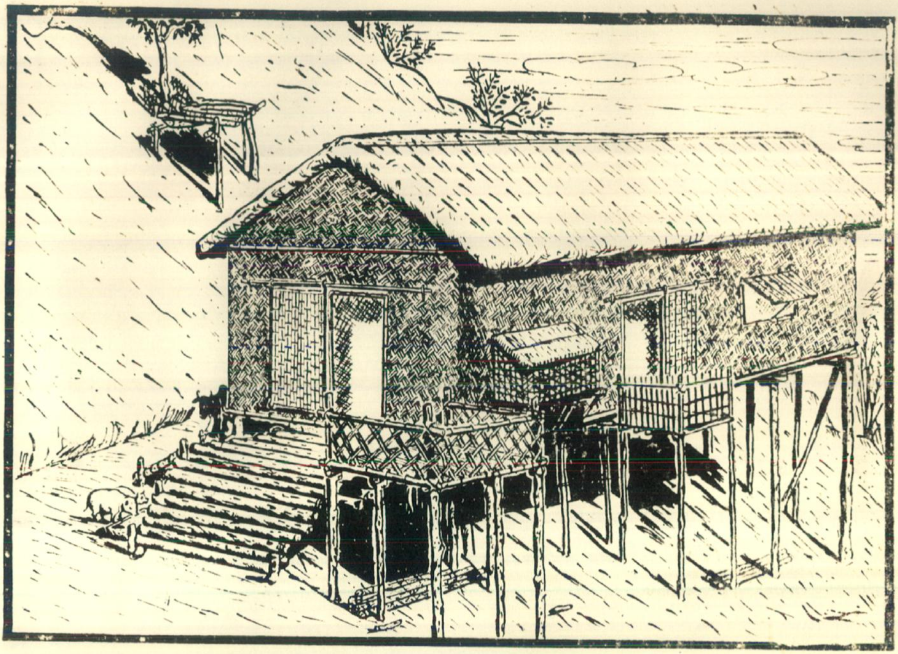


Fig. 35. A typical Mizo house

Fig. 36. A typical immigrant house

CHAPTER 3

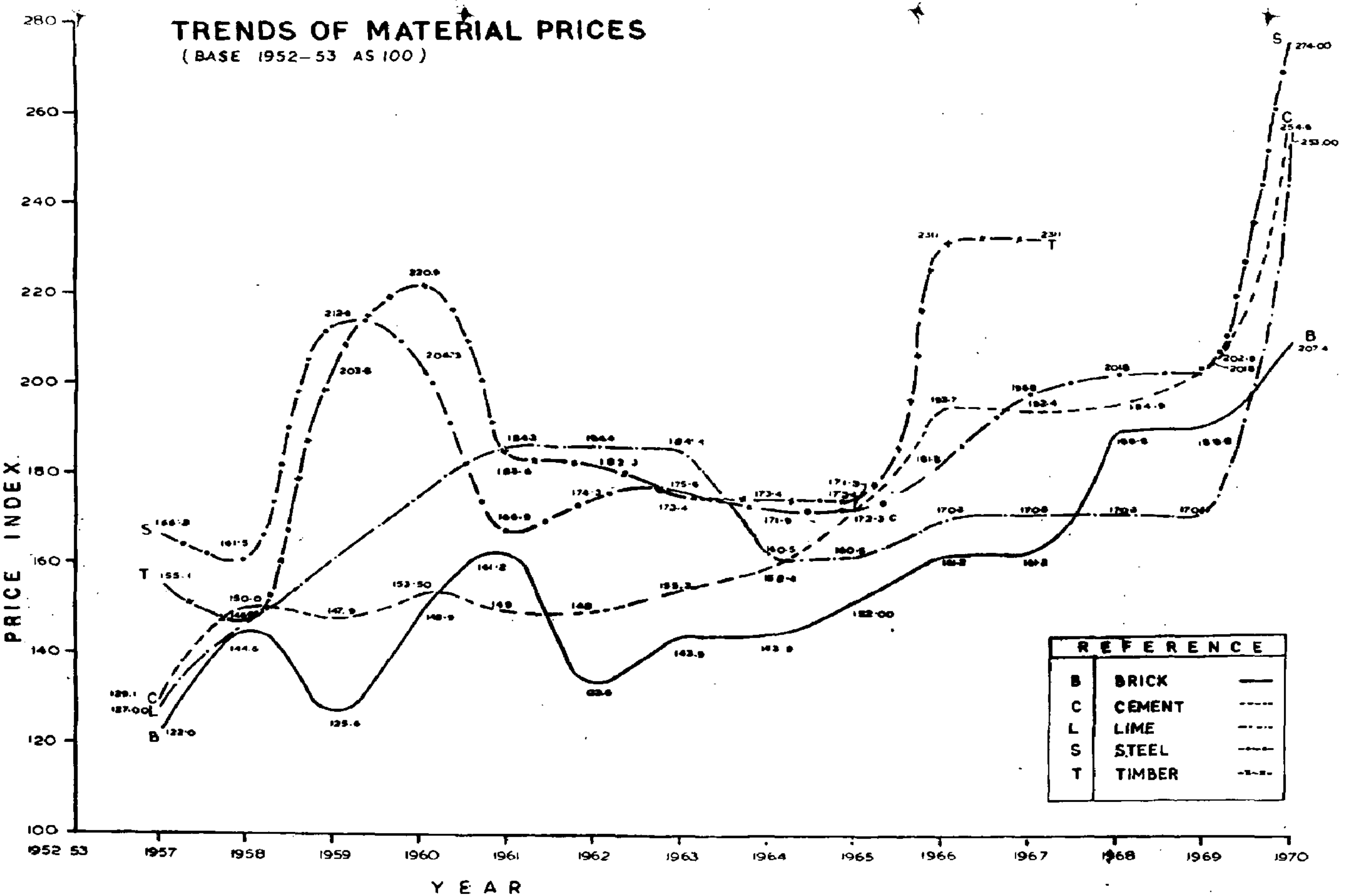
A RATIONAL APPROACH

SPEED AND ECONOMY IN HOUSING

Having analysed the housing situation in earlier chapter and the ensuing problems thereof, the speed and economy become the guiding principles of all the house building programmes. The housing requirement covers a variety of construction starting from simple houses for the non-combetants to the officers of General rank. In fulfilling this wide range of programme, conventional methods which are often inadequate slow and thus uneconomical in the forward areas have to be necessarily supplemented by new techniques and methods covering an overall planning of targets and costs, application of mass production techniques, adoption of relatively more easily and abundantly available building materials and improved construction equipment and proper organisation and management of construction works at site. Due to unprecendented programme of construction of all types in our development programmes, shortage of building materials like steel, cement, timber, to some extent bricks and skilled craftsmen like masons, carpenters is becoming more and more acute. On account of this the building costs have risen sharply. It is therefore necessary to explore possibilities of new building materials and construction techniques and also to reduce the

TRENDS OF MATERIAL PRICES

(BASE 1952–53 AS 100)



From N.B.O.

labour cost percentage in building operations by use of machinery, job simplification, standardisation etc. so as to be able to reduce the cost of the building and speedy completion of the work. For ratio of material and labour cost as obtained now please refer to Table No. 6.

PREFABRICATION - LIMITATIONS IN RELATION TO INDIA

The only solution to the acute shortage of housing stock is undertaking an ambitious programme of construction, fast enough not only to overcome the existing deficiency but also to cope up with the requirements due to increase in population and cheap enough to be undertaken within the limited resources. It is in this context that the feasibility of prefabrication shall be seen. A detailed study will reveal that the prefab technique requires a great deal of development in technical and industrial fields before it can be adopted to advantage. Besides practical difficulties sometimes this may be more costly than conventional construction at most places, where men and material are available in plenty. However its adoption on a limited scale, at inaccessible remote places where basic materials are not available, labour is in short supply and site conditions do not permit conventional construction, would be viable. Specific limitations are as under.

Table 6

(Refer to page 39)

COST BREAKDOWN (BUILDINGS)

Elements of a building	Item of work	Individual Items			Elements		
		Material %	Labour %	Total %	Material %	Labour %	Total %
1	2	3	4	5	6	7	8
(a) Excavation, Earth movement and foundation.	Excavation	0.04	0.31	0.35	5.08	2.16	7.24
	Concrete	2.62	0.65	3.27			
	Brickwork	1.96	0.96	2.92			
	Damproof course	0.46	0.24	0.70			
(b) Structure, walls, partitions and insulation.	Brickwork	10.24	5.04	15.28			
	RCC Sunshade Lintels etc.	2.04	1.09	3.13	12.28	6.13	18.41
(c) Roof	Concrete slab	3.26	2.17	5.43			
	Reinforcement	4.85	1.21	6.06	12.92	5.32	18.24
	Waterproofing	4.11	1.76	5.87			
	Rainwater pipes	0.70	0.18	0.88			
(d) Doors, Windows glass	Doors	5.55	3.70	9.25			
	Windows	6.45	4.30	10.75	12.00	8.00	20.00
(e) Finishing stucco	Plaster	4.35	2.90	7.25			
	White wash	0.38	0.50	0.80	5.14	3.61	8.75
	Painting	0.41	0.21	0.62			

Table 6 (contd.)

(Refer to page 39)

1	2	3	4	5	6	7	8
(f) **Floors:**							
(i) Structural floor	Concrete	3.26	2.18	5.41			
	Reinforcement	4.85	1.21	6.06	13.23	6.14	19.37
	Top Finish	1.57	1.05	2.62			
(ii) Ground floor	Sub-floor	1.98	0.65	2.63			
	Top finish	1.57	1.06	2.62	2.63	1.11	3.74
(g) Stairs	Concrete	1.06	0.71	1.77			
	Reinforcement	1.57	0.40	1.97			
(h) Fittings and Fixtures	Wardrobe	2.34	1.56	3.90			
	Cooking platform	0.24	0.11	0.35	2.58	1.67	4.25
					65.86	34.14	100.00

Source: Central Building Research Institute, Roorkee

Table 7

COST BREAKDOWN (SERVICES)

(Refer to page 39)

Desctiption	Item of work	Individual Item			Element		
		Material %	Labour %	Total %	Material %	Labour %	Total %
Installations for rain water, sewage and electricity	Sanitary	6.48	3.01	9.49			
	Water supply	3.18	1.31	4.49			
	Electrifications	5.69	3.80	9.49	16.57	8.43	25.00
	Path	1.22	0.31	1.53			

Source: Central Building Research Institute, Roorkee

*See N.B.O. Report of the Expert Committee on Methods for Achieving Low Cost Large Scale Housing Construction in Major Cities, tables VIII & IX.

High Initial Cost

A prefabrication method will require high initial investment in research, development and training of personnel for evolving suitable materials, equipment and manufacturing processes. In countries like ours this method can only be successful when industries are geared up in a big way for productionof components as required in terms of available materials and methods of construction. If mass production is resorted to, installations of big plants equipped with heavy machinery may pave the way.

Transportation

It accounts for a considerable part of cost in prefab construction and will require decentralisation of production by the establishment of number of plants all over the country. The size of such plants should be big enough to facilitate mass production economically. Location of plant and their sizes will have to be worked out based on factors like availability of materials and ease of transportation in a particular area.

Regional Planning

For the purpose of planning and establishing a network of such plants there must be a central body which can do such planning based on the present and future requirements on a regional basis to keep the plant going. The designer has little choice as he has to depend on the availability of prefab components in the market and the considerations of economy and suitability become secondary in importance.

Standardisation - Its Difficulties

First requirement to undertake the mass production of prefab components design will have to be standardised based on the availability of materials, site conditions and technical knowledge.

Suitable planning module will have to be adopted which shall enable standardisation of various types of quarters with different plinth areas to be properly planned beside affording economical design, easy handling and erection.

Other factors that effect the module sizes are the availability of building materials, their sizes, strength, quality, utility, life and cost. Also suitability to a construction method which is most economical in terms of labour, material, time and cost.

After the sizes of module have been decided not only standardisation in the industry will be achieved but also the cost of production may come down by mass production.

Economic Implications

The Government must announce its housing policy in terms of resources proposed to be made available. Such a programme will automatically give a boost to prefab production. Thus the industries in anticipation of demand can gear itself to the required extent.

As already stated it will prove economical only if mass production is done in big mechanised plants. Shift to such labour saving devices cannot be easily justified in a country where biggest problem is unemployment. The initial investment will be huge and the returns will not be adequate for quite sometime.

Span of Life*

The life span of prefab construction will be less than that of permanent construction of conventional type and more maintenance is required. Maintenance of prefab building will also present problems in regard to new techniques, requirement of skilled personnel of various types of trades, need for stocking in repair and maintenance store.

Other Problems

Prefab construction will give rise to a number of problems like thermal, acoustical and monotony which must be solved. The cladding material should provide reasonable thermal insulation and sound proofing. It should have resistance to water absorption, fire and attack from termite and fungus. Transportation capacity of roads and railway connecting the factory and site, capacity of erection equipment, like cranes and availability of lifting devices also has to be taken into consideration.

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*Deone, J. M. & J. N. Rastogi — Prefab Construction in Speed and Economy in Building Construction

WHEN PREFAB CONSTRUCTION SUITABLE

Non-Availability of Materials

This is the most important single factor in deciding the type of construction. If the basic materials like sand, stone, timber and water etc. are not available in sufficient quantity or suitable quality it will be easier and more economical to carry light weight prefab components than to carry the building materials.

Shortage of Labour

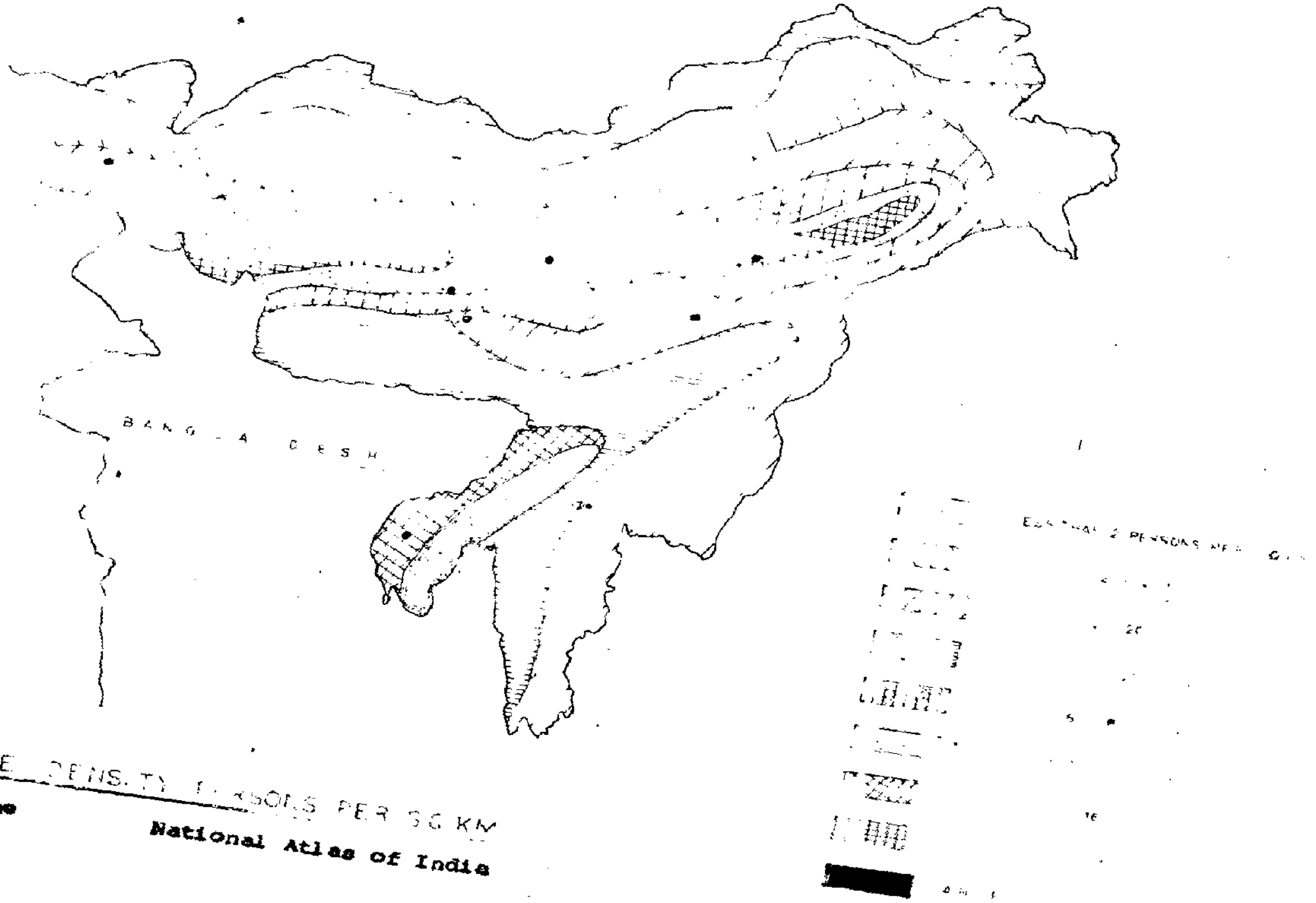
In thinly populated areas where skilled or unskilled labour is in short supply, adoption of conventional construction will be difficult, costlier and slower. In such cases prefab construction requiring minimum labour for erection may be economical.

Limitationof Time

Prefab construction is suitable where a work has to be completed within a specified period, which is not sufficient to complete by a conventional type of construction. This was the only condition why the prefabrication is preferred.

Duration for which Building Required

If certain buildings are required for short periods prefabricated buildings may be raised quickly and dismantled, after they are no longer



HABITABLE DENSITY PERSONS PER SQ KM

*See National Atlas of India

SCOPE OF ADOPTION OF PREFABRICATION

Economic Aspects

The traditional method of construction consists of craft based processes like masonry, carpentry and so on (for wages of building labour please refer to Table No. 8). These processes involve lesser investment in construction equipment and hence capital investment and provide employment to larger number of people and are therefore suited to the conditions prevailing in our country. Therefore, traditional materials and building techniques would continue to be of advantage in building low cost large scale housing projects.

*On the other hand Housing construction has been lagging considerably behind. "The public housing programmes of all Ministries, States, Public undertakings, local bodies etc. could barely provide about 8 lakh houses during the last 15 years. Reliable statistics of houses constructed during the above period in the private sector are not available. However, it has been estimated that this sector might have built about 2 lakh housing units per year. Thus the rate of new houses built comes to about 3.5 units per 1,000 population per annum, whereas in other countries, the new houses per 1,000 of population constructed are 5 to 10 houses - for example, in U.S.A. it is 6.5 units, in France 7.3; in Sweden 10.0; in USSR 10.3. The urban housing shortage has been increasing progressively because of low rate of house

*Expert Committee Report by NBO, New Delhi.

Table 8

(Refer to page 49)

WAGES OF BUILDING LABOUR

Sl No.	Description of Materials/Labour	Unit	RATE Rs. Bombay	Calcutta	Delhi	Madras	Ahmedabad	Kanpur	Gauhati
1.	Mason								
	1st Class	Each	15.00	7.50	9.25	8.50	12.00	8.00	8.00
	2nd Class	"	12.00		8.25		8.00	6.40	5.50
2.	Carpenter								
	1st Class	Each	15.00	7.50	10.00	8.50	12.00	8.00	8.00
	2nd Class	"	14.00		8.50		9.00	6.40	5.50
3.	Beldar	Each	4.00 to 5.00	4.00	3.50	3.50 to 4.00	3.50	3.20 to 3.50	3.00 2.50

Source: On the basis of data supplied by Zonal Office of Central PWD.

construction. The shortage was 28 lakh units in 1951. 93 lakhs in 1961 and estimated to be 119 lakhs at the beginning of Fourth Plan and by mid 1970, it was expected to be 124 lakhs."

In case of Defence* according to Shri Jagjivan Ram, Defence Minister, the sanction has been given for 4,904 houses for officers, 25,347, for other ranks and out of this only 1,641 houses for officers and 12,796 for other ranks has been completed. Therefore it has become a matter of urgency to build large number of houses economically at a faster rate in order to solve this huge problem.

It is also necessary to consider the adoption of non-traditional methods of construction like prefabrication.+* "Though initially the cost of establishment may be high with the successive rise in the cost of traditional building materials and labour wages, as we have been experiencing, at one stage these may break even in cost." Also with the development of prefabricated building methods suited to our conditions and fulfilment of pre-requisites for adoption of prefabrication, it would be possible to make prefab houses economical in years to come.

Reduction in Building Time**

"As regards speed in building indicative studies of some housing projects of four storeyed construction built by traditional methods have

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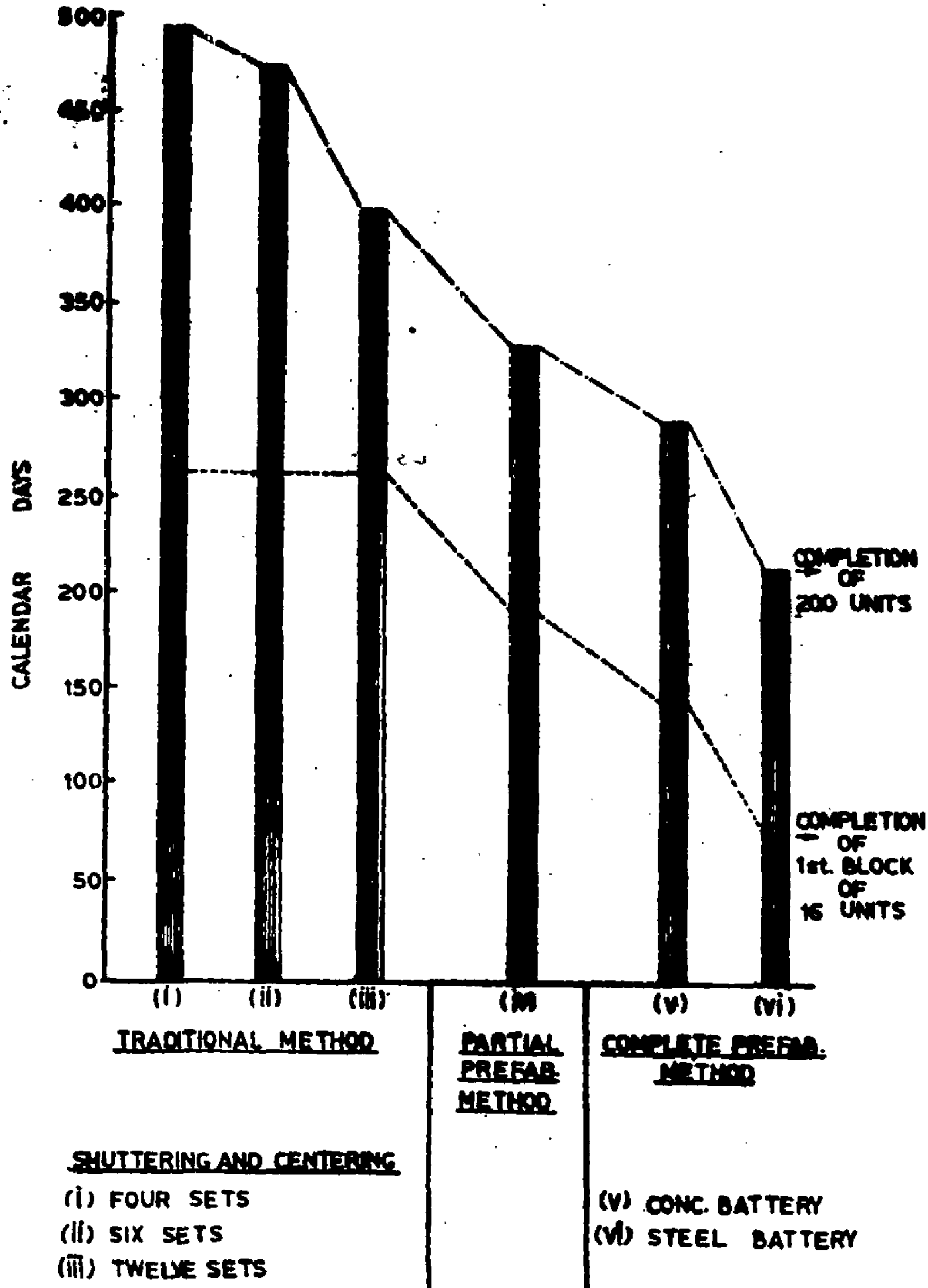
*Statement in Parliament

**Expert Committee Report by NBO, New Delhi.

+* Statement by Mr KG Salvi, Mg. Director, HHF, New Delhi.



ESTIMATED CONSTRUCTION TIME
FOR 200 L.I.G. UNITS WITH
DIFFERENT CONSTRUCTION METHODS

Table 9

(Refer to page 54)

ESTIMATED BUILDING TIME FOR 200 DWELLINGS IN FOUR-STOREYED CONSTRUCTION

With different construction methods: (i) Traditional, (ii) partially prefab, and (iii) Prefab Construction.

Method of construction	Time taken in building first batch of 16 units from start of work on site (days)	Time for completion of 200 houses from start of work on site. (days)	Rate of construction per house (days)	Percentage savings in time (E)	Remarks
1	2	3	4	5	6
1. Traditional Method (with in-situ bearing walls and in-situ RC slab)					For repetition and continuous deployment of gangs a block of 4 units has been considered and these proceed from block to block and floor to floor
(i) Twelve sets of shuttering and centering. (one for each block i.e. 4 uses)	263	400	2.08	-	
(ii) Six sets of shuttering and centering. (one set for two blocks i.e. 8 uses)	263	474	2.47	Base	
(iii) Four sets of shuttering and centering (one set for three blocks i.e. 12 uses).	263	496	2.58	-	

Table 9

(Refer to page 54)

1	2	3	4	5	6
2. <u>Partial Prefab Method</u> With in-situ bearing walls and precast flooring/ roofing components	192	330	1.71	30.37	All horizontal components viz. lintels, shelves, flooring units etc. precast.
3. <u>Complete Prefab Method</u> With on site battery cast large panels for walls and floors					
(i) Concrete battery	145	283	1.47	40.30	Battery formation after 98 calendar days
(ii) Steel battery	77	215	1.12	55.06	Battery formation after 30 calendar days

shown that the completion time of housing project could be reduced to about 40 per cent by adoption of prefabricated horizontal building components. As an exercise on the basis of critical path method of programming (CPM) of execution work, the expected time taken for building by (i) traditional method, (ii) partial prefabrication and (iii) full prefabrication is shown in dwg. plate. Therefore along with the rationalised traditional building methods the use of prefabricated building components particularly for flooring and roofing and large panel prefabricated construction should be considered for increasing the productivity, speed and economy in house construction.

Pre-requisites for Prefabrication

Unlike the traditional methods of construction, prefabricated building techniques cannot take off without accomplishment of essential prerequisites such as:

i. Long range programme of construction on mass scale.

ii. Standardisation and typification of building design, materials, specifications and codes of practices."

iii. To ensure optimum use of building materials like cement and steel through prefabrication and by avoiding wastage.

iv. Establishment of factories for producing building components and housing elements.

v. To ensure consumption of building components and housing elements on regular basis.

vi. "Availability of equipment for handling, transportation and hoisting of building components.

vii. Availability of required type of skilled workers and technicians for production, handling, transportation and erection work at site, of prefabricated building components for housing elements."

viii. Innovation of administration, organisation and management procedures.

ix. Continuous research and development work for evolving better building methods and training programmes for execution of works expeditiously and economically.

Progress Made So Far

"Prefabrication has been developed to some extent, in our country during the last decade. The Hindustan Housing Factory at New Delhi which is a Central Govt. undertaking and some other private firms have been engaged in the production of prefabricated building components and housing elements and have undertaken construction of prefabricated houses and other types of buildings."

The Central Building Research Institute, Roorkee and Structural Engineering Research Centre, Roorkee, have been conducting studies and investigations and have also undertaken experimental constructions. For example, CBRI, Roorkee has taken up the challenging task of constructing about 5000 primary school buildings all over U. P. as also

*See N.B.O. Report of the Expert Committee on Methods for Achieving Low Cost Large Scale Housing Construction in Major Cities, pp. 53-56.

industrial housing for labourers (by Hollo Pan System of construction) at Ghaziabad. Using prefabricated building components and housing elements, for flooring and roofing and hollow panels for walling and flooring. Under the experimental or demonstration schemes of the National Buildings Organisation, some housing projects have also been undertaken to introduce prefabrication in housing construction.

The scope of the study is to apprise the present position of prefabrication as applied in our country and adopted in Defence constructions with regard to building production system and includes study of building organisation and practical case studies of some existing prefabricated housing projects, for Defence personnel, which has been discussed in detail in the next Chapter and four more projects which are discussed and attached as Appendix A to D.

