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To Beam As A Beacon of Knowledge

FUNDAMENTALS OF BUILDING ORIENTATION AND GREEN BUILDING FEATURES



December 2023

INDIAN RAILWAYS INSTITUTE OF CIVIL ENGINEERING

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FUNDAMENTALS OF BUILDING ORIENTATION AND GREEN BUILDING FEATURES

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Foreward to Fifth Edition

The book "Fundamentals of Architecture for Railway Civil Engineers" was first published in 1995. In past two (2) decades, worldwide there has been more acceptance of sustainable buildings in Construction sector.

There is great demand and acknowledgement for construction of all type of buildings as green building or rather more water and energy efficient buildings. Indian Railways also has also set a target to achieve Net Zero Carbon Emission by 2030.

Keeping in view, the measure to be taken for making more sustainable and energy efficient buildings, this edition has included new chapter on water management, energy efficiency. Details of building orientations, brief on Energy conservation building code (ECBS) for commercial buildings; Eco-Niwas Samhita (ENS for residential buildings and IR policy on energy efficiency have been covered comprehensively.

It is hoped that this book will be useful to Engineers while planning the new buildings as well as to make existing buildings more energy efficient in the Railways. It will be great guide for field engineers for achieving IR's energy efficiency target.

November 2023

RAM KARAN YADAV
DIRECTOR GENERAL /IRICEN

Preface to the Fifth Edition

The Book "FUNDAMENTALS OF BUILDING ORIENTATION AND LAYOUT PLANNING" was first published in year 1995. Subsequently it was revised and enlarged as 2nd Edition in 1998, 3rd edition in 2007 with Green Building chapter and 4th edition in 2015 with further updating of on Green buildings.

In past 8 years, there has been huge change in the perception and practice of construction Industry. Sustainable buildings construction is now becoming the preference. Construction Industry is making efforts towards making energy efficient buildings there by helping the country to achieve its mission of Net-zero carbon emission.

In this edition, the text has been revised and updated. Major changes are made in chapter 1. In this chapter revised criteria of climatic zones with complete understanding of building physics (concept of U-value, R-value of are introduced) has been added. Chapter 5 and 6 are new chapters – water management and energy efficiency respectively are introduced. In energy efficiency chapter, brief on Energy Conservation Building code, Eco-Niwas Samhita and Indian Railways energy efficiency policy are included. I am thankful to Shri Shivam Gupta and Shoumik Desai (USAID-SAREP team members) for their help in writing the content on building physics and energy efficiency.

It is hoped that it would be useful for Railway Officers and mainly Civil Engineers while planning for new buildings as Green Building.

In spite of every care taken to ensure accuracy, some errors might have crept in. Suggestion for further improvement of the text would be gratefully acknowledged.

November 2023

D N KATE
Sr Professor/Works
IRICEN

Foreward to Fourth Edition

The book "Fundamentals of Architecture for Railway Civil Engineers" was first published in 1995. With the emphasis on sustainable habits as key solutions to growing infrastructure needs, Indian Railways has also embarked upon making the energy efficient buildings. Therefore, comprehensive features of green Building have been added along with updating the book.

To make this book more useful to Civil Engineers, a comprehensive case study of IRICEN Building has been included. Keeping in view the new features in the book, the title of the book has been appropriately revised as "FUNDAMENTALS OF BUILDING ORIENTATION AND GREEN BUILDING FEATURES".

It is hoped that this book will be useful to Engineers while planning the new buildings in the Railways. Endeavour has to construct New Buildings by spending a little extra, in the initial stages which get set off in a short period of time.

21st October, 2015

VISHWESH CHAUBEY
DIRECTOR/IRICEN

Preface to Third Edition

The first edition of the book "Fundamentals of Architecture for Railway Civil Engineers" published in Oct 95 was very popular among the field engineers as all aspects concerning Fundamentals of Building Architecture were well documented in the book. Its revised and enlarged 2nd edition was also published in June 1998.

During last few years, eco-friendly and energy efficient buildings had gained importance on account of impact of development on environment. Buildings incorporating these features are called as Green Buildings due to use of energy efficient features and environment friendly materials. Different rating systems have been developed in various countries for rating these buildings.

Keeping in view of the above, in this 3rd and revised edition, a new chapter on "Green Building" has been added. Also to make this book more useful and interesting to Civil Engineers, the other chapters have been modified by adding case study. In view of these changes, the title has been changed as "FUNDAMENTALS OF BUILDING ORIENTATION AND LAYOUT PLANNING".

Efforts have been made to make the book more useful for the field engineers. In this effort, the IRICEN faculty and staff have contributed immensely, notably among them are Mrs. Lata Sridhar and Mr. Sunil Pophale. I am particularly thankful to Shri A. K. Rai, Professor Works who has contributed immensely in updating and adding a new chapter on Green Building in this book and also carrying out proof checking. I am also thankful to Shri Rajesh Kumar, Professor Track-1 for providing logistics assistance for printing this book.

Above all, the author is grateful to Shri Shiv Kumar, Director IRICEN for his encouragement and guidance in bringing out the publication.

March, 2007

N. C. SHARDA
Sr. Professor Works
IRICEN

Foreword to First Edition

It is a long felt need that Railway Civil Engineers be given adequate exposure to fundamentals of architecture so as to achieve a better reflection of aesthetics and user-friendliness in customer satisfaction. With this objective in view, IRICEN has compiled this treatise in basic architecture through Sh Dhananjay Datar, a practicing Architect in Pune. I hope this will serve a long way in improving the aesthetic sense of Railway Civil Engineers and will also assist them in interacting with architectural consultants.

October, 1995

S.GHOPALAKRISNAN
DIRECTOR / IRICEN

FOREWORD
(Second Edition June 1998)

This edition has been revised and additional information has been added by Shri S. Gopalakrishnan, formerly Director, IRICEN and Shri Rajesh Agarwal, Professor, IRICEN. This is now treated as Volume 1 with the intention of bringing out more information in Volume 2 in future.

June, 1998

VINOD KUMAR
DIRECTOR / IRICEN

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INTRODUCTION

In many parts of our country except for the metros and cities, the vocation of architecture is relatively unknown. In the villages, it is the local mason who draws lines with a stick directly on the plot of land and physically explains the structure to the end user. After preliminary approval, the construction work commences straight away.

As the function, size and requirement of a structure increased the need for a person who can plan and design is felt. This has led to architecture being evolved as a full-fledged profession. An architect undergoes training for approximately five years, which makes him capable of understanding the importance of planning, design and aesthetics. Along with these, he also gets well acquainted with supporting systems, techniques of construction, etc.

Architecture therefore can be defined as a fine blend of art, creativity and logic, reinforced with a backbone of structural technology. Art and creativity essentially mean sensitivity to form, colours, textures, volumes, compositions, homogeneity, etc. while the technical part includes structural soundness, sanitation and drainage, acoustics, firefighting, electrical services etc.

An architect's role is to design an environment (inside & outside), which caters to human needs, both physical and psychological, human comforts and luxuries.

In today's context, with the complexity of structures increasing rapidly, it is virtually impossible for an architect to cater to all these needs. Specialisation in architecture now, has mushroomed all over the large cities, whereby an architect branches out and becomes an expert in a specific field. Some of the specializations are housing, urban design, town planning, landscape, construction management, industrial architecture and public health. Large projects are being now handled by an architect and his team of consultants. Due to this, it has become Imperativethat an architect should have the following strengths in order to succeed in practice

i) Strength of conceptualization
ii) Aesthetic sensitivity
iii) Communication skills
iv) Management acumen
v) Sound technical knowledge.

A good designer always respects factors which play a major role in designing which are unchangeable and works in tandem with them to come up with a solution which blends rather than upsets the surroundings. Some of these factors are climate of place, local building materials, local landscape, living style of the people and other physical attributes of the site.

Manmade factors which can influence design are the building type, the funds available, the number of users and special facilities and requirements.



CHAPTER 1

FUNDAMENTALS OF LAYOUT DESIGN AND BUILDING PHYSICS

1.1 Process of design

Before undertaking a layout design assignment, one should start off the process of design in a methodical manner. One should consider a number of aspects and factors that are likely to influence design. Some of these factors are related to the location of the site, the prevalent climatic conditions, local materials etc., while others are space requirements, functions of each space, etc. The former are guided by nature and cannot be changed while the latter are man-made and can be marginally flexible. Since the number of building types are large, it is impossible to master all building types, and many a times assignment ends up with building type which has never been done previously. The procedures which are followed can be briefly summed up as follows :

1.1.1 Site Selection/Condition of the site

It may happen that a designer might be asked to make his choice of the site from the available options. In this case, advantages and disadvantages of each location should be compared and then the most suitable site should be selected. The process should be governed by :

- Access to site
- Character of structures around the site
- Availability of services like water connection, drain age lines, power supply, garbage disposal, etc.
- Existing greenery, if any
- Dimensions of the site, so as to get an idea of fore ground, side margins etc.

- Openness from point of view of ventilation, light and view
- Sound and air pollution
- Elevation of the ground (contours) with respect to the existing roads, if any.
- Highest flood level and pattern of surface flow of rain water.

If the site has already been selected, then all physical features like contours and levels, water sources, available greenery, if any, presence of cables, poles, pipelines, etc., should be recorded. The view offered by various authorities should also be kept in mind. The directions and alignment of the plot (length and breadth) with respect to north, determines the location of spaces within the structure, with respect to orientation principles.

1.1.2 Data Collection

Design of any building type is based on the data which needs to be collected before commencement of actual work e.g. a hospital building has a very specific pattern of circulation, which if violated, can cause pandemonium. Smooth movement of people is the key in such a case. Data can be collected by studying various books pertinent to the subject.

Anthropometric data is available in special books which gives ready references and information, and thus save time.

It is also beneficial to visit similar existing structure which has been put into operation. A case study, based on actual visits, discussions and observations can give the designer very good insight into plusses and minuses of the case. A lot of problems can be identified while conducting a case study. Multiple case studies expose the designer to a larger database and comparison of cases can lead to valuable data.

1.1.3 Bubble Diagram

After completion of above two steps the actual process of design commences. Spaces are represented by circles (Refer to Fig. 1.1) with names of the spaces written within the circles. The circulation/movement within the structure, from one space to the

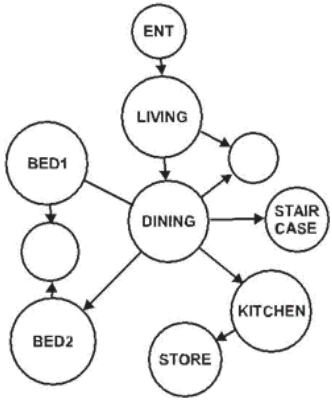


Fig. 1.1 Bubble diagram for a 2 bedroom residential unit

other is represented by arrows. On completion, a bubble diagram represents the basic circulation pattern. The sizes of circles are proportionate to the area of various spaces. This forms a basis for planning. Different alternatives can be explored, leading to more than one alternative.

1.1.4 Sketch Scheme

These involve the translation of each bubble into a room or space with dimensions (lengths and widths) leading to a conceptual plan. It is at this stage that the light and ventilation for each space needs to be attended to. Along with the sketch plan, the effect of the plan on the elevations which evolve are to be studied, i.e. a three dimensional effect of the volumes which are created should be considered simultaneously. Many a times designer tend to give more priority to planning and the elevations are ignored or neglected. This leads to a structure, with an effective plan, but with non-descript elevations. It is equally an undesirable practice to aim at elevation, sacrificing the conveniences of planning.

The actual skill lies in visualization of the volumes that are created, and only then can interesting structures be created. Process of a design should progress in all three axes simultaneously.

1.1.5 Scale Drawing

Thumb nail sketches of plans, elevations and perspectives should be drawn to a convenient scale and various presentation techniques could be used. A few of presentation techniques are listed below:

- rendering in pen and ink
- rendering in crayons on handmade paper
- rendering in colour pencil on glossy white paper
- use of water colours, in the form of washes on hand made paper
- collage
- computer aided techniques

Presentation techniques are responsible for arousing the interest of the viewer and it helps to enliven the scheme by virtue of colours, sciography, etc.

1.2 Internal Layout and Circulation

After a basic circulation pattern is established by means of bubble diagram, the next step is to formalize space by assigning dimensions to the bubble. However, there are other considerations involved in formalizing the space. One of the major aspect is circulation within the room and the internal layout. It is dependent on the function of the space and the location of the objects like furniture inside the room. The dimensions of furniture will have to be predetermined for good planning. The openings in a room like doors and windows are also important as they determine the part of movement, i.e. passages in space. In an ideal plan, this passage space should be kept to the minimum, as this area is effectively unusable for any activity. Corridors bounded by walls on both sides should be minimized. It should be possible to take a stretcher along corridors and negotiate turnings.

The overall functional values of a space are determined based on optimum movement space and maximum usuable space. The movement pattern changes with the various functions. For example, in a library or reading hall, movement or circulation

assumes a very important role. This is because a quiet, undisturbed working environment has to be created in public space or the movement of visitors coming and leaving a hospital, the movement of patients within the hospital etc., directly affects the day to day working of the hospital.

Location of entries and exits to and from a space needs to be worked out based on the furniture layouts. Fig. 1.2 shown below effectively illustrates the importance of circulation. In today's time, where the size of the structure is getting smaller and smaller in the metros, wastage of circulation areas and passages is an uneconomical proposition.

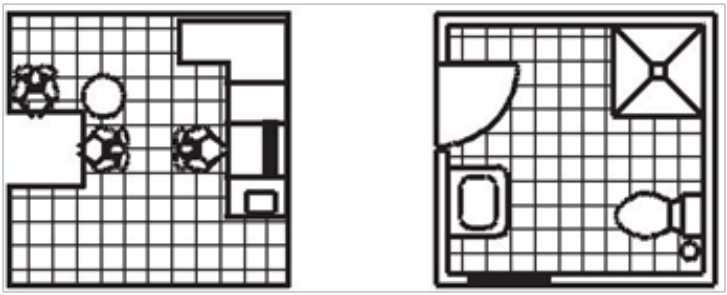


Fig. 1.2 Importance of circulation

A thumb rule that can be followed for this is to filter crowds, (i.e. traffic due to movement of people) and gradually decrease the traffic as one progresses from public areas to private spaces. This led to circulation pattern in which the main entrances directly lead to public areas and a semi-public space is introduced between the public and private zones.

As an example, a railway station can be designed as follows:

1. As regards passenger handling, it should be remembered that there are four categories of people. The first one belongs to those who come for boarding, the second one for those who arrive by some train and depart by some other train by changing platform, the third one for those who arrive and disperse and the fourth for the friends and relatives of passengers who come

to receive or see off the passengers. Taking cue from airports, it should be possible to separate and streamline the movements of arrival, departure and transit passengers in designing major station.

2. The circulating area should cater for different kinds of vehicles, viz., cars, taxis, autorickshaws, buses, etc. Vehicular movements into/out of paid parking areas should be isolated from free access lanes.

3. The main entrance hall or foyer is a large area, enough to accommodate hundreds of people, who form a permanently mobile crowd. Most of the people are directly concerned with the purchase of tickets, thus making it important to locate ticket and enquiry windows as close as possible to the foyer. Notice boards, train schedules, enquiry counters, etc., are always part and parcel of this foyer. This ensures that other than travellers, outsiders do not penetrate the interior, thus increasing congestion inside the station.

4. Separate access and infrastructure are provided for accepting parcels for trains. A road leads directly from the outside to the parcel office. However, parcel booking of accompanied baggage by the passengers should be catered for, near the foyer.

5. Entries and exits should be so provided so as to be controlled by ticket checking staff. Station manager should be so located that people can meet him without the need to purchase platform ticket and also that access exists for Station Manager to enter main platform.

6. The foyer opens out into platforms with a foot overbridge located close by. All trains which have a heavy daily commuter traffic, berth on the platform which is closest to the foyer. By doing this large crowds crossing from one platform to the other is avoided. Through trains, which stop for short time periods, with less number of arriving and departing passengers berth on the subsequent platform. Therefore, by proper use of platforms, human traffic and the walking distances are effectively reduced.

7. Goods train have separate goods sheds, offices, loading and

unloading yards. This should have proper road access and facilities for agents, commercial organization and labourers.

8. Toilets, drinking water facilities and tea stalls are located in positions which are central and have maximum and easy accessibility. Providing small toilet blocks at various locations instead of large central one, reduces cross circulation of people. Railway's own facilities not directly related to train operation, such as Signal & Telecom stores, rest rooms, motor trolley sheds, trade union office, etc should not be located in platforms. Number of stalls on platforms should be kept to the minimum. Pictograms for passenger guidance and signages should be adequately used. On careful observation, one realizes that the smooth functioning of a public place like a railway station largely depends on the circulation within the station and is a study in itself.

Architectural designing always proceeds designing from the whole to the part. As mentioned earlier, a bubble diagram now progresses to a full-fledged plan, with proper and logical circulation. All spaces now have specific sizes and locations, and the skeleton of the building is ready. A plan can be compared to a human body, wherein blood vessels represent the passages and the parts of the body are the various spaces. All blood vessels originate or culminate in the heart, which is like the main entrance.

The next stage in the planning process is the study of each individual space. The function of each space, movement of people to and from the space, i.e. passages, and proper location of entries and exits are established. Locations of windows are based on the quality of light, ventilation and view offered by a particular position. Preparation of furniture layouts for each space is an effective process for achieving this.

This completes the planning process, and now, a fully functional plan is ready.

1.3 Orientation of Building

The main aim of orientation of buildings is to provide physical and psychological comfort to user of building.

1.3.1 Climatic zones:

For the purpose of design of buildings, the country may be divided into the major climatic zones As per NBC 2016 vol. 2, section 1 para 3, which are as under-

Table 1.1

SN	Climatic Zone	Mean monthly Maximum Temperature ^{O}C	Mean Monthly Relative humidity in %
1	Hot-dry	Above 30	Below 55
2	Warm-Humid	Above 30	Above 55
3	Temperature	Above 25	Above 75
4	Cold	25 - 30	Below 75
5	Composite	Below 25	All values

Note: In climatic zones, throughout the year climate is not same. It has it has a particular season for more than six months and may experience other seasons for there maining period. Aclimatic zone that does not have any season for more than six months may be called as compositezone.

1.3.2 Climatic Factors:

From the point of view of lighting and natural ventilation,the following climatic factors influence the optimum orientation of thebuilding:

1. **Solar Radiation:** The best orientation requires that the building as a whole should receive the maximum solar radiation in winter and the minimum in summer. For practical evaluation, it is necessary to know the duration of sunshine, and hourly solar intensity on the various external surfaces on representative days of the seasons. The total direct plus diffused diurnal solar loads per unit area on vertical surface facing different directions are given inTable3 of NBC 2016 (NBC Vol. 2, para 3.4.1 of part 8), for two days in the year, that is, 22 June and 22 December, representative of summer and winter, for latitudes

corresponding to some important cities all over India. Except in cold climatic zone, suitable sun-breakers have to be provided to cut off the incursion of direct sunlight to prevent heat radiation and to avoid glare.

2. **Relative Humidity and Prevailing Winds:** The discomfortdue to high relative humidity in air when temperatures are also high can be counteracted, to a great extent, by circulation of air with electric fans or by ventilation.

i. Electric fans help in circulation of air. However, from cost perspective efforts shall be made for protection from solar radiation where temperatures are very high. When, however, there is less diurnal variation between morning and mean maximum temperatures along with high humidity, as in coastal areas, the emphasis should be on prevailing winds.

ii. For the purpose of orientation, it is necessary to study the velocity and direction of the wind at each hour and in each month instead of relying on generalizations of a month or a period or for the year as a whole. This helps to spot the right winds for a particular period of day or night.

iii. It is generally found that variation up to 30° with respect to the prevalent wind direction does not materially affect indoor ventilation (average indoor air speed) inside the building.

iv. In hot-dry climate, advantage can be taken of evaporative cooling in summer to cool the air before introducing it into the building. But in warm humid climate, it is desirable either to regulate the rate of air movement with the aid of electric fans or to take advantage of prevailing winds.

1.4 Fundamentals of Building Physics:

It is about understanding the fundamental concepts of building physics, including how buildings interact with the environment and the principles of energy-efficient design. Good details on building physics are given in Energy Conservation building Code 2017.

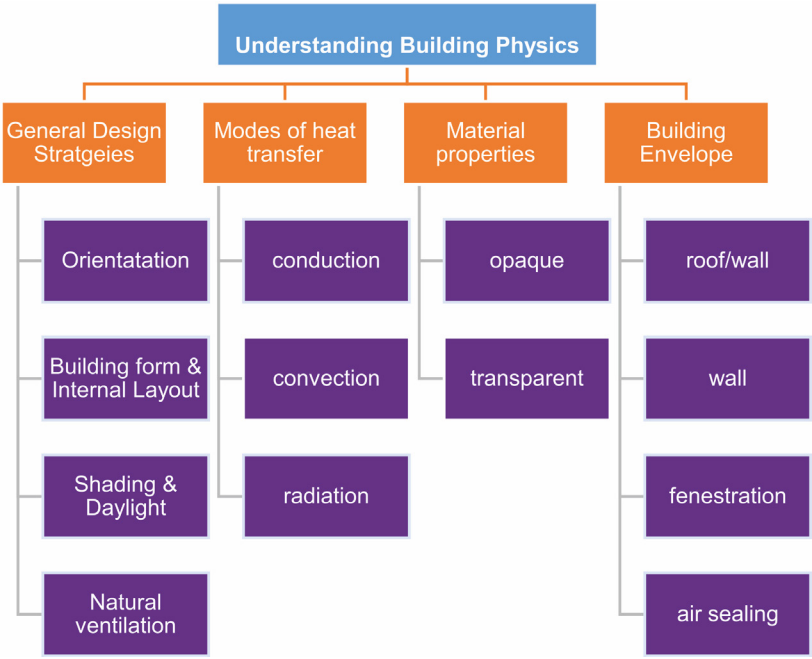


Figure 1.3: Building Physics components

1.4.1 General Design Strategies

Passive design elements refer to building design strategies that aim to improve thermal comfort and reduce energy consumption by reducing reliance on mechanical systems such as air conditioning or heating. Understanding building physics is essential for designing passive design principles because it enables designers to create buildings that are energy-efficient, thermally comfortable, and healthy for occupants.

(a) Orientation

The utilization of form and orientation are key passive design strategies for decreasing energy consumption and has a lasting impact through the lifespan of the building. Orientation impacts the degree of solar radiation falling on surfaces, daylighting, and wind direction which in turn can impact the heat transfer of the building. Building orientation should be based on the location,

context and climate. While designing the building, maximize solar radiation during the winter and minimize it during the summer.

In hot and dry climates, the best practice involves positioning the building with its longer axis in a North-South direction to offer efficient sun shielding. Shading the East and West sides can be challenging, while it's simpler to provide shade for the Southern side, considering that the sun's movement to the North is infrequent. In regions with cold winters, the orientation should maximize passive heat gain during the winter months to enhance thermal comfort.

Warm-humid climate zones, where solar radiation is concentrated on the East and West slopes, benefit from buildings oriented away from the equator, preferably on northern or southern slopes. Sites should be positioned on windward slopes or near beaches. For low-rise buildings, wind direction is more critical, while taller buildings focus on sun protection. In moderate climate zones located on hilly or plateau regions, heat gain reduction is a primary design criterion, making a north-south orientation with cross-ventilation essential.

In predominantly hot regions, buildings should be optimally oriented to minimize solar gains, while the opposite is valid for cold regions. Orientation is also important concerning wind direction. The building form determines the volume of space that needs to be cooled or heated. As a result, a more compact shape is less wasteful in terms of heat gain or loss. In hot and dry regions, as well as cold climates, a building's shape should be compact to reduce heat gain and losses, respectively.

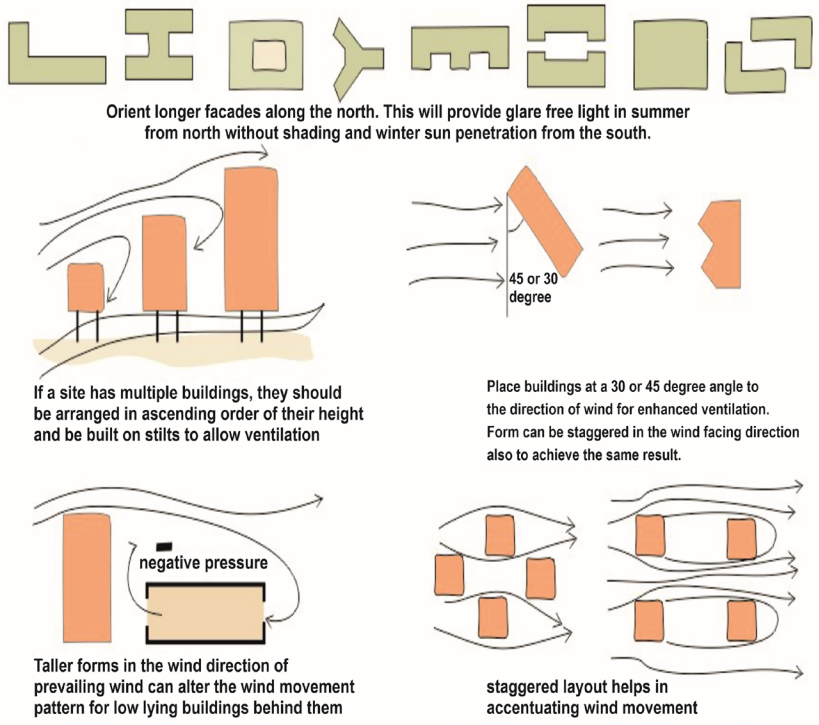
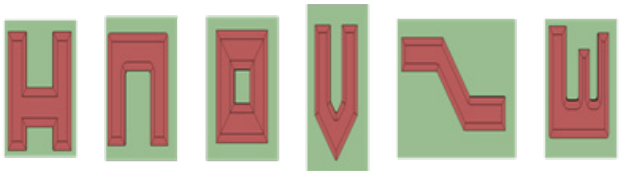


Fig 1.4: Design strategy for building orientation & form

(b) Building form & Internal Layout:

The main strategy in this climate is protection from the sun and good ventilation. Forms with larger surface areas will provide more openings for ventilation and heat emission during the night, however, the building should not have a large surface to volume (S/V) ratio to minimize heat gains. The buildings will perform better if arranged in row houses, group arrangements or with adjoin houses to create a volumetric effect



Form	Form 1	Form 2	Form 3	Form 4	Form 5	Form 6
Built Up (Sq. m)	6000	6000	6000	6000	6000	6000
EPI (Kwh/ yr/ Sq. m)	134	137	133	137	136	141

Fig 1.5: Impact of form on the energy performance index

The internal layout is dependent on the orientation and building function-specific. For commercial buildings, the major contribution to heat loads is from the occupants and equipment's. As a rule of thumb, the rooms should be arranged according to their function and the time of the day they are used.

For hot and dry climate, rooms thermal barriers should be created on the east and west side of the building by placing non-habitable spaces in these orientations. The spaces should preferably be inward looking, with minimal exposure to the sun. For warm and humid climate, rooms on the east side should be used during the afternoon and rooms on the west side during the morning hours. Spaces on the North and south remain relatively cool, due to the high angle of sun in these orientations, but adequate shading needs to be provided.

(c) Shading & Daylight :

Shading of direct sun and its reflection in the surrounding is important. Shading can be through neighbouring buildings, self-shading from the building shape, vegetation or special shading devices such as louvers or perforated screens, lattices, grills, etc. will be required on the East and West façade to protect against the low sun angles, high intensity solar radiations and direct glare. Internal spaces can also be shaded using gallery or balcony spaces.

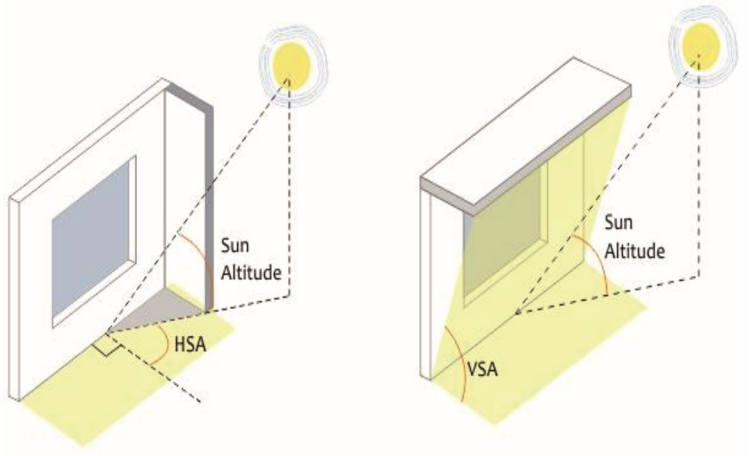


Fig 1.6: Horizontal and vertical shading angle to Shade the wall glazing

Table 1.2 Orientation and effective shading strategy

Orientation	Effective Shading Strategy
Equator Facing	Fixed Horizontal Device
East	Vertical Devices / Louvres (Moveable)
Pole Facing	Not Required
West	Vertical Devices / Louvres (Moveable)

The North façade gets exposed to the sun only during the monsoons, when it is predominantly overcast, thus, shading is not required. A simple overhang is adequate to block the sun in the south orientation. The East façade requires boxed shading, whereas, Special shading devices such as louvers or perforated screens, lattices, grills, etc. will be required on the West façade to protect against the low sun angles, high intensity solar radiations and direct glare. The north and South facades can be protected by an overhang.

(d) Natural ventilation :

Natural ventilation helps in heat transfer by removing hot air from the building and replacing it with cooler outside air. This is achieved by allowing fresh air to enter the building through operable windows, vents, or other openings in the building envelope, and then allowing the hot air to escape through exhaust vents, chimneys, or other means. By promoting this natural flow of air, heat is removed from the building, which helps to maintain a comfortable indoor temperature. Additionally, natural ventilation can reduce the need for mechanical means to ventilate a building, which can result in energy savings and a lower environmental impact.

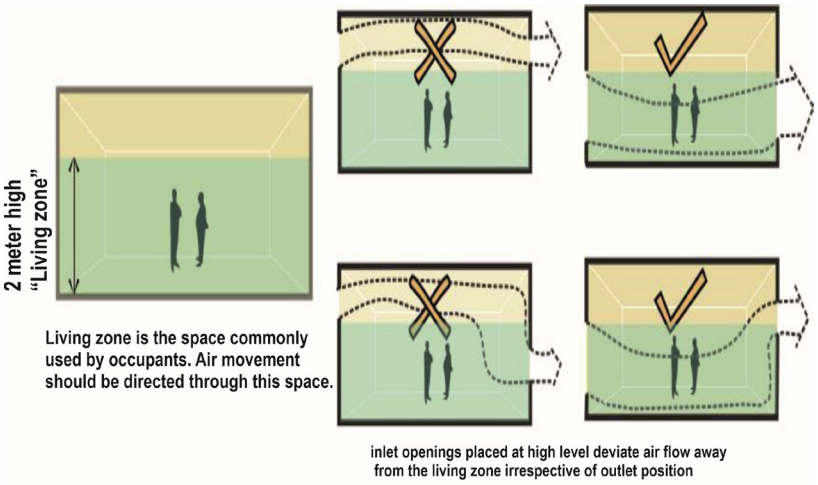


Fig 1.7: Potential window location in wall and its impact of heat transfer

Several building elements can promote natural ventilation, including appropriate building orientation and form, building envelope openings such as windows, doors, and ventilators, operable windows, internal space planning, and other advanced ventilation techniques such as the courtyard effect, stack effect, wind tower, or air earth tunnels. By strategically placing these elements, natural ventilation can be facilitated, allowing for the movement of fresh air into and out of the building, which can help

remove heat and maintain a comfortable indoor environment.

