DEVELOPMENT OF A SUSTAINABLE AND LOW CARBON EMISSION SOCIETY

A Thesis
Submitted in partial fulfillment of the requirements for the award of the Degree of

BACHELOR OF TECHNOLOGY
IN
CIVIL ENGINEERING

By

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MD. FARHAN (BTECH/15171/18)

Under the guidance of

Dr. Anish

DEPARTMENT OF CIVIL ENGINEERING
BIRLA INSTITUTE OF TECHNOLOGY
MESRA, OFF CAMPUS PATNA
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DECLARATION CERTIFICATE

This is to certify that the work presented in the project report entitled **"DEVELOPMENT OF SUSTAINABLE AND LOW CARBON EMISSION SOCIETY"** in partial fulfillment of the requirement for the award of Degree of **Bachelor of Technology in Civil Engineering** of **Birla Institute of Technology, Mesra, Ranchi** is an authentic work carried out under my supervision and guidance.

Date:

(Dr. Anish)
Department of Civil Engineering
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CERTIFICATE TO APPROVAL

The forgoing project entitled **“DEVELOPMENT OF SUSTAINABLE AND LOW CARBON EMISSION SOCIETY”** is hereby approved as a credible study of a research topic and has been presented in a satisfactory manner to warrant its acceptance as a prerequisite to the degree for which it has been submitted.

It is understood that by this approval, the undersigned do not necessarily endorse any conclusion drawn or opinion expressed therein, but approve the project for the purpose for which it is submitted.

(Internal Examiner) (External Examiner)

(Head of Department)

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ABSTRACT

A low carbon society is a society where people collaborate to reduce the amount of carbon dioxide emissions, whether emitted from the goings-on of daily life or industrial and factory processes.

In the coming years, the world will be facing challenges in economic development with the limited resources available, minimal externalities, and large uncertainties to climate. Low-carbon society scenarios visualize social, economical, and technological transitions through which societies respond to climate change.

This project assesses the designing of structures, STP, natural lighting, and ventilation with zero carbon for transiting to a low-carbon future in India. An integrated modeling framework is used for delineating and assessing the alternative development pathways having equal cumulative CO2 emissions during the first half of the 21st century. The pathway assumes a conventional development pattern together with the use of software like AutoCAD, STAAD.Pro and design-builder to design a society in which measurement and control of energy, carbon, lighting, and comfort are ascertained. A comparative analysis of the alternative development strategies is presented on multiple indicators such as energy, natural resources, and carbon emission, and hence conclusions are drawn.

Keywords: low carbon emission, society, sustainable, lighting, ventilation, STP, DesignBuilder.

ANNEXURE – A: SYMBOLS

c/c	-	centre to centre
d	-	diameter
deg	-	degree
E	-	East
Fe	-	Ferrous material
ft	-	feet
f_y	-	Yield strength of steel
L/10	-	Length/10
L/6	-	Length/6
lm	-	Luminescence
l_x	-	Shorter span of slab
l_y	-	Longer span of slab
m^2	-	metre^2
mg	-	milligram
M_u	-	Bending Moment
N	-	North
P_u	-	Axial load
Q	-	Discharge
r	-	radius
V	-	Volume
W	-	Watt

ANNEXURE – B: ABBREVIATIONS

AVTG	-	Actual Visible Transmittance Glazing
BHK	-	Bedroom, Hall and Kitchen
BOD	-	Biochemical Oxygen Demand
C.G.	-	Centre of Gravity
CAD	-	Computer Aided Design
CFD	-	Computational Fluid Dynamics
CO2	-	Carbon Dioxide
CO2e	-	Carbon Dioxide Equivalent
EWS	-	Economically Weaker Section
FAR	-	Floor Area Ratio
GHG	-	Green House Gas
GWP	-	Global Warming Potential
HVAC	-	Heating, Ventilation and Air-conditioning
IAQ	-	Inside Air Quality
IGBC	-	Indian Green Building Council
KLD	-	Kilo Litres per Day
LIG	-	Low Income Group
LPCD	-	Litres per Capita per Day
MLD	-	Mega Litres per Day
MLSS	-	Mixed Liquor Suspended Solids
NBC	-	National Building Code
RCC	-	Reinforced Cement Concrete
RERA	-	Real Estate Regulatory Authority
STAAD	-	Structural Analysis and Design
STP	-	Sewage Treatment Plant
WHO	-	World Health Organization

ANNEXURE – C: TERMINOLOGIES

Apartment building

It means a building having four or more dwelling units in a block.

Apartment or flat

It means a dwelling unit in a building.

Authority

Authority means the Chairman of the respective Planning Authority. In case of areas not covered under the Planning Authority, it shall be the Municipal Commissioner, Executive Officer of the respective Municipalities. The powers and responsibilities of the Authority under these bye-laws cannot be delegated unless specifically provided for in these bye-laws, the Act, the rules, or unless notified by the Government.

