APPROPRIATE BYE-LAWS FOR ENERGY CONSERVATION IN RESIDENTIAL BUILDINGS FOR SOUTH WEST MAHARASHTRA REGION

A DISSERTATION

Submitted in partial fulfilment of the
requirements for the award of the degree
of
MASTER OF ARCHITECTURE

By

PAWAR ANIRUDDHA SUBARAO

DEPARTMENT OF ARCHITECTURE AND PLANNING
INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
ROORKEE-247 667 (INDIA)

JUNE, 2004

CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in this dissertation entitled, **"APPROPRIATE BYE-LAWS FOR ENERGY CONSERVATION IN RESIDENTIAL BUILDINGS FOR SOUTH WEST MAHARASHTRA REGION"** in partial fulfilment of the requirement for the award of the degree of **Master of Architecture**, submitted in **Department of Architecture and Planning, Indian Institute of Technology Roorkee, Roorkee** is an authentic record of my own work carried out during the period from July 2003 to June 2004 under the supervision of **Prof. P. K. Patel**.

I have not submitted the matter embodied in this dissertation for the award of any other degree.

Pawar

Dated: 4th June 2004

Place: ROORKEE (PAWAR ANIRUDDHA SUBARAO)

CERTIFICATE

This is to certify that the above statement made by the student is correct to the best of my knowledge.

Date: 4.6.04

(Prof. P. K. Patel)
Dip. in Architecture, C.E.P.T., Ahmedabad
M.Arch (Buldg. Sc. & Tech.), U.O.R., Roorkee
PG Dip. (Housing, planning, building), I.H.S.
Bouwcentrum, Rotterdam, The Netherlands

Dept. of Architecture and Planning,
Indian Institute of Technology Roorkee.
Roorkee- 247667.

ACKNOWLEDGMENT

Learning does not happen in isolation. Every student learns from his teachers, fellow students, seniors and all learned people around him.

Any activity is complete only after the acknowledgement of the inputs from plural individuals by the beneficiary.

Every input cannot be acknowledged due to the amplitude of individuals and sources, but still an attempt could be made to the effect.

Here, I take this opportunity to do so.

Foremost, I am grateful to His good gracious for giving me an opportunity to attempt learning.

I would like to express my deepest gratitude to my guide **Prof. P. K. Patel**, for his guidance and strong support through the good and bad times.

My sincere thanks go to **Prof. S. Y. Kulkarni**, Chairman PGAPC, **Prof. R. Shankar**, Head of Department, faculty members and non-teaching staff of Department of Architecture and Planning for all the encouragement, help and assistance given to me during my tenure in Roorkee.

I thank one and all; who have helped me directly or indirectly, within and without my knowledge in the completion of this endeavour.

I appreciate the cooperation and support of my friends and seniors, especially I would like to thank ***Sunil E, Gourav R, Arif K, Nilesh, Ratish, Rachna, Sourabh, Yatin, Viren, Kumar, Sunil, Nilesh, Niranjan*** and ***all Jawahar friends*** for the pleasurable and memorable experiences we shared.

I am grateful to **Agarwal Sir** & **Jatinbhai** for the professional insight they have lent.

I cannot express in words my indebtedness to **Shankar Sir** and **Sharda Mam**, who have been a constant source of motivation and inspiration to do the right things in life.

The acknowledgments will not be complete till I express my regards and thanks to **my Parents** for their blessings and encouragement, to my wife, **Prachi** for her support and for standing by me in difficult times. To them I dedicate this dissertation.

Pawar

Roorkee
4th June 2004

(PAWAR ANIRUDDHA SUBARAO)

ABSTRACT

In today's energy scenario the Kyoto Protocol has internationally agreed to Conserve Energy, so as to reduce Greenhouse Gas emissions. To achieve this objective developed countries, where Energy Conservation Legislations are already in practice, are revising the regulations to further make them user friendly and effective. Where as developing countries like India are in the process of formulating Energy Conservation Legislations (evident from the Energy Conservation Act 2001).

In the process of formulating regulations for Energy Conservation in Building Sector, so far the Bureau of Energy Efficiency has formulated Energy Conservation Measures in Commercial and Institutional Buildings. The Housing sector remains outside the purview of the EC Act. It is important to formulate Energy Conservation Codes for the domestic sector as it consumes a considerably large and increasing quantum of energy.

This dissertation examines the precedents to Energy Conservation Regulations for Residential Building Types from the following points of view:

- Procedures for formulating and implementing Energy Efficiency Codes.
- Various types of Prescriptive and Performance Energy Codes.
- Various ways of achieving Code compliance.
- Building elements, which need and can be governed by Codes.

Climatic factors affect the energy performance of buildings and they need to be studied in detail before formulating an Energy Conservation Code. The Climatic Data available is analysed and other needful data is recommended. General and broad data is not sufficient in this area.

In the end appropriate regulations are identified, which can be implemented into building byelaws to achieve energy conservation to a greater extent.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABELS

1 Prologue

"Modern man, for all his impressive knowledge and technological apparatus, often builds less well than did his primitive predecessor. A central reason for his failure lies in consistent underestimation of the environment forces that play upon his buildings and cities, and consistent overestimation of his own technological capacities. Still, the worst he faces is a dissatisfied client. When the primitive architect errs, he faces a harsh and unforgiving nature."

-- Marston FITCH[1]

1.1. Introduction

The preceding quote by Fitch points at the deficient design approach of Architects to design buildings suited to the environmental conditions in which it has been situated. Contemporary Architects depend to a great extent on the mechanical systems of achieving thermal comfort conditions inside the built environment. The extensive use of mechanical means of lighting, ventilation and air conditioning is growing day by day due to the rise in the living standards and comfort expectations of the occupants on the one hand and mechanical equipment becoming more and more affordable on the other. This has led to a remarkable increase in the expenditure of electrical energy to run these mechanical equipments, i.e. operational cost of buildings. This fact was realized most during the "Energy Crisis" of the yesteryears.

Air-conditioned homes are no more a luxury but a necessity of the modern urban dweller. This condition is not because the know-how of building climatically suitable buildings has been forgotten or gone out of practice. Nor is it so because climatically suitable buildings are too expensive to build. One of the primary reason for the non-implementation of the marvelous achievements in research on energy-efficient techniques is that the person who builds a tenement does not stay there, he builds to sell it off to accommodation needy immigrants to the urban areas. This builder is interested in making money thick and fast.

The climatically designed building or energy efficient buildings requires more time in conceptualizing, designing and executing, so also there is slight increase in the initial capital cost of the building. The time and money invested in energy efficient buildings is definitely reimbursed by the considerable saving in the operational cost of the building.

The market forces restrain the builder from going in for energy conservation measures, this fact has been considered by the authorities long ago and steps have been taken to facilitate the increase in implementation of energy conservation measures. The measures taken by authorities include, energy conservation legislations being passed and incentives being given to the complying respondents.

Various methods of energy conservation legislations have been adopted by different governments world over. But since the initiatives have been from western developed countries, their legislations are suited to their requirements of energy conservation, which are dependent on the climate of the particular region.

Today when India has passed the Energy Conservation Act and is about to implement legislation with an aim to conserve energy, it is necessary to study the various legislative approaches and choose a suitable precedent for our own.

In this dissertation the investigator aims to study the different aspects, which are considered whilst choosing a particular legislative approach to Energy Conservation.

1.2. Energy Conservation

Twentieth-century building services, such as heating, ventilation, air conditioning, artificial lighting, and elevators, have led to a great increase in the consumption of electricity; the present energy crisis is due in part to the demands made by them.

The need for construction projects to be sustainable is becoming more widely recognized, partly because of diminishing world energy resources, and partly because recent world developments (like global warming and increasing oil prices) have made those involved in the construction more aware of a new approach to building. We often hear now of buildings with a high environmental rating (e.g. ITC Corporate Office at Hyderabad having a Gold Rating of Green Building), of sustainable development and of improved comfort. The stated objective is to construct comfortable buildings, which use little energy and produce little pollution.

1.3. Climatological Approach

Experience shows that by planning according to climatological rules, in most cases the building costs are not much higher than usual and often there is no difference. On the other hand, the quality of living is improved and using less conventional energy for air conditioning and heating saves money[2]. *A. Bitan* in [2] also emphasizes that there is a need to integrate climatological elements in all levels of planning. Hence the climatological elements, which affect the planning of building, need to be studied, so as to ascertain possible architectural design solutions.

1.4. Legislative Approach

Building energy standards and codes have been developed and used in many countries to provide a degree of control over building design and to encourage awareness and innovation of energy conscious design in buildings. This policy measure is taken by many governments as a means to enhance energy efficiency in the building sector, which typically accounts for 30-50% of the primary energy demand and half of the total electricity consumption[3].

In India the process of preparing the Building Energy Codes has been started. The Energy Conservation Act, 2001 has come into force with effect from 1st March 2002. The Bureau of Energy Efficiency (BEE), a statutory organization set up under the EC Act, is in the process of preparation of energy conservation building codes for different climatic zones. The lacuna in this activity is that the EC Act is applicable only to the designated consumers, which include energy intensive industries and establishments listed in the Schedule; this schedule lists commercial buildings & establishments, but no housing type is included. The overall approach seems to be restricted as the Housing Sector, which constitutes about 50% of the Building Industry has been kept out of the scope of this Act.

Nevertheless, Building Energy Codes for Residential Buildings need to be formulated. There are different requirements of code compliance in different countries, which have to be satisfied for getting building permission. There is a need to study these approaches and the parameters they cater to and choose the right combination suitable in the Indian context.

1.5.Aims and Objectives

This dissertation is aimed at suggesting regulatory guidelines for the Building Energy Code, which would be implemented by the Local Authorities along with Building Byelaws and compliance, would be checked at the time of giving Building Permission.

For arriving at these guidelines the following objectives are decided:

- **To study precedent Building Energy Codes in Other countries**

  There are different approaches to Building Energy Codes viz. prescriptive or performance based, etc. appropriate approach should be adopted. In the process of formulating any legislation it is customary to study similar precedent legislations and their provisions and ascertain their advantages and drawbacks.

- **To study data requirements of Climatological Design**

  Climatological Design requires a proper understanding of the various factors affecting the climate of the place. Much of the analysis depends upon the availability of correct and relevant data.

- **To study the Climatic zones in India**

  There are six climatic zones in India and the climatological requirements are different in each zone. One climatic zone will be studied in detail to ascertain the thermal comfort requirements and the guidelines will be suggested accordingly.

- **To study various latest revised Municipal Building Byelaws in India**

  So as to get an idea of the existing clauses governing the provision of lighting & ventilation in buildings according to the Development Control Regulations.

- **To study the IS Codes governing various Climatological Factors**

  Like the following:

IS:2240-1975 Guide for day lighting of buildings *(second revision)*

IS:3362-1977 Code of practice for natural ventilation of residential buildings *(1st revision)*

IS:7662-1974 Recommendations for orientation of buildings (Part-I) Non-industrial buildings

1.6. Scope and Limitations

Since Climatological Aspects play an important role in Energy Conservation, the Climate of the subject area would deter the regulations required and hence, a specific climatic region and a specific geographical location needs to be decided upon.

Exhaustive Climatic Data availability is restricted to the Meteorological Observation Centers and a city having this facility should be selected.

2. Approaches in Building Energy Standards and Codes

2.1. *Introduction*

Building energy standards and codes have been developed and used in many countries to provide a degree of control over building design and to encourage awareness and innovation of energy conscious design in buildings[4]. This policy measure is taken by many governments as a means to enhance energy efficiency in the building sector, which typically accounts for 30-50% of the primary energy demand and half of the total electricity consumption. In recent years, there has been strong interest in the world to develop or revise building energy codes using a performance-based approach, with the aim to improve flexibility, clarity and effectiveness of the regulatory documents.

2.2. *Building Energy Standards and Codes*

Energy codes can help raise concern and awareness of building energy conservation in the society and overcome the market barriers to energy efficient design in buildings[5]. They can also encourage the development of energy efficient building products and form a basis for assessing building energy performance and developing energy efficiency policy.

Traditionally, building regulations and codes have been prescriptive and they specify for each building component the minimum requirements to satisfy the code, such as minimum insulation levels and equipment efficiencies. Prescriptive requirements are simple to use and follow, but they tend to limit development of new technologies and techniques. Prescriptive codes are not able to consider the interactions between the building systems and measures that would optimize the combined performance. This might serve as a barrier to innovation and make the regulation very restrictive. Therefore, alternative code compliance options are needed to encourage building designers to take a more integrated approach to the design of energy-efficient buildings.

Figure 1 shows the major elements and compliance paths for building energy codes. The major elements include building envelope, lighting, heating, ventilating and air-conditioning (HVAC), electrical power, lifts & escalators and service water heating. The basic/mandatory requirements are fundamental issues that must be satisfied in code compliance. The prescriptive requirements, system/component performance and energy budget/cost are the options available for meeting the criteria of the code. The system/component performance is a partial-performance path and it combines the consideration of several parameters and provides "trade-off" among them in the compliance process, such as the calculation of overall thermal transmission. It can provide more flexibility as compared with the rigid prescriptive requirements. The energy budget/cost method is a full-performance path and will offer the greatest flexibility to manipulate the design parameters since it considers in its evaluation the total energy consumption for the building as a whole.

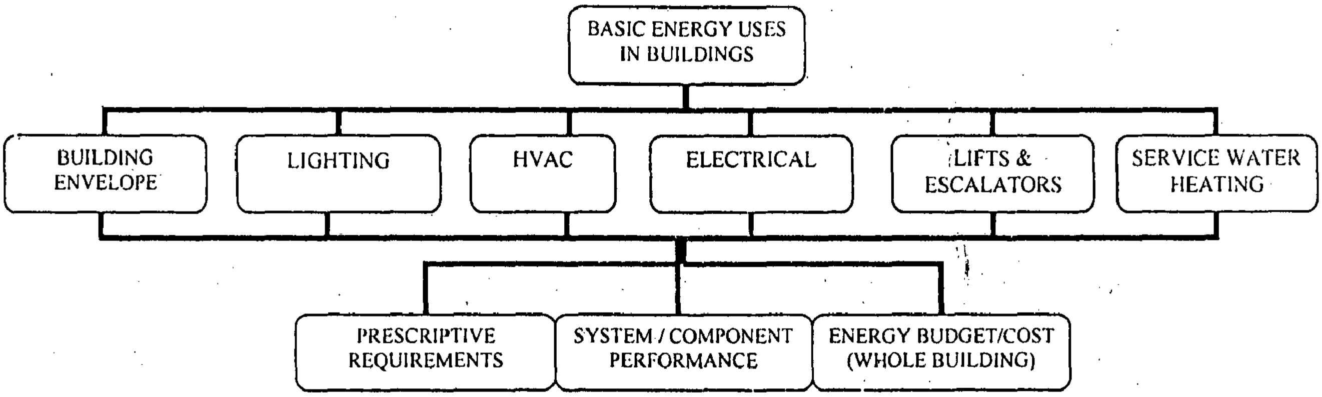


Figure 2.1: Major Elements & Compliance Options for Building Energy Codes

2.3.Performance Based Approach

The term “Performance” is used throughout the world in a regulatory sense yet has many meanings depending on the country and its inherent building environment. Generally speaking, performance means “the objectively identifiable qualitative or quantitative characteristics of the building which help determine its aptitude to fulfill the different functions for which it was designed”[6]. Performance approach is the practice of thinking and working in terms of ends rather than means. It is concerned with what a building or building product is required to do, and not with prescribing how it is to be constructed. In recent years, there is a growing trend around the world to develop and introduce performance-based building codes, such as for fire safety and structural design. The trend towards the performance approach arises from the accelerating rate of change of building technologies, the availability of improved space-planning and design techniques and the higher expectations of the conditions to be provided by buildings[7].

Performance-based building codes state what must be achieved and are therefore by nature very broad and versatile. By the term “performance-based”, it refers to the situation in which regulations are written in terms of the required outcome rather than by prescribing the process by which the specified outcome can be achieved. The adoption of this approach opens up the possibility of new and innovative solutions to the construction process. At the same time it provides a clear definition of the levels of health, safety, and other societal issues that a particular country has chosen to establish as a minimum for its own society. Most performance-based regulatory frameworks are variations of what is known as the “Nordic Five Level System” (see Figure 2). In this system, Level 1 (Objectives) addresses the essential interests of the community at large and/or the needs of the user-consumer. Level 2 (Functional Statements) addresses one specific aspect of the building or a building element to achieve the stated goal. Level 3 (Performance Requirements) specifies the actual requirement to be satisfied. Levels 4 (Verification Methods) and 5 (Deemed-to-satisfy/ Acceptable Solutions) deal with the specifics of meeting the goal. The last two levels are sometimes combined because compliance to a given prescriptive solution (Level 5) is just one of several possible methods of verification (Level 4). Ideally, a performance-based code would also contain a commentary section, which helps clarify the interpretation and application of performance-based provisions. The commentary section explains the basis for each performance criterion and its evaluation or verification.