POSSIBILITY OF EXPLOITING LOCAL BUILDING MATERIALS

We have discussed in Chapter 2, about the local Building Materials and their use in urban and rural areas. Table 5 in Chapter 2 shows that materials which have been used maximum are grass, leaves, reeds or bamboos. These materials have been used extensively in both urban and rural areas for the construction of walls as well as roofs. Other materials which have been used are cement concrete, CGI sheets and the burnt bricks respectively. The structures made of these materials have been classified as the temporary to semi-permanent with life span varying from 1 to 5 years (Refer Chapter 1 type of construction). After this period the maintenance cost increases suddenly and the house is no more economical because of the heavy repairs to be done and recurring expenditure thereon. Some time after a span of 10 to 12 years we have an old structure but with all walls and roof replaced. The reason why these materials only are used frequently is number one the lack of building materials like cement and steel which are to be transported all the way from Bengal or from various distribution agencies in India. Even the burnt bricks are not available everywhere and except a few towns all other places have hardly used any bricks. Second reason is the economic conditions of the habitants. Over all the people are poor employed in agriculture or as labour.Thirdly the climatic conditions of the region is also responsible for not adopting the permanent type of construction as most of the areas are subjected to floods and therefore only suitable construction in these conditions become is what they are using being cheaper and faster in construction.

Now let us see why we should not accept the same materials for the construction in Defence and provide accommodation for men and materials. It has been already discussed in the Chapter 1 that these materials have been used extensively to provide accommodation on emergency basis of temporary or semi permanent nature. In plains except the new Cantonments or the Headquarters buildings, semi-permanent construction have been provided for stores or living (for specification refer Chapter 1). In hilly areas CGI sheets have been used to provide most of the accommodation.

All this accommodation is of temporary or semi-permanent nature and most of the materials have to be transported by roads in hilly areas. Therefore when it was decided that married accommodation for the officers and other ranks will be provided in these areas, it was taken into consideration that most of the materials have to be transported from the plains, permanent accommodation should be provided which was also required for the security point of view and sites should be so located which are easily accessible and local materials like sand, concrete, lime or water is available within the vicinity. Therefore finally prefabrication was found suitable method because good quality stone aggregates and sand are easily available. Only steel and cement have to be transported Also this provides the permanent type of construction faster to built.

CHAPTER 4

CASE STUDY - PREFAB HOUSING PROJECT AT TONGSA VALLEY

Field Marshal Manekshaw* said in 1973 January, the Army is changing fast and constantly adapting itself. The former Army Chief in whose mind things like housing and amenities for men and better equipment were uppermost said the target is to have adequate housing for the entire Army by 1980.

Field Marshal when he was Army Commander in the Eastern Command, initiated the idea of providing accommodation to the troops stationed in forward areas. NEFA was selected for this purpose and much of the preparatory work completed during his tenure as Army Commander. Later on when in June 1969, he took over as Chief of Army Staff sanction was accorded to provide married accommodation for a Mountain Division in Tongsa Valley.

First recce cum siting Board was held in August 1969 with the aims to assess a quick and practical means of construction, to provide married accommodation at Tongsa Valley in shortest possible time. The Board recommended construction of 1605 married quarters as under:

Officers	155
JCOs	180
Other Ranks	116+856+298

*Field Marshal Manekshaw's interview published in Sainik Samachar in January 1973.

In addition to this following civic amenities were also proposed.

i.	Schools	2
ii.	P&T office	1
iii.	Shopping centre	one at each of the 3 locations
iv.	Family welfare centre	-do-
v.	Bank	1

vi. Board also recommended the provision of

(a) security grills in all quarters

(b) fly proofing in all quarters

(c) Geyoers in officers quarters.

Following factors were taken into consideration by the Board to come to the conclusion about the type of construction to be adopted.

Location and Communication

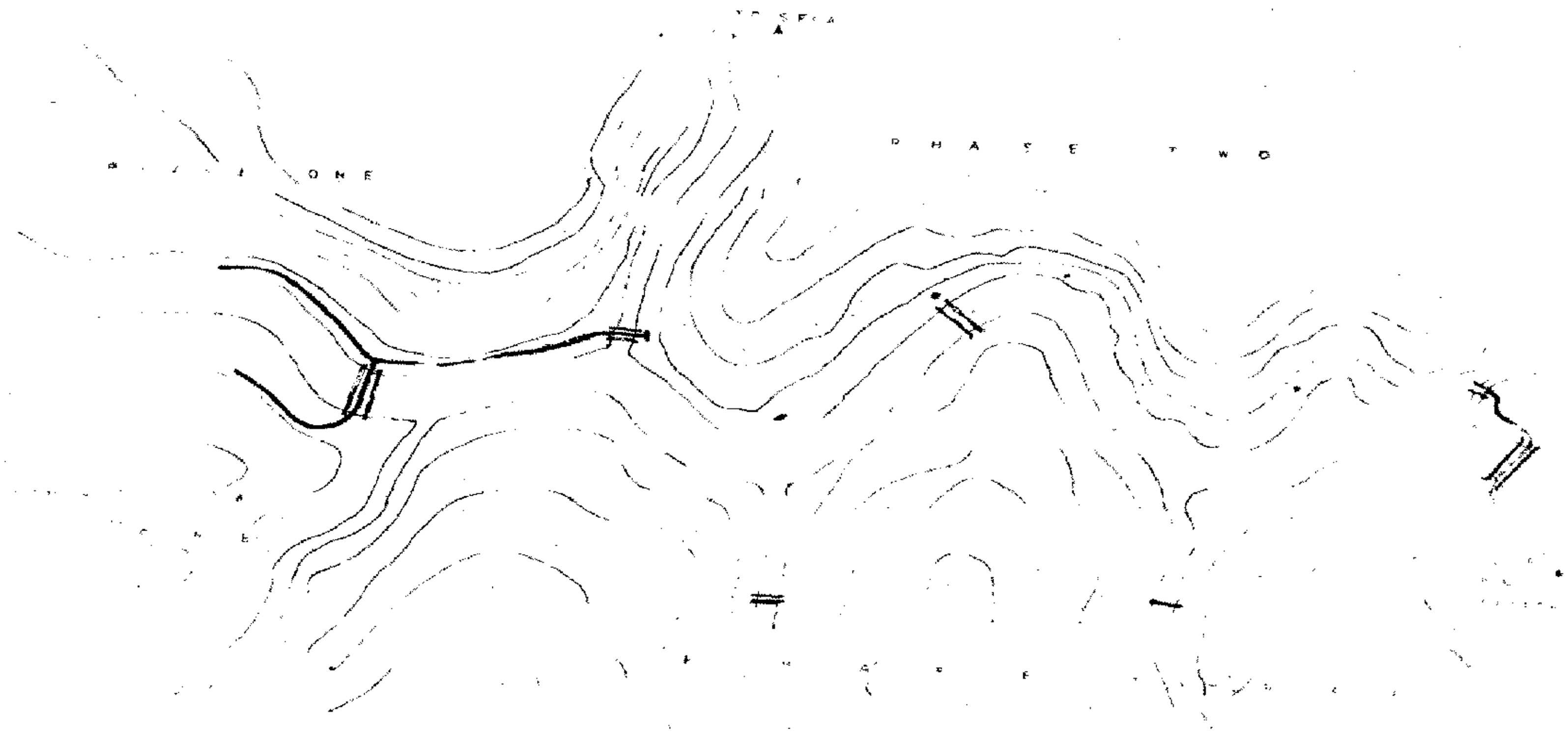
Tongsa valley is situated between KM 100 and KM 129 on the BALIPARA - BOMDILA road in NEFA. The road is class 9 single lane black top road being maintained by DGBR. The stretch of the road which bifurcates towards RUPA and GACHAM villages is looked after by the CPWD. Tongsa valley is being located at an average altitude of approx. 1400 metres above MSL, the valley has a temperate climate and annual rainfall of 200 CM. Nearest rail head is Rangapara North at a distance of approx. 130 km. No air communication exists except two helipads in the valley. The area being under NEFA administration entry to civilians is restricted by permits only. Road is susceptible to land slides and therefore frequent traffic interruptions.

Topography

Valley stretches along river Tongsa for a distance of 20 km with steep mountain slopes on either side. General topography is Mountainous terrain with limited areas of buildable land separated by nullahas and steep mountains, Limited areas of natural terraces on hill tops and sides are also available in valley. Therefore only ribbon type development was possible and resorted to. (see site plan).

Land

Feasibility of locating accommodation for a full mountain division both married and other than married was examined and was found that available land was only 1200 acres as against authorised requirement of approx. 5000 acres, calculated on the standards laid down in the "Manual of Cantonment Planning". If planned in normal KLP standards this area was adequate to accommodate one Brigade and Div. troops. Therefore it was decided to provide married accommodation to the extent of 40%. This has been zoned in various areas segregated from each other due to non-availability of continuous buildable land, it was also decided to provide double storey construction.



SITE PLAN TONGSA VALLEY PROJECT

Local Materials and Labour

Adequate stone boulders are available in the bed of river Tongsa suitable for construction purposes. Sand and pine timber are also locally available. Good quality timber, cement, steel and other building materials are to be transported from plains of Assam. No skilled labour is locally available. Limited number of unskilled labour are available from near by villages.

Water Supply

The main sources of water are river Tongsa and some smaller mountain streams. The discharge from these sources has been observed reliable in the past, and water has been found suitable by medical authorities for consumption after treatment and chlorination.

Roads

Due to mountainous terrain and steep hill side slopes construction of approach roads have been planned keeping in view the permissible gradients and curves. Single lane class 9 black top approach roads are commensurate with the main trunk road running through the valley.

Bridges

At present the river is spanned by a number of suspension/Bailey/Hamilton bridges along the entire length of the valley. For future a class 9 bridge and one foot bridge has been proposed and work for these will commence only after the completion of all the work.

In view of the above and the time it was decided to have double storey construction due to paucity of enough land. For the first time in this area, it was decided to have prefab construction cost for the whole project was estimated to the tune of Rs 11.55 crores in 1969 which is expected to increase to Rs 14 crores.

DESIGN CONCEPT

After it was decided that prefabrication system will be adopted to provide married accommodation. Prototypes were constructed in Calcutta to decide which particular system should be adopted for the construction.

The factors which influenced the design of prototype houses were to meet the needs of the users and their way of life and also location, site conditions, climate and environment. Therefore the houses were designed by utilising different types of materials to test their adaptability to the above requirements.

In order to determine planning module, a superstructure concept, capable of adopting the module dimension in a labour, material, time and cost saving construction, method was evolved with due emphasis on the suitability of easy transportation of the component parts. In prefabricated construction basic elements of superstructure turn out to be (i) the framing, (ii) the cladding system. Each part is to be industrially manufactured and assembled at site with minimum labour.

Each component of the superstructure had to be designed individually to fit into the overall concept of the system to form the three dimensional mass that was to be functionally convenient, structurally sound and aesthetically beautiful.

Finally the system adopted was based on a concept what it is known as "Match Stick Concept". In this system, framing and cladding components had been combined in a system consisting of load bearing RCC frames, supporting precast roof troughs capable of taking care of all structural, thermal and acoustical problems partially involving in-situ wet construction. Having decided the system whose main components to be prefabricated were load bearing frames roof troughs, beams and stairs. With precasting of these components in view planning module had to be arrived at, such that it could be fitted in various types of quarters with different plinth areas. Following were mainly three factors kept in mind while developing the module.

Economic Design*

"The size, strength and quality of materials manufactured in the country act as a restraint on the designers for evolving a planning module. Either the industry should come forward to gear its production to the requirement of the designer or the designer has to accept

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*See Brig. Tolani, J. M.; and H. K. Rakhra — Planning and Architecture of Prefabricated Housing in Symposium on Prefabricated Housing uneconomic non standard modules. Depending upon superstructure concept and the materials to be used, the design module has to be multiple or fraction of planning module. The designer therefore has to do an exercise to arrive at the most economical and workable planning module. The module has to be versatile for adoption in various types of houses. The module has to be such as to fit in all positions."

This particular system was given the name "Match Stick" because when frames put together look like as the structure is made of thin sticks like match sticks (see photograph). There are three precast members in the design. One is load bearing RCC wall frame, the other one is collar beam and the third one is the roof troughs.

Wall Frame

As the ceiling height acceptable was 275 cm planning module of 275 cm x 145 cm was found to be most economical. Instead of having a solid panel, to keep the weight of the panel to the minimum 70% of this was kept hollow. The idea was that firstly it will be much easier to carry it manually, secondly it will save more material and thirdly that any type of cladding could be provided depending upon the requirement at particular locations. The frame has mainly three structural components, two verticals acting as compression members and one top horizontal acting as tension members for transferring load to to the verticals. These are clearly shown in the photographs.

Flooring

Ground floor:	PCC Floor with cement finish
First floor:	Cement finish of screed on top of RCC precast floor troughs with cement skirting.
Roof:	Lime terracing on precast RCC troughs.

Sanitary Fittings

On account of roof trough being only 2" thick there was a problem of sinking the floor for sanitary fittings. These are projecting out and are visible from ground floor bath and lavatories. These are however concealed by providing false ceiling.

Windows

Steel windows have been used. Special door frames or windows frames have been prefabricated.

Doors

Commercial shuttering on steel angle frames have been used.

GENERAL DESCRIPTION

Match stick concept has been adopted for all types of residential accommodation varying from officers quarters to the non-combatants enrolled. Scale of accommodation have already been discussed in first chapter. For officers accommodation cement hollow blocks have been used as infill material for wall panels, while for all other types of accommodation lath plaster over chicken wire mesh have been used. Site wise break up of accommodation in three phases are as under:

Phase I	Officers	46
	JCOs	64
	Others	672
Phase II	Officers	109
	JCOs	72
	Others	358
Phase III	JCOs	44
	Others	410

Accommodation for officers have been sited in compact groups, while for JCO, NCO, ORs and NCE, it is near to their work sites and compact groups.

The construction finally started in 1971 and it was decided that work will be completed in three phases, it has already since been mentioned that the sites were segregated by some distances. Also the construction will be done by the Border Roads Organisation skilled labours from all units were posted to the new office set up to execute the work. Unskilled labour was provided by corps of pioneers, and the gorkhas and bhutias who were taken to the sites.

There were many problems which were faced before the work commenced. First of these was procurement of steel from Calcutta and its transportation to the working site. Contracts were finalised by used as infill material for wall panels, while for all other types of accommodation lath plaster over chicken wire mesh have been used. Site wise break up of accommodation in three phases are as under:

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There were many problems which were faced before the work commenced. First of these was procurement of steel from Calcutta and its transportation to the working site. Contracts were finalised by the office with the firms to supply steel at the rail head North Rangapara. Responsibility to transport the steel upto the North Rangapara was of firms, while from North Rangapara to the working site it was the responsibility of the executing agency. For this also the contract was given to the civilians and there were no problems on this account. Because of 1971 war with Pakistan another difficulty arose and this was of Railway wagons. Therefore the bulk of the steel required was transported by road transport. This system incidentally proved much more efficient as it took only 48 hours from Calcutta to North Rangapara while by rail the transportation time taken was more than double. For supply of cement there was no problem and it was always sufficient to meet the requirements.

Another problem was of establishing factory sites or casting yards. As already discussed that the sites were at different places and the distance involved was more to meet the demand of transporting each and every component from one centralized factory. There was also loss of manpower in loading and unloading and chances of more breakages. Therefore the proposal to have a centralise factory was completely ruled out. It was decided to have two casting yards one for the phase one which has bulk of the accommodation and the other for phase two and three combined.

Next problem that came across when it was decided to use some of Tongsa hydel project.

Electric wiring in all quarters is of concealed conduit type and all fittings and fixtures are of superior quality.

For sewage disposal no central integrated disposal system was possible due to the mountaneous terrain and varying altitudes. Therefore septic tanks have been provided for groups of buildings. Effluent from these tanks is disposed of through filter beds, in the river,

Adequate surface drain in the built up areas and along roads have been provided. Network of roads for the complete project have been completed earlier because this is of great advantage to carry the building stores from casting yard to the working sites.

As the accommodation has been provided on both the sides of the river about five bridges have been constructed which in the long run will be replaced by two or three permanent bridges.

Various stages of construction, casting yard and the components is shown in the photographs which are self explanatory.

DESIGN CRITERIA*

"The design is based on the double storey construction with 275 cm ceiling height. The main governing factor which was kept in mind, was that the size and weight of each component should be such that it is easy for handling and erection. The weight has to be minimised

---

*Maj. Gen. Soni, K. C. & Brig. J. M. Tolani — Prefabricated Low Cost Housing in Symposium on Prefabricated Housing while designing. The following were the design specifications:

- Dead load from double storey construction.
- Live load of 200 kg/m^2 on the floors and 25 kg/m^2 for roofs.
- Wind pressure 150 kg/m^2
- Seismic coefficient 0.089
- Temperature variation 40°F to 95°F
- Rainfall 100 cm or more
- The concrete used for the design is M 150 (1:2:4) and reinforcement provided is of MS round bars.

Permissible stresses as per IS 456-1964

Direct compression	=	950 lbs/sq. in. 40 kg/cm^2
Bending compression	=	700 lbs/sq. in. 30 kg/cm^2
Tension in steel	=	20,000 lb/sq. in. 1400 kg/cm^2

Design Calculations

Loading

Self weight of trough	=	146 kg/m^2
Roof covering/floor finish	=	82 kg/m^2
Live load	=	200 kg/m^2
Total load	=	428 kg/m^2

Trough

Load per panel width (roof trough)

$= 428 \times 0.50 \times 3.05$

$= 655$ kg

$$BM = \frac{655 \times 305}{8} = 2,5000 \text{ kg cm } (21,800 \text{ lb. inch})$$

$$d \text{ required} = \sqrt{\frac{21,800}{138 \times 20}}$$

$$= 2.75 = 7.1 \text{ cm}$$

D provided = 12 cm

d = 12-2.5 = 9.5 safe

$$At = \frac{25000}{1400 \times .87 \times 9.50} = 2.16 \text{ cm}^2$$

Provide 2 no. 12 mm dia bars giving A_s = 2.26 cm^2

and use 3 no. 6 mm dia bars at top for binding purposes.

5 mm stirrups are provided at 15 cm c/c as shown in drawing.

Stair Case Roof Trough

Loading for slab will be the same as per roof trough. Span is reduced to 208 cm. Other dimensions of trough remain the same.

$W = 428 \times 0.5 \times 2.08$

$= 446$ kg

$$BM = \frac{446 \times 208}{8} = 11600 \text{ kg cm}$$

$$At = \frac{11600}{1400 \times .87 \times 9.5} = 1.01 \text{ cm}^2$$

∴ Provide 2 nos. 10 mm dia min bars,

3 nos. 6 mm dia at top as binders

6 mm dia stirrups at 15 cm c/c.

Collar Beam

Load transferred by each leg of trough = 164 kg

Area of contact between collar beam and trough

= 5 x 8.75 = 43.75 sq cm.

Punching area = 5 x 8.75 = 43.75 sq cm.

Allowable compression stress = 40 kg cm^2

.'. Total load = 40 x 43.75 sq cm.

= 174.0 kg safe

Reinforcement has been provided as shown in drawing

Wall Panel Top Beam

Span = 150 cm

Concentrated load of the trough
at 1/3 point = 2 x 164 = 328 kg

BM at centre = 328x75 - 328 x 25

= 16400 kg cm

UDL due to self weight of collar beam = 0.82 kg/cm

$$BM = \frac{0.8 \times (150)^2}{10} = 1800 \text{ kg cm}$$

Total BM = 16400 + 1800 = 18200

= 15900 lbs in.

$$d = \sqrt{\frac{15900}{138x6}} = 4.396 \text{ in. say } 11.2 \text{ cm}$$

D provided = 15 cm

.'. and d = 15 - 2.5 = 12.5 safe

$$At = \frac{18200}{1400 \times 87 \times 12.5} = 1.2 \ cm^2$$

Use 2 nos. 10 mm dia bars

Shear force =328 + 60

= 388 kg

$$\text{Shear stress} = \frac{388}{15 \times 10.0} = 2.84 \ kg/cm^2$$

= 37.6 psi.

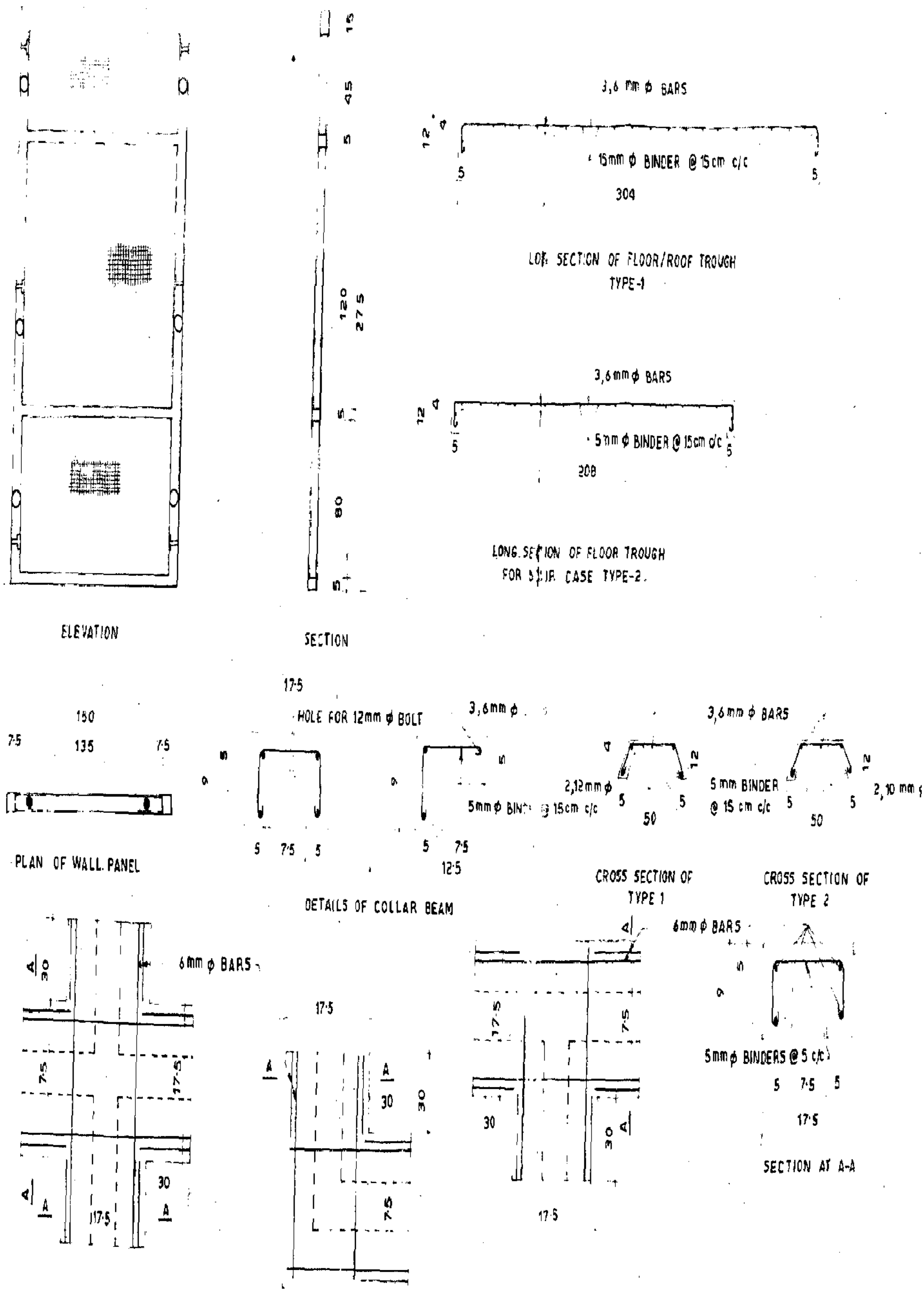
This is less than 75 psi therefore Safe.

Wall Panel Column

Loading

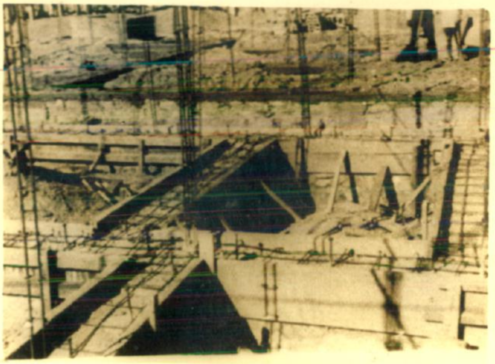
End reaction of the trough = 328 x 3/2 + 0.8 x 75	= 552 kg
Self weight	= 204 kg
Wall load	= 21 kg
Load from cross beams	= 68 kg
	845 kg

Section adopted is 7.5 x 7.5 cm and provided 4 nos 12 mm dia main bars and stirrups 3 mm dia at 15 cm c/c. Safe load for this section is much more than load coming over this."

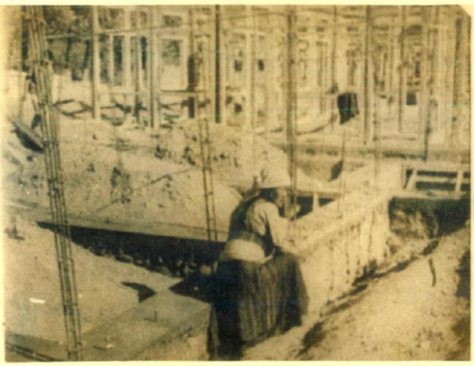


DETAILS OF CAST-IN-SITU JUNCTIONS FOR COLLAR BEAM

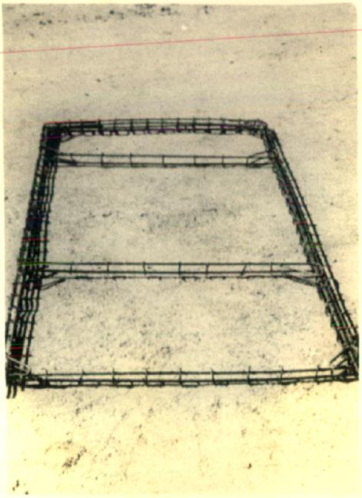
SCALE - 1:20



PLINTH BEAM READY FOR CASTING OVER PLINTH

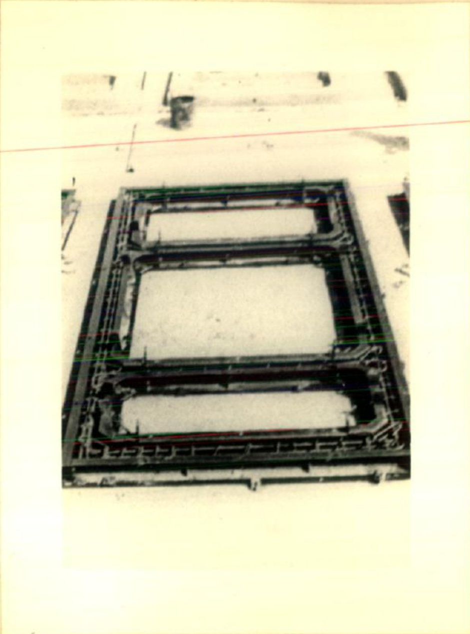


PLINTH BEAM CASTING COMPLETED. PLINTH OF GROUND FLOOR CAN BE SEEN ERECTED AT FAR END.

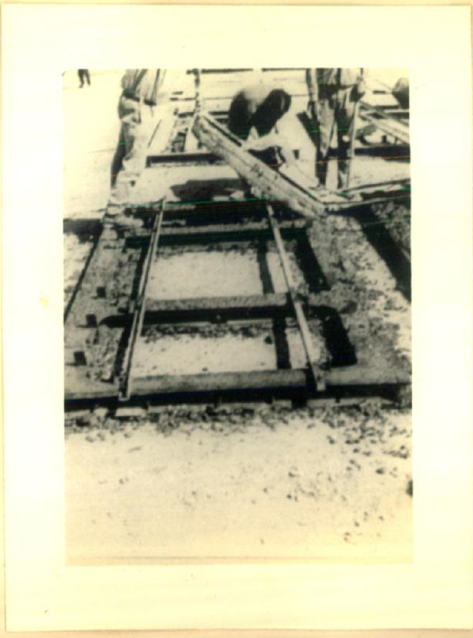


VIEW OF STEEL REINFORCEMENT FOR PANEL

STEEL MOULDS FOR PANELS UNDER ASSEMBLY

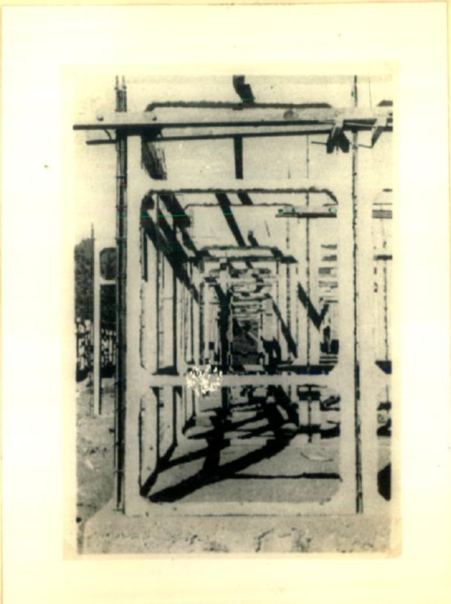


REINFORCEMENT PLACED IN STEEL MOULD



CASTING OF PANEL IN PROGRESS EXTERNAL
VIBRATOR IN USE

PANEL REMOVED FROM MOULD AFTER 24 HRS FOR CURING. THE BASE PLATE (SEEM ABOVE) WILL BE REMOVED HOWEVER ONLY AFTER 48 HRS



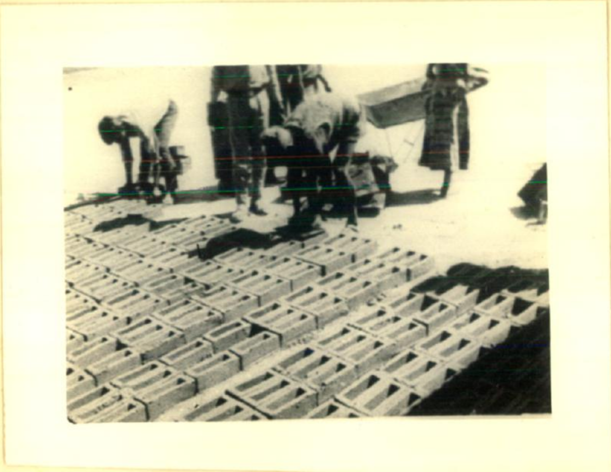
PANELS OF GROUND FLOOR ERECTED AND ALIGNED. GAPS BETWEEN PANELS ARE THEN CAST-IN-SITU.