Builder

Builder means an applicant, land owner, contractor, holder of the power of attorney of the land owner, partnership, trust, or company that has responsibility for construction, leasing, selling, or disposing otherwise of a building for residential and other purposes and duly registered by the Authority.

Building

Building means any structure or erection or part of a structure or erection which is intended to be used for residential, commercial, industrial, or any other purpose whether in actual use or not, and in particular.

Building Height

Building Height means the vertical distance measured in the case of flat roofs, from the average level of the centre line of the adjoining street to the highest point of the building adjacent to the street; and in the case of pitched roofs, up to the point where the external surface of the outer wall intersects the finished surface of the sloping roof and in the case of gables facing the road, the mid- point between the eaves level and the ridges. If the building does `level the ground around and contiguous to the building;

Built-up Area

Built-up Area means the total covered areas on all floors of immovable property.

Carbon Footprint

It is the total greenhouse gas (GHG) emission caused by an individual, event, organisation, service, place, or product, expressed as carbon dioxide equivalent (CO2e).

NOTE: CO2e: It is a metric measure used to compare the emissions from various greenhouse gases based on basis of their Global Warming Potential (GWP), by converting the amount of CO2 with the same global warming potential.

Carpet Area

Carpet Area means the net usable floor area of an immovable property, excluding the area covered by the walls and common area.

Commercial building

Any piece of a building used for business operations and activities.

Covered Area

Covered Area means in respect of the ground floor, the area covered immediately above the plinth level by the building but does not include the open space covered by

i. garden, rockery, well and well-structures, rainwater harvesting structures, plant nursery, water pool (if uncovered), platform round a tree, tank, fountain, bench, chabutara with open top unenclosed on sides by walls, boundary wall, swing, and area covered by chhajja without any pillars, etc touching the ground;
ii. drainage culvert conduit, catch-pit, gully pit, inspection chamber, gutter and the like; and
iii. compound wall, gate, slide/ swing door, canopy, and areas covered by chhajja or similar projections and staircases which are uncovered and open at least on three sides and also open to the sky.

Drain

Drain means a line of pipes including all fittings and equipment such as manholes, inspection chambers, traps, gullies, and floor traps, used for the drainage of a building or several buildings, or yards appurtenant to the buildings within the same cartilage and includes open channels used for conveying surface water.

Drainage

Drainage means the removal of any liquid by a system constructed for the purpose.

EWS House

EWS House means a house or dwelling unit intended for Economically Weaker Sections with a maximum built-up area of 32 sq. mtr or as decided by the State Government.

EWS Plot

EWS Plot means a residential plot intended for Economically Weaker Sections having a maximum plot area of 48 sq. mtr or as decided by the State Government.

Floor

Floor means the lower surface in a storey on which one normally walks in a building.

Floor Area Ratio (FAR)

Floor Area Ratio (FAR) means the quotient obtained by dividing the total covered area on all floors by the area of the plot.

Footing

Footing means the part of a structure, which is in direct contact with the ground and transmitting loads to the ground.

Foundation

Foundation means that part of a structure, which is indirect contact with and meant for transmitting loads to the ground.

Ground Floor

Ground Floor shall mean storey, which has its floor surface nearest to the ground around the building.

Institutional building

Any structure that fulfills the requirement of healthcare, education, recreation or public works.

Layout

The layout shows the plan of its foundation on the ground surface according to its drawings.

LIG House

LIG House means a house or dwelling unit intended for low-income groups with a built-up area of maximum 48 sq. mtr or as specified by the State Government.

LIG Plot

LIG Plot means a residential plot intended for low-income groups with a plot area of maximum 60 sq. mtr or as specified by the State Government.

Net Zero

It is the balance between the amount of greenhouse gas produced and the amount removed from the atmosphere.

Owner

Owner means a person, group of persons, a company, trust, Institute, Registered body, State or Central Government and its departments, undertakings, and the like in whose name the property stands registered in revenue records.

Partition

Partition means an interior non-load bearing wall, one storey or part of a storey in height.

Plan

Set of drawings (2-D) used to describe a place or object, or to communicate building or fabrication instructions.

Plantation

Plantation means plantation of plants and trees.

Recreational building

Any building used for recreational purposes including theatre, stadium, gymnasium, amusement park, etc.

Residential Building

Residential building refers to a building in which sleeping accommodation is provided for normal residential purposes with or without cooking or dining or both facilities and includes one or two or multi-family dwelling dormitories, apartment houses, flats, and hostels.

Residential Society

According to the National Building Code, residential buildings are constructions 'in which sleeping accommodation is provided for normal residential purposes, with or without cooking or dining or both facilities, except any building classified under Group C'.

Road

Road means any access viz. highway, street, lane, pathway, alley, or bridge, whether a thoroughfare or not, over which the public have right of passage or access or have passed and had access uninterruptedly for a specified period and includes all bunds, channels, ditches, storm water drains, culverts, side tracks, traffic islands, road side trees and hedges, retaining walls, fences barriers, and railings within the road line.

