COMPARISON OF 10 STORY BUILDING IN EARTHQUAKE ZONE-I AND ZONE-IV WITH ANALYSIS OF GREEN BUILDING

A

PROJECT REPORT

Submitted in partial fulfillment of the requirements for the award of the degree.

Of

BACHELOR OF TECHNOLOGY

IN

CIVIL ENGINEERING

Under the supervision

Of

Dr. ASHOK KUMAR GUPTA

(Head of Department Civil Engineering) and

Mr. CHANDRAPAL GAUTAM

(Assistant Professor Grade-II, Co-guide)

By

GUNJAN CHAUHAN (171610) and

TSHECHIK DEMA (171679)

To

JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY

WAKNAGHAT, SOLAN – 173234

HIMACHAL PRADESH, INDIA

MAY 17-2021

STUDENT'S DECLARATION

I hereby declare that the work presented in the Project report entitled **"COMPARISON OF 10 STORY BUILDING CONSTRUCTED FOR EARTHQUAKE ZONE-4 V/S ZONE-1 WITH THE ANALYSIS OF GREEN BUILDING"** submitted for partial fulfillment of the requirements for the degree of Bachelor of Technology in Civil Engineering at **Jaypee University of Information Technology, Waknaghat** is an authentic record of my work carried out under the supervision of **Dr. Ashok Kumar Gupta and Mr. Chandrapal Gautam**. This work has not been submitted elsewhere for the reward of any other degree/diploma. I am fully responsible for the contents of my project report.

Gunjan Chauhan
171610
Department of Civil Engineering
Jaypee University of Information Technology, Waknaghat, India
17 May 2021

Tshechik Dema
171679
Department of Civil Engineering
Jaypee University of Information Technology, Waknaghat, India (14)
17 May 2021

CERTIFICATE

This is to certify that the work which is being presented in the project report titled **“COMPARISON OF 10 STORY BUILDING CONSTRUCTED FOR EARTHQUAKE ZONE-4 V/S ZONE-1 WITH THE ANALYSIS OF GREEN BUILDING”** in partial fulfillment of the requirements for the award of the degree of Bachelor of Technology in Civil Engineering submitted to the Department of Civil Engineering, **Jaypee University of Information Technology, Waknaghat** is an authentic record of work carried out by **Gunjan Chauhan(171610)and Tshechik Dema (171679)**during a period from August 2020 to May allowing us 2021 under the supervision of **Dr. Ashok Kumar Gupta and Mr. Chandrapal Gautam** Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat. The above statement made is correct to the best of our knowledge.

Date: 17-05-2021

Signature of HOD
Supervisor
Dr. Ashok Kumar Gupta
Professor and Head
JUIT, Waknaghat
Department of Civil Engineering

Signature of Supervisor
Mr. Chandrapal Gautam (Co-guide)
Assistant Professor Grade-II
JUIT, Waknaghat
Department of Civil Engineering

ACKNOWLEDGEMENT

The completion of this project would not have been possible without the support, hard work, and endless efforts of many individuals. We humbly extend our heartfelt gratitude to all the people involved in making our project a successful and satisfactory one.

First and foremost, we would like to express our sincerest gratitude to Jaypee University of Information Technology (JUIT) for providing such an opportunity to do a final year project which has let us engage in meaningful research. The research project provided us with the experience to gain insight into the study.

Our special thanks to our guide and our advisor **Mr. Chandra Pal Gautam** for giving us this opportunity to work on a topic that is more comfortable and relevant for us and also for letting us groom before we really get into the working world. We would never forget how sir has welcomed us so warmly every time we needed sir's guidance and given us continuous support in every possible way despite his hectic schedule.

We are extremely thankful and pay my gratitude to the head of the department and also our guide **Professor Ashok Kumar Gupta** for allowing us to work under his guidance and providing all the facilities to work on this study.

We would also never forget to thank all the faculty and staff in the Civil engineering Department, our friends, and our family for supporting us and helping us come up with this study.

Lastly, we would like to express a deep sense of thankfulness to all the people involved in helping us work with this project. Without their help, it would have been extremely difficult for us to progress with our project works.

ABSTRACT

To meet the demand of rapid population growth and rapid urbanization, it becomes necessary to extend building vertically in both plain areas and hilly areas as well. However, the vertical extension of building involves high risk, high cost, and even the environment impacts. So, it becomes important to make a tall building earthquake resistant and sustainable. The principal objectives of this project are to compare the design of a 10 storied building in Earthquake zone-4 and Earthquake zone-1 using the STAAD Pro software. The designing of the structure involves modeling, analyzing, and designing the whole structure by using the STAAD Pro software. The design strategies utilized in STAAD Pro analysis are Limit State Design based on the Indian Standard Code of Practice. These involve Staad Modeling and analysis of the member elements due to the effect of Wind & Seismic load for a 30-meter height concrete structure building. The planned structure is a G+9 storied building with a height 3.00 m per floor. The size of the overall plan dimension of the building is 18.288 m x 14.6304 m.

The building sector is one of the largest energy consumers. This increase in energy consumption has led to environmental pollution, which has led to global warming and depletion of the ozone layer. The need for energy-efficient buildings has become one essential road to conserve energy. The modern methods of construction are very expensive to build, maintain, and sometimes uncomfortable to live. Nowadays people are interested in making their homes as cost-efficient and energy efficient as possible. Sustainable and climate-responsive living buildings could be adopted to minimize the negative impact on environmental that a building can have through use of appropriate materials, energy, and water in an efficient manner.

This paper reviews various design components of green buildings and discusses different considerations for the design of the green building. It also contains a detailed explanation of different possible ways to make building energy efficient. In this study, the ongoing construction of the passive building was analyzed for understanding the purpose and also used various case studies from the existing building which is located in Shimla. Finally, the energy-efficient office building has compared with conventional buildings in terms of electricity consumed annually and presented the results.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

i.e.	That is.
DL	Dead Load
LL	Live Load
EQX	Earthquake load in the X direction
EQZ	Earthquake load in the Z direction
WLX	Wind Load in the X direction
WLZ	Wind Load in the Z direction
ASTM	American Society of Testing and Materials
USGBC	U.S Green Building Council
LEED	Leadership in Energy and Environmental Design
LCA	Life Cycle Assessment
IGBC	Indian Green Building Council
GRIHA	Green Building for Integrated Habitat Assessment
BEE	bureau of Energy Efficiency
MNRE	Ministry of New & Renewable Energy)
CFL	Compact fluorescent light
CFC	Chlorofluorocarbon
PV	Photovoltaics
HVAC	Heating Ventilation Air Conditioning
WHO	World Health Organization
VOC	Volatile Organic Compounds

CHAPTER 1
INTRODUCTION

1.1. GENERAL

This chapter contains the introduction of the project that we will be working. The aims and objectives of the project is also mentioned below.

1.2. INTRODUCTION TO TALL BUILDING

As cities continue to expand horizontally, to prevent them from reaching the end of collapse, high-rise buildings as a type of building are a possible solution for conquering vertical space through agglomeration and densification. The population of the world is increasing day by day hence increasing the demand for living spaces. However, the land area is limited which imposes a limit on us to the extent we can construct horizontally. So, a need is felt to construct vertically to fulfill the needs of the human. Moreover, with the population rate skyrocketing and overcrowding the very limited plain lands, it becomes essential to mitigate the sloppy lands available to mankind. But construction of buildings in a hilly area poses a great threat mainly due to landslides. Especially tall buildings in hilly areas are far riskier. So, as we build tall so in addition to the gravity loads i.e., self-weight of the structure, dead and live load on it, we also need to consider the lateral loads i.e., earthquake load and wind load. Also, it is very important to construct lifts and elevators, fire-resistant structures in tall buildings, which make these tall buildings to cost a lot. These lateral loads are of great importance while constructing tall, as they are critical for failure in these cases.

1.3. INTRODUCTION TO GREEN BUILDING

With the growth of population and the unprecedented development of civilization, huge infrastructure development is underway all over the world. Rapid urbanization has become the largest consumption of material resources, environmental degradation, and the main driving force for the loss of many local ecosystems. Mainly dedicated to providing quick solutions for buildings. Due to excessive energy consumption and natural resources, buildings designed and constructed today cause serious environmental problems.

As there is increased development of housing and commercial buildings in urban areas, this has imposed great pressure on our dwindling energy sources and other important resources like water, thus aggravating the already uncontrolled process of environmental degradation.

Moreover, in the past ten years, countries around the world have increasingly generated waste and wastewater problems during construction and construction. Therefore, it is clear that there is an urgent need for current architectural design and construction practices to attract more attention and intelligent transformation. People have come up with the idea of green building, which has proved to be the solution to growing urban concerns.

The EPA of the US states that: "Green building is the process of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life cycle from siting to design construction, operation, maintenance, renovation, and deconstruction."

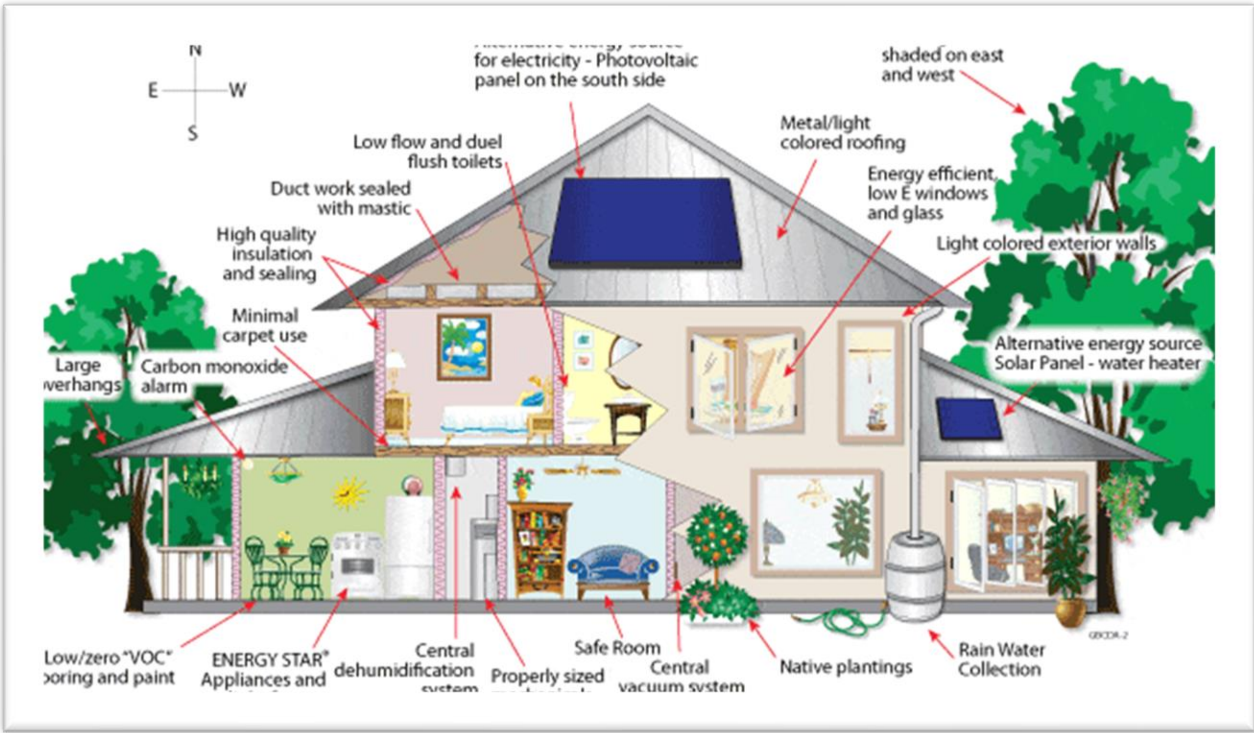

Figure 1.1: The components of green building (Picture Courtesy: The Constructor)

1.4. NEED OF STUDY

1.3.1. WHY TALL BUILDING

- Tall buildings are a need of the future, especially in developed cities, towns, and countries.
- Scarcity of land in urban areas means the buildings must be made taller to accommodate more people in a smaller area.
- More people are migrating to towns and cities due to more job opportunities and better infrastructure facilities.
- The scarcity of land is coupled with increasing demands for business and residential spaces.
- Building the tallest in the world brings with it the honor of the tallest building in the world, which attracts people and boosts the economy of that place.

1.3.2. WHY GREEN BUILDING

- The global energy crisis is one of the biggest challenges to the sustainable development of human society in the 21st century. Among the various methods to deal with or alleviate the energy crisis, improving the efficiency of industrial, commercial, and household energy consumption is the most effective and efficient method. The least controversial.
- Due to limited energy and environmental degradation
- Construction is the leading source of consumption of world energy sources and resources and a major source of environmental pollution.
- Indoor pollution level is usually 2 to 5 times outdoor pollution.
- The energy consumption, waste generation, and cost of building construction have called for a need for sustainable building.

1.4. OBJECTIVES OF THE PROJECT

- ✔ To design and compare a tall building of 10 stories in earthquake zone-I and earthquake zone-IV considering all the loads.
- ✔ Comparison of the design of 10 story buildings in the earthquake zone I and IV.
- ✔ Convert the normal building into a green building.
- ✔ Comparison of the green building with a conventional building.

CHAPTER TWO
REVIEW OF LITERATURE

2.1. GENERAL

This chapter includes the review and critical analysis of the research papers, books, and articles related to tall building design and the green building that we have gone through for our project.

2.2. TALL BUILDING: A NEED OF THE TOWNS AND CITIES

The population of human beings has been increasing every decade and century throughout the world in an exponential manner. Moreover, the trend of migration of people from underdeveloped places to more developed places has been noted for the improvement of their lifestyle due to easy availability of better infrastructure, employment, education and other facilities in towns and cities, as compared to rural areas and villages.

Hence, this makes more population to be concentrated in a smaller area, more population of humans residing in the small area, even more than the capacity of the land area to hold that population. This occurs especially in developed areas like cities and towns like in Delhi, Bombay, Chennai, Kolkata etc. in India. So, the Solution to accommodate more population in the smaller horizontal area, is to build vertically i.e., to build tall.