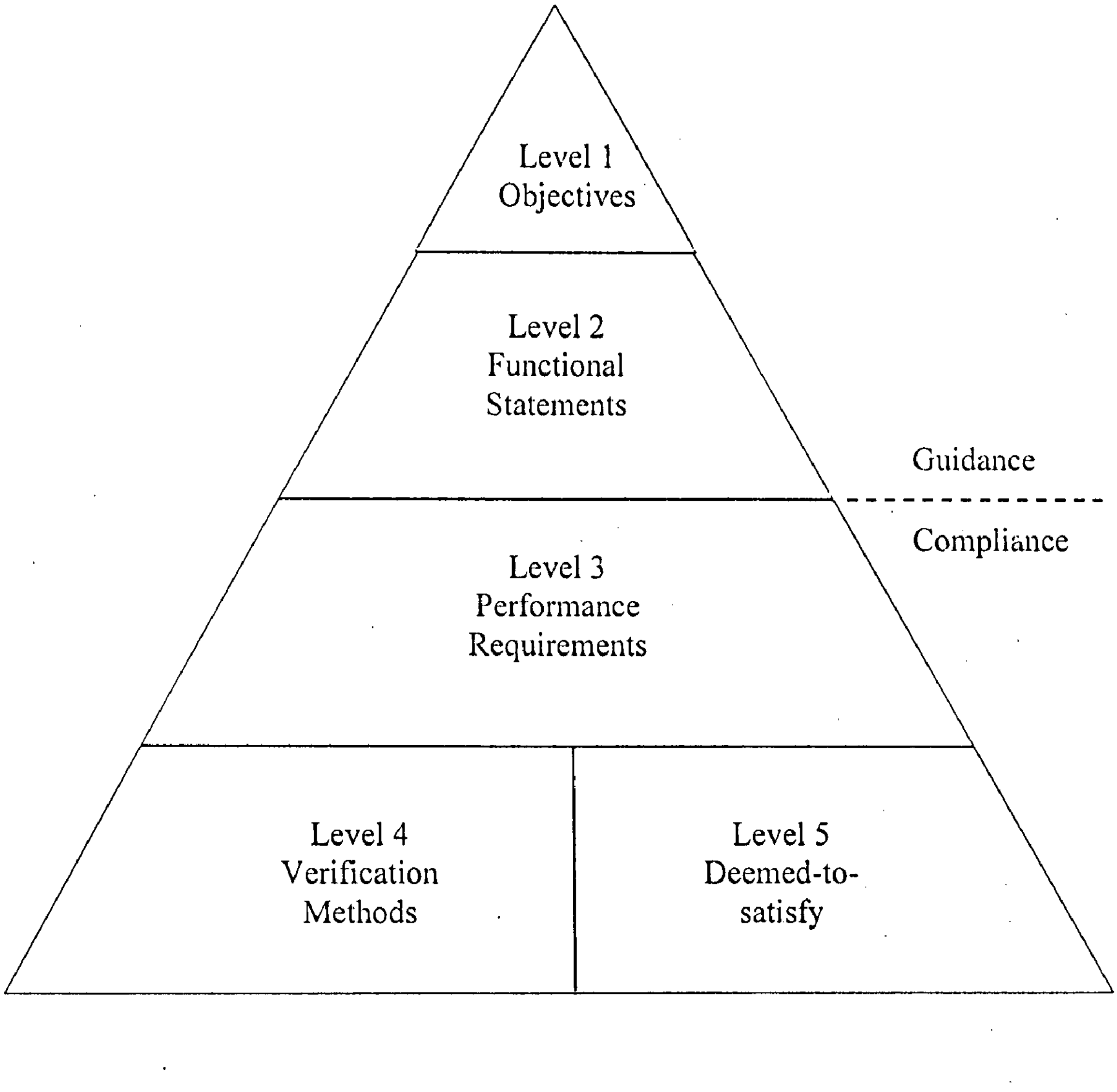


Figure 2.2: Nordic Five Level System for Performance – based Hierarchy

1.1 2.4 Performance-Based Building Energy Code

A performance-based building energy code sets a maximum allowable energy consumption level without specification of the methods, materials, processes to be employed to achieve it. The onus will be on the designer to present a design solution together with appropriate predictive evidence of its energy behavior. Compliance through the performance option will need to study and estimate the likely consumption levels based on the integrated performance of the elements concerned, such as building envelope, lighting and HVAC. But the actual number of areas to be included in the evaluation may vary depending on the purpose and scope of the assessment. The performance criteria is based on calculating the energy consumption for the proposed building and ensuring that it does not exceed an energy budget or target. This approach allows flexibility in the design of the building and individual components, but it often requires the application of rigorous analysis and scientific method to demonstrate code compliance. The energy budget, expressed in kWh or MJ per square meter of conditioned floor area per year, is determined either from a fixed level set out by the policy maker or from a custom-made energy budget for a standardized building. When the later is being used, compliance is achieved if the annual energy consumption for the proposed building is less than the annual energy consumption for a similar building known as the "reference building".

The reference building and the proposed building must have the same energy sources, geometry, floor area, exterior design conditions, occupancy, thermal data, etc. the reference building is designed with its envelope, building elements and energy – consuming systems confirming to the prescriptive requirements for the building elements. Figure 5.3 shows the compliance procedure for performance based building energy code.

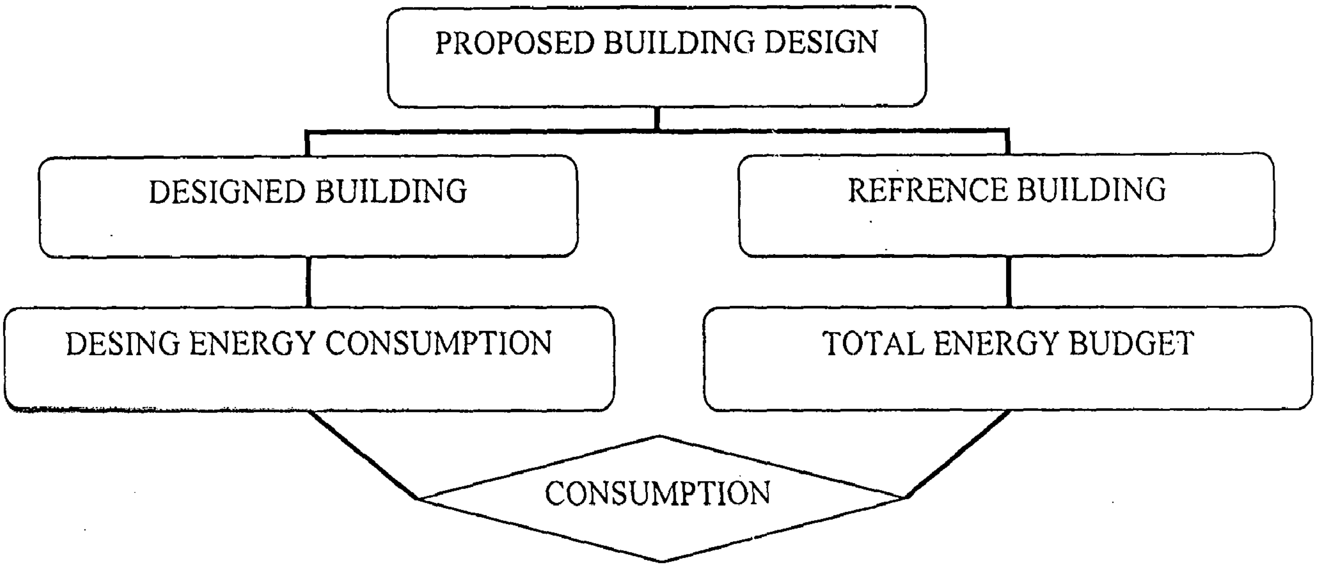


Figure 2.3: Compliance Procedure for Performance – based Building Energy Codes

The performance – based building code allows greater design flexibility and can consider innovative features such as day – lighting, passive solar heating, heat recovery, better zonal temperature control, thermal storage, off peak electrical energy, etc. (Briggs & Brambley 1991)

In most of the countries the performance requirements are described in qualitative terms in the building code; in New Zealand, USA and Canada, the performance is usually quantified. The performance requirements in the Building Code of Australia are deliberately written in a qualitative manner. Qualitative, meaning that they must have certain attributes or qualities to achieve a certain level of performance. An example of this is contained in the Victorian Appendix which states: "A building must have an adequate level of thermal performance to ensure efficient use of energy for internal heating and cooling". On the other hand, some countries like New Zealand have quantitative performance requirements (Isaacs, 1999). They specify a certain level or quantity that the performance of the building or element must achieve. For example the New Zealand's performance requirement states: "The building envelope shall be constructed to ensure that the building performance index shall not exceed 0.13 kWh". In this case, a quantitative measure has been applied to the performance requirement. USA and Canada have been actively promoting building energy codes since the energy

crisis in 1970s. The ASHRAE Standard 90 series is by far the most widely accepted reference model for designing building energy codes in North America and in the world (ASHRAE, 2001). In ASHRAE Standard 90.1 (both the 1989 and 1999/2001 versions), an energy cost budget method is being used to evaluate the whole building's energy performance. This is basically a method that compares annual energy costs of the proposed building to a similar prototype or reference building, using computer-based building energy simulation techniques. In Canada, a similar approach called building energy performance method is being used as an alternative to the prescriptive path for the major building elements. The calculations for this method of compliance must be carried out using software that conforms to specifications set out by the authority.

Some developing countries are trying to establish or revise their building energy codes using the performance approach. For example, Singapore is developing a building energy performance standard using energy analysis method. A Windows-based computer program, called Building Energy STandard (BEST), has been developed to facilitate the implementation of the energy budget method (Chou, 2001). Calculation by BEST is based on a cooling degree-day method, correlated with key parameters such as envelope thermal transfer value (ETTV) and part-load performance. The aim of BEST is to provide a user-friendly tool for people to do compliance checking and evaluate their building design.

In general, the trend In the world for modern building energy codes is to move towards a greater use of building energy simulation and modeling techniques to express building energy performance. Building energy codes need to be flexible to adapt to dynamic conditions such as technological advances. They also should increase incentives for industry to invest in development of more energy efficient technology. However, even in the case of the performance-based provisions, the prescription of a minimum required level is necessary. Most of the codes in use today have a mix of performance and prescriptive language; no code has been written strictly as a prescriptive or performance document. Building energy codes for residential buildings are often more prescriptive with their extensive use of tables and diagrams while the codes for commercial or non-residential buildings lean more to the Performance side. Most design briefs agreed between building owners/clients and designers are a mixture of prescriptive and performance specifications. The more performance-oriented the specification is, the more freedom the designers have to provide alternative solutions or products. A lower-level specification is more prescriptive and constraining. But the higher the level of specification in terms of performance, the more difficult it is to find a universally acceptable method for the verification of performance.

3. Case Study 1: Efficiency Standards for New Buildings

3.1. Introduction

Efficiency standards for the buildings sector concern both residential (single and multi-family) dwellings and non-residential buildings (public and private service sector, and to a certain degree industrial buildings). Buildings make a large contribution to the energy consumption of a country. This is true in cold regions and, perhaps even more so, in hot regions (where electricity use for air conditioning is combined with relatively bad building performance). In the EU, for example, it is estimated that buildings account for 40% of overall energy consumption.

Most OECD countries have set up energy efficiency standards for new dwellings and service sector buildings: this includes all European countries, Australia, Canada, the USA, Japan, Korea and New Zealand (see questionnaire synthesis in Annex 2). Some non-OECD countries outside Europe have recently established mandatory or voluntary standards for service buildings: Singapore and the Philippines were among the first. Several other countries planned to introduce efficiency standards in 2000 or 2001: Mexico, Turkey, Algeria, India, Malaysia, and Indonesia.

This chapter evaluates trends and general features from a selection of countries and regions in order to draw conclusions on more general trends. These are: Australia; California (USA); the EU; Germany; Hong Kong, China; Japan; Poland; Slovakia; Thailand. A summary of the case studies is given in Table 2.2.

3.2.Description of Codes and their Implementation

3.2.1. From component-based to overall performance-based thermal building codes

Thermal building codes exist in many variants, relying on as many different approaches as there are countries. Nevertheless, it seems possible to attempt a classification into five different types (Table 2.1):

- *Type 1: Envelope component approach*

This approach considers the heat transfer (heat losses or gains) through individual components of the building shell, such as external walls, roof, windows, etc. Typically this standard specifies mandatory maximum k-values (U-values) in terms of W/m2K through the individual component, or a minimum heat resistance (r-value). Most early European building codes in the 1970s were of this type, and today it is still often used for single houses.

- *Type 2: Overall envelope approach*

This approach sets a limit on the overall heat transfer through the building envelope, but leaves flexibility as to whether more is done to limit the heat transfer through the walls or the roof or the windows, for example. In Australia, the state of Victoria allows two different sets of component values in order to trade off values for the ground floor against those for external walls. This is a simple way of setting some overall envelope limit. The limit value specified is typically the mean k-value (U-value or thermal resistance) of the building shell.

- *Type 3: Limitation of heating/cooling demand*

This type of code also takes into account the contributions from ventilation losses/gains, passive solar gains through building components (in particular through windows), and internal heat sources. The standard is specified in terms of heating/cooling demand per cubic metre of volume or per square metre of floor area. An example is the building code WSVO 95 currently used in Germany.

- *Type 4: Energy performance standard*

This standard is the first to consider the whole building as a system. It integrates not only the demand for heating and cooling, but in addition all (or most) of the building equipment such as heating and air conditioning systems, energy for ventilation, hot water preparation, pumps, elevators, etc. In particular, it also includes all active solar energy gains from solar collectors, photovoltaic units, etc. The standard is specified in terms of annual (primary or final) energy consumption per cubic or square metre. Examples of this type are the performance standards in California, the new standards in Germany and France, and the proposed EU building code.

- *Type 5: Life cycle standard*

This standard is not yet realised in any country, but is under research. In addition to items covered in Type 4, it would include the energy incorporated in the buildings. This recognises that, as energy consumption of buildings becomes lower and lower, so-called "grey energy" (e.g. energy used to produce the insulation materials) becomes more and more important compared to the direct consumption of the building. This is certainly a matter of further research, and must be made transparent in future building codes.

The most common types of prevailing building code by far are Type 3 and Type 4, i.e. thermal building codes that are performance based. There has been a clear trend away from the component approach prevailing in the 1970s to a performance-based approach. The performance-based approach can be implemented jointly with standards on specific equipment or materials (insulation, windows, boilers), in order to ensure the dissemination of the most efficient equipment in the retrofitting of existing buildings.

Type 1	Type 2	Type 3	Type 4	Type 5
Envelope Component Approach	*Overall Envelope Approach*	*Heating /Cooling Demand Standard*	*Energy Performance Standard*	*Life Cycle Standard*
Limitation of heat transfer (loss/gain) through individual building components	Limitation of heat transfer (losses/gains) through the building shell	Limitation of the annual heating/cooling demand of buildings	Limitation of the annual (final or primary) energy consumption of the building	Limitation of lifecycle energy/ primary energy consumption of the building
k-value (U-value) or r-value of components: W/m^{2}K (or inverse)	Mean k-value (U-value) or r-value of building shell: W/m^{2}K (inverse)	Mean annual heating/ cooling demand per m^2/ m^3	Mean annual (final or primary) energy consumption per m^2/ m^3	Lifecycle (primary) energy consumption per m^2/ m^3
		Includes: Transmission through the building envelope Ventilation losses or gains. (Passive) solar gains Internal heat sources	Includes: All energy consumption for heating or cooling, including heating or cooling system. Energy consumption for hot water including distribution, for ventilation, lighting, motors/pumps, elevator. All energy gains from active solar energy (e.g. PV, solar-collectors. etc)	Includes: Energy use for production of material and products, transport, construction of building, maintenance and decommissioning.

Table 3-1: ComparativeTypes of thermal building codes

3.2.2. Towards a regular reinforcement of building codes

Over the past 20-25 years, in many cases standards have been reinforced two to four times, including some very recent revisions (Table 2.4). In Europe in particular, standards have been continuously tightened whatever the energy price situation. The effort is not yet finished, as eight EU countries were planning to again reinforce their standards after 2000 (see survey synthesis in Annex 2). The cumulative energy saving achieved for new dwellings, compared to dwellings built before the first oil shock, is about 60% on average in the EU. The additional savings that are targeted with future revisions in the standards is still impressive, at 20-30%.

Table 3-2: Number of revisions of thermal building codes

Australia	USA (California)	China	European Countries	Germany
1	2 (+minor revisions)	2	3-4 (on average)	3 (4)
Hong Kong, China	Japan	Poland	Slovakia	Thailand
2	3	3	3	1 (2)

Number in brackets includes planned revisions.

3.2.3. Mandatory versus voluntary standards

All standards considered in the case studies were mandatory standards, although some countries remain with voluntary standards, e.g. Canada. There is no clear argument in favour of one or the other approach. In the case of mandatory standards, it takes in general 5-6 years to introduce revisions, due to consultative and legislative processes. This time period, however, appears short compared to the lifetimes of the buildings. In terms of effectiveness, there is no proof so far that voluntary approaches have been more effective than mandatory standards. Even economies like Hong Kong, China, which in principle put a strong emphasis on the independent functioning of the market, have opted for a mandatory approach.

3.2.4. Types of buildings concerned

Most countries cover the whole buildings sector, although there are cases where the residential sector only (Australia) or non-residential buildings only (e.g. Chile; Hong Kong, China; Philippines; Taiwan, China) are covered. In the latter case, this is motivated by the fact that commercial buildings make the largest contribution to energy consumption, and show the strongest increase. Regulations for commercial buildings are usually less severe than for residential, except in less developed countries and economies, where there are usually mandatory standards for large commercial buildings, but not for dwellings (e.g. Chile; Hong Kong, China; Philippines; Taiwan, China).

Table 3-3: Types of building codes by country or region

	Australia	California	China	European Union	Germany
Degree days[1] Heating Cooling			1431-7159	0-7500 (depending on member state)	3600 -
Climatic zones	By state/territory (ACT: 1, Victoria: 1, South Australia: 3)	16 (S,M) 5 (NR)	15 (by mean outdoor temp. during heating season)	Climatic zones of EU member states	1
Steps [2]	1996 (varies by state)	about 1985	1995 (1996)	2001	2001 (2002)
Type [3]	Type 2; Type 1	Type 4	Type 3/4 ; Type 1	Type 4	Type 4
	Heating/cooling demand	Space-conditioning (heating/cooling); service water heating (SWH), lighting.	Index of heat consumption (heating demand); heat transmission	Heating/cooling demand/supply, building equipment, position/ orientation, heat recovery, active solar + other renewable	Heating demand, heating system, hot water, renewables
Mandatory/ Voluntary	M/V	M	M cold regions	M	M
Typical standard	3 or 4 star rating/ r-value external wall (insulation only!)	External walls (wood frame), package D	Index heat cons.; heat transfer coefficient external walls	Energy consumption (performance)	Heating demand
	1.3-1.7 m²K/W	R13 (about 40 W/m²K)	20-22.7 W/m²; 0.40-1.10 W/m²K	Heating demand under Danish conditions: 50 kWh/m²/year (performance level to be set by member states)	37-92 kWh/m²
Standard varying according size [4]	**S M**	**S M NR**		**S M NR**	**S M NR**
A/V dependence [5]	No	No	Yes	Member states regulation	Yes
Building certificate	Yes (star system)	Yes	No	Yes	Electricity
Distinction energy carriers	No	Yes	Yes (coal)	Member states regulation	Yes
Additional costs [6]	None (economic potential!)			None (economic potential)	

Table 3-4: Types of building codes by country or region (continued)

	Hong Kong, China	Japan	Poland	Slovakia	Thailand
Degree days [1] Heating Cooling		500-2500			
Climatic zones	1	6	1	1	1
Steps [2]	2000	1999	1997	1997	1995
Type [3]	Type 3	Type 3/4 Type 2 (S)	Type 3 (M, S) Type 1 (S, NR)	Type 3	Type 3
	Overall thermal transfer value (OTTV)	Heating/cooling demand + building equipment (NR)	Heat demand	Heat demand	Overall thermal transfer value (OTTV)
Mandatory/ Voluntary	M	M	M	M	M
Typical standard	OTTV	Annual heating + cooling load	Heating demand	Heat demand	OTTV
	30 W/m² (tower) 70 W/m² (podium)	81-128 kWh/m² (S, M)	29-37.4 kWh/m² (S, M)	85 kWh/m² (S, M)	45 W/m² (external walls), 25 W/m² (roof)
Standard varying according size [4]	NR	S M NR		S M NR	M NR
A/V dependence [5]	No	No	Yes	No	No
Building certificate	Yes		Yes	No	Yes
Distinction energy carriers	No	No	No	No	No
Additional costs [6]					

The picture is mixed with respect to a distinctive treatment of single-family, multi-family or non-residential buildings. While some countries require similar standards for all, some countries also use different standards. This takes into account that larger buildings have a much higher degree of complexity and need correspondingly more detailed standards, in particular when it comes to Type 4 standards where all or most of the building equipment is considered.