FIRST FLOOR PANELS AND COLLAR BEAMSERECTED AND ALL CAST-IN-SITU WORK COMLETED

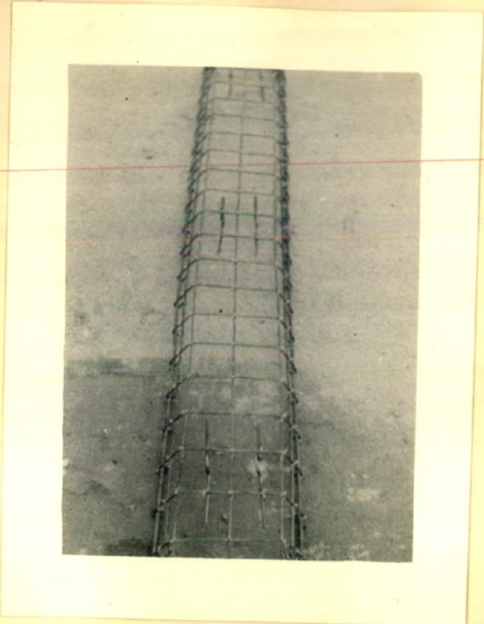
FOREGROUND SHOWS DOUBLE STOREY FRAME WORK READY FOR LATHPLASTER/ HOLLOW BLOCK MASONRY. NOTICE THAT THE FRAME WORK APPEEARS LIKE MATCHTICK HENCE THE NAME OF "MATCHTICK DESIGN OF PREPABRICATED CONSTRUCTION".

13

14. CEMENT HOLLOW BLOCK CAST OVER PLATFORM VIBRATOR

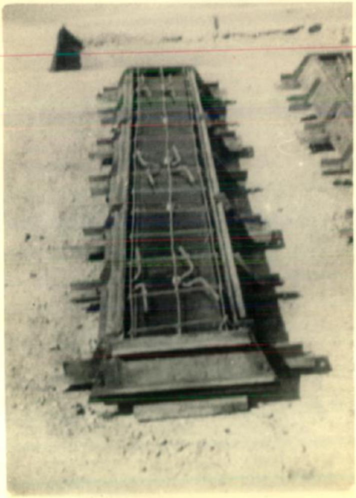


15. HOLLOW BLOCK LAID FOR CURING. TWO SETS OF MOULD CAN BE SEEN BEING STRUCK OFF FROM THE HOLLOW BLOCKS

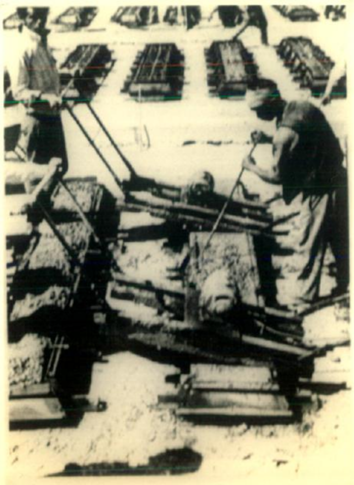


VIEW OF STEEL REINFORCEMENT FOR TROUGH

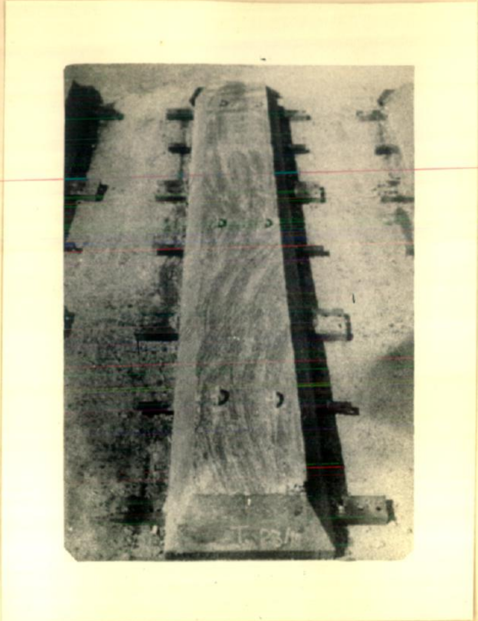
TROUGH REINFORCEMENT PLACED IN STEEL MOULDS



TROUGH READY FOR CASTING



CASTING OF TROUGH IN PROGRESS (EXTERNAL VIBRATOR IN USE)



19

TROUGH REMOVED FORM MOULD AFTER 24 HOURS OF CURING. THE BASE PLATE (SEEN ABOVE) WILL BE REMOVED HOWEVER ONLY AFTER 43 HOURS

VIEW OF VARIOUS STAGES OF LATH PLASTER AS AN ALTERNATIVE TO HOLLOW BLOCK INFILL.

VIEW SHOWING WALL PANELS COMPLETED WITH INFILL MATERIAL OF CEMENT HOLLOW BLOCKS. WINDOW/VERANDAH CHAJJAS CAST-IN-SITU CAN ALSO BE SEEN.

EXTERNAL CEMENT PLASTER COMPLETED. BUILDING READY FOR LIMB COLOUR WASH

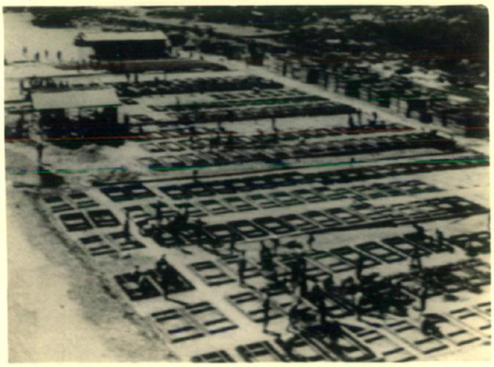
23

CLOSE UP VIEW JCO'S QUARTERS

VISIT TO THE JCO'S QUARTERS
(VIEW SHOWN OF ONE BLOCK OF 4 JCO'S QUARTERS)

25

CLOSE UP VIEW OF COMPLETED OR QUARTERS (BLOCK OF 8)



PANORAMIC VIEW OF PANEL CASTING YARD

27

VIEW OF TROUH CASTING YARD

VIEW OF COLLAR BEAM CASTING YARD

CHAPTER 5

PROPOSED DESIGN APPROACH

DIMENSIONAL AND MODULAR COORDINATION

Since every building involves the assembly of materials of various sizes, dimensional coordination between the materials is a basic necessity to achieve smooth work without delay and wasteful cutting of materials. There are essentially three aspects of dimensional coordination namely as under:

i. The choice of basic modular of which the materials dimension should be a multiple.

ii. The choice of a preferred series of such multiples of the modular from which the sizes of building materials could be selected.

iii. The choice of the correct limits and tolerances to achieve the best efficiency.

*"Dimensional coordination can be defined as the establishment of a range of related dimensions for common use in planning the sizes of components and buildings. It is a tool in the hands of architects and engineers for arriving at suitable dimensions in building so as to reduce the types of building components which can be used without alterations in the construction of a building. Dimensional coordination must allow the architect enough flexibility, in planning, at the same time,

"the types of components should be as few as possible.

*Modular coordination is a form of dimensional coordination using a basic module. A basic module of 10 cm has been agreed upon internationally, designated as M. However, for planning a building, the basic module is too small a dimension. Hence, normally a multi-module, which is a multiple of the basic module, is adopted as the planning module.

Application of the principles of modular coordination by itself may not result in full economy and desired efficiency. In order to achieve this fully, reduction in the variety, even of those components and units made to modular sizes, has to be done. This leads to the question of standardization by the selection of preferred dimensions. A preferred dimension may be defined as a modular dimension adopted for planning of buildings and their components, which permits considerable reduction in the number of standard sizes of building components. It is preferred multiple of the basic module."

Considerable study has been made on dimensional coordination with regard to the Building industry in USA, U.K., USSR and other countries. Along with dimensional coordination arises the study of dimensional tolerances of various building materials, their relation to one another and to the workmanship and assembly tolerances. This is essentially a mutual agreement between those who manufacture building

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*Dr. Chetty, S. M. K. & M. P. Jaisingh — Modular Coordination in Building in Symposium on Standardization in Construction of Buildings components and those who design buildings. On the one hand the manufacturers of components and system want the variety of sizes to be limited so that they can obtain advantage from bulk production and so that they are encouraged to invest in plant, machinery and management. On the other hand the designers of building need to be assured that the sizes chosen will give them enough flexibility in design to meet the user requirements of their clients in planning and to allow them enough freedom of choice in materials.

Work done to promote and implement
modular coordination

To promote and implement standardisation and modular coordination in the building industry a Seminar was organised by NBO with the help of United Nations expert team in 1969, under the sponsorship of ECAFE. Many useful recommendations were made by the Seminar in which architects, engineers and planners from all over the country participated. A National Modular Group has been set up for implementation of standardisation and modular coordination. The Indian Standards Institution has also brought out standards on modular planning which deal not only with specified sizes of building materials but also with the planning and layouts of buildings on the basis of modular grid, dimensions of room and storey heights, sizes of doors and windows, spacing of columns etc. These are as under:

i. Recommendations for Modular Coordination of dimensions in the Building Industry, IS 1233-1958.

ii. Recommendations for Modular Coordination applied to RCC Framed Structure IS 2375-1963.

iii. Recommendations for preferred Dimensions for storey height IS 2718-1964.

The first standard lays down the size of the basic module as 10 cm to be used for the purpose of dimensional coordination and a planning module as 100 cm to be adopted wherever possible and convenient.

It lays down a clearance of 2.5 cm to be provided for fitting door and windows into position.

It gives the system of tolerances and the assembly of components and a terminology on Modular Coordination for design, manufacture of components and construction.

The second standard gives the method of general setting out of columns and beams and cross-sectional dimension of columns, beams slabs and braces. The preferred range of cross-sectional dimensions for beams and slabs is given as 10 cm, thereafter 5 cm upto 60 cm and thereafter in multiples of 10 cm. In the column height, the range is given as 10 cm, thereafter 5 cm upto 60 cm and then 10 cm.

The third standard gives definitions of storey height, room height, floor finish etc. and gives a preferred range of dimensions for storey heights ranging from 2.60 (mainly for residential buildings) to 53.80With an increment of 20 M. It however lays down that wherever practicable, the storey height, the room height and the height of the floor thickness plus the thickness of floor finish should be in multiple of the basic module of 10 cm. The tolerance for the actual storey height is given as 10 cm.

Over and above the three standards described above the ISI has given the modular dimensions of principal building materials as follows:

Building bricks	Modular dimension	Work dimension
(IS 1077-1957)	20x10x10 cm	19x9x9 cm
	20x10x5 cm	19x9x4 cm
Stone		
(IS 1128-1957)	20x20x20x20 cm	19x19x19 cm
	40x20x or 30x20 cm	39x19 or 29x19 cm
	150x150x5 cm	149.5x149.5x5 cm
Tiles		
(IS 1037)	20x20 cm	19.85x19.85 cm
	30x30 cm	29.85x29.85 cm
Metal doors & windows		
(IS 1038-1957)	210x10 cm	207.5x57.5 cm
	90x60 cm	37.5x57.5 cm
Timber doors & windows		
(IS 1003-1957)	190x80 cm	187.6x77.5 cm
	210x90 cm	207.5x87.5 cm

Possible economy in building industry

A need for some simplification of both, planning and building methods to avoid waste of time and material which is very common in the building industry everywhere, perhaps much more in our country is very much recognised now.

*Studies and actual trials have proved economical in the following beyond doubt.

i. Drafting time

The saving in amount of time in drafting and preparation of detailed drawings could be seen from the experiment carried out, where the number of sheets of drawings for steel work in the case of a school building based on the use of steel frame was reduced from 114 sheets to 33 sheets only for component parts, when modular scheme was introduced, further it also showed that each school required only one general layout drawing and only 41 sheets of steel work drawings were adequate for 8 schools although layout varied considerably.

ii. Waste of Materials

Though there are no precise figures available it is accepted that a general practice is to over order materials to the extent of 10 to 15% to allow for wastage. It was found in a study carried out on plaster boards required to line walls of a three bed rooms house that

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*Lt. Gen. Williams, H. Paper on Modular and Dimensional Coordination in Building Industry the requirements varied by as much as 350 sft for a house. In modular system the sizes of walls and sheets being coordinated such a big variation would not occur.

iii. Cutting and fitting of materials

Studies by the Ministry of Works have shown that a large amount of time is spent on cutting and fitting materials on the site. The following figures give times relating to some materials used in construction of semidetached house.

	Per cent
Brickwork	05 to 15
Partition block	19 to 21
Timber work	11 to 45
Boards, CGI sheets	31 to 37

*Studies on modular brickwork in CBRI have shown that the use of modular bricks would give an increase of output by about 21.4 %. Saving in mortar by 26.6% and in masonry by 11.1%.

The use of modular bricks alone, in building project of Bharat Heavy Electricals at Hardwar gave a proved economy of 2.5% to 4% in floor space, 10% in the consumption of bricks. The question of economy in time labour and materials in case of modular coordination thus appears to be beyond any doubt.

Essential Requirements for Implementation of MC

For the effective implementation of modular coordination in the

*Information supplied by Shri Narendra Varma during discussion building industry it is essential to lay down National Standards wherever necessary and sort out important problems effecting various aspects. Following are the two important requirements:

i. Emperical studies of most frequent used sizes of various components and to select range or ranges of sizes of existing components.

ii. To design detail and construct full scale experimental building based on modular coordination system.

It is also necessary to arrive at a reasonable understanding and agreement on the following;

i. The size of the module. - basic and planning.

ii. The size of submodule measures.

iii. Range of sizes of components

iv. Sizes of joints and their type design.

v. Preferred increments for components, structural members and space requirements.

vi. Tolerances for manufacturing, location and fitting requirements.

CHOICE OF PLANNING MODULE

As already mentioned, choice of basic module is aimed at simplifying the system of measurement that would ultimate by coordinate economically and functionally all the process like production, design and assembly. However because of diversified requirements of these processes one value cannot serve all the purposes. Basic module either becomes large or small for one requirement or the other. For this reason it is necessary to evolve a series or different series for diversified requirements. These series will be as a rule, based on the basic module and will bear a simple mathematical relation with it.

Main aim of preferred sizes to reduce the variety of sizes of components. They should aim at simplifying process of standardisation of components. They should help reduce the minimum range of sizes of components.

This is achieved with basic module itself. Basic module puts certain limitations on number of different sizes, as any coordinating dimension has to be always multiples of basic module. But from production point of view, no building component can be made economical in all the multiples of basic module. Hence number of different sizes must further be reduced.

Preferred Sizes and Industrial Production

As already mentioned, it is never economical to produce the sizes of components in all multiples of Basic module. Hence for manufacturers, it is necessary to have additional dimensional guide (nxM) to provide certain range of sizes for components. Especially in case of "large single components" (single components are large components performing one or more functions, for instance room size floor slab and room height wall panel), modular sizes to be met have got to be restricted. Thus this dimensional guide (nxM) becomes multi modular which as a rule is based on basic module. Multimodule of 3 m and 6 m are commonly used. However 6 M module is useful where rigid standardisation is suitable.

For walls and slab thicknesses, cross section of columns and beams or partition walls etc. '10 cm' or '1 M' increment becomes large. Next increment of 10 cm will be 20 cm. Whereas slab thickness or wall thickness may have to be 12 cm or 15 cm or even less than 10 cm. For this reason a fraction of basic module is chosen. Different sub-modules that are very useful are 1 cm or 2.5 cm or .1 M or .25M. These have been adopted widely for planning purposes.

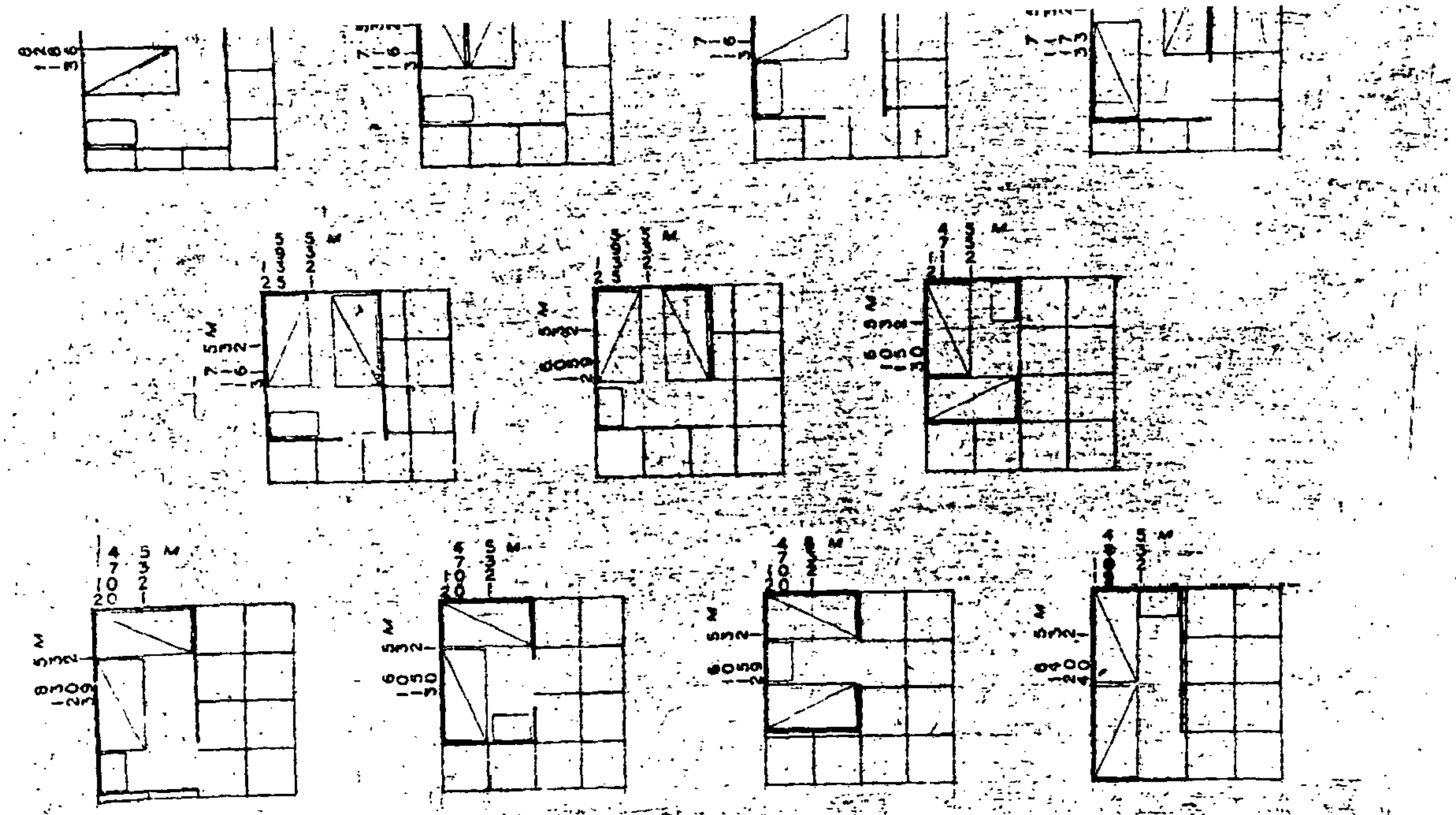
For meeting the functional requirements to reduce the size variation of components to coordinate and economise the production of components, multimodule should be chosen for planning of houses. It is very important that in the planning of houses, dimensions of human body provides basic dimensions for planning. Many functional requirements, space for various activities are based on dimension of human body. Based on this, certain number of common and coordinating dimensions can be established. Thus even by standardising certain dimensions based on basic module flexibility can be achieved which is very important in residential buildings.

As mentioned above there are many variants or variables governing choice. Architect is free to choose with proper analyais of all factors, any planning module which is based on basic module and is found more economical.

Effective planning demands maximum utilisation of spaces consonant with the pattern of living. Internal planning and arrangements are extremely vital for space economy. In view of this few typical arrangements have been developed. These arrangements cover for the minimum, optimum and liberal provisions of areas. The space requirements based on the functional needs have been considered to provide for all essential activities, which are, as under:

Sleeping areas
Living and Dining
Kitchen
Toilet

Different arrangements for these activities have been shown in the drawing plates. The dimensions for all these activities are in terms of 1 M, 2 M, 3M and 5M module. These figures form the basis of arriving at the final dimensional study. This study shows that while 5M module has been used maximum in various activities the 2M module has the minimum repetition. But in two cases 2M module has more flexibility. It gives us more freedom during design while 5M module gives us more rigidity. Therefore we have to come to the compromise

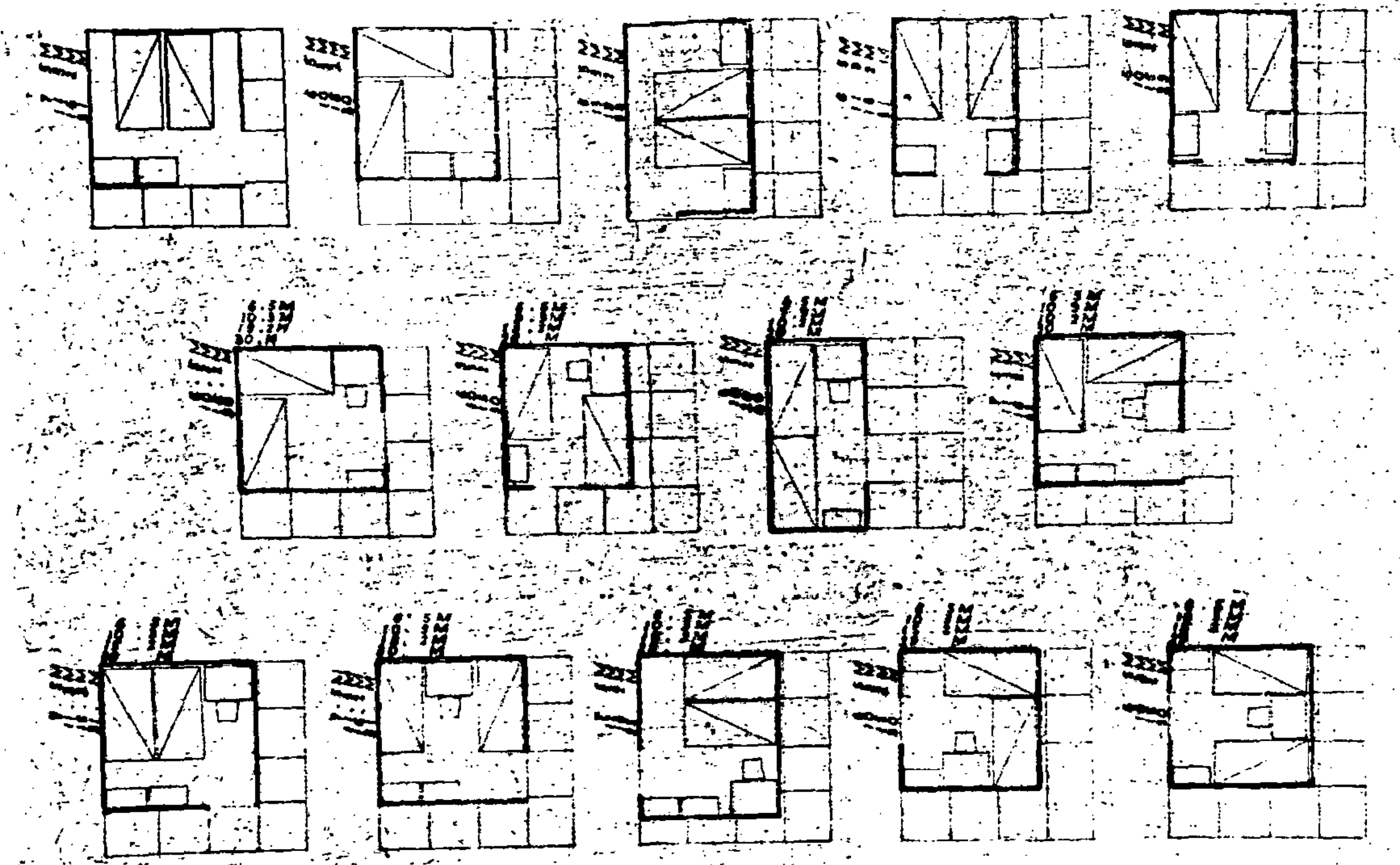


SPACE STUDY

sleeping areas

BNP

1



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SPACE STUDY

sleeping areas

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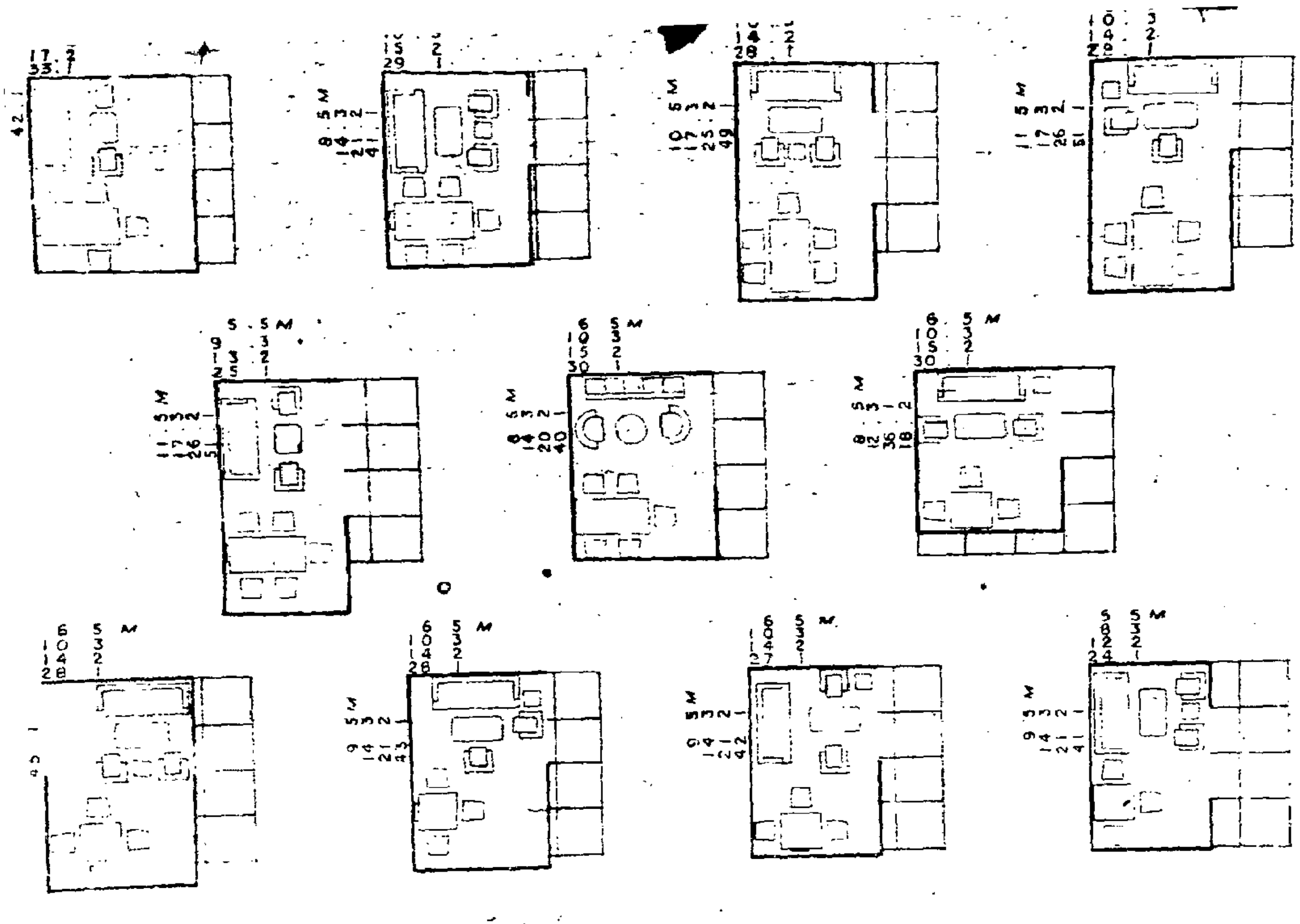