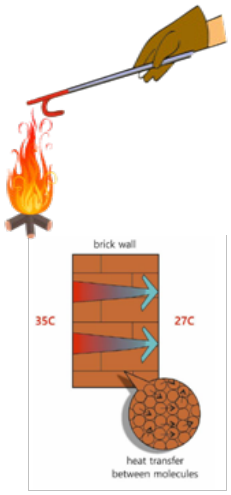
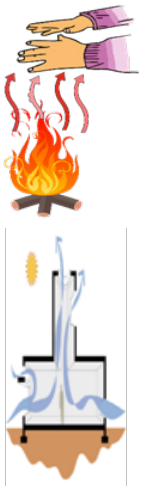
1.4.2 Heat Transfer Mechanism:

In buildings, heat moves from higher temperatures to lower temperatures through walls, windows, and roofs. In predominantly hot climates like India, heat transfer mostly occurs from the outside to the inside, making cooling a more significant need than heating. There are three major modes of heat transfer in a building These are:

- Conduction
- Convection, and,
- Radiation

Learning about the heat transfer properties of building materials is essential for choosing materials that are suitable for the building based on the location and climate. Let us understand each mode of heat transfer in detail.

Table 1.3
Table showing conduction, convection adiation with example

Conduction	Convection	Radiation
		
It is the heat transfer through a solid medium due to temperature difference Conduction takes place through all, roof, floor and fenestrations.	Convection is the heat transfer through fluid medium such as air due to temperature difference.	Radiation heat transfer results when thermal energy in the form of electromagnetic waves is emitted from a body due to its temperature. About 80% of the heat gain in the daytime is by radiation.

1.4.3 Thermal Properties of Material

a) Opaque materials :

Properties of opaque materials that are affected by conduction heat transfer

Table 1.4

Thermal properties of material that is affected by conduction heat transfer

Thermal Property	Units	Definition
Conductivity[K]	W/m.K	Rate of heat transfer through unit thickness of material. eg. 1m brick wall
Conductance	$W/m^2.K$	Heat transfer through specific thickness of material. eg. 230 mm brick wall
U- Value	$W/m^2.K$	Heat transfer through the entire composite material assembly. eg. Plaster + brick wall + gypsum board
R-Value (Resistance)	$m^2.K/W$	Heat resistance by a material assembly
Thermal Capacity	kJ/ cu.m C	Measure of heat storage capacity

To put simply conductivity accounts for unit thickness, conductance accounts for specific thickness and U-value accounts for entire composite assembly. We need to focus on U-value.

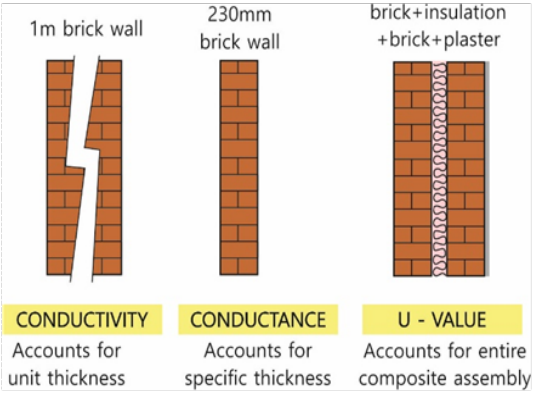


Fig 1.8: Difference between conductivity, conductance and U-value

i) How to calculate U-value:

For example, if there are following layers in a wall assembly

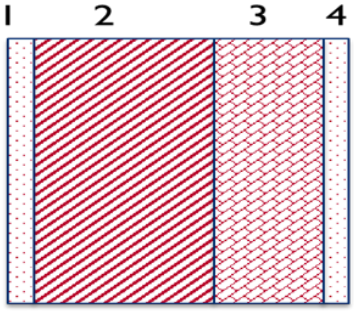


Fig 1.9: Wall assembly for U-value calculation

Table 1.5

Table showing list of layers, material thickness and thermal conductivity

Layer name	Material name	x - Material thickness (m)	k - Thermal conductivity (W/m.K)
Layer 1	Cement plaster	0.025	1.40
Layer 2	Brick, Fired clay	0.230	1.47
Layer 3	Lightweight brick	0.115	0.20
Layer 4	Cement plaster	0.013	1.40

- **Resistance for each layer can be calculated as follows:**

Table 1.6

Table showing step by step method to calculate U-factor of an example wall assembly

Step 1	Step 2	Step 3
$R_1 = \frac{x_1}{k_1} = \frac{0.025}{1.400} =$ 0.017 m^2.K/W $R_2 = \frac{x_2}{k_2} = \frac{0.230}{1.470} =$ 0.156 m^2.K/W $R_3 = \frac{x_3}{k_3} = \frac{0.115}{0.200} =$ 0.575 m^2.K/W $R_4 = \frac{x_4}{k_4} = \frac{0.013}{1.400} =$ 0.009 m^2.K/W R = Resistance x = material thickness k = thermal conductivity of material	**R_t**: R-value for the composite wall = $R_1 + R_2 + R_3 + R_4$ = 0.017+ 0.156 +0.575 +0.009 **= 0.757 m^2.K/W** **R_{se}**: external heat transfer resistance = 0.13 m^2.K/W **R_{si}**: Internal heat transfer resistance = 0.04 m^2.K/W RT = Rse + Rt + Rst = 0.13 + 0.757+ 0.04 **= 0.927 m^2.K/W**	U = $\frac{1}{R_t}$ U = $\frac{1}{0.927}$ U = 1.07W/m^2.K

For the calculation of the thermal transmittance the mean values of the exterior and interior surface thermal transmittance can be obtained from the following table. These values are result of empirical studies and merely represent magnitudes of order. They consider both convection & radiation influences.

Values of Surface Film Resistance Based on direction of heat flow					
Rsi			Rse		
Direction of heat flow			Direction of heat flow		
Horizontal	Up	Down	Horizontal	Up	Down
0.13	0.10	0.17	0.04	0.04	0.04

You can refer to the Typical Thermal Properties of Common Building and Insulating Materials from ECBC Appendix A: Default Values for Typical Constructions

ii) Frequently asked Questions :

- How can the U-value be improved?

  Adding insulation is an effective way to enhance the U-value.
- What precautions should be taken during insulation installation? It's crucial to ensure there are no thermal bridges, which can allow heat transfer. Install insulation so that it runs continuously across the entire wall section.
- What is a thermal bridge?

  Thermal bridge is like a shortcut for heat to escape or enter a building because it's an area that doesn't have proper insulation. Imagine a cozy, warm house in the winter, but there's a small crack around a window frame where cold air can sneak in. That crack is a thermal bridge because it lets heat escape more easily, making your house colder and your heating bill higher.

iii) Properties that affect radiation heat transfer :

Table 1.7

Thermal properties of the material that are affected by radiation heat transfer

Emittance	Absorptance	Reflectance	Transmittance
Ability to release heat by radiation	Ability to absorb heat by radiation	Ability to reflect (bounce off) radiation	Ability to transmit radiation
Reduces the sensible heat content	Will increase the sensible heat content of the object	Prevent overheating	Object is unaffected
Surface finish	Surface color	Surface color and finish	Transparency of the material
ε	α	R	T
Perfect emitter = 1 [white body]	Perfect absorber = 1 [black body]	-	-
Values range from 0 to 1			

Emittance, absorptance, reflectance, and transmittance values are specified by manufacturers for their products, especially building materials like insulation or glass. They can measure these values in a laboratory under controlled conditions to provide specifications for their products.

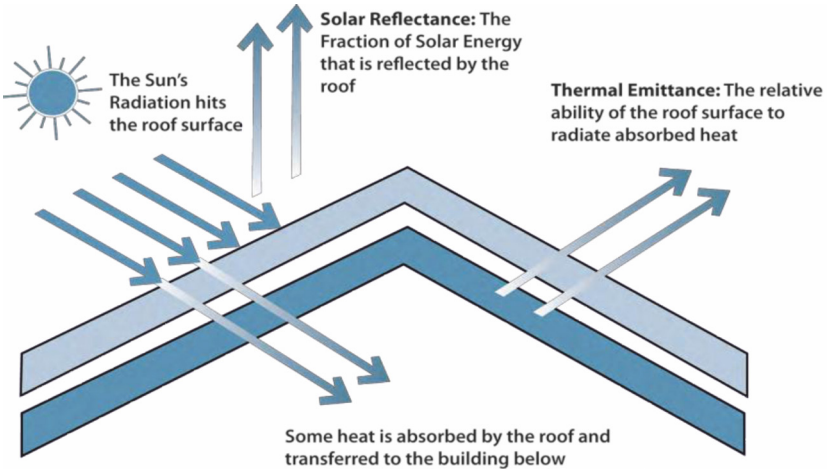


Fig 1.11: Image showing how the properties of a material is impacted by radiation

iv) Frequently asked Questions:

- How do I find products with the desired Emittance, Absorptance, Reflectance, and Transmittance characteristics?
  Manufacturers often specify these values for their products. Look for this information in product datasheets or consult with suppliers.
- How do Emittance, Absorptance, Reflectance, and Transmit tance affect the energy efficiency of a building?
  These values impact how materials absorb, reflect, or transmit heat. Higher reflectance and lower emittance can reduce heat absorption, improving energy efficiency.

- How are these values measured or calculated for building materials?
  They are typically measured through standardized tests in laboratory settings, and some manufacturers provide these values for their products.

b) Transparent materials:

Properties of transparent materials that are affected by conduction & radiation heat transfer

Table 1.8
Thermal properties of glazing

Thermal Property	Units	Definition
U- Value	W/m2.K	Heat transfer through the entire composite material assembly. Eg. Plaster + brick wall + gypsum board
Solar Heat Gain Coefficient (SHGC)	Unitless	SHGC is the ratio of the solar heat gain that passes through the fenestration to the total incident solar radiation that falls on the fenestration. It ranges from 0 to 1. Higher the SHGC higher the heat gain.
Shading Coefficient (SC)	Unitless	It is a measure of the total amount of heat passing through the glazing (known as the total solar heat transmittance) compared with that through a single clear glass. It ranges from 0 to 1. The lower the number, the better the glazing prevents solar heat gain. The shading coefficient is calculated by the equation SC = SHGC / 0.86
VLT	Unitless	Visual Light Transmittance (also known as Visual Transmittance VT) refers to the fraction of visible light transmitted through the glazing. It ranges from 0 to 1.

Conduction heat flow through the fenestration (e.g., glass windows) is similar to the process discussed for walls and roofs.

However regardless of outside temperature, heat gain through the fenestration is also dependent on direct and indirect solar radiation. The ability to control this heat gain is characterized in terms of SHGC. SHGC is the ratio of the solar heat gain that passes through the fenestration to the total incident solar radiation that falls on the fenestration. The solar heat gain includes directly transmitted solar heat and absorbed solar radiation, which is then re-radiated, convected, or conducted into the interior space. SHGC indicates how well the glazing/glass and fenestration products insulate heat caused by sun falling directly on the glass.

In hot climates, SHGC is more important than the U-factor of the glazing. A lower SHGC means that lesser heat can pass through the glazing. The SHGC is based on the properties of the glazing material, whether the window has single, double, or triple glazing, and the window operation (either operable or fixed). Glazing units with a low SHGC will help reduce the air conditioning energy use during the cooling season.

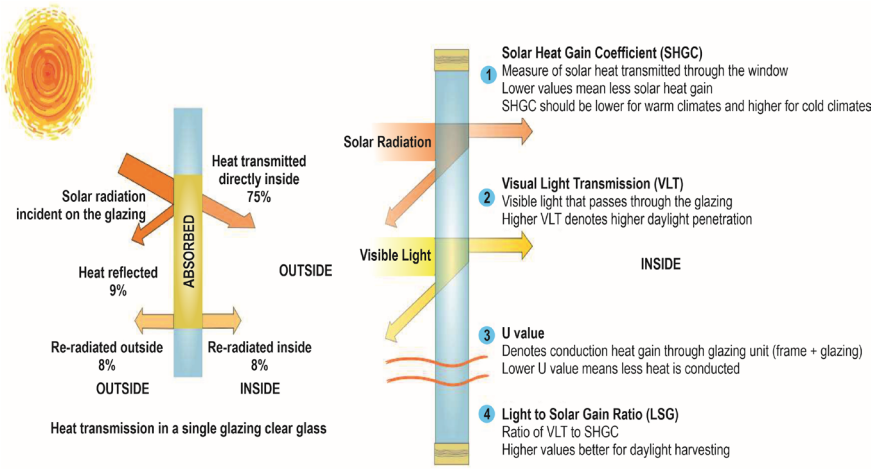


Fig 1.11: Heat transfer mechanism in a glass material

Clear glass, which is the most common type of glass used today, has no significant thermal resistance (R-value) from the pane itself. It has a value of R-0.9 to R-1.0 due to the thin films of air on the interior and exterior surfaces of the glass. The U-factor (thermal

conductance), must account for the entire fenestration system including the effects of the frame, the spacers in double glazed assemblies, and the glazing. There are a wide variety of materials, systems, and techniques used to manufacture fenestration products, and accurately accounting for these factors is of utmost importance when meeting the fenestration requirements. The U-value is specified in W/m^2K, whereas SHGC is unitless and varies between 0 and 1.

i) Energy-Efficient Fenestration Products/Assemblies

- **Exception to SHGC**

For fenestration with a permanent external projection, including but not limited to overhangs, side fins, box frame, verandah, balcony, and fixed canopies that provide permanent shading to the fenestration, thee equivalent SHGC for the proposed shaded fenestration may be determined as less than or equal to the SHGC requirements as per Table 1.10. Equivalent SHGC shall be calculated by following the steps listed below:

- **Calculating Equivalent SHGC**

The SHGC requirement of a fenestration can be affected by overhangs on a building, which reduce solar gains. ECBC uses a term called a projection factor to determine how well an overhang shades the building's glazing. The projection factor is calculated by measuring the distance from the window to the farthest edge of the overhang and dividing that by the distance from the bottom of the window to the lowest point of the overhang demonstrates how to calculate a projection factor. SHGC indicates how well the glazing/glass and fenestration products insulate heat caused by solar radiation falling directly on the glass.

Projection factor (PF) for the external permanent projection, shall be calculated as per the applicable shading type listed in table 1.9. The range of projection factor for using the SEF is $0.25 \leq PF \leq 1.0$. The SEF is applicable for both side fins shading only other than overhangs. The projection factor shall be calculated for both side fins and the lower projection factor of each fin shall be considered.

ii) How to calculate Equivalent SHGC?

For example: The window has an SHGC of 0.5. The latitude is greater than 15˚N.

However, the windows have an overhang of 3' depth on North, East, South & West.

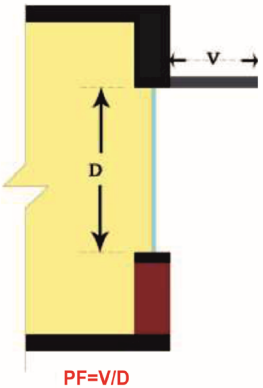
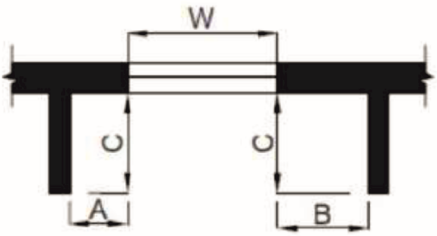
It also has side fins (left and right-side fins) with 3' depth on North, East, South & West.

Calculate the equivalent SHGC for this case.

For the purpose of the calculations, we will first calculate the projection factor (PF). The second step will be to choose the shading equivalent factor (SEF). And lastly, equivalent SHGC value will be calculated by dividing fenestration SHGC by Shading Equivalent Factor (SEF).

Step 1: Calculating Projection Factor.

Table 1.9
How to calculate projection factor for an overhang, and sidefin

For windows with Chajja (overhang)	For windows with side fin
 **PF=V/D** V = depth of chajja D= height of window	 **PROJECTION FACTOR FOR LEFT FIN = C/(A+W)** **PROJECTION FACTOR FOR RIGHT FIN = C/(B+W)** **For Side fins, consider** C = depth of fin W = width of window A or B = distance till the inner surface of fin
Calculate PF for a window with chajja. If, D= 3' and, V= 3'	Calculate PF for a window with chajja. If, W= 6' C= 3' A= 1' B= 2'
$PF\ for\ chajja = \frac{V}{D}$ $= \frac{3'}{3'} = 1$	$PF\ of\ left\ fin = \frac{C}{(A+W)} = \frac{3'}{(1'+6')}$ $= 0.42$ $PF\ of\ right\ fin = \frac{C}{(B+W)}$ $= \frac{3'}{(2'+6')} = 0.37$ In case there are two side fins, calculate the PF separately for each fin and consider the lower PF value. In this case, PF for fin = 0.37
For a combination of overhangs and fins, calculate the PF separately for both types of shading devices and then take the AVERAGE. $Average\ of\ 3\ PF = \frac{PF\ for\ Chajja + PF\ of\ left\ fin + PF\ of\ right\ fin}{3}$ $= \frac{1 + 0.42 + 0.37}{3}$ $= 0.59$ PF is 0.59 for windows on all the orientation.	

Step 2: Calculating Shading Equivalent Factor (SEF).

Following steps are applicable only PF ≥ 0.25.

In our case PF is 0.59 for all orientation which is ≥ 0.25. So, we can move ahead. If the PF < 0.25, then increase the overhang/fins depth and recalculate.

Once you have the PF, you can identify the SEF listed in Table 1.10.

For our case, we need to choose overhang + side fin and PF 0.6

Table 1.10
Shading equivalent factor

Shading Equivalent Factors (SEF) for latitudes greater than or equal to 15°N									
SEF	PF	North	East	South	West	North-East	South-East	South-West	North-West
Overhang + Fins	0.25	1.25	1.37	1.58	1.36	1.47	1.47	1.42	1.53
	0.3	1.29	1.48	1.72	1.43	1.54	1.65	1.57	1.58
	0.35	1.34	1.58	1.88	1.51	1.62	1.81	1.73	1.65
	0.4	1.39	1.67	2.06	1.61	1.70	1.97	1.89	1.75
	0.45	1.43	1.76	2.26	1.71	1.78	2.11	2.06	1.87
	0.5	1.47	1.85	2.47	1.83	1.86	2.25	2.23	2.00
	0.55	1.51	1.94	2.69	1.96	1.94	2.38	2.40	2.13
	0.6	1.55	2.03	2.92	2.09	2.02	2.51	2.58	2.27
	0.65	1.59	2.13	3.15	2.24	2.10	2.64	2.76	2.40
	0.7	1.63	2.24	3.18	2.39	2.18	2.77	2.94	2.53
	0.75	1.66	2.37	3.19	2.56	2.25	2.90	3.12	2.64
	0.8	1.70	2.52	3.20	2.72	2.33	3.04	3.18	2.73
	0.85	1.73	2.69	3.21	2.90	2.40	3.11	3.23	2.80
	0.9	1.76	2.89	3.24	3.07	2.46	3.15	3.25	2.84
	0.95	1.79	3.11	3.28	3.25	2.52	3.17	3.27	2.85
	≥1	1.80	3.30	3.33	3.33	2.57	3.23	3.30	2.82

Above data is as per Table 4.12 from ECBC 2017
(with Amendments up to 2020)

So, in present case

North SEF = 1.55; East SEF = 2.03; South SEF = 2.92; West SEF = 2.09

Step 3: Calculating Equivalent SHGC.

An equivalent SHGC is calculated by dividing the SHGC of he unshaded fenestration product with a Shading Equivalent Factor (SEF).

Equivalent SHGC= (SHGC of unshaded fenestration)/(Shading Equivalent factor (SEF))

Equivalent SHGC (North)=0.5/1.55=0.32

Equivalent SHGC (East)=0.5/2.03=0.24

Equivalent SHGC (South)=0.5/2.92=0.17

Equivalent SHGC (West)=0.5/2.09=0.23

Note that by using window shading could lower the SHGC values.

How to select a glass?

Selecting glass is an easy task. Once you have the brochure you can identify the respective values and choose most appropriate glass.

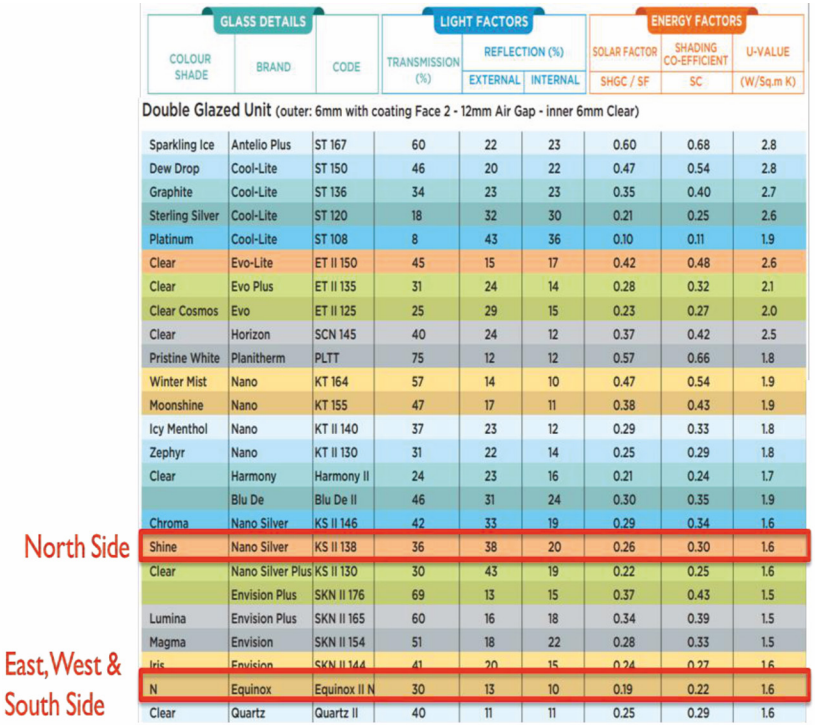
Remember as per ECBC,

Minimum allowable Visual Light Transmittance (VLT) is 0.27

Maximum U-factor = 3 W/m2.K

Maximum SHGC North for latitude ≥ 15 = 0.5. In our case calculated Equivalent SHGC (North) is 0.32 (So SC = 0.32/0.86 = 0.37).

Maximum SHGC Non-North = 0.27. In our case calculated Equivalent SHGC (East), (South), (West) is 0.24, 0.17 and 0.23 respectively (So SC East = 0.24/0.86 = 0.27; SC South = 0.17/0.86= 0.19; SC West = 0.23/0.86 = 0.26).



GLASS DETAILS			LIGHT FACTORS			ENERGY FACTORS		
COLOUR SHADE	BRAND	CODE	TRANSMISSION (%)	REFLECTION (%) EXTERNAL	REFLECTION (%) INTERNAL	SOLAR FACTOR SHGC / SF	SHADING CO-EFFICIENT SC	U-VALUE (W/Sq.m K)
Double Glazed Unit (outer: 6mm with coating Face 2 - 12mm Air Gap - inner 6mm Clear)								
Sparkling Ice	Antelio Plus	ST 167	60	22	23	0.60	0.68	2.8
Dew Drop	Cool-Lite	ST 150	46	20	22	0.47	0.54	2.8
Graphite	Cool-Lite	ST 136	34	23	23	0.35	0.40	2.7
Sterling Silver	Cool-Lite	ST 120	18	32	30	0.21	0.25	2.6
Platinum	Cool-Lite	ST 108	8	43	36	0.10	0.11	1.9
Clear	Evo-Lite	ET II 150	45	15	17	0.42	0.48	2.6
Clear	Evo Plus	ET II 135	31	24	14	0.28	0.32	2.1
Clear Cosmos	Evo	ET II 125	25	29	15	0.23	0.27	2.0
Clear	Horizon	SCN 145	40	24	12	0.37	0.42	2.5
Pristine White	Planitherm	PLTT	75	12	12	0.57	0.66	1.8
Winter Mist	Nano	KT 164	57	14	10	0.47	0.54	1.9
Moonshine	Nano	KT 155	47	17	11	0.38	0.43	1.9
Icy Menthol	Nano	KT II 140	37	23	12	0.29	0.33	1.8
Zephyr	Nano	KT II 130	31	22	14	0.25	0.29	1.8
Clear	Harmony	Harmony II	24	23	16	0.21	0.24	1.7
	Blu De	Blu De II	46	31	24	0.30	0.35	1.9
Chroma	Nano Silver	KS II 146	42	33	19	0.29	0.34	1.6
Shine	Nano Silver	KS II 138	36	38	20	0.26	0.30	1.6
Clear	Nano Silver Plus	KS II 130	30	43	19	0.22	0.25	1.6
	Envision Plus	SKN II 176	69	13	15	0.37	0.43	1.5
Lumina	Envision Plus	SKN II 165	60	16	18	0.34	0.39	1.5
Magma	Envision	SKN II 154	51	18	22	0.28	0.33	1.5
Iris	Envision	SKN II 144	41	20	15	0.24	0.27	1.6
N	Equinox	Equinox II N	30	13	10	0.19	0.22	1.6
Clear	Quartz	Quartz II	40	11	11	0.25	0.29	1.6

Fig 1.12: Saint-Gobain brochure for double glazed unit Remember

- **U-value should be as low as possible.**
- **VLT should be as high as possible**
- **SC should be as low as possible**

1.4.4 What to Take Care in Building Envelope

a) Roof: Why it is important to address about a roof?

The roof of a building typically receives the maximum amount of solar radiation because it is the uppermost surface exposed to the sun. Roofs with prescribed U-value can reduce heat gain/loss. This helps to maintain a comfortable indoor environment and reduce energy consumption for cooling.

How to impact roof's thermal properties

- Green roof: The green cover over roofs function as a second skin having significant insulation due to its composition.

- It helps in protecting the roof surface against direct solar radiation, and there is also regulating effect on humidity. and ambient temperature.
- Cool roof: A high reflective and light-colored roof can be an effective strategy in minimizing solar gains by reducing the roof surface temperatures A cool roof can remain almost 38°C cooler than a traditional dark roof. A cool roof coupled with insulationcan provide higher savings.
- Ventilated Double Roof: A properly ventilated double roof can be an efficient solution compared to a single leaf roof construction. A double roof allows the movement of hot air, therefore reducing the warming of adjoiningspaces Due to convection.

b) WALL: Why it is important to address walls?

Walls with prescribed thermal properties can reduce the need for heating and cooling systems. This leads to lower energy consumption which in turn leads to lower utility bills.

The ability of an element to transmit heat from a warm space to a cold space in a building, and vice versa can be quantified using U-value and has units of W/m²K. The lower the U-value, the better insulated the building element.

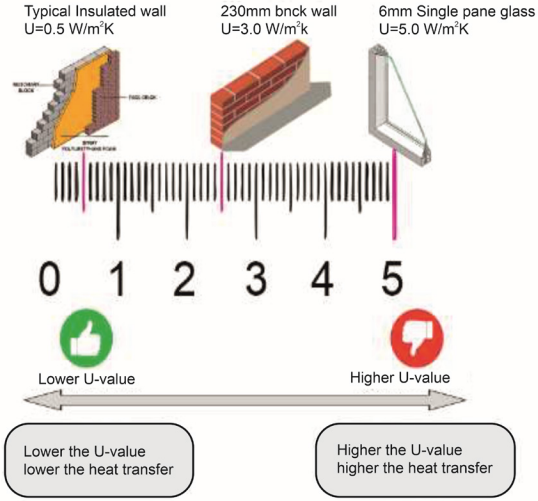


Fig 1.13: Impact of U-value on heat transfer on various materials

How to impact wall's thermal properties

- Thermal insulation is a material that prevents heat transfer, typically by slowing down the movement of heat. It's used to keep the heat out in hot weather and in during cold weather. For example, a thermocol sheet is an insulation material.
- Thermal mass refers to materials that can absorb and store heat. They help stabilize indoor temperatures by releasing heat slowly. They're used to keep indoor temperatures comfortable. Examples of thermal mass materials are concrete floors and walls, brick, stone, or even large water containers. These materials absorb heat during the day and release it slowly at night, helping to keep indoor temperatures steady.
- The difference between the two is that insulation prevents heat from entering or leaving a space, while thermal mass absorbs and releases heat to help maintain stable indoor temperatures. They serve different roles in managing a building's thermal performance.

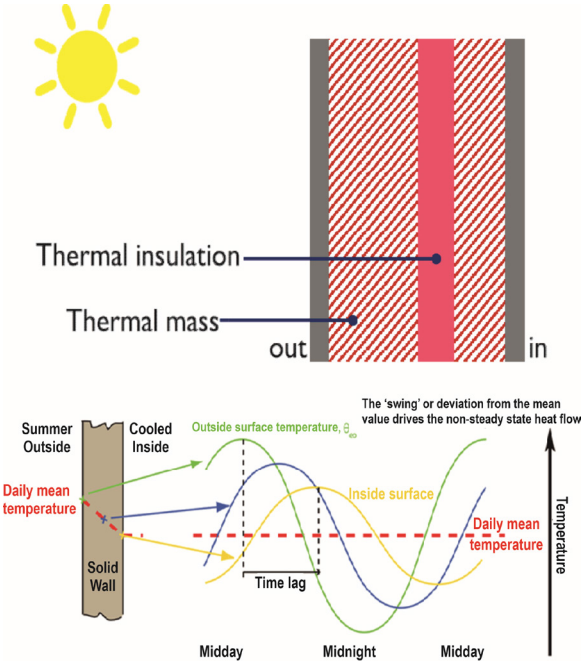


Fig 1.14: Difference in between thermal mass and thermal insulation.
Source: CIBSE Journal

c) Fenestration:

Why it is important to address fenestration?

Fenestrations provide light, ventilation and views. Glazing, such as windows is susceptible to heat gain or loss. This is because glass is a poor insulator compared to materials like walls or roofs. Glass is used extensively in buildings and therefore it is important to address it for achieving energy efficiency. This can be addressed by using glazing material with lower U-value and lower SHGC. Ordinary glazing materials available in market have a very high U-value of 5.88 W/m2.K and SHGC of 0.8. Whereas, standard double glazing and double glazing with low-e and argon gas have low U-value of 1.67 – 2.81 W/m2.K and SHGC of 0.3 - 0.5. A good glass should have low U-value, and low SHGC.

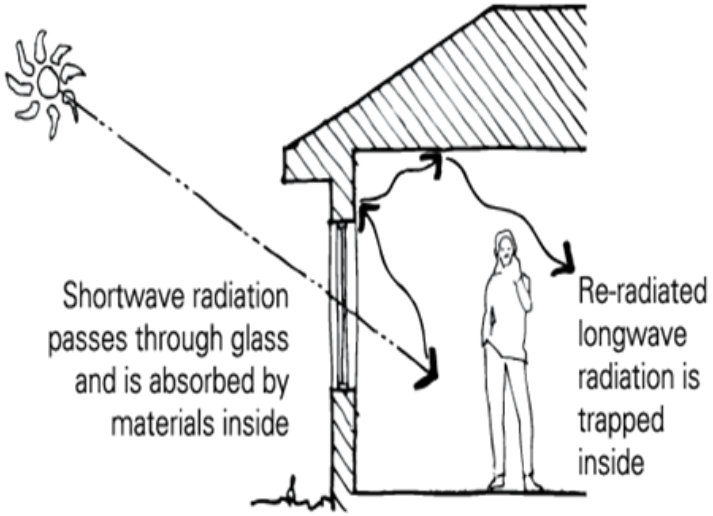


Fig 1.15: How glass is opaque to longwave radiation and transparent to shortwave radiation

How to impact fenestration's thermal properties

- Low-E (Low Emissivity) Coatings: These coatings are applied to window glazing to reduce the amount of heat transferred through the glass while still allowing light to pass. They are

effective in controlling heat gain and loss.