3.3. The building as a system

The trend towards performance-based standards and the fact that buildings are increasingly understood as a system is best illustrated by the development of standards for non-residential buildings in Japan (Table 2.5). While initially, at best, the building envelope, heating system and/or the air conditioning system were taken into account, over time ventilation, lighting, hot water supply, and elevators have been added.

The necessity for such a trend is immediately evident. While in the 1970s the building envelope was the major component in determining energy consumption, with the improvement in the envelope over recent years other end-uses have become more important. In moderate climates in Europe, for example, with the reduction in demand for heating, it becomes interesting to link electricity generation with heat generation, or to link heating and cooling applications.

In the future, even single family houses could become more complex with the introduction of renewables and other micro-power systems, such as fuel cells, micro-turbines, CHP based internal combustion engines, etc. This will put new requirements on thermal building codes and increase the trend towards the performance-based types of building codes.

Table 3-5: Development of energy saving standards for non-residential buildings in Japan

		Offices			Commodity Stores			Hotels			Hospitals/ Clinics		Schools		Restaurants
Facilities	Year of notification	1980	1993	1999	1985	1993	1999	1991	1993	1999	1993	1999	1993	1999	1999
Heat demand	PAL Mcal/m² * year MJ/m² * year	80	80	72 300	100	90	90 380	110	100	100 420	85	80 340	80	76 320	131 550
Air conditioning	CEC/AC CEC for air conditioning	1.6	1.5	1.5	1.8	1.7	1.7	2.6	2.5	2.5	2.5	2.5	1.5	1.5	2.2
Ventilation	CEC/V CEC for ventilation	▨	1.2	1.0	▨	1.2	0.9	▨	1.5	1.0	1.2	1.0	0.9	0.8	1.5
Lighting	CEC/L CEC for lighting	▨	1.0	1.0	▨	1.2	1.0	▨	1.2	1.0	1.0	1.0	1.0	1.0	1.0
Hot water supply	CEC/HW CEC for hot water supply	▨	▨	▨	▨	▨	1.7	▨	1.6	1.5	1.8	1.7	▨	▨	▨
Elevators	CEC/EV CEC for elevator	▨	1.0	1.0	▨	▨	▨	▨	▨	1.0	▨	▨	▨	▨	▨

Source: Energy Conservation Center, Japan

3.3.1. Reduction of complexity

In the trend towards performance-based thermal building codes, many countries have developed computer tools to allow professionals to evaluate the performance of a building. Verifying compliance with the codes has become a rather difficult mathematical exercise. For example, California has tried to reduce the complexity of the calculations by defining in its standards preset packages which can help professionals, and also home owners, to check whether buildings correspond to the latest norm.

3.4. Software Compliance Approach

1992, 1993, and 1995 Model Energy Code Version 2.07 are implemented in the U.S. The Building Energy Standards Program at Pacific Northwest National Laboratory developed MEC *check* for use by the U.S. Department of Housing and Urban Development (HUD) and the Rural Economic and Community Development (RECD) under contract with the U.S. Department of Energy's Office of Codes and Standards.

3.4.1. Focus of Model Energy Code:

The Model Energy Code (MEC) contains energy-related building requirements applying to many new U.S. residences. The U.S. Department of Housing and Urban Development (HUD) loan guarantee program requires compliance with the MEC. The Rural Economic and Community Development (RECD, formerly the Farmer's Home Administration) loan guarantee program requires that single-family buildings comply with the MEC. Several states have also adopted the MEC as their residential energy code.

A major focus of the MEC provisions is on the building envelope insulation and window requirements, which are more stringent in colder climates. Other requirements focus on the heating and cooling system (including ducts), water heating system, and air leakage.

3.4.2. Scheduled Buildings:

The MEC applies to new residential buildings, three stories or less in height, and additions to such buildings. Residential buildings are defined as detached one- and two-family buildings (referred to as single-family buildings) and multifamily buildings (such as apartments, condominiums, townhouses, and row houses).Multifamily buildings have three or more attached dwelling units.

Throughout this workbook, generic references to "building(s)" signify residential buildings three stories or less in height.

3.4.3. Exemptions:

The following building categories are exempted from the provisions of the MEC:

- Existing buildings
- Very low-energy buildings (<3.4 Btu/h*ft or 1 W/ft)
- Buildings (or portions of buildings) that are neither heated nor cooled
- Buildings designated as historical.

3.4.4. MEC compliance demonstration:

Commercial buildings are required to use ASHRAE Standard 90.1-1989 by reference, the 90.1 codified version, or Chapter 7 of the 1998 IECC. The U.S. Department of Energy has developed COM check-EZ, a simple, prescriptive approach to demonstrating compliance with commercial energy codes.

Methods for residential buildings include the use of a computerized building simulation tool to determine the energy use of the proposed design; a component-by-component approach that uses tables in the code appendix; and a whole building trade-off approach. The U.S. Department of Energy has developed a compliance tool set, MEC check, which makes it fast and easy for designers and builders to determine if new homes and additions to existing homes meet the MEC requirements.

4. Case Study 2: ECODOM Std. in French Tropical islands

4.1. Introduction

This is the case study of global quality standards for natural and low energy cooling in French tropical island buildings. Electric load profiles of tropical islands in developed countries are characterised by morning, midday and evening peaks arising from all year round high power demand in the commercial and residential sectors, mostly due to air conditioning appliances and bad thermal conception of the building. In early 1995, a DSM pilot initiative has been launched in the French islands of Guadeloupe and Reunion through a partnership between the French Public Utility EDF, institutions involved in energy conservation, environment preservation (ADEME) and construction quality improvement, the University of Reunion Island and several other public and private partners (low cost housing institutions, architects, energy consultant, etc.) to set up a standard in the thermal conception of buildings in tropical climates. This has led to definition of optimized bio-climatic urban planning and architectural design, the use of passive cooling architectural components, natural ventilation and energy efficient systems. The impact of each technical solution on the thermal comfort within the building was evaluated with an airflow and thermal building simulation software (CODYRUN). These technical solutions have been edited in a pedagogical reference document and have been implemented in 300 new pilot dwelling projects through the year 1996 in Reunion Island and in Guadeloupe island. An experimental follow up is still in process in the first ECODOM dwellings for an experimental validation of the impact of the passive cooling solutions on the comfort of the occupants and to modify them if necessary.

4.2. Background

Each year 20,000 dwellings are built in the French Overseas Departments. There are four French Overseas Departments (DOM): two islands are located in the Caribbean (Martinique and Guadeloupe), one situated 400 km to the east of Madagascar in the Indian Ocean (Reunion Island) and the fourth Department is in the North of Brazil (French Guiana). Each experiences a hot climate, tropical and humid in the islands of Guadeloupe, Martinique and Reunion and equatorial in French Guiana. Three quarters of this development is welfare housing. Initially this new housing was built without the comfort of air conditioning or hot water which has led to the haphazard installation of instant electrical hot water boilers and badly situated, thought out and maintenanced individual air conditioning systems. The lack of thermal regulations, combined with a building design widely inspired from temperate climates and the economic constraints of a tight budget for construction have led to the development of buildings totally un-adapted to the tropical climate. The large population increase in the DOM, the rise in living standards, and the decreasing costs of air conditioning appliances constitute a real energetically, economical and environmental problem.

When considering the economical aspects, the high production cost also generates a continual high deficit for the French Electricity Board (EDF). EDF losses 350 millions Euros every year in overseas departments. The average selling price of electricity is less than 9 Euro cents (less then half than the real production-distribution cost) because of the French pricing policy (selling price of electricity is the same as in mainland France).

All these factors point out that passive solar cooling in thermal conception of buildings is therefore of great economical, social and environmental importance. A long term overall programme to improve comfort and energy performance in residential and commercial buildings has been set up in the overseas territories.

In the new housing sector, a quality standard seal has been launched concerning the building structure, the hot water production systems and the air conditioning appliances.

4.3.THE ECODOM STANDARD

A Demand Side Management pilot initiative called ECODOM was launched in early 1995 in the French islands of Guadeloupe and Reunion through a partnership between the French electricity board (EDF), institutions involved in energy saving and environmental conservation (ADEME) and construction quality improvement, the ministries of Housing, Industry and the French Overseas Department, the University of Reunion island and several other public and private partners, such as low cost housing institutions, architects, energy consultants, etc...

4.3.1. The objectives

The ECODOM standard aims to simplify the creation of naturally ventilated comfortable dwellings whilst avoiding the usual necessity of a powered air-cooling system consuming electricity. The ECODOM standard provides simple technical solutions, at an affordable price.

The existing bibliography in the passive thermal design of buildings is extremely rich and various. Publications often focus either on the optimization of one component of the building (Bansal,1992)[8], (Malama 1996)[9], (Rousseau 1996)[10] (Peuportier, 1995)[11] or on the presentation of a performant bioclimatic project (Filippin et al, 1998)[12], (Ashley and Reynolds, 1993)[13] or on a global approach of the building with a description of the passive solar options to apply on it (Garg, 1991)[14], (Hassid, 1985)[15], (Millet, 1988)[16], (Gandemer 1992)[17]. These publications often present an obvious interest for the building physicians but cannot be easily integrated in a national overall program to improve the thermal performances of building because the scientific language is often far from the economical building reality.

Architects and engineers lack of time to appropriate themselves the scientific tools and to read all the research reports in the fields of thermal design of building. Thus, to bridge the gap between building designers and building physicians, a simple, common, and instructive language must be spoken. One of the objectives of the ECODOM project was to define simply rules that can be easily understood by the whole building community. A reference document comprising a instructive presentation of the technical passive options was published in 1996. This document allows all the building designers to speak the same language in the study of futures ECODOM buildings.

Once the document made, the next step was obviously to implement the standard to 300 pilot new dwelling projects throughout the year 1996, then, after a technical and social validation period, to expand this pilot phase in the residential sector on a much broader scale (2000 new dwellings per year), and complete similar global energy efficiency projects in existing housing and large and medium size commercial buildings.

Finally, ECODOM has also social objectives because more than half of the 20,000 dwellings in the French overseas departments are constructed by public housing companies. This allow to give minimum comfort for people who will never be able to afford air conditioning investments and subsequent electricity bills.

4.3.2. The prescriptions[18]

Comfort level is reached through an architectural building design adapted to the local climate: the dwelling is protected from the negative climatic parameters (the sun) and favors the positive climatic factors (the wind).

The achievement of a good level of thermal comfort necessitates the application of a certain number of compulsory rules. These rules concern immediate surroundings of the dwelling and its constituent components. They cover five points:

4.3.2.1.Location on site (vegetation around the building);

4.3.2.2.Solar protection (roof, walls, windows);

4.3.2.3.Natural ventilation (exploitation of trade winds, and optimized ratio of inside/outside air-permeability of the dwelling) or mechanical ventilation (air fans);

4.3.2.4.Domestic hot water production (servo-controlled night electric drum, sized according to requirements, solar or gas water heaters);

4.3.2.5.Option, air-conditioned bedrooms (closed room and efficient, regulated appliances).

For each section, a choice of technical solutions is proposed to guide the architect in the design of the building without using a dynamic simulation tool.

4.4.METHODOLOGY

To reach these quality standards, an important number of simulations were computed on each component of the building in order to quantify the thermal and energetic impact of each technical solution on the thermal comfort within the building.

The work of various authors on specified problems concerning the outside structure of the building: (Bansal, 92) on the effect of external colour, (Malama, 96) on passive cooling strategies for roof and walls, (Rousseau, 96) on the effect of natural ventilation, (De Walls 93)[19] for global considerations on the building adapted for a defined climate, has been used in the simulation process. ECODOM approach consisted in the study of typical dwellings, selected as the most representative type of accommodation built in the Reunion island, in terms of architecture and building material (see figure 1).

The simulations were carried out with the use of a building thermal and airflow simulation software on the constituent components (roof, walls, windows) and on natural ventilation, in a way to estimate the influence of each of the above prescriptions, in terms of thermal comfort and energetic performances. This has led to the definition of performant passive technical solutions for each comprising part of the structure and likewise a minimum ratio to optimise the natural ventilation.

4.4.1. Example of Implementation: the Phoenix project[20]

Now let us see an example of the working method applied in all ECODOM projects. The 'Phoenix' project was set up in the north-east of Reunion island, which is and area with extreme weather conditions (intense sunshine, high temperatures and little wind). 66 low cost dwellings are involved, divided into two large building blocks (see Figure 4.1). The buildings labeled A-F have three or four floors, and the buildings G-J have two floors. The first plans were drawn up at the beginning of 1999, and the project was completed in June 2001.

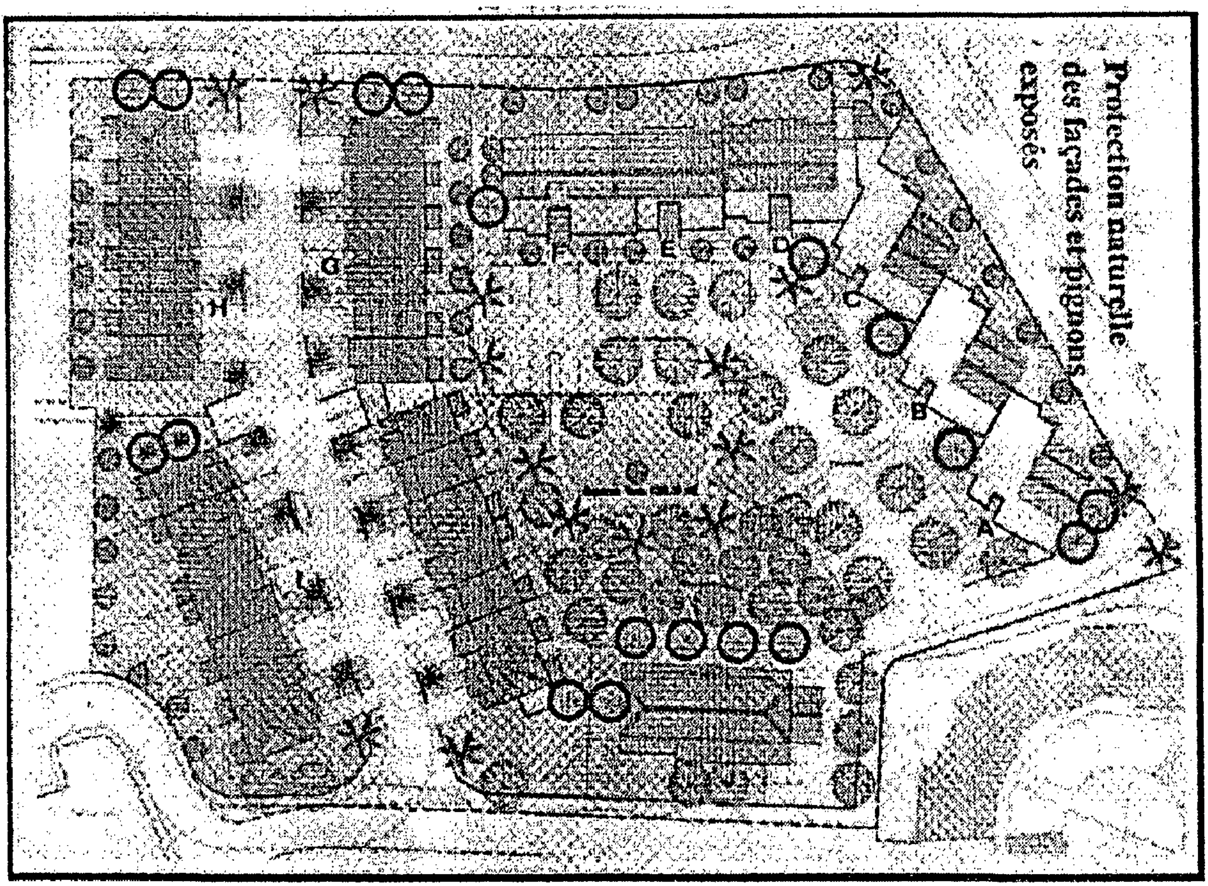


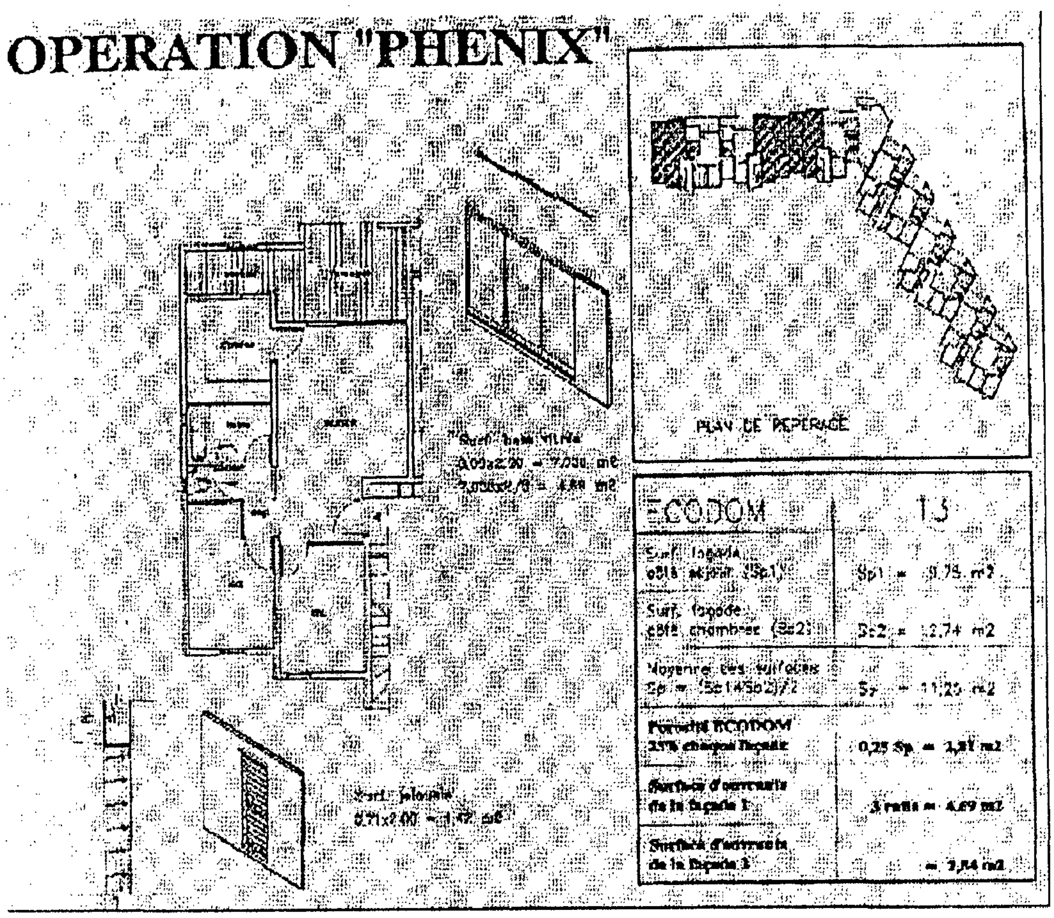
Figure 4.1: Overall plan of the Hibiscus operation. Description of the main ECODOM principles at the sketch stage. Description of solar protection as a function of the orientation of the buildings, and *introduction of vegetation.*

4.4.1.1.Sketch of the project

This is our first contact with the architect and the construction project leader. The essential elements of the project are covered (peripheral vegetation in the building grounds, solar protection of the roofing and the exterior facades, natural ventilation and cross-ventilated buildings). At this first meeting, the overall plan is studied and some modifications are suggested. In Fig. 4.1, the vegetation is already placed to protect the exterior facades, which would be directly exposed to solar radiation.