Room Height

Room Height means the vertical distance measured from the finished floor level to the finished ceiling.

Schedule

Schedule means a Schedule appended to these bye-laws.

Site

Site means a parcel or piece of land enclosed by definite boundaries.

Ventilation

Ventilation means the supply of outside air into a building through a window or other openings due to the wind outside and convection effects arising from temperature, or vapor pressure differences (or both) between inside and outside of the building.

CHAPTER – 1: INTRODUCTION

1.1 Introduction

In today's scenario, we have left our villages and shifted to studio-type apartments due to the increasing cause of real estate we are forced to dwell in small apt.

Almost all of the citizens residing in urban areas prefer to get accommodated in the heart of urban areas. But with the advent of a modern and improved transportation system, it has now become possible to decentralize the population from the core places of urban areas. This decentralization will help in reducing the stress on the cities and improving the quality of living.

In today's scenario, we have been forced to leave the joint family to the nuclear fly system thereby facing a lot of problems. The best example is the people living in the individual residential complex are less benefitted as compared to residents of society.

Due to the constant development of the nation (infrastructure), we have moved away from nature. human beings have been constantly mining natural resources which has resulted in the depletion of these resources and generating more carbon footprints. For example, People have moved away from mud houses to concrete structures thereby forced to use artificial sources of cooling with respect to natural cooling. the use of artificial cooling has resulted in the development of more carbon emissions and also the use of modern construction materials.

1.2 Residential Society

A residential society is a cluster of buildings 'in which sleeping accommodation is provided for normal residential purposes, with or without cooking or dining or both facilities, except any building classified under Group C' [1].

1.2.1 Types of residential buildings

1.2.1.1 Lodging or rooming houses

Boarding (lodging or rooming) house means a building, or portion thereof, where lodging and/or meals for five or more persons, but not more than twenty persons, are provided for compensation.

1.2.1.2 One or two-family private dwellings

A building designed for occupancy by 2 families living independently of each other.

1.2.1.3 Dormitories

Dormitory typically refers to residence halls, which are sleeping quarters or entire buildings primarily providing sleeping and residential quarters for large numbers of people, often boarding school, college, or university students.

1.2.1.4 Apartment houses or flats

The concept of Apartments is derived from American societies while Flats are derived from British societies. An apartment (American English), or flat (British English, Indian English, South African English), is a self-contained housing unit (a type of residential real estate) that occupies part of a building, generally on a single storey [1].

i. No Apartment building shall be permitted on plots less than 800 Sq. m.in size.
ii. In an apartment building with joint ownership of land, the owner /developer shall provide floor space for the house owner's society Office /assembly at the rate of 1 Sq. m. per/flat provided that the minimum area shall not be less than 12 sq. m.
iii. One staircase for every 6 dwelling units or fraction thereof in a floor shall be provided.
iv. The minimum width of the approach road to the plot shall be 9 meters for non-high rise and 12 meters for high-rise apartment buildings. There shall be space for flanks on both sides of the road.

1.2.1.5 Hotels

Place where people pay to stay. These structures are also taken under the umbrella term of residential buildings as mostly all the amenities provided here are the same.

1.3 Design requirement of the township.

The concept of housing has exploded with a bang due to the ever-increasing housing demand. High-end amenities within the apartments are a part of the package. The concept of a township embraces all the basics, the highly essential schools, hospitals, and the much-needed recreational facilities. The location is a very important factor as it should signify pride and dignity for the customer. Premium and exclusive condominiums, villas, penthouses, and row houses with beautiful landscapes are the new address of the rich who seek a sumptuous lifestyle. The amenities in the apartment should enhance the locational experience and make the apartment a part of its natural surroundings [2].

Some laws related to the design of the township are mentioned below:

i. No building shall be constructed on any site on any part of which there is deposited refuse, excreta, or other offensive matter objectionable to the authority. Until such refuse has been removed therefrom and the site has been prepared or left in a manner suitable for building purposes to the satisfaction of the Authority.
ii. No permission to construct a building on-site shall be granted if the site is within 9m of the highest water mark of a tank unless the owner takes responsibility to prevent any risk of domestic drainage of the building passing through the tank.
iii. Wherever the dampness of a site or the nature of the soil renders such precautions necessary, the ground surface of the site between the walls of any building erected thereon shall be rendered damp-proof to the satisfaction of the authority.
iv. Any land passage or other area within the cartilage of a building shall, if the authority so requires, be effectively drained by surface water drains or other means.
v. If the foundation of the external wall along a street is located at a distance less than 1m from the edge of the street or road margin including the drain.