- Double or Triple Glazed Windows: Multiple layers of glass with insulating spaces in between reduce heat transfer, improves both thermal insulation and soundproofing.
- Tinted or Reflective Glass: Tinted or reflective window glass can reduce solar heat gain by blocking or reflecting a portion of the sunlight.
- Window shading: Shading prevents direct sunlight from heating the interior, reducing the need for air conditioning and cooling costs.

d) Air sealing:

Why it is important to address air sealing?

Sealing the building envelope improves the thermal integrity of the space. A 'leaky' envelope, i.e., one which allows movement of air into (infiltration) and out of (exfiltration) the building in an uncontrolled manner can cause thermal discomfort. While all construction joints are potential leakage points, the following key sources of leakage require careful planning and execution,

- The junction of wall and frames for openings (i.e., doors, windows and ventilators, etc.),
- The junction between frames for openings and door and window sash.
- The space between the floor and door,
- The junction of wall and roof, etc.

How to impact building's air sealing

- Install weather strips around the door and window sash to seal the junction between frames for openings.
- Use low Volatile Organic Compounds (VOC) sealants to fill joints and seams between framing and opening.
- For sloping roof, install underlayment secured at the eaves with sealant tape applied at joints. Apply foam spray sealant to fill roof-slab and wall junctions.

- Seal all the door, window, ventilator, joints in building envelope. Windows and doors can be sealed using materials like rubber gaskets, weather-stripping, or caulk. These are placed around the edges to close any gaps and prevent air from leaking in or out.
- Seal entire duct network. Ductwork can be sealed by applying mastic sealant or using specialized metallic tape. The sealant or tape is applied to cover any gaps or joints in the ducts, preventing air leakage. Seal all the T's, Y's and L's in plenum duct.

1.5 In this chapter we have studied orientation aspect of buildings. Additional details are discussed in chapter 6 "Energy Efficiency".

CHAPTER 2

HOUSING AND SEMI-PUBLIC BUILDINGS

2.1 HOUSING:

Housing or shelter is one of the basic needs of man. History of mankind shows the evolution of a habitat or a shelter from the pre-historic caves to modern housing complex of the present age. Housing also happens to be the most primary and basic building type, and the range of housing covers everything between a single room tenements to large townships. Since man is a social animal, his preference for staying in groups has led to the formation of clusters, with common facilities finally developed into small settlements. As the size of the settlements grew, towns were born. Today housing has become a highly specialized form of building design and now is a specialized subject in architecture.

2.1.1 Two main factors govern design of residential units, namely, the cost and the type. Based on the cost of a residential unit, it is categorized as :

i) Housing for the Economically Weaker Sections (EWS)

ii) Housing for the Lower Income Group (LIG)

iii) Housing for the Middle Income Group (MIG)

iv) Housing for the Higher Income Group (HIG)

EWS Housing :

This usually include rehabilitation/slum redevelopment schemes promoted by the Government/local bodies/cooperatives and usually provide for the barest basic amenities namely one multi purpose room and a common toilet block.

LIG Housing :

This too is designed for the economically lower classes like industrial works, menial labourers, etc., whereby the user can pay a very limited sum of money towards the total developmental costs. It usually comprises a multi-purpose room, kitchen and a toilet block, either separate or common.

MIG Housing :

This is the ideal housing solutions for nuclear families, essentially for the middle income group in cities, where land costs are prohibitive and plot size are small. Usually, it has 3 rooms plus toilet or 4 rooms plus toilet. e.g. an apartment block. All amenities are provided within the tenement, but luxuries are hardly catered to.

HIG Housing:

Luxury housing includes single tenements with large rooms, well equipped with utilities and facilities like servants quarters, gardens/terraces, exclusive parking, etc, e.g. independent bungalow.

2.1.2 Different types of houses :

i) Detached

ii) Semi-detached

iii) Row housing

iv) Group housing.

Detached housing :

Detached housing is a single tenement located ex-clusively in a plot of land. It is an independent structure, usually a bungalow, which enjoys its own privacy (Fig.2.1A).

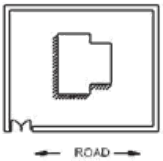


Fig.2.1A Bungalow

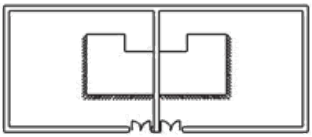


Fig.2.1B Twin Bungalow

Semi-detached housing :

Semi-detached is a slight variation of detached housing in which two tenements share a plot, whereby each user enjoys half the plot. For example, twin bungalows shown in Fig. 2.1B.

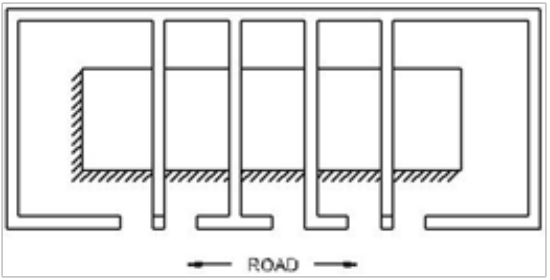


Fig.2.2A Row Housing

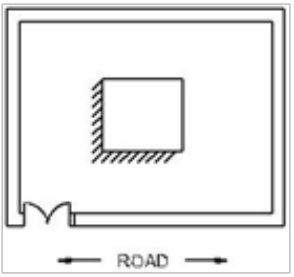


Fig.2.2B Group Housing

Fig. 2.2 Types of Houses

Row housing :

Row housing enables the user to have his exclusive front court, rear court and terrace and share common walls on the both the sides (Refer Fig. 2.2A).

Group housing :

In group housing the plot and boundaries are shared by number of tenements which are built one atop the other in the form of floors, For e.g. Condominiums, apartments. See Fig. 2.2B.

2.2 Infrastructure Required for Large Scale Housing

The success of a housing project, primarily depends on certain factors. The absence of any of these creates a disadvantage, which can discourage a prospective user. They are :

1. **Water Supply :** A rich water source (river, well,municipal, supply etc.) is the most primary requirement as this is the only factor which is beyond human control. The water requirement for the total number of users should be worked out well in advance, and the yield of water source should be ascertained. The standards for water consumption are mentioned below :

Water consumption

a. Per capita requirement : 135/liters/person/day

b. Flushing requirement : 270/liters/w.c. + 180 liters per additional w.c.

c. Domestic storage capacity:500/liters/tenement

d. Downtake fittings :

   taps : 70 liters/tap

   shower: 135 liters/shower

   bath tub : 200 liters/tub

2. **Access** : The site should be properly accessible byroad and proximity to the railroad, airport, etc., are added advantages. The access should be shortest from the nearest development, and should be sufficiently wide.

3. **Power :** Electric supply should be worked out inadvance.

4. **Parking space:** Sufficient open spaces/coveredspaces should be created in order to have proper parking facilities within the scheme. Parking standards are :

One parking space for every	Cars	Scooters	Cycles
2 tenements of carpet areas 101-200 m2	01	04	02
1 tenement exceeding 201m2	01	04	04
1 tenement having carpet area between 40 m2 and 100 m2	----	02	04

Parking Areas :Type Area

Car	2.5 x 5 m
Scooter	3.0 sqm
Cycles	1.4 sqm

5. Drainage/Sewerage: Availability of a municipalsewer line should be checked. If no such facility is available, then a self sufficient sewage disposal system has to be provided. The effluent generated by the system can be recycled effectively for water requirements of landscape. The minimum sanitary requirements are:

1. Bathroom : 1 no. with tap
2. Water closet : 1 no. with tap
3. Sink : 1 no. with tap
4. Water tap : 1 no.

6. Amenities: The proximity of amenities is alsoof great importance, as this tends to make day to day life a little less arduous for the inhabitants. Amenities should be (20 developed within the scheme, if the scale of development is large. Provision can be made fora

- Canteens
- Bank
- Hotels and restaurants
- Post Office
- Tea shop
- Essential shopping
- Fire station
- Public phone
- Hospital/primary health center

- Primary school
- Electric sub-station
- Bus stop
- Repairing facility
- Petrol pump
- Town hall/theatre/sports facility
- Parks and gardens.

7. **Landscape :** Good natural vegetation, sceniclocation of the site and well developed landscape are conducive to growth. The local temperature also drops substantially. In case of a good tree cover, open space should be converted into parks, and road sides, etc., should be landscaped as this can make the entire complex more appealing and beautiful.

2.3 Development of A Residential Unit

Individual residential units, as we saw earlier, can range from a single room tenement to a palatial private residence. Each unit has to have good planning and circulation, sufficient light and ventilation, indoor and outdoor spaces and proper facilities. Each space has to function according to its designated use.

The general planning principles have been described in the earlier chapters. The evolution of a residential unit from a single room tenement to a four rooms tenement is shown in Fig 2.3 A & B

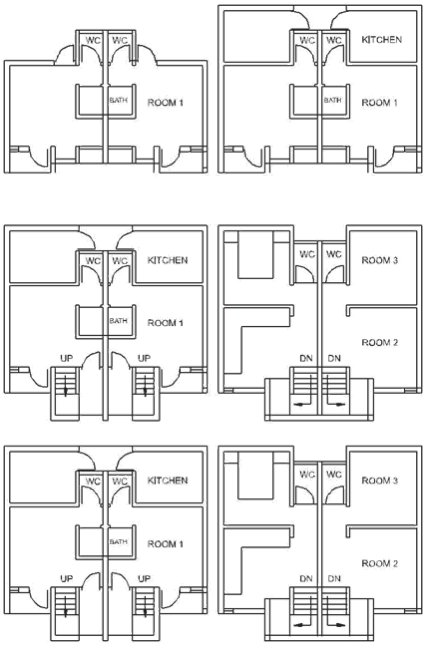


Fig 2.3A Evolution of Residential unit

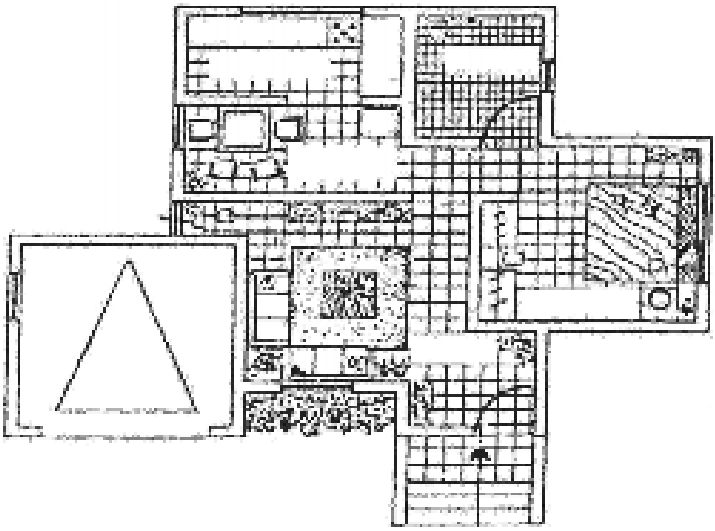


Fig. 2.3B Evolution of Residential unit

2.3.1 Important Dimensions for the Residential Buildings :

1	HABITABLE ROOMS		
	minimum plinth	:	45 cm above surrounding ground level
	minimum height (clear)	:	Not less than 2.75m
	minimum area	:	9.5 sqm
	minimum width	:	2.4 m
2	KITCHENS		
	minimum size	:	5.00 sqm
	minimum width	:	1.8 m
3	KITCHEN + DINING		
	minimum area	:	7.50 sqm
	minimum width	:	2.10 m
4	BATHROOM		
	minimum size	:	1.8 Sq.m.
	minimum width	:	1.2 m
	height		Not less than 2.10 m
5	WATER CLOSET		
	minimum area	:	1.1 Sq.m.
	minimum width	:	0.9 m
6	BATH & WC combine		
	minimum area	:	2.8sqm
	minimum width	:	1.2m
	minimum height	:	2.10 m
7	STAIRCASE		
	flight width		1.0 m
	minimum tread		300 mm
	maximum riser		150 mm
	maximum rises/flight		12 nos
8	IDEAL SET BACKS : It depends on many factors. May pls refer to para no. 8.2 of NBC 2016 Vol. 1		
9	PARAPET		
	minimum height		1.0m

2.4 Development of a Layout

A housing layout can be designed and developed in a very systematic manner. In this the principle of "part to a whole and a whole to a part" is followed. A layout of houses consists of :

i) the individual unit
ii) the implications of a cluster of units and
iii) the infrastructure

After a site is accessed for all its infrastructural values, the requirements of the project come into play, whereby the size, number and density of units is considered as the basis for planning. Individual unit plan alternatives are prepared, and their grouping is worked out. The unit and its grouping, both, have to be considered simultaneously, giving rise to a cluster of buildings. When such clusters are grouped together, a sector emerges which has to have its own micro infrastructure and amenities like parking, open space, access, etc.

Many such sectors go on to form a layout (Refer to fig. 2.4 below).

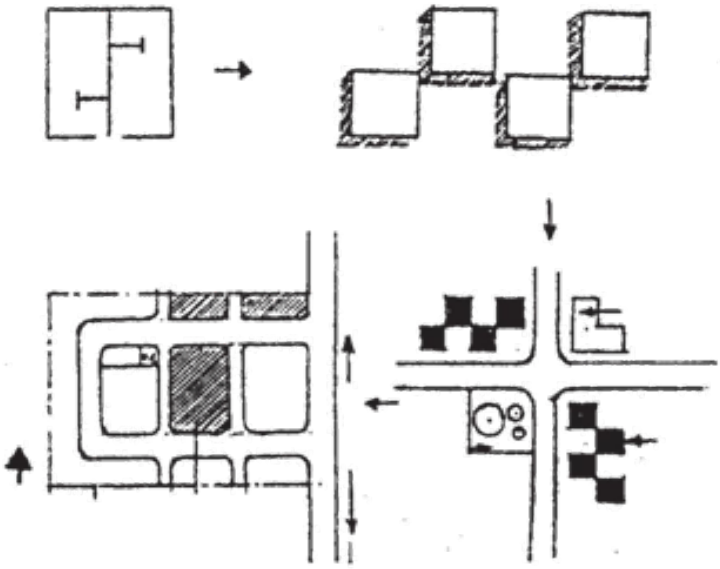


Fig 2.4 Layout Development

Even planned cities are developed along the same lines. Infrastructure and amenities are provided to each and every unit, cluster and sector and are classified asindividual amenities and common amenities. In general, out of the gross area of a housing site :

10% should be left as open space
15% as amenity plots and
15% for roads and pathways

2.5 Buildings for Semi Public Use

These are buildings which have the functions of a residential unit, but wherein the users are continuously changing. Such building types include rest houses, hotels and lodges, waiting rooms, holiday resorts etc. A few of these are studied below, with respect to the broad planning guidelines and circulation patterns in the form of bubble diagrams wherever needed.

2.5.1 Waiting rooms :

These are found at almost all public buildings like stations, hospitals etc. The planning of the same should be guided by the following (Ref Fig. 2.5) :

1. **Location :** Ideally in the center with easyaccessibility and should be away from noise and traffic generating spaces like lobbies, foyers and parking spaces. Good lighting and ventilation are important, and a pleasant view from the windows could be an added advantage.
2. **Features :** A wide entrance with self closing doors,with a cloak room/luggage store next to it is recommended. The interiors should be cheerful, with comfortable seating and easy chairs etc., for optimum numbers. Passageways should be wide and well lighted, with sanitary blocks at suitable locations. A good drinking water facility is a must. Specifications should be comfortable and maintenance free.

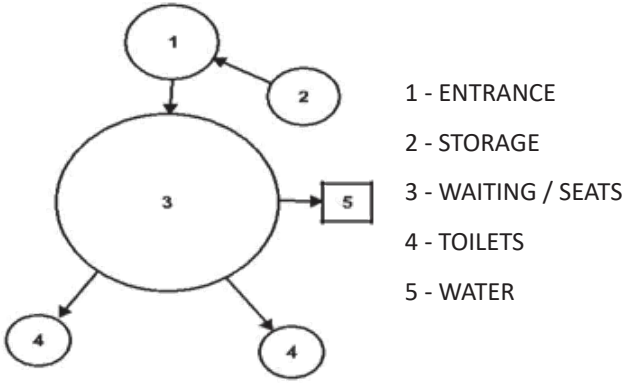


Fig. 2.5 Bubble diagram of waiting room

2.5.2 Railway Rest Houses :

The rest houses in Railway organization serve two purposes, namely, as official accommodation to officers on tour and as Holiday home for the benefit of employees. Since the utility of both the places is different, the planning concepts will also be different.

The first category rest houses should be closer to the Railway Station so that it is convenient to walk to the platforms without requiring any road vehicles. The close vicinity to station also facilitates availing of railway catering. It is desirable to locate rest houses on the upper floor of the station building so that the noise level is reduced. Such rest houses are used for short duration stay hence, each suite needs to be provided with only bedroom and toilet. Wherever possible, it is better to provide separate bath and closet in each suit instead of combined toilet. A small lounge separated by a curtain in each suite or a centralized lounge may be provided with adequate furniture, because many times officers may like to discuss issues among themselves or with their subordinate staff. It is necessary that along with such rest houses, at a suitable locationarrangements are made for the Steno and other staff accompanying officer on tour.

The Holiday Home type rest houses should be located at centers of tourist importance, beaches and hill stations. In the latter case, the location should be at a vantage point such that good view

of beach, hills and valley is available, through a wide window in each suite. Care is to be taken not to locate it at an inconvenient distance from the city's hub-center, not connected by public transport.

These rest houses are meant for longer duration stay and most of the time will be occupied by families of the staff. Such places should be provided with good lawn and greenery. A common recreation room, kitchen, caretaker's room, parking place, servant rest place etc., are also to be located. Each suite must have a sit-out and kitchenette.

The furniture in each suite has to be appropriate to accommodate atleast four members of a family. Foldable cots can be used if the space has to be economized.

2.5.3 Running room :

Running rooms are the rest houses for the crew and guards of the trains, who have to take adequate rest before working a train. The requirements of a running room are enlisted as follows (Ref fig. 2.6) :

- It should be located at a short walkable distance from the railway station/crew booking center.
- Location should be so selected that noise level is low. Green fencing/high hedging should be used to reduce noise level.
- The plot size should be big enough to accommodate some greenery.
- The plan includes provision of sleeping areas, dining hall,kitchen, bathrooms, toilets, dressing room, reading room, store room and caretaker's desk.
- It is essential that sleeping area get least disturbance in view of the fact that operational requirements of the railway necessitates arrivals and departures of users at random timings. To ensure this condition, it is necessary to locate the sleeping area away from the entrance, dining hall, kitchen etc. The floor immediately above the sleeping area should not permeate any sound.

- It is always better to provide privacy to sleeping people. It helps in not affecting others from the peculiar habits like smoking, snoring, reading while lying, using ointments which give off smell, coughs, etc. Cubicles to accommodate two persons at a time can reduce such incidences. Use of sound absorbing materials can also help in this matter. Cubicles should be well ventilated. Some cubicles should be earmarked for smokers because of the lingering smell.

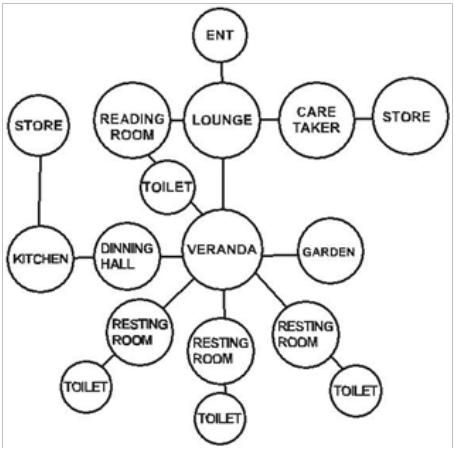


Fig. 2.6 Bubble diagram for running room

- Smoking should not be permitted in common areas.
- The illumination in the sleeping areas should be such that neither is too bright nor too dim. The colours for the walls and drapery should be soft and cool. Use of wall posters depicting greenery helps in relaxing the stresses. Separate reading lamp for each cot should be provided. By the use of thick curtains, light intensity can be reduced even in day time so that the resting staff can comfortably sleep.
- The kitchen, dining hall, store, bathrooms, toilet, dressing room can be clustered together in one or two different places in the case of large running rooms, so as to avoid noise infiltration to the resting area.
- The sound making gadgets should be avoided near resting area, such as Television, grinders/ mixers, etc. Even telephone should

be placed at appropriate location.

- The occupancy of the running room is scattered throughout the 24 hr. duration. Hence the size of kitchen, dining hall, bathroom and toilets can be optimized to keep the initial running costs low. Bathrooms and toilets should receive natural light. Exhaust fans should be provided. For the workers of running rooms, separate toilet should be provided.
- Kitchen should have adequate arrangements for storing the cooked food, including fridge, warmers. Microwave ovens will be very useful.
- Bathroom should have arrangement for continuous hot water supply.
- 24 hr. water and electrical supply is to be ensured for the running room.
- A notice board should be placed at a central place to display information relevant for the users.

2.5.4 Railway office :

The offices of railways can be broadly classified into three categories, namely, booking/reservation/parcel/ goods, depot offices and administrative offices. The planning for each type will differ. The important features to be incorporated while designing an administrative office are highlighted as follows :

Each office is an activity center. There will be main activity and sub activities. These sub activities are inter-related. A link diagram is to be prepared depending upon the interaction level. To explain the planning, the example of a Divisional Office is taken. The principles can be extended to any administrative office.

Here the main activity is to coordinate the various organs of a divisional railway set up. The nodal officer i.e. Divisional Railway Manager has to interact with team of branch officers. The branch officers in turn look after the routine works. Hence, the sub activity center of such an office are the branch officers. These branch offices can be classified into three types :

- User departments i.e. Operating and Commercial Branches.
- Service departments like Engineering, Mechanical, Electrical, Signal & Telecommunication, Electrical Traction, etc.
- Supporting departments like Personnel, Accounts, Stores, Security, Medical, etc.

If we define the level of interaction between various departments as intensity of inter-movements, then to reduce the cross currents it is possible to arrange the locations of different departments in a designed matrix form. The Operating Department's interaction is maximum with Mechanical, Traction, Engineering and Signal departments. The Commercial department will have to interact with Accounts, Security and Engineering departments.

Hence the location of Engineering Branch should be nearer to Operating and Commercial Branches. Mechanical, Electrical and Signal & Telecommunication can be located nearer to Operating but not necessarily close to Commercial and Engineering. The Accounts Branch will have to be closer to Commercial, Personnel and Engineering. Stores Branch should be closer to Electrical, Mechanical branches.

The location of General Branch which includes PRO and the chambers of Commercial and Operating Officers should be in the foremost part of the office complex. All other departments can be either in upper floors or in rear blocks. Conference Hall should be nearer to DRMs chamber. The main entrance to the building should have a Reception with a Visitor's lobby. In addition to these branch offices, many common facilities should be preferably at such a location so that the staff from all the branches can easily make use of them. Toilets should receive plenty of natural light and should be provided with exhaust fans.

The location of branch officers room should be such that they have effective control over the staff working under their control. Glazed partitions should be liberally provided. Officers should walk through the working areas, rather than through exclusive corridors.

2.5.5 Canteens :

Canteens are again a part and parcel of institution or public campus, and is a combination of semi-public and public use (Refer Fig. 2.7).

1. **Location** : of a canteen can be secondary, i.e. notcentral, as only a small portion of a crowd will be visiting it any given time. It can be at a distance from the main activity area. However, a service access (vehicular) is desirable for smooth movement of material to and from the canteen.
2. **Features :** Large comfortable passages should be provided between seating arrangements. The seating arrangements can consist of groups 4 to 6 or can be continuous.

Service areas, counters, etc., should be properly located, so as to ensure minimum travel distance from the kitchen to seating arrangement. Service counters should have a large empty space in the front, in order to cater to a group of people at once.

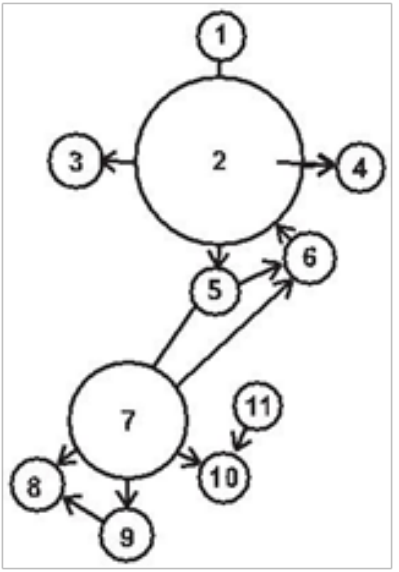
Toilets should be concealed and properly ventilated, with separate facilities for gents and ladies. Wash basins should be provided in adequate numbers. Bathing facilities can be deleted.

Location of cash/coupon counter should be at vantage points and should be located near entrances. Supervision of the entire dining and service areas should be possible from this location.

The planning of kitchens is very critical. The cooking space, the preparation area and wet areas are to be clearly demarcated. Proper ventilation is essential.

Storage of raw material and the stocks should be a separate facility, which can be under lock and key. It should have an external service access.

A separate scullery (wet area) with storage of crockery and good garbage collection system is required.



1. ENTRANCE
2. SEATING
3. TOILETS
4. COUNTER
5. PANTRY
6. SERVICE
7. KITCHEN
8. UTENSIL STORE
9. SCULLERY
10. RAW MATERIAL STORE
11. SERVICE ACCESS

Fig. 2.7 Bubble diagram for Canteen

CHAPTER 3

PUBLIC BUILDINGS

3.1 Types of Public Buildings:

Public buildings are structures which are open to one and all, the crowds throng to these places for varied reasons. The activity carried out inside these buildings directly concerns the masses, and all buildings standards undergo a change. The types of public building are as under:

a) Assembly buildings : Theatres, Museums, Religious buildings, Exhibitions, Pavilions.

b) Public buildings : Stations, Airports, Governments offices, Commercial complexes.

c) Institutional buildings : Schools, Colleges, Universities.

The difference between the three is very subtle. Assembly buildings are operational throughout the day and lie vacant during the nights, and the flow of vehicles and people in numbers is at specific hours : for e.g. in a theatre, the crowds enter and leave before or after a show.

In case of public buildings, they can operate round the clock without a break, all throughout a year, and movement of people to and fro is almost continuous.

Institutional buildings have a different motive, and a specific crowd utilizes them at fixed hours. However, the creation of a good environment or a pleasant campus is very important.

The planning and circulation along with design requirements are very complex and vary from type to type in case of public buildings. Major deviations from the optimized solutions can lead to lot of drawbacks. A very few of these can be studied as examples.

3.1.1 Primary Health Centres :

1. Location and general:

Such centres are found inthe mufosil areas or in large

establishments like industrial campuses, and render medical services to limited extent. The number of out patients who come every day exceeds the in patients by far. The staff and other facilities are limited.

2. Features :

Large courtyards in front of the centresare very useful, and open verandahs with a roof reduce the load in the waiting areas. It should have good and central access to its premises, with sufficient light and ventilation. Garbage/waste disposal should be very effective and fool proof. A thick tree cover along the periphery can enhance the courtyard and can double as parking space.

The bubble diagram shown in fig. 3.1 indicates the most appropriate circulation.

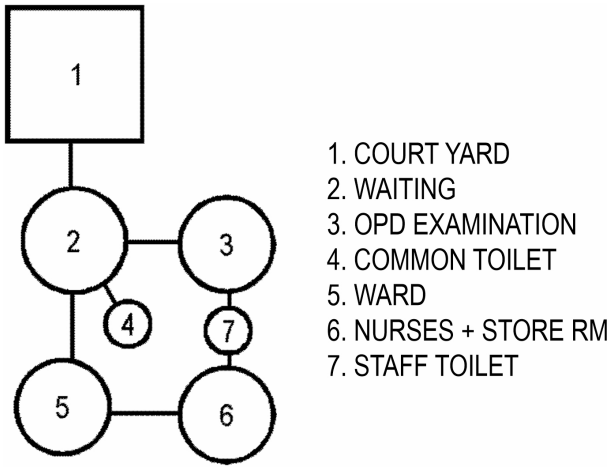


Fig. 3.1 Bubble diagram for Primary Health Centre

3.1.2 Hospitals :

A hospital is a building type which has a very complex set of requirements with a lot of technical specifications. The circulation patterns recommended are also extremely technical and the anthropometric requirements are not as per standard norms. The structurecomprises simple and complicated components and building services like power supply, fire fighting etc., get priority of the highest order. Each component has a time scale/life span after

which alterations, replacement and repairs form a very major area.

Designing essentially is based on grouping together activities which have similar characteristics/nature or are inter-related. This is done so as to avoid duplication of services.

The departments in a medium/large hospital are :

1. Patient accommodation
2. Medical/Technical facilities
3. Engineering services
4. Laboratories
5. Pharmacies
6. Catering and laundry (cleaning)
7. Library
8. Supply, services and disposal
9. Lecture halls/hostels/canteens/parking
10. Research and development facility
11. Expansion facility
12. Good landscape.

There are separate in patient and out patient departments. The inter-relationship can be illustrated in Fig. 3.2.

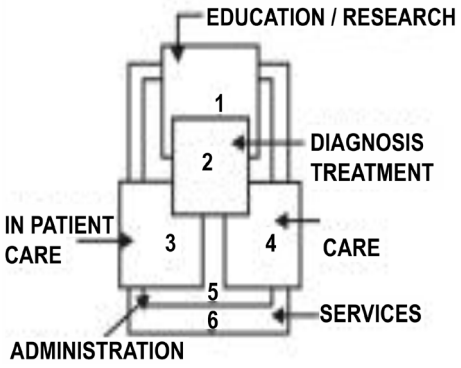


Fig. 3.2 Bubble diagram for Hospital (Sector Relationship)

Case studies and data collection for public buildings has multiple functions and complex inter-relationships.

3.2 Landscaping

Landscape architecture is a fully developed super specialization in architecture, which has more or less supplementary function, it essentially deals with the surrounds of a building except in cases of aforestation and creation of gardens and parks. Greenery is always a very welcoming sight, and landscaping enhances the beauty of a structure. It has physical and psychological repercussions on man. Pollution control, thermal control and increase in rainfall are the physical aspects, while the effect of the green colour and its shades is psychologically calming to the human mind. The only drawback is that the end result of landscaping is fully felt only after passage of time, as trees/shrubs take their own time for growth.

Another advantage of good landscape is that once it is fully developed, the effect keeps on changing with the size of trees, and seasons lead to interesting change of colours of leaves and flowers.

Landscape deals with living and non-living objects. It is not merely plantation of trees and shrubs, but involves creating an entire environment which comprises living objects and non living materials. In the olden days, it was considered more as an art form which was used to enhance and enrich the main structure (e.g. The Taj Mahal).