4.4.1.2.First stage of the project

This second phase with the architect allows us to work on the inhabited quarters. The architect shows us the plans for these quarters. At this stage of the study, the dwellings are identified by type (T2, T3, T4, T5, where T is the code for an apartment, and the number refers to the number of bedrooms plus the living room). For each dwelling type, porosity calculations are performed during the meeting, using the working document (which requires 25% of the average of two exterior facades), in order to correctly dimension the external openings. In this way, the architect knows which surfaces are required to ensure good ventilation in the dwellings, and can reflect on the best solution. The different kinds of solar protection for the openings are demonstrated, but the dimensions are not calculated at this stage.



ECODOM	T3
Surf. façade côté séjour (Sp1)	Sp1 = 9,75 m2
Surf. façade côté chambres (Sp2)	Sp2 = 12,74 m2
Moyenne des surfaces Sp = (Sp1+Sp2)/2	Sp = 11,25 m2
Porosité ECODOM 25% chaque façade	0,25 Sp = 2,81 m2
Surface d'ouvrants de la façade 1	3 vantaux = 4,69 m2
Surface d'ouvrants de la façade 2	= 2,84 m2

Figure 4.2: Example of an ECODOM calculation sheet produced by the architect and the .thennal engineer at the first stage of the project. Iterations through to the detailed project.

4.4.1.3.Detailed project

This third meeting allows us to iterate and validate the calculations performed in the previous meeting. For each type of dwelling, the architect prepares a calculation sheet of the kind shown in Fig. 4.2. The architect and the thermal engineer validate the porosity calculations and the technical choices for woodwork. The example in Fig. 4.2 shows a T3 type dwelling, which is a two bedroomed apartment with a living room. The porosity of the dwelling should be 2.81 m2 on each facade. In the living room, this is achieved with a sliding French window composed of three casements, and in the bedrooms, two aluminium slatted blinds each providing a porosity of 1.41 m2, giving 2.82 m2 for the facade. The dimensions of the solar protections for these blinds are also calculated at this time. For the living room, this protection is provided by the verandas and balconies, and for the bedrooms, by a concrete prolongation of the wall and by opaque panes built into the slatted blinds. With regard to the interior architecture, the positioning of the doors is investigated to optimise the airflow; the architect tries to place them perpendicular to this flow. We also check that the porosity is as required in the interior of the dwelling. In our example, the bedroom doors each measure 1.6 m2, which gives an interior porosity of 3.2 m2, which is in excess of the required figure. A sheet equivalent to Fig. 4.2 is available for every type of dwelling in the operation.

The architect also refines the work on the facades. The collaboration with the thermal engineer allows the inclusion of colour schemes on the facades once these have efficient solar protection (see Fig. 4.3).

This detailed project stage is extremely important because the architect is forbidden to change the architecture of his facades once the construction permit has been granted. The technical solutions required in order to reach the ECODOM standard must, therefore, be found during this phase.

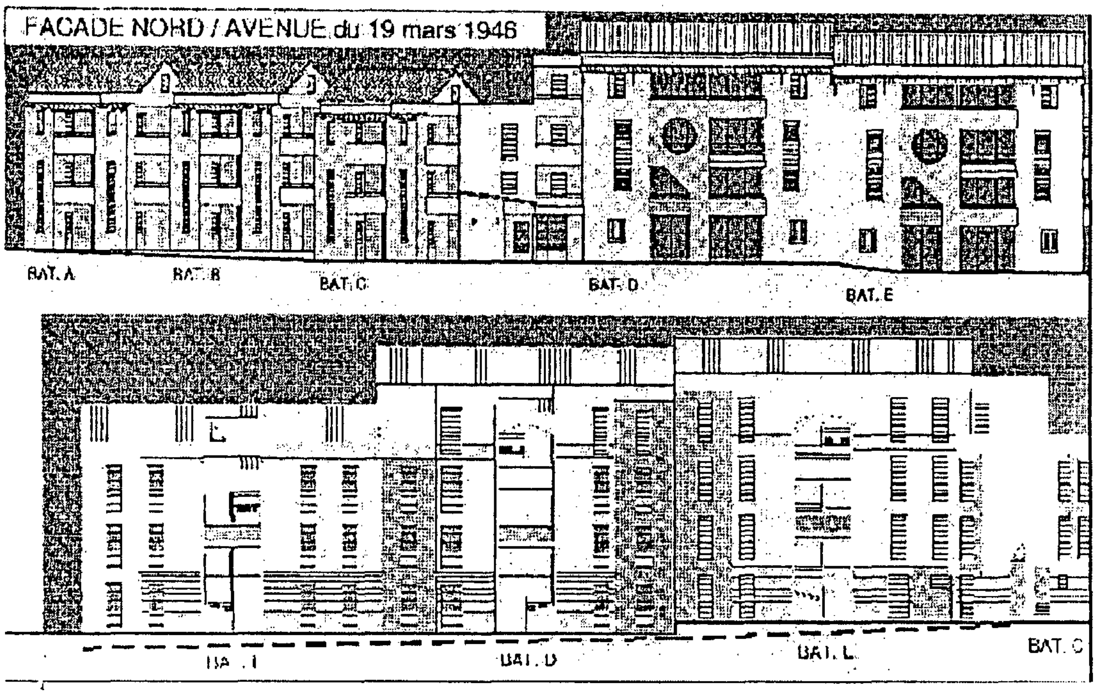


Figure 4.3: Detailed project stage of north-east (upper) and south west (lower) facades. The architect can colour the facades provided the have good solar protection.

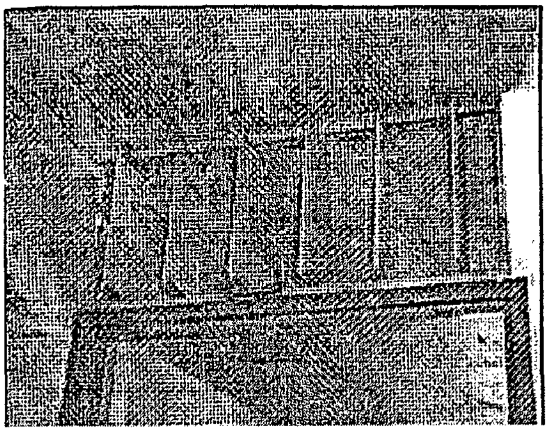


Figure 4.4: Vertical louvers over the doors to improve the interior ventilation of the dwelling

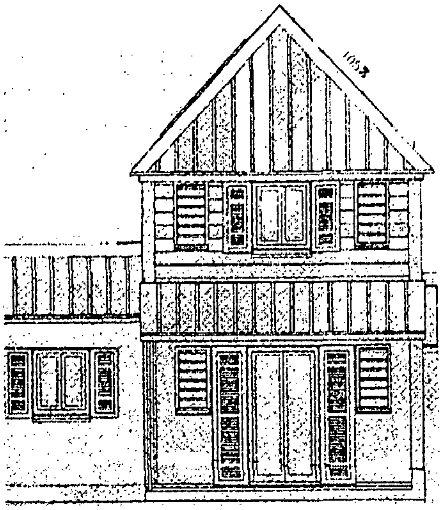


Figure 4.5: Introduction of new windows (classic windows coupled with blinds) on the new projects to increase natural ventilation

4.4.1.4. Final stage of the project

During this phase, ECODOM completed a report giving an analysis of the overall project.

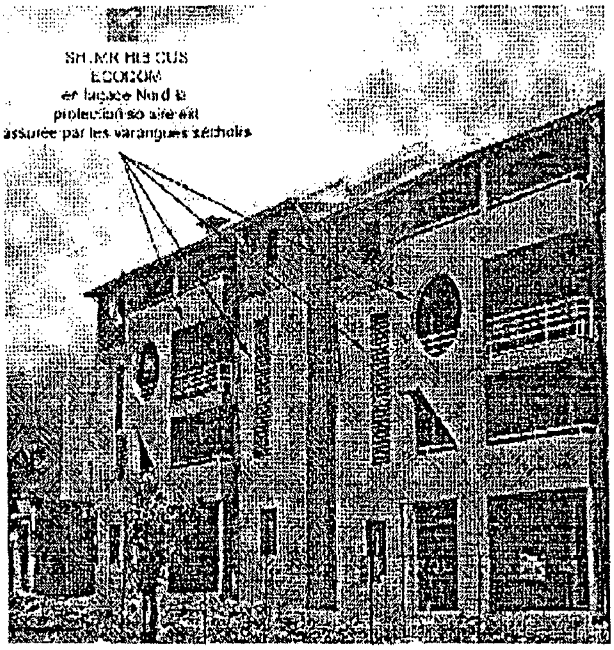


Figure 4.6: North facade, building D, E, F. the solar protection of the poenings in the living room is provided by verandas and balconies, which serve as a buffer zone.

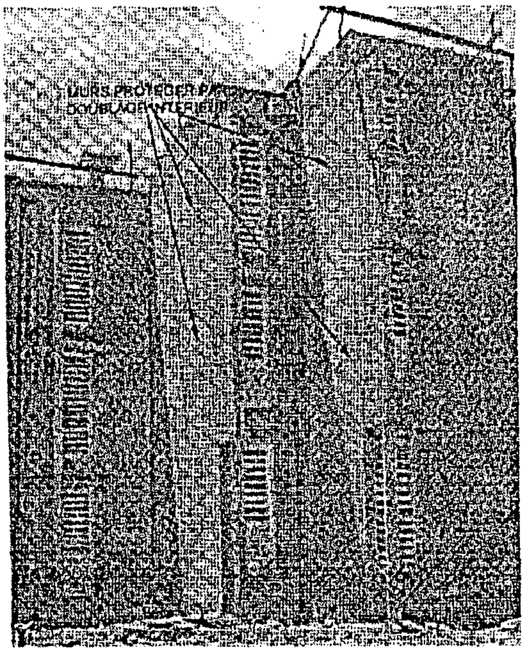


Figure 4.7: Southwest facade of buildings A, B and C. the solar protection of the gables is provided by 2 cm of polystyrene, that of the opening by the concrete wall projections. The natural ventilation is provided by shutters measuring 1.50 m^2

4.4.1.5.The construction stage

The running of the building site was organised by Promotelec, a French organisation normally responsible for checking that electrical installations conform to standards. As part of its role as one of the partners in the initiative, this organisation has agreed to also check that the project meets the ECODOM standards.

Thanks to the analysis report put together in the final stage, the person responsible for over-seeing the building site can verify with the thermal engineer that the technical solutions are respected, and thus validate at the end of construction the conclusions reached at the planning stage. As we can see in Figs. 4.6 and 4.7, solar protection is provided by verandas and balconies, and ceiling-high blinds in the bedrooms, which include opaque panes in their lower parts. Further, the dimensions of the vertical concrete wall projections give the solar protection intended during the planning stage. The exposed gables are thermally insulated with polystyrene lagging inside.

We can therefore see that, given an efficient collaboration between the architect and the physicist with the aid of a reference document, a project can be efficiently taken from the initial sketch through to completion of the construction. This working method guarantees not only that all the dwellings satisfy the ECODOM criteria, but also allows an aesthetically pleasing project with attention paid to the colour of the facades and the introduction of surrounding vegetation.

4.5.ECODOM: THE REFERENCE DOCUMENT

Let us see the final results, which are presented in the ECODOM reference document. This reference document is very helpful and essential because it is used as a tool for the study of the new ECODOM projects between the architects, the building physicians and the engineers.

4.5.1. Position on site

Performant thermal and energetic housing conception starts immediately from their location on the building site. The immediate surroundings of a building have a significant influence on the conditions of thermal comfort inside. This is particularly the case of the surrounding surface of the building, which should neither reflect the solar radiations towards the house nor increase the ambient air temperature.

The results concerning the surroundings are :

The finished surface around the building should be protected from direct sunlight on more than three quarters of its perimeter, with a width of at least 3 metres. This can be satisfied by either vegetation (lawn, bushes, flowers) around the building, or by all vegetation sun-blocks. These prescriptions are similar to the recommendations of (De Wall, 1993) concerning urban planning for warm humid climates.

4.5.2. Solar protection

In a humid tropical climate, the sources of uncomfort arise from a temperature increase due to bad architectural conception, concerning insulation. 80% of this is due to solar radiation, the rest, to conduction exchanges. The setting up of an efficient solar protection constitutes the second fundamental phase in the thermal design of buildings. This protection concerns all the exterior separations of the dwelling : roof, walls and windows.

4.5.2.1.Solar protection of the roof

Thermal inflows represents up to 60% of the overall inflows from the separations in the dwellings. An efficient solar protection for the roof is therefore of prime urgencies for a good thermal conception.

The following table is valid for terrace roofs, inclined roofs without lofts, roofs with closed or barely ventilated lofts. Well ventilated lofts should have ventilation ducts spread out uniformly throughout the perimeter, which surface conforms to the following equation :

$$\frac{S_o}{S_t} = \frac{Total\_area\_of\_opening}{Roof\_area} \geq 0.15$$

Equation 1: Loft Ventilation Duct Area

In this case, the ceiling under the loft should satisfy certain prescriptions (see table 4.1).

Table 4.1 only gives results for polystyrène and polyurethane, as these kinds of insulation are the most commonly used at an affordable price under humid tropical climates. Other alternatives exist and can be used if their equivalent thermal resistance is sufficient compared to the results given in Table 1.

Table 4-1: Roof solar protection

Insulated simple roofs		
Roof colour	Polystyrene type insulation λ=0.041 W/m.K	Polyurethane type insulation λ=0.029 W/m.K
Light (α=0.4)	5 cm	4 cm
Medium (α=0.6)	8 cm	6 cm
Dark (α=0.8)	10 cm	8 cm
Roofs with well ventilated lofts		
Roof colour	Polystyrene type insulation λ=0.041 W/m.K	Polyurethane type insulation λ=0.029 W/m.K
Dark (α=0.4)	No insulation needed	
Medium (α=0.6)	2 cm	0 cm

4.5.2.2.Solar protection of walls

The thermal gains from the walls represents 20 to 30% (40 to 65 % for the dwellings which are not under the roof) of the thermal gains from the separations. Various solutions enable a protection of the walls from the sunlight: horizontal or vertical canopy or overhang, thermal insulation of the walls. The results obtained from the simulations constitute the following table, which give the optimum dimensions of the canopy in relation to the orientation of the walls and the walls inertia for Reunion Island.

When the walls do not have a canopy, the minimum thickness of insulation (in cm) needed for the different types of walls and in different orientations are shown in Table 4.2

If the values of d/h seem excessive, other alternative such as vertical shading with an airgap may be considered. In that case, no recommandation are needed for each orientation of the wall. Meanwhile, these values are fully compatible with the Creole architecture components such as veranda and balcony which insure an efficient solar protection of walls and windows.

Table 4-2: Over hang of canopy - minimum d/h ratio values to be respected

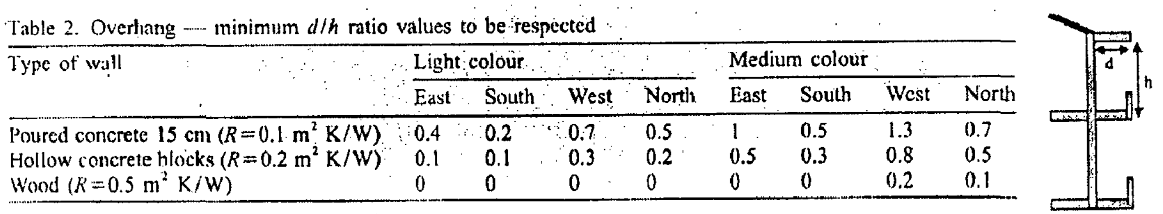


Table 2. Overhang — minimum *d/h* ratio values to be respected

Type of wall	Light colour				Medium colour			
	East	South	West	North	East	South	West	North
Poured concrete 15 cm ($R=0.1$ m^2 K/W)	0.4	0.2	0.7	0.5	1	0.5	1.3	0.7
Hollow concrete blocks ($R=0.2$ m^2 K/W)	0.1	0.1	0.3	0.2	0.5	0.3	0.8	0.5
Wood ($R=0.5$ m^2 K/W)	0	0	0	0	0	0	0.2	0.1

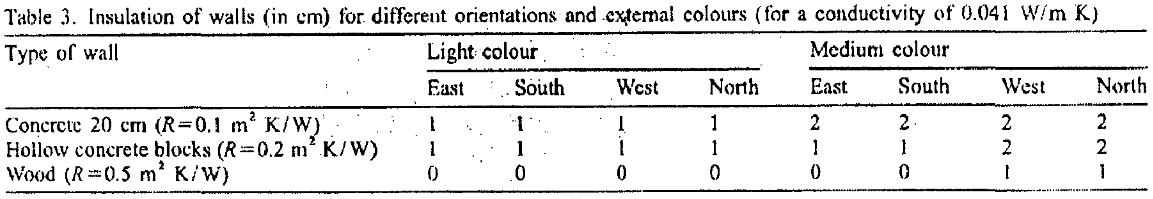


Table 3. Insulation of walls (in cm) for different orientations and external colours (for a conductivity of 0.041 W/m K)

Type of wall	Light colour				Medium colour			
	East	South	West	North	East	South	West	North
Concrete 20 cm ($R=0.1$ m^2 K/W)	1	1	1	1	2	2	2	2
Hollow concrete blocks ($R=0.2$ m^2 K/W)	1	1	1	1	1	1	2	2
Wood ($R=0.5$ m^2 K/W)	0	0	0	0	0	0	1	1

Table 4-3: Insulation of walls (in cm) for different orientations and external colours (for conductivity of 0.041 W/m.K)

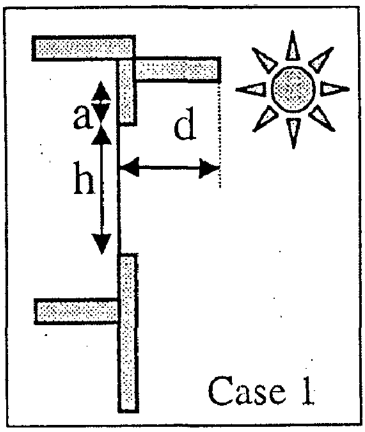
4.5.2.3.Solar protection of windows

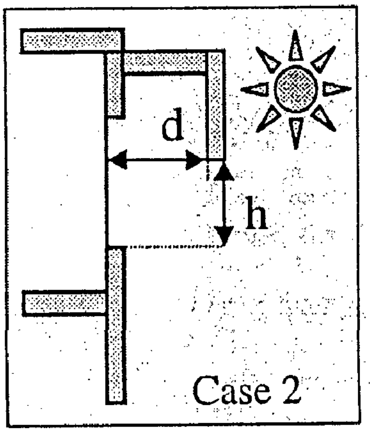
The protection of the windows is fundamental, not only because they represent 15 to 30% of the thermal gains but also because they contribute to the increase in the uncomfort experienced by the occupant, due to the instant heating of the

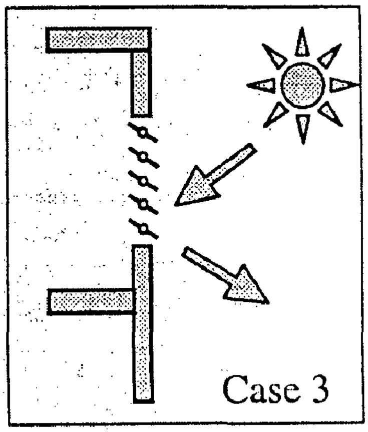
ambiant air temperature and an exposion to direct or reflected sunlight. All the windows must therefore be protected by some sort of window shading, such as horizontal canopies and other shading devices such as venitian blinds or opaque, mobile strips. The simulations enabled us to optimize the geometric characteristics of the horizontal canopies in relation to the orientation of the glazing. (see table 4.4).