Other bye-laws for Integrated Township [2]:

i. At least 20% of the total area shall be reserved for parks and open spaces. It shall be developed and maintained by the developer.
ii. At least 10% of the site area shall be reserved for public and semi-public use and shall be handed over to the Authority free of cost and the same shall be allotted to the Authority either to the developer or others on a lease basis. RCC structure for recreational uses shall not exceed 25% of the total area.
iii. The FAR (floor area ratio) shall be calculated on the total area.
iv. Roads shown in the development plan shall be incorporated within the plan and shall be handed over to the local authority free of cost after development.
v. The FAR and coverage shall be 3 and 30% respectively. However higher FAR can be allowed if the road width is as per the provisions made for new areas.
vi. At least 25% of the housing units developed will be earmarked for EWS/LIG category.
vii. At least one of the major interconnecting roads shall be 18m wide and shall be open-ended. All internal roads shall be developed with pathways and street lighting with good design and practices. Minimum road width with pathways of such roads shall be 12m.
viii. All amenities shall be developed by the developer and shall be handed over to the Authority free of cost through a registered gift deed with a completion certificate to obtain occupancy permission.
ix. Zoning:
    a. In the Planning area or areas where various use zones viz, residential, commercial, industrial, administrative, institutional, open space uses, transport & communication, green belt, natural drainage channel and water bodies having their zonal boundaries have been indicated, they shall be regulated as per the Table 2. Except as otherwise provided no structure or land hereinafter shall be used and no structure shall be erected, re-erected, or altered unless its use conforms with these bye-laws.
    b. For all non-confirming land use, no expansion shall be permitted. At the time of redevelopment, stipulated zoning regulations shall be followed.
x. Permissible land use within the township (%):
    a. Residential: 35-50

b. Commercial: 10-15
c. Institutional: 10-15
d. Recreational: 15-25

1.4 Sustainable construction

The construction business largely affects the indigenous environment, economy, and profitability, around the world, it consumes 40% of absolute energy production, 12-16% of all water accessible, 32% of non-sustainable and inexhaustible assets, 25% of all timber, 40% of every single raw material produces 30-40% of every solid waste and transmits 35-40% of carbon dioxide (CO_2). These have brought about rising worries about the hindering impacts of the construction business on the indigenous environment and human well-being and have expanded the prominence of green buildings all around.

As per the Ministry of Urban Development of India, by 2030, India is aimed to achieve 68 urban communities with a populace of more than 1 million, 13 urban areas with more than 4 million individuals, and 6 megacities with populaces of 10 million or more, with Mumbai and Delhi among the greatest urban communities around the world. This suggests the fact that the private division expends about 24% of the electrical energy produced, which would keep on rising.

1.5 Concept of zero carbon emission society

We are approaching a decisive moment for international efforts to tackle the climate crisis – a great challenge of our times. The number of countries that have pledged to reach net-zero emissions by mid-century or soon after continues to grow, but so do global greenhouse gas emissions. This gap between rhetoric and action needs to close if we are to have a fighting chance of reaching net-zero by 2050 and limiting the rise in global temperatures to 1.5 °C.

Net Zero is the balance between the amount of greenhouse gas produced and the amount removed from the atmosphere. It is achieved when the amount of carbon emission we add is not greater than the amount we take away.

1.6 Concept of HVAC (Heating, Ventilation and Air-conditioning)

Heating, Ventilation, and Air Conditioning (HVAC) refers to the equipment, distribution systems, and terminals that provide, either collectively or individually, the heating, ventilation, or air-conditioning requirement to a building or a portion of the building.

HVAC systems also affect the health, comfort, and productivity of occupants. Issues like user discomfort, improper ventilation, lack of air movement and poor indoor air quality, and poor acoustic design are linked to HVAC system design and operation and can be improved.

The best HVAC design considers all the interrelated building systems while addressing indoor air quality, thermal comfort, energy consumption, and environmental benefits. Optimizing both the design and the benefits requires that the architect and mechanical system designer address these issues early in the schematic design phase and continually revise subsequent decisions throughout the remaining design process. It is also essential that a process be implemented to monitor the proper installation and operation of the HVAC system throughout construction.

1.7 Lighting

Lighting alone accounts for almost 15% of the total energy consumption in India. Lighting is an area that offers many energy efficiency opportunities in almost any building facility, existing or new.

Using efficient lighting equipment and controls is the best way to ensure lighting energy efficiency while maintaining or even improving lighting conditions.

For a lighting designer, an energy-efficient lighting design involves careful integration of many requirements and considerations such as building orientation, interior building layout, task illumination, daylight strategies, glazing specification, choice of lighting controls, etc.

1.8 Energy savings

Several studies have recorded the energy savings due to daylight harvesting. Energy savings for electric lighting in the range of 20-60% are common. Savings are very dependent on the type of space the light-harvesting control system is deployed in, and its usage. Savings can only accrue in spaces with substantial daylight where electric lighting would have been otherwise used. Therefore, daylight harvesting works best in spaces with access to conventional or clerestory windows, skylights, light tube groups, glass block walls, and other passive daylighting sources from sunlight; and where electric lighting would otherwise be left on for long periods.

It is too simplistic to try to increase energy savings by increasing the size of windows. Daylight over-illumination may cause glare for occupants, causing them to deploy blinds or other window shading devices.