Different styles of landscape architecture are practiced all over the world. The scales also differ from a small balcony garden to large parks and gardens. A few of the prominent landscape styles are :

1. **English Landscape :** it is essentially symmetricalwith a strong central axis. These are extremely formal gardens, with geometrically laid out lawns and flower beds.
2. **French/Italian Landscape** : This is extremelyornate and profuse with a lot of features like cascades, statues, cabanas etc. It is almost crowded and does not have geometry, making it very informal.

3. **Japanese Landscape :** It is a special art in itself,which is closely linked with Japanese culture and religion. Entire stores are depicted in constricted areas in the form of miniature gardens leading to ornate and miniature landscapes. Use of bonsai and ikebana is very popular.

4. **Islamic :** Landscaping in most of the Islamiccountries even today is extremely formal and strongly axial. The use of large lawns, is restricted and paved surfaces are large. Trees are used as features. Use of shallow and still pools of water and fountains are extensive. Landscape comprises hard and soft materials. Trees, shrubs and lawns are soft materials while paving, statues, pools, street furniture, lampposts, low walls etc., are the hard materials. The two have to be combined.

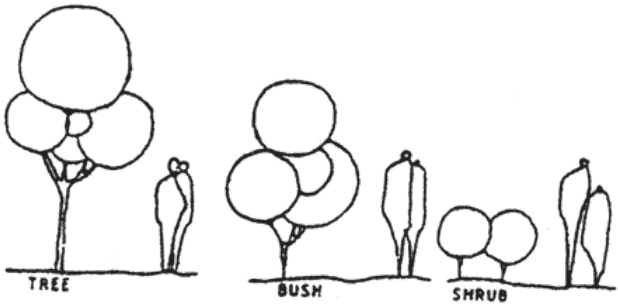


Fig. 3.3 Plant Materials

effectively to achieve a good design. Plant materials are classified into (see fig. 3.3) :

1. Trees : above 8 – 10 feet height
2. Bushes : below 8 – 10 feet height
3. Shrubs : below 2 feet height

The factors which affect landscaping are :

1. Soil type
2. Rainfall
3. Sunlight/heat
4. Manures/fertilizers

Soil types include :

1. **Clay :** It is adhesive and homogenous, where plants rot due to

an excess of water. A surface and storm water drainage has to be provided for successful landscaping.

2. **Sandy :** This soil is very loose and the grip of theroots suffers. Minerals and manure get washed away. Water and watering retention is poor and the only solution for this is regular watering & manuring.
3. **Loam :** It is a combination of (1) and (2) and isideal for trees and shrubs.
4. **Alluvial :** It is soil, which is humus from river beds,and is ideal for cultivation.
5. **Peat :** it is usually found in marshlands andswamps. It comprises decayed organic material. Growth of landscape here is almost impossible.

Selection of plant material is based on the function. For example as illustrated in Fig. 3.4, trees can be used.

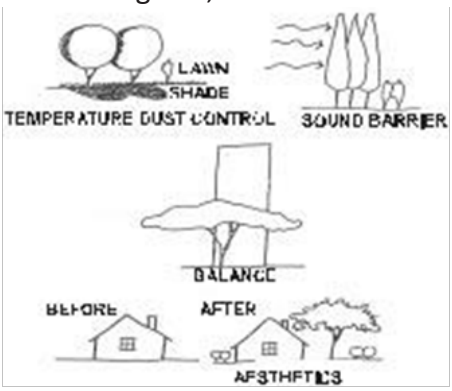


Fig. 3.4 Functions of Plant Material

- for shade
- barriers to sound/ pollution
- for mass greening effect
- for reducing temperature and
- increasing rainfall
- colours of flowers
- balance and
- aesthetic.

CHAPTER 4

GREEN BUILDINGS

4.1 Introduction:

Earth is home to more than 7 billion people, and populations continue to grow. Many experts fear that we are using natural resources too rapidly to be sustained. Supplies of energy resources and water are specially threatened. Moreover, we are using these resources in ways that pollute and otherwise harm earth.

A green building, built on principles of ecological sustainability, is one which uses less water, optimizes energy efficiency, conserves natural resources, generates less waste and provides healthier spaces for occupants, as compared to a conventional building. It focuses on:

a) Efficient utilization of resources – energy, water, and building materials;

b) Protection o occupant health (improved air quality) and enhancement of employee productivity (Better use of day light and natural ventilation);

c) Reducing waste, pollution and environmental degradation as compared to conventional building. Emphasis is on energy efficiency and water conservation techniques (storm water harvesting, and sullage recycle, reduction in green house gas emissions, use of recycled waste products (Fly ash based building elements) by adopting an integrated design approach for reducing the operation, and maintenance costs over the building life cycle.

4.2 Sustainable Development:

Bruntland Commission on Environment and Development set up by U.N. defined in its report in 1987 ecological sustainability as a pattern of resource use that aims to meet the needs of the present without compromising the ability of future generations to meet their needs'. It implies that we are borrowing the planet, its resources, and its environmental function and quality from future generations.

4.3.1 Non Renewable Resources:

For the past century or more, much of the world has run on the energy in petroleum, coal and natural gas – the fuels known as fossil fuels. Fossil fuels come from underground deposits that were formed millions of years ago from the remains of the plants and animals. Today, we know that supplies of fossil fuels are dwindling and will eventually run out. Thus they are called non-renewable resources.

4.3.2 Renewable Resource:

A natural resource is termed as renewable resource if it is replaced by natural processes at a rate comparable or faster than its rate of consumption by humans. Solar radiation, tides, winds and hydroelectricity are perpetual resources that are in no danger of a lack of long-term availability. Renewable resources may also mean commodities such as wood, paper, and leather, if harvesting is performed in a sustainable manner.

4.4.1 Green House Gases (GHG):

Fossil fuels must be burned to use their energy, which releases the gas carbon dioxide (CO_2). Carbon dioxide is a key part of Earth's atmosphere because it helps regulate (control) the temperature by returning some of the sun's heat. This process is called greenhouse effect. CO_2 and other gases (methane, nitrous oxide, halogenated fluorocarbons, ozone, per fluorinated carbons, and hydro fluorocarbons) that trap the sun's heat are called **greenhouse gases.** Without these gases, heat would escape back into space and Earth's average temperature would be about 200 colder. It is this greenhouse effect that makes life on the planet possible.

As we burn fossil fuels and put more CO_2 into the atmosphere, more and more heat is trapped. The irony of the situation is that excess production of these GHGs caused by human activity (auto emissions, burning of coal in power plants, etc.) is now threatening our very existence by leading to global warming.

4.4.2 Global warming:

Scientists have shown that the air temperature of Earth has been rising for decades due to growing levels of CO_2 and other

GHGs. Nearly all scientists believe that rising temperatures are caused by human activity, which in turn causes changes in climate in unpredictable ways.

4.5.1 Green Buildings: Global and local perspective

The construction sector poses a major challenge to the environment. Globally, buildings are responsible for at least 40% of energy use. An estimated 42% of the global water consumption and 50% of the global consumption of raw materials is consumed by buildings when taking into account the manufacture, construction, and operational period of buildings. In addition, building activities contribute an estimated 50% of the world's air pollution, 42% of its greenhouse gases, 50% of all water pollution, 48% of all solid wastes and 50% of all CFCs (Chlorofluorocarbons) to the environment.

Buildings have major environmental impacts during their life. Resources such as ground cover, forests, water, and energy are dwindling to give way to buildings. Resource-intensive materials provide structure to a building and landscaping adds beauty to it, in turn using up water and pesticides to maintain it. Energy-consuming systems for lighting, air conditioning, and water heating provide comfort to its occupants. Hi-tech controls add intelligence to 'inanimate' buildings so that they can respond to varying conditions, and intelligently monitor and control resource use, security, and usage of fire fighting systems and other such systems in the building. Water, another vital resource for the occupants, gets consumed continuously during building construction and operation. Several building processes and occupant functions generate large amounts of waste, which can be recycled for use or can be reused directly. Buildings are thus one of the major pollutants that affect urban air quality and contribute to climate change. Hence, the need to design a green building, the essenceof which is to address all these issues in an integrated and scientific manner. It is a known fact that it costs more to design and construct a green building compared to other buildings. However, it is also aproven fact that it costs less to maintain a green building that has tremendous environmental benefitsand provides a better place for the occupants to live and work in. Thus, the challenge of a green building is to achieve all its benefits at an affordable cost.

A green building depletes the natural resources to a minimum during its construction and operation. The aim of a green building design is to minimize the demand on non-renewable resources, maximize theutilization efficiency of these resources when in use, and maximize the reuse, recycling, and utilization of renewable resources. It maximizes the use of efficient building materials and construction practices; optimizes the use of on-site sources and sinks by bioclimatic architectural practices; uses minimum energy to power itself; uses efficient equipment to meet its lighting, air conditioning, and other needs; maximizes the use of renewable sources of energy; uses efficient waste and water management practices; and provides comfortable and hygienic indoor working conditions. It is evolved through a design process that requires input from all concerned - the architect; landscape designer; and the air conditioning, electrical, plumbing, and energy consultants - to work as a team to address all aspects of building and system planning, designing, construction, and operation. They critically evaluate the impacts of each design decision and arrive at viable design solutions to minimize the negative impacts and enhance the positive impacts on the environment. In sum, the following aspects of a green building design are looked into in an integrated way.

- Site Planning
- Building envelope design
- Building system design (HAC{heating ventilation and air conditioning}, lighting electrical and water heating)
- Integration of renewable energy sources to generate energy on-site
- Water and waste management
- Selection of ecologically sustainable materials (with high recycled content, rapidly renewable resources with low emission potential, and so on)
- Indoor environmental quality (maintain indoor thermal and visual comfort and air quality)

4.5.2 Benefits of green buildings:

A green building has lower resource consumption as

compared to conventional buildings. The following is the percentage reduction of various resources in a building and their respective reasons.

- Green buildings consume 40% to 60% (depending on the range of measures adopted) lesser electricity as compared to conventional buildings. This is primarily because they rely on passive architectural interventions in the building design, and high efficiency materials and technologies in the engineering design of the building.
- Green Buildings also attempt to work towards on-site energy generation through renewable energy utilization to cater to its energy needs. For instance, solar thermal systems can help generate hot-water and replace the conventional electrical geyser in buildings. Solar PV panels can help generate electricity which can reduce the buildings dependence on grid power.
- Green buildings consume 40% to 80% (depending on the range of measures adopted) lesser water as compared to conventional buildings. By utilizing ultra low-flow fixtures, dual plumbing systems, waste-water recycling systems and rain-water harvesting, green buildings not only reduce their demand for water use but also look at on-site supply options to cater to its internal and external (landscape) water demands.
- Green buildings generate lesser waste by employing waste management strategies on site.They may also employ waste to energy or waste to resource (like manure, or compost) strategies on site, to minimize their burden on municipal waste management facilities and landfills.
- Green buildings generate lesser pollution both during construction as well as while in use. Through best-practices such as proper storage of construction materials, barricading of the site to prevent air and noise pollution during construction, proper storage and disposal of waste during construction and operation, and so on, ensures reduced impact on the surrounding environment.
- Green buildings ensure proper safety, health and sanitation

facilities for the labourers (during construction) and the occupants (while in use).

- Green buildings restrict the use of high ODP (ozone depleting potential) substances in their systems as well as in finishes.
- Green buildings offer higher image and marketability.

All of these can be achieved at a minimal incremental cost with an estimated payback period of about 3-5 years (excepting renewable energy for power generation).

4.5.3 Cost of Going 'Green'

The green buildings cost more than the conventional buildings, the difference of cost being dependent on green features being incorporated in the design and construction. A green building may cost 20% to 50% more but annual energy costs would go down by 30% to 65%. However, over a certain period, depending on the energy requirement of the building, the additional expenditure will be compensated by the reduction in annual energy bill. This pay back period would vary from building to building. However, over the life cycle the green buildings would turn out to be more economical as compared to conventional buildings.

4.6 Strategies For Green Buildings

A large pool of green features and techniques are available for adoption in design and construction of buildings. Appropriate ones have to be selected depending on function and type of the building, climatic conditions etc. Some such feature which aim at fulfilling the criteria for green buildings are as follows:

i) Sustainable site development

The site planning should ensure minimal damage to site and surroundings.

a) Land should be disturbed only to the extent it is unavoidable.

b) Preserve land in the surrounding area.

c) Avoid disturbance to water courses.

d) Minimise cutting of trees. Undertake compensatory plantation.

e) Replant the grown up trees.

f) Preserve the excavated top soil and use it in landscaping.

g) Adopt erosion control measures to prevent erosion of exposed soil.

ii) Social responsibility

The following aspects must be taken care of during planning and construction.

a) Ensure safety provisions at construction site.

b) Provide sanitary facilities for workers.

c) Raise screens to minimize air pollution in the area around the construction site.

iii) Appropriate landscape design

The following aspects must be taken care of during planning and construction.

a) Landscape to be designed to avoid 'heat island effect'.

b) Hard surface to be minimised. If hard surface is provided it should be porous and shaded by vegetation to the extent feasible.

c) Species of plants requiring less water for survival and growth to be preferred.

d) Native species of plants to be preferred.

iv) Construction material and practices

The following aspects must be taken care of during selection of material and construction.

a) The design of the building should be resource efficient. Requirement of material should be less than that for a conventional building.

b) Low energy intensive materials to be preferred. These include regionally available material and material which require less energy during manufacturer e.g. local stones, composite woods,

form wood etc.

c) Materials derived from waste of other industrial processes such as fly ash and other eco-friendly material to be used in construction.

d) Utilisation of construction waste at the same site or at other construction sites.

v) Water Management

It consists of reduction in water demand, avoiding wastage of water and conservation strategies like rain water harvesting and waste water utilization.

a) Some measures which can go a long way in reducing water demand for landscape has already been discussed under 'Appropriate landscape design'. These include planting of native species (shrubs / trees) and other species requiring less water.

b) Use of sprinklers for lawns and drip irrigation for shrubs and rees.

c) Waste water treatment and use of treated water for irrigation of landscape.

d) Rain water harvesting and use of stored water for irrigation.

e) Use of low discharge fixtures such as double discharge flush in the building to bring down water demand.

f) Intelligent feature such as urinals having sensors in public places and mass use locations.

vi) Energy Efficiency

Energy efficiency is one benefit from green buildings which appeals to all. The green buildings incorporate energy efficiency primarily through reduced requirement of power for lighting and air conditioning.

Several traditional Indian designs provide for efficient natural lighting, ventilation and thermal insulation. For example the Indian circular courtyard design enhances air and light. The jali work used in several medieval building including Taj Mahal cools

the air. There are a number of features which contribute to energy efficiency of buildings. Some of these are discussed below:

a) Architectural design should aim at creating optimum thermal and visual conditions in the building thus reducing the need for artificial lighting, forced ventilation and air-conditioning.

b) Bio-climatic architectural principles for optimum use of nature for lighting and space conditioning should be applied. These include orientation; positioning; coating and shading of windows; selection of suitable materials for wall, roof and windows; and thermal insulation of roof and walls. If the building is designed taking the bio-climatic principles into consideration, the energy load can be easily reduced by about 20%.

c) There are several solar passive features such as courtyard pattern, solar chimney, wind tower and earth tunnel which can be incorporated in the design. With the use of courtyard pattern and solar chimney the hot air is made to move upwards so that cooler air from vegetated areas can move in. The wind tower and earth tunnel facilitate cooling of air before it is supplied to the air-conditioning system.

d) Use of efficient air conditioning and water cooling systems having intelligent features.

e) Use of efficient light fittings such as CFLs, T-5 lamps etc. and use of sensors (illumination meters) to avoid wastage.

f) Another important component of Green Building concept is harnessing non-conventional sources of energy such as solar energy for heating and electricity generation or gasifier system to utilize bio-waste. Solar water heaters and solar photo- voltaic cells are obvious options for harnessing solar energy. Similarly bio-gas plants are to be used to generate energy from bio-waste.

vii) Health and well being

The following suggestions can be considered for improving health and well being of occupants :

a) Indoor air quality should be improved by using non-toxic (low

VOC) paints, adhesives and other materials.

b) CFC free HVAC and refrigeration system should be used.

c) Halogen-free fire suppression systems should be used.

4.7 The Indian Scene

In recent years some major buildings constructed in the country have adopted green features. These includes the CII- Godrej Green Business Centre, Hyderabad; TERI's Retreat Building, Gul Pahari, Gurgaon; Laboratory Building IIT Kanpur; ITC Green Centre, Gurgaon; Wipro House, Gurgaon; and Transport Corporation of India Ltd, Gurgaon.

Some of these building have succeeded in getting prestigious LEED (Leadership in Energy and Environmental Design) Rating. The Godrej Green Business Centre, Hyderabad was the first building in the world to get Platinum Version 2 Rating. ITC Green Centre and Wipro House have also got Platinum rating.

It is a matter of great pride for Indians that the CII Sohrabji Godrej Green Business Centre at Hyderabad was adjudged as world's 'Greenest' building in the year 2003 (Fig. 4.1). In that year the CII – Sohrabji Godrej Green Buisiness Centre in Hyderabad (Fig. 4.1), a 20000 sq. feet building designed by Vadodara based architect Karan Grover was awarded 'Version 2 Platinum' rating by United States Green Building Council (USGBC), Pittsburg. The Council recognises structures for environment friendly materials and techniques; and energy efficient architecture.

The 'Version 2 Platinum' was the highest rating achieved by any building, under the Leadership in Energy and Environment Design (LEED) Systems for rating for environmentally conscious buildings. The Hyderabad building was credited with 57 of 62 parameters it had competed in. Three buildings in U. S. A. had won the next lower rating i.e. 'Version 1 platinum' till then.



Fig 4.1 CII - Godrej Green Business Centre, Hyderabad

The green features of The CII – Sohrabji Godrej Green Business Centre building include the following :

1. Ninety percent of the building doesn't require any artificial lighting during the day.
2. Two forty feet wind towers and screen walls provide air pre-cooled by 100C to the air conditioning systems.
3. Photovoltaic panels are built in to generate solar energy which fulfill 20% of building's energy requirement.
4. Thermal insulation of walls, glazings and roof.
5. Electric fixtures have been automated to save power.
6. Material used were recycled and eco-friendly broken mosaic tiles, steel, wood, glass, fly ash brick, locally available stones and non-toxic paints.
7. Water is treated on-site and used for gardens.
8. Rain water Harvesting.

4.8 Green Building Rating System

The green buildings in India are not a new phenomenon.

Earlier buildings were used to be made on Green building concepts due to constraint of resources.Over the years, due to the availability of resources at door steps and at subsidised costs, the resources have been overutilized, particularly energy and water. This had led to a crunch of resources & adverse impact on environment. People started realising that if we keep on over utilising the resources, nothing will be left for future generations. Therefore, Green Building movement had again started, and some voluntary rating systems came into existence.

There are a number of green building rating systems available worldwide which are as follows:

- GRIHA (Green Rating for Integrated Habitat Assessment), developed in India
- IGBC (Indian Green Building Council), developed in India
- LEED (Leadership in Energy and Environmental Design), developed in USA
- BREEAM (Building Research Establishment Environmental Assessment Method), developed in UK
- CASBEE (Comprehensive Assessment System for Building Energy Environmental Efficiency), developed in Japan
- BCA (Building and Construction Authority) Green Mark Scheme, developed in Singapore.

In this chapter, we will discuss the building certification systems that are popular in India. In each of the system, the breakup of key areas rating points as well as certification levels are covered. However, reader shall note that these key areas rating points as well as certification levels are revised time to time, hence at the time using this rating system/certification level reader shall access the updated details available on the websites of these certifying systems. The details given here, are with intention that the reader to know how the various elements of green building are given importance while certification.

Also, the validity of specific certification is revised time to time, hence, reader shall access the updated details available on the websites of these certifying systems.

4.8.1 GRIHA (Green Rating for Integrated Habitat Assessment):

GRIHA Council is, a not for profit, society founded by TERI (The Energy and Resources Institute, New Delhi) with support from MNRE (Ministry of New and Renewable Energy, Government of India) along with a handful of experts in the sustainability of built environments from across the country. The GRIHA Councilis mandated to promote the development of buildings and habitats in India. GRIHA was adopted as the national rating system for green buildings by the Government of India in 2007.

The GRIHA Council has various rating systems:

1. SVAGRIHA (Simple Versatile Affordable GRIHA) :

All new construction projects with built-up area more than or equal to 100 sq.m and less than or equal to 2500 sq.m. are eligible for certification under SVAGRIHA V.3. Basically, it covers stakeholders like bungalows and small office owners. This rating system has a maximum 50 points.

This rating is valid for 5 years from the date of rating award. Thereafter, projects need to apply for Re- Certification.

Rating points Break up is as under :

SN	Key Areas	Maximum points
1	Sustainable Site Planning	12
2	Sustainable Building Materials	7
3	Energy Optimization	8
4	Occupant Comfort and Wellbeing	7
5	Water Management	8
6	Solid Waste Management	3
7	Sustainable Lifestyle	5
	Total	50
8	Innovation	2
	Grand Total	50 + 2

The Rating based on points scored is as under :

Points	SVAGRIHA Rating	
25 – 29	*	One Star
30 – 34	**	Two Star
35 – 39	***	Three Star
40 – 44	****	Four Star
45 - 50	*****	Five Star

b) GRIHA V2019: The 2015 version of GRIHA has been thoroughly revised by GRIHA council. This version is called as GRIHA V2019., This version (i.e. GRIHA v2019) integrates concepts like life cycle cost analysis, life cycle analysis, and water performance index, to name a few. This version has taken into consideration the incorporation of user experience, market feedback, and enhanced ease of implementation and adoption. It is used for all new construction projects with built up area more than 2500 sqm. (excluding parking, basement area, and typical buildings). This rating basically covers the stakeholders like bungalows and small office owners. This rating system has maximum of 100 points.

This rating can be kept valid by submitting an audit data report (over a span of three consecutive years) comprising energy, water, and waste (report to be prepared by BEE-certified energy auditor), or by enrolling the project for GRIHA EB rating to maintain its certification for the next cycle of 5 years.

Rating points Break up is as under:

SN	Key Areas	Maximum points
1	Sustainable Site Planning	**12**
	a) Green Infrastructure	5
	b) Low Impact Design	5
	c) Design to Mitigate UHIE	2

2	Construction Management	**4**
	a) Air and Soil Pollution Control	1
	b) Top Soil Preservation	1
	c) Construction Management Practice	2
3	Energy Efficiency	**18**
	a) Energy Optimization	12
	b) Renewable Energy Utilization	5
	c) Low ODP and GWP Materials	1
4	Occupant Comfort	**12**
	a) Visual Comfort	4
	b) Thermal and Acoustic Comfort	2
	c) Maintaining Good IAQ	6
5	Water Management	**16**
	a) Water Demand Reduction	3
	b) Wastewater Treatment	3
	c) Rainwater management	5
	d) Water Quality and Self-Sufficiency	5
6	Solid Waste Management	**6**
	a) Water management-Post Occupancy	4
	b) Organic Waste Treatment On-Site	2
7	Sustainable Building Materials	**12**
	a) Utilisation of Alternative Materials in Building	5
	b) Reduction in GWP through Life Cycle Assessment	5
	c) Alternative Materials for External Site Development	2
8	Life Cycle Costing	**5**
9	Socio-Economic Strategies	**8**
	a) Safety and Sanitation for Construction Workers	1
	b) Universal Accessibility	2
	c) Dedicated Facilities for Service Staff	2

	d) Positive Social Impact	3
10	Performance Metering and Monitoring	**7**
	a) Commissioning for Final rating	7
	b) Smart Metering and Monitoring	0
	c) Operation and Maintenance Protocol	0
	Total	**100**
11	Innovation	**5**
	Grand Total	**100 + 5**

The Rating based on points scored is as under:

Points	GRIHA Rating	
25 – 40	*	One Star
41 – 55	**	Two Star
56 – 70	***	Three Star
71 – 85	****	Four Star
86 or more	*****	Five Star

c) GRIHA EB (Existing Building): All operational buildings having a built-up area greater than 50 sq. m. are eligible for certification GRIHA for existing buildings rating. The typology of buildings include: offices, retail spaces, institutional buildings, hotels, hospital buildings, healthcare facilities, residences, and multi-family high-rise buildings. This rating system has maximum of 100 points.

SN	Key Areas	Maximum points
1	Site Parameters	**6**
	a) Accessibility to basic Services	2
	b) Microclimatic Impact	4
2	Maintenance & Hosekeeping	**17**
	a) maintenance, green procurement and Waste management	7
	b) Metering and Monitoring	10
3	Energy	**35**
	a) Energy Efficiency	20
	b) Renewable Energy Utilization	15
4	Water	**25**
	a) Water Footprint	15
	b) Reduction in Cumulative Water Performance	10
5	Human health & Comfort	**12**
	a) Achieving Indoor Comfort Requirements	8
	b) Maintaining Good IAQ	4
6	Social Aspects	**9**
	a) Universal accessibility & Environmental Awareness	5
	b) Bonus	4
	Total	100 + 4

The Rating based on points scored is as under

Points	GRIHA EB Rating	
25 – 40	*	One Star
41 – 55	**	Two Star
56 – 70	***	Three Star
71 – 85	****	Four Star
86 or more	*****	Five Star

d) GRIHA AH (Affordable Housing): With the purpose of taking sustainability to the masses, GRIHA has developed a new rating variant called as "GRIHA for Affordable Housing" which is aligned to the Pradhan Mantri Aawas Yojna (PMAY). With the help of GRIHA AH rating, many low-income households shall be able to reduce the operational costs and Green House Gares (GHG) emissions by improving their resource efficiency. The rating would evaluate the environmental performance of residences holistically over its entire life cycle. The rating thus provides a definitive standard for what constitutes a 'Green building' as it is a dedicated assessment cum rating tool, and a pre-fed calculator based system.

4.8.2 IGBC (Indian Green Building Council): The Indian Green Building Council (IGBC), part of the Confederation of Indian Industry (CII) was formed in the year 2001. The vision of the council is, “To enable a sustainable built environment for all and facilitate India to be one of the global leaders in the sustainable built environment by 2025”. IGBC is the founding member of World Green Building Council discussing global issues at COP (“Conference of Parties” – The United Nations annual climate change conference) and similar global platforms.

IGBC has various rating systems – Residential, Commercial, Industrial etc.

a) IGBC Green Homes – Version 3.0: It is used for new and major renovation of individual/multi-dwelling residential units, Apartment complexes, gated communities, guest houses, service apartments, resorts, hostels etc. Thereafter, projects need to apply for Re- Certification. This rating system has maximum of 100 points.

Rating points Break up is as under:

SN	Key Areas	Maximum points
1	Sustainable Design	20
2	Water Conservation	23
3	Energy Efficiency	20
4	Materials and Resources	18
5	Resident Health & wellbeing	14
6	Innovation & Design	5
	Grand Total	**100**

The Rating based on point scored is as under:

Certification Level	Points	Recognition
Certified	50 – 59	Best Practices
Silver	60 – 69	Outstanding Performance
Gold	70 – 79	National Excellence
Platinum	80 – 100	Global Leadership

b) IGBC Green New Buildings (Version 3.0, Sept. 2016): It is designed primarily for new commercial buildings. New Buildings include (but are not limited to) offices, IT parks, banks, shopping malls, hotels, airports, stadiums, convention centers, libraries, museums, etc., Building types such as residential, factory buildings, schools will be covered under other IGBC rating programmes. IGBC Green New Buildings rating system is broadly classified into two types:

- Owner-occupied buildings are those wherein 51% or more of the building's built-up area is occupied by the owner.
- Tenant-occupied buildings are those wherein 51% or more of

the building's built-up area is occupied by the tenants.

Based on the scope of work, projects can choose any of the above options.

Rating points Break up is as under:

SN	Key Areas	Maximum Points	
		Owner occupied Buildings	**Tenant occupied Buildings**
1	Sustainable Architecture and Design	**5**	**5**
	• Integrated Design Approach	1	1
	• Site Preservation	2	2
	• Passive Architecture	2	2
2	**Site Selection and Planning**	**14**	**14**
	• Local Building Regulation	Mandatory	Mandatory
	• Soil Erosion Control	Mandatory	Mandatory
	• Basic Amenities	1	1
	• Proximity to Public Buildings	1	1
	• Low-emitting Vehicles	1	1
	• Natural topography or Vegetation	2	2
	• Preservation or Transplantation of Trees	1	1
	• Heat island Reduction, Non-Roof	2	2
	• Heat island Reduction, Roof	2	2
	• Outdoor Light Polllution Reduction	1	1
	• Universal Design	1	1

	• Basic Facilities for Construction Workforce	1	1
	• Green Building Guidelines	1	1
3	Water Conservation	**18**	**19**
	• Rainwater Harvesting, Roof & Non-roof	Mandatory	Mandatory
	• Water efficient Plumbing Fixtures	Mandatory	Mandatory
	• Landscape Design	2	2
	• Management of Irrigation Systems	1	1
	• Rainwater Harvesting, Roof & Non-roof	4	4
	• Water efficient Plumbing Fixtures	5	5
	• Wastewater Treatment and Reuse	5	5
	• Water metering	1	2
4	Energy Efficiency	**28**	**30**
	• Ozone Depleting Substances	Mandatory	Mandatory
	• Minimum Energy Efficiency	Mandatory	Mandatory
	• Eco-friendly refrigerants	1	1
	• Enhanced Energy Efficiency	15	15
	• On-site Renewable Energy	6	8
	• Off-site Renewable Energy	2	2
	• Commissioning, Post-Installation of Equipment & systems	2	2
	• Energy Metering and Management	2	2
5	Building Materials and Resources	**16**	**16**

	• Segregation of Waste, Post-occupancy	Mandatory	Mandatory
	• Sustainable Building Materials	8	8
	• Organic Waste management, Post-occupancy	2	2
	• Handling of Waste Materials, During Construction	1	1
	• Use of Certified Green Building Materials, Products & Equipment	5	5
6	Indoor Environmental Quality	**12**	**9**
	• Minimum Fresh Air Ventilation	Mandatory	Mandatory
	• Tobacco Smoke Control	Mandatory	Mandatory
	• CO2 Monitoring	1	1
	• Daylighting	2	2
	• Outdoor Views	1	1
	• Minimise Indoor and outdoor Pollutants	1	1
	• Low-emitting materials	3	3
	• Occupant Well-being Facilities	1	-
	• Indoor Air Quality Testing, After Construction and before Occupancy	1	1
	• Indoor Air Quality	1	1
	Testing, After Construction and During Occupancy		
7	Innovation and Development	**7**	**7**
	• Innovation in Design Process	4	4

	• Optimization in Structural Design	1	1
	• Waste Water Reuse, During Construction	1	1
	• IGBC Accredited Professional	1	1
	Grand Total	**100**	**100**

The Rating based on points scored is as under:

Certification Level	Points	Tenant occupied Buildings	Recognition
Certified	40 – 49	40 – 49	Best Practices
Silver	50 – 59	50 – 59	Outstanding Performance
Gold	60 – 74	60 – 74	National Excellence
Platinum	75 – 100	75 – 100	Global Leadership

c) IGBC Green Existing Buildings O&M (Pilot Version 2013):

It is used for certifying the existing commercial buildings. IGBC Green Existing Buildings O&M (operations & maintenance). The buildings includes office buildings, IT Parks, BPOs, shopping malls, hotels, hospitals, airports, banks, etc. This rating system is fundamentally designed to address national priorities of resource conservation while providing quality of life for occupants. It is designed primarily for new commercial buildings.