Table 4-4: Values of d/(2a+b) (case1), d/h (case2)

	Orientation of windows			
	East	South	West	North
Reunion island	0.8	0.3	1	0.6
Guadeloupe	0.8	0.6	1	0.3







4.5.3. Natural ventilation

In warm climates, natural ventilation is the most usual means of heat transfer from both occupants and buildings:

The natural ventilation, depending on its importance, ensures three functions:

- Weak flow (1 to 2 vol/h) for the preservation of hygiene conditions by air renewal;
- Moderate flow (40 vol/h), for the evacuation of internal gains and the cooling of the outside structure;
- High flow (more than 100 vol/h) to assure the comfort by sudation.

Thus the high air speed and its good layout betters the sudation process. This is the only means, which enables the compensation of the high temperatures, coupled to a high rate of hygrometry.

Their aim was therefore to find the exterior/interior permeability coupling which enables us to obtain the rate of air renewal of 40 vol/h. On the one hand the structure of the dwelling will be sufficiently cooled and on the other, such an air renewal rate allows us to hope for wind speeds of 0.2 à 0.5 m.s-1 , which is largely sufficient, when taking into account the climatic parameters (outside temperature rarely greater than 32°C), to assure a good level of comfort.

We found from the simulations that the critical air renewal rate of 40 vol/h is obtained for a configuration of exterior permeability equal to 25% and interior permeability of 25%, equally for a light structure, as for a heavy structure. The natural ventilation is simply more effective during the night for the heavy structure, whereas in the light structure it serves mainly to evacuate the overheating from during the day. Thus the dwelling should have complete cross ventilation (see Fig. 4.2). At each level or floor, there should exist openings in the principal rooms, on at least two opposing facades (the principal rooms being the bedroom and the living room). Also the interior lay-out should be designed in a way that the outside air, flows through the principal rooms and the corridoors, from one façade to the other, by the doors and the other openings in the partitions.

The details of calculation needed to determine the exterior and interior permeabilities of 25% are exposed below. The first thing to do is to calculate the mean of the permeabilities of the two opposite facades of the building. The ECODOM permeability (internal and external) required is 25% of the mean.

$$P1 = \frac{So1}{Sp} \geq 0.25$$

So1 : Net surface of

external openings,

principal rooms (façade 1);

$$P2 = \frac{So}{Sp} \geq 0.25$$

So2 : Net surface of

$Sp = \frac{Sp1 + Sp2}{2}$

1.1.1.1.1 $Si1 \geq So1$ or $So2$

external openings,

principal rooms (façade 2);

Sp1, Sp2 : Total surface of principal rooms of façades 1 and2;

Si1 and Si2 : Total surface of internal openings

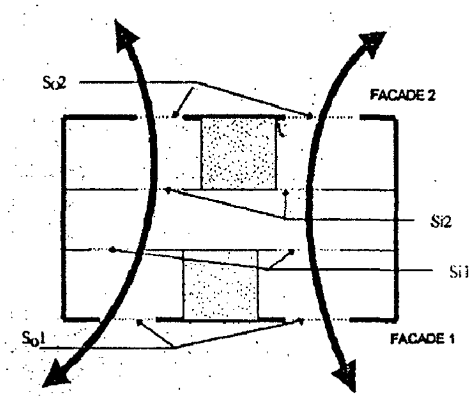


Figure 4.8: Cross ventilated Dwelling

$Si2 \geq So1$ or $So2$

- *Air fans:*

When natural ventilation air speed is unsufficient, air fans can additionally be used. This enables an increase in the comfort range of more than 2°C (Fuad, 1996).

Each room in the dwelling should be equipped with electric wiring in the ceiling, wired to a wall switch, destined exclusively for the installation of air fans.

4.5.4. Air conditioned bedroom option:

In certain dwellings, and at certain times of the year, natural ventilation, even with the existence of air fans, is not adequate for an acceptable level of comfort. In this case we can choose to air condition the bedrooms using efficient appliances. The simulations which we carried out show that the air conditioning charges can be reduced through good structure conception and control of the air renewal rate. For a light structure these savings reach 3.4 cooling kWh per day, and 11 kWh for a heavy structure, where the inertia plays a dominating role in the air conditioners consumption. Throughout the whole of the wet season, the consumption was diminished by half with a good structure conception (1000 cooling kWh). The maximum cooling power is therefore 80W/m².

Practically, the air conditioners should meet certain standards of efficiency (cooling efficiency of 2.5 for the window units and 3 for split-systems), of permeability (each room should be equipped with a mechanically controlled air renewal of 25m3/h) and a maintenance contract.

4.5.5. Domestic hot water

ECODOM have not carried out simulations in this domain, however a certain number of prescriptions need to be verified, and we feel that they need to be specified as water heating consumes greatly and constitutes a real energy problem. It is important that the dwellings are equipped with efficient long-lasting and economic, domestic hot water heating systems. The water heater can be solar, electric or gas.

In the case of solar water heaters, the apparatus must conform to the technical control CSTB. The total minimum surface of the solar captors, should be installed in relation to the size of the dwelling.(see table 4.5). The capacity of the water storage should be 60 and 120 litres per square metre per net square metre of captor. The conventional minimum annual production should be 700kWh per net square metre of the capting surface.

Table 4-5: Technical Characteristics of Solar and Electric water heaters

	Solar water heaters	Individual electric water heater	
Type of dwelling	Minimum captor surface installed for each dwelling	Minimum storage capacity	Cooling Constant
F1-F2	1.5 m^2	100 l.	0.32
F3 (3 rooms)	2.0 m^2	150 l.	0.23
F4 (4 rooms)	2.5 m^2	200 l.	0.22
F5 (5 rooms)	3.0 m^2	250 l.	0.22
F6 and more	3.5 m^2	300 l.	0.22

When considering electrical heaters the appliance must have the mark of the approved French standard of manufacture NF (Norme Française). The instant hot water heaters are high energy consuming, so therefore are excluded.The capacity of the water heater and its.cooling constant are calculated in function to the number of principal rooms within the dwelling (see Table 4.5). The power supply should be equipped with a three position commutation swich: servo-controlled to the off peak hours, over-ride, off. The gas water heaters must have the French Standard Mark and also provision must be made for a burnt gas outlet.

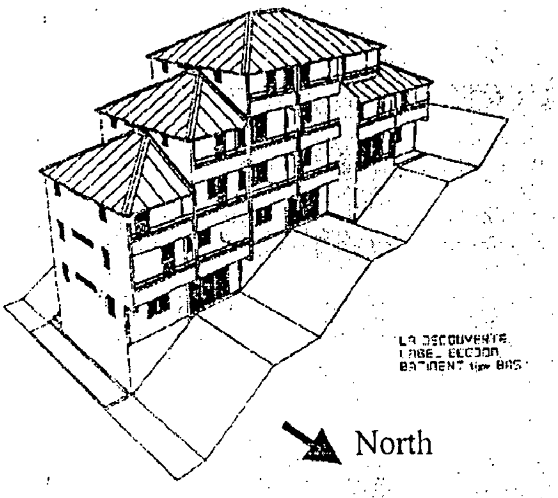
4.6. Case Study ECODOM PROJECT: "LA DECOUVERTE"

At the present time, three experimental operations have been built in Reunion Island, and two in Guadeloupe, that is to say a total number of 300 dwellings. One of these called "La Decouverte" is represented by figure 4.9.

44 dwellings were studied with the ECODOM prescriptions as part of the project "La Decouverte" This project started in 1996 when the first contacts were taken between the architect and the building owner. The main problem was to create a confident relationship because ECODOM must be presented as a partnership with no interference with the creativity of the architect.

Figure 4.10 represents the project after the application of the ECODOM prescriptions

The ECODOM modifications applied on the project are explained in the following.



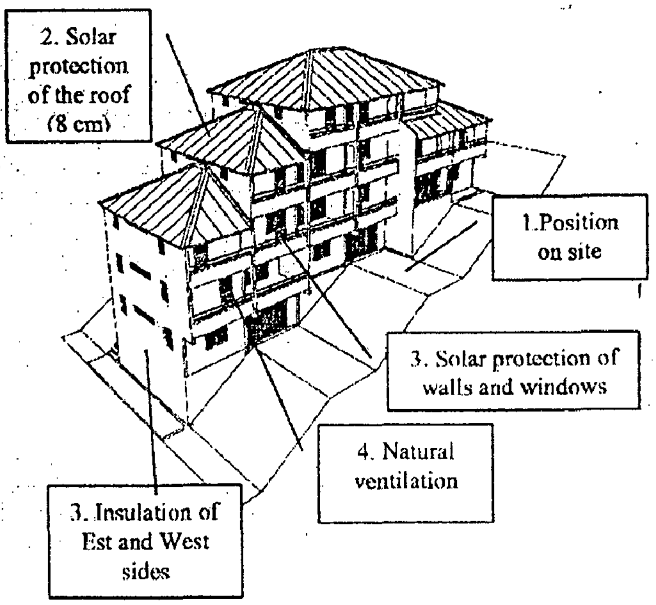


Figure 4.9: ECODOM "La Decouverte", 44 dwellings, 1997

Figure 4.10: Modifications of the original projects

No modification was made for the position on site because gardens around the buildings have already been planned (see figure 4.10). Otherwise, the project has an attractive orientation as the main façades have a north and south orientation, with small west and east sides. Therefore, the only façade to be processed is the north one as the south one is seldom sunny (in the southern hemisphere, the sun goes to the south only in December). Relating to the solar protection of the roof, the architect has provided 5 cm of insulation for red and blue roofs. According to table 4.1, it is not enough. Therefore, the architect was asked to increase the insulation thickness up to 8 cm (medium colours) and to rather use polystyrene as type of insulation than mineral wool. This kind of insulation is very cheap but not very adapted to tropical climates: the mineral wool loses its thermal properties because of the condensation.

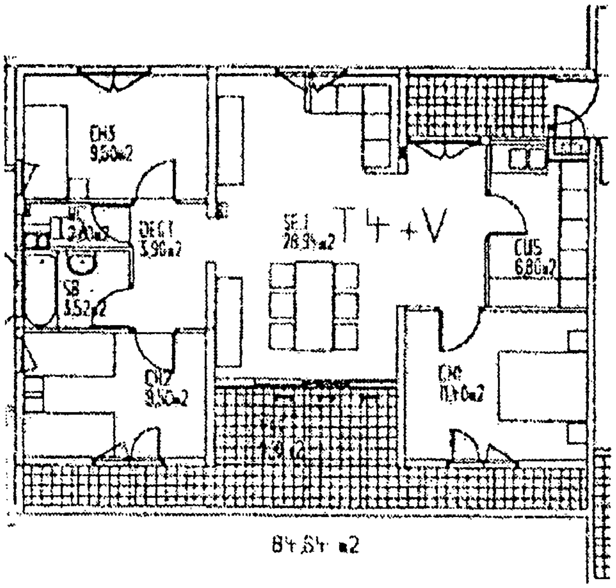


Figure 4.11: Plan of one ECODOM dwelling.
Increase of permeability of bedrooms (door windows and solar protection of the north facade (balcony)

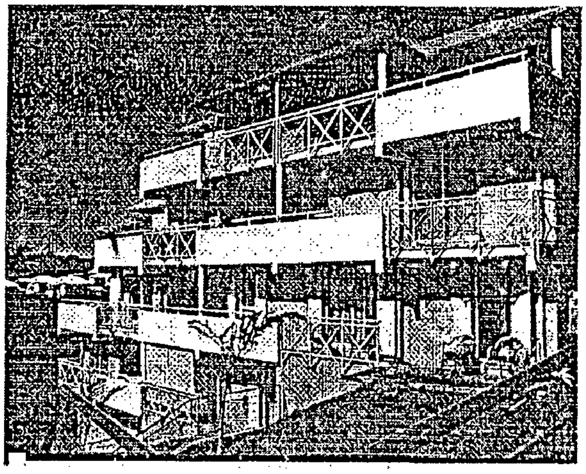


Figure 4.12: The Final Project
"LA DECOUVERTE" 1999

Regarding to the solar protection of walls, the colour is light and the materials used are hollow concrete blocks. In table 4.2, it is recommended to put 1 cm to the East and West sides. The south façade was not treated because of the important number of overhangs and entrances to the dwellings. Thus, as the initial project didn't provide solar protection of the bedrooms windows, was asked to add overhangs above the exposed windows on the north facade.

However, the solar protection of windows is strongly correlated to the natural ventilation. The bigger is the opening, the longer must be the overhang size.

Concerning natural ventilation, the dwelling permeability in the initial project was not sufficient. ECODOM needs a permeability of 2 square meters and the initial project has only 1.44 square meter. That is why all the windows have been suppressed and replaced by door windows to increase the permeability. Balconies were also added all along the facade for the solar protection of the openings and of the walls.

4.7. Description of the social and technical follow up

An experimental follow up has been launched for the first ECODOM dwellings in order to validate experimentally the impact of the passive cooling solutions on the comfort of the occupants.

The operation was delivered in April 1999. With the agreement of the housing company, four dwellings have been instrumented during the warm season (from January to April). A portable data-logger was set up close to the buildings to record all the climatic variables (external temperature and humidity, solar radiation, wind speed and wind direction).

This experimental period was done to estimate the impact of the prescriptions on the building thermal performances without taking into account the influence of the occupants.

A second instrumentation period is scheduled during the next warm season with the occupants inside. This second experimental step will be coupled with a social study while the people are living inside in order to understand how they feel in terms of thermal comfort, acoustic comfort (because in tropical climates, it is difficult to reach in the same time thermal comfort and acoustic comfort), visual comfort, environment.

The dwellings were selected in order to compare various parameters such as the roof and walls thermal insulation, the influence of natural ventilation.

During the non-occupied period, the probes used are thermocouples for the measurement of air temperature, resultant temperature, surface temperatures on walls and roofs, thermo-hygrometers for the relative humidity, accurate anemometer for the air speed inside the dwellings.

During the occupied period, the probes are small white boxes with internal memory which can be fixed on a wall. They give the temperature/hygrometry couple measurements each 30 minutes during several months.

By the time this article is been writting, the measurements are still in process.

The experimental results will allow to have some feed back informations about the ECODOM dwellings and to supply the appropriate corrections on the numerical data of the passive solar solutions. Above all, this will allow to know if the dwellings are fitted to the occupant way of life

4.8. CONCLUSION

All the methodology used for the elaboration of the ECODOM standard, from the simulations to the experimental results, has been presented.

The whole work has led to define performant solar passive cooling solutions for each comprising part of the structure and likewise a minimum ratio to optimise the natural ventilation.

The dwellings to be constructed following the ECODOM specifications should satisfy the criteria of these technical solutions. The simplicity of the specifications allow all the ECODOM actors (architects, building physicians, building designers) to speak the same language.

An experimental follow up has been made for the first ECODOM dwellings in order to validate experimentally the impact of the passive cooling solutions on the comfort of the occupants. This experimental period is still in process and the feed back will be available in the beginning of the year 2000.

This follow up is important, as the setting up of the ECODOM standard will be the first step towards the setting up of thermal regulations in the French overseas departments, by the year 2002.

5. Climatic Design of Buildings in Tropical Climates

5.1.An Overview

Climatic design means the design of thermally efficient building (for air-conditioned buildings) or a thermally comfortable building (for passive cooled buildings).[21]

For the purpose of Climatic Design of building, an Architect or a designer of a building in a tropical climate may consult the textbooks listed in table1.

Table 5-1: Climate classifications *Source: 1*

LEGEND ◊ : Climate • : Subclimate	Tropical island	Warm Humid	Transit	Monsoon	Monsoon with a cold season	Savannah	Hot dry (desert)	Maritime desert	Upland
Atkinson (1950)	•	◊		•			◊		◊
Dreyfuss (1960)		◊	•	◊			•	•	•
Ayoub (1960)		◊					◊		◊
Olgyay (1963)		◊					◊		
Griffiths (1966)	◊	◊				◊	◊		◊
Lippsmeier (1969)	•	◊		◊		◊	◊		•
Givoni (1969)	◊	◊		◊			◊		
Koenigsberger (1973)	•	◊		◊			◊	•	•
Evans (1980)	◊	◊		◊	◊		◊	◊	◊

All author agree upon the existence of at least two climates, the warm humid and the hot dry, with the following characteristics:

- Warm humid:

  $\overline{T} = 27 - 32°C$;

  $\overline{\Delta T} = 4 - 9K$;

  $VP = 2.5 - 3.5\,kN/m^2$;

  much rainfall, cloudiness and cyclones, strong global winds;

- Hot dry:

  $\overline{T} = 33 - 40°C;$

  $\overline{\Delta T} = 15 - 20K;$

  $VP = 1.0 - 1.5\,kN/m^2$;

  no rainfall, clear sky, local winds;

There has also been general agreement on how to build in these two climates. For the warm humid climate it is recommended to provide ample air movement through and around the buildings, to build with north-south orientation, with large open windows, a thin insulated roof and thin breeze transparent internal walls, with a reflective external wall, and to plan a covered verandah. For the hot dry climate it is recommended to build with north-south orientation, compact, with small windows and reflective outside surfaces, with heavy walls and roof and to plan a shaded courtyard. Obviously these recommendations are based on the traditional building styles in these two climates.