SPACE STUDY

living and dinning

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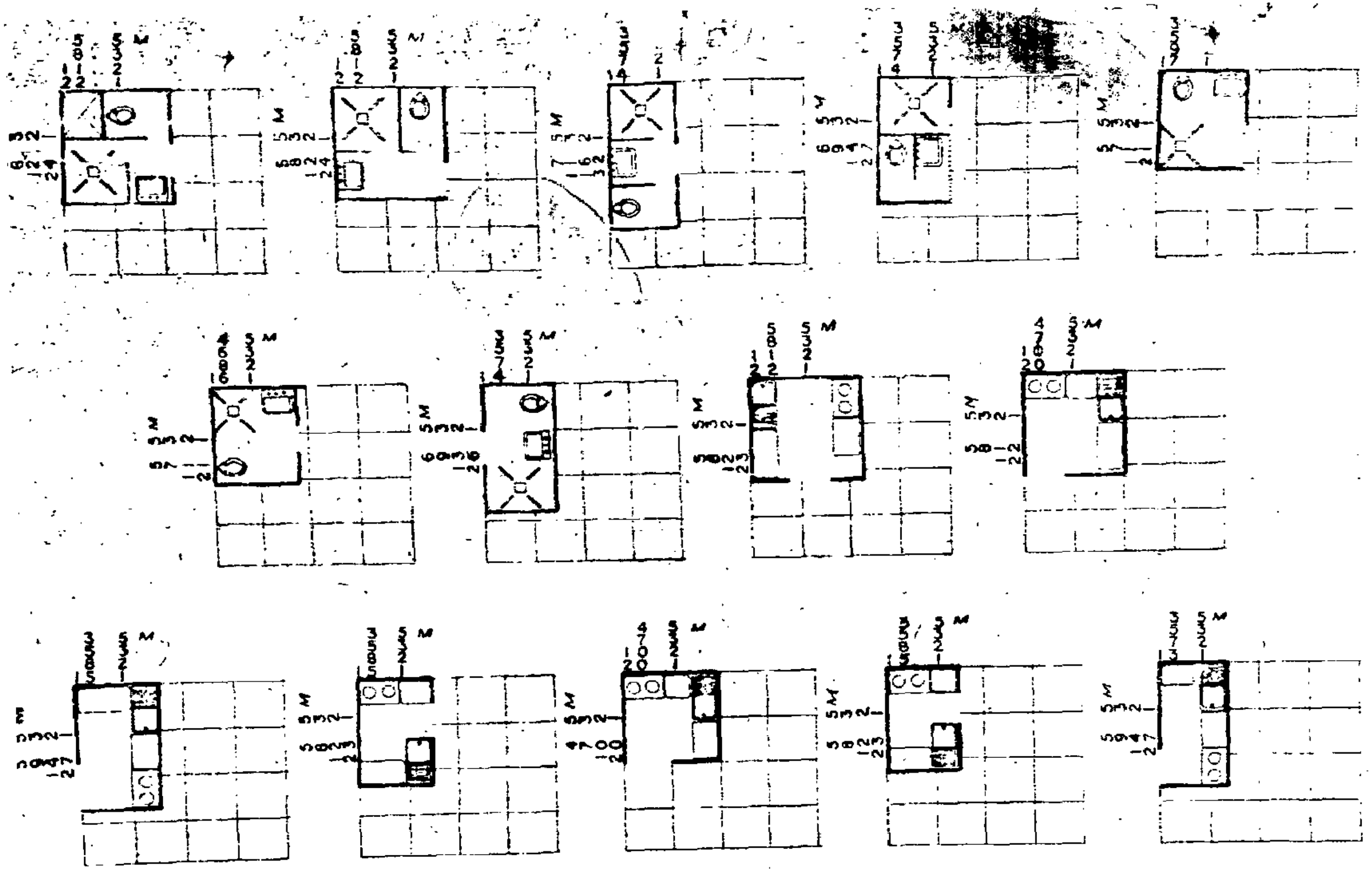


SPACE STUDY

KITCHEN and TOILET

BNP

4

	2 M																				3 M													5 M								
MODULE INCREMENT	140	160	180	200	220	240	260	280	300	320	340	360	380	400	420	440	460	480	500	520	150	180	210	240	270	300	330	360	390	420	450	480	510	150	200	250	300	350	400	450	500	550
				4	1		6		4	3	1	1		2									5	1	6	4	4		1	1					5	3	7	4	3			
				2			4	1	12	6		L	1	1									1		4	14	6	1	1	1					1	2	17	6	2			
						1		3	1			1			8		1							1	7	4		1		3	1					1	4		1	4		
							1	2	2			1		1	2				1	2					1	4	1			3			2			1	4	1	3		1	2
	1	5		3	2	3		2														4	8	6	2									4	3	2						
	3	1	1		4	2	1	1		1											3	1	2	6	0		1							8	1	6	2	1				
TOTAL INCIDENCE OF SPANS	4	4	1	9	7	6	12	9	12	10	1	4	1	4	5		1		1	2	3	5	11	12	15	26	12	2	2	8	1		3	8	10	20	34	12	9	4	1	2

RECURANCE OF SPANS

2 M INCREMENT

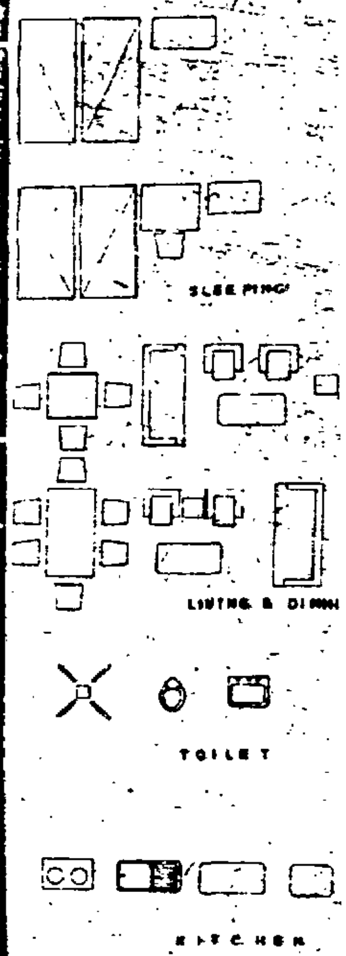
1. 300 — 19
2. 260 — 12
3. 320 — 10

3 M INCREMENT

1. 300 — 26
2. 270 — 15
3. 300 240 — 12

5 M INCREMENT

1. 300 — 34
2. 250 — 20
3. 350 — 12



5

DIMENTIONAL STUDY

BNP

and use 3M module which have used in various activities 26 times - 7 times more than 2M module. This also has been accepted by ISI as the Planning module. This 3M module helps us to obtain various space requirements and gives freedom to the architect during design.

SELECTION OF BUILDING SYSTEM

To select a particular building system, let us first see what are basic types of systems of construction. These are as under:

i. Load bearing wall system

ii. Skeleton construction or a Frame system

iii. Skeleton - Panel system in mixed type

iv. Box prefabrication.

Depending upon the weight of components, these systems are further classified into heavy and light systems. The system employing components weighing more than 1000 kg/m^2 are heavy systems and those employing components weighing less than 1000kg/m^2 are light systems.

As the Box prefabrication is the highest level that can be achieved, this is impossible to be adopted in defence construction because of lack of know-how complicacy of work, need for powerful transport facilities and better communication system, absence of heavy cranes and other handling equipment. Therefore box prefabrication is completely ruled out at this stage. Thus the choice is left between load bearing wall or panel construction and frame construction.

Load Bearing Panel Systems

This is further divided into following types:

i. Long wall system

ii. Cross wall system

iii. Two way span system

Long Wall System

Main characteristics of this system are that the load bearing walls are parallel to main axis of building i.e. longitudinally placed.

- Walls carry floor load also
- Width of openings like windows are restricted
- Small and minimum openings are preferred.
- Orientation of slab panels is right angle to long walls.

Cross Wall System

Main characteristics of this system are as under:

- Load bearing panels run at right angles to the longer axis.
- Cross walls are structural walls.
- They carry self weight and floor load also.
- External walls (longitudinal) do not carry floor load, but if they carry self weight elevational treatment may not differ much from long wall system.

- If long walls are supported at each floor level the width of openings are unrestricted.

Two way span system

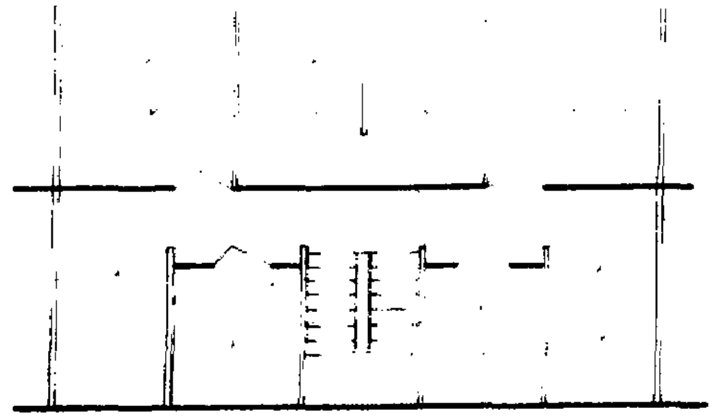
Main characteristics of this system are as under:

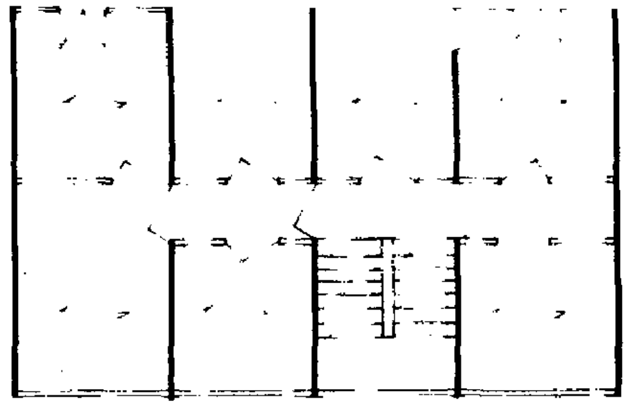
- Both long and cross walls are load bearing
- Outside walls carry part of load
- Floors are normally supported on all four edges and span in two direction.
- In skeleton construction, based on this system, slab units may rest on columns, completely eliminating the beams as structural member.
- Structurally it is more sound than first two systems and also much steel is saved while designing two way reinforced slabs.

Choice between Long and Cross Walls Systems

Choice between these two systems should be based on economical analysis, however, at the beginning long wall system was common for residential building, but experience has shown that cross wall system is more economical than long wall system. Following are some of the reasons that makes cross wall construction more economical.

Usually span in cross wall construction are small, say from 2.4 M to 5 M, whereas in long wall system, spans between long walls





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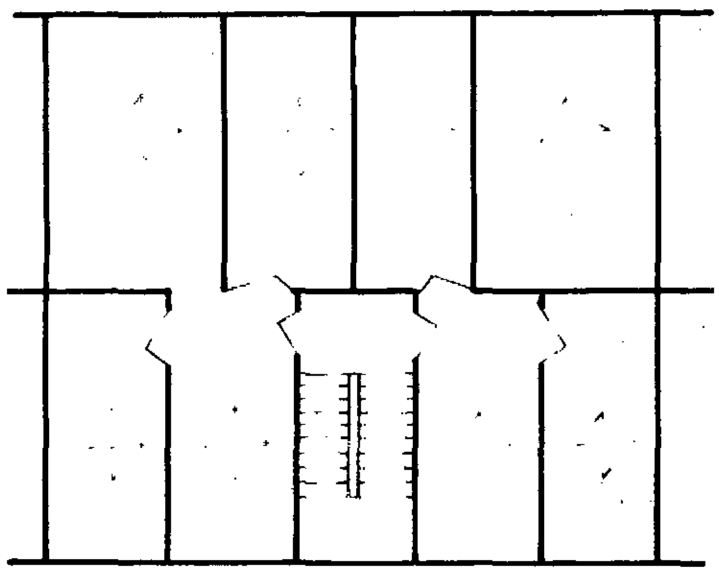


A. LONG WALL SYSTEM

B. CROSS WALL SYSTEM

C. TWO WAY SPAN SYSTEM

1. LOAD BEARING WALLS

2. DIRECTION OF FLOOR SPAN

ARRANGEMENT OF LOAD-BEARING WALLS IN BUILDINGS are large (usually correspond to depth of flat). Hence due to smaller spans less reinforcement is required in cross wall construction, thereby resulting into economy.

Secondly, in long wall system, longitudinal walls have to act as structural members and as climatic barrier also. Therefore the walls are thick and heavy and hence uneconomical. On the other hand, in case of cross-wall system there is a clear distinction between structural and thermal function of walls. Therefore lightweight material and insulating material can be introduced easily and economically in longitudinal walls.

However, amount of walling may be more in case of cross walls which could be avoided by replacing some walls or lintels or making it multifunctional. For instance wall may be part of cupboard or it may carry conduits etc.

Skeleton Construction

Cross Frame

In this sytem, skeleton structure consists of prefabricated columns and beams. The major characteristic of this system is that there are no longitudinal edge beams used as in case of monolithic in-situ framed building, walls are directly fixed to the column.

Beamless Skeleton Construction

The essential features of this construction are:

i. Floor panels usually span in two directions which result in economy of steel.

ii. More economy can be achieved by keeping columns close to each other.

iii. This system provides more scope for flexibility in planning than load bearing wall system.

Large Blocks and Large Wall Panels

Large blocks and large panels both are used in load bearing wall construction and are mainly differentiated by their shapes. Wall blocks are usually less than storey height and they are rarely of room size. Whereas wall panels are usually storey height and can be of room size or bigger. However in both the cases, there are small intermediate ie in case of large blocks as well as wall panels.

They are further differentiated by type of material or materials used. Wall blocks are never reinforced with steel except lifting hooks etc and act as ordinary masonry walls.

Whereas wall panels are reinforced with steel. Because of this characteristic jointing method also differs. Wall panel can be joined with reinforced concrete joint or welding. But joint between wall blocks is done with concrete or mortar. Wall blocks do not require temporary bracing during erection whereas wall panels do.

Advantages of Large Panels

i. Reduction of site labour and increase in productivity.

ii. Larger elements reduce erection and assembly operations, thereby shortening construction cycles.

iii. Number of joints are reduced, larger the element minimum will be the joints.

iv. Mass production becomes possible.

v. Completely finished large penels will reduce the work on site

vi. It saves in scaffolding.

vii. Speed of construction increases and ultimately cost is improved.

MODULAR DESIGN APPROACH

For coordinating entire building process (i. e. production, pre-assembly, assembly, positioning of components into their respective spaces etc), and layout of house should be based on modular system. This calls for modular designing. Unlike traditional design process, modular designing calls for choice of main components and important junction details etc. The difference in process of traditional designing and modular designing is as under:

Traditional

i. Sketch Design

ii. Working Drawings

iii. Details.

Modular

i. Sketch Design

ii. Modular details

iii. General arrangement drawings

Thus in modular planning, conceptual design has got to be evolved, like traditional design process. But in the next step, one has to work out various component combinations, details at junctions etc.

We can say that modular designing is additive, whereas architectural design is sub-dividing as the space is sub-divided into various units. But in modular design, modular space is filled or enclosed with choice of variety of components and their combinations. Thus by adding two or more components one single functional unit maybe formed. Composition using different combinations and permutations of modular components can be as subtle and rewarding as the ordinary way of dividing into many equal parts.

Unlike usual architectural design process, right from the beginning, architect has to keep many factors in mind during modular design process. He has to be aware of structural system to be applied, combination of various sizes of components, their flexibility or versatility, production, erection and transportation limitations, assembly possibilities sizes, shapes and essential modular details etc.

In short every aspect of building and production assumes equal importance at design stage itself. Structural concept plays equally important role as other design considerations. Hence it is not just like evolving at random plan or concept which has resulted from completely subjective out look but it is an objective approach. It is not merely like evolving any plan with any sizes and shapes of rooms combined or arranged in any manner (with off sets, set backs etc) and then modifying it to fit any structural system and standard components.

Criteria for Selecting Standard Spans

Standard spans should be determined in such a way as to make it possible to design a large number of different and satisfactory types of designs or plans. Secondly, the accepted engineering requirements and performance should be duly regarded.

In this study, spans are selected based on the space requirements for various activities (refer drawing plates of space & dimensional studies.

Following are the standard spans adopted:

240 cm; The study of space requirements shows that the dimension 240 cm caters for the space requirements for various activities and accommodates activities like cooking, wc, bath and staircase width etc. Next to 240 cm is 210 cm.
This has also been used in various activities but standardisation of spans become difficult in this. Therefore 240 cm is taken as minimum standard span.

300 cm: This dimension is very suitable for sleeping and living etc.

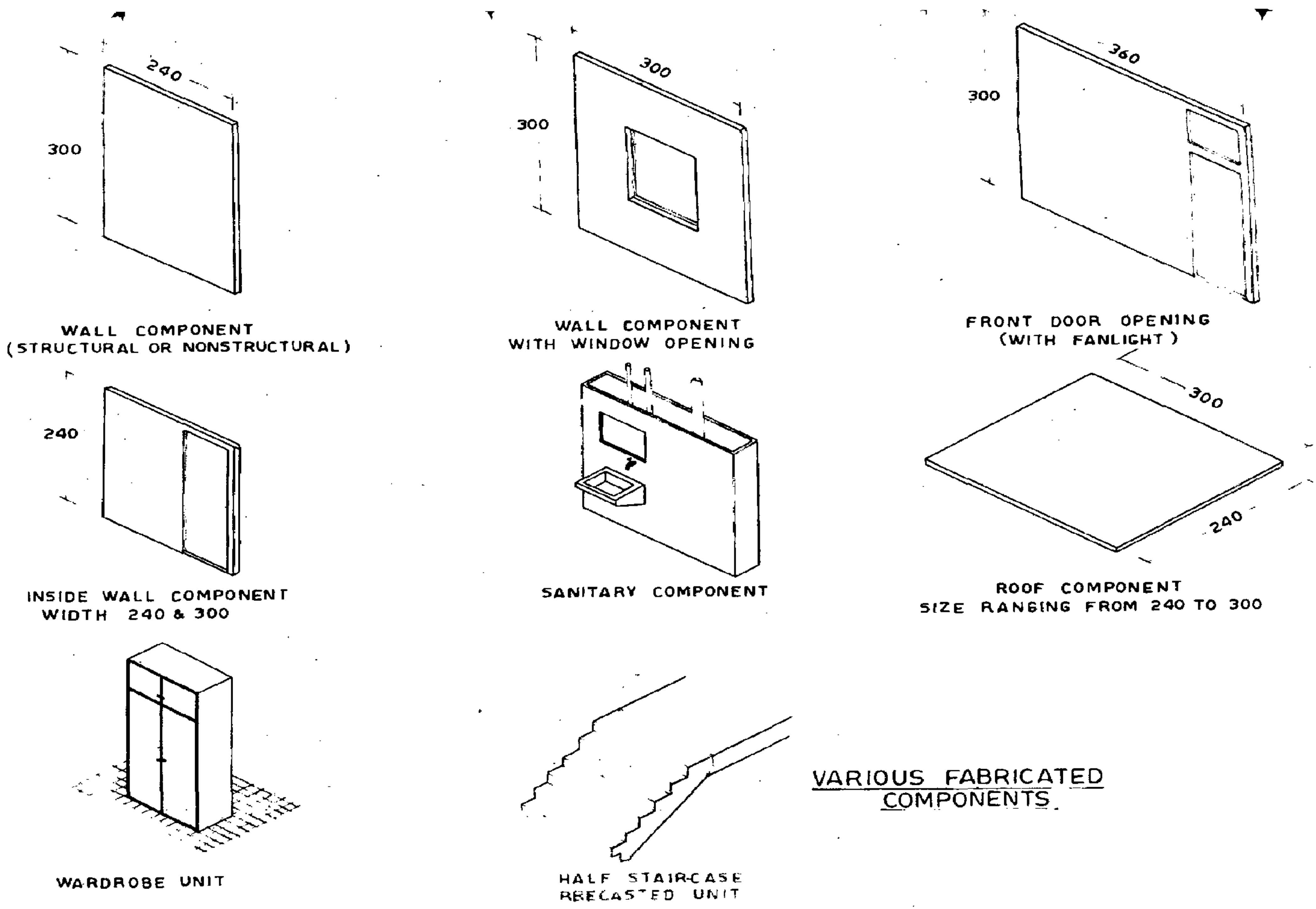
and has been used for the maximum number of times. Another important advantage of this dimension is that this dimension accommodates standard width of circulation (9 M or 90 cm) and sufficient area for kitchen or toilet etc.

360 cm: This is specially suitable for living and same time many other activities can be performed. Another advantage is that with half the dimension of minimum standard span (240 cm + 120 cm) 360 cm can be obtained which is very helpful while planning.

RANGE OF COMPONENT SIZES

It has been mentioned in earlier Chapter that for economical production of components usually a range of sizes of components is suggested. It is necessary because components cannot be produced in every increment of 1M (10 cm) economically.

Secondly from standardisation point of view, it is difficult to think in terms of single component, being used for all purposes in building. It is because the structural behaviour and nature of function differ fundamentally e.g. that of wall and roof. Therefore idea of using one component for all purposes becomes impracticable. Due to these facts, usually components are standardised according to specific functions in building and for various components, minimum range of sizes is fixed. The main components can be classified as under:



VARIOUS FABRICATED COMPONENTS.

- Walls (structural)
- Partition wall
- Roof components
- Stair way component
- Miscellaneous

List of components and their sizes adopted in the design is given in Appendix G.

Design Analysis

Some common modular characteristics employed in all designs are as under:

i. All plans are referenced on planning module grid of 30 cm or 3M. This is applied both horizontally and vertically.

ii. Room height is taken as 300 cm or 30 M (from finished floor to finished floor).

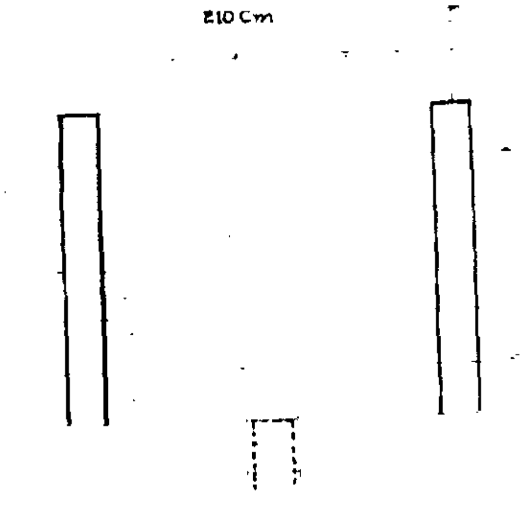
iii. Door-set width of 90 cm or 9M is applied in all plans. Height of door is 21M. In all plans, minimum modular space governing the plan is 90 cm left for circulation.

iv. In all plans, some system, of placing the components with respect to modular lines is applied (refer drawing).

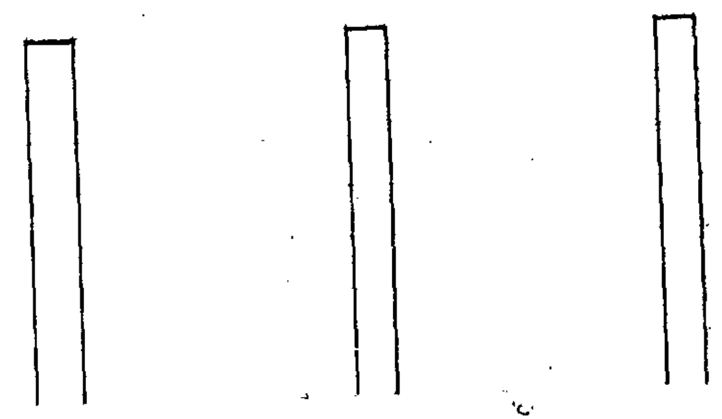
   a. Structural components are centered on modular lines.

   b. Internal face of external long walls lie on modular line.

   c. All partition walls and other non-structural components are referenced on basic module of 1M.



A



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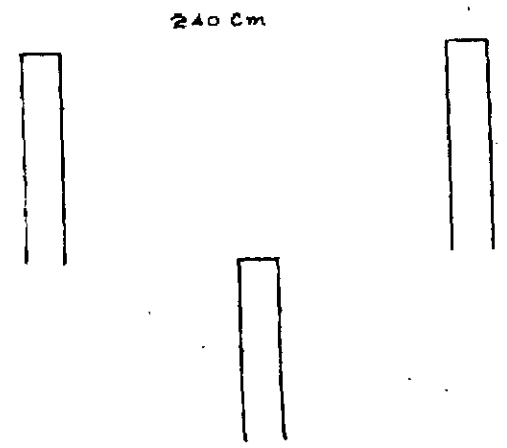
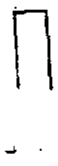


D

STANDARD SPAN	NOMINAL	CLEARE SPAN
24 M.	240 Cm.	220 Cm.
30 M	300 Cm.	280 Cm.
36 M.	360 Cm.	340 Cm.
48 M.	480 Cm	460 Cm.



STRUCTURAL COMPONENT

MODULAR LINE

A. [illegible] MEM[illegible] FR[illegible] [illegible] SPAN DIFFICU[illegible]

B. WHEN THE THICKN[illegible] OF THE COMPONE[illegible]TS CO-IN-SIDE WITH MODULAR SYSTEM [illegible] CAN BE PLACED BETWEEN MODULE [illegible]NES. BOTH THE BOUNDRY SURFA[illegible] OF COMPONENT LIE ON MODULAR [illegible] [illegible]IS SOLVES BOTH THE PROB[illegible] [illegible] APPLICATION OF UNIFORM SYSTE[illegible] PLACING THE COMPONENT AND [illegible]EVIDING THE MODULAR SPACE E[illegible] ALLY.

C. [illegible]UCTURAL COMPONENT [illegible] BE ADOPTED FOR THE [illegible]

D. [illegible]WING TO ABOVE DISCUSSION [illegible] STANDAR SPAN HAS EVEN [illegible] [illegible]RUCTURAL COMPONENT [illegible] [illegible]ROBLEMS ARE SOLVED [illegible] [illegible] INTERNAL DIMENSION [illegible]OLVED WITH USE OF [illegible] [illegible] ETC

Design Efficiency

Design efficiency of all plans varies from 72 to 75 %. Break-up is as follows:

Under circulation	10 to 12% approx.
Under-walls	12 to 15% "

Wall thickness is assumed to be 20 cm throughout the calculation (in case of both load and non-load bearing walls). In some cases more area going under wall is compensated by thin wall.

PLANS ANALYSIS

I. One stair case serving two flats at each floor level.

i.	Accommodation - one room flat	Refer drawings
ii.	Area	25.8 sq m
iii.	Area under staircase	4.3 "
iv.	Standard spans -	240 cm 360 cm
v.	Range of component sizes used	240 cm 360 cm
vi.	Three sizes of partition walls	50 cm 60 cm 70 cm

Cross walls enclosing living room are of the length of 360 cm whereas room width is 300 cm. This helps in supporting the balcony and midlanding also, thereby eliminating complete over hang.

II.	One room flat	Refer drawings
	Area	26.5 sq m
	Area under staircase	4.3 sq m
	Standard spans	240 cm 360 cm
	Floor components	240 x 240 cm 300 x 360 cm
	Wall components	240 cm 300 cm 360 cm

Here terraces are provided at the end of the block which is approachable from kitchen as well as from living.

III.	Accommodation - two room flats	Refer drawings
	Area	35.5 sq m
	Area under stair case	14.5 sq m
	Standard spans used	240 cm 300 cm
	Floor components	240 cm 300 cm
	Wall components	240 cm 300 cm
IV.	Accommodation three room flats	Refer drawings
	Area	44.5 sq m
	Area under staircase	14.5 sq m
	Standard span used	240 cm 300 cm 480 cm
	Floor components	240, 300 & 480 cm
	Wall components	240 and 300 cm.

II.	One room flat	Refer drawings
	Area	26.5 sq m
	Area under staircase	4.3 sq m
	Standard spans	240 cm
		360 cm
	Floor components	240 x 240 cm
		300 x 360 cm
	Wall components	240 cm
		300 cm
		360 cm

Here terraces are provided at the end of the block which is approachable from kitchen as well as from living.