Building tall structures has both advantages and disadvantages like everything has. So many people are for the construction of tall structures considering the economic development of the place, while others are against them as these tall structures may cause many environmental problems and even hazards if they collapse, when not designed properly. It is important to design the tall structures with greater care or else it can cause a lot of damage if they collapse. Greater care needs to be taken as in addition to the gravity loads that occur due to self-weight of the structure and live load on the structure, we also need to consider the lateral or horizontal loads due to the wind and earthquakes dynamic loads. Some of the disadvantages of tall buildings are that they place considerable demands on the transport infrastructure and systems and are redesigning the city's skyline. They also affect the microenvironment by casting shadows and blocking views and sunlight from surrounding buildings. Tall buildings consume an enormous amount of energy and require high operating costs. For these reasons, some critics consider tall buildings to be an undesirable structure.

However, tall buildings are the need of the future due to huge growth in the human population, to fulfill the human need of shelter from the limited land resource available, it is logical to build vertically. Also, steps are taken to convert buildings to green buildings and construct green scrapers so that the building produces more energy than it consumes and turns environmentally friendly.

2.3. DESIGNING TALL BUILDINGS

These days there is much more software available to analyze and design the structures, especially tall structures. However, the most widely and commonly used of them are Staad Pro and ETABS. Earlier all the calculations were done manually, this process was lengthy and had higher probability of having errors. Now we use software that makes the design easy, fast and error free as the calculations are done by the software itself. We just need to provide the materials used, their grades and dimensions of the structure. The software analyzes the structure and shows us if the structure is safe with the given dimensions and grade of materials or not. If it is not safe, then we redesign by changing the dimensions and grade of material and analyze it again and again until the analysis shows that the structure is safe. Then we get the final dimensions of the structure and the quantity of materials used.

Research shows that ETABS has more advantages over STAAD PRO. Facts have proved that ETABS is easy to use, more accurate and more compatible with analysis and design results. However, in India most commonly and widely used is STAAD PRO, as it is very basic and preferred here as used from a long time in India. Hence, we would also be designing our 10-story building using the STAAD PRO software.

2.4. DEFINITIONS OF GREEN BUILDING

Green building can be defined in various ways. Although some definitions focus more on the operation and performance of buildings, other definitions look at green buildings in a more holistic style, including the well-being and health of the people living in the building.

According to the (ASTM) a green building is defined as: “a building that provides the specified building performance requirements while minimizing disturbance to and improving the functioning of local, regional and global ecosystems both during, and after its construction and specified service life.”

Compared with traditional buildings, an energy-efficient building which is also called a green building are buildings that consume less water, optimize energy efficiency, save natural resources, reduce waste, and provide residents with a healthier living space.

The green design and construction practice go beyond the conventional building codes and practices. It considers the entire life cycle of a building, which includes planning, design, construction, operation, maintenance, and also demolition and disposal. All aspects including the environmental, economic, and social effects of a building as a whole are considered,

Green design and construction practices go beyond traditional building codes and practices. It takes into account the entire life cycle of a building, including planning, design, construction, operation, maintenance, and even demolition and disposal while also considering the social impact of a building as a whole.

2.5. BARRIERS TO ENERGY EFFICIENCY

The most common barriers in the successful implementation of energy efficiency in buildings are basically summarized as technical, informational, regulatory, financial and market.
The people lack technical knowledge and skills to adopt energy efficiency projects. Moreover, most of the people have limited or no knowledge about the energy efficiency and so lack awareness. Often there is limited market for green products and after sale services. Sometimes, there is no government support and proper policies and regulations in the country for energy efficiency.

The high capital cost of efficient technology is considered the main economic barriers towards the use of energy efficient technology (Carbon Trust, 2005; Levine, et al., 2007; Caird, et al., 2008). This is highlighted in the developing countries where the high cost of the energy efficiency technology is believed to be paid back over many years (Koeppel and Ürge-Vorsatz, 2007; Balce and Zamora, 2000).

CHAPTER 3
GREEN BUILDING: FUTURE OF CONSTRUCTION

3.1. GENERAL

As the construction of building pose a greater threat to the non-renewable resource and energy as well as impacting the environment and the people, it becomes necessary for all the builders and the people to know about the concept of green building. This chapter will talk about the benefits of green building and what are various components and design principles for the green building.

3.2. AIMS AND OBJECTIVES OF GREEN BUILDING

The main objectives and purpose are:

- ***Design efficiency***

This is the concept of integrating sustainable design practices into building project and implementation processes in order to lessen the impact on the environment associated with all the life cycle stages of the building process.

- ***Energy efficiency***

Energy efficiency can be achieved through the lowering of energy consumption in lighting, air conditioning, and other building operations and through the maximum use of renewable energy sources which does not produce any harmful emissions.

Green buildings aim to minimize dependency on non-renewable sources of energy by using solar panels to generate energy from the sun and using natural daylighting in order to reduce the use of artificial light.

- ***Water efficiency***

In order to achieve water efficiency, water resources need to be used effectively so that present and future generations can also have a reliable source of clean water sources.

The use rainwater through rainwater harvesting as alternative sources of water and reusing of treated wastewater can reduce the water consumption.

- ***Materials and Resource efficiency***

Material efficiency involves minimum use of materials without compromising the quality of the outcome. Sustainable materials such as locally available materials, long lasting and durable materials and even recycled products can be utilized. Moreover, buildings can be designed in a manner that will use fewer materials and employ processes that use less water, raw materials, and energy.

- ***Improved Indoor Air Quality***

The quality of the indoor environment depends on the interior condition of the building and how they affect the residents of the building. A high-quality of indoor air can protect the health of people in the building, reduce stress and improve their quality of life.
Green building aim to provide healthy indoor air quality by adopting various green practices.

- ***Waste reduction***

The Green Building concept emphasizes the use of efficient waste management design and operation practices, re-using and recycling materials thereby reducing the generation of waste.

- ***Improving Health and Productivity***

Green Building aims to provide clean and safe working conditions for employees and other occupants thus increasing the wellbeing of people.

- ***Reduces Strain on Local Resources***

As the population grows, so does the demand for limited common local resources such as water and energy, and as a result, they come under significant pressure. Green buildings aim to reduce this strain through the use of technologies and processes that increase water and energy efficiency.

- ***Reduce operation and maintenance costs.***

- ***Better Environment***

By Minimizing external pollution and environmental damage, Green building aims to keep the environment clean thus providing a better surrounding environment.

3.3. PROS AND CONS OF GREEN BUILDING

3.3.1. BENEFITS OF GREEN BUILDING

Besides conserving our environment and its natural resources, green design and construction offer many benefits which are important for us.

Some of the advantages of green buildings are:

- Decrease the pressure on the environment by efficient use of energy, water, and resources.
- Increase in the wellbeing and health of people by providing improved indoor air quality.
- increased life and durability of the building
- reduction in maintenance and operation cost
- Reduction of construction and demolition waste
- Increase in cost savings.
- add to the aesthetic view of the building.
- provide a better and healthier living environment for residents.

3.3.2. DISADVANTAGES OF GREEN BUILDING

Some of the downs of green building are.

- the initial construction cost of Green buildings is more than conventional buildings.
- Takes time to construct.
- The design of green buildings requires skilled and trained professionals.
- green materials are costly and rarer

3.4. ENERGY EFFICIENCY IN DESIGN OF A BUILDING

Energy efficiency refers to the effective use of energy to reduce waste and the amount of energy required. Therefore, improving efficiency means reducing energy consumption to ensure acceptable comfort, air quality.

There are numerous ways in which we can plan and design the building as energy efficient. Following are the components of energy-efficient buildings.

1) Site selection
2) Proper Landscaping and building orientation.
3) Selection and Use of green materials.
4) Building envelope and fenestration design
5) Indoor Air Quality
6) Daylighting
7) Management of waste from construction
8) Passive Design
9) Design energy-efficient HVAC (heating, ventilation, and air conditioning)
10) Reduced use of transportation

3.4.1. SITE SELECTION AND PLANNING

In order to design a house that will minimize its effect on the environment, minimize the utility of resources and provide better and healthier living environment for residents the first important step is to understand the site.

Therefore, site analysis includes studying of the site location, knowing the physical characteristic like topography, geology, hydrology, vegetation, wildlife, climate, and other aspects which need to be considered.

Climate

For the green design, it is crucial to analyze the climatic condition of the place which involves the following consideration.

- The path (vertical and horizontal angle) of the sun during the year
- The direction and intensity of wind
- The most likely direction of storms, cold or strong winds
- The direction of good breezes

Hot or Dry Climates

In hot/dry climates where the diurnal temperature swings considerably building materials with high thermal capacity and adequate thickness are used. This helps reduce and delay the effects of temperature fluctuations from the outer wall to the inside of the wall. In addition, the high heat capacity of the material allows heat to slowly penetrate the wall or ceiling. The design of the opening on the north and west facades are smaller and bigger in the south so that it avoids direct sunlight in summer but admit in winter.

Hot/wet climates

In hot/moist climates, where night temperatures do not drop considerably below daytime highs, light materials with low thermal capacity could be used. Roofs and walls could be protected by plant materials or overhangs. Usually, large openings protected from the summer sun could be located primarily on the north and south sides of the building envelope to catch breezes or encourage stack ventilation.

Temperate climates

In temperate climates, materials with a required thermal capacity based on location and the heating/cooling strategy can be used. Walls should be well insulated. Openings in the skin could be shaded during hot times of the year and unshaded during cool months.

- **Cold climates**

In colder climates design air-tight and well-insulated building envelopes. The thermal capacity of materials used in colder climates will depend upon the use of the building and the heating strategy employed.

3.4.2. PROPER LANDSCAPING

Landscaping plays an important role in changing the microclimate of a place. A good landscaping can provide a microclimate with a relatively cooler and healthier environment compared to the nearby areas.

It can contain vegetation and trees which can both provide needed shade on a summer day and starve the house of natural light when it is needed most.

It also helps to create different airflow patterns and can be used to direct or divert the wind as required by creating pressure difference.

3.4.3. GREEN MATERIAL AND RESOURCES

Not to forget, selection of materials also plays a vital role in the green building. Building and construction activities worldwide consume 3 billion tons of raw materials each year or 40 percent of total global use (Roodman and Lessen, 1995). So, the use of environmentally friendly building materials and products helps protect the non-renewable resources that are already diminishing. In addition, integrating environmentally friendly building materials in construction projects can help reduce the environmental impact associated with mining, transportation, processing, manufacturing, installation, reuse, recycling, and disposal.

- **<u>Analysis of the environmental impact of building materials</u>**

For the construction of buildings and related infrastructure, resources and materials come directly or indirectly from nature. Similarly, these building materials also often return to nature. Therefore, any construction will have an impact on the environment, and if it is not carefully managed, the effects are usually negative. So, when looking at environmentally friendly materials and resources, the environmental impact should be properly analyzed.

“The Life Cycle Assessment (LCA) is the important method for evaluating the overall environmental impact of a product, process, or service design to disposal i.e., throughout its entire lifecycle, the so-called cradle to grave method. The life cycle assessment of a product is the sum of its effects of; extraction of relevant raw materials, refining and transformation into process materials, production and packaging processes, transportation and distribution in each phase, operation or use during its service life, and at the end of their useful life, final transport, waste treatment and disposal [24]”.

Sustainable materials

Following are some of the materials to be used for green building design.

- ✔ locally available Materials and resources
- ✔ Low Embodied Energy materials
- ✔ Materials with minimal air, land, and water pollution footprint
- ✔ Biodegradable Materials
- ✔ Renewable Material resources
- ✔ Durable materials
- ✔ Materials having a long life.
- ✔ Materials should be Reusable & Recyclable.
- ✔ Materials that offer Reduced maintenance/replacement costs over the life of the building.
- ✔ materials should not affect the health and wellbeing of the occupants.
- ✔ do not emit toxic gases, solvents, or harmful compounds.
- ✔ require do not large sources of power energy, oil, or water for its maintenance.

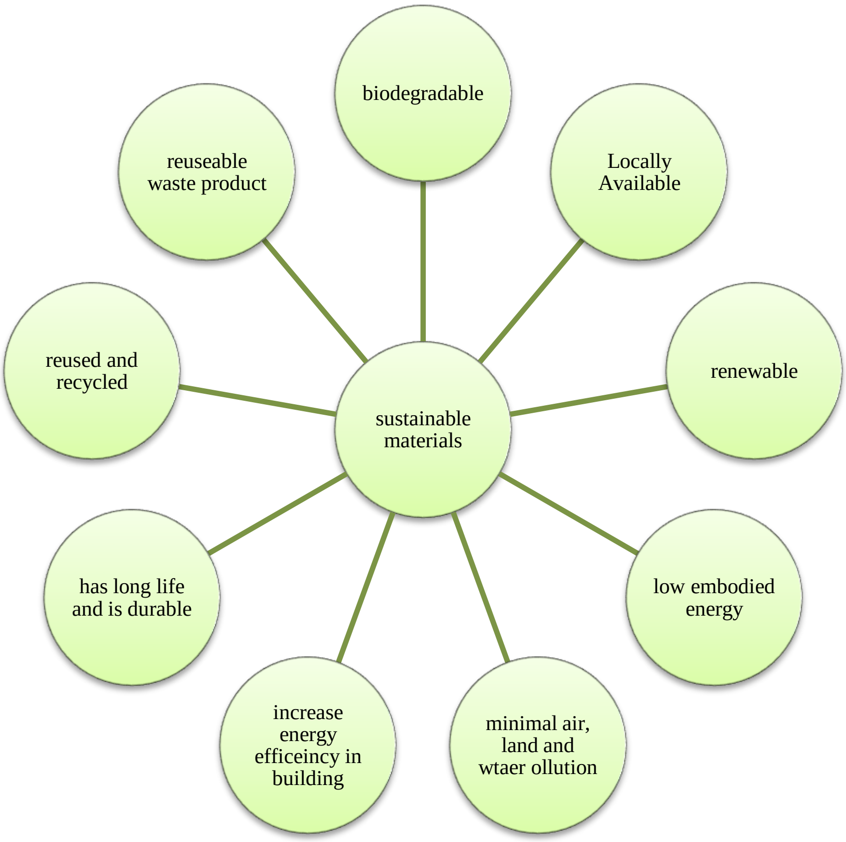

Figure 3.2: Sustainable materials

Overall, Green materials or products should fulfill certain criteria like resource efficiency, indoor air quality, energy efficiency, water efficiency and affordability. Some of the common examples of green materials used are earthen materials, wood, bamboo, polystyrene etc.