The adoption of daylight harvesting technologies has been hampered by high costs and the imperfect performance of the technologies. However, studies have shown that by using daylight harvesting technologies, owners can see an average annual energy savings of 24%.

1.9 Study Area

1.9.1 Overview

In this project, various aspects of civil engineering have been combined and tried to develop a sustainable and zero carbon emission society over an area of 25 Acres. The dimensions of the plot are 1089 ft. x 1000 ft. The proposed site is located alongside the Patna-Bakhtiyarpur highway. The coordinates of the site are 25°33'59.6"N, 85°15'14.0"E. The Google map views of the site are shown in Fig. 1.1 and Fig. 1.2.

Figure 1. 1 - Google earth view of the proposed site location

Courtesy: Google Earth [3]

Figure 1. 2 - Google earth view of the proposed site location

Courtesy: Google Earth [3]

1.9.2 Plan layout

The plan layout of the entire 25 Acres society is shown in Fig 1.3.

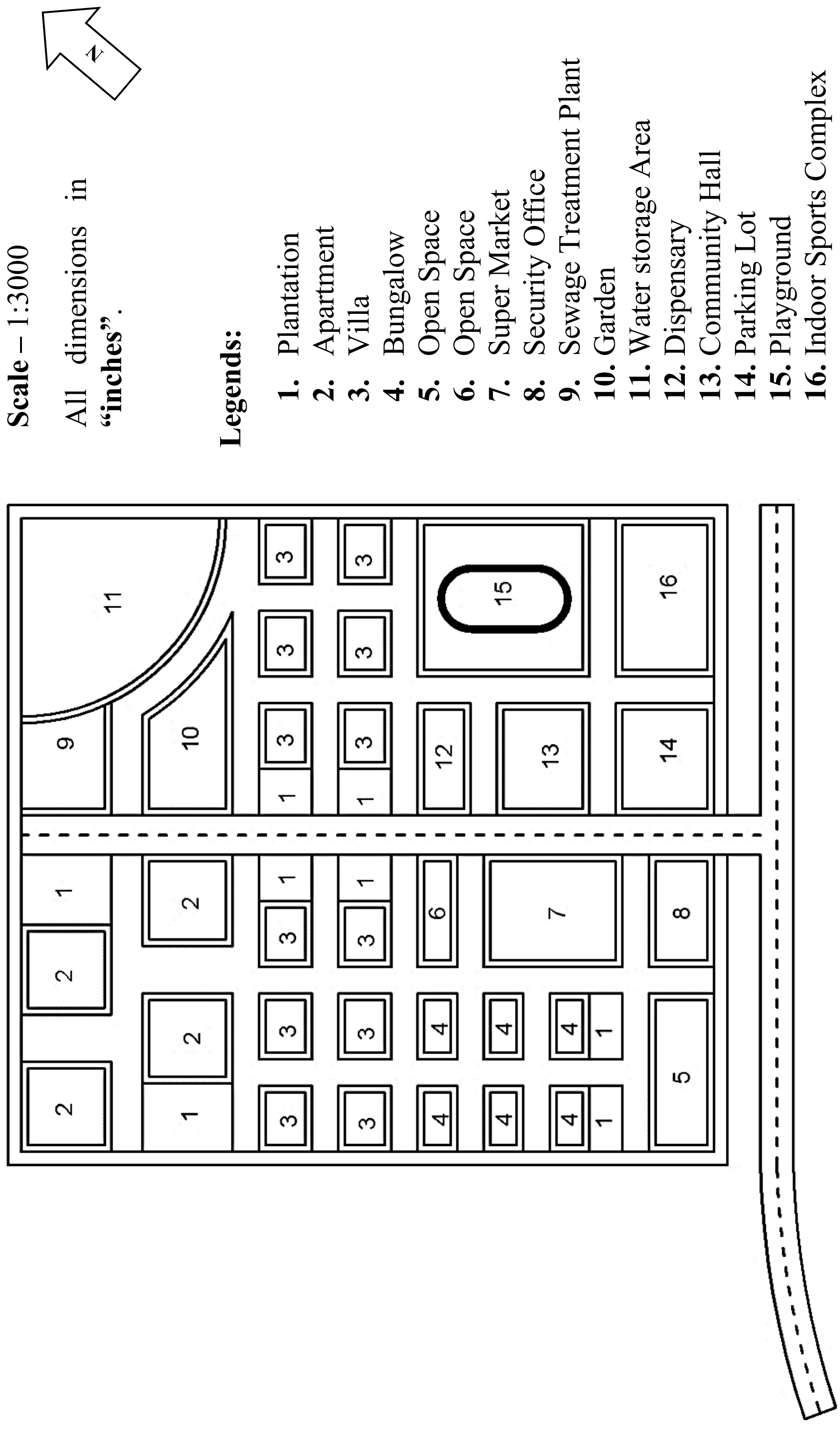


Figure 1. 3 - Plan view of the society

1.10 Conclusion

In this project, a residential society has been tried to be developed which is sustainable in nature as well as eco-friendly by restricting the carbon footprints. The concept of a township embraces all the basics, the highly essential schools, hospitals, and the much-needed recreational facilities. Laws governing the design of the township have been discussed in section 1.3. Sustainable construction is an important aspect kept in mind during the designing of this township as discussed in section 1.4. A minimum amount of carbon emission is generated in this township to attribute to the high carbon rising in today's world. The importance and concepts have been discussed in section 1.5. adding to section 1.5, section 1.6 discusses the concept of HVAC which again helps the structures to provide maximum comfort while delivering ventilation and cooling all-round the year reducing the usage of artificial coolers and air conditioners which contribute to greenhouse gas emissions. The study area has been explained in section 1.9 and a detailed project analysis has been discussed with the aerial mapping and plan layouts.

CHAPTER – 2: LITERATURE REVIEW

Various researchers have carried out work on different aspects of this project in the past. Some have been listed below:

Axaopoulos et al. [4] had focused this paper on finding such steps that make a solar system more economical and efficient. The authors have presented Economic spider diagrams to indicate how legislation and fuel prices would affect the value of such systems. Jiang et al. [5] used a Large Eddy Simulation (LES), a Smagorinsky subgrid-scale (SS) model, and a Filtered dynamic subgrid-scale (FDS) model, to study airflow in buildings with natural ventilation. All these methods have been used to find the best way of ventilation in two of the models designed in the paper.

Kumar et al. [6] studied a building in an urban city of India where the percentage area of light and ventilation were analyzed. Analysis showed the percentage of light is thrice and ventilation is twice the prescribed limits by Indian Green Building Council (IGBC). This analysis can be useful while constructing a new infrastructure to improve the standard of living as 90% of the time is spent indoors.

Axley [7] reviewed the application of natural ventilation in commercial buildings, the technology, its potential advantages, and related issues that need to be addressed. The report also addresses opportunities and issues specific to the application of natural ventilation to commercial buildings.