III.	Accommodation - two room flats	Refer drawings
	Area	35.5 sq m
	Area under stair case	14.5 sq m
	Standard spans used	240 cm
		300 cm
	Floor components	240 cm
		300 cm
	Wall components	240 cm
		300 cm
IV.	Accommodation three room flats	Refer drawings
	Area	44.5 sq m
	Area under staircase	14.5 sq m
	Standard span used	240 cm
		300 cm
		480 cm
	Floor components	240, 300 & 480 cm
	Wall components	240 and 300 cm.

1 ALL PLANS ARE REFERENCED ON [illegible]

THIS MODULATION IS APPLIED BOTH HORIZONTALLY AND VERTICALLY.

2 ROOM HEIGHT IS TAKEN AS 300 CM OR 30 M (from finished floor to finished floor).

3 DOOR-SET WIDTH OF 80 CM OR 8 M IS APPLIED IN ALL PLANS. HEIGHT OF DOOR IS 210 CM. HOWEVER THIS SELECTION OF DOOR-SET WIDTH HAS NO INFLUENCE ON PLANNING. IN ALL PLANS, MINIMUM MODULAR SPACE GOVERNING THE PLAN IS 0.90 metre OR 90 CM TO BE LEFT FOR CIRCULATION. THIS DIMENSION MAY COVER MODULAR SPACE FOR W.C. ALSO

4 IN ALL PLANS, SAME SYSTEM OF PLACING THE COMPONENTS WITH RESPECT TO MODULAR LINES, IS APPLIED. i.e.

I STRUCTURAL COMPONENTS ARE CENTERED ON MODULAR LINES.

II INTERNAL FACE OF EXTERNAL LONG-WALLS LIE ON MODULAR LINE.

III ALL PARTITION WALLS AND OTHER NON STRUCTURAL COMPONENTS ARE REFERENCED ON BASIC MODULE OF 10 CM OR 1M

5 LASTLY COMPONENTS FROM THE SAME RANGE (given in the chart) ARE USED THROUGHOUT

DESIGN EFFICIENCY:

DESIGN EFFICIENCY OF ALL PLANS VARIES FROM 72 to 75%

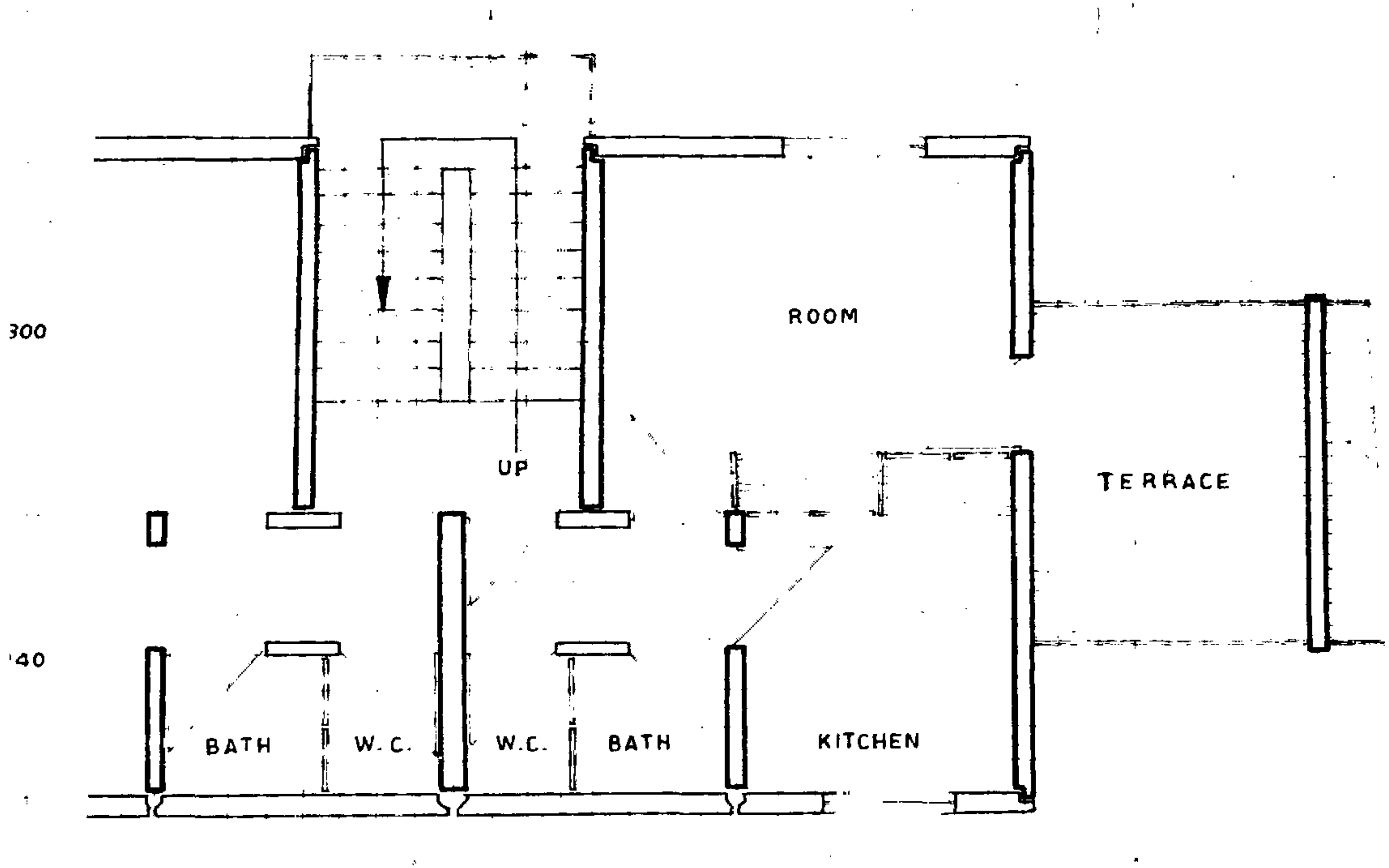
BREAK-UP IS AS FOLLOWS :-

ABOUT 10 to 12% AREA UNDER CIRCULATION

ABOUT 15% AREA UNDER WALLS.

WALL THICKNESS (whether structural or non structural) is assumed to be 20 cm throughout the calculation.

IN SOME CASES, MORE AREA UNDER CIRCULATION IS COMPENSATED BY THIN WALLS.

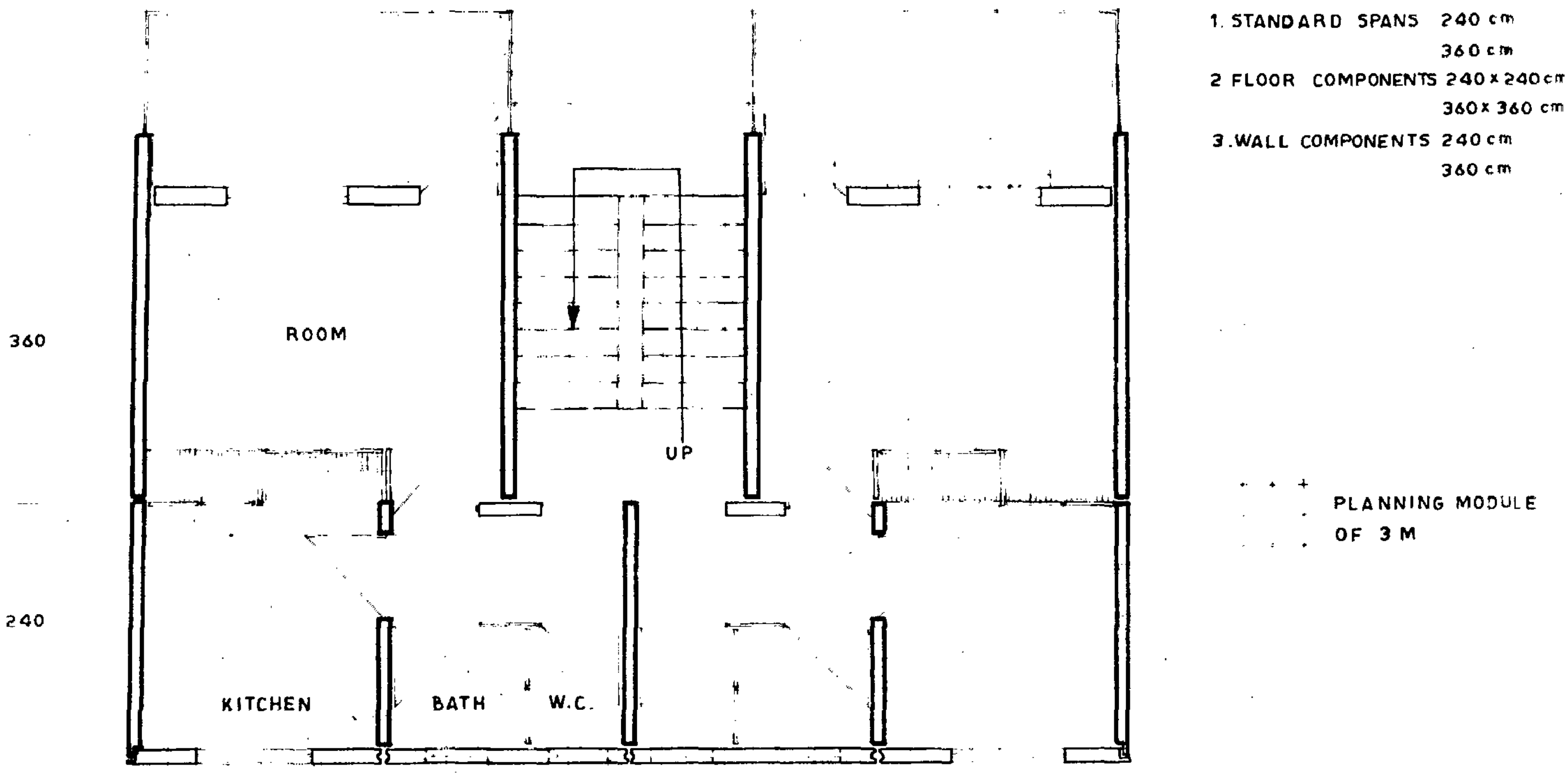


1. STANDARD SPANS 240 cm
360 cm
2. FLOOR COMPONENTS 240×240 cm
300×360 cm
3. WALL COMPONENTS 240 cm
300 cm
360 cm

PLANNING MODULE
OF 3 M

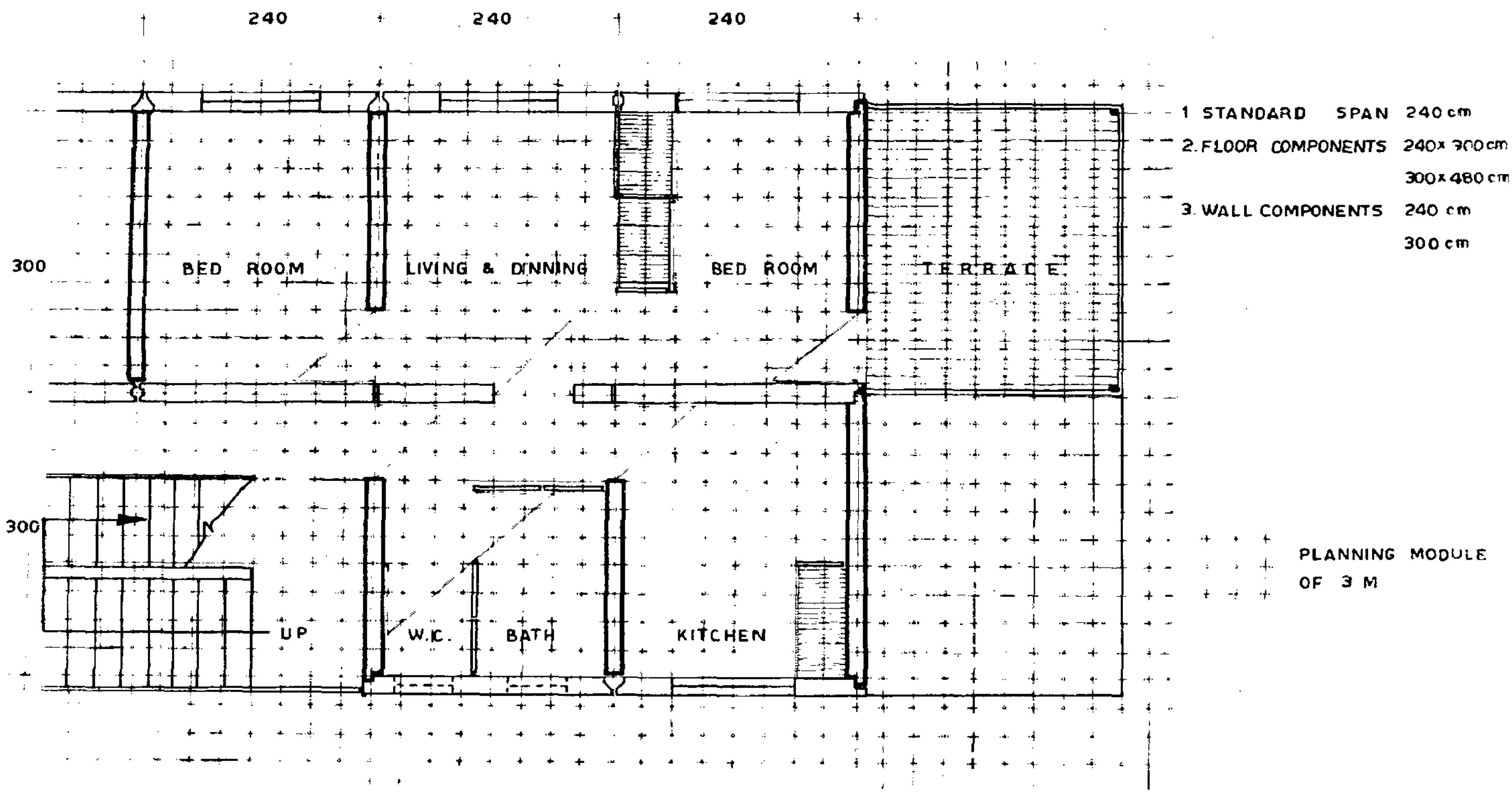
TYPICAL FLOOR PLAN

TWO – ONE ROOM FLATS



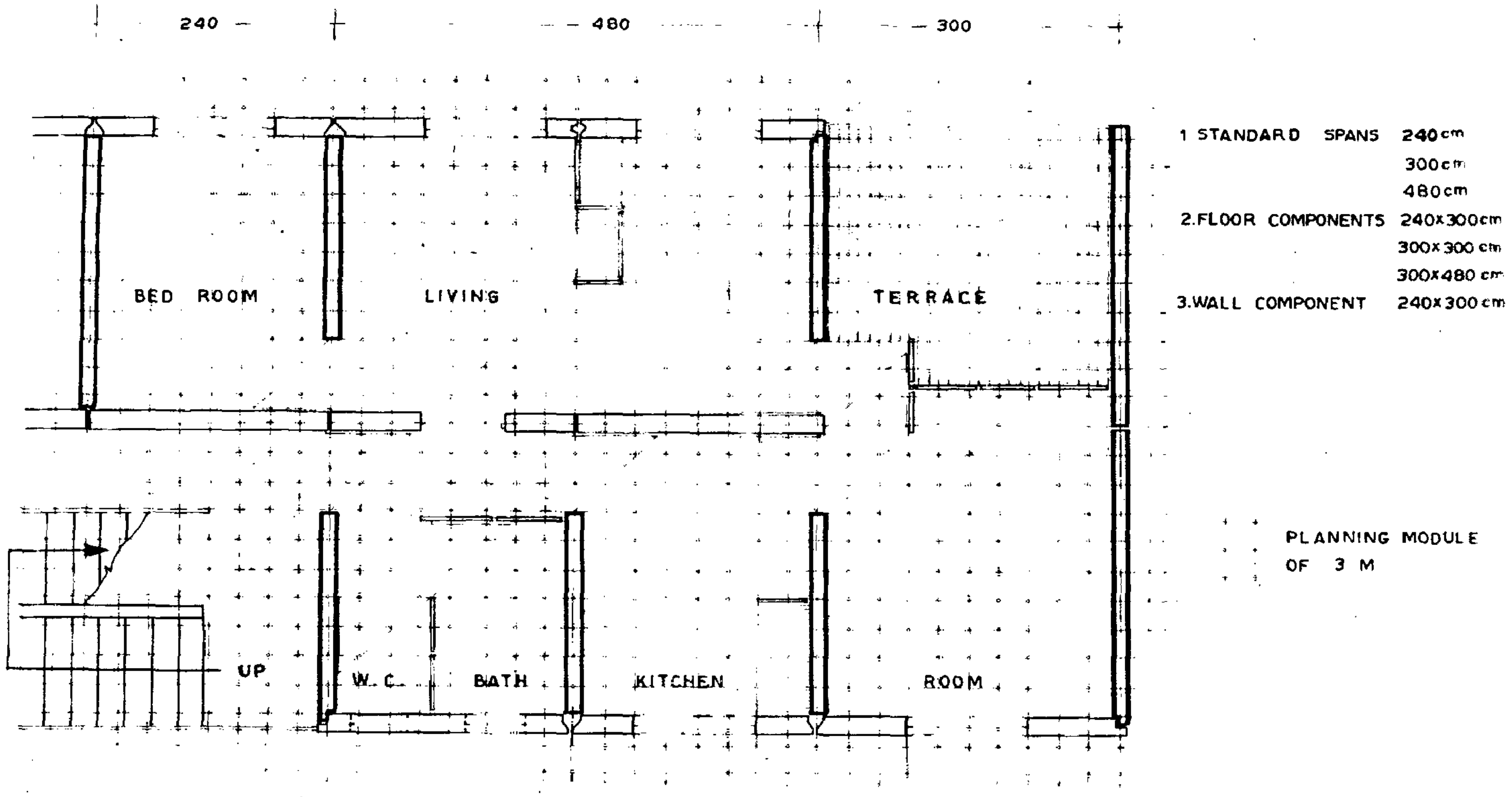
TYPICAL FLOOR PLAN

TWO – ONE ROOM FLATS



TYPICAL FLOOR PLAN

TWO – TWO ROOM FLATS



TYPICAL FLOOR PLAN

TWO - THREE ROOM FLATS

TOLERANCE AND JOINTS

Tolerance

Tolerance is a degree of inaccuracy that can be ignored or discounted. This comes into picture at the time of assembly. This is as important as Modular coordination itself. When all parts and elements of building are prefabricated away from site and assembled together on site their coordination is achieved by Modular Standardisation. But this provides a broad basis and exercise overall dimensional control. Here exact, shape, size and edge profile cannot be specified or regulated. However in modular coordination the provision of tolerance could be incorporated.

Here it has not been discussed in details as it involves too much calculations and technical factors. It is only intended to show how in the design tolerance can be ensured. In order to coordinate the component size and modular space for it in design and to make provision for tolerance, one guiding principle should be as under.

Modular coordination is more successful in cases where component size does not exceed modular space.

Tolerance Limits*

"The majority of the work done in setting out the tolerance limits is based on component inaccuracy and little on overall accuracy of a building due to the overall effect of the different inaccuracies in the component, like deviations in length, breadth and thickness, bow and

---

*Dr. Chetty, S. M. K. & S. C. Chakrabarty — **Tolerance in Prefabricated Buildings in Symposium on Standardization in Construction of Buildings** twist etc.

The tolerance limits which are set for prefabricated components in National Building Code of India, 1970, are inadequate in many respects. As for example, a tolerance of ±10 mm in length may be very difficult to obtain for large panel wall/slab members. Similarly the other limit of tolerance i.e. 0.1 per cent of length is set at a high accuracy level and seems to be impracticable in most of the cases. To take a specific case, a panel of 4 metre length will have only ± 4 mm deviation or ± 10 mm deviation in length as per clause given in the National Building Code. The deviation of ± 10 mm will thus always be the guiding figure for tolerance in most of the prefabricated components."

Joints

Both vertical and horizontal gaps exist between units or components forming external walls. These gaps are called joints. These joints which are also called as Vertical Joints and Horizirt al Joints must be stiff enough to resist any impact forces applied to them during the laying of floor system or roof system. These must be able to withstand the forces as would exist in monolithic wall. Suitable connections must be formed between adjacent wall panels and roof or floor members.

The general classification of joints can be:

i. Wet Joints

ii. Dry Joint/Semi-Dry Joints

twist etc.

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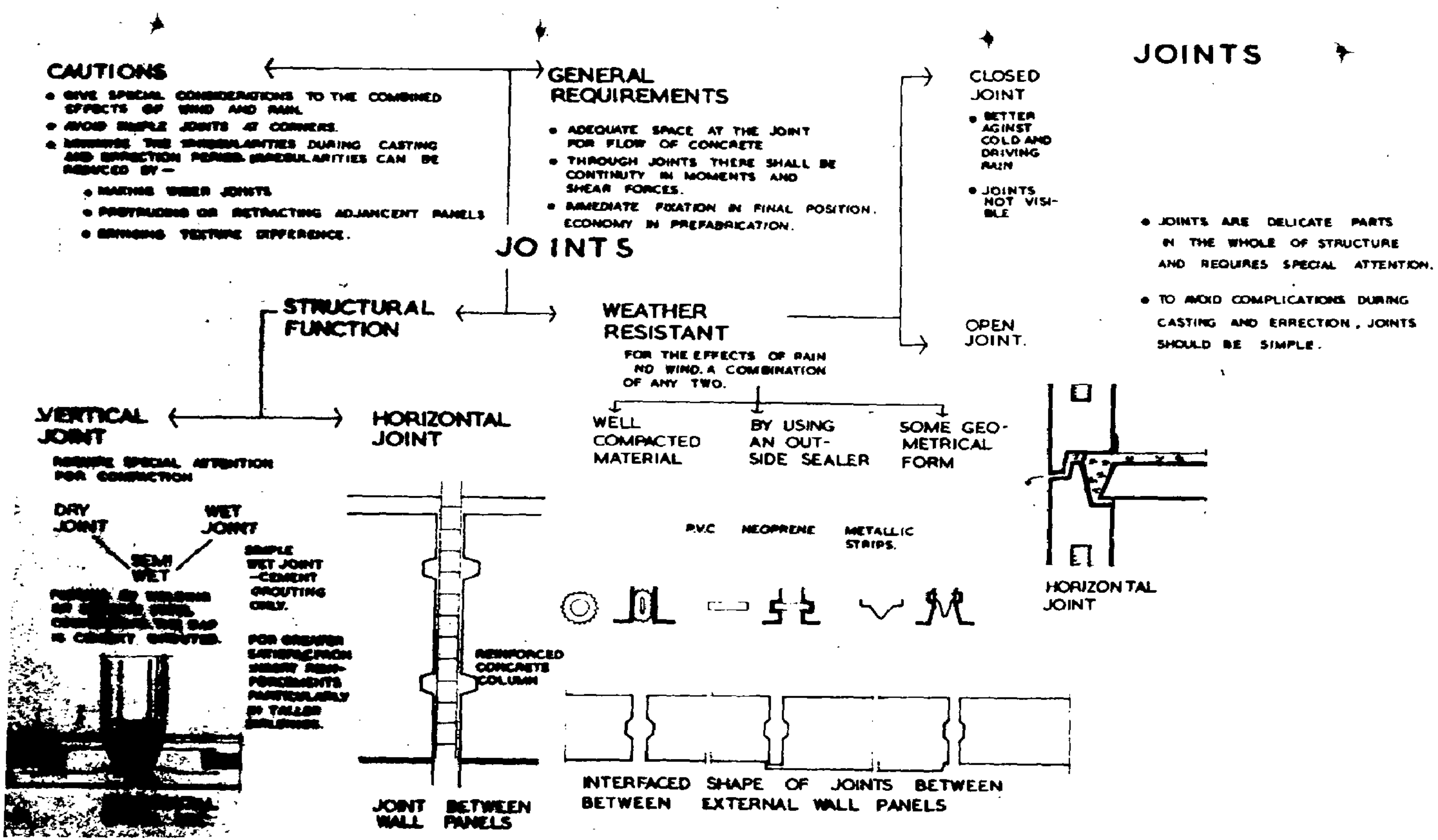


Sikka, S. Report on Industrialized Methods of Produ...

Wet Joints

These are made by filling the gaps between the precast components. The gaps are usually filled with cement grout or concrete but it may or may not contain reinforcement. The reinforcement which extends at the surface of the precast members are tied together with ties or even welded.

Dry Joints

These are formed by welding or bolting together the steel ends in the panel as shown in Drawings. The gaps are again filled with cement concrete. This type of joints can be designated as semi-wet or semi-dry. The cement concrete used to fill the gap must be compacted sufficiently.

Special consideration must be given to the combined effects of wind and rain because experience has shown that the wind drives rain water into the joints. For this reason grouting by itself cannot be accepted since after sometime the formation of cracks is unavoidable and therefore finds its way through these into the walls.

At the external surfaces there are joints in two directions which are as under:

i. Horizontal Joints

ii. Vertical Joints

Horizontal Joints

The functionsof horizontal joints in a structural wall is to transfer the load from upper storey and from floor slab which are supported at the joints. Transfer of the load through different compressibility shall be avoided. Longitudinal reinforcement in the joints does not effect the strength of the wall unless otherwise it is so required in the design to check horizontal tangential forces or vertical tension due to bending in its own plane under the action of horizontal loads or because of unequal load.

Lower surface of joint is weathered which offers adequate protection against wind driven rain etc. To protect joint further, from severe exposure overlap has been provided.

Vertical Joints

Vertical joints extends from floor to floor and take up

i. Vertical tangential forces

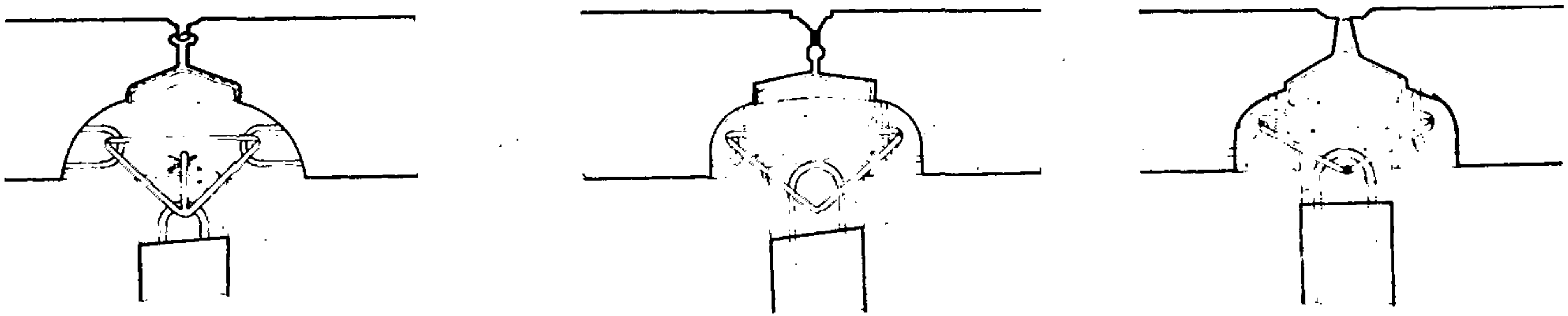
ii. Hor.tangenrial force due to buckling tendencies of the adjoining walls.

The joint is designed to check inward flow of water and air infiltration. The three main features kept in mind are as under:

i. Drainage zone

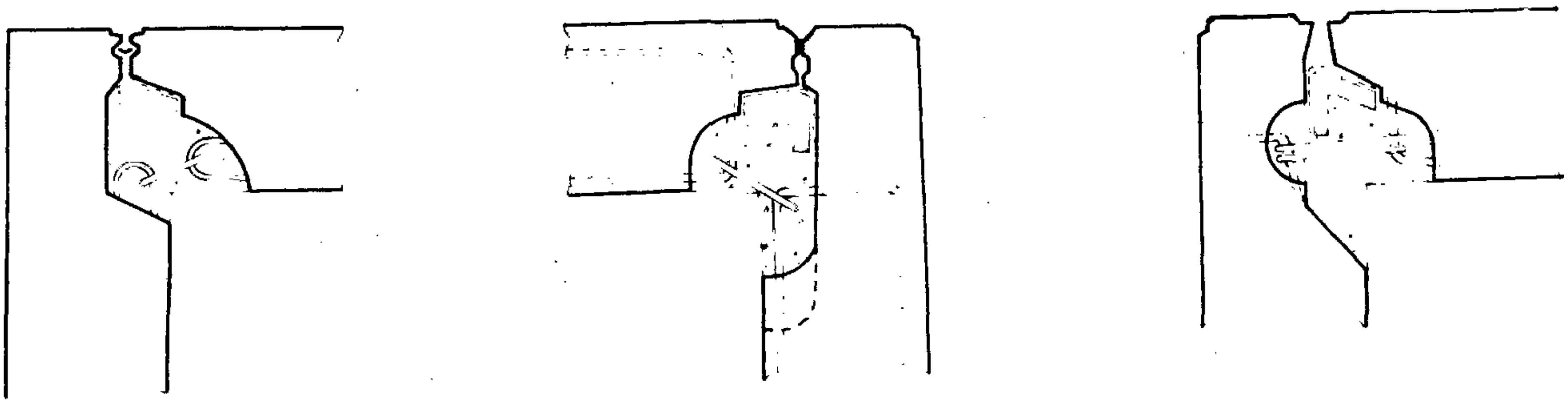
ii. Baffle and ventilated cavity

iii. Air barrier.