Buildings which are 80% occupied (with respect to the carpet area) and operational for a minimum of 1 year are eligible for certification under IGBC Existing Buildings O&M rating.

SN	Key Areas	Maximum points
1	Site & Facility Management	**18**
	• Green Policy	Mandatory
	• Waste Collection & Disposal	Mandatory
	• Eco-friendly Commuting practice; 25%, 50%	4
	• Eco-friendly Commuting practice; 50%, 75%	2
	• Heat Island Reduction, Non-roof: 50%,75%	4
	• Heat Island Reduction, Roof: 50%,75%	4
	• Outdoor Light Pollution Reduction	2
	• Building Operation & Maintenance	2
2	Water Efficiency	**26**
	• Water Efficient Fixtures	Mandatory
	• Water Efficient Fixtures; 20%, 30%, 40%	6
	• Rainwater Harvesting:25%, 50%	4
	• Waste Water Treatment: 100%	4
	• Waste Water Reuse: 75%,100%	4
	• Water Metering	4
	• Turf Area: 50%, 25%	4
3	Energy Efficiency	**30**
	• Eco-friendly Refrigerants & Halons	Mandatory
	• Minimum Energy Performance	Mandatory
	• Improved Energy Performance: 10%, 12.5%, 15%, 17.5%, 20%, 22.5%, 25%	14

	• On Site Renewable Energy: 2.5%, 5%, 7.5%	6
	• Off Site Renewable Energy: 25%, 50%, 75%	6
	• Energy Metering	4
4	Health & Comfort	**14**
	• Tobacco Smoke Control	Mandatory
	• Fresh Air Ventilation	Mandatory
	• CO2 monitoring & Control	2
	• Isolation of Polluting Equipment & Systems	2
	• Eco-friendly Housekeeping Chemicals	2
	• Thermal Comfort, Indoor Temperature & RH	2
	• Facilities for Differently Abled People	4
	• Occupant Well-being Facilities	2
5	Innovation Category	**12**
	• Innovation Credits	10
	• IGBC AP	2
	Total	**100**

The Rating based on points scored is as under:

Certification Level	Points	Tenant occupied Buildings	Recognition
Certified	40 – 49	40 – 49	Best Practices
Silver	50 – 59	50 – 59	Outstanding Performance
Gold	60 – 74	60 – 74	National Excellence
Platinum	75 – 100	75 – 100	Global Leadership

Note: Following more certifications are available for various categories of assets:

1. Residential Buildings: IGBC Green Residential Societies, IGBC Green Affordable Housing, IGBC NEST.
2. Commercial buildings: IGBC Health and Well-being, IGBC Green Healthcare, IGBC Green Data Center, IGBC Green Service Buildings, IGBC Green Resorts.
3. Industrial Buildings: IGBC Green Factory Buildings, IGBC Green Logistic Parks and Warehouses.
4. Other Buildings: IGBC Green Schools, IGBC Green Campus, IGBC Green Interiors, IGBC Green Place of Worship.
5. Green Environment: IGBC Green Township, IGBC Green Cities, IGBC Green Existing Cities, IGBC Green Hill Habitat, IGBC Green Mass Rapid Transit System, IGBC Green Existing Mass Rapid Transit System, IGBC Green Railway Stations, IGBC Green High Speed rail, IGBC Green Landscapes, IGBC Green Villages.

4.8.3 LEED (Leadership in Energy and Environmental Design):

Is the world's most widely used green building rating system. LEED certification provides a framework for healthy, highly efficient, and cost-saving green buildings, which offer environmental, social and governance benefits. LEED rating system was developed & piloted in USA by United State Green Building Council (USGBC), in 1998. Later in 2006 LEED-INDIA version based on LEED rating system developed by Indian Green Building Council (IGBC) based at Hyderabad. However, now the certification of LEED is not being done by IGBC. The green building certifications (LEED certification) are being done by USGBC's partner organization "Green Business Certification Inc. (GBCI).

USGBC prepares the reference manuals, prepares and upgrades rating system training.

LEED v5 is the latest version of LEED. This version, is an important milestone in the effort to align the built environment with the Paris Climate Accord's 2030 and 2050 targets. The rating system addresses crucial issues such as equity, health, ecosystems,

and resilience.

Various rating system under LEED are discussed as under -

a) LEED V4 Building Design and Construction (BD+C): It is used for new construction or major renovations. It is applicable to New Construction; Core & Shell development; Data Centers; Healthcare, Hospitality, Retail, Schools, Warehouses & Distribution Centers.

The Breakup of points for New Constructionand Major Renovation is as under -

S. N.	Key Areas	Maximum points
1	Integrative Process	**1**
2	Location and Transportation (LEED for neighborhood development location)	16
	• Sensitive Land Protection	1
	• High Priority Sites	2
	• Surrounding Density and Diverse Uses	5
	• Access to Quality Transit	5
	• Bicycle facilities	1
	• Reduced Parking Footprint	1
	• Green Vehicles	1
3	Sustainable Sites	**10**
	• Construction Activity Pollution Prevention	Mandatory
	• Site Assessment	1
	• Site Development – Protect or Restore Habitat	2
	• Open Space	1
	Rainwater management	3
	Heat Island reduction	2
	Light Pollution Reduction	1

4	Water Efficiency	**11**
	Outdoor Water Use reduction	Mandatory
	Indoor Water Use Reduction	Mandatory
	Building- Level Water Metering	Mandatory
	Outdoor Water Use Reduction	2
	Indoor Water Use Reduction	6
	Cooling Tower Use	2
	Water Metering	1
5	Energy and Atmosphere	**33**
	Fundamental Commissioning and verification	Mandatory
	Minimum Energy Performance	Mandatory
	Building- Level Water Metering	Mandatory
	Fundamental Refrigerant Management	Mandatory
	Enhanced Commissioning	6
	Optimize Energy Performance	18
	Advanced Energy Metering	1
	Demand Response	2
	Renewable Energy Production	3
	Enhanced Refrigerant Management	1
	Green Power and Carbon Offsets	2
6	Material and Resources	**13**
	Storage and Collection of Recyclables	Mandatory
	Construction and Demolition Waste Water Management and planning	Mandatory
	Building Life- cycle Impact Reduction	5
	Building Product Disclosure and Optimization – Environmental Product Declaration	2
	Building Product Disclosure and Optimization – Sourcing and Raw Materials	2

	Building Product Disclosure and Optimization – Material Ingredients	2
	Construction and Demolition Waste management	2
7	Indoor Environmental Quality	**16**
	Minimum Indoor Air Quality Performance	Mandatory
	Environmental Tobacco Smoke Control	Mandatory
	Enhanced Indoor Air Quality Strategies	2
	Low-Emitting Materials	3
	Construction Indoor Air Quality Management	1
	Indoor Air Quality Management	2
	Thermal Comfort	1
	Interior Lighting	2
	Daylight	3
	Quality Views	1
	Acoustic Performance	1
8	Innovation	**6**
	Innovation	5
	LEED Accredited Professional	1
9	Regional Priority	4
	Regional Priority: Specific Credit	1
	Regional Priority: Specific Credit	1
	Regional Priority: Specific Credit	1
	Regional Priority: Specific Credit	1
	Total	**110**

The Rating based on points scored is as under:

Certification Level	Owner occupied Buildings
Certified	40 – 49
Silver	50 – 59
Gold	60 – 79
Platinum	80 – 110

b) LEED V4 Building Operation and Maintenance (O+M): It is used for existing buildings that are undergoing improvement work or little to no construction. It is applicable to Existing Buldings; Schools, Retail, Hospitality, Data Centers; and, Warehouses & Distribution Centers.

The Breakup of points for New Construction and Major Renovation is as under -

S. N.	Key Areas	Maximum points
1	Location and Transportation	**14**
	Transportation Performance	14 (Min. 6 required)
2	Sustainable Sites	**4**
	Renewable Mangement	1
	Heat Island Reduction	1
	Light Pollution Reduction	1
	Site Management	1
3	Water Efficiency	**15**
	Water Performance	15 (Min. 6 required)
4	Energy and Atmosphere	**33**
	Energy Efficiency Best Management Practices	Mandatory
	Fundamental Refrigerant Management	Mandatory

	Energy Performance	33 (13 points required)
	Enhanced Refrigerant Management	1
	Grid Harmonization	1
5	Material and Resources	**9**
	Purchase Policy	Mandatory
	Facility Maintenance and Renovation Policy	Mandatory
	Water Performance	8
	Purchasing	1
6	Indoor Environmental Quality	**22**
	Minimum Indoor Air Quality	Mandatory
	Environmental Tobacco Smoke Control	Mandatory
	Green Cleaning Policy	Mandatory
	Indoor Environmental Quality Performance	20 (8 points required)
	Green Cleaning	1
	Integrated Pest Management	1
7	Innovation	1
	Innovation	**1**
	Total	100

The Rating based on points scored is as under:

Certification Level	Owner occupied Buildings
Certified	40 – 49
Silver	50 – 59
Gold	60 – 79
Platinum	80 – 110

Note- 1: Following more certifications are available for various categories of assets:

- **Interior Design and Construction (ID+C)**:For complete interior fit-out projects. Includes Commercial Interiors, and also includes applications for Retail and Hospitality.
- **Neighborhood Development (ND):**For new land development projects or redevelopment projects containing residential uses, nonresidential uses, or a mix. Projects can be at any stage of the development process, from conceptual planning to construction. Includes Plan and Built Project.
- **Homes:** For single family homes, low-rise multi-family (one to three stories) or mid-rise multi-family (four or more). Includes Homes, Multifamily Lowrise, and Multifamily Midrise. Homes and residential buildings that are greater than four stories may also use LEED BD+C.
- **Cities:** For entire cities and sub-sections of a city. LEED for Cities projects can measure and manage their city's water consumption, energy use, waste, transportation and human experience.

Note- 2: Validity period: The LEED rating for the building lasts for a period of 5 years. After that, re-certification of the building is required.

Buildings certified originally as New Buildings or Major Renovation cannot be re-certified under the same category. They have to be certified under existing building categories.

4.9 Adopting Green Features In Buildings

The green buildings involve additional initial costs but over the life cycle these buildings turn out to be more economical. Besides, from the environmental and social consideration, it is desirable to go for green buildings. It is not necessary to incorporate all green features in each building. Even if some of the green features are incorporated in individual buildings considerable benefit would accrue for the occupant and the environment.

4.10 Green Building: A Case Study Of New Iricen Administrative Building

A state of art New Administrative Building near the existing

Hostel at Koregaon Park was constructed to reduce travel time from hostel to Institute. Being a Premier Institute imparting training to all Civil Engineers of Indian Railways, the building was planned as a Green Building to impress upon all the trainee officers the importance of Green Environment. In building construction many environmental friendly measures such as reuse of material like released wooden sleepers, released wooden beams & purlins from existing rest house etc, use of recyclable material like Gypsum Board, Zyproc partitions, fly ash in bricks & cement were planned. Building saves 44% of energy by use of energy efficient fittings, day light integration & use of solar energy. The building also saves 59% of water by use of low flow fixtures & sewerage treatment plant. The building has been awarded LEED-INDIA Platinum rating by Indian Green Building Council (IGBC) with 61 credits, out of maximum possible 69 credits. The building got Five Star rating under GRIHA rating system by The Energy & Resource Institute (TERI).

Over the years the demand for buildings are increasing due to increase in population. Due to change in technology and life style the demand for energy & water has increased many fold in construction & operation of buildings. Buildings consume almost 50% of energy globally. Therefore there is a need to reduce energy & water demand as well as other resource in construction & operation of building to reduce negative impact on environment.

4.10.1 Green Building:

A green building is one constructed with design and construction processes which significantly reduce or eliminate negative impact of buildings on the environment and occupants.

It conserves nature & natural resources, increase energy efficiency & reduce negative impact on occupants. For this nature shall be optimally used for lighting & space conditioning by way of proper orientation of building, proper positioning & size of windows including shading & coatings, proper selection of material for roof, wall & windows including insulation and other features like landscape & water bodies etc. Energy efficient light fittings, intelligent control like daylight sensor, occupancy sensor etc & renewable energy shall be used to reduce energy demand. Use of

low flow fixtures, rain water harvesting & recycling of water shall be planned to reduce water demand.

The Green Building saves 30 to 60% energy demand as well as 20 to 50% water demand. It also saves requirement of virgin material due to extensive reuse of material as well as use of high recyclable content in new material.

4.10.2 Planning of new administrative building:

The institute was initially started in a heritage building near Pune Railway Station. Due to increased demand of training & to improve quality of training, few more wings like Library wing, Auditorium, modal room, Laboratory wing & Annex wing etc. were added. Over the years it was felt to have proper campus with hostel, Institute and other facilities in one place to optimise the use of all facilities even after office hours particularly the Library & computer center with the establishment of permanent hostel at Koregaon park. Initially it was tried to get extra land from Defence at Koregaon park, however that proposal did not materialise. It was even tried to have full campus at a different location but finally it was decided in 2004 to construct new administrative building in Koregaon park adjacent to hostel by shifting the Officers Rest House. This has also reduced time & energy which was being wasted in travel to & fro from hostel to institute.



Fig 4.2 IRICEN New Administrative Building

The building was planned as a state of art Building having stilt plus four floors. At planning stage itself, it was decided to construct the building as energy efficient building. Subsequently during 2nd Works Standard Committee meeting at Shillong in 2005, which was attended by all Chief Planning & Design Engineers of Zonal Railways along with representative from Railway Board, IRICEN and Research Development & Standardisation Organisation (RDSO), it was decided that Indian Railways shall adopt Green Building technology. IRICEN being Premier Institute imparting training to all Civil Engineers of Indian Railways, its new building shall be planned as Green Building to impress upon all the trainee officers the importance of Green Environment and shall be rated by reputed certifying agency.

4.10.3 Intelligent Design features:

This building has been constructed in RCC framed structure of stilt + 4 floors with a total plinth area of 8700 sqm. The facilities at each floor have been provided keeping functionality and access required by various users and outsiders. On Ground floor Museum cum model room, which is also visited by many engineering college students as a part of their curriculum; Laboratory and Auditorium are also provided on this floor. On first floor Library, reading room which shall be accessed by Trainees during extended hours in evening and office are provided. On 2nd floor 5 class rooms with two having capacity of 70 & three having capacity of 40 including one computer class room have been provided. On this floor conference room and computer center have also been provided. On top floor all faculty rooms along with a committee hall for internal meetings have been provided.

The building has been provided with 2 skylights and one atrium cut on all floor & other big cut out on top two floor to utilize day light to maximum extent. The skylight above atrium is covered with polycarbonate dome whereas the other skylight has been provided with BIPV (Built In Photo Voltaic) panels which generate 10 KW of electricity.



Fig 4.3 Skylight with BIPV



Fig 4.4 Polycarbonate dome over Atrium

Energy saving to the tune of 44% has been achieved which is rare for such type of buildings. This feat has been accomplished by providing insulation to walls on south & west side (double wall of fly ash bricks with 25mm insulation filler in cavity), double glazed windows on south, west & east side of buildings with high performance glass, and terrace insulation by providing 40mm EPS boards and high SRI value (>90%).

The water usage has been reduced by 59% by use of sensor based low flow fixture in toilets. 20 KLD capacity sewage treatment plant is constructed which treats all the water generated from this building as well as from adjacent hostel to tertiary level and this treated water is used for watering of landscape bringing down the fresh water requirement for landscape to NIL.



Fig. 4.5 Urinals with Sensors



Fig. 4.6 Low flow fixtures with sensors

Released wooden track sleepers have been extensively used for cladding in auditorium and atrium. Released teakwood from dismantled Officer's Rest House has also been used for door frames and false ceiling of porch. Released Maple wood flooring of Badminton Court was used for stage floor of the Auditorium.

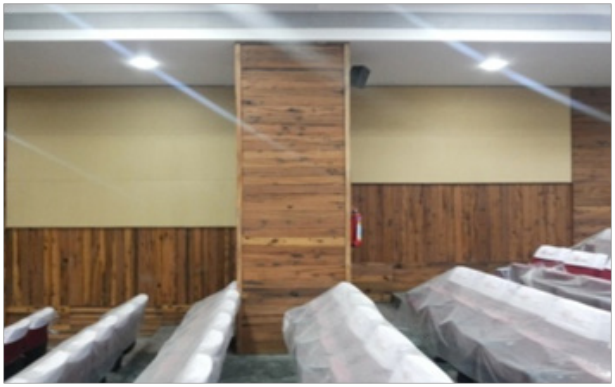


Fig. 4.7 Released Teak Wood For False Ceiling



Fig. 4.8 Released Teak Wood for False Ceiling

4.10.4 Green Features provided:

4.10.4.1 Consruction waste management and resousrce reuse:

The building has been constructed on a previously developed plot which housed officers' Rest House (ORH). During demolition of ORH, due care was taken to salvage wooden beams and posts, granite flooring and other materials that could be reused in the new building. The project has diverted 97.63% of onsite construction waste generated for landfill & other uses. Air & water Pollution Prevention during construction was achieved by provision of proper barricading & regular spraying of water. Resource Reuse achieved up to 10.79% by using materials like released sleeper wood, released teakwood from ORH, Badminton Court, maple wood flooring and use of old furniture in new Building.

Materials having Recycled Contents like Gypsum false ceiling, zyproc partition, fly ash bricks, PPC, RMC with fly ash etc. were used up to 11.67% of total material usage. 57.22% of the total value of the construction materials used in the project was manufactured with local material within 800 km of the project site.



Fig. 4.9 Construction site barricading



Fig. 4.10 Spraying fo water at construction site

4.10.4.2 Energy Conservation:

Energy Efficient LED lighting fixtures with Occupancy and Daylight Sensors have been used including provision of Task lighting & dimmers. Most Efficient VRV (Variable Refrigent Volume) AC Units with COP (Coefficient of Performance) up to 4.85 have been provided. The total estimated energy generation from on site photo voltaic (PV) is 51982 kWh including BIPV which is 11.24 % of the total

energy required by the building is 461,877 kWh. Measurement and Verification of Energy and Water Consumption with BMS (Building Management System). Timer Based Exterior Lighting Fixtures have also been provided. With this project was able to save 44% energy which is rare for such types of buildings.

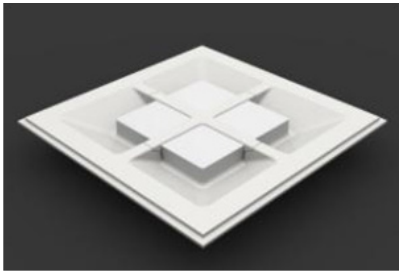




Fig. 4.11 LED Fixtures & Fig. 4.12 Air conditioning with VRV

4.10.4.3 Indoor Air Quality Management:

Fresh Air Design was made in all parts to meet International Ventilation Codes of ASHRAE. The entire campus site is declared as "No Smoking Zone". CO2 monitoring in all densely populated spaces such as Auditorium & classrooms is provided. Low VOC Adhesives, Sealants, Paints were used. Urea-Formaldehyde resins were not allowed in all composite wood and agri fibre products were used in the building. Operable windows & Thermostats provided for Thermal Comfort & fresh air control.

4.10.4.4 Other Green Features:

Top soil was preserved and re-used. Full-grown trees that existed on the site weretransplanted.54.35% (3,061 sq.m.) of the site area (excluding the building footprint) was restored with native/adaptive vegetation. 100% Parking has been provided under cover. Separate area has been nominated for pooled cars and electric charging points provided to encourage people to reduce dependence on fossil fuel.



Fig. 4.13 Preservation of landscape



Fig. 4.14 Tree Transplantation



Fig. 4.15 Top soil preservation

4.10.4.5 Other Important Measures:

Fire fighting measures have been provided as per NBC (National Building Code) norms. Smoke sensors are provided in each room. Whole building campus has been declared as no smoking zone. Fire hydrant has been provided on each floor. Two way fire brigade entry has been provided at ground floor. The location is such that it is easily accessible by fire brigade vehicle. One separate overhead RCC tank is provided on the terrace for the firefighting purpose. Licensed authorized vendor was engaged for providing the fire fighting system.

The building has been designed as earth quake resistant structure, by following the IS code. 456,875(part I to V), 1893,13920,3370 part I to IV. The building has been designed as a framed structure. Light weight aerated concrete block (siphorex) and Gypsum board (Zyproc) have been used for partition walls to reduce loads. No overlap was permitted in the reinforcement of foundation. No overlap was permitted in bottom and top 1/3 rd length of columns. Staggering of splices of reinforcement bars has been done columns and beams. Extra reinforcement bars have been provided at the junction of column and beam. Expansion joint has been provided.

The various architect effects such as Bust of Sir M Visvesaryya in atrium, Monogram of IRICEN & Other beautification works in atrium & Porch were provided with the help of Sir J.J.School of Arts, Mumbai.



Fig. 4.16 Monogram of IRICEN



Fig. 4.17 Bust of Sir M. Viserayya

4.10.5 Contribution of Participants:

Integrated Design and Construction process had enabled project team members to work closely from the project outset till its completion thus helping the project team to achieve appropriate solutions that have produced multiple benefits. The building was built by the Construction Organization of Central Railway. It was a team work comprising of General Manager, Chief Administrative Officer & construction Engineers of Central Railways, Faculty from IRICEN and various construction agencies & consultants.



Fig. 4.18 Discussion of Stakeholden

4.10.6 Agencies associated with Project & their work :

- M/s KCPL, Miraj (Civil Construction)
- Shri Ravi Jante, Latur (Balance Works Civil Construction)
- Shree Electricals, Pune (HVAC)
- Omega Enterprises, Ahmedabad (Lift)
- Shalakha Infraprojects Ltd., Pune (Sub-station, DG)
- Data Com, Mumbai (Communication, PA system, networking Consultants

- CII Godrej, Hyderabad : Feasibility Study for LEED Certification.
- M/s Shashi Prabhu & Associates, Mumbai : Architectural & Structural Consultant
- M/s Conserve, Chennai : Energy Simulator
- M/s Inertia, Hyderabad : LEED Facilitator
- Sir J.J.School of Arts, Mumbai – Bust of Sir M Visvesaryya, Monogram of IRICEN & Other beautification works.

Sub Consultants :

- M/s V.N. Purandare & Associates, Pune : Auditorium & Acoustics
- M/s NECON Engineers, Pune : General Electrical
- M/s REFRISYNTH Engineers, Pune : HVAC
- Green One, Pune : Landscape
- SGS India Pvt. Ltd., Gurgaon : Building Commissioning Agent

4.10.6 Summary :

Our country is witnessing a boom in the construction sector which leads to environmental pollution, global warming etc. Green Buildings can reduce the energy demand and optimize the use of other resources. **The best part of this building is that it is part of curriculum of trainee officers at IRICEN which helps them in propagating the green concept throughout the country.** New Administrative Building for IRICEN at Koregaon Park, Pune is one step taken by Railways in the Direction of Greener Environment of future.

CHAPTER 5

WATER MANAGEMENT

The previous chapter introduced the concept of green buildings. It gave a brief on components of green building like Sustainable development; Energy Efficiency; Water efficiency; Indoor Air Quality; Material and resources etc. This chapter will elaborate more on the water efficiency aspect of Green buildings.

5.1 Why Water Management

Water is most precious resource and is essential for human life. It is essential for human, livestock, agriculture, industries etc. Today, if think the water is in abundance it is going to be a big great mistake. Over the years the water sources are depleting specifically fresh water resources.

The population on the earth is growing multi-fold and also the industrialisation is increasing at enormous pace resulting in higher demand of water. To take care of the depleting resource of water the efficient "Water Management" is the need of time.

5.2 What Is Water Efficiency

Water efficiency is the practice of reducing water consumption by measuring the amount of water required for a particular purpose and is proportionate to the amount of essential water used. Water efficiency differs from water conservation in that it focuses on reducing waste, not restricting use. Solutions for water efficiency not only focus on reducing the amount of potable water used but also on reducing the use of non-potable water where appropriate (e.g. flushing toilet, watering landscape, etc.).It also emphasizes consumers can have on water efficiency by making small behavioural changes to reduce water wastage, and by choosing more water-efficient products.

5.3 What Is Water Conservation

Water conservation is all about reducing the water wastage and preventing unnecessary use of water. The key activities that

conserve water include reduction in water loss, use and waste of resources, avoiding any damage to water quality; and improving water management practices that reduce the use or enhance the beneficial use of water.

5.4 Water Policy On Indian Railway

Water management is an integral part of sustainability efforts. Indian Railways has formulated "Indian Railways Water Policy, 2017" and same was circulated vide letter no. 2016/ EnHM/03/01 dt. 11.04.2017. The policy envisages holistic water management through"Reduce, Recycle & Recharge".

5.5 Water Management In Green Buildings

Water management can be done in green buildings by adopting 3Rs – Reduce, Reuse and Recycle.

5.5.1 Reduce: Reduce the demand for water through technological up-gradation such as use of water efficient sanitary fixtures.Identify water losses and leakages and plug the same Educating consumers to economise the use of water and avoid wastage.

5.5.2 Reuse: This is achieved by using the waste water for non-drinking purposes after treating the waste water.

5.5.3 Recharge: This is achieved by recharging the ground by rainwater.

5.5.4 Measures to Reduce the water use.

1. Sub-metering:

For sustainable design of buildings individual water meters may be installed for each individual household. This meter gives exact idea to the user as how much water is used by them. This is one of the criteria in green building rating criteria followed by one of the rating systems.

These individual sub meters help as under

a) Consumption of water

b) Detection of water leakages

c) Makes resident water use conscious

d) Saves the electrical energy – indirectly

2. Use of water efficient fixtures:

Water efficient fittings & fixtures play an important role in demand side management. Most of the water consumption by the end users is through valves, stop-cocks/faucets, flushing cistern, urinals etc., it is essential to choose such design of fittings and fixtures of sanitary fittings / fixtureswhichareefficientin waterconsumption.Highly – efficient or low-flow plumbing fixtures provide effective saving of water as well as energy bills. Certain water efficient fixtures are as under

a) Water taps with sensors: helps in reducing the usage of water. Normally, for washing hands, sensor based taps uses @ 300-400ml water as compared to 1-2 litre water in manual taps.

b) Dual flush toilets use up to 67% less water than conventional toilets.

c) Waterless urinals or urinals with sensors can be used.

d) Low-flow shower heads reduce the water consumption about 50-70% while bathing.

e) Faucets like faucets, shower heads, and toilets have with low discharge can be used.

f) Use of washing machines and dish washers substantially saves water.

g) Use of sprinklers for lawns and drip irrigation for shrubs and trees.

However maintainability of these items/fixtures shall be kept in view while choosing the design/make and specific fittings and fixtures.



Fig. 5.1 Water Efficient Appliances/Fixtures

5.6 Reuse of Water:

This is achieved by collecting the used waste water and treating it.

1. Grey water treatment :

The grey water generated from the bath, wash basins, washing machines, manual utensil cleaning, dish washers, kitchen sinks, and wash basins. This water is about 65-70% of the total water used in a household.

This waste water can be treated by-

1. Sedimentation
2. Passing through grease trap
3. Aerobic or anaerobic digestion
4. Filtering
5. UV disinfection

This water can be used for toilet flushing, washing of clothes, gardening etc.

2. Sewage water treatment :

The sewage water generated from the water closet, urinals can be treated is sewage treatment plant (STP). Now a days, very compact STPs are available in the market.

This waste water can be treated by -

1. Filtering
2. Sedimentation
3. Aerobic or anaerobic digestion
4. UV disinfection

This water can be used for toilet flushing and gardening etc.

5.7 Recharging of Ground Water and Reuse

Rain water harvesting (RWH): is a technique of collection and storage of rain water at surface or in subsurface aquifer before it is lost as a surface run off.

a) Direct use of stored water:

In buildings, the rainwater is collected from the roof top and redirected to a storage tank. Designing the storage tank must consider the catchment's availability, rainfall, and water consumption.

Harvested rainwater can be used for different applications that do not require drinking water quality such as toilet flushing, garden watering & irrigation.

Rainwater harvesting systems generally consist of six basic elements:

- Collection (catchment) area
- Conveyance system
- Filtration
- Storage facility, cisterns or tanks
- Purification
- Delivery system

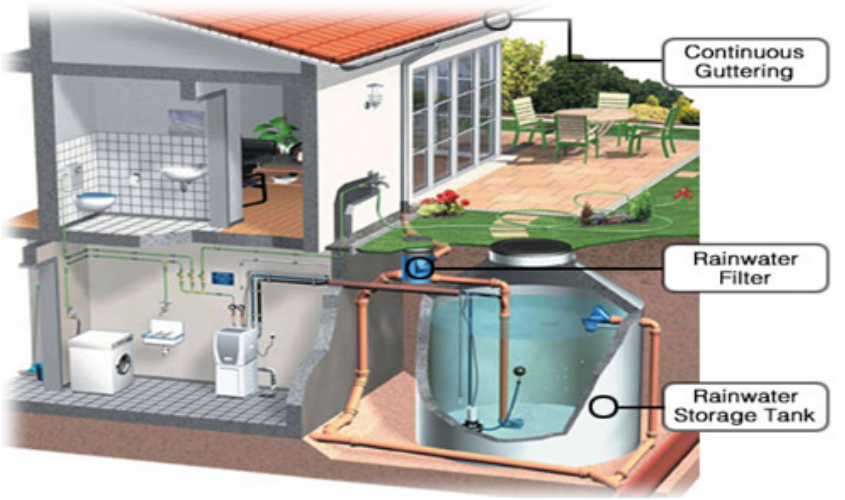


Fig 5.2 Schematic diagram of a rooftop rainwater harvesting system

b) Recharging the ground:

The rainwater is collected from the roof top and redirected to the natural ground in order to replenish the ground water. Harvested rainwater can be used for different applications that do not require drinking water quality such as toilet flushing, garden watering & irrigation.

Rainwater harvesting systems used for recharging the ground water are as under -

- Through recharge pit
- Recharge through abandoned hand pump
- Recharge through abandoned well
- Through recharge trench
- Recharge through shaft
- Recharge trench with bore

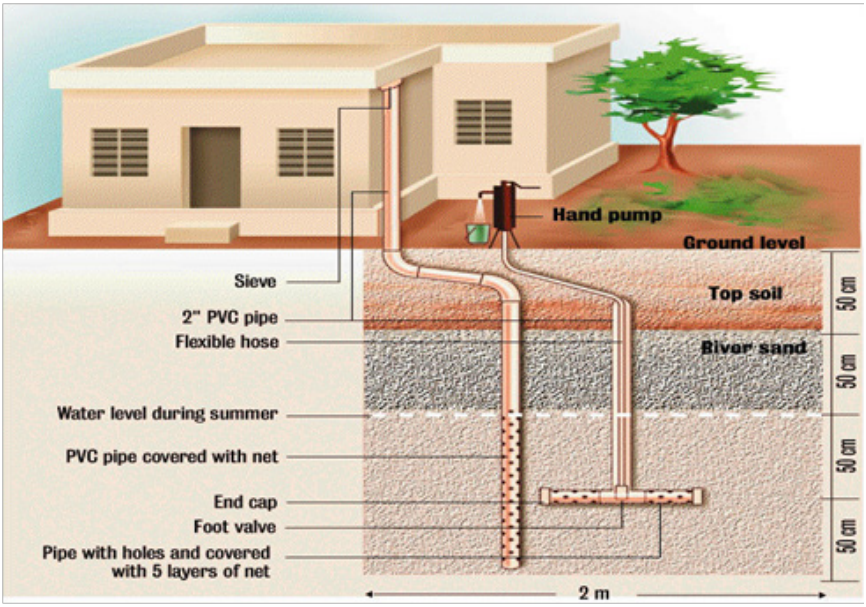


Fig 5.3 Schematic diagram of a ground water recharging system

5.8 Provisions of Indian Railway Water Policy

1. Vide Board's letter no. 2013/ LMB/9/ 1 dt. 09.09.13, RWH systems have been made mandatory in construction of all built up assets. It has been decided that RWH systems shall be provided in all existing establishments (station buildings, service buildings, residential quarter and other units) having roof top area of more than 200 sqm subject to techno-economic feasibility. Out of these, priority be given to those areas where Ground Water Block falls in 'Semi-critical' or 'critical' or 'Over- exploited' category as per Central Ground Water Board categorization. This is subject to the requirement forground water recharge for a particular area as per the CGWA's guidelines.
2. Technology for treatment (i.e. design & type of Waste water recycling pant/ Effluent Treatment plant/ Sewage Treatment plant) needs to be chosen to get maximum benefits with a minimum cost. While deciding the technology, capital cost, O&M cost, treatment efficiency, resource recovery, ease of operation and sustainability may be kept in view. Wherever

feasible, Natural Sewage / Waste Water Treatment systems instead of conventional STPs may be used keeping in view of the advantage of sustainability.