Zhai et al. [8] reviewed the important natural ventilation models and simulation tools and the comparisons of their prediction capabilities. On one hand, a review of the analytical models reveals that these models are generally only applicable to specific geometries and driving forces. On the other hand, results of comparison and assessment between airflow models have shown that the current one can be used to model most NV mechanisms.

Causone [9] proposed a methodology to evaluate the climatic potential for natural ventilation. The methodology does not address a particular ventilation strategy or system. It includes adaptive comfort models and introduces an approach that integrates humidity constraints.

Aslanoğlu [10] collected data and conducted a short-term analysis of residential lighting as a part of more comprehensive research. The study focused on the day- and artificial lighting systems, conditions, and people's assessments in interiors of residential buildings.

Kamali and Abbas [11] investigated how the quality services provided by the nurses could be achieved through proper lighting design in a recently built healthcare center in Putrajaya, Malaysia. Data collection involved personal site observations and photographic documents.

Al-Ashwal et al. [12] reviewed the impact of daylighting on building occupants, particularly in schools and office buildings. Many studies have proven that a large number of students and office workers (60-85%) prefer daylighting as a source of illumination. It was found that proper daylighting designs help maintain good health, reduce stress levels of office workers and alleviate headaches.

Darula et al. [13] reviewed and discussed the principles of natural light standardization with a short introduction to the history and current state, with a trial to focus on the possible development of lighting engineering and its standards in the future.

Iyati et al. [14] have briefly explained strategies that can be done to improve natural lighting in the cultural heritage buildings with a deep floor plan. A case study of cultural heritage buildings was also used in this research to provide a description of specific natural lighting techniques that can be applied.

Huisingh et al. [15] presented the work which is focusing on topics such as Carbon emission reduction, improved energy use efficiency, carbon capture storage, and carbon trade/tax schemes. The author has a deep concern about human societies that are facing problems due to climate changes which are interconnected by their social, environmental, economic, and ethical consequences.

Sharma et al. [16]presented the energy simulation modeling for carbon emission reduction. The process was a computer-based simulation that helped in the evaluation of the energy performance of a building. The author also performed a case study on natural ventilation.

Farhan et al. [17] reviewed the current state and published research trends on low carbon emission buildings with a focus on the establishment of the non-conventional or renewable energy systems, selection of low carbon emission materials, and development of advanced design and assessment techniques.

Reddy [18] presented a paper that focused on certain issues be in effect to energy, sustainability of building construction, and carbon emission with reference to the Indian construction industry. The author also analyzed the total embodied energy in conventional buildings and alternative buildings.

Wailkar et al. [19] designed a residential building using STAAD.Pro which included generating a structural plan, getting a model, analysing the structure, and designing of structure.

Bano et al. [20] paper focused on the differences and similarities between different RC design codes and to utilize to develop a common code. RC Code from INDIA, USA, EUROPE, and BRITISH are observed.