TWO EXTERNAL & ONE INTERNAL PANELS

THREE PANELS V. JOINTS



TWO END PANELS V. JOINTS

BOTH EXTERNAL

VARIOUS TYPES OF JOINT

Drainage Zone

This extends from front of joint to baffle or air barrier (if baffle is not provided). Much of water entering into joint is removed in the drainage zone. Usually drainage zone is 5 cm in plan.

Baffle or Ventilated Cavity

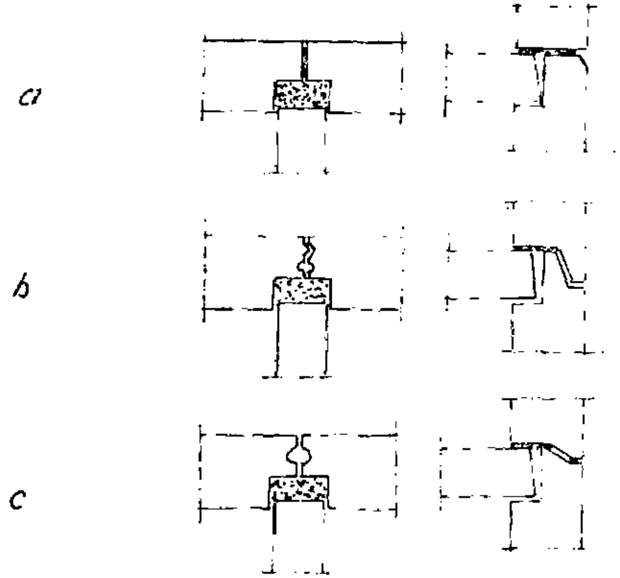
This protects air barrier. Whatever small quantity enters into cavity is drained down.

Air Barrier

Simple air barrier of roofing felt with gap filling. Bituminous adhesive can also work.

The gaps on the external face determine as to whether the joint is closed or open. In case of open joint the gap extends along an uninterrupted straight line across the full thickness of the wall. It is called closed joints if the gaps consists of several discontinuous lengths, although still extending through the full thickness of the wall. (See Drawing).

Closed joints provide better protection against cold and driving rain and can be formed by giving suitable shape to the adjacent external wall. It also can be formed at the point where the external adjacent panel meet to the internal partition wall. Joints so formed are not visible from inside.

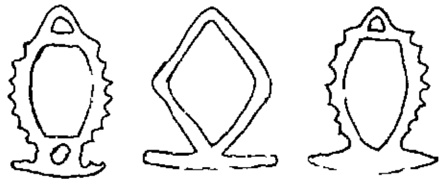


TYPES OF JOINT WRT PROTECTION AGAINST WATER PENETRATION:

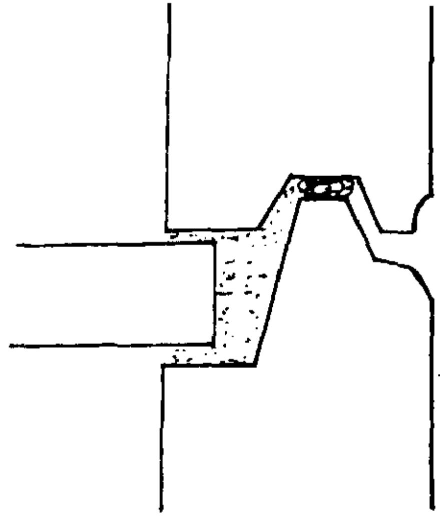
a. FILLED JOINT

b. OPEN JOINT

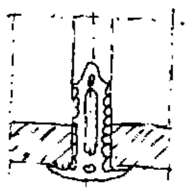
c. SEALED OPEN JOINT



PLASTIC SEALST PROTECTING OPEN JOINTS.



HORIZONTAL JOINT



SEAL PLACED IN JOINT

Lewicki, B.: Building with Large Prefabrication.
&
Koncz, T. : Manual of Precast Concrete Construc

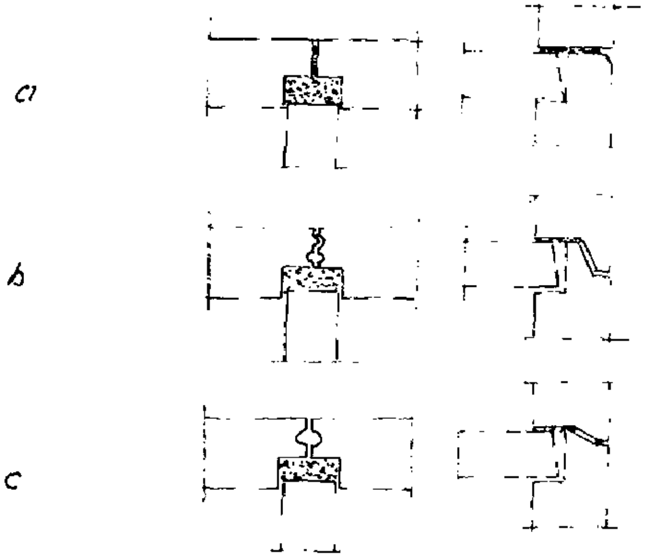
CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

CONCLUSION

The Corps of Engineers who are concerned with buildings or any other construction are concerned with mainly three aspects namely, speed of construction, overall economy and quality. Only one of these could be fixed factor and the other two will be variables. It is accepted that when time of construction is fixed, cost or quality may not be controlled. Nevertheless we often tend to confuse cost with economy. The word 'Economy' is to be related to the long term economy in any construction. By economy we mean not only reduction in the cost of the building as a whole, but reduction by affective economy in the use of scarce materials, reduction without impairing the stability of the buildings and finally reduction in the maintenance costs. Only when all these factors are taken into account together, they contribute to real reduction in cost.* We see that the cost of material and labour is rapidly increasing. In the first ten years from 1950 to 1960 the increase in the building costs has been only 20 to 25 points, between 1960 to 1965 the increase in building costs has been about 50 points and therefore 1965 to 1970 the increase has been about 60 to 70 points. So every effort on our part is necessary to conserve labour and every bit of

*Expert Committee Report, NBO, Delhi.



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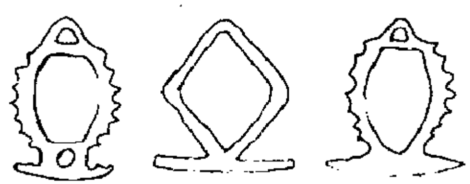

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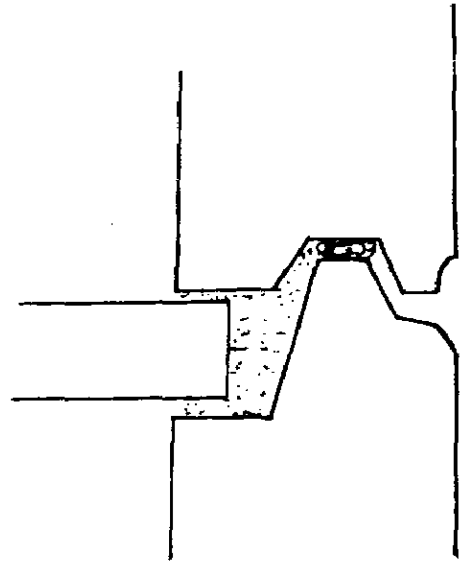
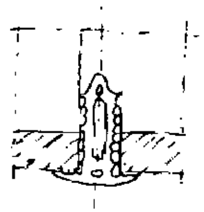


HORIZONTAL JOINT



SEAL PLACED IN JOINT

Lewicki, B.: Building with Large Prefabrication.
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Koncz, T. : Manual of Precast Concrete Construc

Sealing of Joints

For filling up the joints the use of mortars and allied mixtures cannot ascertain reliability of damp proof layers, since in due course of time, wind can drive water through these materials. Synthetic rubber strips of rectangular or tubulor profiles have proved suitable. These are adequately durable and have sufficient resistance to weather. Even the use of metalic strips could be made but these would prove a costly proposal.

The following forms of joints between the elements of wall panel can occur:

i. Simple butting joint

ii. Enlarge face by the formation of vertical groove in the internal wall.

iii. Enlarge gap by a recess in the internal face of the external wall.

iv. Joints formed by penetration of external and internal panels.

The selection of one joint over the other depends upon whether the joint is to serve for structural purposes or it has to resist weather conditions only. In case of structural joints it must be capable of transmitting forces without undue deflection or deformation. It is preferable to use sealed open joints with water proof barrier such as PVC or Asphalt etc.

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

CONCLUSION

The Corps of Engineers who are concerned with buildings or any other construction are concerned with mainly three aspects namely, speed of construction, overall economy and quality. Only one of these could be fixed factor and the other two will be variables. It is accepted that when time of construction is fixed, cost or quality may not be controlled. Nevertheless we often tend to confuse cost with economy. The word 'Economy' is to be related to the long term economy in any construction. By economy we mean not only reduction in the cost of the building as a whole, but reduction by affective economy in the use of scarce materials, reduction without impairing the stability of the buildings and finally reduction in the maintenance costs. Only when all these factors are taken into account together, they contribute to real reduction in cost.* We see that the cost of material and labour is rapidly increasing. In the first ten years from 1950 to 1960 the increase in the building costs has been only 20 to 25 points, between 1960 to 1965 the increase in building costs has been about 50 points and therefore 1965 to 1970 the incraase has been about 60 to 70 points. So every effort on our part is necessary to conserve labour and every bit of

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*Expert Committee Report, NBO, Delhi.

material used. Even a little saving in labour and materials would go a long way in bringing about significant economies.

In view of the limited resources, we should exercise judgement in the selection of materials, employment of labour and choice of construction techniques. What is suitable for one area may not be suitable for another. Construction techniques influence the design methods and selection of materials and the administration of works. Selection of systems will be influenced by the availability of material labour and climatic conditions. Prefabrication is one of the solution. The technique of prefabrication is not yet fully developed and need a big research and development programme. Large panel construction is one of the solution which has been proposed and is very suitable to meet our requirements. This also is the fastest method of construction. After we procure some plants to precast the large panels at the work site this method will further help us to save time and cost.

RECOMMENDATIONS

In present context it may not be possible to introduce full scale industrialisation due to lack of technical know-how, plants and machineries for erection and handling and finally the production of building components and materials to meet the demand.

Keeping in view the need of speedy construction and to provide a suitable alternative to the traditional type of construction, following recommendations are made:

i. Beginning should be made for a gradual change over from traditional type of construction to prefabrication for housing.

ii. In the construction of houses, until full scale mechanisation and prefabrication becomes feasible, prefabricated elements may be used in combination with traditional materials. Introduction of partial mechanisation and the use of small and medium sized prefabricated elements, especially for the roof and intermediate floors be made. It accounts for 25 per cent to 45 per cent of saving. Completion time of housing project could be reduced to 40 per cent by adoption of large panel prefabricated building methods and about 30 per cent by adoption of prefab building components for roofing and flooring.

iii. Preplanning and programming of building projects in detail.

iv. Introduction of standardisation and modular coordination in building design.

v. Integration of design and production ensuring proper communication and feed back of experiences.

vi. Application of quality control methods and modern management system for planning and execution.

vii. Encouragement to undertake research and development programmes.

viii. Production agency and consuming agency should preferably be affiliated or closely linked up as in the case of Defence housing in the Public Sector.

ix. From the case study of Tongsa valley housing project completed in Eastern Command by partial prefabricated techniques has definitely proved the possibility of adopting this system of construction for mass housing on large scales as envisaged in the Defence construction.

x. Atmosphere should be created to encourage contractors to adapt themselves to new technology. In other words a modification in the existing contracting system,as laid down in the MES hand book or CPWD schedules, may required to be modified.

xi. Lead should be taken by large construction agencies/ enterprises by adopting prefabrication system. The possible agencies/enterprises can be following:

a. Central Govt. agencies e.g. CPWD

b. State Govt. agencies e.g. PWDs, Housing Boards

c. Big private industrial housing as in case of Modys' Tatas' and Birlas'

d. New townships

e. Slum clearance programme for rehabilitation housing like Calcutta.

CONSTRUCTION EQUIPMENT

Use of simple building plants and equipments not only become inescapable due to adoption of prefabrication but is also desirable in terms of speed,economy and quality. Following recommendations are made:

i. Procurement and utilisation of better machinery and equipment for production of prefabricated building components and housing elements.

ii. Procurement of machinery for erection work which can be classified as under:

a. Cranes of 3 to 5 ton capacity

b. Vibrators

c. Tamping machine *

d. Power trowel *

e. Unit frame scaffolding *

f. Scaffold hoist. *

Finally it will be good if contractors can be advised to take up work in the remote areas and also they should be given incentive to adopt the new methods of construction and keeping that in view they should procure necessary plant and machinery.

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*Brief Specifications along with photographs are appended at the end.

APPENDIX A

LARGE PANEL PREFABRICATED CONSTRUCTION BY HINDUSTAN HOUSING FACTORY, DELHI

In India, fully prefabricated large panel housing construction is not as yet, an accepted practice. The volume of this type of construction put up so far is quite insignificant as compared to the total volume of house building. Only two agencies in the country, namely Hindustan Housing Factory Limited, Delhi and Shah Construction Company Limited, Bombay are engaged in large panel construction. The Central Building Research Institute, Roorkee, is devoting itself to the problems associated with large panel housing and to the development of a system suitable for the country.

The Hindustan Housing Factory, which is a government agency, has been trying to introduce prefab large panel housing in the country. Four storey apartment blocks were first put up by the factory at Safdarjang as an experimental measure in the year 1964. Later on the Factory has put up 336 houses of the large panel type in Hauz Khas, New Delhi, for the Delhi Development Authority. These houses have floor area of 68 sq. m. and were intended for hire purchase. A typical plan is shown in photograph.

The houses are constructed in 4-storeys with each block having 8, 16 or 32 houses. One single staircase is provided per unit of 8 houses.

APPENDIX A

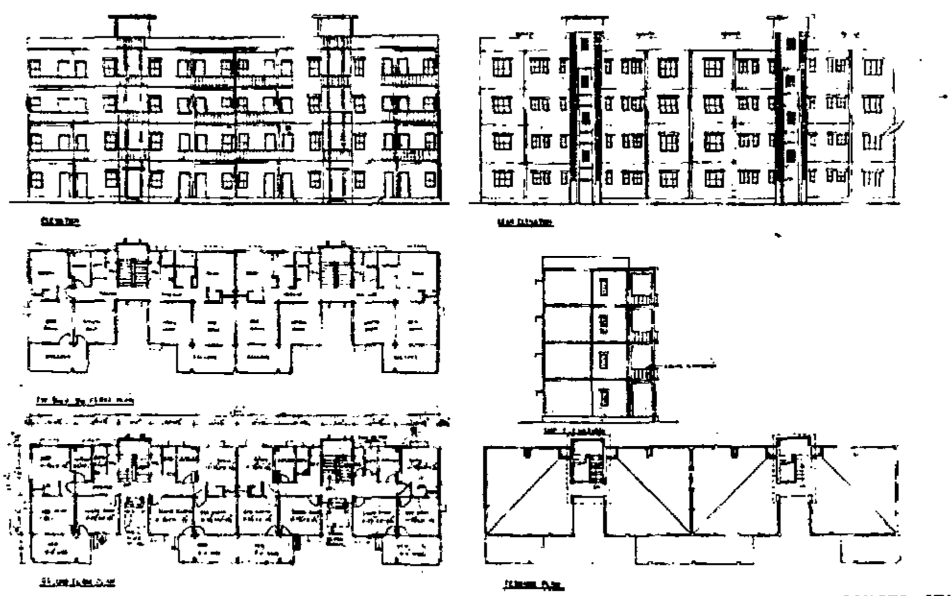
The construction upto plinth is in brick and is made in the conventional way. The load bearing walls are of precast reinforced concrete 125 mm thick. The non-load-bearing external walls are of sandwiched construction and are also 125 mm thick with 50 mm foam concrete insulation. The internal non-load bearing walls are 100 mm thick and are made of solid concrete. Single brick partitions are used for making building in cup boards, box rooms, bath and WC etc.

The flooring/roofing scheme consisted of factory made pres-tressed concrete battens of inverted tee type with hollow lean concrete filler blocks and 5 cm thick structural in-situ deck concrete topping. The weathering course on the roof consists of 10 cm thick and phuska topped with brick tiles grouted in cement mortar. The full room size floor slabs were not adopted due to limitation of the handling equipment. Only mobile type jib crane was available for the construction.

The joints between the panels have been made by casting concrete in-situ. No sealants are used in the joints and the in-situ part of the joint are exposed. It was feared that the performance of such a joint would not be satisfactory against rain penetration, however, no leakages through the joints have been observed so far. The joints require further detailing and improvement for water proofing against rain.

The Factory has constructed these houses for Delhi Development Authority at price approximately Rs 14,000 excluding electricity and internal water supply sanitary installations. The Factory is engaged on putting up similar type of apartments in other localities. Although the Factory has production potential of 1500 dwelling units per year, it has put up only about 1000 units in the last three years, the reason being lack of orders. For the low rise apartment buildings, fully prefabricated large panel housing is not found to be very competitive against the traditional type of construction. The average labour consumption, including that at factory and on site, is stated to be 12 men days per 1 m^2 of the effective floor space.

The system can be adopted with minor modifications on mass scale for the janta housing, low and middle income group housing.



LARGE PANEL CONSTRUCTION

APPENDIX B

HOLLO PAN SYSTEM OF CONSTRUCTION BY PWD, ROORKEE

This system of prefabrication which has been evolved by the CBRI, Roorkee, is very efficient, speedier and economical. The salient features of this system are:

i. All components used for the construction are prefabricated except foundation which can be either prefabricated or conventional type.

ii. The method of casting is very simple, easy and, therefore, no special skilled labour is required.

iii. Almost all the components weigh below 100 kg means easy to handle.

iv. There are total seven type of components used for the construction.

v. Minimum reinforcement required to be used for the construction.

vi. The most important factor is the flexibility it allows to the designer.

vii. Finally during construction no special equipment or skilled labour required for carriage or during execution of task.

viii. All the components are standardised and can be easily fabricated in factory.

ix. Reduced weight of structure by 70%.

APPENDIX B

This system as already mentioned has only 7 members of components which includes solid panel, window panels, window and door frames, ventilator unit, beams and collar unit. Panels are cast either of 1m x 1m x 0. 10 or of 1m x . 75 m x 0. 10 size. Generally the latter one is used. For better construction only . 75 m or 1 m of construction should be done on any working day. This gives enough time to column and panel to gain sufficient strength for the 2nd layer which is going to come over the first. The sizes of windows and doors are in multiple of . 75 m because this helps in standardisation of various components and restrict the number of total elements in use. No lintel is required for these openings as the post itself is strong enough to take the load coming over it. Even the chhajas are not required to be built as it forms part of door and windows' frame.

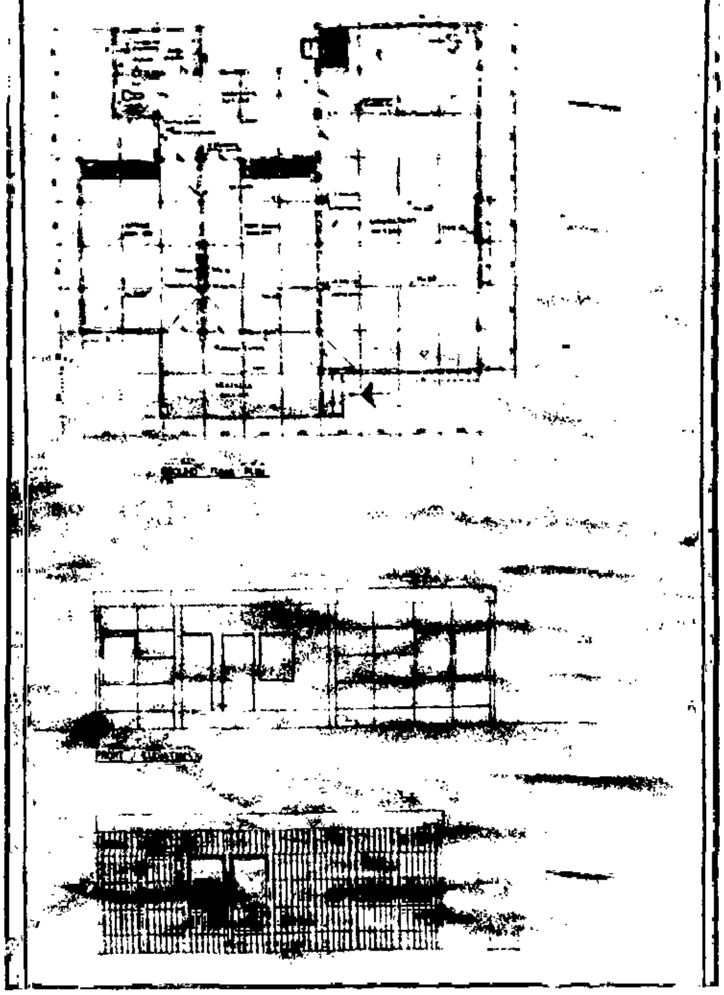
For structural system the column has been used of 10 cm x 10 cm. These columns takes the load of the roof system which is transmitted to the columns through beams and collar units. Columns are to be provided in any one direction preferably longitudinally. Nominal reinforcement is provided. There is no reinforcement provided in the panels which gain its strength because of their geometric shape of hollows.

Over the columns rest the beams which support the roof panels which are again of the same type of panel used for wall construction. Only difference between these two types of panel is that wall panel has a shear key at the edges while roof panel has got L-section at the edges which rests on the beam. Finally 4 to 5 inches thick concreting is done over the slab and beams to make it a monolithic structure.

Foundation can be used both either of conventional type or of prefabricated type. But it is preferable to use the conventional type of foundation with lime concrete base and brick footing. The prefabricated foundation requires highly skilled labour as any difference in levels will create more problems at later stages. Also it is more costlier as excavation has to be done as in case of normal type of foundation plus the transportation of these units which being heavy create more problem of lifting and carriage.

The prototype was constructed for the PWD, Roorkee and was completed within three months almost about half the time required by conventional type of construction. The cost per square feet came to Rs 17 as against Rs 25.00 of conventional type. The cost is expected to come down further to Rs 16.00 when system is adopted on a large scale. Two projects by UP PWD have been undertaken for construction under supervision of CBRI in Ghaziabad.

APPENDIX-B



APPENDIX C

CONSTRUCTION SYSTEM WITH LARGE CONCRETE PANEL

A system using large panel for load bearing walls and floor/roof and bricks for facade walls has been worked out which is known as construction scheme with large concrete panels or mixed type of construction. This type of construction is better thermal insulated and eliminates the problem of water penetration through joints associated with large panel construction. The salient features of the construction are as under:

FOUNDATION

The system being a load bearing wall type, strip type of foundation is adopted. In both insitu and precast foundations, excavation of trench, levelling and compaction of base are common features. However, in case of precast foundations uniform distribution of load may not be attainable because of undulations in the base. Further special joint details between precast strips will be required. In view of these aspects as well as from economical considerations, traditional type of foundation is adopted.

WALLS

The cross walls are load bearing with room-sized prefabricated concrete panels coupled at the intersecting longitudinal walls. The panels are cast at site in a battery of concrete moulds with necessary provision for fenestration and jointing. The other advantages of the battery casting are, it produces self finished surfaces on both faces, thereby avoiding screeding and trowelling associated with horizontal casting, reduces handling stresses, ensures better dimensional control.

The external walls are self load bearing and one brick thick to provide the required insulation. These are constructed in the normal way and different architectural treatments can be provided.

The partition walls are half brick thick or precast concrete panels. Insitu brick wall is preferred as it is easier to provide partition wall of desired configuration to accommodate shelvings.

LINTELS AND SHELVES

Precast lintels on brick work and precast horizontal members in cupboards for shelving are adopted to avoid delays in progress in the brickwork.

FLOOR/ROOF

Room size RC panels prefabricated in battery are adopted which present jointless soffit as insitu work. A typical layout plan based on the scheme is shown in Fig. 1 of Appendix 3.

TRANSPORATION

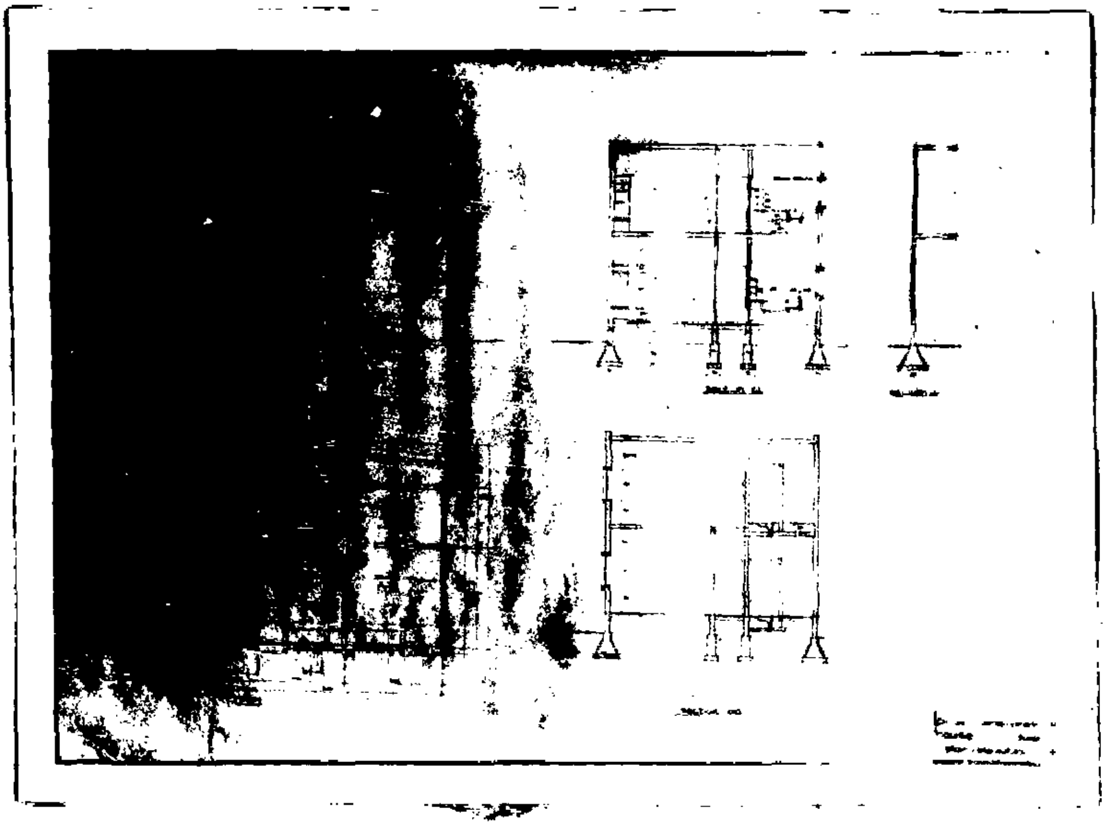
Since the wall panels contain nominal reinforcement for temperature and shrinkage stresses only, these are to be transported in either vertical or inclined position on a special frame fitted to a boggey chesis. Floor slabs are also transported in a similar way.