3. STPS/ETPs/WRP shave to be provided at railway stations, colonies, workshops/sheds, hospitals etc., including other units as per the CGWA's guidelines and/or as per the recommendations of Water Audit report.

CHAPTER 6

ENERGY EFFICIENCY

The chapter 4 introduced the concept of green buildings. It gave a brief on components of green building like Sustainable development; Energy Efficiency; Water efficiency; Indoor Air Quality; Material and resources etc. Chapter 2 introduced the fundamental of building orientations and building physics.

This chapter will elaborate more on the Energy efficiency aspect of Green buildings, various building energy codes and IR policy on energy efficiency.

6.1 What Is Energy Efficiency

Use of less energy by adopting certain method/products to perform the same task or produce the same result which are done by conventional or routine methods/products.

The building sector in India is experiencing unprecedented growth. This sector alone accounts for over thirty per cent of India's total electricity consumption. It is estimated that India is building 3,00,000 square feet of commercial floor space every day and will see one of the largest commercial and residential building construction boom over the next two decades. India is at an inflection point where forty per cent of the building stock that will exist in the next twenty years is yet to be built. This would generate greater demand for energy and hence there is an urgent need to optimise building energy demand in upcoming as well as existing building stock.

6.2 Energy Efficiency Measures

In buildings, energy efficiency is achieved through following measures:

6.2.1 Architectural design :

to aim at reducing need for artificial lighting, forced ventilation and air conditioning.

6.2.2 Bio-climatic architectural principles :

for optimum use of natural lighting- orientation, positioning, coating and shading of windows, thermal insulation of roof and walls etc.

a. **Orientation:** This has adequately covered in chapter 1.

b. **Thermal mass:** Thermal mass is the energy required to raise temperature by 1^0C per unit area (unit $W/^0C/m^2$).

c. **Building envelopes measures:** How much glass is to be used in building?

High glazing: Tremendous day light but higher heat ingress. Hence, balance of day light & ingress of heat need to be balanced.To balance, we can use high performance glass & glazing with low U-value, low shading co-efficient, High VLT (Visual Light Transmittance).



Fig 6.1 Double Glazed Window

d. **Wall options:**

- Brick wall with insulation
- Extruded polystyrene,
- Expanded polystyrene (thermocol),
- Glass wool etc.,
- Brick wall with air cavity
- Hollow blocks, Fly-ash bricks
- Autoclaved Aerated Concrete Blocks (AAC)

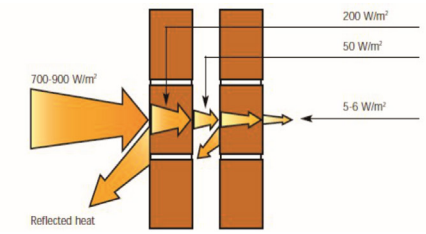




Fig. 6.2 Good Wall design – Cavity Wall Fig. 6.3 Glass Wool Stuffed Cavity Wall

6.2.3 Adopt solar passive features i.e. courtyard pattern, solar chimney, wind tunnel, earth tunnel etc.

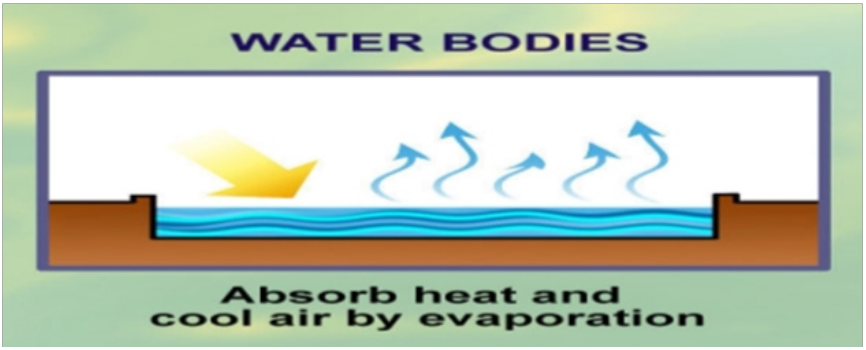


Fig 6.4 Courtyard Effect

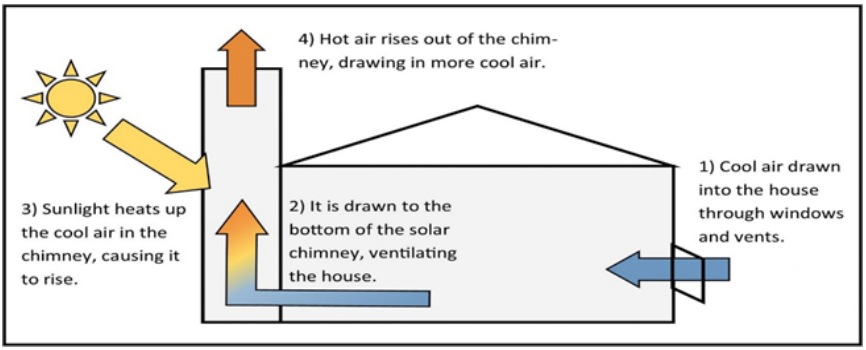


Fig 6.5 Solar Chimney

6.2.4 Use of solar active features: Use of efficient air conditioning and water cooling with intelligent features.

a. **Solar panels:** Separate solar panels on building top or Building Integrated photo voltaic (BIPV) can be used.



Fig 6.6 BIPV in Roof



Fig 6.7 Solar Panels on building Top

b. **Solar Water Heater:** can be used forhot water requirement for bathing.

6.2.5 Use of efficient air conditioning:

Efficient VRV (Variable Refrigent Volume) AC Units can be used.

6.2.6 Use of efficient light fittings and sensors to avoid wastage:

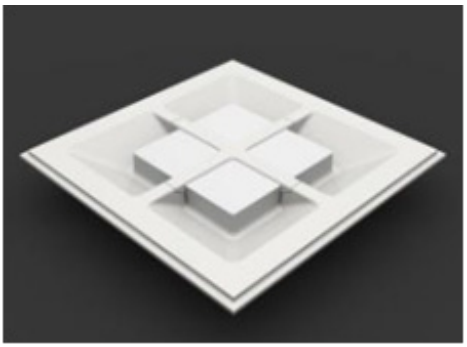


Fig 6.8 LED Fixtures

Above explained are very few measures of energy efficiency however there are number of measures available and used practically in the building industry. Readers are requested to

explore the details of such through various websites.

6.3 Introduction To Building Energy Codes

For saving the energy in buildings, there are various measures are available and few of it are explained in previous paragraph. In order to have control over the energy consumption in buildings there has to be certain regulatory authority & norms. For this, there are various building energy codes are available.

6.3.1 Brief History

The journey of energy conservation in India commenced in the 1970s, triggered by the global oil crisis. As the country faced the challenges of a growing industrial economy and increasing energy demands, the need for drastic reductions in consumption became apparent. Sectors like industry, infrastructure, agriculture, and housing were heavily reliant on energy inputs, necessitating a focus on reducing wastage and enhancing efficiency.

1947-1970: Post-Independence Surge in Energy Demand:

The post-independence period witnessed a surge in energy demand, with electricity being a crucial sector. However, the emphasis during this time was primarily on the supply of electricity, oil, and coal to support growth. Conservation of energy was not a priority in the initial decades.

1970s: Energy Conservation to Address Energy Access Crisis:

The 1970s marked a significant shift as India faced the consequences of the world oil crisis. The Fuel Policy Committee (FPC), established in 1970, played a key role in introducing the concept of efficient fuel use. The inter-ministerial Standing Committee on Furnace Oil and the Petroleum Conservation Action Group (PCAG) were instrumental in implementing energy conservation measures.

1980s: Energy Productivity and Energy Management:

In 1981, the Inter-Ministerial Working Group on Energy Conservation (IMWG) proposed the creation of an apex body to co-ordinate and monitor energy conservation measures. The focus shifted toward optimizing energy use, reducing consumption

intensity, and increasing reliance on renewable sources. The Petroleum Conservation Research Association (PCRA) was formed in 1978 to make oil conservation a national movement. In 1989, an Energy Management Centre (EMC) was also set up as an autonomous organization, with the assistance of the World Bank and United Nations Development Program (UNDP), to promote energy conservation.

1990s: Energy Demands of an Unregulated Economy:

The economic reforms of the 1990s, including deregulation and privatization, influenced the energy sector. Despite previous efforts, there was no legislation on energy conservation until 1994. In 1997, the proposal for the Energy Conservation Bill and the establishment of the Bureau of Energy Efficiency (BEE) gained momentum. The ninth Plan (1997-2002) recognized the need for conservation and renewable energy use.

Innovations and International Collaborations:

The 1990s witnessed the introduction of the voluntary Ecomark Scheme in 1991 and the initiation of Oil Conservation Week (OCW). The government declared December 14 as National Energy Conservation Day. Various bilateral bodies collaborated with the Ministry of Power, bringing expertise and technical support to national-level energy conservation.

6.3.2 Energy Conservation Act 2001 and Bureau of Energy Efficiency (BEE): Brief Overview

The EC Act 2001, alongside the BEE, outlines a comprehensive framework for energy efficiency, emphasizing standards, enforcement, and funds to drive progress in India's energy conservation journey.

Legislation and Establishment:

- Initiation: The Energy Conservation Bill was introduced in February 2000.
- Approval: Passed in both Houses in September 2001, the Energy Conservation Act (EC Act) became effective from March 1, 2002.

- Publication: Published in the Gazette of India in October 2001.

Role of Bureau of Energy Efficiency (BEE):

- Re-institution: In 2002, the Energy Management Centre became the Bureau of Energy Efficiency.
- Statutory Body: Identified as the statutory body with regulatory powers under the Ministry of Power.
- Penalty Provisions: Empowered with penalty provisions for non-compliance.

Significance of EC Act and BEE:

- Energy Efficiency Movement: Marks a crucial step in advancing the energy efficiency movement.
- Addressing Power Demand: Important as economic growth accelerates power demand and appliance installations.
- End-use Efficiency Impact: Emphasizes the impact of saving at the end-use on the overall generation side.

Key Directives of EC Act 2001:

- Minimum Standards and Labelling: Sets standards and mandates labelling for energy consumption of appliances.
- Prohibition: Forbids the manufacture, sale, and import of non-conforming equipment.
- Designated Consumers: Identifies energy-intensive industries and establishments.
- Improvement in Unorganized Sectors: Encourages energy efficiency in unorganized sectors.
- Energy Audits: Requires audits and implementation of viable recommendations.
- Building Codes Amendment: Allows amending building codes for local conditions.
- Establishment of Funds: Sets up Central and State Energy Conservation Funds.

- Energy-use Inspection: Mandates inspection of energy use by Designated Consumers.
- Enforcement of Norms: Enforces energy consumption norms.

ECBC Development:

- The Energy Conservation Building Code (ECBC) was developed by the Govt. of India for new commercial buildings on 27th May 2007. However, the ECBC came into the spotlight as part of the National Mission on Enhanced Energy Efficiency (NMEEE) in 2008. Its primary objective was to regulate the energy performance of commercial buildings and large developments.
- Following the launch of ECBC, it was progressively incorporated into building regulations across states. States and Union Territories were encouraged to adopt and enforce the ECBC to ensure uniformity in energy-efficient building practices.

Acknowledging the evolving energy landscape and advancements in technology, the ECBC underwent a revision in 2017. The updated code aimed to align with contemporary energy efficiency standards and promote green building practices.

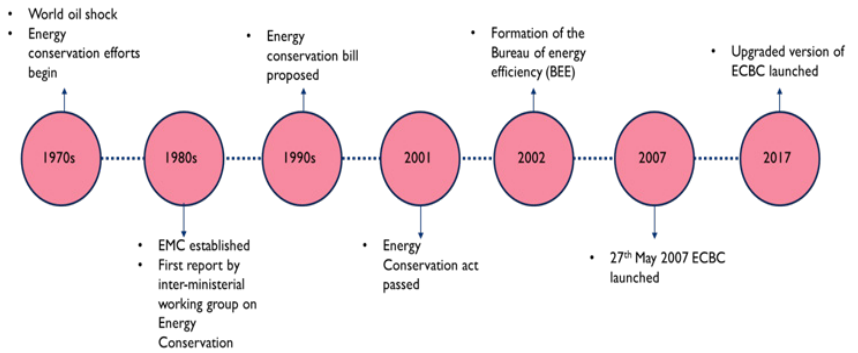


Fig 6.9: A brief timeline of ECBC development in India

This timeline reflects a comprehensive approach, involving the establishment of key institutions, the formulation of codes and standards, and the enactment of supportive legislation to promote energy conservation and efficiency in India.

6.4 Brief Summary About ECBC And ENS

6.4.1 Summary of Energy Conservation Building Code (ECBC)

a. Objective of ECBC

The primary objective of the Energy Conservation Building Code (ECBC) in India is to establish minimum energy performance standards for commercial buildings and large developments.

b. Scope of ECBC

ECBC is applicable to commercial building with connected load of greater the 100 kW or a contract demand of greater than 120 kVA. The building typology includes Hospitality, Shopping Complex, Business, Educational, Healthcare and Assembly. Private residential purpose buildings are not covered by this code. **For Indian Railways, ECBC is applicable to all upcoming buildings with connected load of greater than 30 kW. This stricter measures is adopted by Railways as its own policy.**

c. Energy Efficiency Performance Levels

There are three levels of energy efficiency for the building.

- **ECBC Compliant building:** This level of compliance involves adopting the mandatory and prescriptive requirements listed in the ECBC Compliant Building requirements (§4 to §7) or following the provisions of the Whole Building Performance (WBP) Method (§9). ECBC compliant building is a mandatory minimum standard for commercial buildings and is estimated to be 25% better as compared to the Business-as-usual buildings and incremental cost of 0-2%.
- **Energy Conservation Building Code Plus Building (ECBC+ Building):** To achieve this level, buildings must follow the mandatory and prescriptive requirements outlined in the ECBC+ Compliant Building requirements (§4 to §7) or utilize the provisions of the Whole Building Performance (WBP) Method (§9). ECBC+ compliant building is a voluntary minimum standard for commercial buildings and is estimated to be 35% better as compared to the business-as-usual buildings with incremental cost of 1-4%.

- **Super Energy Conservation Building Code Building (Super ECBC Building):** The most stringent level of compliance, Super ECBC Buildings, require adherence to the mandatory and prescriptive requirements detailed in the Super ECBC Compliant Building requirements (§4 to §7) or following the provisions of the Whole Building Performance (WBP) Method (§9). SuperECBC compliant building is a voluntary minimum standard for commercial buildings and is estimated to be 50% better as compared to the business-as-usual buildings with incremental cost of 3-5%. It is also estimated that the incremental cost of the building is justified by a payback period of 1-4 years.

d. Code provisions: The provisions of this code apply to

- Building envelope,
- Mechanical systems and equipment, including heating, ventilating, and air conditioning, service hot water heating,
- Interior and exterior lighting, and
- Electrical power and motors, and renewable energy systems.

The provisions of this code do not apply to plug loads, and equipment and parts of buildings that use energy for manufacturing processes, unless otherwise specified in the Code.

For the purpose of this book, we will be looking specifically into key provisions for building envelope.

6.4.2 Summary of Eco-Niwas Samhita (ENS)

a. Objective of ENS

Eco-Niwas Samhita is a set of energy efficiency building codes and guidelines introduced by the Bureau of Energy Efficiency (BEE) in India. The primary objective of Eco-Niwas Samhita is to promote energy efficiency and sustainable building practices in residential construction.

b. Scope of ENS

Eco-Niwas Samhita (ENS) applies to buildings intended for regular residential use, providing sleeping accommodations, with or without cooking or dining facilities, on plots of land equal to

or greater than 500m2. It also covers the residential portions of mixed-use buildings on plots of the same size. However, it does not pertain to lodging, dormitories, or hotels.

c. Code provision: The provisions of this code apply to

- Building Envelope
- Building Services
- Indoor Electrical End-Use

Under Building Envelope, there are following provisions:

- Openable Window to Floor Area Ratio
- Visible Light Transmission
- Thermal Transmittance of Roof
- Residential Envelope Transmittance Value for Building Envelope (Except Roof) for four Climate Zones, namely, Composite Climate, Hot-Dry Climate, Warm-Humid Climate, and Temperature Climate
- Thermal Transmittance of Building Envelop (Except Roof) for Cold Climate

d. Compliance approach

The Eco-Niwas Samhita (ENS) has been designed to be user-friendly and doesn't require complex calculations or simulation software. It's intended for architects and engineers. If a building project includes multiple blocks, each block needs to follow the code, but if the blocks are identical and face the same way, compliance can be demonstrated for just one block. To comply with the code, a building must meet all the mandatory requirements and follow one of two approaches:

- **Prescriptive Approach:** This means the building has to meet all the mandatory requirements in Chapter 4 of ENS Part II and also follow all the specific guidelines outlined in Chapter 5 of ENS Part II.
- **Points-Based System Approach:** In this method, the building must adhere to all the mandatory requirements listed in Chapter

4 of ENS Part II. Compliance is achieved by earning points based on various energy-efficient features and practices outlined in Chapter 6 of ENS Part II.

6.5 Requirements oF ECBC

It gives the summary of mandatory and prescriptive requirement.

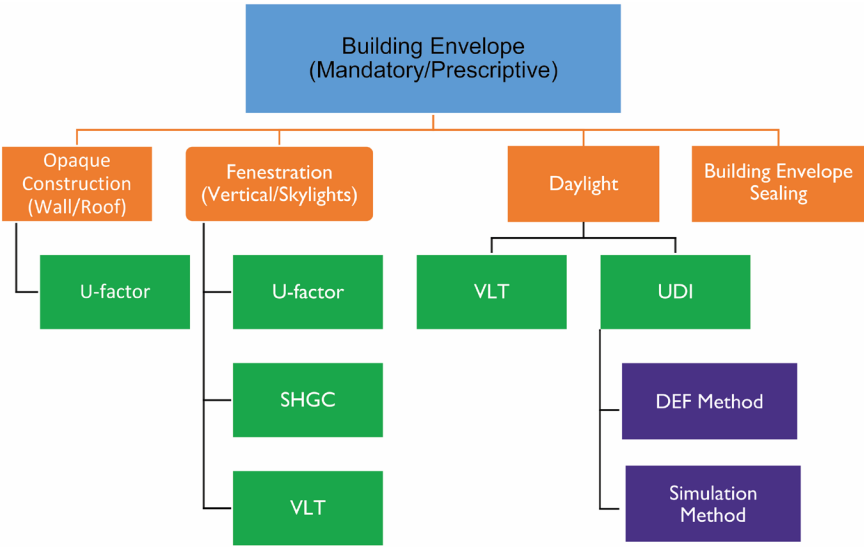


Fig 6.10: The building envelope components and their parameters

6.6 Opaque Construction Requirements

6.6.1 Mandatory Requirements

- U-factors shall be calculated for the opaque construction in accordance with ISO-6946.
- Solar reflectance for the external opaque roof construction shall be determined in accordance with ASTM E903-96 by an accredited independent laboratory, and labeled or certified by the manufacturer.
- Emittance for the external opaque roof construction shall be determined in accordance with ASTM E408-71 (RA 1996) by an accredited independent laboratory, and labeled or certified by the manufacturer.

6.6.2 Prescriptive Requirements

a. Roof

Roofs shall comply with the SuperECBC requirements. The roof insulation shall be applied externally as part of the roof assembly and not as a part of false ceiling.

Table 6.1
Table showing U-factor Roof Assembly U-factor (W/m2.K) Requirements for Super ECBC Building

Climate	Composite	Hot and dry	Warm and humid	Temperate	Cold
All building types	0.20	0.20	0.20	0.20	0.20

Vegetated and cool roof

All roofs that are not covered by solar photovoltaics, or solar hot water, or any other renewable energy system, or utilities and services that render it unsuitable for the purpose, shall be either cool roofs or vegetated roofs.

- (For qualifying as a cool roof, roofs with slopes less than 20° shall have an initial solar reflectance of no less than 0.70 and an initial emittance no less than 0.75. Solar reflectance shall be determined in accordance with ASTM E903-96 and emittance shall be determined in accordance with ASTM E408-71 (RA 1996).
- For qualifying as a vegetated roof, roof areas shall be covered by living vegetation of >50 mm high.

b. Wall

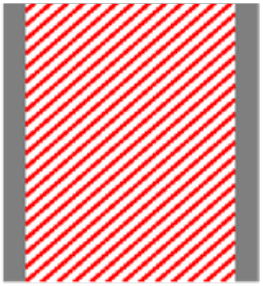
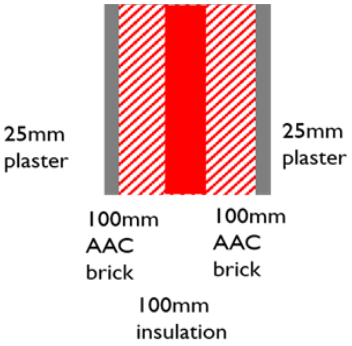
Opaque above grade external walls shall comply with the SuperECBC requirements.

Table 6.2
Table showing Opaque Assembly Maximum U-factor (W/m2.K) Requirements for Super ECBC Building

Climate	Composite	Hot and dry	Warm and humid	Temperate	Cold
All building types	0.22	0.22	0.22	0.22	0.22

6.6.3 Example

Table 6.3
Table showing example of a SuperECBC compliant and a non-compliant wall assembly

Non-compliant wall assembly	Complaint wall assembly
If there's a standard brick wall with cement plaster on either side. U-value will be 1.7 W/m2.K  This does not comply with Super ECBC requirements in any climate	So, what can be done? Consider adding insulation, and, change from brick wall to AAC block wall.  U-value is now 0.22 W/m2.K This wall assembly now complies with the Super ECBC requirements

6.7 Fenestrations

6.7.1 Mandatory requirements

- U-factors shall be determined for the overall fenestration product (including the sash and frame) in accordance with ISO-15099 by an accredited independent laboratory, and labeled or certified by the manufacturer.
- SHGC shall be determined for the overall single or multi glazed fenestration product (including the sash and frame) in accordance with ISO-15099 by an accredited independent laboratory, and labeled or certified by the manufacturer.
- Visible light transmittance (VLT) shall be determined for the fenestration product in
- accordance with ISO-15099 by an accredited independent laboratory, and labeled or certified by the manufacturer.

6.7.2 Prescriptive requirements

a. Vertical Fenestrations

- For all climatic zones, vertical fenestration compliance requirements for all three energy efficiency levels, i.e., ECBC, ECBC+, and Super ECBC, shall comply with the following:
- Maximum allowable Window Wall Ratio (WWR) is 40% (applicable to buildings showing compliance using the Prescriptive Method, including Building Envelope Trade-off Method)
- Minimum allowable Visible light transmittance (VLT) is 0.27
- Assembly U-factor shall be determined for the overall fenestration product (including the sash and frame)

Vertical fenestration shall comply with the maximum Solar Heat Gain Coefficient (SHGC) and U-factor requirements of Super ECBC buildings.

Table 6.4 Vertical Fenestration U-factor and SHGC Requirements for Super ECBC buildings

	Composite	Hot and dry	Warm and humid	Temperate	Cold
Maximum U-factor (W/m2K)	2.20	2.20	2.20	3.00	1.80
Maximum SHGC Non-North	0.25	0.25	0.25	0.25	0.62
Maximum SHGC North for latitude ≥ 15°N	0.50	0.50	0.50	0.50	0.62
Maximum SHGC North for latitude < 15°N	0.25	0.25	0.25	0.25	0.62

Exceptions to SHGC requirements:

I. Vertical fenestration, located such that its bottom is more than 2.2 m above the level of the floor, is exempt from the SHGC requirements in Table 6.4, if the following conditions are complied with:

   a. The Total Effective Aperture (WWR X VLT) for the elevation is less than 0.25, including all fenestration areas more than 1.0 meter above the floor level; and,

   b. An interior light shelf is provided at the bottom of this fenestration area, with a projection factor on interior side not less than:

      i. 1.0 for E-W, SE, SW, NE, and NW orientations

ii. 0.50 for S orientation, and

iii. 0.35 for N orientation when latitude is less than 15°N.

II. Vertical fenestration on all unconditioned buildings or unconditioned spaces may have a maximum U-factor of 5 W/m2.K provided they comply with all conditions mentioned in following Table.

Table 6.5

Table showing Maximum SHGC, Minimum VLT and PF requirements for unconditioned buildings or unconditioned spaces.

Building type	Climate zone	Orientation	Maximum Effective SHGC	Minimum VLT	PF
Unconditioned buildings or unconditioned spaces	All except cold	Non-North for all latitudes and North for latitude <15°N	0.27	0.27	≥0.40
		North for latitude ≥15°N	0.27	0.27	≥0.0

Skylights:

Skylights shall comply with the maximum U-factor and maximum SHGC requirements of Table 6.6. Skylight roof ratio (SRR), defined as the ratio of the total skylight area of the roof, measured to the outside of the frame, to the gross exterior roof area, is limited to a maximum of 5% for Super ECBC Building, when using the Prescriptive Method for compliance.

Table 6.6

Skylight U-factor (W/m2.K) and SHGC Requirements

Climate	Maximum U-factor	Maximum SHGC
All climatic zones	4.25	0.35

6.8 Building Envelope Sealing

6.8.1 Mandatory requirements

Following areas of the building envelope, of all except naturally ventilated buildings or spaces, shall be sealed, caulked, gasketed, or weather-stripped:

- Joints around fenestration, skylights, and door frames
- Openings between walls and foundations, and between walls and roof, and wall panels
- Openings at penetrations of utility services through roofs, walls, and floors
- Site-built fenestration and doors
- Building assemblies used as ducts or plenums
- All other openings in the building envelope
- Exhaust fans shall be fitted with a sealing device such as a self-closing damper
- Operable fenestration should be constructed to eliminate air leakages from fenestration frame and shutter frame

6.8.2 Prescriptive requirements

There are no prescriptive requirements for this section.

6.8.3 Example

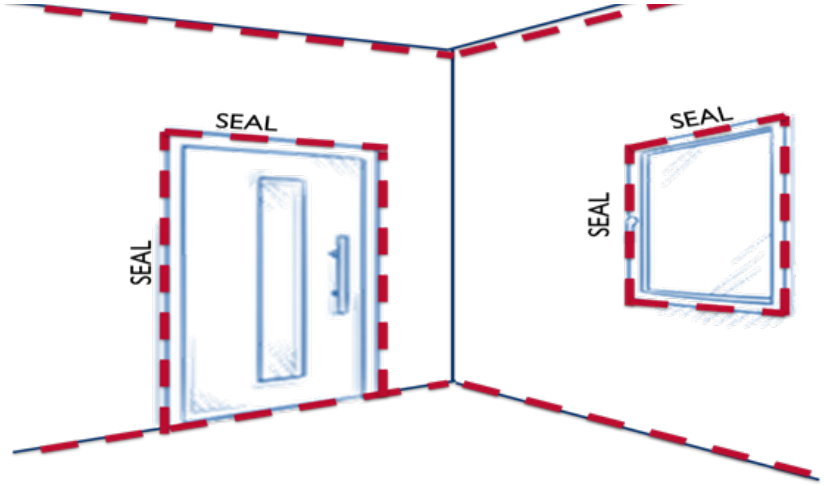


Fig 6.11: Application of foam tape on door to prevent air leakage

6.9 Daylight

6.9.1 Mandatory requirements

- Above grade floor areas shall meet or exceed the useful daylight illuminance (UDI) area requirements listed in following table for 90% of the potential daylit time in a year.
- Compliance shall be demonstrated either through daylighting simulation method or the manual method.
- Assembly buildings and other buildings where daylighting will interfere with the functions or processes of 50% (or more) of the building floor area, are exempted from meeting the requirements listed in the following table.

Table 6.7
Daylight requirements

Building Category	Percentage of above grade floor area meeting the UDI requirement for 90% of the potential daylit time in a year		
	ECBC	ECBC+	Super ECBC
Business Educational	40%	50%	60%
No Star Hotel Star Hotel Healthcare	30%	40%	50%
Resort	45%	55%	65%
Shopping Complex	10%	15%	20%
Assembly (Railway stations are under assembly category)	Exempted		

6.9.2 Prescriptive requirements

There are no prescriptive requirements for this section.

6.9.3 Example

Useful Daylight Illuminance (UDI) is defined as the annual occurrence of daylight between 100 lux to 2,000 lux on a work plane. This daylight is most useful to occupants, glare free and when available, eliminates the need for artificial lighting.

Daylight extent factor provides a ratio of window sizes to floor area receiving UDI in accordance to window orientation.

Calculating Useful Daylight Illuminance (UDI) :

An office building located in New Delhi, India is pursuing ECBC compliance. Table 14 lists the minimum daylight area requirements for compliance. The table specifies that for all buildings more than 3 stories above the ground other than resorts and shopping malls,

minimum 40% of its floor area shall receive daylight in range of 100 – 2,000 lux for at least 90% of the year.

This typical floor has a rectangular layout (33 m x 38 m) of 1,254 m2. Visible light transmission (VLT) of glazing in all orientations is 0.39. Windows in regularly occupied spaces have light shelves and external shading devices with Projection Factor (PF) ≥ 0.4. Head height of fenestrations is 3.0 m.

For compliance at least 502 m2 (40% of 1,254 m2) of floor area shall fulfil the UDI requirements. Daylit area should be indicated in floor plans submitted to code enforcement authorities. Design guidelines on daylighting stated in NBC (Part 8: Building Services, Section 1: Lighting and Natural Ventilation, Subsection 4.2: Daylighting) should also be referred to achieve the ECBC, ECBC+, or Super ECBC requirement.

Compliance with Daylight Requirements can be checked for through two approaches.

a. Analysis through software

If the whole building performance approach is used, compliance for daylighting requirements can be checked by analysing the façade and floor plate design in an analytical software approved by BEE. The image below, developed through an approved software, specifies the lux levels and time-period of a year during which lighting levels would be available. With this information, designers can check if the required minimum area as per table 6.7 has the required daylight levels.