3.4.4. BUILDING ORIENTATION

Orientation of buildings is the major design consideration with regards to solar radiation, daylight, and wind.

Orientation refers to the location of a building that fluctuates seasonally in the path of the sun and prevailing wind. The best orientation requires the entire building to receive the maximum amount of sunlight in winter and the least in summer. For this, it is important to understand the position of the sun through the sun path diagram and prevailing wind direction.

In green buildings aspect, building orientation is a way of cladding buildings to maximize energy savings. It is important for building owners to align the buildings so that they can use the free energy of the sun. Proper orientation can improve the energy efficiency of a house, making it more comfortable and cheaper.

Another environmental factor that should be considered in orientation of a building is prevailing winds. A building should be positioned so as to minimize the effects of winter wind turbulence upon the envelope. This is to say that a building needs to be designed in such a way that it can take advantage of summer breezes for passive cooling while also protecting against adverse winds that can further cool the interior atmosphere on an already cold winter day.

As energy costs rise, the orientation of the building is critical to take advantage of the sun when it is wanted, however avoid overheating and glare through window placements, roof overhangs, reflective barriers, lighter finishes, and other techniques. Introducing sunlight and vision into the living space of the building allows highly personalized control of the ventilation and lighting system to maintain health, increase productivity, and create a comfortable atmosphere between indoor and outdoor spaces.

To ensure good orientation it is required to face the building within 30° due south as south-facing facades will receive maximum winter solar radiation about 90 percent and overhangs protect summer heat gain.

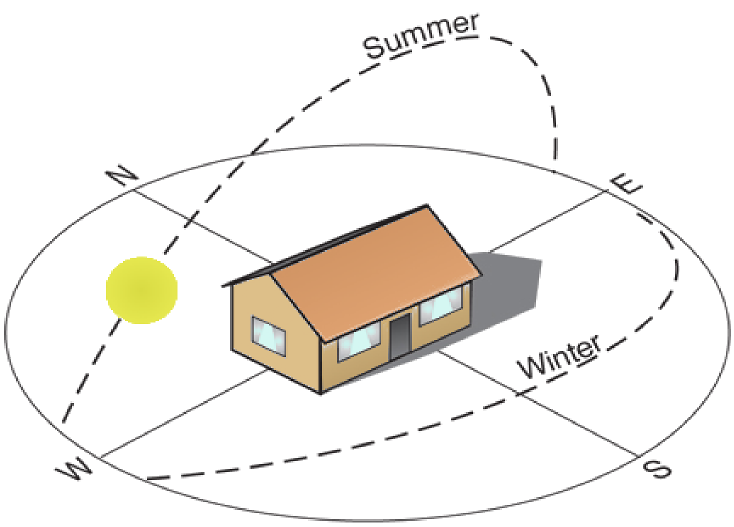

Figure 3.3: The building orientation (Source: NextDay Inspect, May 23, 2020)

3.4.5. BUILDING ENVELOPE AND FENESTRATION DESIGN

The building envelope, also known as skin or shell consists of structural material that acts as a boundary between the outdoors and conditioned interior of a building. It plays a vital role in protecting the interior space of the building from the effects of the outside environment like wind, precipitation, temperature, humidity, and solar radiation. This includes building components like roofs, walls, floors, doors, windows, and openings. The nature of these components and their characteristics like resistance, thermal capacity, absorption, transmission, and emission, controls the amount of heat flow and the wind entering the building envelope. Therefore, the materials for the building envelope have to be chosen properly based on specific requirements.

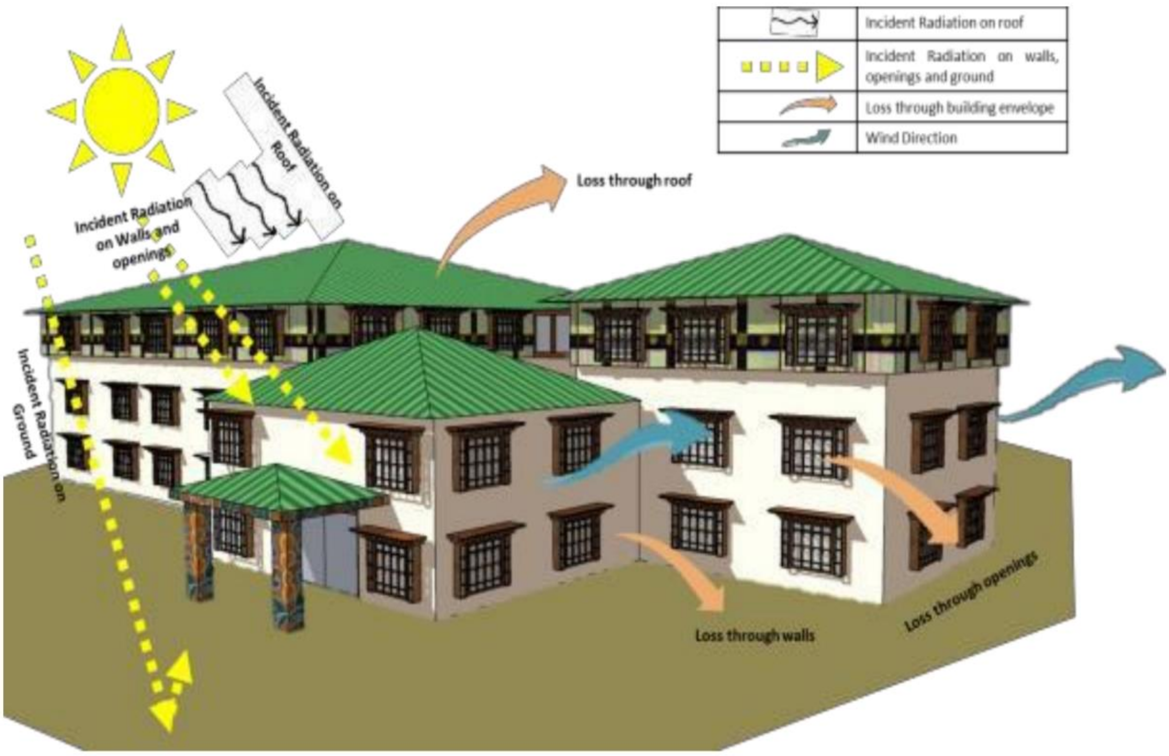

Figure 3.4: Heat movement (Source: Bhutan Building Energy Efficiency Study, September 2015)

The various elements of a building envelope are listed below.

1) Roofs

The roof of a building receives a large amount of direct solar radiation. So, it is important to design the roof to reduce the heat gain. The heat gain reduction through roofs can be achieved by installing insulating materials either on the external or internal of roofs. A rooftop can also be covered with a shining and reflecting material in order to reflect the sun's rays. However, White coatings of the roof are found to be more effective.

A green roof is also another method of sustainable roof design. It is usually a roof that is covered with vegetation planted over a waterproofing medium. Besides adding beauty to the building, a green roof provides shade and reduces the temperature of the roof surface and surrounding air. This can reduce the need for air conditioning in summer and also provides insulation in winter. A green roof protects the roofing material from the harmful influences of sun, wind, and rain thereby increasing the life span of the building roof.

Figure 3.5: Green Roof (Source: Urbanscape, May 23, 2016)

2) Walls

A building consists of Walls as a major part of it which contribute to receiving a huge amount of direct sunlight. The resistance to heat flow through the exposed walls may be increased by increasing the thickness (thermal mass), using the cavity wall, using insulating material, or by applying light-colored whitewash on the exposed side of the wall.

The concept of architectural Green walls also contributes to sustainable building. A green wall also called a living wall or vertical garden is a building wall covered with vegetation. The green wall provides a variety of benefits like visual benefits, noise pollution reduction, improving indoor air quality, and energy cost reduction. Besides, it protects a building from direct solar rays and heat penetration. This reduces the demand for cooling systems in summer and in winter. Living walls provide an additional layer of insulation which helps in keeping the interior warm and the cold air out.

Green walls can also naturally absorb and filter stormwater. This collected rainwater can be used for different purposes.

Figure 3.6: Green Walls (Source: Nic Tamlin Interior Design)

3) Fenestration (Windows and doors and openings)

The windows or the fenestration are very important component of any structure or building. These help in ventilation, let the sunlight to enter into the building. These somewhat connect the external and internal environment in controlled manner. They serve the purpose of warming the indoors through heat gained or heat absorbed by the materials in the indoors or walls or structure. During daytime it lets in the sunlight and fulfills the lighting requirement of the occupants without any need for artificial lighting system. It also provides natural means of air, helping in regulating indoor air quality and controlling indoor temperatures. These things control the comfort level of the people occupying the indoor spaces and also influence the energy efficiency of the building. Openings helps people to enter or exit the building, helps them to see their surroundings and enjoy the views outside the buildings. It allows natural light and air to enter into the interior spaces and also help in heating the indoors. Hence, it is important to design the building properly with proper sizing of the openings like doors, windows, and vents etc. for proper lighting, heating, cooling and ventilation conditions within the building for effective use of natural energy within the structure.

Air locking the outdoor conditions from adversely impacting the indoor conditions of heating, cooling, or ventilation etc. is very important to provide optimal temperatures, indoor air quality for comfort of the people in the building. This can be done by shading the openings to prevent the sunlight from directly entering into the structure. For this purpose, the design such as shading the openings with trees overhangs, orienting the building towards southern direction planting more plants on roof and surroundings during the summer seasons. The use of design solutions such as overhangs or deciduous plant materials on southern orientations to shade exterior walls during warmer seasons should be considered. This helps in saving energy, hence leading in savings in the electricity bills.

- **<u>Windows</u>**

The windows should be designed in such a way that they allow maximum amount of sunlight to enter within the structure but minimize the heating indoors during warm conditions of summer and maximize heating indoors during cold winters. For proper amount of heat, light, and natural energy to enter within the structure, it is important to make right choices of the dimensions, location, orientation and glazing of the openings

Energy flow or balance depends upon the atmospheric conditions, category of the structure, the operation of the structure etc. If the structure is located in a region where hot climate exists most of time then, its preferred to have smaller window sizes in the northern, western and eastern directions for regulation of temperature. The windows in the southern direction need high SHGC to maximize heating and low U-factor to reduce heat transfer and a high VT for good visible light transfer. In cold climatic conditions, to maintain warmth within structure the windows should have less U value and more SHGC value to decrease loss of heat. In hot temperature conditions the windows allow only light to enter and prevent heating indoors which would mean using low SHGC windows must be used.

The main objective is to provide both thermal and visual comfort to the users. The use of double-glazed windows should be considered with improved frames.

- ***Lower Emission windows***

It is an energy efficient design of the window glass that reduces the loss of heat during winter, while also reducing the heat gained during summers. It prevents heat from escaping through your windows to the cold outdoors and vice versa for summer districts. These windows must be used in buildings with a greater number of windows like sunrooms for better and comfortable conditions to prevail indoors.

- ***Double Glazed Windows***

They are considered very good to prevent heat gain or heat loss, which would help one to keep their house comfortable during all seasons, i.e., warm in winters and cool in summers. The gap or the space between the two glasses prevents the travel of heat into and out of the window hence insulating the structure and creating comfortable temperature within the structure, also allowing light to enter in and not even altering the temperature within.

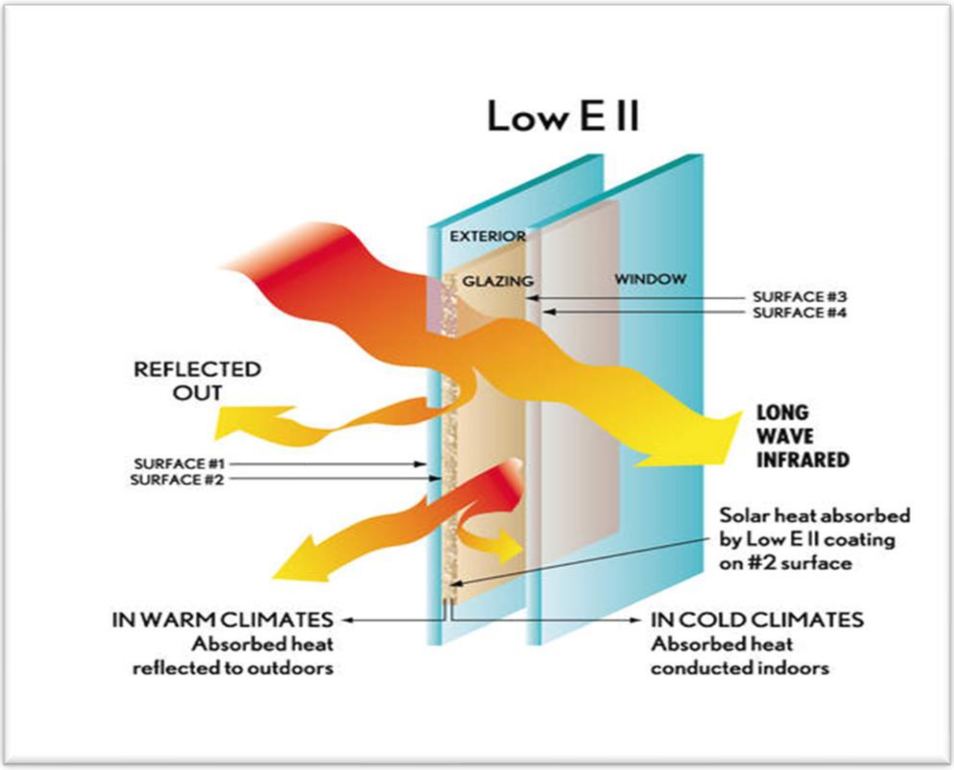

Figure 3.7: Low-E double glazing window (Source; Green building advisor)

- ***The windows frame.***

These are important component of window plying important part in glazing. They constitute 20% of the window area, hence play significant role in controlling the total performance of the window. It is observed that most of the heat escapes through the frame of the glass so more importance is to be given to it during design.