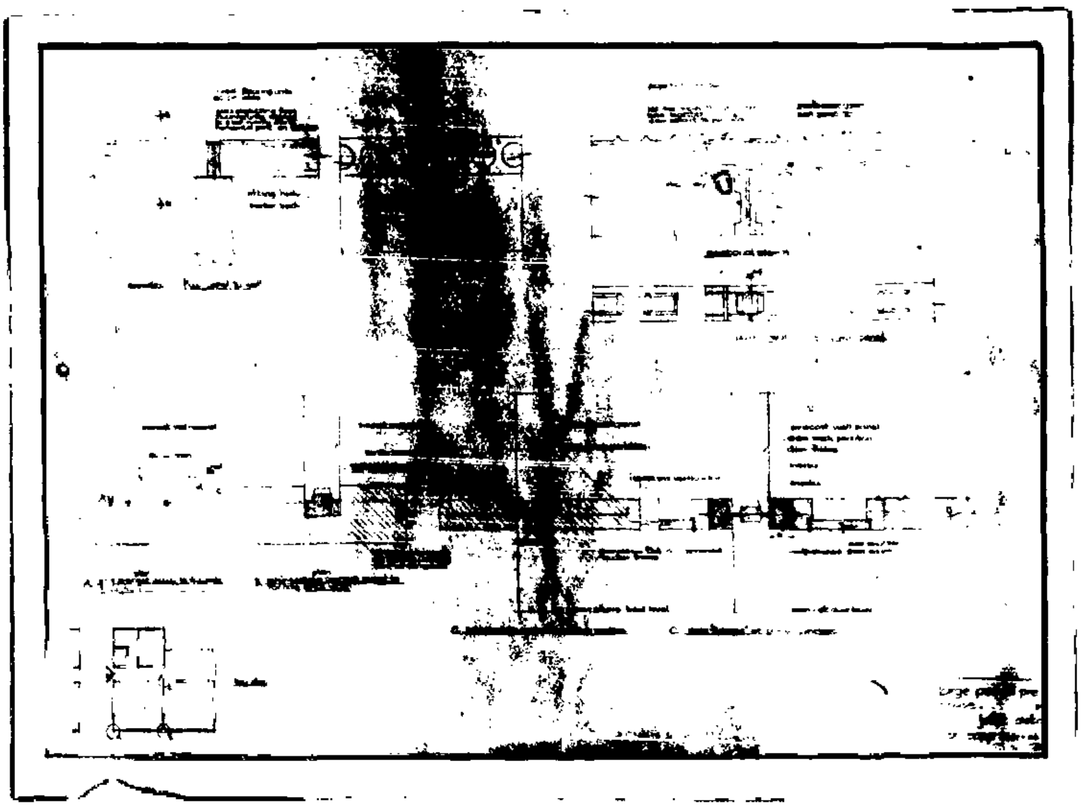
ERECTION

The wall panels are placed with the help of a crane, on the plinth in their respective position. Each panel is supported by two telescopic props before the crane is relieved. These props are subsequently used to bring the panels to true plumb.

The steel bars provided in the panels at top are welded by putting additional bar to join two adjacent panels. The floor slabs are then placed on the cross walls. All vertical and horizontal joints in the panels are concreted in one single operation. The props except those at the end walls are then removed. The end ones are retained till the longitudinal walls have been built. The above sequence of construction is repeated for the upper storeys. All the walls and floor panels have been provided with threaded sockets to which the props are fixed. The construction sequence is illustrated in Fig. 2 of Appendix 3.

One prototype house has been constructed in CBRI and this costs Rs 5,000 more than the normal construction. The main reason given for this is that the system will be economical only when it is adopted on a large scale and for row housing.





JOINT DETAILS

APPENDIX D

PREFABRICATED COLUMNS AND PANELS SYSTEM

In Defence prefabrication system although has been adopted for housing in a larger scale but for the construction of barracks it is still on the preliminary stage. Recently a project has been completed to provide residential and Administrative accommodation for one battalion strength of a unit. Here for the first time all prefabricated components were used and the project was completed within a very short duration and financial resources available. The plan was prepared at Zonal Chief Engineer's office and sent to Hindustan Housing Factory for improvement and correction to meet their requirements.

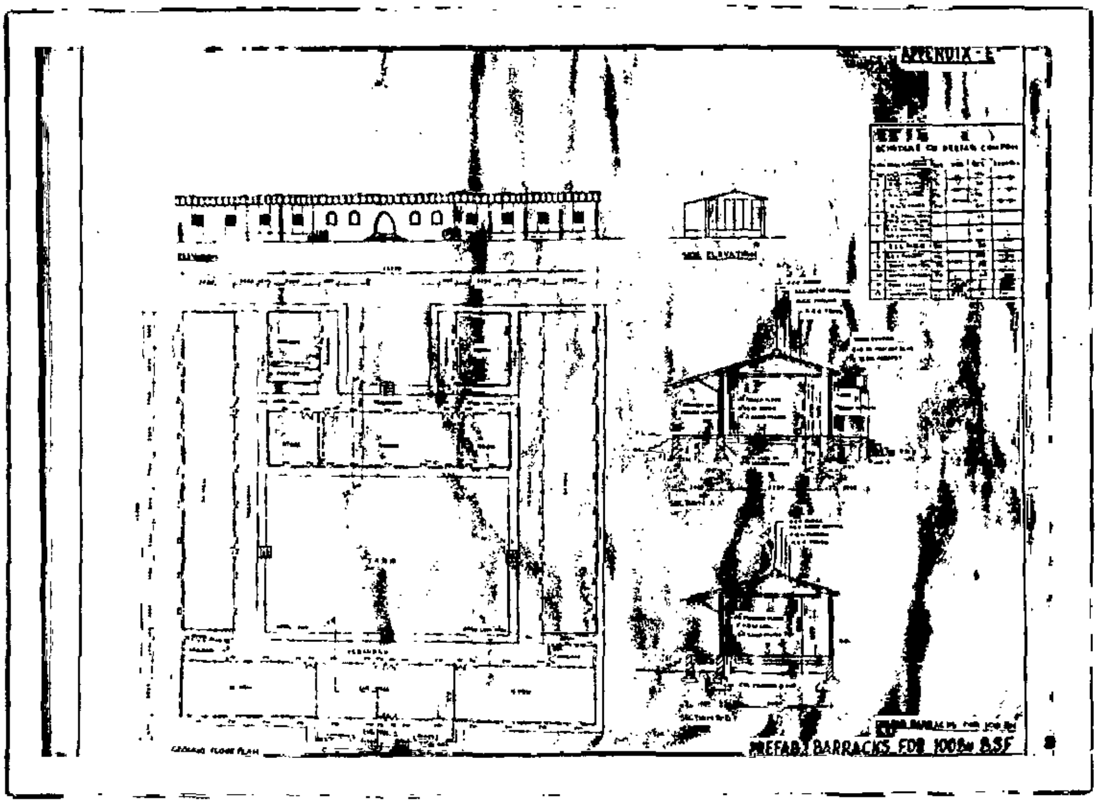
All the components were prefabricated at the factory and then transported to the site, where these were assembled with the help of skilled and unskilled labour. There are only two basic modular panels, one for cross walls and the other for longitudinal walls. All panels are of the same thickness and were produced manually from same type of moulds with little variation. For example solid panels for walls and panels with opening for doors and windows. These openings were created by simply placing inserts in the moulds.

The structural scheme consists of columns and RCC trusses. Columns are used with three different sections at 3.66 m c/c spacing. One type of columns is with truss for 6' verandah while the second one is with a truss for 8' verandah. The third section is without any truss.

For cladding the wall panels are of four different sections. There are different panels for doors and windows end walls. These panels are known as ribbed panels. The standard width of ribbed panels available is 900 mm which has been used in the cross walls only. All other panels which have been used are of 100 mm width with 2900 mm height. Construction of walls with ribbed panels is very simple. The panels are placed side by side and then joints between them are grouted with concrete. The advantage of this is that all shuttering work is eliminated and therefore construction time is cut down considerably.

The roofing system consists of factory made prestressed concrete purlins and RCC trusses. Asbestos cement sheets have been used for roofing with asbestos cement ridge. The total accommodation which is provided for a battalion strength, is scattered in various blocks. Each block providing accommodation to one company strength including kitchen, dining and recreational spaces. Same accommodation has been used for the Administrative block with slight variation.

This project was completed in about six months. The money spent though was less than that of conventional type of construction but it could have been reduced further by saving transportation expenditure if fabrication of components had been done at the site itself.



APPENDIX - E
SIDE ELEVATION
GROUND FLOOR PLAN
PREFAB. BARRACKS FOR 100 Nos. B.S.F

APPENDIX E

Table 1
(Refer to page 19)

SCALE OF ACCOMMODATION FOR DEFENCE SERVICE PERSONNEL (MARRIED)
(in planes)

Sl No.	Appointments	Plinth area	Servants quarter	Garage	Stairs of stair landing/ common passage	Sleep ing out bal cony	ADC room
	Units	FSq	FSq	FSq	FSq	FSq	FSq
1.	Major Gen. in Staff Apptt.	2750	2x240	225	-	-	215
2.	Major Gen. in Comd. troops	2750	2x240	225	-	-	215
3.	Lt. Col. & above	2100	240	225	100	96	-
4.	Major	1500	240	225	100	96	-
5.	Captain	900	-	125*	75	84	-
6.	Lt. / 2nd Lt.	900	-	125	75	84	-
7.	JCOs	800	-	-	75	60	-
8.	Havildars	570	-	-	50	60	-
9.	O. Rs.	570	-	-	50	60	-
10.	NCSE 1/NCS II	365	-	-	54	60	-
	FOR SEPARATED FAMILIES OF DEFENCE SERVICE OFFICERS						
1.	Lt. Col. & above	1500	180	125*	100	-	-
2.	Major	900	180	125	75	-	-
3.	Captain	900	180	-	75	-	-
4.	Lt. / 2nd Lt.	900	-	-	75	-	-
5.	JCOs.	800	-	-	75	-	-
6.	Havildars	570	-	-	50	-	-
7.	O. Rs.	570	-	-	50	-	-
8.	NCSE. I	365	-	-	50	-	-

*HALE GARAGE

Table 2

(Refer to page 19)

FURNITURE AUTHORISATION (RESIDENTIAL ACCOMMODATION)

Sl No.	Description	Lt. Col. & above	Major	Capt.	2nd Lt/ Lt	JCOs	Hav.	ORs	NCSE	Remarks
1.	Almirah steel medium		2	2	2	-	-	-	-	
2.	Bath mat		2	2	2	-	-	-	-	
3.	Bed with MNF		6	4	4	-	-	-	-	
4.	Bin soild linen (large)		1	1	1	-	-	-	-	
5.	Book case		1	1	1	-	-	-	-	Built in
6.	Chair dining		8	6	6	4	-	-	-	
7.	Chair easy		3	-	-	1	-	-	-	
8.	Chair verandah		4	4	4	-	-	-	-	
9.	Chair writing		2	2	2	-	-	-	-	
10.	Drawing board (K)		1	1	1	-	-	-	-	Built in
11.	Durries		2	1	1	-	-	-	-	Where po-
12.	Ladder (for Loft)		1	1	1	-	-	-	-	lished floors
13.	Peg table		4	4	4	-	-	-	-	not provided
14.	Hot-case small (K)		1	1	1	-	-	-	-	Built in
15.	Meat safe (K)		1	1	1	-	-	-	-	"
16.	Pegs set of six		6	6	6	-	-	-	-	"
17.	Plate rack		1	1	1	-	-	-	-	"
18.	Receptacle		1	1	1	1	1	1	-	
19.	Shelving		As per design							
20.	Side-board		1	1	1	-	-	-	-	
21.	Sofa set of 4 seats		1	1	1	-	-	-	-	
22.	Stool dressing		3	2	2	-	-	-	-	
23.	Table bed side		4	2	2	-	-	-	-	

contd.....

Table

(Refer to page)

Sl No.	Description	Lt. Col. & above	Major	Capt.	2nd Lt/Lt	JCO	Hav.	ORs	NCSE	Remarks
24.	Table centre		1	1	1	-	-	-	-	
25.	Table cook		1	1	1	-	-	-	-	Built in
26.	Dining table		1	1	1	-	-	-	-	
27.	Table dressing (Gents)		2	1	1	-	-	-	-	
28.	Table dressing (Ladies)		1	1	1	-	-	-	-	
29.	Table pantry		1	1	1	-	-	-	-	Built in
30.	Table writing		1	1	1	-	-	-	-	
31.	Tea poy		2	2	2	-	-	-	-	
32.	Tea poy verandah		1	1	1	-	-	-	-	
33.	Towel rail		2	2	2	-	-	-	-	
34.	Wardrobe (large)		3	2	2	-	-	-	-	Built in
35.	Charpoy (Newar) with mnf set		-	-	-	4	-	-	-	
36.	Table with drawer (3'x2')		-	-	-	1	1	1	-	
37.	Table without drawer (3'x2')		-	-	-	1	1	1	-	
38.	Almirah 1/2H 1/2S		-	-	-	2	2	2	-	
39.	Charpoy wooden with mnf set		-	-	-	4	4	4	2	Built in
40.	Chair WB without arms		-	-	-	-	2	2	-	
41.	Glass looking		-	-	-	-	1	1	-	
42.	Almiragh (Built in)		-	-	-	-	-	-	1	

APPENDIX G

(Refer to page 96)

VARIOUS C

Sl No.	Type of Component	... of Sizes
1.	Walls: i. load bearing	Constant 300 cm 240 cm 300 cm 360 cm
	ii. Non-load bearing i...	
2.	Roof	...single component thereby ...entire room area. ...sizes are as under: 240 x 240 cm 240 x 300 cm 300 x 360 cm 300 x 480 cm
3.	Door and Window	...ear opening in the wall ...omponent left is 80 x 210 cm ...tandard dimensions inter-...ationally agreed) ...opening for window is ...20 x 120 cm. Sill level is 90 cm.

contd....

Appendix 'F' being a secret documents will be placed at the time of discussion.

APPENDIX G

(Refer to page 96)

Sl. No.	Type of Component	Thickness	Range of Sizes
4.	Partition walls (non-load bearing)	Thickness to vary from 3 to 5 cm	This consists of three sizes with 1M increment to give more flexibility to the designer. i. 50 cm ii. 60 cm iii 70 cm
5.	Sanitary	Sufficient thickness to accommodate pipes etc. Usually - 20 cm or more.	Either in the structural wall itself provision is made for incorporation of pipes by providing hollow cores or separate sanitary components is used of size 60 cm 20 x 20 cm to produce desired length.
6.	Staircase	-	In this case height is constant (300 cm) Dog leg stair case is used. Half landing and half flight is a precast unit. Width of the flight is 110 cm and landing (half) is of size 110 cm x 90 cm clear.

REFERENCES

1. Koncz, T. Manual of Precast Concrete Construction
Vol. I & III
Adler's Foreign Books, Inc., New York, 1971.

2. White, R. B. Prefarbication
Her Majesty's Stationery Office, London, 1965.

3. Lewicki, B. Building with Large Prefabricates
Elsewier Publishing Company, Amsterdam - London - New York, 1966.

4. Kelly, B. The Prefabrication of Houses
The Technology Press of Massachuttes Institute of Technology & John Wiley & Sons, Inc., New York, 1951.

5. - Census of India, Vol. III, Assam, 1965.

6. Govt. of India, National Atlas of India
Ministry of Education & Social Welfare, Govt. of India, 1957.

7. Sikka, S. Report on Industrialised Method of Production 1971.

8. C.B.R.I. Symposium on Standardization in Construction of Buildings.
Central Building Research Institute, Roorkee, December 1971.

9. N.B.O. Report of The Expert Committee on Methods for Achieving Low Cost Large Scale Housing Construction in the Major Cities
National Building Organization, New Delhi, May 1970.

10. Speed and Economy in Building Construction
College of Military Engineering, Pune, 1971.

11. Scale of Accommodation and Space Allocation
Army Headquarters.

12. Manual of Cantonment Planning
Directorate of Cantonment Planning, 1965.

13. Symposium on Prefabricated Housing
Chief Engineer, Eastern Command, Calcutta, Aug. 1970.

14. U.N.O. Organisation of Building Operation in Asia and Far East
United Nations Organisation.

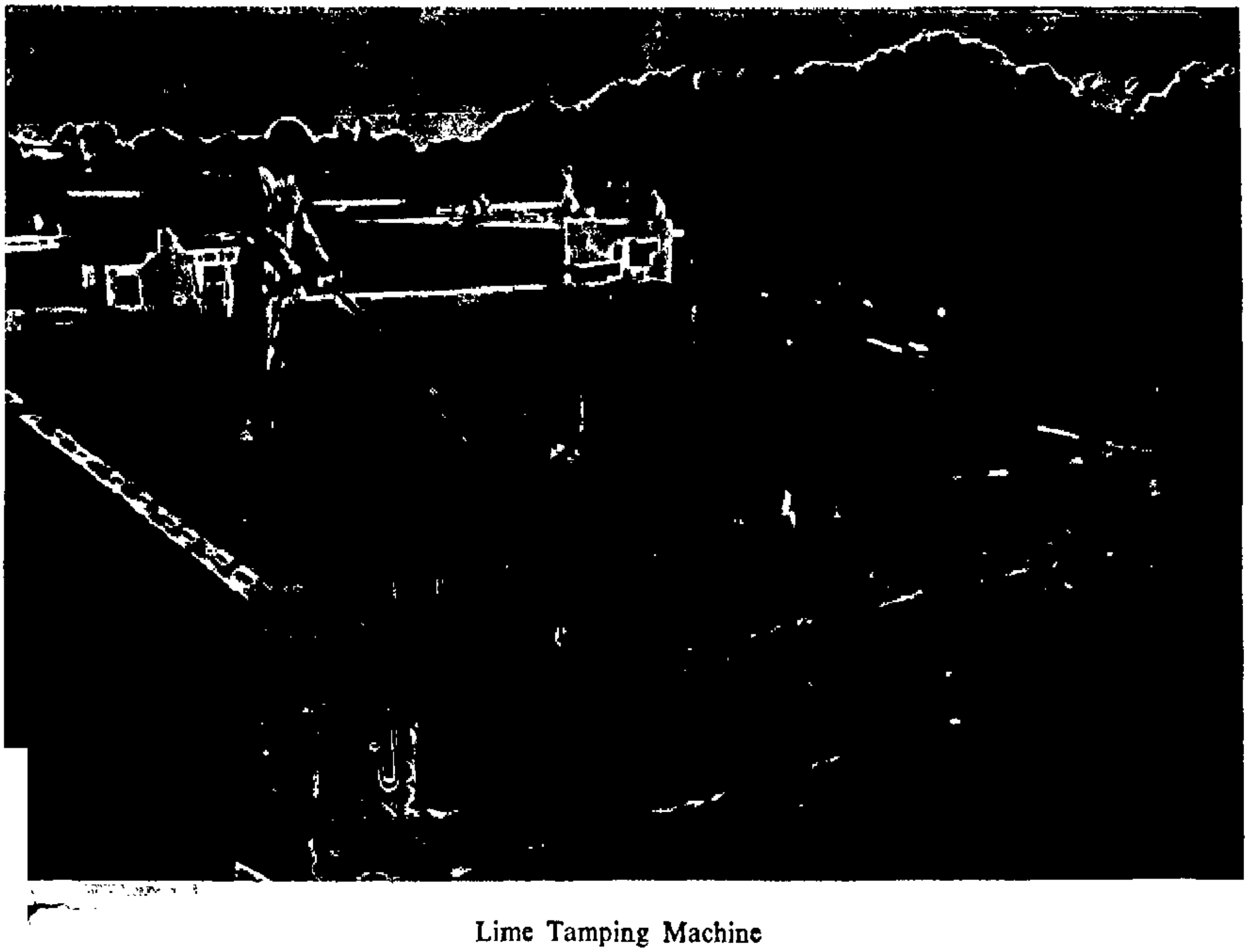
15. C.B.R.I. Climatological and Solar Data for India
Sarita Prakashan, Meerut, 1969.

LIME CONCRETE TAMPING MACHINE

Lime concrete terracing is an effective and cheaper treatment for thermal insulation and water proofing of flat roofs. Such a treatment gives good results only when the lime concrete is properly and adequately compacted. The manual method of tamping suffers from several drawbacks and the quality of hand tamped terracings has not been upto the mark mainly due to inadequate and non-uniform tamping. Further with the rising cost of labour the manual tamping is becoming more uneconomical.

A machine has been developed at the institute for the consolidation of lime concrete. This has proved a more effective means for the compaction and does not suffer from any of the above mentioned drawbacks. The salient features of the machine are as follows :

Prime mover	Electric motor of 0.5 H.P.
No. of tampers	3
No. of blows	1000 per minute.
Self weight	70 kg approximately.
Length (excluding handle)	500 mm.
Width	430 mm.
Height	300 mm.
Output	50 sq metre per hour.



Lime Tamping Machine

The machine tamped terracing have been found possessing more bulk density and better resistance against water penetration. The machine has won National award in 1968. The following firms are manufacturing this machine under licence from the institute through the N.R.D.C., New Delhi.

1. M.S. J. (Engineers) & Co.
   Khanjarpur,
   Roorkee (U.P.).

2. M/s Roorkee Engineering Co.,
   20, Civil Lines,
   Roorkee (U.P.).

POWER TROWEL

Large concrete surfaces such as floors and horizontally cast large panels, are required to be finished in any building project. Although the casting operation has been semi-mechanised in the country but the finishing of the top surface of concrete is still accomplished by hand trowelling. The resulting finish, besides time consuming, is not always satisfactory. A power trowel developed at the institute, performs the finishing operation of concrete with speed and economy as well as ensures better quality control.

The salient features of the machine are :

Prime mover		Petrol engine of 3 H.P. or electric motor of 2 H.P.
Area trowelled per revolution	...	0.5 m^2
R.P.M. of blades	...	30 to 80
No. of blades	...	4
Blade guard ring dia.	...	890 mm
Weight	...	70 kg
Output	...	100 sq m per hour

The machine is simple in construction and can be easily fabricated from indigenously manufactured/locally available standard parts and other materials. It is comparable in performance to similar imported machines.

Power trowel

The machine has been extensively tried in laying floor panels and it has been observed that the machine finished floor panels are of dense structure with a uniform top surface, free of spots, ripples and trowel marks. The use of machine enables finishing of concrete surfaces involving the use of coarse, dry economical mixes of lower slump which otherwise are difficult to manage with by hand trowelling. Because of high speed of trowelling, the machine can be used effectively and economically wherever large concrete surfaces are involved. The use of power trowel is highly recommended for laying industrial and other floors where top surface of the floor has to be highly resistant against abrasion.

IMPROVED METHOD OF PLASTERING

Among the finishing items in building construction, plastering is a major operation and costs about 8 per-cent of the building cost. Plastering is required to conceal unevenness in the background, provide a finish that is smooth, resistance to damage and for ease in decoration. To increase the productive efficiency on plastering operation, a method study investigation which covered the method of working, layout and the tools has been carried out.

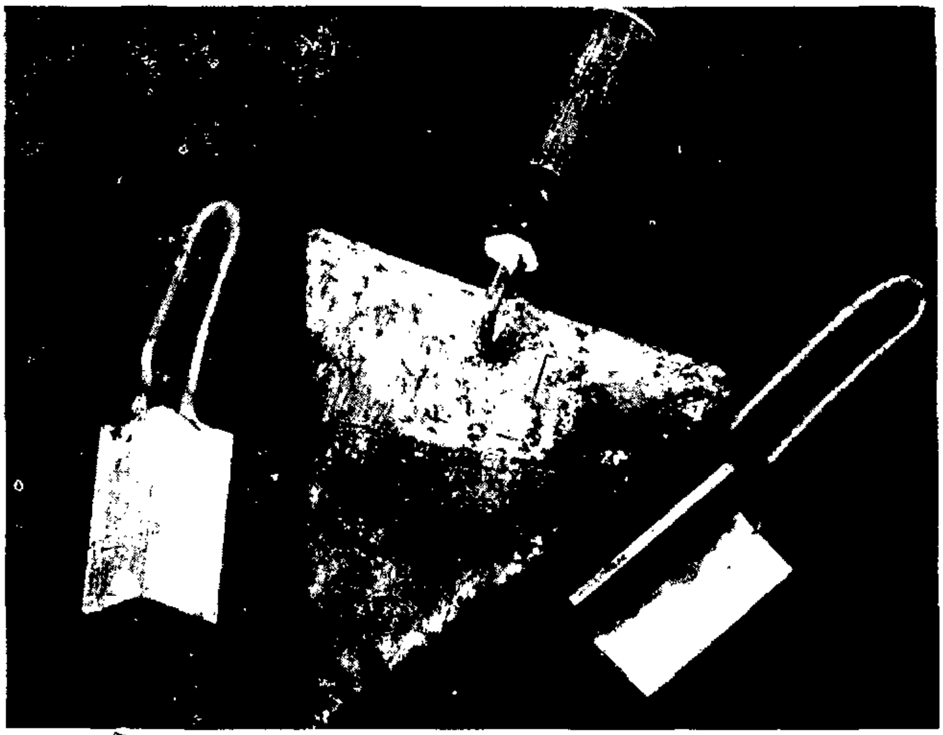
The traditional plastering operation on walls and ceiling is carried out in three stages viz.

(i) Dashing mortar by trowel with a strong wipping motion to obtain intimate bond with the background as well as pressing and spreading the dashed mortar.

(ii) Scrapping and levelling the spread mortar by a wooden screed to bring the surface roughly to level.

(iii) Scouring i.e. vigorous rapid circular motion to even the surface and finally finishing smooth with a float.

It was observed that the plasterer spends 38, 8 and 54 percent of his time in these three operations and the output on an average is 8.45 m^2 per hour. The plasterer uses the same shape and size of trowel as used in brick laying and few tools and implements. The mortar is kept in metal pans which are kept at



Triangular trowel and gadgets for plastering the same level where the plasterer stands. The elevated sides of the metal pan cause hinderance in picking up mortar. Also the plasterer has to bend his body down to pick the mortar and raise to dash it off the trowel on the wall surface. This causes excessive mortar lead and requires greater effort. The dashing and pressing the mortar are the most hazarduous and laborious operations. For a 12 mm thick plaster on wall, the mortar is picked and dashed about 55 number of times to cover an area of 1 m^2 and about 90 number of times the effort is applied for pressing and spreading as the trowel used has a blade area of 140 cm^2 only. Of the 54 percent time spent on scouring and finally finishing smooth, about 36 percent is spent for float finishing and 18 percent on edges and corner finishing.

Improved Method

(a) Triangular shaped trowels.

(b) L shaped gadgets for edges and corner finishing.

(c) Wooden board of 50×50 cm as mortar board instead of metal pans.

(d) A two deck scaffold and tripod.

There is no change suggested in the sequence of operations except that at a time the dashing of mortar should be done for an area of about 1 m^2 or so. The major change is in the size and shape of trowel and use of new simple gadgets. For wall plaster use of 180×220 cm triangular trowel and for ceiling use of 150×190 cm triangular trowel is recommended. The other two smaller sizes viz. 100×125 cm and 40×75 cm triangular trowels are meant for use at the corners, edges, jambs and other restricted areas.

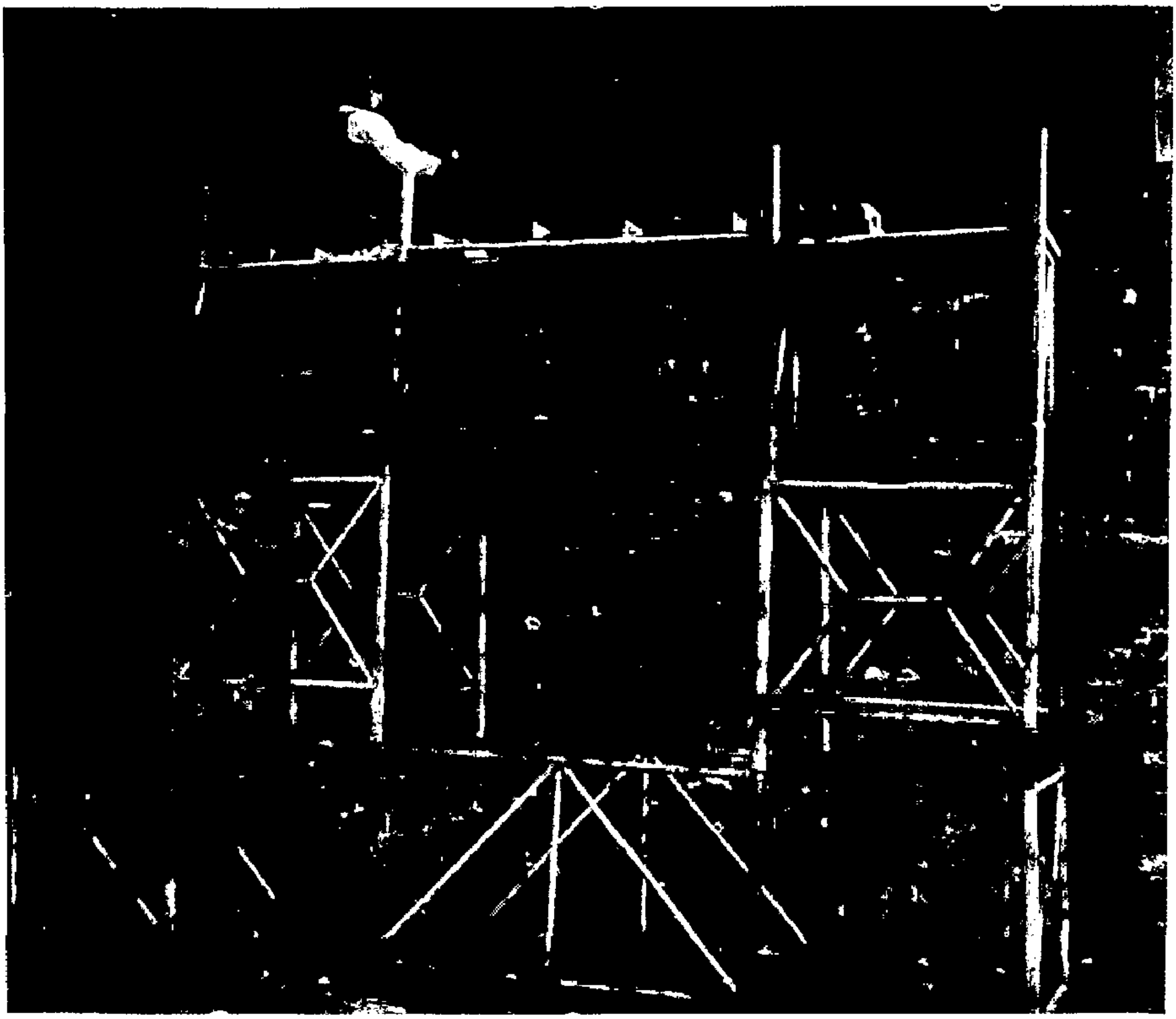
With the help of triangular shaped trowel and having the blade area of about 200 cm^2 the number of trowels full for dashing on the background is reduced by 25 percent and also due to centre of gravity of mortar weight being nearer to the wrist of the plasterer, he can handle more efficiently without incurring extra fatigue due to larger weight. The wooden mortar board allows the plasterer to pick up mortar without any hindrance and placing the mortar at a level 40 cm higher than the level, where the plasterer stands, reduces the load of mortar and the bending effort. The L shaped gadgets enable quick and accurate finishing at the ends and corners. The tools and gadgets are simple and do not require any special training.