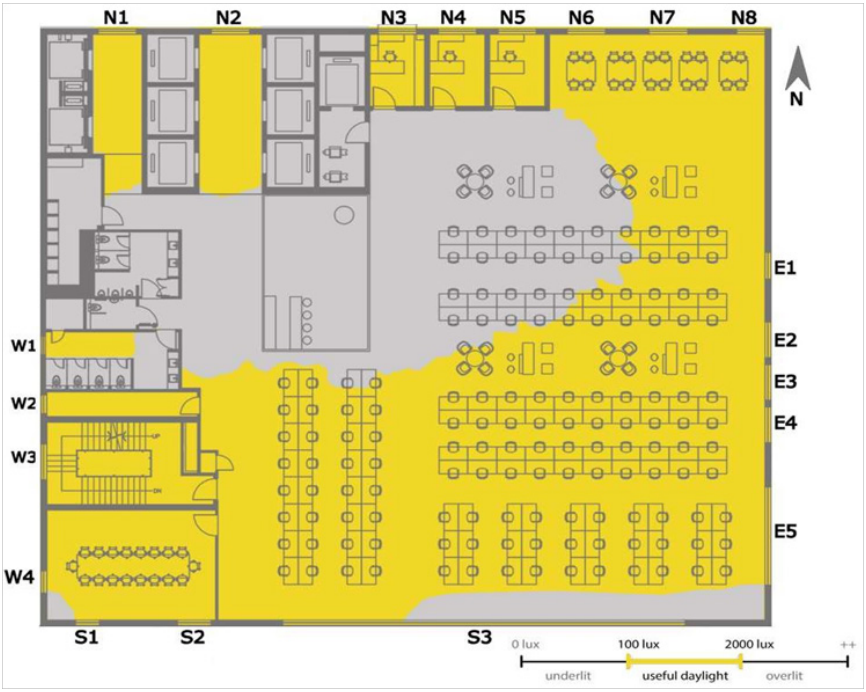


Fig 6.12 : UDI analysis with a Daylighting software

b. Manual calculation method

For projects adopting the prescriptive compliance approach, manual calculation method can be used for UDI compliance.

- Step 1 : From the following table, determine the daylight extent factor (DEF) for each orientation. For a building located in Delhi

(latitude > 15 degrees), with glazing of VLT ≥ 0.39, shading PF ≥0.4 and light shelves in windows, DEFs for windows in North = 3.5, in South = 3.0, in East = 2.1, and in West = 1.8. Head height is 3.0 m.

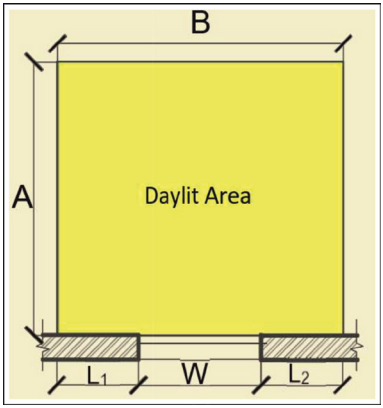
Table 6.8

Daylight Extent Factors (DEF) for manually calculating daylight area

Shading	Latitude	Window Type	VLT < 0.3				VLT ≥ 0.3			
			North	South	East	West	North	South	East	West
No shading or PF < 0.4	≥ 15° N	All window types	2.5	2.0	0.7	0.5	2.8	2.2	1.1	0.7
	< 15° N		2.4	2.0	0.8	0.6	2.7	2.2	1.5	0.8
Shading with PF ≥ 0.4	All latitudes	All window types without light shelf*	2.8	2.3	1.5	1.1	3.0	2.5	1.8	1.5
		All window types with light shelf*	3.0	2.5	1.8	1.6	3.5	3.0	2.1	1.8

* To be considered a light shelf, the part inside the building must meet the required conditions. For checking the required conditions, you can navigate to the "Prescriptive requirements" in section 6.7.2, and within that, pay attention to point I.b, which falls under the sub-section named "Exceptions to SHGC Requirements."

- Step 2: For fenestration clear of any opaque obstructions calculate daylit floor area (AxB).



- A: In the direction perpendicular to the fenestration, daylit area extends to head height of the fenestration multiplied by the daylight extent factor (DEF) or distance till an opaque partition higher than head height of the fenestration, whichever is less.
- B: In the direction parallel to the fenestration daylit area extends a horizontal dimension equal to the width of the fenestration plus either one meter on each side of the aperture or the distance to an opaque partition,orone-halfthedistanceto anadjacentfenestration,whicheveris least.

- Step 3:



Fig 6.13 : UDI Analysis with manual calculations

As per the calculations 616.5 m^2 of floor area will meet the UDI requirements during 90% of the year. This is 49.2 % of the total above grade floor area of 1,254 m^2. Thus, the building floor will comply with UDI requirement. Following Tables shows calculated Daylight Area Meeting UDI Requirement.

Table 6.9n for Day light Area Meeting UDI Requirement

Orientation-**NORTH**,**DEF-3.5**,*Fenestration Head Height H -**3m***				
Window without opaqueobstructions	*Fenestration WidthW (m)*	*A=HxDEF (m)*	*L1+W+ L2 (m) L1 = L2 =1m*	*Area meeting the UDI requirements = AxB(m2)*
N7	2.0	10.5	4.0	42.0
N6	2.0	10.5	4.0	42.0
N2	2.0	10.5	4.0	42.0
Window with opaque obstructions	*Fenestration WidthW (m)*	*A=Distance till parallel Obstruction (m)*	*B=L1+W+L2(m) L1 = L2=Distance toper pendicular Obstructions*	*Area meeting the UDI requirements = AxB(m2)*
N1	2.0	10.5	0.3+2+0.3=2.6	27.3
N3	2.0.	4.0	0.4+2+0.4=2.8	11.2
N4	2.0	4.0	0.4+2+0.4=2.8	11.2
N5	2.0	4.0	0.4+2+0.4=2.8	11.2
N8	1.5	10.5	0+1.5+1.0=2.5	26.3
Day lit area meeting UDI requirement				**213.2**

Orientation-**SOUTH,DEF-3**,*Fenestration Head HeightH-**3m***				
Window without opaque obstructions	*Fenestration WidthW (m)*	*A=HxDEF (m)*	*L1+W+L2(m)* *L1 = L2=1m*	*Area meeting the UDI requirements = AxB(m2)*
S1	1.2	6.2	1.0+1.2+1.0=3.3	20.1
S2	1.7	6.2	1.0+1.7+0.3=3.0	18.6
S3	21.0	9.0	1.0+21.0+1.0=24	216.0
Day lit area meeting UDI requirement				**254.7**

Orientation-**EAST**,**DEF-2.1**,*Fenestration Head Height H -**3m***				
Window without opaque obstructions	*Fenestration WidthW(m)*	*A=HxDEF (m)*	*L1+W+L2(m)* *L1 = L2=1m*	*Area meeting the UDI requirements = AxB(m2)*
E1	1.5	6.3	1.0+1.5+1.0= 3.5	22.1
E5	5.5	6.3	1.0+5.5+1.0= 7.5	47.3
Adjacent fenestration less than two meter apart	*Fenestration WidthW(m)*	*A=HxDEF (m)*	*B=L1+W+L2(m)* *L1,L2=onehal fof distance to* adjacent fenestration	*Area meeting the UDI requirements = AxB(m2)*
E2	2	6.3	1.0+2.0+0.2=3.2	20.2
E3	2	6.3	0.2+2+0.2=2.4	15.1
E4	2	6.3	0.2+2+1=3.2	20.2
Day lit area meeting UDI requirement				**124.9**

Orientation-**WEST**,**DEF-1.8**,*Fenestration Head Height H - **3m***				
Window without opaque obstructions	*Fenestration WidthW(m)*	*A=HxDEF (m)*	*L_1+W+L_2(m) L_1 = L_2=1m*	*Area meeting the UDI requirements = AxB*(m^2)
W3	2.0	5.4	1.0+2.0+1.0=4.0	21.6
W4	1.4	5.4	1.0+1.2+1.0=3.2	17.3
Window with opaque obstructions in daylit area	*Fenestration WidthW(m)*	*A=Hx DEF(m)*	*B=L_1+W+L_2 (m) L_1 = L_2=Distance toperpendicular Obstructions*	*Area meeting the UDI requirements = AxB*(m^2)
W1	1.0	5.4	0.3+1+0.3=1.6	8.6
W2	1.0	5.4	0.3+1+0.3=1.6	8.6
Day lit area meeting UDI requirement				**56.1**

Overlapping area calculations			
Window with overlap areas	*Width(m)*	*Depth(m)*	*Area* (m^2)
N4 and S1	3.3	3.3	10.9
S3 and E5	3.3	6.5	21.5
Overlapping daylight area (b)			**32.4**

Total Daylit area	
ORIENTATION	*Daylit Area* (m^2)
NORTH	213.2
SOUTH	254.7
EAST	124.9
WEST	56.1
Total day light area (a)	648.9
Total Overlapping daylit area (b)	32.4
Total daylit area meeting UDI requirement during 90% of the year (a-b)	**616.5**

Summary

Summary of ECBC requirements:

Building envelope			
Daylighting	≥ 60%	UDI	Railway stations are exempted
Roof insulation	≤ 0.2	W/m^2K	In all climatic zones
Wall insulation	≤ 0.22	W/m^2K	In all climatic zones
Vertical Fenestration			
Solar Heat Gain Coefficient (SHGC) Non-North	≤ 0.25		In all climatic zones except cold
SHGC North for latitude ≥ 15°N	≤ 0.50		In all climatic zones except cold
SHGC North for latitude ≤ 15°N	≤ 0.25		In all climatic zones except cold
SHGC	≤ 0.62		Cold climate zone
U Value	≤ 2.20	W/m^2K	In composite, Hot and Dry & Warm and Humid
U Value	≤ 3.00	W/m^2K	In Temperate climate zone
U Value	≤ 1.80	W/m^2K	In Cold climate zone
Visual Light Transmittance	≥ 0.27		In all climatic zones
Skylights			
U Value	≤ 4.25	W/m^2K	In all climatic zones
Solar Heat Gain Coefficient	≤ 0.35		In all climatic zones

6.10 INTRODUCTION ABOUT INDIAN RAILWAYS ENERGY EFFICIENCY ACTION PLAN (IREAP)

India has made comprehensive climate commitments to achieve Net Zero Emissions and has set ambitious goals for energy efficiency and reduced carbon intensity of the economy. Aligned with this vision, Indian Railways has set a target of Net Zero Carbon Emission by 2030. Non-Traction end-uses account for over 2,100 GWh of electricity use per year, projected to increase by 30% by 2030 as IR network and infrastructure expands. Achieving the Net Zero Emissions target requires an integrated approach to reducing energy use intensity of existing and future infrastructure along with a shift to renewable energy sources. IR has started work on many of these fronts including energy demand management, shift from diesel to electricity, greening of electricity supply, and offsetting emissions. Lowering of energy consumption by adoption of energy efficient measures would be one of the key measures to achieve this target.

IR has formulated an energy efficiency policy with an action plan comprising of five action points (APs) for reducing energy use in non-traction applications. This policy has been issued by Railway Board vide letter no. 2022/EEM/150/09 dt. 30.12.2022. This policy and the action points are based on an integrated approach of life-cycle carbon reduction strategies, with a scalable implementation approach, and continuous measurement and verification through an online system, along with capacity building of IR officers and staff at all levels. The policy includes provision for online monitoring energy use along with a dashboard for tracking progress of the policy action plan. The policy also addresses the need for training on broad issues of sustainability and carbon reduction, along with specific technical training for energy efficiency.

The energy efficiency strategies are designed for both new and existing buildings, encompassing three primary building types: station buildings, non-residential structures, and residential buildings. Each category includes a list of available measures to implement.

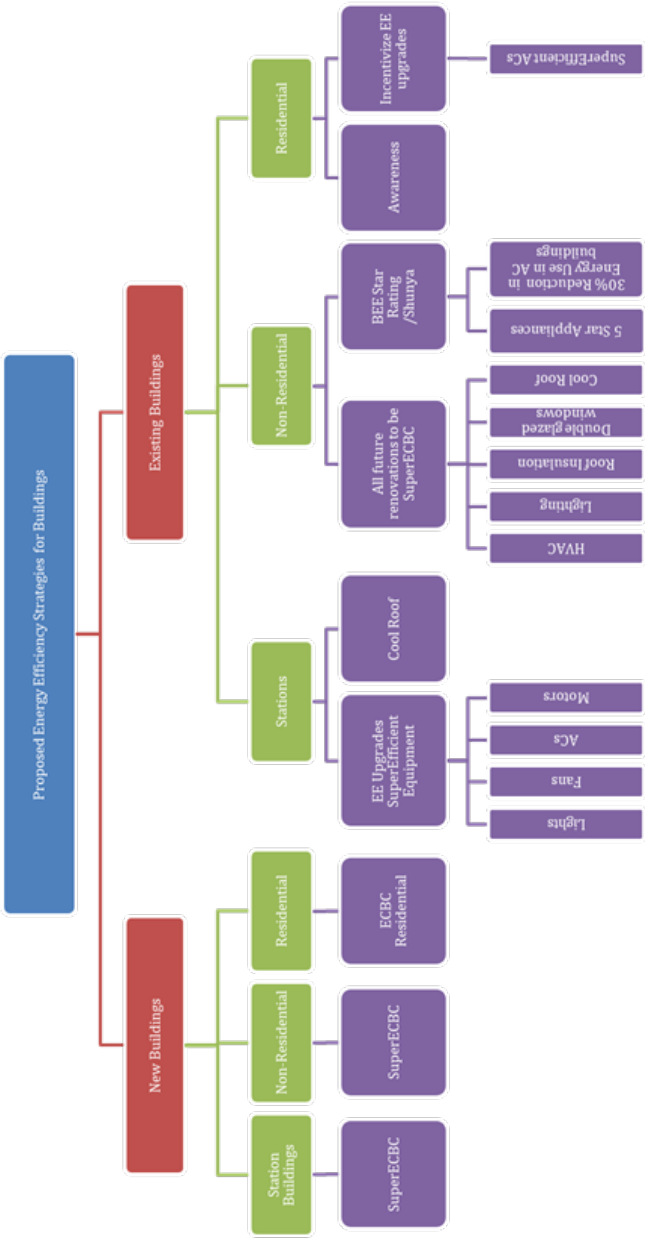


Fig 6.14: Five (5) Action Points of the IREAP Policy

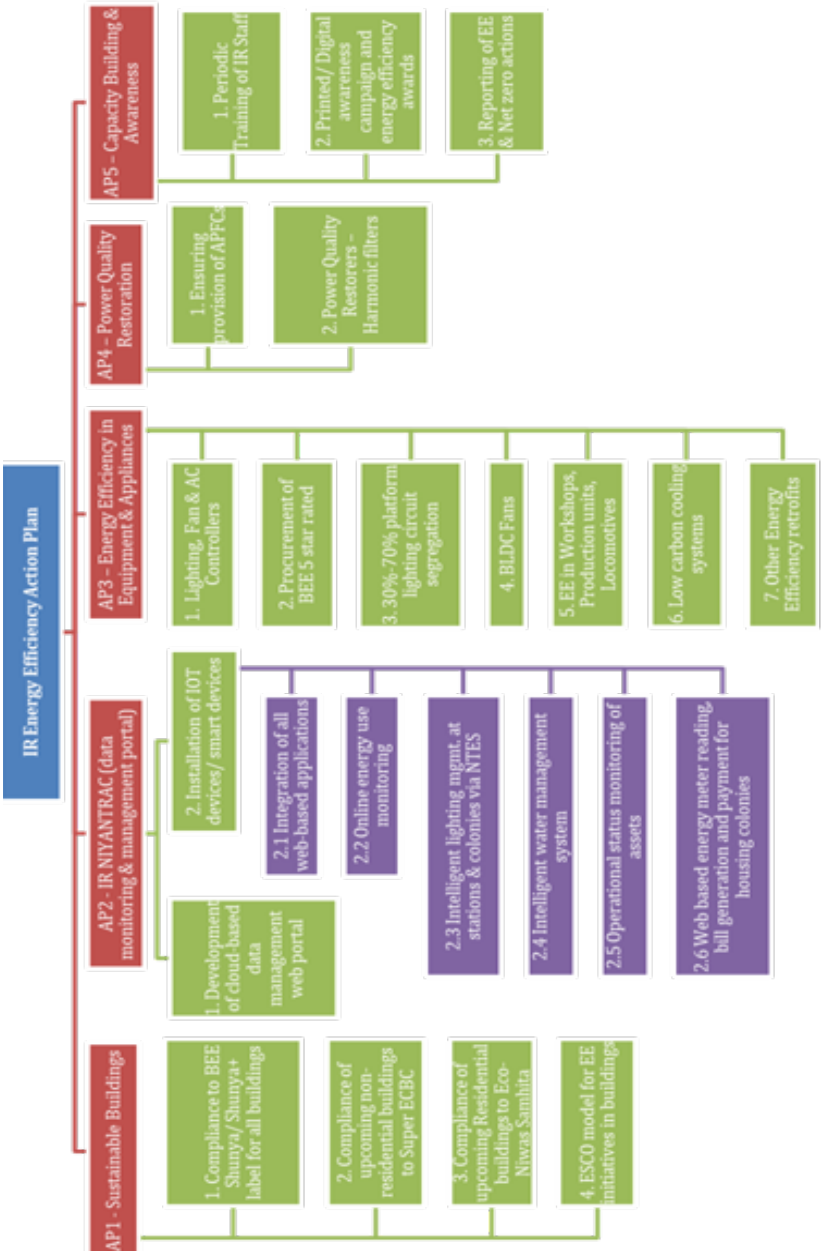


Fig 6.15: Applicability of IREAP's policy on existing and new buildings

6.11 HOW DOES ECBC AND ENS CONNECT TO IREAP

Indian railways is working round the clock to meet the transport needs of the growing India. IR is expanding its infrastructure throughout the country for ensuring trade and public transport even from the remotest part of the country. To enable this expansion, IR is going to build a lot of buildings (stations, offices, hospitals, institutes, running rooms, colonies etc.) in the near future.

IR should ensure these buildings should be designed considering the natural geography of the site. Climate responsive building design concepts like optimum orientation, natural daylighting, natural ventilation (in case of un-conditioned buildings) and efficient building envelope should be integrated in building design. That’s why, building energy codes like ECBC and ENS play a crucial role in Indian Railways' energy efficiency policy by providing specific standards and guidelines for constructing energy-efficient buildings. By adhering to these codes, Indian Railways can reduce the energy consumption of its buildings, which aligns with its broader goal of achieving net-zero carbon emissions by 2030. Following are the key connections.

- ECBC (Energy Conservation Building Code) and ENS (Eco Niwas Samhita) complement the IREAP (Indian Railways Energy Efficiency Action Plan) policy by providing the necessary guidelines and standards to achieve energy efficiency in building-related aspects. These codes offer recommendations for insulation, lighting, heating, cooling, and other aspects of building design and operation.

- IREAP outlines broader objectives for reducing energy consumption, while ECBC focuses on energy conservation in commercial buildings, and ENS addresses residential buildings. This, in turn, contributes to the policy's objective of lowering energy usage in non-traction loads and promoting sustainability in the railway infrastructure.

- These codes align with IREAP's goal of reducing non-traction energy consumption by promoting sustainable construction practices, efficient equipment and appliances, and power quality improvements.

CHAPTER 7

BASICS OF ARCHITECTURE

7.1 Principles of Aesthetics and Its Components:

Aesthetics can be defined as sensitivity to aspects like colour, texture, form, balance, rhythm, composition relief, etc. This sensitivity varies from individual to individual, and because of this variation, we find that not every person can draw or paint well. Certain theories and principles, do however, govern aesthetics. Some of them are listed as below:

7.1.1 Colour

In 1931 A.D., J.E. Le Blon, laid down a theory of colours, which states that all colours are derived from 3 basic colours – Red, Yellow and Blue. These were called primary colours. A mixture of these primary colours leads to the secondary colours – orange, green and purple. It later leads to the tertiary colours – olive, and citron and quarternary colours – buff, sage and slate.

As is common knowledge, white light is composed of seven colours namely VIBGYOR. The colour that is reflected by a particular object after absorbing the other six colours is perceived by humans as the colour of that particular object e.g. when a ray of light falls on a red rose, all the other colours except red are absorbed by the flower, and red is reflected by it. That it why it is perceived to be red in colour.

A combination of various colours leads to colour schemes. Different types of colour schemes are as follows :

1. Achromatic : Use of black and white
2. Monochoromatic : Different values of the same colour
3. High Key : Use of dark colours
4. Low Key : Use of light colours
5. Polychromatic : Use of various colours

6. Analogous : Yellow-Red-Orange
7. Complimentary : Red-Green, Purple-Green-Yellow, (Complimentary)
8. Adjacent : Red-Green-Blue,Red-Green-Yellow (Complimentary)
   Blue-Orange-Yellow
   Blue- Orange-Red.

Colours have a distinct psychological impact on the viewer and directly affects his state of mind, level of calmness and enthusiasm. A few examples are listed down for reference :

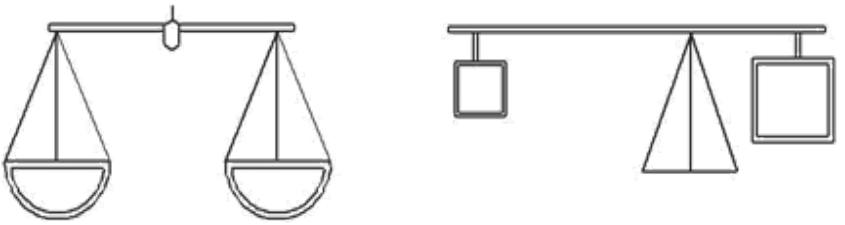
i. Red : Danger, excitement, War, revolution, upsurge
ii. Yellow : Warmth, cheer, a beginning
iii. Blue : Calm, coolness, royalty, seniority
iv. Orange : Fire, stimulus, autumn
v. Green : Life, growth, freshness
vi. Pink : Love, health
vii. Grey : Dullness, indecisiveness
viii. Black : Fear, end, termination, sorrow
ix. White : Purity
x. Brown : Earthiness

A combination of these colours lad to two simple categories of colours, namely the warm and the cool colours (Warm – Red, Orange, Yellow, etc) (Cool – Blue, green, etc.)

7.1.2 Balance

Balance is a quality, which though hard to define comes across very strongly in every composition. it can be categorised as shown in Fig. 7.1.

i) Formal Balance ii) Informal Balance



Formal **Informal**

Fig. 7.1 Balance

Formal balance usually symbolizes symmetry, dignity, unity while informal balance conveys as sense of excitement and unpredictability. For example, a court building is usually symmetrical in plan and elevation, i.e. is formal and thus conveys honesty and fairness. However, an exhibition pavilion is the opposite whereby, by virtue of informal layout and appearance leads to feeling of excitement and enthusiasm amongst the viewers.

7.1.3 Textures :

Textures i.e. the relief of a particular surface, helps highlight, downplay or identify particular elements. This is a quality of the material itself, which can create interesting results when used in composition with other materials e.g. the soft texture of a carpet

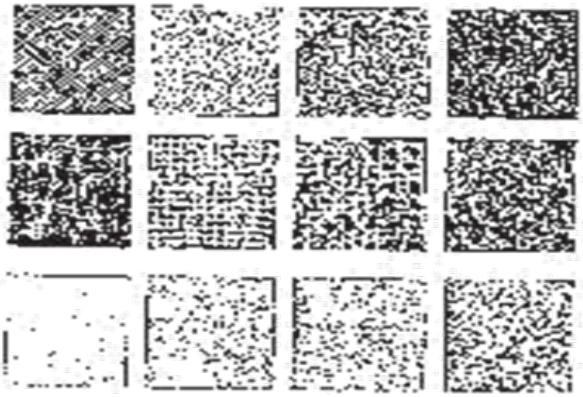


Fig. 7.2 Different Types of Textures

laid on the floor helps an interior of a room by giving it a soft and comfortable look. Different types of textures such as rough, smooth, grainy, undulating, pitted, rubbery, mottled are shown in Fig. 7.2.

7.1.4 Rhythm

Visual flow governing the movement of the eye from one part of a design to another in a particular pattern creates rhythm. Rhythm is a movement created by a regular succession of strong and weak elements in design. Examples are shown in Fig. 7.3 A to C.

i. Repetitive rhythm : e.g. laid out on a grid IRON pattern.

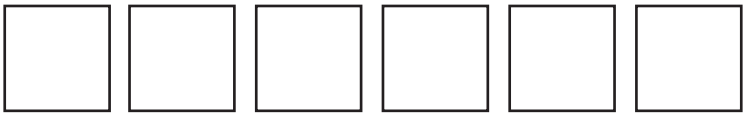


Fig. 7.3 A

ii. Flowing rhythm : e.g. pathways in garden

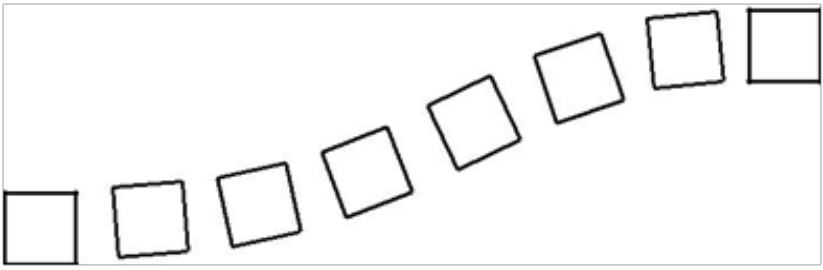


Fig. 7.3 B

iii. Progressive rhythm: e.g. small patterns leading to large ones.



Fig. 7.3 C

7.1.5 Proportions

Proportions can be defined as a comparison of various elements between two or more objects. These elements include physical dimensions, colour, texture and the relationship between the background, middle ground and foreground (i.e. the third dimension). If proportions in a composition are not proper, it is enough to render it useless, irrespective of the other qualities of the composition. ''Vitruvian Man'' is a fine example of proper proportion (Fig. 7.4).

Objects with different elements of aesthetics, when, organized and grouped together form a "composition." All the objects which we see in our day to day life, are thus, three dimensional compositions of different objects.

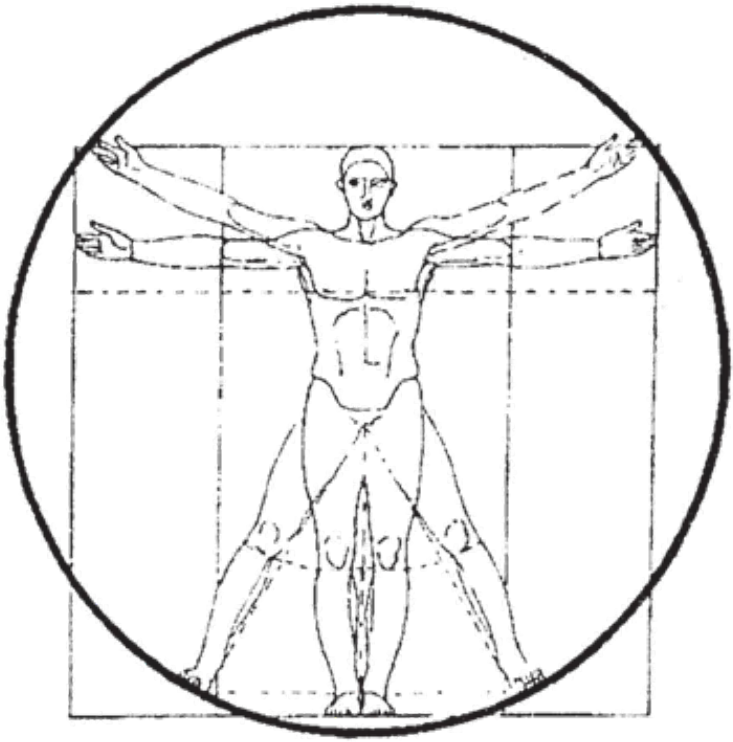


Fig. 7.4 Vitruvian Man

7.2 Form and Function Relationship

This is the guiding principle of design, be it architectural, structural or product design. The function of a particular element or object leads to its basic form and a deviation in this can lead to failure of design.

7.2.1 "Form" in architecture can be defined as thecoming together of similar elements in a symmetrical or asymmetrical manner. Some of the form used frequently are :

7.2.1.1 Grid form :

Whenever modules are arranged at aspecific regular interval, they lead to grid form, e.g. a large factory building laid out on a grid (Refer Fig. 7.5).

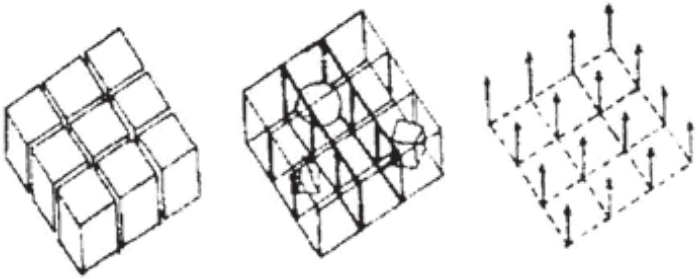


Fig. 7.5 Different Grid Forms

7.2.1.2 Centralised forms :

Grouping of several formswith a central focal point usually lead to centralized forms as shown in Fig. 7.6. Due to their strong central focus, they tend to dominate a composition e.g. a circular dining table with chairs around it.

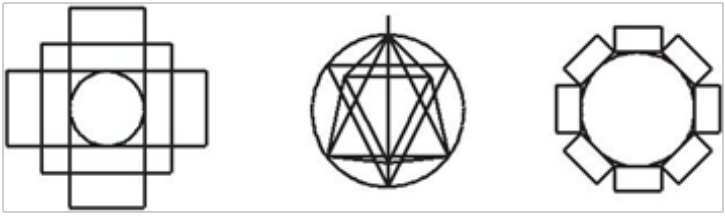


Fig. 7.6 Different Centralized Forms

7.2.1.3 Linear forms :

When elements are aligned alonga central spine and grow or get added only along this spine, a linear form gets evolved e.g. growth of a town along a river, platforms along a railway track (Fig. 7.7).

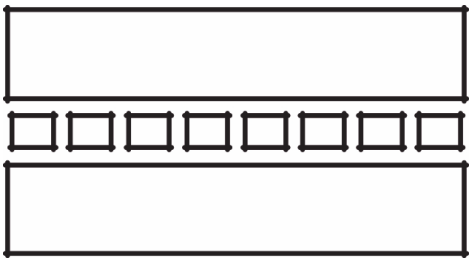


Fig. 7.7 Linear Form

7.2.1.4 Radial form :

Any composition which haselements extending away from a central local point lead to a radiant form, e.g. New Delhi (Fig. 7.8).

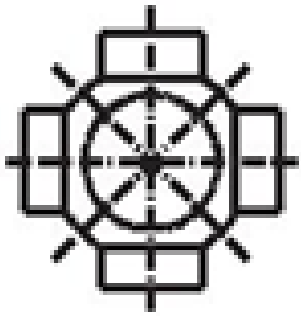


Fig. 7.8 Radial Form

7.2.1.5 Clustered form :

The grouping of elementsasymmetrically, but at the same time, having an inter relationship, lead to cluster, e.g. a cluster of houses in a small village (Fig. 7.9).