Window size and orientation when combined with the use of best widow frame as part of the double-glazing window, can have a huge effect on energy efficiency all year round. Some of the materials from which frames can be made of are aluminum, wood, vinyl, fiberglass, and composite.

3.4.6. NATURAL DAYLIGHTING

"Using artificial sources to light up the spaces inside uses more energy and also create losses that create the heating or cooling load (Zain-Ahmed, Sopian, Othman, Sayigh & Surendran, 2000)".

As there is excessive rise in the temperature throughout the world due to excessive greenhouse gas emissions leading to global warming, planning is now an essential requirement for utilizing the natural resources like sunlight to meet the comfort requirements of heating, cooling, lighting in all types of structures to create better conditions for human beings to live. This would reduce the dependence on artificial means, create better indoor conditions, and reduce the use of electricity, helping in better economy.

Daylighting is the practice of bringing natural light into a building interior and distributing it in a way that provides more desirable and better-quality illumination than artificial light sources. Natural sunlight should provide ambient and comfortable visibility, lighting, and thermal conditions. This will help in saving energy by substituting the use of artificial light and related cost and pollution. The building and all its components like openings should be constructed in such a way that they allow maximum sunlight to enter within the structure creating better lighting condition naturally throughout the day without any thermal discomfort.

3.4.7. INDOOR AIR QUALITY

Indoor air quality is described as the environmental conditions inside a building. It, therefore, does include the air quality alone, but the entire environmental quality of a space, including air quality, access to daylight and views, pleasant acoustic conditions, and occupant control over lighting and thermal comfort.

The WHO has identified that the pollution within and outside the building can cause many chronic ailments such as long-term problems in breathing, heart related disorders etc. This may be caused by pollutants such as volatile organic compounds, harmful gases like the oxides of Sulphur, carbon, nitrogen, colloidal dust particles, smoke, heavy metals like lead, mercury etc. This is termed as SBS or the sick building syndrome. It may cause many health-related problems, can even cause death. It was found to be the maximum cause of deaths around the world. Hence, it is important to control and monitor the quality of the indoors, especially the air quality inside since people spent most of their time inside the building. This would help in creating better and healthy conditions for the occupants, leading to improvement in their health.

For a good and healthy indoor air quality:

- ✓ Incorporating Natural cross-ventilation to ensure fresh air.
- ✓ Effective design of HVAC Systems
- ✓ Use of Zero- Or Low-emission finish materials.
- ✓ Using VOC materials, paints & adhesives

3.4.8. MANAGEMENT OF WASTE

Construction activities always generate significant quantities of waste. Green design aims to reduce the waste generation. For the waste management from construction, the perfect method is to start from the beginning stage of design where the choice of materials and their characteristics are focused to ensure minimum waste.

The concept 3 R‟s hierarchy is one of the most common ways of waste management.

Figure 3.8: The 3Rs (Source: Bhutan-GREEN-Building-Design-Guidelines)

3.4.9. PASSIVE DESIGN AND HUMAN COMFORT, HEALTH AND WELLBEING

In addition to saving material resources, it is widely recognized that passive design contributes to human comfort, satisfaction, and well-being. It improves the quality air, water and light which are the main elements on which humans depend, thus keeping the residents of the building healthy and sound.

In passive solar design, building elements like windows, walls, and floors, which are the main components of the passive system are designed properly considering the sun and landscape to collect, store, and distribute solar energy in the form of heat in the winter and reject solar heat in the summer to allow for heating and cooling.

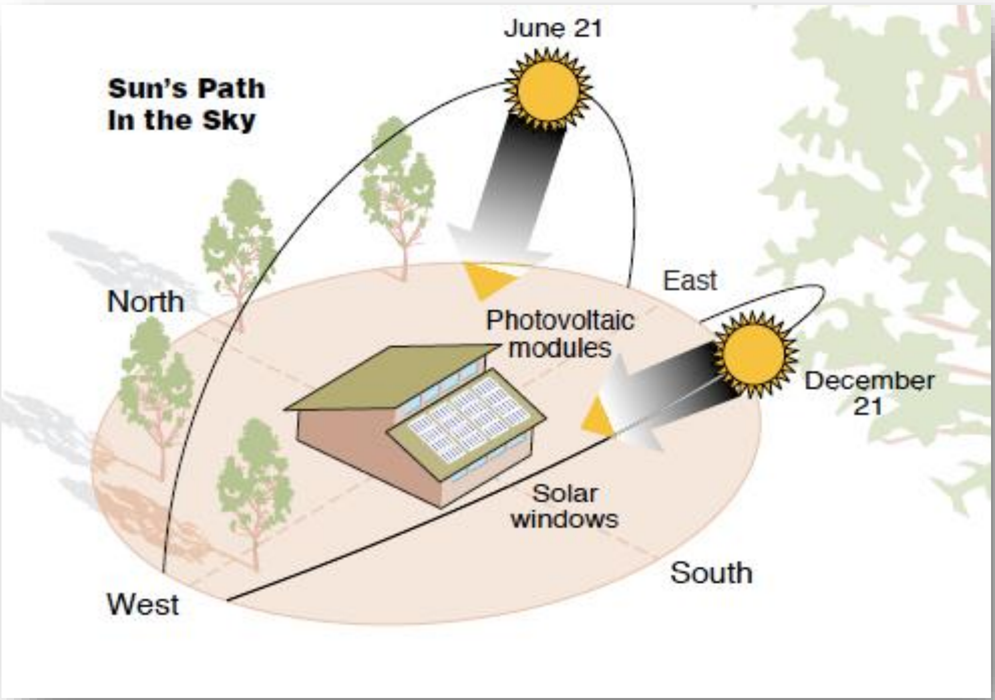

Figure 3.9: Passive solar design (Source: Green Passive Solar Magazine)

CHAPTER 4
PASSIVE DESIGN

4.1. GENERAL

Passive solar design refers to the use of the solar energy to heat and cooling the indoor spaces by exposure to the sun. When sunlight hits a building, the building materials can reflect, transmit, or absorb the solar radiation.

4.2. PASSIVE SOLAR HEATING

The passive solar heating systems trap the solar heat within the building's elements and release that heat during the absence of sun, while also ensuring that a comfortable indoor temperature is maintained.

Basically, passive solar heating involves:

- The **collection** of solar energy through properly oriented, south-facing windows
- The **absorption** and **storage** of solar energy in thermal mass
- The **distribution** of the stored solar heat back to the living space, when required.
- Window specifications to allow higher solar heat gain coefficient in south glazing.

Passive solar heating is classified as follows:

1. Direct gain
2. Indirect gain and
3. Isolated gain

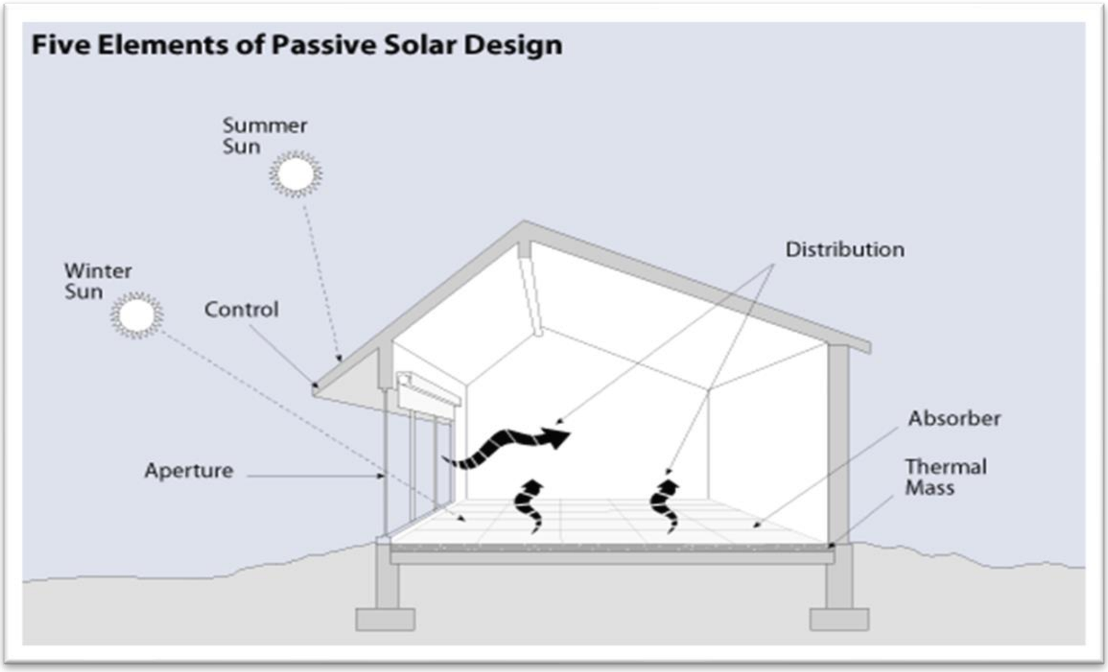

Figure 4.10: Five elements of passive solar design (Source: energy efficiency and renewable energy, US department of Energy)

4.2.1. DIRECT GAIN

Direct gain is the simplest and the least expensive because the elements of the system are building components where the indoor or living space acts as a solar collector, heat absorber, and distribution system. Sunlight enters the building interior through the south-facing glass windows in the northern hemisphere (north-facing in the southern hemisphere). The sunlight then strikes the thermal mass such as masonry floors and walls which absorb and store the solar heat. The floors and walls acting as thermal mass are incorporated as functional parts of the building and temper the intensity of heating during the day. At night as the room cools, the heat stored in the thermal mass conducts and radiates into the indoor space thus heating the room.

4.2.2. INDIRECT GAIN

An indirect-gain system has its thermal mass located just behind the south-facing glass and in front of the heated indoor space and so there is no direct heating. The position of the mass prevents sunlight from entering the interior space and also obstruct the view through the glass. The most common example of indirect gain system is the Trombe walls system.

Trombe Wall

In this system, it consists of a south facing wall of an 8 to 16 inches thick which is coated with a glass, spaced a few inches away. Materials such as cast-in-place concrete, adobe, brick, stone, or solid (or filled) concrete masonry units can be used construct the wall. The solar energy is absorbed by the wall and stored in its mass. Both the glass and the air void filled prevents the heat from radiating back to the outside. Heat is transferred by conduction since the masonry surface warms up and is slowly delivered to the building interior at night. This wall system can provide passive solar heating without excessive window area and glare in interior spaces unlike a direct gain system. The main advantage is it provides privacy and prevents glare due to direct sunlight.

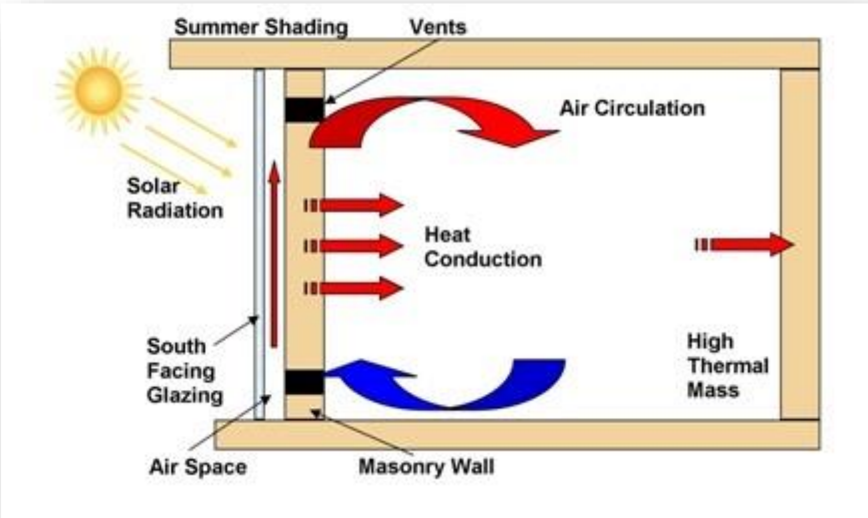

Figure 4.11:Trombe wall (Source: Google sites)

4.2.3. ISOLATED GAIN SYSTEM

A sunspace also known as a solar room or solarium is used for this approach. This approach is a combination of direct gain and indirect gain system. A sunspace can be built as part of a new home or as an addition to an existing one. The distribution of heat to the house can be accomplished through ceiling and floor level vents.

Solar radiation directly heats the solar space, which in turn heats the living space (separated from the solar room by the solid wall) by convection and heat conduction through the solid mass wall. Insulation panels, curtains or blinds are more important for solar rooms than Trombe walls because they sometimes occupy sunny rooms.

4.3. PASSIVE COOLING

Passive solar cooling systems work by reducing unwanted heat gain during the day, producing non-mechanical ventilation, exchanging warm interior air for cooler exterior air when possible, and storing the coolness of the night to moderate warm daytime temperatures. Passive solar cooling systems include strategies like overhangs or shades on south facing windows, natural ventilation, and air cooling through radiative cooling and evaporative cooling. These strategies are capable of reducing demand for mechanical cooling while also maintaining thermal comfort.

4.3.1. SOLAR SHADING

One of the simplest and most practical way of reducing unwanted heat gain in the summer and cooling a home is by shading windows, doors and walls by an overhang or other shading devices such as awnings, shutters, and trellises. Shading usually means partial or complete obstruction of the sunrays directed towards a surface by an intervening object or surface.