Laboratory and field trials with the improved method have been carried out. It has been observed that the overall output of plastering on brickwalls including jambs, lintel edges, corners etc., was 24% higher than that with the traditional method. In case of ceiling plaster an increase of 20% in output was noted.

UNIT FRAME SCAFFOLDING

In the construction, maintenance, or repair of buildings it is common to use scaffoldings. The prevalent practice so far had been to use timber scaffoldings. This suffers from the limitations of reuse, it is time consuming both in erection and dismantling and also calls for experienced labour. In view of these points a 'unit frame scaffolding' has been developed at this institute.

The main advantages of this scaffolding lie in greater rigidity and stability, larger reuse and quickness and ease in erection and dismantling. It consists of simple unit frames each 1 m × 1 m which can be handled by a single person. It does not involve any coupler or threaded joints and can be easily assembled by an unskilled worker. The heights can be varied by one metre or half a metre depending upon the requir-



Scaffold hoist

ment. A novel feature 'Double Decking' at working level has been adopted which enables keeping of materials at higher level than the standing level of the workmen so that the frequent bending and rising for picking and placing the material is reduced thereby giving higher productivity.

This type of unit frame scaffolding can be used upto two storeys without providing any lateral supports and for greater heights the supports at every storey height may be provided from the building under construction or any other existing structure or with the help of guy ropes.

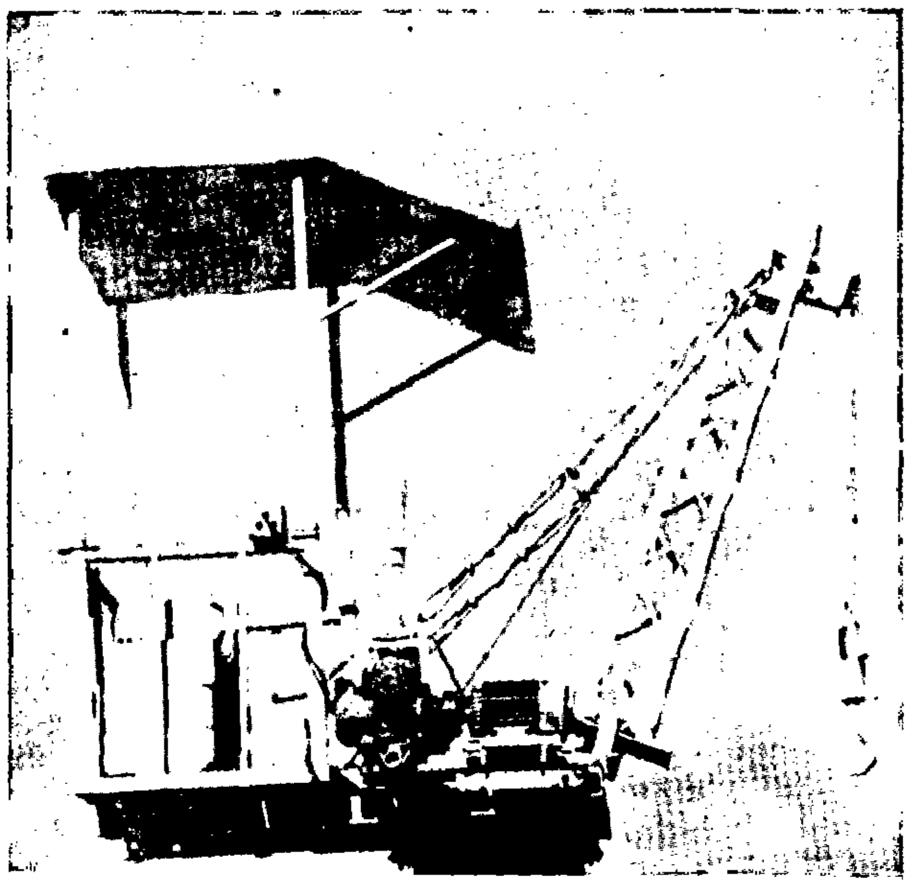
Apart from the unit frame scaffolding, for use of only single storeyed buildings and internal work, a double deck scaffolding consisting of m.s. flat for vertical members and m.s. bars as ties has also been developed. This is cheap and simple to fabricate but is useful only for internal work and single storeyed buildings.

HOIST FOR LIFTING BUILDING COMPONENTS

1. Power Scaffold Hoist

Handling of building components and materials involves considerable time and labour. With the increasing rate of labour, time consciousness for completing a building project and the complexity of new construction techniques it has become desirable to use some mechanical means to aid handling operation. Keeping in view the normal range of building materials more particularly the loads and also the existing demands of a normal contractor, it is the light duty range of material handling in which machines have readily acceptable prospects. Bearing all these ideas, a powered scaffold hoist has been developed. It has following features :

1. Lifting capacity :
   (a) Load ... 50 kg at a radius of 1.5 metres
   (b) Height of lift ... 10 to 30 metres
2. Hoisting speed ... 13 metres per minute
3. Power required ... 2 H.P. Electric motor
4. Boom angle adjustable at 30°, 45° and 60°
5. Motorised swivelling of load through 360° in either direction
6. Self weight ... 350 kg
7. Capable of being split up into number of small assemblies for providing ease in transfering the hoist to different levels.

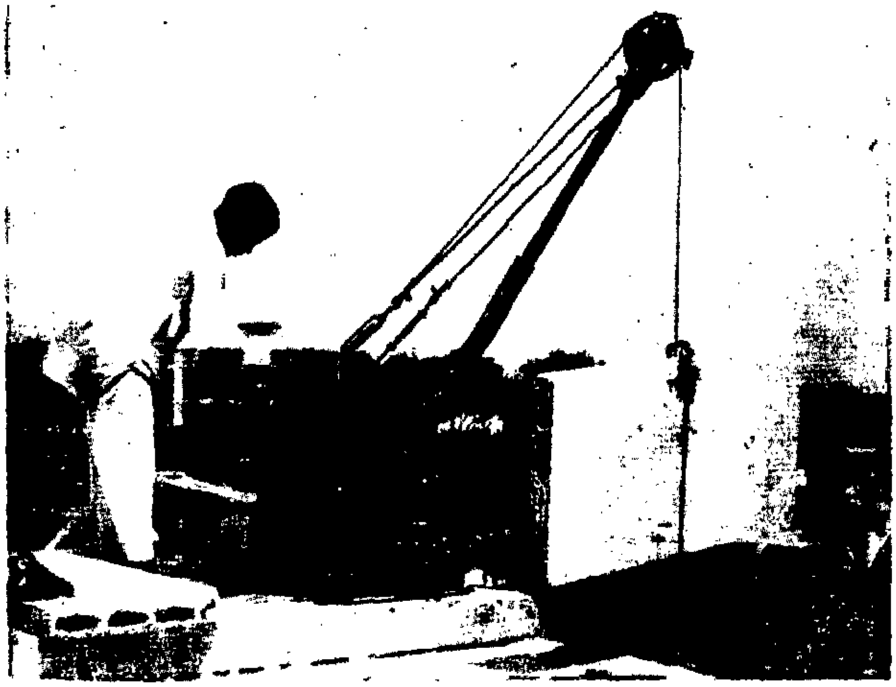


Power scaffold hoist

The hoist can be mounted on 'bally' or steel pipe scaffolding or any other structure. The operation of the hoist is very simple. The unit is compact and possesses a high potential compared to its size and cost for different lifting jobs.

2. Manual Scaffold Hoist

This has been developed to place in the hands of small contractors a cheaper device for lifting loads upto 200 kg at a radius of 1.2 metres and to a maximum height of 10 metres. The unit is very compact and requires no other power source except that a man can easily crank up the load during hoisting. It has an additional feature of swivelling by which it is capable of placing the load suitably by revolving through 360° in either direction. The hoist can be mounted on any type of scaffolding or structure. The self-weight of the hoist is about 100 kg but for ease in transportation from one level to the other, it is capable of being split into a number of sub-assemblies. The hoist has been extensively used at number of construction sites in Roorkee and Delhi and has proved to be a good mechanical aid in material handling.



Manual scaffold hoist

wherever it is possible and convenient. The statement* of Field Marshal Manekshaw in this connection is quoted here. "We must change with social changes, when I joined Army, the soldier never brought his family. He used to gohome on leave very occasionally. But today the men want to bring their families. The attitude is changing".

At present there is a little married accommodation available in Eastern sector. The various stations where married accommodation is either available or has been proposed in the near future are discussed below.

In first Corps area the Cantonments that have come up so far are Binajura where married accommodation has been provided and where area division of this Corps is located. In Siliguri also the construction for married accommodation has been started and the work is likely to be completed in a short time. Gauhati and Shillong are also having married accommodation since they are old Cantonments in this region. A new Cantonment has been constructed at a place called Misa South of Brahamputra on Gauhati Nawgaon road. Married accommodation for one brigade has been provided here. In Tejpur the married accommodation for 2nd Corps HQ is almost on the finishing stage and the families have started moving in. Misamori is also having married accommodation. This is the extension of Tejpur Cantonments. No married accommodation has been provided or planned for a division,

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*See Field-Marshal Manekshaw - Interview In Sainik Samachar, Jan. 1973 there is a proposal to have more housing projects in the proposed new Cantonments which may come up at the places where previously no one thought of taking families.

With this the question arises of the educational institutes and other supporting population required. For education the Central Schools will be provided within the Cantonments. The students therefore will not have any problem of their studies being interrupted when they have to shift places due to the transfers of the officers and other ranks.

For supporting population it is assumed that the local people from around the country side will come and work and will go back. Except the accommodation for servants which has been provided along with the houses. But some accommodation has been catered for essential staff like contractors and teachers etc.

Till July 1973, the following married accommodation has been provided in whole of the Eastern region.

i.	Married officers	1231
ii.	Married JCOs	846
iii.	Married other ranks	4662
iv.	Married NCSE	1260
	TOTAL	7999

By the end of 1975 it is expected that the total accommodation available will be as under:

i.	Married Officers	1350
ii.	Married JCOs	950
iii.	Married O. Rs.	5875
iv.	Married NCSE	1380
	TOTAL	9555

FINANCE*

The Government had sanctioned Rs 152 crores for construction purposes in the Defence. Out of this amount Rs 75 crores had been allocated for housing only. According to Field Marshal Maneckshaw* this amount will be raised by another Rs 15 crores i.e. Rs 90 crores will be allocated for housing projects only in year 1973-74. According to him, Army will be in a position to provide 100% accommodation by 1980.

CLASSIFICATION AND SCALE OF ACCOMMODATION FOR VARIOUS CLASSES OF EMPLOYEES

The scales of accommodation provided in the Tongsa valley project and the types of houses are given below. These scales of accommodation are less than the scales which are provided in the plains or the rear locations. The scales of accommodation in plains and authorisation of furniture are attached as Appendix E (Table 1 & 2).

*See Field-Marshal Manekshaw - Interview In Sainik Samachar, Jan. 1973

The scales provided in Tongsa valley are as under:

Sl. No.	Category	Type of House	Plinth area/ flat sq. ft.	Additional Staircase area/flat sq. ft.
1.	Senior Officers Flat	I	1500	100
2.	Junior Officers Flat	II	900	75
3.	Three-room Flat	III	800	50
4.	Two-room Flat	IV	570	50
5.	One-room Flat	V	400	50

Married accommodation of various types is provided at the following percentage.

1.	*Officers	100%	of auth.	establishment
ii.	JCOs	100%	"	"
iii.	O.Rs. and NCSE	15-50%	"	"

So far in all constructions of MES normal conventional methods of construction were adopted. For the first time prefabrication has been introduced in the first housing project at Tongsa valley in remote areas which is only connected by Cl 9 single line road. (Detailed discussion in chapter 4). Experience gained from here shows that for construction areas like this prefabrication is the best system of construction. With the technically trained team the work at other places

*See Scale of Accommodation and Space Allocation.

is used as frame but instead of the lime plaster mud mixed with cowdung is used as plaster. In the case of Gauhati, Dibrugarh and other towns of Assam, the frame of the walls is generally made of split bamboo to which lime or mud plaster is used. Bamboo is available in great quantities in the plains of Assam and that is the reason why it is mainly used as the main material for walls. What is true of the towns in the plains of Assam is also true of all the villages in the plains of Assam with the only difference that in the rural areas, mud mixed with cowdung is mostly used as plastering material, wherever plaster is used in the rural areas of the plains because the climate is not hot and so they can do without plaster. In the interior of the hills districts of Meghalaya bamboo is also used as a material for walls because of its local availability.

In the United Khasi and Jaintia hills timber is also used in great quantities even in the interior because pine trees are available in great quantities and they can easily be cut into planks and the cost is also comparatively cheap. In the towns in the plains of Assam, bricks are available locally and so many well-to-do people now-a-days use bricks as material for walls. The materials that are not locally available are corrugated iron sheets and cement. These are imported from the factories outside Assam.

The climate and rainfall of a place are great factors in determining the materials of walls. In the United Khasi and Jaintia

Hills where the rainfall is the greatest in the world, many people who can afford it, prefer corrugated iron sheets as material for walls to protect their houses from the rain. Others who cannot afford, use wire-crete or plain sheets in the lower portions of the walls and ekra with lime plaster in the upper portions of the walls to protect their houses from the rain. Similarly in the plains people use brick walls upto about $2\frac{1}{2}'$ to $3'$ from the plinth and ekra walls in the upper portion. The system is locally termed as 'half-walling'. In the highland portions of - United Khasi and Jaintia hill districts - plastering or walling with timber or corrugated iron sheets is common to protect the people from the severe cold in winter. As already stated above, due to the hot climate in the plains many people in the interior do not use any plastering on the walls at all because they prefer some breeze to enter inside their houses to keep off the heat.

Materials of Roof

In the rural areas of Assam the following materials are used for roofing per 1000 houses.

Grass, leaves, reeds, thatch, wood or bamboo in 847 houses, tiles, slate, corrugated iron sheets, lime or metal sheets in 119 houses, Asbestos cement sheets in 9, brick and lime 1, concrete slab 1 and all other materials in 23 houses. It is thus seen that most of the houses in

WHEN PREFAB CONSTRUCTION SUITABLE

Non-Availability of Materials

This is the most important single factor in deciding the type of construction. If the basic materials like sand, stone, timber and water etc. are not available in sufficient quantity or suitable quality it will be easier and more economical to carry light weight prefab components than to carry the building materials.

Shortage of Labour

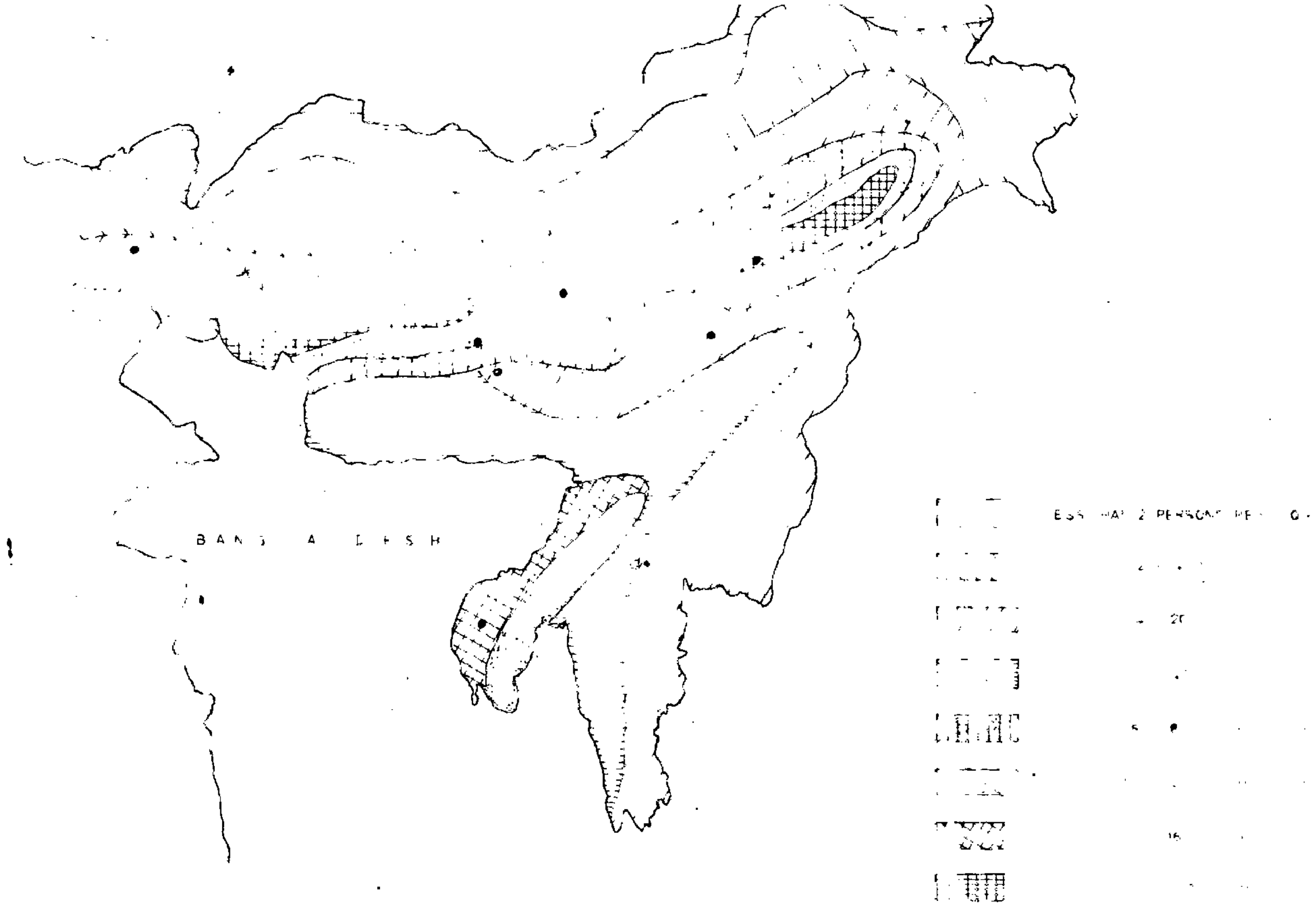
In thinly populated areas where skilled or unskilled labour is in short supply, adoption of conventional construction will be difficult, costlier and slower. In such cases prefab construction requiring minimum labour for erection may be economical.

Limitationof Time

Prefab construction is suitable where a work has to be completed within a specified period, which is not sufficient to complete by a conventional type of construction. This was the only condition why the prefabrication is preferred.

Duration for which Building Required

If certain buildings are required for short periods prefabricated buildings may be raised quickly and dismantled, after they are no longer



HABITABLE DENSITY PERSONS PER SQ KM

*See National Atlas of India

v. In Estern region working time is reduced to barely six months in a year due to heavy rains.

vi. Communication system through vastly improved during the last few years still problematic in northern frontier or in Nagaland or Mizo hills.

vii. Due to these difficulties contractors are hesitant to take up the construction work. In such areas, it may be economical to use prefab components which are light enough to be carried easily and economically and can be erected by relatively few trained men. This will require manufacturing plants as near to the work site as possible e.g. for North Eastern region it will be highly uneconomical to transport prefab components from Calcutta or Delhi. Factories therefore need to be put up at places like Tezpur or North Rangapara etc.

Typical Defence Requirements Necessitating Use of Prefab Components

i. Large number of dwelling units required in plain or remote hilly areas.

ii. Structures like pill boxes, bunkers required in border areas where there is no water or labour available.

iii. Structures required at high altitudes, sometimes requiring air dropping in times of emergency.

iv. Construction of bridges at short notice.

v. Structures like office buildings, SM barracks, Field Hospitals or Advance dressing stations etc.

required. Of course these components will have to be light in weight easier to erect and dismantle.

Prefabrication - Utility for Defence Construction

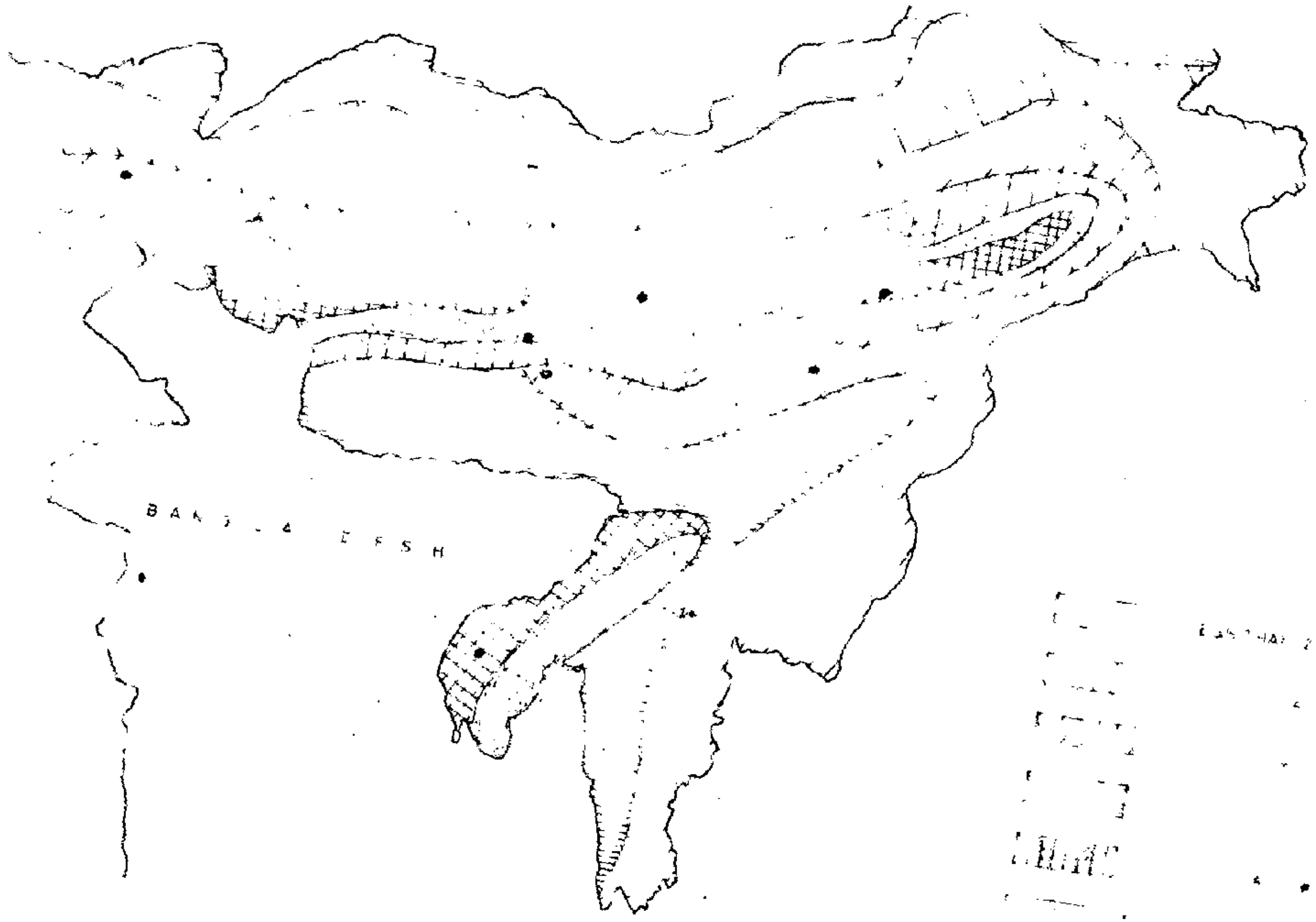
In Defence services the total construction activity is more than in any other single organisation. (Refer Finance in Chapter 1). Good part of this is being done in remote, inaccessible areas which pose some special problems, mainly due to lack of some or all traditional building materials. Some of these areas suffer from most of the limitations which favour adoption of prefabricated construction.

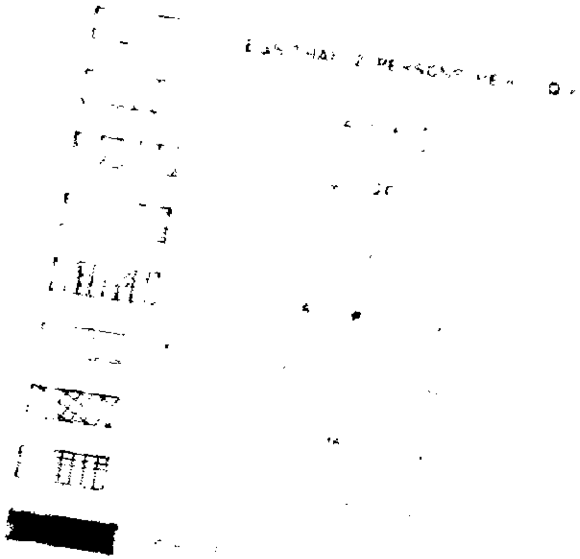
i. Bricks are not available in general. In some areas like parts of Mizo hills, stone suitable for masonry or concrete is also not available. At other places even suitable sand is not available in required quantity or quality.

ii. Though timber is available it is not of the normally specified standards. In areas like Ladakh, Himachal Pradesh, it is not at all available.

iii. Shortage of water is usually encountered at high altitudes and it is necessary more often than not to pump water to heights upto 500 ft or more.

iv. Some of the areas of Eastern Region are very thinly populated and practically no labour is available (Refer to Map indicating density. Troop labour is therefore normally used and has to be supplemented by civilian skilled labour.





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the office with the firms to supply steel at the rail head North Rangapara. Responsibility to transport the steel upto the North Rangapara was of firms, while from North Rangapara to the working site it was the responsibility of the executing agency. For this also the contract was given to the civilians and there were no problems on this account. Because of 1971 war with Pakistan another difficulty arose and this was of Railway wagons. Therefore the bulk of the steel required was transported by road transport. This system incidentally proved much more efficient as it took only 48 hours from Calcutta to North Rangapara while by rail the transportation time taken was more than double. For supply of cement there was no problem and it was always sufficient to meet the requirements.

Another problem was of establishing factory sites or casting yards. As already discussed that the sites were at different places and the distance involved was more to meet the demand of transporting each and every component from one centralized factory. There was also loss of manpower in loading and unloading and chances of more breakages. Therefore the proposal to have a centralise factory was completely ruled out. It was decided to have two casting yards one for the phase one which has bulk of the accommodation and the other for phase two and three combined.

Next problem that came across when it was decided to use some different cladding material* in place of lath plaster over chicken wire mesh. Two alternatives were thought. One was use of bricks and the second was to use hollow blocks. Transporting bricks from plains of Assam was an impossible task and no contractor was willing to come and establish a brick kiln in the locality. Departmentally it was tried to manufacture bricks but with no success. Then the 2nd alternative was used and the hollow blocks were prefabricated (as shown in photograph).

In the initial stages of construction there was tendency of developing crack in the plaster and also it was more time consuming to plaster over chicken wire mesh surface. But after experiments and trials by changing the ratio of cement and sand with different grades the problem of cracks was completely solved and for ordinary plastering, lath plastering was used where the mortar was sprayed over the surface under pressure of 10 to 12 lbs/sq. in. This solved the difficulty in applying plaster over the chicken wire mesh. Plastering over hollow blocks was no problem.

Water supply system is going to be centralise Very little pumping will be required for boosting. In most of the areas supply will be under gravity system.

Electricity is being generated by Kirloskar generating sets. Different generators will be used for different localities till the completion

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*For officers accommodation.