Gong et al. [21] presented a paper that focused on the strength and maintenance of RC structure. Taha et al. [22] studied the life cycle assessment of the different buildings and investigated building sustainability and how to achieve the criteria for green buildings. The author took steel as the main construction material to fulfilled the green building standard.

Raghavi et al. [23] presented a paper that focuses on steel as a construction material. The paper focuses on sustainability in the construction area. Steel was found to be more sustainable as compared to other buildings' construction materials.

Qasim [24] discussed the technical and non-technical issues that are faced during the planning and designing of wastewater treatment facilities. Also, the following topics were discussed like planning, process description, mass balance calculation, design calculation, and concepts for equipment sizing.

Samal [25] presented the design of a sewage treatment plant and its stages or components that are responsible for the sewage treatment process. The project covered an approximate population of about 10000 including all the buildings in the locality for a maximum period. With the help of this project, the author calculated the entire sewage of the proposed area that can be treated efficiently and effectively.

CHAPTER – 3: METHODOLOGY

3.1 SOFTWARES USED

3.1.1 STAAD.Pro

STAAD is powerful design software licensed by Bentley. STAAD stands for structural analysis and design. Any object which is stable under a given loading can be considered a structure. So first find the outline of the structure, whereas analysis is the estimation of what is the type of loads that acts on the beam, and calculation of shear force and the bending moment comes under the analysis stage. The design phase is designing the type of materials and their dimensions to resist the load. This is done after the analysis. To calculate S.F.D. and B.M.D. of a complex loading beam takes about an hour. So, when it comes into the building with several members it will take a week. STAAD Pro is a very powerful tool that does this job in just an hour STAAD is the best alternative for high-rise buildings. This software can be used to carry RCC, steel, bridge, truss, etc. according to various country codes.

3.1.2 AutoCAD

AutoCAD is powerful software licensed by Autodesk. The word auto came from Autodesk Company and cad stands for computer-aided design. AutoCAD is used for drawing different layouts, details, plans, elevations, and sections that can be shown in AutoCad.

It is very useful software for civil, mechanical, and also electrical engineers. The importance of this software makes every engineer compulsion to learn this software. AutoCAD has been used for drawing the plans.

3.1.3 DesignBuilder

DesignBuilder is a software tool used for energy, carbon, lighting, and comfort measurement and control. It is developed to ease up the building simulation process. DesignBuilder uses a comparative study of alternative building designs by using function and performance-based methods of various results quickly and economically.

Design-Builder combines 3-D building models with dynamic energy simulations with its unique ease of use. It has been specially developed for modules to be used effectively at any stage of the design process. Only a few parameters are provided and a wide range of opportunities to work up to the more detailed design of any particular design opens up. Its innovative productivity features allow even complex buildings to be modeled rapidly by non-expert users.

DesignBuilder has been developed to be used for a wide range of professionals such as architects, engineers, building services workers, energy consultants, and related departments of universities. Some typical usage purposes are summarized below:

i. To evaluate facade options in terms of overheating, energy consumption, and shading parameters.
ii. Evaluation of the optimum use of daylight.
iii. Modeling of lighting control systems and determining the savings rate in the corresponding electricity.
iv. To calculate the buildings in/around temperature, velocity, and pressure distribution by using the CFD (Computational Fluid Dynamics) module.
v. Thermal simulation in buildings that are ventilated with natural ventilation.
vi. Determining the capacity of heating and cooling equipment to include the issues to help HVAC design.

DesignBuilder uses the EnergyPlus simulation engine for running its energy calculations. The data can be extradited in tabular form or presented by graphs.

EnergyPlus is the most comprehensive building energy simulation program developed by the US Department of Energy, to model building heating, cooling, lighting, ventilation, and other energy flow, which has been constantly being improved. EnergyPlus is a simulation program with a user-friendly graphical interface. DesignBuilder has created an elegant and easy-to-use interface for EnergyPlus.

3.2 RCC design

A structure can be defined as a body that can resist the applied loads' appreciable deformations. Structure analysis involves the determination of the forces and displacement of the structure or components of a structure. The design process involves the selection and detailing of the component that makes up the structure system. The main object of reinforced concrete design is to achieve a structure that will result in a safe economical solution.

The design of each part may be designed separately as follows:

i. Slab Design
ii. Beam Design
iii. Column Design
iv. Foundation Design

These are all designed under Limit State Method.

3.2.1 Limit State Design

The acceptable limit for the safety and serviceability requirement before failure occurs is called a limit state. This method of design is adopted widely in recent practice. This method is followed and all the design works are carried out in accordance with IS 456:2000 [26]. In the limit, state design structure shall be designed for safety as well as serviceability.

3.2.2 Limit State of Collapse

This corresponds to the maximum load-carrying capacity. Violation of the collapse limit state implies failure in the source that a definite limit state of structural usefulness has been exceeded [27]. However, it does not mean complete. The limit state corresponds to:

i. Flexural
ii. Compression
iii. Shear
iv. Torsion

3.2.3 Limit State of Serviceability

This state corresponds to the development of excessive deformation and is used for checking members in which magnitude of deformation may limit the rise of the structure of its components [27].

i. Deflection
ii. Cracking

iii. Vibration

3.2.4 RCC Elements

The RCC elements are slab, beam, column, footing, and staircase, etc.