Table 1 suggests that some research-workers in this field were able to describe recommendations for more climates than the warm humid and the hot dry. Mostly they were not.

The above recommendations suffer from three main drawbacks:

- They are (partly) incorrect, especially because no difference has been made between high-rise or low-rise buildings, between passive cooled or air-conditioned buildings and between dwellings (day & night use) and offices (only day use).
- Directives are not quantitatively described.
- A division is made into only two climates.

5.1.1. Basic Concept

"*Weather*" is the set of atmospheric conditions prevailing at a given place and time. "*Climate*" can be defined as the integration in time of weather conditions, characteristics of a certain geographical location[22]. At the global level climates are formed by the differential solar heat input and the uniform heat emission over the earth's surface. The movement of air masses and of moisture-bearing clouds is driven by temperature differentials and strongly influenced by the Coriolis force.

5.1.2. Importance of Climatic Design

Climate has a major effect on building performance and energy consumption. The process of identifying, understanding and controlling climatic influences at the building site is perhaps the most critical part of building design. The key objectives of climatic design include:

- To reduce energy cost of a building
- To use "natural energy" instead of mechanical system and power
- To provide comfortable and healthy environment for people

5.1.3. Classification of Climates

Many different systems of climate classification are in use for different purposes. Climatic zones such as tropical, arid, temperature and cool are commonly found for representing climatic conditions[23]. For the purposes of building design a simple system based on the nature of the thermal problem in the particular location is often used.

- *Cold climates*, where the main problem is the lack of heat (under heating), or an excessive heat dissipation for all or most parts of the year.
- *Temperate climates*, where there is a seasonal variation between underheating and overheating, but neither is very severe.
- *Hot-dry (arid) climates*, where the main problem is overheating, but the air is dry, so the evaporative cooling mechanism of the body is not restricted. There is usually a large diurnal (day - night) temperature variation.

- ***Warm-humid climates***, where the overheating is not as great as in hot-dry areas, but it is aggravated by very high humidities, restricting the evaporation potential. The diurnal temperature variation is small.

The general climate (*macroclimate*) is influenced by the topography, the vegetation and the nature of the environment on a regional scale (*mesoclimate*) or at a local level within the site itself (*microclimate*).

5.1.4. Climate in India

India is a country with a diverse climate. Many different climatic regions can be identified in the country from the cool of the mountains in the North through the composite climate of the Gangetic plain, the hot desert of Rajasthan down to the humid breezes of the South and East.[24]

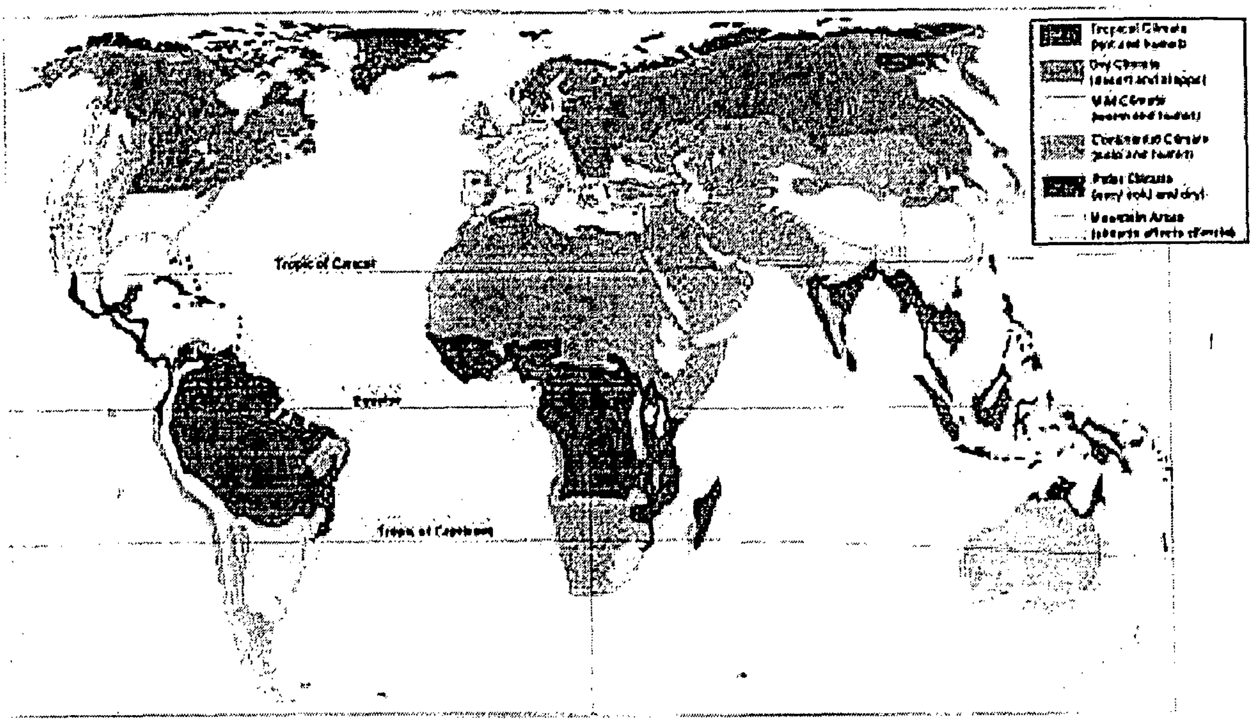


Figure 5.1: Map of world's climate

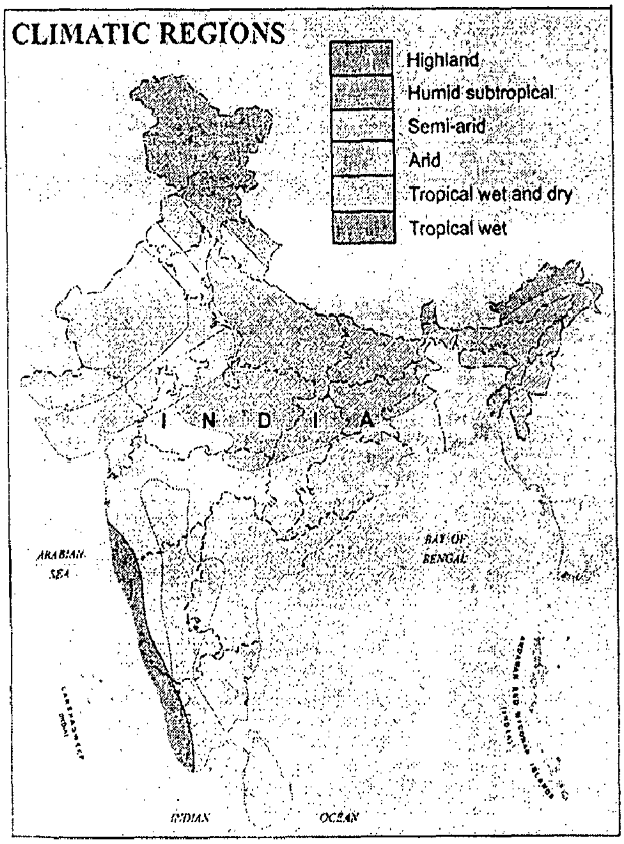


Figure 5.2 : Climatic regions of India

In India there are the following Climatic Regions:

- Highland
- Humid subtropical
- Semi-arid
- Arid
- Tropical wet and dry
- Tropical wet

Pune in West Maharashtra comes under the Tropical Wet & Dry Climatic Region.

5.2. CLIMATIC DATA

5.2.1. Climatic Elements

The main climatic elements, regularly measured by meteorological stations, and published in summary form are:

- ***Temperature*** - dry-bulb temperature.
- ***Humidity*** - expressed as relative humidity or absolute humidity, or the web-bulb temperature or dew-point temperature may be stated, from which the humidity can be deduced.
- ***Air movement*** - both wind speed and direction are indicated.
- ***Precipitation*** - the total amount of rain, hail, snow, dew, measured in rain gauges and expressed in mm per unit time (day, month, year).
- ***Cloud cover*** - based on visual observation and expressed as a fraction of the sky hemisphere (tenths, or 'octas' = eights) covered by clouds.
- ***Sunshine duration*** - the period of clear sunshine (when a sharp shadow is cast), measured by a sunshine recorder which burns a trace on a paper strip, expressed as hours per day or month.
- ***Solar radiation*** - measured by a pyranometer, on an unobstructed horizontal surface and recorded either as the continuously varying irradiance (W/m^2), or through an electronic integrator as irradiance over the hour or day.

As the four environmental variables directly affecting thermal comfort are *temperature, humidity, solar radiation and air movement*, these are the four constituents of climate most important for the purposes of building design. *Rainfall* data may sometimes be needed, such as for designing drainage systems and assessing the level of percipitation.

Table 5-2:Common climatic elements for building design

Temperature:	- monthly mean of daily maxima (deg C) - monthly mean of daily minima (deg C) - standard deviation of distribution
Humidity:	- early morning relative humidity (in %) - early afternoon relative humidity (in %)
Solar radiation:	- monthly mean daily total (in MJ/m^2 or Wh/m^2)
Wind:	- prevailing wind speed (m/s) and direction
Rainfall:	- monthly total (in mm)

5.2.2. Sources of Climatic Data

The *raw weather data* from the meteorological station are usually analyzed and presented in tabular form and/or in graph form. Some design handbooks and standards also provide general climatic data for building design. *Outdoor design conditions* which are determined from the statistical analysis of climatic data over the long term (say, 30 years) will offer a summary of weather information for a particular location. To study year-round and part-load building performance, annual weather data will be required and they may given as bin data, simplified hourly data or full hourly data.

In architectural design, *climatic graphs and charts* are very useful for climate analysis since they can assist understanding at a glimpse and a quick comparison of data. Much more detailed data may be required for the purposes of some building thermal and energy simulation programs, such as hourly data for a year, which itself may be a composite construct from many years of actual data. Depending on the time and resources, suitable amount and quailty of weather data should be obtained for analysis in developing a building design. The question in the study of climatic data is to strike a balance between the two extremes of:

- *too much detail*: such as hourly temperature for a year, 24 x 365 = 8,760 items, - it would be very difficult to glean any meaning from such as mass of numbers and, - if many years are to be considered, it would be an impossible task.
- *oversimplification*: such as a statement of the annual mean temperature of - say - 15 deg C may indicate a range between 10 and 20 deg C or between -10 and +40 deg C. The greater the simplification, the more detail is concealed.

5.2.3. Factors Affecting Climatic Design

The local microclimate and site factors will affect the actual environmental conditions of the building. The important site-related factors should be considered when making the climate analysis:

- ***Topography*** - elevation, slopes, hills and valleys, ground surface conditions.
- ***Vegetation*** - height, mass, silhouette, texture, location, growth patterns.
- ***Built forms*** - nearby buildings, surface conditions.

Major thermal design factors to be studied include: solar heat gain, conduction heat flow and ventilation heat flow. The design variables in architectural expression that are important will include:

- ***Shape*** - surface-to-volume ratio; orientation; building height.
- ***Building fabric*** - materials and construction; thermal insulation; surface qualities; shading and sun control.
- ***Fenestration*** - the size, position and orientation of windows; window glass materials; external and internal shading devices.
- ***Ventilation*** - air-tightness; outdoor fresh air; cross ventilation and natural ventilation.

5.3. CLIMATE ANALYSIS

5.3.1. Use of Climatic Data

Different design situations will require different weather data for the study.

Climate analysis carried out at initial design stage may be used for:

- develop design strategies
- check condensation problems in some cases
- optimisation of insulation

Load and energy calculation carried out at outline and detail design stages will require weather data for:

- calculation of cooling and heating requirements
- design of heating, ventilating and air-conditioning (HVAC) systems
- energy estimation of buildings

5.3.2. Sunshade Analysis

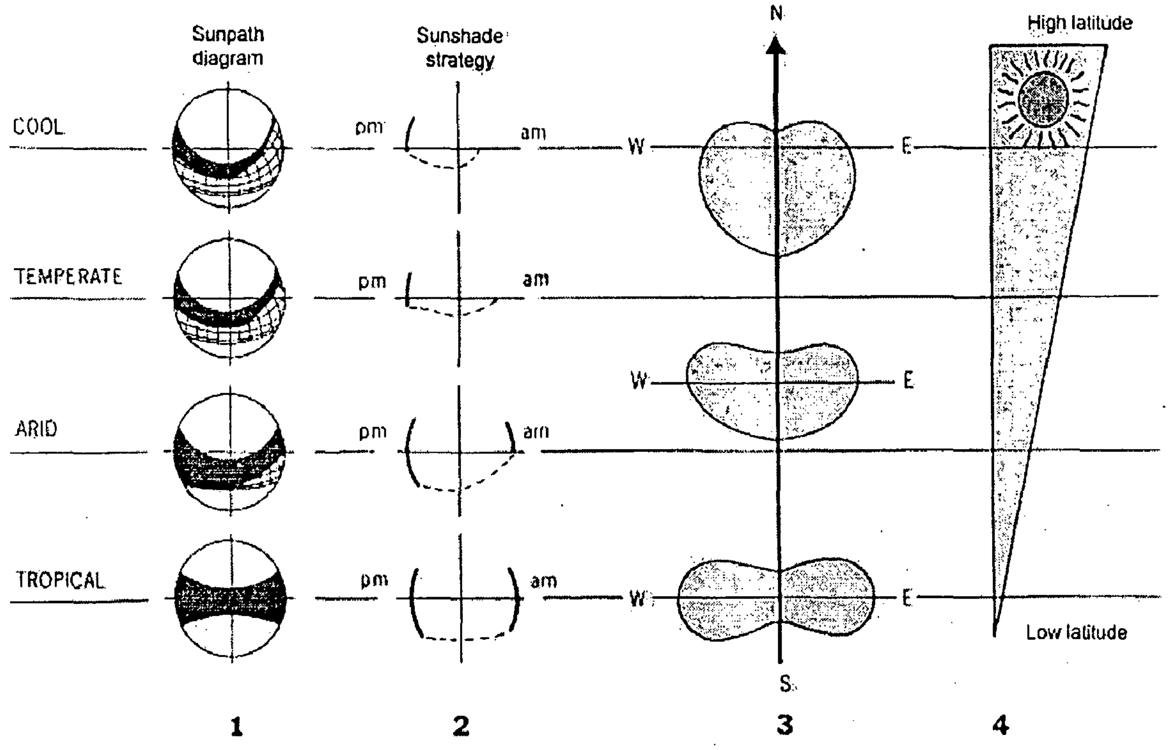


Figure 5.3: EXAMPLE OF SUNSHADE ANALYSIS

1. Solar paths requiring shade

Studying the sunpath diagram for each climatic zone, the shaded areas represent the periods of *overheating*, related to undesirable solar gain. In the lower latitudes there is total overheating, whereas in the higher latitudes overheating only occurs during the summer months.

2. Sunshade analysis (vertical and horizontal)

The diagrams show the optimum location of vertical sun shading, shielding the building from low sun angles in the morning and evening, & horizontal sun shading blocking the high midday sun. Tropics need both vertical & horizontal shading throughout the year. In higher latitudes, horizontal & vertical shading is only needed during the summer on the south sides.

3. Insolation

The sunpath becomes more southerly as we move north, changing from a 'bow-tie' pattern near the equator to a heart-shape pattern in the temperate zones.

4. Sun requirements during winter

There are obviously seasonal variations near the equator. Solar heating becomes more important than in the upper latitutdes. Beginning at the equator and moving north, the need for solar heating increases while the need for solar shading dimishes.

5.3.3. Wind Analysis

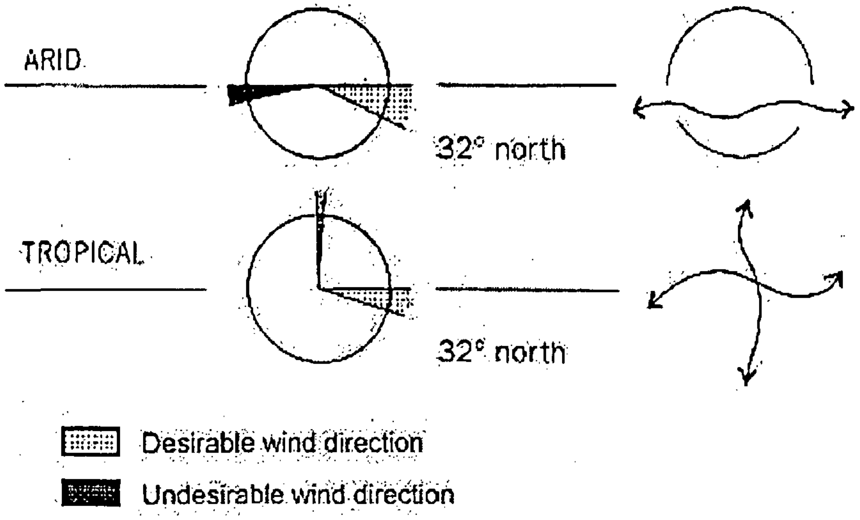


Figure 5.4: Wind Analysis

Wind direction

Desirable and undesirable winds in each the climatic zones depend largely on local conditions. Any breeze in the lower latitude (tropical & arid climates) is beneficial for most of the year whereas in higher latitudes most wind is detrimental & has to be screened. There is also a small %age of the time in a year (spring &/or autumn) when comfortable conditions can be achieved naturally, without any need for wind screening or additional breezes.

Cross ventilation

Cross ventilation is far more important in the tropics than in temperate zones. The theoretical strategy for blocking or inducing wind flow into a building is based on local *prevailing wind conditions*. Genrally, for the tropics as much ventilation as possible is desired. For the arid zone cross ventilation is required, but care has to be taken to filter out high-velocity winds. In the temperate zone, cross ventilation and shielding are both necessary (for summer and winter, respectively). In the cool region, the building should be protected from cold, high-veolcity winds, although cross ventilation is still required.