"It is important that overhangs are properly sized. If they are too short in summer, south-facing glass can act as a solar cooker for the living spaces. If they are too long, living areas will stay dark and cool not only in the summer but in the winter as well. Solar shade sizing analysis is used for designing proper sized overhangs (Anon, PATH, A Public-Private Partnership for Advancing Housing Technology, 2005)".

The shading devices should be placed on a south facing window such that it protrudes to half of a window's height. This will block the higher solar radiation during the summer and allow low winter sun it to enter into the house. "The sun is low on the horizon during sunrise and sunset, so overhangs on east and west facing windows are not as effective. In the summer, when the sun is high in the sky, the overhangs should shade the room completely and in winter, when the sun is low, the overhangs should allow the full sun to enter, warming the air, as well as the floor, wall, and other features (Anon, National Concrete Masonry Association)".

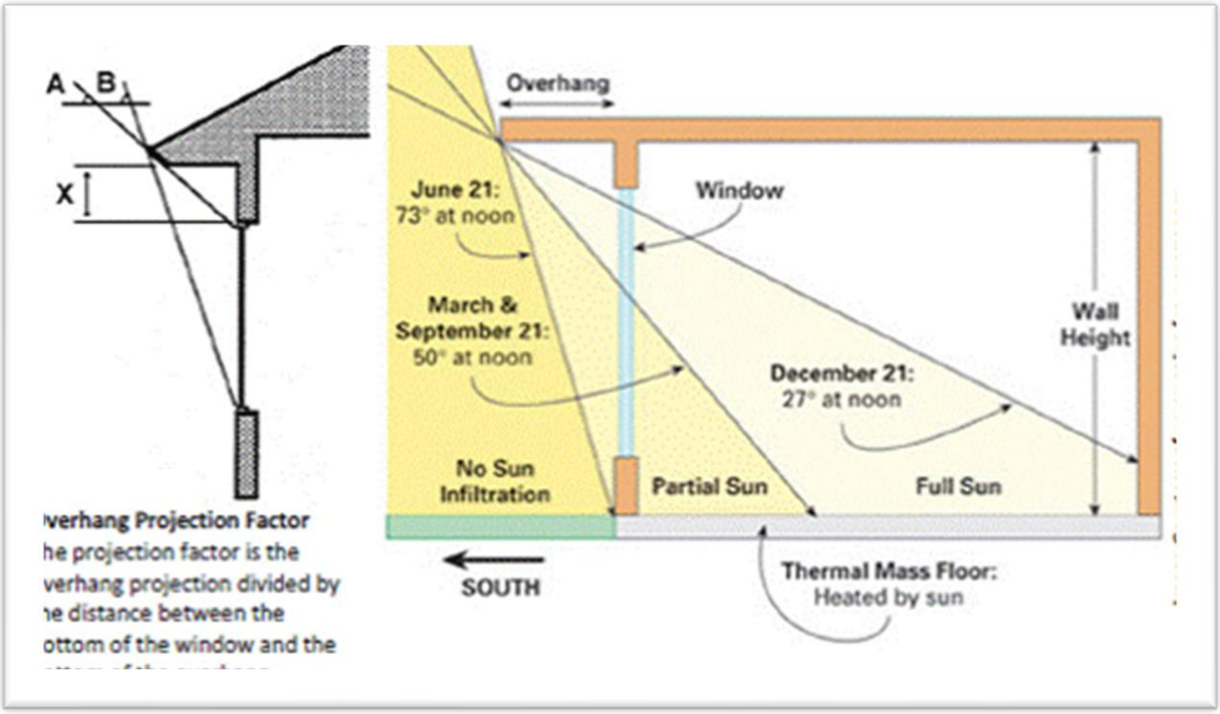

Figure 4.12: Overhangs for passive cooling (Source: WBDG)

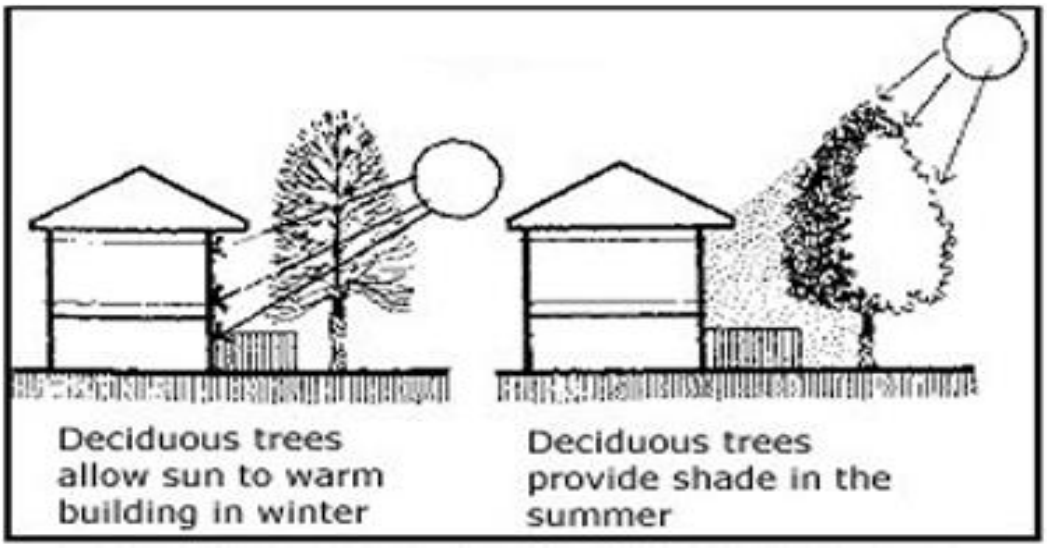

Figure 4.13: Shading using vegetation (Source: WBDG)

Vegetation can be also used for shading. Deciduous trees are most common form of shading used because in warm areas where more shading is needed, it leaves out earlier while in cold region where solar heat is important late into the spring, it waits until the weather warms up before they leaf out. Trees can be planted on east and west sides of the building to block the rising and setting of the sun. Landscaping in general can be used to reduce unwanted heat gain during the summer.

4.3.2. VENTILATION

Natural ventilation is the process of exchanging air between indoor and outdoor environments without using mechanical systems. It takes advantage of natural wind or outdoor air for cooling and indoor air renewal. Natural ventilation maintains an indoor temperature that is close to the outdoor temperature, so it is only an effective cooling technique when the indoor temperature is equal to or higher than the outdoor one.

In places where the wind blows during the day and you want to ventilate during the day, the windows facing to the cool breeze side and the opposite side of the building can be opened for cross ventilation. The windows should be designed such that it faces the prevailing wind and opposite walls. Wing walls can also be used to create ventilation through windows in walls perpendicular to prevailing winds. A solid vertical plane can be placed perpendicular to the wall between the two windows, which can accelerate the natural wind speed due to the pressure difference generated by the side walls.

4.3.3. THERMAL MASS

Thermal mass are solid or liquid materials such as concrete slabs, masonry wall, wallboard and tile floors which are used to store heat. They absorb heat during sunlit days and slowly releases as the temperature drops. Through ventilation, the thermal mass can be cooled during the night, allowing it to be ready to absorb heat again the next day.

Thermal mass and energy storage are key characteristics of passive solar design. They can store the excess heat, therefore reducing the cooling load, while storing heat that can be slowly released back to the building when needed like during the night and even when there is no sun shining. A thermal mass basically moderates the interior temperature reducing the need for mechanical cooling and winter heating requirements.

Insulation

Proper insulation helps in reducing heat loss in winter and cold climates and keeping out excess heat and maintaining cool temperature in hot weather thereby maintaining a comfortable indoor temperature throughout the year. Since insulated materials are poor conductors of heat, they create a barrier between interior and exterior spaces thus keeping the required indoor and outdoor temperature according to the season.

Insulation materials are commonly used on roofs, walls, and floors. The resistance to heat is measured by R-value. Higher the R value, the greater is the insulation.

There are variety of insulating materials used for a passive design of building. The most common examples are fiberglass, polyurethane, mineral wool, cellulose etc.

Reflective painting

No matter how well a building is insulated, the building will never achieve maximum energy efficiency if the roof and walls are allowed to absorb thermal heat. The shape of the roof and materials and the direction in which the roof faces all play a part in how much heat the roof retains but reflective roof paint and walls can reduce the amount of the sun's heat that penetrates on the roof and walls.

Using suitable colors and surface finishes is very effective technique to reduce interior temperature. In hot regions with significant cooling loads, the use of exterior finish materials with light colors and high reflectivity should be considered. The reflective painting will reflect back radiation to the environment and reduce the heat gain of the building (Brady & Media, 2011).

CHAPTER 5
GREEN BUILDING RATING SYSTEM

5.1. GENERAL

There is various rating system based on different criteria where green buildings are certified. This page will provide an overview of the most widely recognized green building rating and certification programs currently in use.

5.2. INTRODUCTION

Buildings directly or indirectly have a significant impact on the environment. During construction, housing, renovation and demolition processes, buildings consume energy, water, and raw materials, generate waste, and emit harmful emissions into the atmosphere. This led to the creation of, aiming to introduce environmental protection building standards, certification, and classification systems through sustainable design to reduce the impact of buildings on the environment. With the introduction of, the BREEAM method (Environmental Assessment Method for Building Research Institutions) in 1990, which is the world's first environmental protection building classification system the pursuit of sustainable design is increasing. In 2000, the United States Green Building Council (USGBC) formulated and issued a standard that also aims to improve the environmental performance of buildings through its LEED (Leadership in Energy and Environmental Design) rating system for new buildings. Others have also responded to the growing interest and demand for sustainable design, including the launch of the Green Building Initiative (GBI), which aims to help the American Association of Home Builders (NAHB) promote its residential building guidelines:

In the 21st century, with increasing attention and research on global warming and resource depletion, the number and types of green product standard and certifications system has continued to increase. The focus has also been expanded to include broader environmental issues and the impact of products during manufacturing, use, and reuse.

The green building rating or certification system expands the focus from the product to treating the project like anything. A building certification system is the one that evaluates, or rewards relative performance levels based on specific environmental goals and requirements.

Green building certification and rating systems require an integrated design process to create environmentally conscious and resource-efficient projects throughout the building life cycle: From the construction site to planning, construction, operation, maintenance, repair, and dismantling.

Benefits of using standards and certification systems in green buildings Sustainable design has a wide range of general advantages, which can usually be achieved through the use of standards, classification systems, and certification systems. "According to a study of LEED certified buildings, the USGBC has found that energy, carbon, water, and waste can be reduced, resulting in savings of 30 to 97% respectively. Operating costs of green buildings can also be reduced by 8–9% while increasing in value up to 7.5%. Many sustainable buildings have also seen increases of up to 6.6% on return on investment, 3.5% increases in occupancy, and rent increases of 3% [29]".

5.3. LEED

LEED is a green building certification rating system which focuses on efficiency and leadership to deliver the triple bottom line returns of "People, Planet and Profit." It was designed by the USGBC to evaluate the influence of building design and construction on the environment.

5.3.1. LEED CERTIFICATION CATEGORY

Table 5.1: LEED Certification Points

Category	***Points***
Sustainable sites	26
Water Efficiency	10
Energy and Atmosphere	35
Material and Resources	14
Indoor Air Quality	15

Innovative and Design	6
Regional Priority	4
Total Points	110

5.3.2. LEED CERTIFICATION LEVEL

Table 5.2: LEED rating

LEED certified	40-59
Silver	50-59
Gold	60-79
Platinum	80+

5.4. GREEN BUILDING RATING SYSTEM IN INDIA

India has currently green rating system given below.

- Green Rating for Integrated Habitat Assessment (GRIHA)
- IGBC rating system
- BEE

5.4.1. GREEN RATING FOR INTEGRATED HABITAT ASSESSMENT (GRIHA):

Green Rating for Integrated Habitat Assessment (GRIHA) is the national rating system of India for any completed construction, endorsed by the Ministry of New & Renewable Energy (MNRE), Government of India and TERI. It is an assessment tool to measure and rate a building's environmental performance.

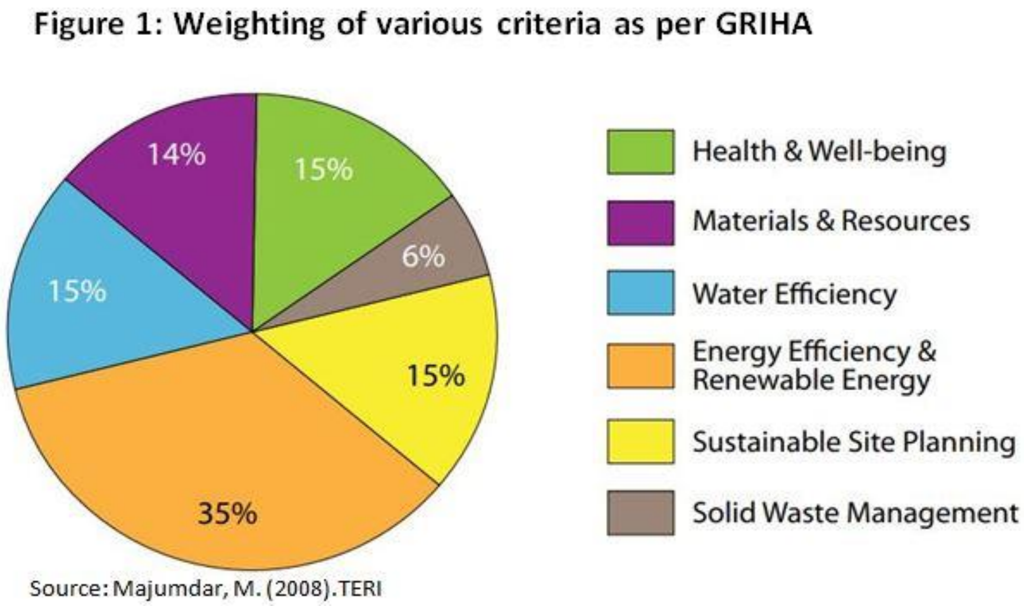

Figure 5.14: GRIHA Rating criteria

5.4.2. IGBC RATING SYSTEM

All the IGBC rating systems are voluntary, consensus based, market-driven building programs. The rating systems are based on the five elements of the nature (Panchabhutas) and are a perfect blend of ancient architectural practices and modern technological innovations. The ratings systems are applicable to all five climatic zones of the country.