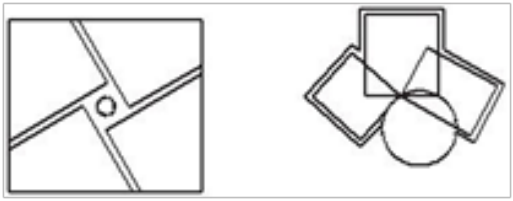
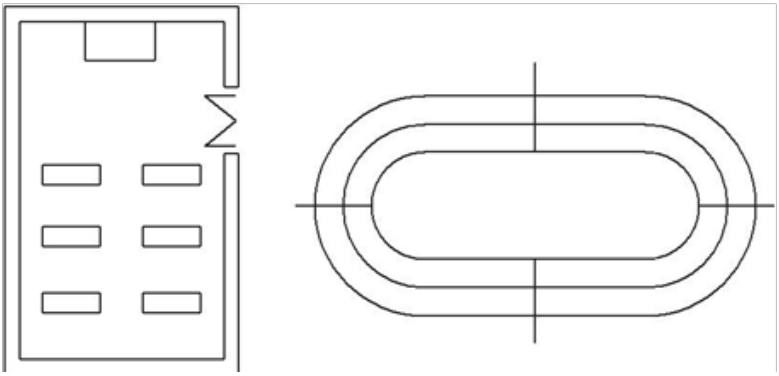


Fig. 7.9 Different Clustered Form

7.2.2 The importance of the "form and function"relationship can be clearly understood by studying some examples.

If we consider a sports stadium, the form of the stadium building, which, in principle, is a centralized form, has seats and tiers arranged around the main ground, spectators and viewers who sit on these tiers, can concentrate on the activity in the center. Also, hundreds of people witness the activity simultaneously. If a deviation was made from this basic form, the function of a stadium would not be achieved and would lead to the failure of the design.



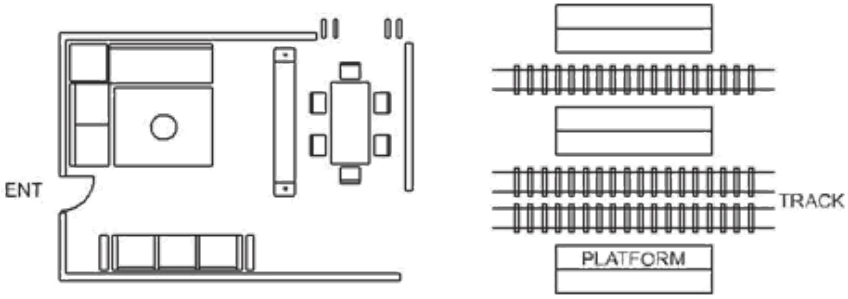
CLASS ROOM **STADIUM**

Fig. 7.10 Differences in form

However, if the same form was to be used for classroom, it would fail as the blackboard would be visible to only those who are directly in front of it. These differences are shown in Fig. 7.10.

Railway platforms have to be aligned parallel to the tracks to enable travellers to access any bogie along the entire length of the train. An attempt to change this form would defeat the purpose as it would not function properly.

This principle guides the designing of all objects, ranging from a hair pin to a large airport (Fig. 7.11)



LIVING CUM DINING ROOM **RAILWAY STATION**

Fig. 7.11 Differences in form

7.3 Anthropometry

This can be defined as the relationship between the human body and movement of the body with things and spaces that it comes in contact with in day to day life. This science is extremely important to all designers, as it is an unchangeable component of any design data. The proportions of a human body are also a part of this study, i.e. the ratio of the height of the torso to the legs.

Dimensions of the static human body and the human body in motion can be classified as :

i. Structural dimensions (Refer Fig. 7.12)

ii. Functional dimensions (Refer Fig. 7.13)

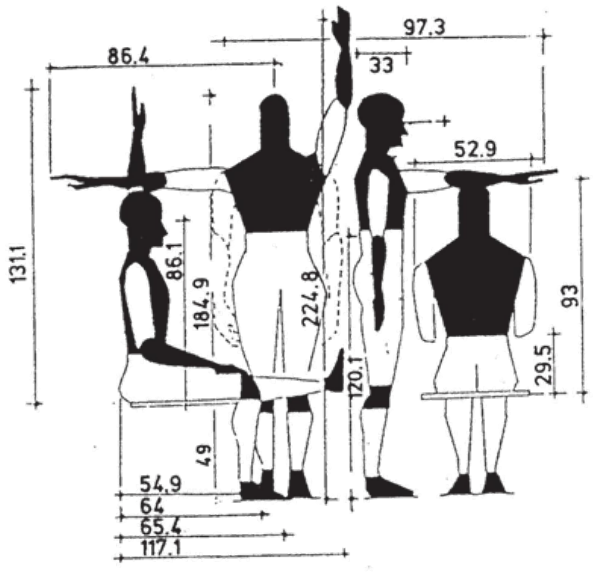


Fig. 7.12 Structural Body Dimensions.

Structural dimensions are static i.e. measurements of the head, torso, limbs, arm length, etc. These are essentially fixed, and based on a large case studies, an average set of measurements is worked out.

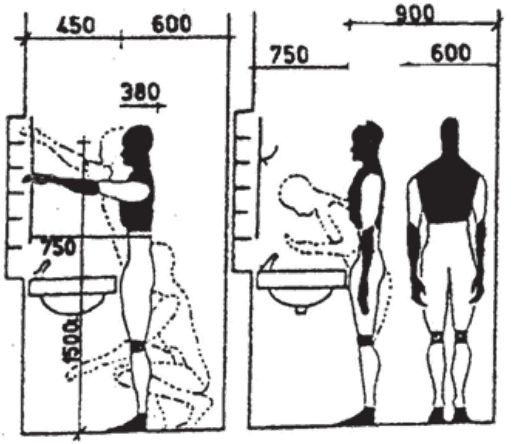


Fig. 7.13 Functional Body Dimensions

Functional dimensions are dynamic are related to the positions and movements of the human body associated with tasks e.g. sitting, climbing, walking, sleeping etc. These become extremely critical in architectural designing, as they determine the standards of comfort while implementing the task.

A variation in any of these can lead to design mistake. If a kitchen platform gets too tall, cooking on it would become extremely difficult. Some important standard functional dimensions are listed in Annexure 7A, at the end of this book for ready reference.

7.4 Building Components

Any structure is a composition of various building components. The components by themselves, are non-functional. However, when composed together, they acquire a value of their own. Each component has to fulfill two aspects, namely functional and aesthetical. A window, for example, is useless unless it is set into a wall of a room. Once placed in a position, it carries out the function of providing light and ventilation to the interior. Along with this, a proportionate and elegant window opening can add to the aesthetical value of that particular elevation.

Basic components include the structural members, walls, ceilings, floors, roofs, etc. while secondary components include windows, doors, weather sheds, porches, pergolas, etc.

7.4.1 Analysis of building components

The analysis of building components forms a very important part in the process of designing and detailing. It can be carried out as follows :

1. Type
2. Function
3. Location
4. Material
5. Aesthetical impact

This can be properly explained by studying an example.

1. The type of component would include the physical attributes like thickness, size etc., i.e. 4 1/2 “, 6”, 9” thick brick masonry or in case of windows, whether it is sliding, pivoted or top hung determines its type.
2. The function of the component determines all the other factors. A 4 ½” thick brick wall is used on external faces as an infill panel whereas 14” thick brick masonry acts as a load bearing wall.
3. The location of the component depends on the function. For example, if windows are placed on the windward sides then the quality of ventilation is satisfactory. Careful attention is required while finalizing their locations.
4. Each component can be cast or fabricated in different materials and the aesthetical value of the structure is determined largely by the material used. Brickwork, stonework, cement blocks, special block, etc. can perform the function of a wall but by virtue of the material used, the external appearance can change.
5. All the above factors help to enhance or lower the visual impact of the component. As seen in Fig. 5.14 below, the offset in the dining room spoils the appearance to a certain extent.

7.4.1.1 Structural Members

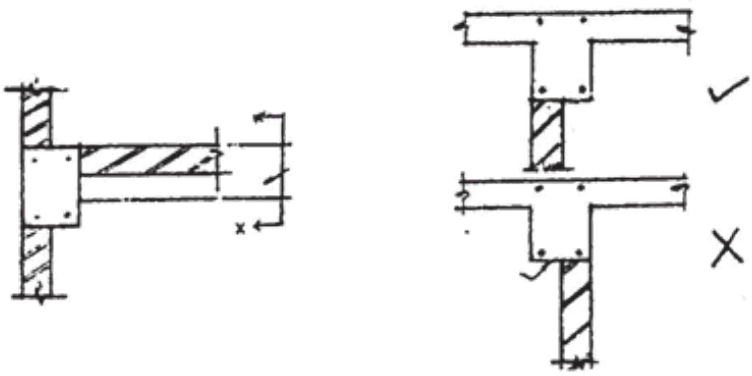


Fig. 7.14 Visual Impact of the Component

Columns of a structure can protrude out to the elevation and can appear highly unsightly. However, these can be highlighted instead and can be used as features, e.g. in factories a rhythm can be established using the same. Structural members create ugly offsets and can spoil the entire interior of a room. Beam offsets result in breaking the continuity of walls. Lintels can create ugly patches on elevations. An effective method to avoid this is by co-relating the structural drawings with architectural drawings prior to construction.

7.4.1.2 Roofs

Various roof forms can be used and different shapes can be explored, like flat slabs, sloping roofs, vaults, domes, pyramids. Flat slabs are generally used in offices, apartment blocks, institutional buildings, etc. Bungalows, cottages, holiday resorts with sloping roofs have their own charm. Entrance foyers of large public building and hotels look impressive if they have high roofs. This just goes to show the different effects which are created by the skillful use of components.

7.4.2 Secondary Building Components

Some of these components are doors, windows, weather sheds, planters and flower boxes, grooves/ mouldings, window grills, entrance steps, porches, patios, sitouts, awnings, terraces, cornices and arches. These are being continuously upgraded and new inventions and building materials lead to an overall change in the elevational values of a building. However, care has to be taken while selection of components and materials as wrong choices can lead to shocking disparity. For example if aluminium sliding windows are used in a structure with Gothic facades, the effects would not be harmonious.

Combination of various building components leads to various elevations and thus to the overall effect. This has lead to different architectural styles being evolved. For example in Gothic structures, ornate facades, moulding in plaster, stained glass windows, false fronts, false columns etc., contributed towards the evolution of surface decoration skills to perfection.

The real skill of a designer lies in the combination of these components in order to create a volume which is interesting in appearance, without compromising on the function.

CHAPTER 8

THE PROFESSIONAL ARCHITECT

8.1 Services Rendered By An Architect

As in all professions, even architecture has its ethics and norms of practice. A qualified architect can practice in the country provided he is a member of the Council of Architecture, which is the central governing body. On completion of his professional studies he is awarded the membership of this Council which enables him to practice anywhere in the country provided he follows the norms laid down by the Council. The duties and functions of an architect are listed below, and the fulfillment of each of these is required for a good design solution. The services rendered by an architecture are as under :

1. Visit to the proposed site to get a feel of the layoff, the land, surroundings, roads, electrical cables, drainage & water lines, existing vegetation, etc. which are likely to affect the site and design.
2. Preparation of conceptual sketch designs based on the requirements given by the client.
3. Preparation of detailed sketches before finalisation.
4. Finalisation of sketch design.
5. Preparation of the submission drawings, etc., to be sent for sanctioning to the various government bodies.
6. Assisting the client in the approval of plans .
7. Preparation of initial estimates based on standard cost guidelines and material specifications.
8. Preparation of detailed working drawings and working details pertaining to civil work.
9. Assisting the client in the appointment of various consulting agencies, if required.

10. Preparation of final estimates based on the final architectural and structural drawings.
11. Explaining the available option regarding the various types of civil contracts and assisting the client in finalisation of the type of contract.
12. Assisting the client in the scrutiny and analysis of tenders.
13. Assisting the client in negotiating the finalisation of the civil contractor.
14. Drafting of agreements between clients and contractors (optional).
15. Supervision on site to ensure quality, speed and trueness of the work and to prevent any deviation from the approved plans.
16. Submission of site visit reports to the client.
17. Checking of bills raised by the civil contractor and certification of the same on behalf of the client.
18. Issuing stage completion certification to the client for submission to financial institution, if required.
19. Preparation of landscape scheme on the completion of the civil work to enhance the working environment and to minimize pollution (optional).
20. Assisting the client in getting the completion certificate for the work from the authorities.

8.2 Additional and Optional Services

1. Obtaining the contour survey of the site from an associate agency.
2. Making a model of the structure/campus.
3. Assisting the client in appointment of structural, landscape, water and sewerage consultants.

8.3 Proposed IRICEN Building - A case study

1. General :

A new administrative building for the Indian Railways Institute of Civil Engineering (IRICEN) is proposed to be constructed in Koregaon Park at Pune. In view of the specialized nature of the job, Railways decided to go in for Architectural and Structural Design Consultancy for the said work. The tender documents, schedule and other details in connection with fixing up the agency for the above work are given below.

2. System of Tendering :

The tender will be in two packet system – Technical & Financial. Two separate envelopes, one for each bid will be prepared and both the bids will be submitted together after putting both the envelopes in one single envelope. The details of each packet are mentioned below :

a) Packet-I (Technical Bid) : For packet-I, the tenderers will be required to submit following documents :

1. Architectural Drawing & Design with plan, elevation and perspective view.
2. Brief report giving important features of drawing, design and other important aspects.
3. The estimated cost of the project based on the design and drawing submitted by the Consultants. (The consultants are required to develop the design/scheme keeping in view the total cost of the project.)

Bidders will be shortlisted on the basis of details furnished by them. If required, bidders may be asked to make presentations.

b) Packet-II (Financial Bid) : Packet-II will be the financial bid based on detailed design and drawing, conceptual plan etc. furnished by the consultants. Packet-II of only the selected bidders, which will comprise of detailed offer for Architectural and Structural design as per Railways schedule, will be opened in their presence about which they will be informed in writing.

3. Submission of Bids :

The tenderers shall be responsible for the proper submission of the bid to the proper authority in time. The tenderers are required to sign each and every page of tender document before submission. It may please be noted that Railways will not be responsible for any postal delay.

4. Eligibility Criteria for Tenderers :

Only those firms, which in their individual capacity satisfy the following criteria need to quote for this tender.

a) Total contract amount received during the last three financial years and in the current financial year should be minimum of 150% of advertised tender value.

b) Should have completed in the last three financial years (i.e. current year and three previous financial years) at least one similar single work, for a minimum value of 35% of advertised tender value.

Note:-

(1) Criterion (a) : Following documents will be relied upon for working out the total contractual amount received by the tenderer to evaluate credientials against criterion (a) above :

1. Attested copies of Annual Income Tax returns field with Income Tax Department.
2. Attested certificate of the tax deducted at source (TDS certificate)
3. Audited balance sheet duly certified by Chartered Accountant.
4. Attested certificate from Employer/Clients about the contractual payment received for the work done.

(2) Criterion (b) : The word completed would mean having satisfactorily executed the single work of requisite value in the qualifying period specified in criterion (b) above.

Tenderers should submit documentary proof in regard to fulfilling these eligibility criteria along with their offer. The offers of tenderers who do not meet the eligibility criteria as mentioned vide

(a) to (b) above shall not be considered. The tenderers who fail to submit documentary proof along with their offer will, normally, not be considered.

5. Scope of Consultancy Services :

Consultancy is required to be carried out for the following:

1. New administrative building complex including its surroundings.
2. New 10 suite Officers' Rest House.
3. Conversion of part of the existing IRICEN Building to 20 room Officers' Rest House.

With respect to all of the above, the Consultants will be required to carry out the following:

1) Preliminary Concept Design :

The Consultant shall :

a) Furnish a preliminary report bringing out Consultant's visualization of the project, the design proposal highlighting how it addresses the various issues discussed in the prelude/ introduction section of this document and also site evaluation and analysis with basic approach to circulation, activity, distribution and interaction and external linkage.

Note : The report should not be in more than 10 pages.

b) Prepare site plan (layout plan) showing contours, features and services and facilities available, general layout of buildings and services, preliminary sketch and design with drawing, giving details of useful areas, services areas, circulation area and total plinth area to provide information in respect of magnitude of work and its component and service. The Consultant should submit the design and modify it if considered necessary by the Railways. Site inspections for finalisation of above details shall be conducted by the Consultant at their own cost.

c) Obtain the approval of the Employer to (b) above and supply 6 copies of approved site plan (Layout Plan).

Note : The layout plan shall be a dimensioned plan.

2) Master Plan :

a) Furnish a detailed report bringing out Consultant's visualization of the project, the design proposal highlighting how it addresses the various issues discussed in the prelude/introduction section of this document and also site evaluation and analysis with basic approach to circulation, activity, distribution and interaction and external linkage.

The narrative report will specifically mention if the proposal would need approval from Municipality or any other authority.

b) Furnish preliminary report on environmental impact of the project if required and finalize it after discussion with the Railways clearly outlining the measures required for mitigating the adverse impact.

c) Prepare Master Plan showing planning for all internal and external utility services like water supply, sewerage, storm water drainage, electrical, HVAC (Heating, Ventilation and Air-conditioning) Fire Alarm & Fire-fighting appliances, accoustics, telephone conduit, street/compound lighting, landscaping, development plans showing roads, paths, parks, paved areas, drains, culverts, compound walls, external lighting, interior design and graphic signage, security system, telecommunication system etc. indicating scope, specifications and costs separately of such sub-head. The scope of work shall be as defined above, however, the employer reserves the right to exclude any of the above services from the scope of the Consultant's work.
Proposed structures in appearance should be aesthetically appealing and matching with the cultural heritage of local area. The elevations will normally show the treatment given to the Exterior surfaces all round as well as other details viz. Doors, Windows, Openings, Balconies, Arches, Canopys, Projections, etc. along with the colour schemes. The plan will also show type of Floor, Wall Treatment, Staircase including & railings, provision for Water supply, Sanitary, drainage including type and location of fittings and fixtures; the type and locations of Electrical wiring, Fittings and Fixtures. The specifications of material proposed to be used, will be given, if not covered by standard

specifications of Central Railway. The complete inventory of all fittings and fixtures will be given.Architectural features should not be unduly complicated to cause any problem in execution.

d) Obtain approval of the Railways to (c) above.

e) Architect will submit abstract or preliminary estimate on plinth area rates basis of the works proposed in the Master plan. The estimate will be supported with details of area/size and rates adopted. The approximate cost of the work is Rs.3.84 Crores. The architect is expected to submit the proposals, execution of which will cost around Rs.3.84 Crores.

f) Obtain the approval of the Railways to (e) above.

g) Submit the proposal to local body complete as per requirement of local bodies including preparation of Model/ Presentation of Model etc. if any.

h) Obtain the approval of layout plan & drawing from the competent authority and statutory body, if necessary, according to the local Acts, Laws, Regulations etc. and make any changes desired by such authorities. The approved/modified layout plan and drawings are to be submitted to Railways.

i) Submit program of work assigned to them, up to the stage of tender document.

j) Submission requirement:

1. Detailed report in bound booklet of A-4 size.
2. A diagram of the general functional arrangements as designed, showing the distribution of activities at different levels.
3. Summary schedule of usable and gross areas expressed in the metric system.
4. Drawings:
    1. Lay-out drawing on a 1:5000 scale shall indicate the lay-out of propose building with the extg. Buildings, urban form and necessary infrastructure and area details as per Railways requirements along with corresponding sections.

It should also indicate the landscaping, types of plantations etc. in and around the proposed building. It should also indicate the parking arrangements.

2. Detail drawing on a scale of 1:400 of the administrative building.
3. The conceptual details and sketches of various modules.
4. The plans for circulating area showing the dimensions and layout of circulating area with arrangements for Drainage; Entry, Exit and Parking for Vehicles; Garden, Flower beds, Trees; External Lighting; Footpaths, etc. and Landscaping in general.
5. Three dimensional Illustrations : As may be felt necessary by the Architect.
6. CD of proposal : The entire proposal should also be submitted on CD should be in "dwg" format, readable in AutoCad release 14.
7. MODEL: A building model including the campus at a scale l:500. The architects are free to give perspective drawings etc. explaining their proposal in detail in addition to building model. It will show the proposed building and the surrounding area including circulating area, parking and approaches. It should be sturdy enough to withstand shifting for display purposes.

k) Number of copies of drawings:

The Consultant shall supply to the Railway a minimum of 6 (Six) copies of plans at each stage along with original tracings with cross sections, front and side elevation to explain in details and soft copy on CD.

I) Alterations in drawings :

The Consultant shall not make any deviations, alterations, additions or omissions from the approved drawing without the knowledge and prior written consent of the Railways. In case of any change required due to site conditions, Consultant will supply

modified plans to the extent necessitated without any additional charges.

3) Detailed estimate, working drawings and schedule of rates and quantities stage :

The preparation of detailed working drawings incorporating services and schedule of quantities.

a) Preparation of working and detailed architectural and structural drawings and detailed estimate as per Railways norms for civil, electrical and telecom works, for all items of the above work, including internal and external utility services, along with details of quantities (Bill of quantities), supporting calculations and details of structural design for whole of the work to facilitate call of tender.

   For items not covered by the schedule of rates the Consultant would provide detailed specifications, description of the item and market rates. Railways will work out the analysis of rates and modify the cost of individual items, if required in consultation with the Consultant.

b) Obtaining approval of Railway to the above and modify them if considered necessary by the Railways and/ or if the cost exceeds the approved preliminary cost by over 5%.

c) Obtain the approval of the Railways to (a) & (b) above and to all computations of all structural designs and all services designs which shall be in accordance with the latest IRS/IS codes of practice. Such detailed computations of all designs shall be made available to the Railways for any check and approval the employer may like to exercise, before sanction detailed estimates and call of tenders. The Consultant shall indicate the names of his Associates, if any, for various services and structural designs, their organizational affiliation, qualifications and experience and shall be fully responsible for the correctness and accuracy of structural and service designs and the responsibility for safety of the structure shall be entirely that of the Consultant, notwithstanding the approval by the Railways of these designs. The Consultant and their associates, if any, shall certify in

writing that the designs are in accordance with the up to date and relevant codes of practice.

d) Obtaining approval of local authorities, if any, and make changes required by them.

e) All the structural designs and drawings shall be got proof checked by IIT Mumbai/VJTI Mumbai/Govt. College of Engg. Pune at consultant's cost for which nothing extra will be payable.

f) Supply to the Railways eight copies of the detailed working drawings, specifications (Bill of quantities) and detailed estimates etc. free of charge for use during execution of work.

g) While designing the structures, relevant IS codes and supporting specifications of Central Railway, wherever applicable will be considered. All the working drawings should show the dimensions of beams, columns, slabs as well as reinforcements, etc. in metric units. Detailed estimate will be prepared taking into account prevailing market rate of labour and material and overhead expenses. This will also include the price list of all the fittings and fixtures as well as of any special material or workmanship proposed by the architect.

4) Construction Stage:

a) Supply to the Employer such further drawings, specifications or details which may be required for proper execution of work.

b) Obtain Employer's approval for any material deviation in design, cost, working drawings, schedule and specifications from the approved scheme.

c) SITE VISITS : The architect will be required to visit the site of work during execution(construction) which may start within 6 months of approval of detailed drawings and may continue for one and half year or so. During this period, services of architect may be required to visit the site of work to clarify any decision or interpretation of the drawings and specifications that may be necessary and attend conferences and meetings as and when required, After each site visit the architect should confirm that the work is being executed as per drawings & specifications and

deviations if any shall be brought to the notice of Employer. The architect may also offer suggestions, to improve appearances and workmanship or/and offer necessary guidance in executing the work as per approved architectural drawings. The payment shall be made on pro-rata basis per visit.

5) Completion Stage:

a) Obtain completion and occupations certificates, wherever necessary from the local bodies, after, completion of work and inspection by Municipal/Fire/Electrical Inspectors and supply the same to the Employer. For this purpose any assistance required from the employer will be extended to Consultant. Any fee payable to local bodies for issue of completion certificate shall be borne by the employer.

b) Prepare completion drawings, including 1:100 scale plans, elevations and cross sections etc. indicating the details of the building and all internal and external services as completed and supply 4 sets of completion drawings to the Employer and also hand over the original of the completion drawings to the Employer. The changes, if any, during the execution of work will be intimated by the employer to the Consultant for preparation of above drawings.

c) Assist the employer in Arbitration/Litigation case that may arise out of the contract entered into, in respect of above work, regarding clarifications/interpretations, supply of drawings, designs, specifications as and when required. The Consultant's role will be limited to these clarifications only and unless specifically required by Arbitrator/Court, he shall not be required to participate in actual Arbitration/ Litigation.

6) Payment Schedule :

The estimated cost of the work as mentioned above is Rs.384 lakhs. The consultant is required to quote his offer on lumpsum basis taking into account the items of work/consultancy required as listed in the tender documents viz. para 1 to 5 above and other terms and conditions. However, after acceptance of offer, the payment for individual item/activity shall be released as a

percentage of accepted offer value according to following schedule:

The fees for the Architectural consultancy for the above project will remain unchanged even if the total cost of the project increases subsequently. The fee includes the cost of providing local representative for day to day liaisoning during the designing and executing the project and travel expenses towards periodical supervision by the Architects, Engineers and other technical persons. All taxes are to be borne by the architect.

Description of item/activity	Payment as a percentage of accepted offer
On submission of conceptual drawings thereof and reports and the approval by the Railways.	10%
On submission of Master plans, all 20%architectural drawings and detailed drawings (excluding those related to structural design) with abstract Estimate and approval thereof.	20%
On submission of model.	10%
On obtaining necessary clearance from local bodies, if required.	10%
On submission of detailed designs duly proof checked by IIT,Mumbai/VJTI, Mumbai/Govt. Engg. College, Pune, working drawings.	7.5%
On approval of detailed designs duly proof checked by IIT, Mumbai/VJTI,Mumbai/Govt. Engg., College,Pune,working drawings.	7.5%
On submission and sanction thereof by the Competent authority of the detailed estimate.	10%
On submission and approval thereof by the Railways, of the Schedule of Rates and quantities and Rate analyses.	15%
For conducting site visits	10%

7) Completion Period :

The entire work is to be completed within 6 months. The time schedule for submission of various plans by the Architect is as under :

i)	Date of issue of acceptance letter.	D
ii)	Submission of conceptual plans after issue of acceptance letter.	D+15
iii)	Approval of conceptual plan after receipt of the same.	D+30
iv)	Submission of master plan and abstract estimate after approval of conceptual drawings.	D+45
v)	Approval of master plan.	D+60
vi)	Submission of detailed architectural plan after approval of master plan.	D+75
vii)	Submission of detailed plans for circulating area after approval of master plan.	D+75
viii)	Obtaining clearance from the local bodies, (If required) after approval of master plan.	D+75
ix)	Approval of detailed architectural plan.	D+90
x)	Approval of detailed plans for circulating area.	D+90
xi)	Submission of Model after approval of Master plan.	D+90
xii)	Submission of detailed estimate after approval of Master Plan.	D+90
xiii)	Submission of schedule of rates and quantities and rate analyses in Railways format, after approval of Master Plan.	D+90
xiv)	Approval of model.	D+105

xv)	Submission of designs and detailed structural drawings duly proof checked by IIT, Mumbai/VJTI,Mumbai/Govt.College of Engg., Pune after approval of detailed architectural plan for the building.	D+120
xvi)	Sanction of detailed estimate	D+120
xvii)	Approval of structural designs and drawings	D+150
xviii)	Miscellaneous activities.	D+180

8. Assessment Criteria for Technical Bids :

The Technical bid of the Architect will generally be assessed on the basis of its ability to meet the requirements outlined in the 'Nature and Scope' section of this document. The assessment will be made on the basis of following broad parameters. Marks allotted against each is also indicated :

i. Functionality : 10

This includes ability of the proposed building to meet the functional requirements as outlined in the introduction section of this document, optimum use of available space, ability to meet emergencies, reduce noise pollution from adjacent tracks and roads etc. and innovative solutions for various services required, etc.

ii. External linkages : 10

This includes its ability to integrate with the existing IRICEN Hostel and the proposed Sports Complex, facilitate quick and organized movement from one to the other and conservation and enhancement of onsite landscape elements, etc.

iii. Energy saving features : 10

This includes maximum use of natural daylight, features such as window sizing and shading, insulation and use of efficient light fittings, use of sensors for lights and air conditioning and maximum use of renewable energy sources, intelligent features for energy conservation etc.

iv. Cost of Construction : 10

This includes ability to meet out all the requirements at least construction cost.

v. Environment friendliness : 10

This includes ability of the design to conserve and improve the environment, conservation of scarce natural resources such as water and energy, efficient methods for rain water harvesting, effluent treatment and water recycling and sufficient green spaces, etc.

vi. Aesthetics : 10

This includes the visual appeal of the building and the surroundings and its ability to integrate with the other structures in the vicinity, etc.

vii. Communication efficiency : 10

This includes the efficiency of communication amongst faculty, between Trainee Officers and faculty, between IRICEN and other departments of the Railways etc. primarily pertaining to telecom and internet facilities by incorporating latest technology in terms of electronic connectivity and convergence of data – voice – video in one single network, etc.

viii. Maintenance free features, provision for future expansion, overall perception etc. : 10

This includes incorporation of such construction/ finishing material which will require least maintenance during its life time, flexibility of addition, expansion and alternative uses required to accommodate growth and wider institutional horizons in the decades ahead, etc. and the ability of the building to qualify as a landmark structure and also its ability to reflect the vision and the values of the Indian Railways.

9. Procedure for selection of Architect :

A 5 member Tender Committee covering all functions i.e. Civil, Electrical, S&T and Finance will evaluate the Technical bids. Conceptual plans, drawings, layout plans and design submitted by Architect will be evaluated by the Tender Committee by allotting marks independently by each member to the details submitted by the tenderer and as outlined above. The evaluation will be done independently. The marks so obtained, as allotted by all the members independently, will be added to obtain the total marks for the tenderer. Based on the total marks obtained, the tenderers will be ranked and financial bids of six firms ranking from first to sixth based on total marks obtained shall be opened.



Annexure 7A

(Para 7.3) STANDARD HEIGHTS/DIMENSION/CLEARANCES FOR FIXTURES FITTINGS/ELEMENTS

Architectural Element/Fitting/Fix	Height /Dimension/ Clearance (cm)
Top of Kitchen platform	80
Minimum clear opening below slab of kitchen platform to accommo date a cooking gas cylinder	68
Top edge of kitchen sink	74
Height of 30 cm wide shelf (to provide full reach upto back of shelf) (Maximum)	150
Lowest shelf in kitchen	50
Front top edge of wash hand basin	85
Top of partitions for urinals	130
Lip of urinal for gentlemen	70
Bottom edge of reflecting surface of mirror fixed behind wash basin	130
Height of Rod of towel rail	90
Bottom of shower rose	200
Height of Stop cock for shower rose	100
Height of Tap in water closet	22
Height of Tap in kitchen ground sink	40
Height of Tap in bathroom	70
Height of Tap in bathroom-if used for taking bath sitting on floor, below the tap	110
Bottom of ceiling fan	260
Top of railing in balcony	90
Top of stair case railing (measured from edge of nosing of steps)	85
Clearance between ceiling fan and ceiling (minimum)	30
Projection of tap in bathroom	20
Projection of shower	50
Distance between centre of W. C. and adjacent wall	45
Min. space in front of W. C.	60