5.3.4. Humidity, Rainfall and Seasonal Variations

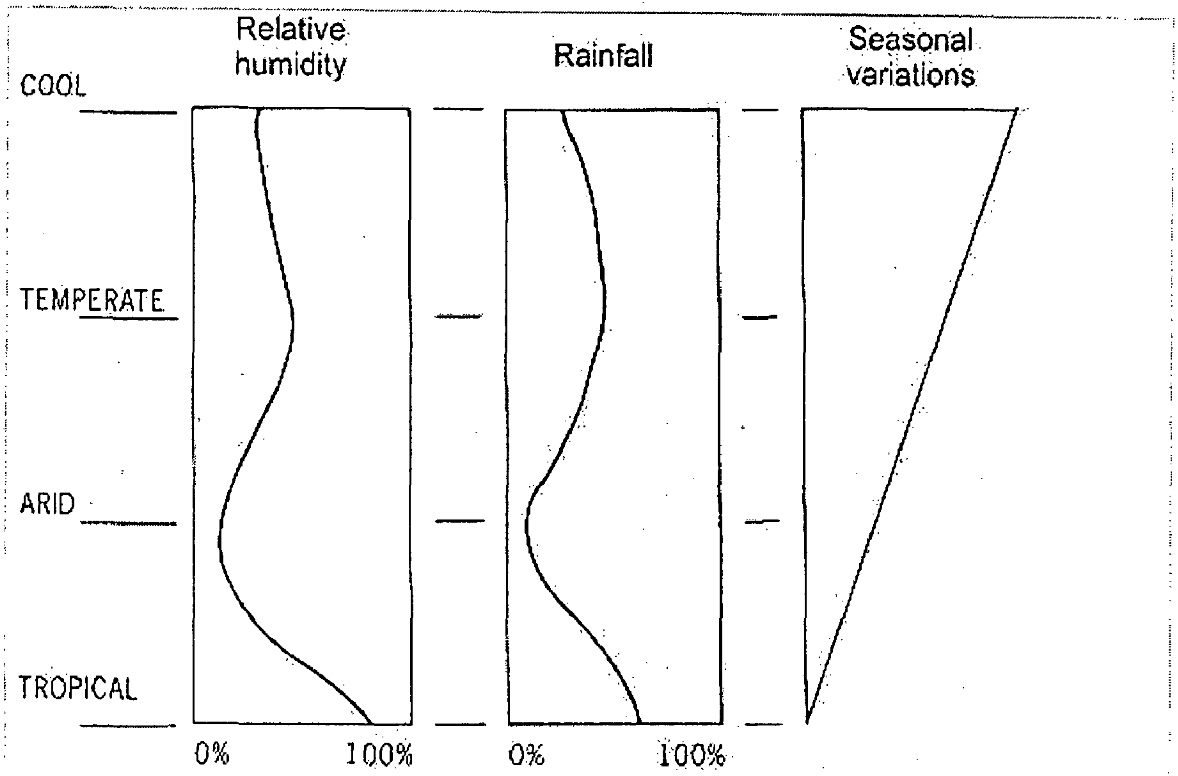


Figure 5.5: Humidity, Rainfall and Seasonal Variations

Annual Average Relative Humidity

The curve on the left represents the annual average relative humidty in the four climatic zones. In the arid zone, the low level of humidity can be beneficial for *evaporative cooling*. In the tropical zone the high level of humidity can be very uncomfortable.

Annual Average Rainfall

The middle curve represents the annual average rainfall in the four climatic zones. Rainfall level can be seen to have a direct relationship with humidity levels.

Annual Seasonal Variations

The distance of the angled line from the vertical represents the annual seasonal variations in the four climatic zones. Higher latitudes, the cold and temperate zones, have pronounced seasonal variations. The lower latitudes have constant climates throughout the year.

5.3.5. Influences on Built Form[25]

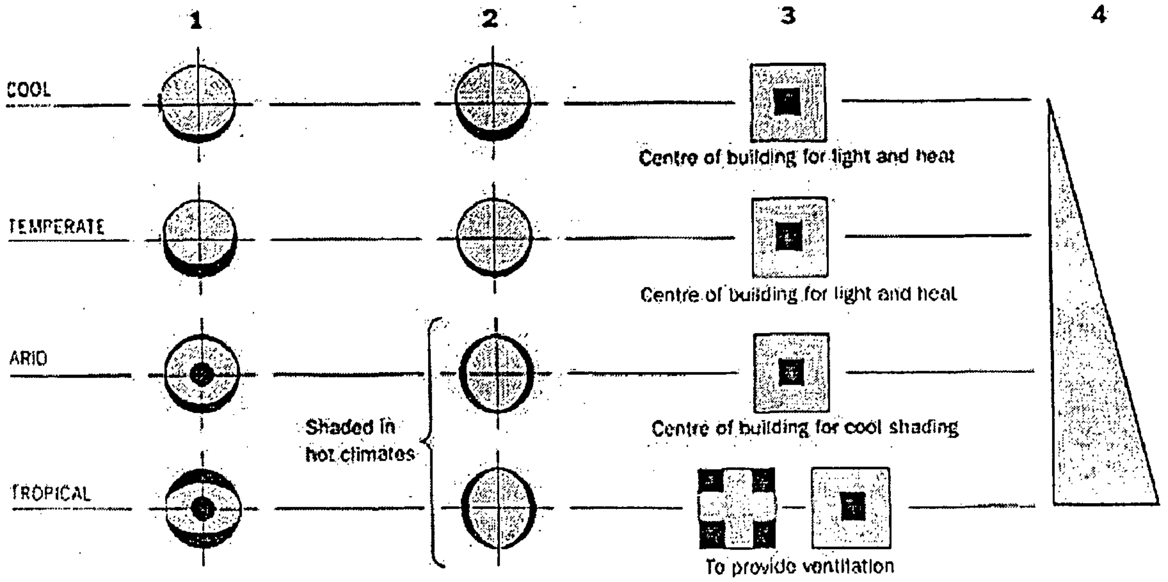


Figure 5.6: Influences on Built Form

1. Zoning for trasitional spaces

The black areas represent the traditional spaces used for lobbies, stairs, utility spaces, circulation, balconies and any othe areas where movement take place. These areas do not require total climatic control and natural ventilation is sufficient. For the tropical and arid zones, the transitional spaces are located on the north and south sides of the building where the sun's penetration is not as great. An atrium can also be used a transitional space. In temperate and cool zones the transitional spaces should be located on the south side of the building to maximize solar gain.

2. Zoning for solar gain

The black areas are spaces that can be used for solar heat gain. They follow the varying path of the sun in each of the climatic zones: in the tropical and arid zones the east and west sides; in the temperate and cool zones the south side.

3. Use of atrium

The diagram show the optimum position for atrium spaces in each building form in each of the climatic zones. in the tropical zone the atrium should be located so as to provide ventilation within the built form. In the arid zone the atrium should be located at the centre of the building for cooling and shading purposes. For the cool and temperate zones the atrium should be at the centre of the building form for heat and light.

4. Potential of roof/ground floor as useable exterior space

The distance of the angled line from the vertical represents the potential of each zone's roof and ground planes to be used a exterior spaces. In tropical and arid climates there is a high potential to make use of all external spaces, whereas moving towards the northern latitutdes the external spaces have to be covered to be used.

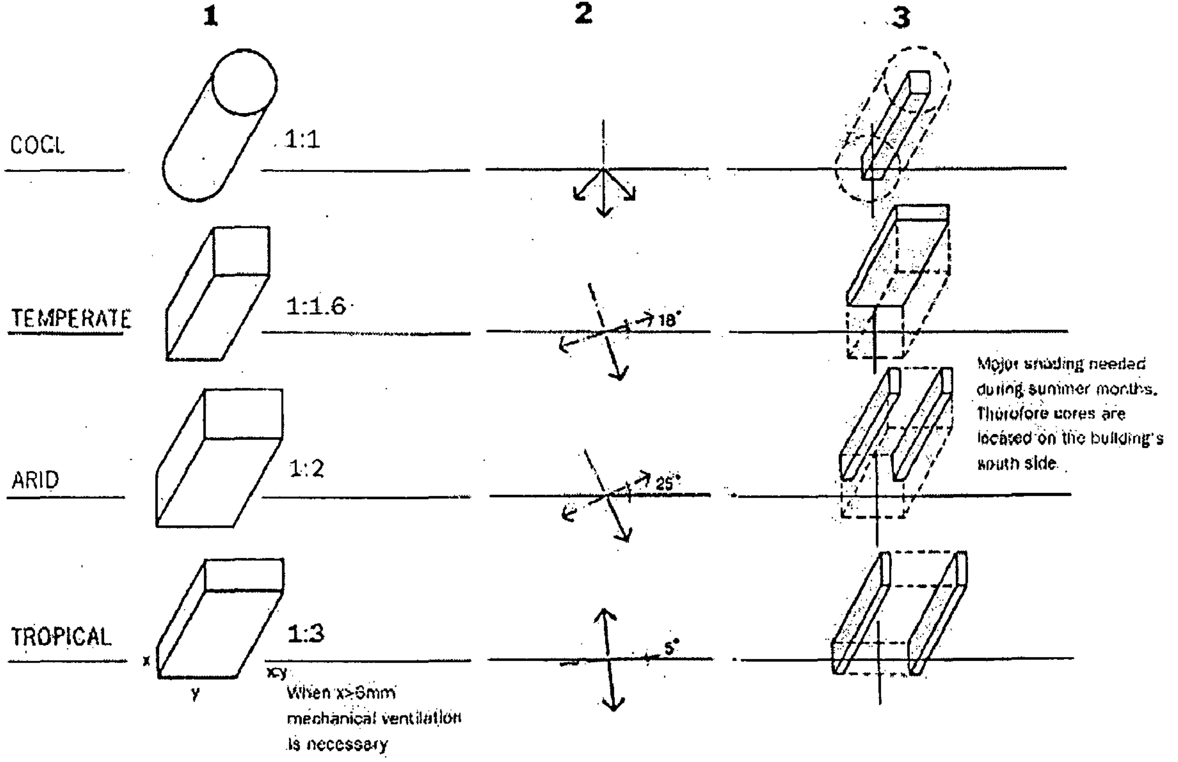


Figure 5.7: Influences on Built Form

1. Form

The diagrams show the optimum building form for each climatic zone. Research has shown that the preferred length of the sides of the building, where the sides are of length x:y, are:

- tropical zone - 1:3
- arid zone - 1:2
- temperate zone - 1: 1.6
- cool zone - 1:1

Analysis of these ratios shows that an elongated form to minimize east and west exposure is needed at the lower latitudes. This form slowly transforms to a ratio of 1:1 (cylindrical) at the higher latitudes. This is a direct response to the varying solar angles in the various latitudes.

2. Orientation

Orientation as well as directional emphasis changes with latitude in response to solar angles.

Zone	Building's main orientations	Directional emphasis
Tropical	On an axis 5° north of east	north-south
Arid	On an axis 25° north of east	south-east
Temperate	On an axis 18° north of east	south-south-east
Cocl	On an axis facing south	facing south

3. Vertical cores and structure

The arrangement of primary mass can be used as a fator in climatic design as its position can help to shade or retain heat within the building form.

For the tropical zone, the cores are located on the east and west sides of the building form, so as to help shade the building from the low angles of the sun during the major part of the day. In arid zone, the cores should also be located on the east and west sides, but with major shading only needed during the summer. Therefore, the cores are located on the east and west sides, but primarily on the south side.

The arrangement of the primary mass in the temperate zone is on the north face, so as to leave the south face available for solar heat gain during the winter. The cool zone requires the maximum perimeter of the building to be open to the sun for heat penetration. Therefore the primary mass is placed in the centre of the building so as not to block out the sun's rays and to retain heat within the building.

5.4.Kolhapur Weather

5.4.1. Climate Characteristics

Kolhapur is located at latitude 16° 42' north and longitude 74°16' east. According to a climatological method of classification, the weather of Kolhapur may be classified as "Twd" (Tropical wet and dry climate). In the summer months between May and September, the monsoon blows from the south and southwest directions. The weather is tropical, hot and dry in the summers, hot and humid in the rainy season and cool-dry during the winters. The autumn is short as it lasts from mid-September to early November. The winds become more easterly in direction. The amount of cloud in sky and humidity decrease rapidly at this time.

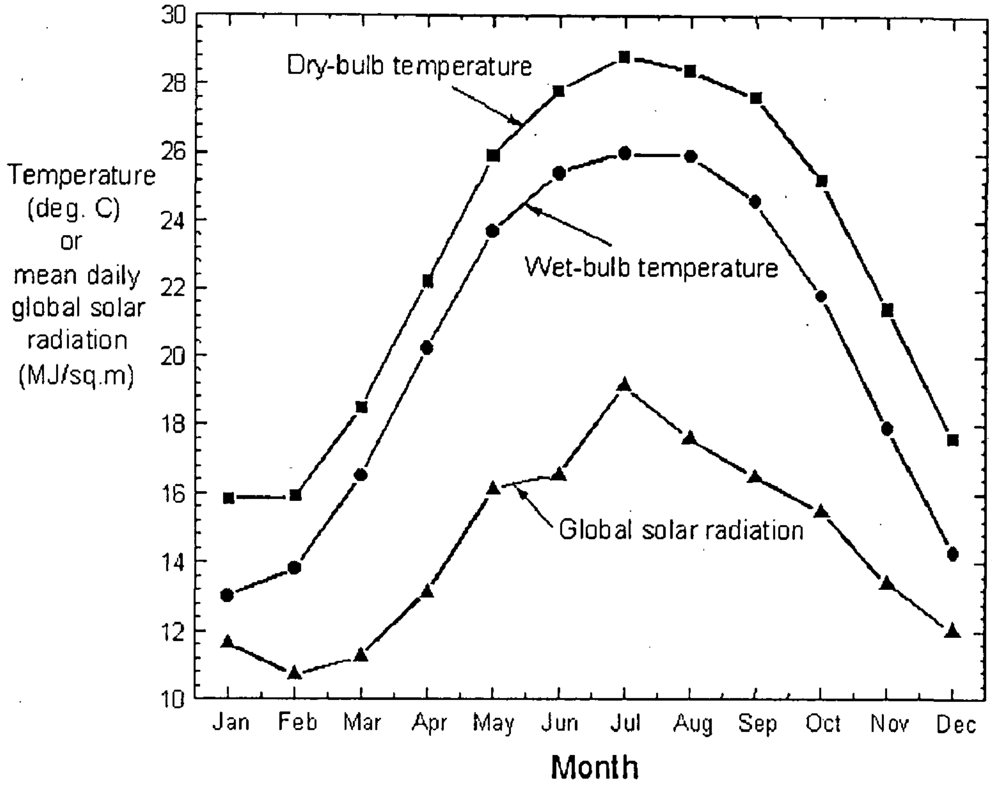


Figure 5.8: Temperature Chart of Kolhapur

5.4.2. Outdoor Design Conditions

Essential information for the assessment of the climate and determination of design strategies is required[26]. The "design temperatures" are usually the most commonly used and two sets of design temperatures (one for comfort HVAC and one for critical processes) are required. Other data required include extreme temperatures, diurnal ranges of temperatures and wind data.

5.4.3. Graphical Analysis

The climate of a particular place can also be studied using the following graphical methods and charts[27].

- *Contour map of dry-bulb temperature (DBT)*
- *Contour map of wet-bulb temperature (WBT)*
- *Contour map of relative humidity (RH)*

- *Contour map of global solar radiation (GSR)*
- *Frequency distributions of DBT*

Information relating to sun path and solar design is of much interest to Architects and the following figure shows example of the graphs indicating the sun paths.

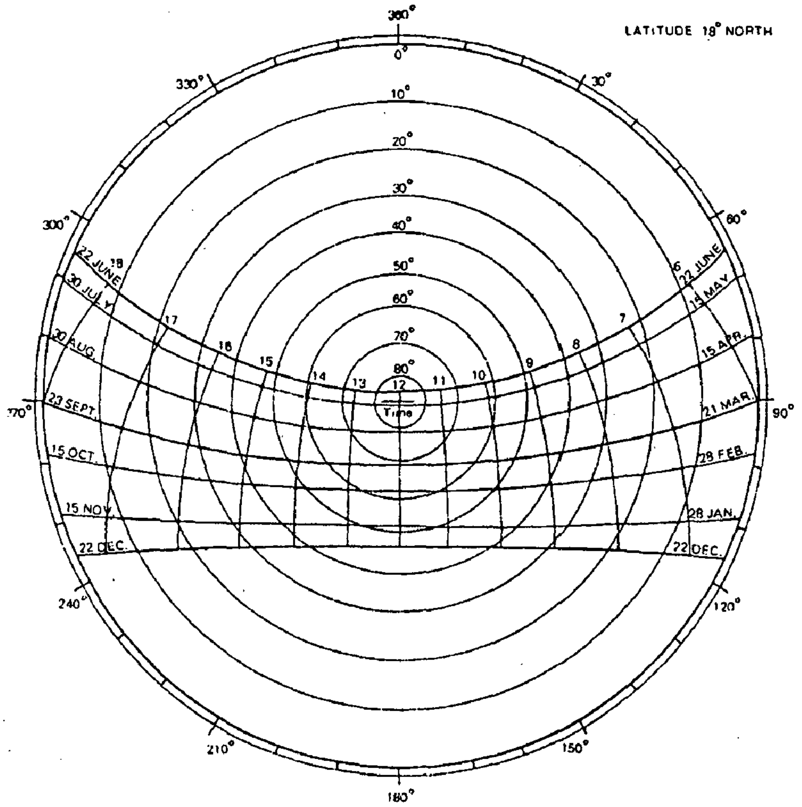


Figure 5.9: Sun path diagram at: 18° North latitude

6. Energy Conservation Initiatives in India

6.1. Energy Conservation Act 2001

The Energy Conservation Act, 2001 has come into force with effect from 1st March 2002. The Bureau of Energy Efficiency (BEE), a statutory organization set up under the EC Act, [28] is in the process of preparation of energy conservation building codes for different climatic zones of India. The lacuna in this activity is that the EC Act is applicable only to the designated consumers, which include energy intensive industries and establishments listed in the Schedule; this schedule lists commercial buildings & establishments, but no housing type is included. The overall approach seems to be restricted as the Housing Sector, which constitutes about 50% of the Building Industry has been kept out of the scope of this Act.

The BEE has instituted certain thrust areas in their Action Plan, and the Thrust area 4 and 5 deal with the implementation of Energy Conservation Measures.

6.2. BEE Thrust Area 4: Energy Efficiency in Buildings & Establishments

6.2.1. Background

In the Commercial sector, there is vast scope for energy efficiency improvement in buildings. Energy audit studies conducted in several office buildings, hotels and hospitals indicate energy savings potential of 20-50 % in end – uses such as lighting cooling, ventilation, refrigeration, etc. This potential is largely untapped , partly due to lack of an effective delivery mechanism for energy efficiency. Performance Contracting through energy service companies (ESCOs) is an innovative delivery mechanism for overcoming many of the barriers faced by energy users.