Each rating system divided int to different levels of certification are as follows.

- ✓ ‘Certified’ to recognize best practices.
- ✓ ‘Silver’ to recognize outstanding performance.
- ✓ ‘Gold’ to recognize national excellence.
- ✓ ‘Platinum’ to recognize global leadership.

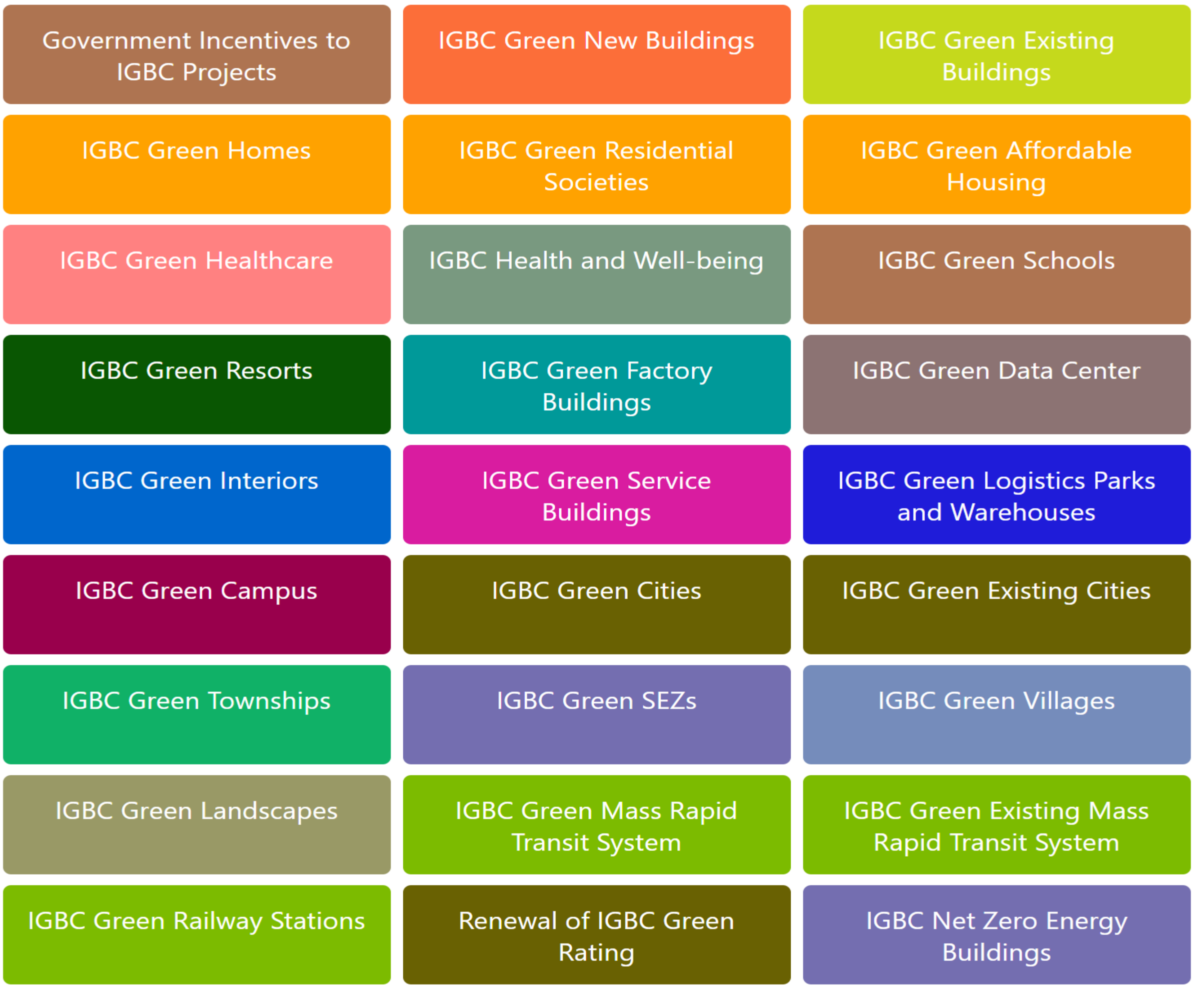

Figure 5.15: Different IGBC rating programs (Source: IGBC)

IGBC LEED India encompasses rating systems for:

- Existing Buildings (EB)
- New Construction (NC)
- Core and Shell (C&S)
- Green Homes

Examples of LEED building in India are.

1. ICT Green Center, Gurgaon
2. NEG Micon, Chennai-Gold Rated

5.4.3. BUREAU OF ENERGY EFFICIENCY (BEE)

BEE has developed its own building rating system with a scale ranging from 1 to 5 stars. The more stars, the higher the energy efficiency. They developed the EPI based on which buildings were rated. The unit of kilowatt-hour per square meter per year applies to the Reserve Bank of India buildings in Delhi and Bhubaneswar, the CII Sohrabji Godrej green business center and many other buildings that have received five-star BEE ratings. The architectural concept from scratch. Conventional houses with burnt red bricks and clay walls are a good example of energy-efficient structures that keep them cool in summer and warm in winter. Rural areas in India continue to use natural materials such as clay, wood, and jute rope to use this type of construction technology. Today, we have advanced technology to create smarter indoor temperature control systems, lighting systems, electricity and water supply, and waste generation. Green buildings may be a bit heavy, but they are good for the environment. In this rapidly changing world, we must implement technologies that can help us conserve precious natural resources and achieve true sustainable development.

CHAPTER 6
METHODOLOGY

6.1. GENERAL

The content below consists of the case study of CII Soharabji Godrej Green Business Centre which we have worked upon and analyzed.

6.2. METHODOLOGY

i. Reading research papers on Green buildings and Tall building design.
ii. Learning to use structural software STAAD Pro to design the building.
iii. Design a 10-story building in a hilly region and in a plain region using STAAD Pro. Then comparing their design.
iv. Learning how to use Revit software to design and analyze green buildings.
v. Site selection for the case study
vi. Working on case study
vii. Comparing the green building with conventional building
viii. Writing final report

6.3. CII SOHARABJI GREEN BUSINESS CENTRE, HYDERABAD

6.3.1. INTRODUCTION

The Soharabji Green Business Centre in Hyderabad is the first LEED Platinum Rated green Building in India which was then inaugurated on July 14, 2004.

Extensive energy modeling exercises were performed to orient the building to minimize heat input and have plenty of natural light. The building consolidates a few top-notch energy and environment friendly including sun-oriented PV frameworks, indoor air quality checking, a high proficiency HVAC framework, passive cooling system with wind tower, efficient glass, beautiful roof garden, rainwater collection, root zone treatment system, etc. The broad landscape also home to a variety of tree species, most of which are local and adapted to climatic conditions. Green buildings can save 50% of total energy consumption, 35% of energy consumption, and clean water and water consumption by 35%, and utilization 80% recyclable/recyclable materials.

Most importantly, the building has contributed to the widespread adoption of green buildings in India.

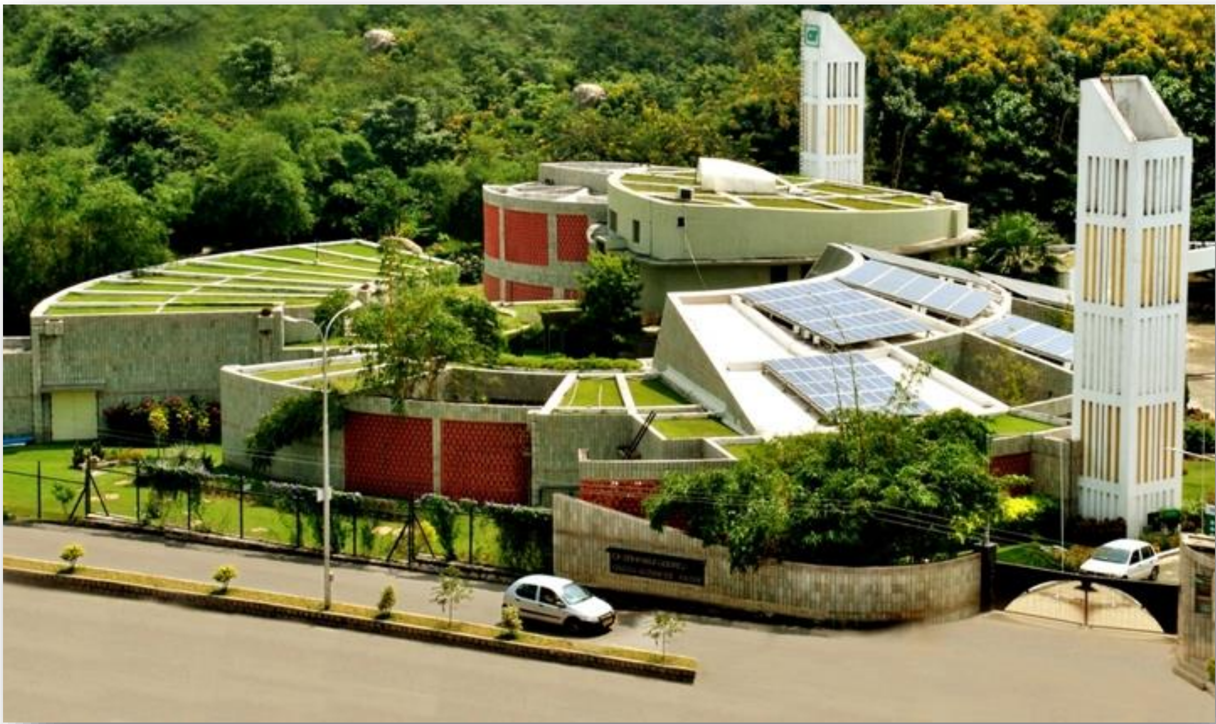

Figure 6.16: CII Soharabji Godrej Business Centre (Source: IGBC)

6.3.2. GREEN BUILDING FEATURES

1. Energy efficiency

- Use of Double-glazing
- Use of neutral glass to reduce heat gain.

- Use of CFC refrigerant in refrigerators and air conditioners.
- Online monitoring system to monitor the environment.
- Use of electric car for transport and travelling within the premise in helping in preventing pollution.
- Orientation for Maximum day lighting
- Operable windows and light controls for better day lighting and views
- Building layout ensures that 90% of spaces have daylight access and views to outside.
- Natural daylighting- no lights are used until late in the evening.
- Energy-efficient lighting systems through CFLs bulbs

2. Water efficiency

- Rainwater harvesting for external use like garden or car washing.
- Water-less urinals in men’s restroom
- Use of Water-efficient fixtures i.e., ultra-low and low-flow flush fixtures.
- Reducing irrigation and surface water runoff
- Zero Water discharge
- Treatment of all wastewaters biologically through Root Zone Treatment.

3. Minimum Disturbance to the Site

The design concept of the building was to minimize the interference to the surrounding environment. During the construction process, damage to the site was limited to 40 feet away from the supporting surface of the building. This preserved most of the existing flora and fauna and natural microorganisms in the area. Extensive erosion and sediment control measures were taken during the construction period to prevent the erosion of topsoil on the construction site during the construction period.

4. Sustainable Materials and Resources

- 80% of the materials used in the building are sourced within 500 miles from the project site.
- Most of the building material also uses domestic and industrial waste as a raw material in the manufacturing process.
- Fly-ash based bricks, glass, aluminum, and ceramic tiles, which contain consumer and industrial waste, are used in constructing the building to encourage the usage of recycled content.
- Even the office furniture's were made of wood pulp-based composite wood.

More than 50% of the construction waste is recycled within the building or sent to other sites.

5. Renewable Energy

20% of the building energy requirements are catered to by solar PV ***(photovoltaics)***. The solar PV has an installed capacity of 23.5 kW.

The solar panels are placed on the eastern side such that it is sloping which helps production of energy throughout the day.

Figure 6.17: Solar Panels (Source: IGBC)

6. Indoor Air Quality

- Indoor air quality is continuously monitored, and a minimum fresh air is pumped into the conditioned spaces at all times.
- Fresh air is also drawn into the building through ***wind towers*** with evaporative cooling.
- The use of low volatile organic compound (VOC) paints and coatings, adhesives, sealants, and carpets also help to improve indoor air quality.

7. Health and well-being.

- Consider healthy lighting, color and sound controlled temperature and humidity and good indoor air quality to enhance the living environment.
- Using pollution fighting indoor plants
- Design safe and user-friendly space

8. Use of traditional Jali.

Jali walls are screens with perforations which is made from lattice or stone and other materials. They provide various functions such as lowering the temperature.

Jali walls are extensively used in CII-Soharabji Godrej Green Business Centre.

- to prevent glare of direct sunlight and heat gain while ensuring adequate day lighting and views.
- The rainwater can seeps through the openings which can be used by the plants
- Throw patterns of light and shadows on the floor enhancing aesthetic.

Figure 6.18: Traditional Jalli walls (Source: IGBC)

9. Landscape and vegetation

Large vegetative spaces with green covers which act as a modifier of microclimate. The building environment is surrounded by vegetation like canopy trees, large trees, shrubs, understory trees, and ground cover each of which provides various benefits to the environment and the people.

Unique species of plants are also found like Ashoka tree, coral jasmine, mimosa plant, spear mint, Basil, Sarpagandha and many more.

10. The courtyard

The courtyards act as "light wells," illuminating adjacent work areas. When this light is not sufficient, sensors trigger the deployment of efficient electric lights. Dimmers automatically control the illumination levels, turning the lights off when they are unnecessary. Also, occupancy sensors prevent a light from being switched on at an unoccupied workstation. Courtyard function as a convective thermostat and gives protection from extremes of weather.

Figure 6.19: Courtyard (Source: IGBC)

11. Roof Garden

- covers 60% of building area.
- helps in absorbing heat and radiating it into the building.
- also helps in absorbing rainwater for rainwater harvesting.

CHAPTER 7
PROGRESS REPORT

7.1. GENERAL

This chapter contains the progress report and the work that have been completed.

7.2. DESIGN OF 10 STORY RESIDENTIAL BUILDING FOR EARTHQUAKE ZONE-I

In this study, we modeled and designed a 10-story building having plan dimensions of 18.288 m (60 feet) x 14.6304 m (48 feet) and with story height of each of the 10 floors as 3m, hence obtaining the total height of the building as 30m.

7.2.1. SPECIFICATIONS

Earthquake Zone	- I
Zone Factor Value (Z)	- 0.075
Soil Type	- Hard (1)
Basic Wind Speed (Vb)	- 33m/s
Location	- Mysore
Importance Factor (I)	- 1
Damping Ratio (DM)	- 0.05
Response Reduction Factor (RF)	- 1
Unit Weight of Concrete	- 25KN/m^3
Unit Weight of Wall	- 20KN/m^3
The thickness of the main wall	- 0.23m
Height of parapet wall	- 1.2m

The thickness of parapet wall - 0.225m

The thickness of partition wall - 0.115m

The thickness of floor finish - 0.05m

Live Load on each floor - 2KN/m

Unit weight of floor finish - 20KN/m^3

7.2.2. LOAD CALCULATIONS

1.) Main wall weight = 0.23*3*20 =13.8 KN/m (UDL)

2.) Partition wall weight = 0.115*3*20 = 6.9 KN/m (UDL)

3.) Parapet wall weight = 0.225*1.2*20 = 5.4 KN/m (UDL)

4.) Slab weight= 0.12*25 = 3 KN/m^2

5.) Floor Finish weight = 0.05*20 = 1KN/m^2

7.2.3. LOAD COMBINATIONS

Table 7.3: Load combination Earthquake zone I

S.NO.	Load Combinations
1.	1.5*(DL +LL)
2.	1.2*(DL+LL+WLX)
3.	1.2*(DL+LL+WLZ)
4.	1.2*(DL+LL-WLX)
5.	1.2*(DL+LL-WLZ)
6.	1.2*(DL+LL-EQX)

7.	1.2*(DL+LL-EQZ)
8.	1.2*(DL+LL-EQX)
9.	1.2*(DL+LL-EQZ)
10.	1.5*(DL+WLX)
11.	1.5*(DL+WLZ)
12.	1.5*(DL-WLX)
13.	1.5*(DL-WLZ)
14.	1.5*(DL+EQX)
15.	1.5*(DL+EQZ)
16.	1.5*(DL-EQX)
17.	1.5*(DL-EQZ)
18.	0.9*DL+1.5*EQX
19.	0.9*DL+1.5*EQZ
20.	0.9*DL-1.5*EQX
21.	0.9*DL-1.5*EQZ

7.2.4. STRUCTURE SPECIFICATIONS

Number of joints = 1051

Number of members=950

Number of supports=37

Number of plates=660

Number of surfaces=3

Number of solids=0

Total Primary load cases=6

Total Primary load combinations=21

Total Degree of freedom=6084

7.2.5. MATERIAL SPECIFICATIONS

Grade of concrete - M25

Grade of steel - Fe 500

Secondary Bars - Fe 250

7.2.6. DIMENSIONS

Beam size- 0.3m*0.23m

Column size- 0.6m*0.6m (Floor- 1to2), 0.45m*0.5m (Floor- 3to10)

Slab Thickness- 0.12m

Surface Thickness- 0.23m

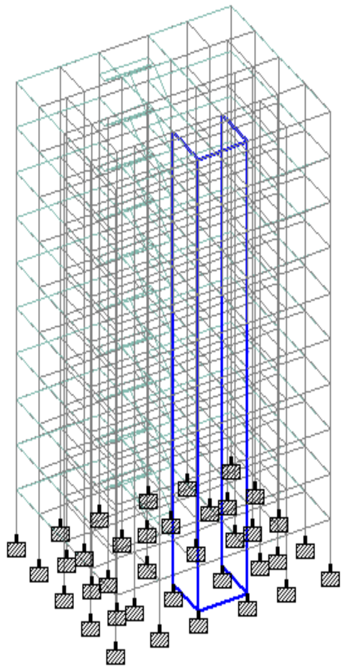

Figure 7.20: 3D structure model EQ Zone-I

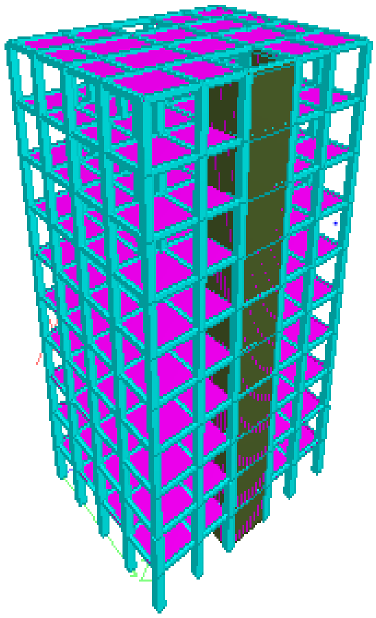

Figure 7.21: 3D Rendered view EQ Zone-I

7.3. DESIGN OF 10 STORY RESIDENTIAL BUILDING FOR EARTHQUAKE ZONE-IV

In this study we modeled and designed a 10-story building having plan dimensions of 18.288 m (60 feet) x 14.6304 m (48 feet) and with story height of each of the 10 floors as 3m, hence obtaining total height of building as 30m.

7.3.1. SPECIFICATIONS

Earthquake Zone	- IV
Zone Factor Value (Z)	-0.24
Soil Type	- Medium (2)
Basic Wind Speed (Vb)	-39 m/s
Location	- Shimla
Importance Factor (I)	- 1
Damping Ratio (DM)	- 0.05
Response Reduction Factor (RF)	- 1
Unit Weight of Concrete	- 25KN/m^3
Unit Weight of Wall	- 20KN/m^3
The thickness of the main wall	- 0.23m
Height of parapet wall	- 1.2m
The thickness of parapet wall	- 0.225m
The thickness of partition wall	- 0.115m
The thickness of floor finish	- 0.05m
Live Load on each floor	- 2KN/m

Unit weight of floor finish -20KN/m^3

7.3.2. LOAD CALCULATIONS

1.) Main wall weight = 0.23*3*20 =13.8 KN/m (UDL)

2.) Partition wall weight = 0.115*3*20 = 6.9 KN/m (UDL)

3.) Parapet wall weight = 0.225*1.2*20 = 5.4 KN/m (UDL)

4.) Slab weight= 0.12*25 = 3 KN/m^2

5.) Floor Finish weight = 0.05*20 = 1KN/m^2

7.3.3. LOAD COMBINATIONS

Table 7.4: Load combination Earthquake zone-IV

S.NO.	Load Combinations
1.	1.5*(DL +LL)
2.	1.2*(DL+LL+WLX)
3.	1.2*(DL+LL+WLZ)
4.	1.2*(DL+LL-WLX)
5.	1.2*(DL+LL-WLZ)
6.	1.2*(DL+LL-EQX)
7.	1.2*(DL+LL-EQZ)
8.	1.2*(DL+LL-EQX)
9.	1.2*(DL+LL-EQZ)
10.	1.5*(DL+WLX)

11.	1.5*(DL+WLZ)
12.	1.5*(DL-WLX)
13.	1.5*(DL-WLZ)
14.	1.5*(DL+EQX)
15.	1.5*(DL+EQZ)
16.	1.5*(DL-EQX)
17.	1.5*(DL-EQZ)
18.	0.9*DL+1.5*EQX
19.	0.9*DL+1.5*EQZ
20.	0.9*DL-1.5*EQX
21.	0.9*DL-1.5*EQZ

7.3.4. STRUCTURE SPECIFICATIONS

Number of joints = 1051

Number of members=950

Number of supports=37

Number of plates=660

Number of surfaces=6

Number of solids=0

Total Primary load cases=6

Total Primary load combinations=21

Total Degree of freedom=6084

```
P R O B L E M   S T A T I S T I C S
-----------------------------------

NUMBER OF JOINTS       1051  NUMBER OF MEMBERS     950
NUMBER OF PLATES        660  NUMBER OF SOLIDS        0
NUMBER OF SURFACES        6  NUMBER OF SUPPORTS     37


SOLVER USED IS THE IN-CORE ADVANCED MATH SOLVER

TOTAL      PRIMARY LOAD CASES =      6, TOTAL DEGREES OF FREEDOM =    6084
TOTAL LOAD COMBINATION  CASES =     21  SO FAR.
```

Figure 7.22: Structure specification

7.3.5. MATERIAL SPECIFICATIONS

Grade of concrete – M35

Grade of steel - Fe 500

Secondary Bars - Fe 25

7.3.6. DIMENSIONS

Beam size- 0.5m*0.45m

Column size- 0.75m*0.75m (Floor- 1to2), 0.55m*0.6m (Floor- 3to10)

Slab Thickness- 0.12m

Surface Thickness- 0.3m

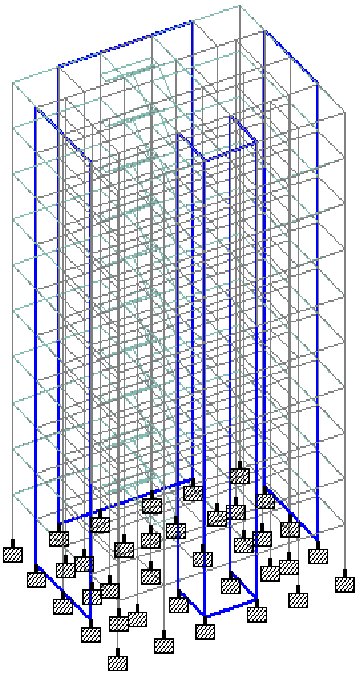

Figure 7.23: 3D structure model EQ Zone-IV

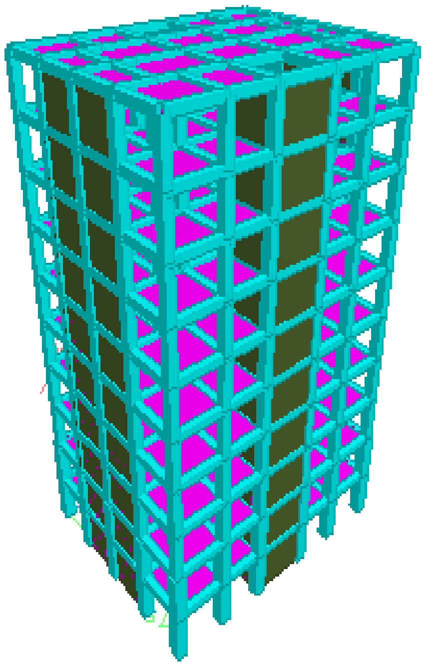

Figure 7.24: 3D Rendered view EQ Zone-IV

CHAPTER 8

RESULTS AND DISCUSSIONS

8.1. GENERAL

On analysis and design of the 10-story building in the two earthquake zones (Earthquake Zone-I and Earthquake Zone-IV) the following results were obtained, and we made the comparisons as given below.

8.2. TAKE OFF QUANTITY FOR EARTHQUAKE ZONE – I

Total Quantity of concrete in Slab, beam, a column for structure in Earthquake Zone-I =394.6 m^3

8.2.1. THE TOTAL WEIGHT OF STEEL USED.

Table 8.5: Total weight of steel used in zone-I.

S. No.	Bar Diameter in mm	Weight of Steel in Newton
1.)	8 mm	90650
2.)	10 mm	38405
3.)	12 mm	208771
4.)	16 mm	4755
5.)	20 mm	2949
	Total =	345530

8.3. TAKE OFF QUANTITY FOR EARTHQUAKE ZONE – IV

Total Quantity of concrete in Slab, beam, a column for structure in Earthquake Zone-IV = 728.0 m^3

8.3.1. TOTAL WEIGHT OF STEEL USED.

Table 8.6: Total weight of steel used in Zone-IV.

S. No.	Bar Diameter in mm	Weight of Steel in Newton
1.)	8 mm	68173
2.)	10 mm	58868
3.)	12 mm	339564
4.)	16 mm	140966
5.)	20 mm	148608
6.)	25 mm	72715
7.)	32 mm	35679
8.)	40 mm	9289
	Total =	873862

```
************** CONCRETE TAKE OFF **************
      (FOR BEAMS, COLUMNS AND PLATES DESIGNED ABOVE)
NOTE: CONCRETE QUANTITY REPRESENTS VOLUME OF CONCRETE IN BEAMS, COLUMNS, AND PLATES DESIGNED ABOVE.
      REINFORCING STEEL QUANTITY REPRESENTS REINFORCING STEEL IN BEAMS AND COLUMNS DESIGNED ABOVE.
      REINFORCING STEEL IN PLATES IS NOT INCLUDED IN THE REPORTED QUANTITY.

TOTAL VOLUME OF CONCRETE =       394.6 CU.METER

                 BAR DIA         WEIGHT
                 (in mm)         (in New)
                --------         --------
                    8              90650
                   10              38405
                   12             208771
                   16               4755
                   20               2949
                              ------------
                  *** TOTAL=      345530
```

Figure 8.25: Take-off Quantity for structure in Earthquake Zone-1

```
************** CONCRETE TAKE OFF **************
      (FOR BEAMS, COLUMNS AND PLATES DESIGNED ABOVE)
NOTE: CONCRETE QUANTITY REPRESENTS VOLUME OF CONCRETE IN BEAMS, COLUMNS, AND PLATES DESIGNED ABOVE.
      REINFORCING STEEL QUANTITY REPRESENTS REINFORCING STEEL IN BEAMS AND COLUMNS DESIGNED ABOVE.
      REINFORCING STEEL IN PLATES IS NOT INCLUDED IN THE REPORTED QUANTITY.

TOTAL VOLUME OF CONCRETE =       728.0 CU.METER

                 BAR DIA         WEIGHT
                 (in mm)         (in New)
                --------         --------
                    8              68173
                   10              58868
                   12             339564
                   16             140966
                   20             148608
                   25              72715
                   32              35679
                   40               9289
                              ------------
                  *** TOTAL=      873862
```

Figure 8.26: Take-off Quantity for structure in Earthquake Zone-1

8.4. RESULTS FROM THE CASE STUDY

From the result it had been found out that though the initial cost of green building may be high, in the long run, it provides cost saving due to energy saving and no or less maintenance cost. It also provided lots of benefits in overall performance of the building and the environment.