Government buildings by themselves constitute a very large target market. The objective of this thrust area is to promote energy efficiency in government buildings, and government institutions and establishments through the delivery mechanism of performance contracting by ESCOs. After demonstration of exemplary adoption and implementation of energy efficiency measures in government buildings, this can then be extended to other commercial buildings in a phased manner.

6.2.2. Provisions in the Energy Conservation Act

The provisions in the Energy Conservation Act regarding Energy Efficiency in Buildings and Establishments provide for the Following:

1. Defining building as any structure or part of a structure having connected load of 500 kW or contract demand of 600 kVA and above and intended to be used for commercial purposes.
2. Directing owners or occupiers of buildings or buildings complexes, being designated consumers, to comply with the provisions of energy conservation buildings codes.
3. Directing designated consumers to get energy audit of the building conducted by an accredited energy auditor in the specified manner and intervals of time.

These powers have been provided to the central government as well as the state governments.

6.2.3. Approach

Commercial buildings and establishments are included in the list of energy intensive industries and other establishments specified as designated consumers in the Schedule to the Act. Hence, all mandatory requirements for designated consumers, as given earlier, would be applicable.

Initially, about 10-15 buildings would be notified as designated consumers, and investment grade energy audit conducted to fix baseline consumption and establish energy savings potential. ESCOs. Would then be invited to undertake project implementation based on performance contracting and shared savings with the government. This would be extended to cover more government buildings and can subsequently be extended to other commercial buildings in a phased manner.

6.2.4. Action Plan

The initial activities to be undertaken in this thrust area include:

Table 6-1: Initial Activities Of Thrust Area 4

S.No.	Activity	Completion Date
1.	Notifying 10-15 buildings as designated consumers	September 2002
2.	Conduct of investment grade energy audit	March 2003
3.	Preparation of model performance contract and model monitoring and verification protocol	March 2003
4.	Inviting energy service companies (ESCOs) to implement projects on performance contract basis.	March 2003

In the medium–to-long-term, the activities would include:

Table 6-2: Medium to long term Activities Of Thrust Area 4

5.	Implementation of projects on energy performance contract basis
6.	Third party monitoring and verification of energy savings
7.	Expansion of programme to cover more government buildings.
8.	Expansion of programme to cover other commercial buildings.

6.2.5. Role of BEE

The role of BEE would be to:

- Carry out regulatory functions relating to notifying designated consumers and monitoring their compliance.
- Prepare bidding document incorporating standard performance contracting provisions to enable ESCOs to participate in the process.

- Leverage financial support from multi-lateral and bilateral agencies and domestic financial institutions.
- Coordinate with various agencies like CPWD, Ministry of Finance, financial institutions, ESCOs etc.
- Promote performance contracting through ESCOs as an energy efficiency delivery mechanism.

6.2.6. Benefits

The benefits of the approach and activities would be the following:

- Energy savings possibilities of over 30 %
- Reduction of fiscal deficit: additional income to Government through shared savings.
- Demonstration of energy efficiency delivery mechanisms.

6.2.7. Sections of EC Act, 2001:

15.The State Government may, by notification, in consultation with the Bureau,

(B) direct every owner or occupier of a buildings or building complex being a designated consumer to comply with the provisions of the energy conservation building codes.

(C) direct, if considered necessary for efficient use of energy and its conservation, any designated consumer referred to in clause (b) to get energy audit conducted by an accredited energy auditor in such manner and at such intervals of time as may be specified by regulations.

6.3.BEE Thrust Area 5: Energy Conservation Building Codes

6.3.1. Background

While the focus of the thrust area of "Energy Efficiency in Buildings & Establishments" is on improving energy efficiency in existing buildings, it is essential that new buildings be designed and built with energy efficiency considerations having been incorporated right from the initial stages. The development of energy conservation buildings codes is necessary for this purpose. The codes would be applicable to commercial buildings constructed after the relevant rules are notified under the Energy Conservation Act.

6.3.2. Provisions in the Energy Conservation Act

The provisions in the Energy Conservation Act regarding Energy Conservation Building Codes provide for the following:

- Defining energy conservation buildings codes as the norms and standards of energy consumption expresses in terms of per square metre of the area wherein energy is used.
- Prescribing energy conservation building codes for efficient use of energy and its conservation in the building or building complex.
- Amending the energy conservation building codes to suit regional and local climatic conditions.
- Directing owners or occupiers of buildings or building complexes, being designated consumers, to comply with the provisions of energy conservation building codes.

These powers have been provided to the Central Government as well as the State Governments.

6.3.3. Approach

Energy conservation building codes are to be prepared for each of the seven climatic zones of India for centrally heated and air conditioned buildings centrally air conditioned buildings, and non-centrally air conditioned/ heated buildings. The codes will cover buildings aesthetics; buildings envelope; materials used in building; heating ventilation and air-conditioning (HVAC) system; lighting system; electric power and distribution system;

service water pumping and heating system; thermal comfort in non-centrally air conditioned/ heated buildings; and integration of renewable energy systems.

A Committee of Experts would be constituted to guide the development of the codes. The development of codes will involve compilation and review of codes and work done relating to such codes in India and other countries of the region, followed by preparation of draft codes consistent with prevalent Indian standards and building byelaws. The draft codes for each of the regions would be extensively discussed with experts and the concerned local authorities prior to adoption. State governments could amend the Energy Conservation Building Codes to suit regional and local climatic conditions.

The local authorities while approving building plans would also ensure that the energy conservation building codes are incorporated in the building plan itself.

6.3.4. Action Plan

The initial activities to be undertaken in this thrust area include:

Table 6-3: Initial Activities of Thrust area 5

S.No.	Activity	Completion Date
1.	Constituting Committee of Experts	September 2002
2.	Preparation of energy conservation building codes for different climatic zones	July 2003

the medium-to-long-term, the activities would include:

Table 6-4: Medium to long term activities of thrust area 5

3.	Modification of energy conservation building codes by states to suit regional and local climatic conditions.
4.	Development of software for easy incorporation of the codes by authorities of state and local bodies.

6.3.5. Role of BEE

The role of BEE would be to:

- Constitute Committee of Experts.
- Network with and ensure participation of stakeholders such as architects builders, interior decorators, R&D institutions, academic institutions, town planning authorities of state and local bodies, housing finance organizations, Bureau of Indian Standards, etc. at all stages in the entire process.
- Network with state institutions for monitoring

6.3.6. Benefits

The Benefits of the approach and activities would be the following:

- Construction of energy efficient buildings
- Reduced electrical demand.

6.3.7. Sections of EC Act, 2001:

14. The Central Government may, by notification, in consultation with the Bureau,

(p) prescribe energy conservation building codes for efficient use of energy and its conservation in the building or building complex.

6.4 Deficiencies of Building Byelaws in India

The existing Building Byelaws contained in the Development Control Regulations of four major cities in Maharashtra, viz. Kolhapur, Solapur, Nagpur, Navi Mumbai, were studied from the context of Climatological Aspects. The Clauses regarding the lighting and ventilation of buildings have been attached in Appendices 1-4.

It can be seen from these clauses that are following flaws from Climatological point of view:

- it is not mandatory for the Architect to provide cross-ventilation through the building
- it is not mandatory to protect the windows form extreme solar gain

- the wall and windows on all sides of the building have the same requirement
- the window sizes and overhangs on all four directions are same
- the Part IIV Section 1 in the National Building code pertaining to Natural lighting & ventilation is not referenced to in the clauses like those for artificial lighting & ventilation

7. Conclusions and Recommendations

7.1. Introduction

It has been discussed that the climatic data is very important to ascertain the exact climatic requirements of a building in a particular site. For achieving effective energy conservation measures, it is necessary to properly classify climate to the most detailed level, so that when we use the simulation program for the initial ratification of various energy conservation techniques, the environmental load is exactly estimated by the program.

7.2. Summery of findings about Legislative Approaches

There are numerous routes to achieving compliance with energy efficiency regulations. As we have seen they vary in degree of detail and are used independent of each other as substitutes for each other or are used in combination in different countries.

Let us now discuss in brief the advantages and disadvantages of each of them, when we try and implement in our country.

7.2.1 Whole-building simulation

There are no readily available simulation tools for housing that calculate the total energy consumption. Tools such as ResCheck, NatHERS, the Building Energy Rating Scheme and FirstRate only estimate space heating and cooling energy requirements (not actual consumption) and do not include hot water, lighting and appliances. Thus it is something of a misnomer to refer to whole-building simulation in the context of housing. These tools in fact evaluate the envelope system only.

Simulation Programs assign a rating of between nought and five stars according to a house's requirement for heating and cooling energy compared to local standardised levels of performance. Simulation Programs could be used as the basis for housing energy provisions by setting a minimum star-rating requirement. There is widespread and growing acceptance of the concept of assigning a star rating to the building envelope, which allows some flexibility in design, rather than relying only on simple prescriptive insulation provisions. Thus one option for compliance for the building envelope is to achieve a minimum star rating using an acceptable rating tool. The advantages and disadvantages of this route are similar but not identical to those identified for buildings other than housing.

7.2.2.1 *Advantages*

This option offers considerable flexibility to designers in terms of balancing various elements of the building envelope.

7.2.2.2 *Disadvantages*

- This option requires one or more simulation tools to be available, which have sufficient accuracy to handle most of the design configurations used in the area of jurisdiction.
- Designers and assessors must be trained in the use of the simulation tools, in order that the estimates are sufficiently accurate and verifiable.
- Currently the standardized internal conditions usually assume full heating and cooling, controlling dry bulb temperature. The assumption of a fully conditioned building may disadvantage some designs using other approaches, in particular naturally ventilated open designs, passive solar requiring larger temperature variations, evaporative cooling, radiant comfort effects. While such designs may perform well in the unconditioned mode, it should be borne in mind that air-conditioning may be installed at a later date and so it is desirable that these designs also perform well when conditioned.

1.1.2.3 Issues

If a Simulation Program rating were to be used as a compliance option, some further development of the scheme and the Simulation software would need to be undertaken, in particular:

- Improve the user interface.

- Review the star bands and consider the option of expanding the number of available stars to give recognition to houses that easily exceed the five-star level.
- Improve the treatment of naturally ventilated house designs in warm-humid and hot-humid climates.
- Deal with the problem of small houses obtaining lower ratings than equivalent large houses.

This route only evaluates the envelope. Therefore compliance with any requirements on other energy consumers must be demonstrated separately.

7.1.3 Elemental requirements

While in principle the use of a simulation tool for the building envelope is attractive in that it integrates all components of the envelope, it becames clear that simpler routes to compliance are likely to be needed. For the building envelope this implies elemental requirements or something similar. The challenge is to avoid excessive complexity in the elemental requirements.

The wide variety of climates must be taken into account. Climate classifications are available with various degrees of fineness; for example, temperate, hot-arid, hot-humid, or cool temperate, temperate, dry warm temperate, hot arid, sub-tropical humid, tropical humid. Identification of an appropriate set of climate zones will need further research.

7.2.3.1 Glazing

Appropriate treatment of glazing is crucial. Glazing performance is determined by its area, U-value, shading coefficient, orientation and presence of fixed shading. The Window Energy Rating Scheme (WERS) separately rates the summer and winter performance of windows in Australia. Ratings range from one to five stars. The WERS rating could form the basis of window requirements for various climate zones. This has the advantage of simplicity and builds on work already completed.

Another possibility is to calculate for glazing on each façade an Equivalent Clear Unshaded Glass Area (ECUGA) and to specify requirements in terms of, say, maximum values of WWR based on this area. This gives designers some flexibility in specifying glazing and avoids the complexity that would result from specifying each glazing parameter separately. The ECUGA for a window with area A w can be calculated as follows:

ECUGA = SC*f*A w

Where; SC is the shading coefficient and f is a seasonal shading factor (calculated under some specified conditions). The disadvantage of this approach is that it does not account for the glazing R-value.

7.2.3.2 *Conduction gains and losses*

The key parameter characterising conduction gains and losses that is readily amenable to regulation is the overall thermal resistance (R-value). Thermal mass can be very important in determining the envelope performance, but it is more difficult to establish simple requirements. If a designer wishes to exploit thermal mass, this can be done via the whole-building simulation route. A minimum R-value could either be specified for each element, or a minimum area-weighted average R-value could be specified for the whole building. The area-weighted average R-value is calculated as:

$$R_{ave} = \frac{\sum A_i}{\sum (A_i / R_i)}$$

where; R_i and A_i are the R-values and areas of element *i* (for example, wall, window).

This has the advantage of including the R-value of glazing, allowing some flexibility by trading off performance between elements. However, it gives equal weight to all elements by ignoring the differences in driving temperatures between roofs, walls and floors, whereas insulating the roof/ceiling should be given first priority, for example, because of the high solair temperatures generally achieved on roofs in summer. Accounting for different driving temperatures would introduce additional complexity.

Minimum average R-value requirements and maximum WWRs for each orientation could be specified for each climate zone.

Alternatively, minimum R-values could be specified for individual opaque elements (for example, roof/ceilings, walls, floors) for each climate zone. This would allow the different driving temperatures to be reflected in the requirements.

The minimum R-value of the individual opaque elements could be set by assuming that windows are sized at maximum WWR and are single glazed with standard eaves, and examining the marginal cost-effectiveness of adding insulation to each element. Either table would need to be accompanied by reasonably comprehensive examples of complying constructions or by examples of complying combinations of window, roof/ceiling, wall and floor constructions (in the case of average R-value requirements).

- Advantages

- The regulation of conduction gains and losses is simple.
- The data required are readily available.
- Disadvantages
- A system to regulate conduction gains and losses needs considerable work to develop.
- Compatibility with results from whole-building simulation may be a problem.
- The system does not deal with infiltration.
- Issues

A method needs to be developed to assign any location to a climate zone.

Rules and guidelines need to be developed for calculating f.

Such an approach need not exclude or disadvantage lightweight 'open' highly ventilated designs in tropical areas. These designs still require at least roof/ceiling insulation, and rely on well-shaded windows, which can be handled via the WWR requirements.

7.3. Recommendations

1. Alternative Energy efficient techniques Recommended for the Climatic conditions of Kolhapur should be used and designs for typical residential buildings should be prepared.
2. These designs should be simulated using whole building simulation programs available and the most efficient combination of techniques should be recommended for use with the highest rating.
3. Keeping in mind the results from the above exercise an overall rating standard should be prepared.

7.4. Conclusions

Thus it can be concluded that with a combination of Whole building simulation and rating system with a ceiling of certain rating energy efficient building regulations can be formulated for residential buildings. The Regulations should be formulated for each administrative area, separately right from the first stage of Collection of Climatic data, analysis, recommendation of energy efficient techniques to the whole building simulation and then the ratings should be given.

Given this comprehensive approach, the aim of energy efficiency will be achieved to the fullest.

REFERENCES

---

[1] James Marston Fitch (December 1960): "Primitive Architecture and Climate", *Scientific American*, vol. 203, no. 6

[2] A. Bitan (1988): "The Methodology of Applied Climatology in Planning and Building", Energy and Building, vol. 11, pp. 1-10,

[3] S. C. M. Hui: "Using performance-based approach in building energy standards and codes", *Proc. of the Chonquing – Hong Kong Joint Symposium, July2002, Chonquing China, pp. A52-61*

[4] Janda and Busch, 1994; UN-ESCAP, 1999

[5] Hui and Cheung, 1998

[6] CIB, 1988

[7] Follente, 2000

[8] Bansal N.K, Garg S.N., and Kothari S. (1992). "Effect of Exterior Surface Color on the Thermal Performance of Buildings." *Building and Environment.* 27, 31-37.

[9] Malama A. and Sharples S. (1996). "Thermal and Economic Implications of Passive Cooling Strategies in Low-Cost Housing in Tropical Upland Climates." *Architectural ScienceReview.* 39, 95-105.

[10] Rousseau P.G. and Mathews E.H. (1996). A new integrated design tool for naturally ventilated buildings. *Energy and buildings.* 23, 231-236.

[11] Peuportier B. and Michel J. (1995). Comparative analysis of active and passive solar heating systems with transparent insulation. *Solar Energy.* 54, 1, 13-18.

[12] Filippin C., Beascochea A., Esteves A., De Rosa C., Cortegoso L. and Estelrich D. (1998). A passive solar building for ecological research in Argentina : The first two years experience. *Solar Energy.* 63, 2, 105-115.

[13] Ashley R. and Reynolds J.S. (1993). Overall and zonal efficiency end use in an energy conscious office building. *Solar energy.* 52, 1, 75-83

[14] Garg N.K. (1991). Passive solar options for thermal comfort in building enveloppes – An assessment. *Solar energy.* 47, 6, 437- 441.

[15] Hassif S. (1986). A linear model for passive solar evaluation. *Solar Energy.* 37, 2, 165-174.

[16] Millet J.R. (1988). *Conception thermique des bâtiments en climatisation naturelle dans les D.O.M. Document d'application. C.S.T.B n° 88.4343,* 124 p.

[17] Gandemer J., Barnaud G., Sacre C., Millet J.R. (1992). *Guide sur la climatisation naturelle en climat tropical humide.Tome 1 : Méthodologie de prise en compte des parameters climatiques dans l'habitat et conseils pratiques.* C.S.T.B., 1992. 133 p.

[18] Célaire R. (1997). *Opération expérimentale ECODOM, cahier de prescriptions. Document de référence.*

[19] De Waal H.B. (1993). New Recommendations for Building in Tropical Climates. *Building and Environment.* 28, 271-285.

[20] Garde F., Boyer H., Gatina J.C. (1999) Elaboration of global quality standards for natural and low energy cooling in French tropical island buildings. *Building and Environment.* 34, 71-83.

[21] De Wall, H.B., *New Recommendations for Building in Tropical Climates,* Building and Environment, Vol. 28, No. 3, pp 271-285, 1993

[22] Koenigsberger, O. H., et al., 1973. *Manual of Tropical Housing and Building,* Longman, London.

---

[23] Gut, P., *Climate Responsive Building: Appropriate Building Construction in Tropical and Subtropical Region*, First Edition, Swiss Centre for Development Cooperation in Technology and Management, St Gallen, Switzerland, 1993.

[24] Fergus Nicol: *"Climate and Thermal Comfort in India"*, Climate Responsive Architecture, Tata McGraw-Hill Pub. , New Delhi, 2001

[25] Watson, D. (Ed.), *The Energy Design Handbook*, Chapter 1, The American Institute of Architects Press, Washington, DC

[26] Lam, J. C. and Hui, S. C. M., Outdoor design conditions for HVAC system design and energy estimation for buildings in Hong Kong, *Energy and Buildings*, 22 (1995): 25-43.

[27] Szokolay, S. V., *Thermal Design of Buildings*, RAIA Education Division, Canberra, Australia, 1987.

[28] Energy Conservation Act 2001, No.52 of 2001,The Gazette of India, Extraordinary, Part II, Section I, Published by Authority, New Delhi, Monday, October 1, 2001.