8.4.1. CII-SOHARABJI GODREJ BUSINESS CENTRE

Benefits achieved so far:

- ✓ Over 120,000 kWh of energy savings per year
- ✓ Potable water savings to tune of 20-30%
- ✓ Excellent indoor air quality
- ✓ 100%-day lighting
- ✓ Higher productivity of occupants
- ✓ Energy savings of 88 percent
- ✓ Vegetation lost to the built area replaced by roof gardens.
- ✓ 35 percent reduction of municipally supplied potable water.
- ✓ 77 percent of the building materials use recycled content.

8.4.2. COMPARISON OF CONVENTIONAL AND GREEN BUILDING

The below table will show the CII- Soharabji Godrej Business Centre being compared with normal conventional building.

Table 7.7: Comparison of Green building and Normal building

	Green Building (IGBC)	Conventional building
Windows and openings	Insulated double glazed glass	Aluminum
Light fixtures	Natural daylight CFLs	Tube light
Plumbing fixtures	Normal fixtures	Ultra-low and low flux fixtures
Paint finishes	Plastic VOC	Plastic Non-VOC
Walls	Normal brick walls	Fly ash bricks Traditional Jali
Roofs	Green roof, Roof garden	Normal roof
Rainwater harvesting	Practiced	Not provided
Orientation	Orientated for maximum daylight	Not considered
Landscape	surrounding space covered with vegetation like trees	Not really considered
Energy source	Installation of solar panels	Use electricity
Waste management	Recycled and reused	Dispose of waste
Water management	Rainwater harvesting Wastewater treated and reused	No treatment of wastewater
Pavement	Permeable pavement	Non-permeable pavement
Construction materials	Sustainable materials, Locally available materials	Imported materials

CHAPTER 9
SUMMARY AND CONCLUSIONS

9.1. GENERAL

This chapter contains the overall summary of the project that we have worked upon. It contains all the conclusion of the analysis and understanding of the work done.

9.2. CONCLUSION

This was a great learning experience for both of us. We learned to use a new software i.e., STAAD Pro, for modeling, analyzing, and designing buildings and structures. Here we analyzed and designed a 10-story building for earthquake zone-I and earthquake zone- I, and we compared their design results i.e., we compared their design take-off values for concrete volume and the total weight of steel.

We observed that the design of building in earthquake zone-IV required more volume of concrete and more weight of steel as compared to the building designed in earthquake zone-I.

This is because for tall structures the lateral loads have a significant impact on the design of structures in addition to the gravity loads. The dynamic forces areas important to be considered. So, despite the same plan area and same story model, the building in earthquake zone-IV requires more material to construct compared to the building in earthquake zone-I. Hence, it costs more to construct a building in earthquake zone-IV as compared to earthquake zone-I. This is as it requires more strength to oppose the highly impacting dynamic forces in earthquake zone-IV whereas the dynamic earthquake force in earthquake zone-I is minimal.

As the changing world continues to pose extensive threat to the dwindling natural resources and the surrounding environment because of the construction processes, it calls for an energy efficient design in building. Energy-efficient buildings as the name suggests, are designed in a way that use energy efficiently.

In this paper, detailed strategies to design green building is outlined which includes use of natural renewable resources, sustainable materials, water conservation, environmental protection, waste management, and passive solar technique.

We also worked upon a case study IGBC center building and compared it with a conventional building. The results showed that green building offer far more positive outcomes compared to the normal building in terms of energy consumption, indoor air quality, environmental impact and even wellbeing of the people.

9.3. FUTURE SCOPE OF THE PROJECT

Green building is growing in importance in today’s world where there in increase in construction process due to population explosion. The increase in modern construction to meet peoples demand for living spaces and working places are causing adverse effects to the natural environment and the health of the people.

So, the concept green building can be the solution in the rising crises of energy and resource depletion.

In the growing world of chaos green building can provide a better way of living for the people with better environment.

Especially, in a country like Bhutan where the conservation of natural resources is one of the pillars of GNH (Gross National Happiness), moving towards green design practice can fulfill the vision of the GNH while also provide benefits socially, economically, and individually as a whole. However, since the concept of energy efficiency is less known in the country, the project can provide an overview of the concept creating awareness.

Moreover, even in developed nation like India, there is growing numbers in green building across the country and so the architectures and builders should be well known about the importance and details of green architecture.

REFERENCES

[1] M. M. Ali, K. Al-Kodmany, "Tall Buildings and Urban Habitat of the 21st Century," in *Buildings*, 2012.

[2] K. R. Raju, M. I. Shereef, N. R. Iyer, S. Gopalakrishnan, "Analysis and Design of RC Tall Building Subjected to Wind and Earthquake Loads," in *National Conference on Emerging Technologies in Civil Engineering (ETCE'13),* 2013**.**

[3] A. P. Patil, A. A. Choudhari, P. A. Mudhole, V. V. Patole, A. D. Dange, S. K. Chendake, "Design & Analysis of Multi Storeyed Building (G+10) By Using Staad Pro V8i (Series 4)," in *International Journal of Advanced Engineering, Management and Science (IJAEMS),* 2017.

[4] S.V. B. Reddy, V. Madhu, "Comparative Study on Design Results of a Multi-storied Building using STAAD PRO and ETABS for Regular and Irregular Plan Configuration," in *International Journal of Applied Engineering Research*, 2018.

[5] U. A. Umar, M. F. Khamidi, H. Tukur, "Sustainable building material for green building construction, conservation and refurbishing," in *Management in Construction Research Association (MiCRA),* 2012.

[6] B. Neyestani, "A Review on Sustainable Building (Green Building)," in *Social Science Research Network (SSRN),* 2017.

[7] S. K. Sharma, "Zero energy building envelope components: A review," in *International Journal of Engineering Research and Applications (IJERA).* 2013.

[8] M. Khoi Le, "AutoDesk Green Building Studio for an energy-efficient, sustainable building," in *HAMK University of Applied Science,* 2014.

[9] N. Sharma, Er. B. Kaur, Er. S. Salhotra, "Green building based on Building Information Modelling," in *International Research Journal of Engineering and Technology (IRJET),* 2018.

[10] Dr. Siba, A.A., and Prof. Chris, T. (March 2014). "Building's Energy Efficiency Codes: A Literature Review." *International Journal of Applied Science and Technology, Vol.4, No.2.*

[11] S. Sharifi, "5 ways Revit support green building," 2018.

[12] Shristi Khosla, S.K. Singh, “Energy Efficient Buildings,” in *International Journal of Civil Engineering Research*, 2014.

[13] F. Celina, “Energy analysis with Revit insight and green building studio.” in *Autodesk University*, 2020.

[14] Izzet Yüksek, Tülay Tikansak Karadayi, “Energy-Efficient Building Design in the Context of Building Life Cycle,” in *WEB of Science*, 2017.

[15] Mohmed Solla, Lokman Hakim Ismail, Riduan Yunus, “Investigation on the potential of integrating BIM into Green Building Assessment Tools,” *Journal of Engineering and Applied Sciences*, 2016.

[16] A. Balali, A. Valipour, “Identification and selection of building façade's smart materials according to sustainable development goals,” in *Sustainable Materials and Technologies*, 2019.

[17] M. A. Khan, M. N. Khan, “Comparison of Indigenously developed Green Building Rating System - Outlining the Subtle Distinct Features,” in *International Journal for Research in Applied Science & Engineering Technology (IJRASET)*, 2020.

[18] Chenari, B., Carrilho, J. D. & da Silva, M. G. (2016). “Towards sustainable, energy-efficient and healthy ventilation strategies in buildings, A review,” in *Renewable and Sustainable Energy Reviews*, 59, pp.1426-1447.

[19] Chiras, D. D. (2002). “The solar house: passive heating and cooling,” in *Chelsea Green Publishing*, 2002, Volume. 1, pp. 189-200.

[20] “10 Benefits of Green Building.” *New School of Architecture and Design*.

<https://newschoolarch.edu/blog/10-benefits-of-green-building/>

[21] Nick, G., and Ben, G. “Building Orientation for Optimum Energy.” *International Association of Certified Home Inspectors*

<*https://www.nachi.org/building-orientation-optimum-energy.htm*>

[22] Geetha, N. B., & Velraj, R. (2012). “Passive cooling methods for energy efficient buildings with and without thermal energy storage–A review,” in *Energy Education Science and Technology Part A: Energy Science and Research*, 29(2) pp. 913-946.

[23] Gratia E, Bruyère I, De Herde. (2004). "How to use natural ventilation to cool narrow office buildings," in *Build Environ*, Volume 39, pp. 1157–1170.

[24] "Bhutan Green Building Design Guidelines." (2014). MoWHS <https://www.mowhs.gov.bt/wp-content/uploads/2014/05/Bhutan-GREEN-Building-Design-Guidelines-PDF-for-website-FI.pdf>

[25] "LEED RATING SYSTEM", in *Expanded Shale, Clay and Slate Institute (ESCSI)*

<https://www.escsi.org/sustainability-without-compromise/leed-rating-system/>

[26] "Green Building 101: What is LEED?" (Dec. 16, 2020). USGBC,

<https://www.usgbc.org/articles/green-building-101-what-leed>

[27] "IGBC Rating System." IGBC,

<https://igbc.in/igbc/redirectHtml.htm?redVal=showratingSysnosign>

[28] Patricia.A.(August 23, 2019). "What are the Green Building Rating System in India?"

<https://media.biltrax.com/what-are-the-green-building-rating-system/>

[29] Stephanie, V. (August 8, 2019). "Green Building Standards and Certification Systems." WBDG (Whole Building Design Guide),

<https://www.wbdg.org/resources/green-building-standards-and-certification-systems#:~:text=Green%20building%20rating%20or%20certification,specific%20environmental%20goals%20and%20requirements.>

[30] Katherine, S. (November 30, 2018). "Energy Efficient Windows." Build It,

<https://www.self-build.co.uk/energy-efficient-windows/>

[31] Sunanda, S. (August 2012). "CII-Soharabji Godrej Business Centre Case Study." StuDocu,

<https://www.studocu.com/in/document/amity-university/master-in-business-management/tutorial-work/cii-sohrabji-godrej-green-business-centre-case-study/5555868/view>

[32] "LEED India+Case Study: CII Soharabji Godrej, ITC Green Centre." (Sep. 01, 2014),

<*https://www.slideshare.net/baburajiv2007/leed-india-case-study-cii-sohrabji-godrej-itc-green-center*>

[33] "Bhutan Building Energy Efficiency Study." (Sep. 2015). Department of Renewable Energy, Ministry of Economic Affairs,

<*https://www.moea.gov.bt/wp-content/uploads/2018/07/Building-energy-efficiency-Main-Report.pdf*>

[34] Don, P. (August 09, 2016). "Sun Control and Shading Devices." WBDG,

<*https://www.wbdg.org/resources/sun-control-and-shading-devices*>

[35] Dhivya, RK. (December12, 2020). "Elements of Site and Its Importance in Architectural Design." *International Journal of Creative Research Thoughts (IJCRT), Vol.8.*

<https://www.ijcrt.org/papers/IJCRT2012353.pdf>

[36] < *https://www.slideshare.net/RajSingh326/green-building-vs-conventional-building*>

JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY, WAKNAGHAT

PLAGIARISM VERIFICATION REPORT

Date: 17 May 2021

Type of Document (Tick): PhD Thesis | M.Tech Dissertation/ Report | B.Tech Project Report ✔ | Paper

Name: Tshechik Dema, Gunjan Chauhan **Department:** Civil Engineering **Enrolment No** 171679, 171610

Contact No. +97577461533, 8219191060 **E-mail.** 171679@juitsolan.in, 171610@juitsolan.in

Name of the Supervisor: Dr. Ashok Kumar Gupta and Mr. Chandra Pal Gautam

Title of the Thesis/Dissertation/Project Report/Paper (In Capital letters):

DESIGN OF 10 STORY BUILDING IN EARTHQUAKE ZONE-I AND ZONE-IV WITH ANALYSIS OF GREEN BUILDING

UNDERTAKING

I undertake that I am aware of the plagiarism related norms/ regulations, if I found guilty of any plagiarism and copyright violations in the above thesis/report even after award of degree, the University reserves the rights to withdraw/revoke my degree/report. Kindly allow me to avail Plagiarism verification report for the document mentioned above.

Complete Thesis/Report Pages Detail:

- Total No. of Pages = 80
- Total No. of Preliminary pages = 12
- Total No. of pages accommodate bibliography/references = 4

(Signature of Student)

FOR DEPARTMENT USE

We have checked the thesis/report as per norms and found **Similarity Index** at ……28……….(%). Therefore, we are forwarding the complete thesis/report for final plagiarism check. The plagiarism verification report may be handed over to the candidate.

(Signature of Guide/Supervisor) **Signature of HOD**

FOR LRC USE

The above document was scanned for plagiarism check. The outcome of the same is reported below:

Copy Received on	Excluded	Similarity Index (%)	Generated Plagiarism Report Details (Title, Abstract & Chapters)	
17 May, 2021	• All Preliminary Pages • Bibliography/Images/Quotes • 14 Words String	28%	Word Counts	11963
Report Generated on			Character Counts	66138
17 May, 2021		**Submission ID**	Total Pages Scanned	74
		1587730299	File Size	14 MB

Checked by
Name & Signature **Librarian**

……………………………………………………………………………………

Please send your complete thesis/report in (PDF) with Title Page, Abstract and Chapters in (Word File) through the supervisor at plagcheck.juit@gmail.com