3.2.4.1 Slabs

Slabs are plane structure members whose thickness is small as compared to their length and breadth. Slabs are most frequently used as a roof covering and floors in various shapes such as square, rectangular, circular, triangular, etc. in the building. Slabs support mainly transverse loads and transfer them to the supports by bending action in one or more directions. Beams or walls are the common supports for the slabs [27].

3.2.4.2 Types of slabs:

a. One-way Slab

When the slab is supported on two opposite side parallel edges. And the ratio of the shorter span (ly/lx) is greater than and equal to 2 are called one-way slabs. One-way slab bends in one direction, along the shorter span and hence it needs main reinforcement in one direction only (along the shorter span).

b. Two-way slab

When the slab is supported on four edges and the load distribution is also on four edges of the panel. If the ratio of the longer span to the shorter span (ly/lx) is less than 2, the slab is likely to be bent along the two spans and such slabs are called two-way slabs. The load transfer in both directions to the four supporting edges and hence main reinforcement has to design in both directions to resist two-way bending.

3.2.4.3 Beams

A reinforced concrete beam should be able to resist tensile compressive and shear stresses induced in it by the load on the beam. Concrete is fairly strong in compression but weak in tensile strength. Plain concrete beams are thus evaded in carrying capacity by the law of tensile strength. Steel is very strong in tension. Thus, the weakness of concrete is overcome by the provision of reinforcing steel in the tension zone around the concrete to make a reinforced concrete beam. The design of the beam mainly consists of fixing the breadth and depth of the beam and arriving at the area of steel and the diameters of bars to be used. The breadth of the beam is generally kept equal to the thickness of the wall to avoid offset inside the room. It shall not exceed the width of the column for effecting transfer of the load from beam to the column. The depth of the beam is taken by L/10 to L/6. There are two types of reinforced concrete beams [27].

3.2.4.4 Singly reinforced beams

In singly reinforced, simply supported beams steel bars are placed near the bottom of the beam where they are effective in resisting in the tensile bending stress.

3.2.4.5 Doubly reinforced beams

It is reinforced in both compression and tension zone. The necessities of steel for the compression region arise due to two reasons.

3.2.4.6 Columns

A column or strut is a compression member, which is used primarily to support the axial compressive load and with a height of at least three, it is the least lateral dimension. A reinforced concrete column is said to be subjected to axially loaded when the line of the resultant thrust of loads supported by the column is coincident with the line of C.G of the column in the longitudinal direction [27].

A column, in general, may be defined as a member carrying a direct axial load that causes compressive stresses of such magnitude that these stresses largely control its design. The columns are subjected to axial loads (P_u) and uniaxial bending moment (M_u). The column section shall be designed just above and just below the beam-column joint and the larger of the two [27].

3.2.5 Design requirement of the residential society

The Ministry of Housing and Urban Affairs, India specifically mentions the Space requirements for different parts of a building.

These specifications are widely accepted across India and are minimum requirements.

3.2.6 Space requirement for different parts of building[28]

3.2.6.1 Main Building

The plinth or any part of a building or outhouse shall be so located with respect to average road level from the site so that adequate drainage of the site is assured but at a not height less than 45 cm.

3.2.6.2 Interior Courtyards, Covered Parking Spaces, and Garages

These shall be raised at least 15 cm. above the surrounding ground level and shall be satisfactorily drained.

3.2.6.3 NBC guidelines

S. No.	Component of building	Min. requirement for plots up to 50 sq m.	Min. requirement for plots above 50 sq m.
1	HabiTable room	Area 7.50 sq m	Area 9.50 sq
		width 2.10	width 2.40 m.
		height 2.75	height 2.75 m
2	kitchen	Area 3.30	Area 4.50 sq m
		width 1.50	width 1.50 m
		height 2.75	height 2.75m
3	Pantry	Area -NA-	Area 3.00 sq m.
		width -NA-	width 1.40 m.
		height -NA-	height 2.75 m
4	bathroom	Area 1.20	Area 1.80 sq m
		width 1.00	width 0.90 m
		height 2.20	height 2.20 m.
5	W.C.	Area 1.00	Area 2.80 sq m
		width 0.90	width 1.20 m
		height 2.20	height 2.20 m
6	Combined and W.C. (Toilet)	Area 1.80	Area 2.80 sq m
		width 1.00	width 1.20 m.
		height 2.20	height 2.20 m.
7	Store	Area NO RESTRICTION	Area No restriction
		width NO RESTRICTION	width No restriction
		height 2.20	height 2.2 m
8	Projection	Permitted within the setbacks	Permitted within the setbacks
		upto 0.75 m. width	upto 0.75 m. width
9	Canopy	NA	NA
10	Garage	NA	Area 14.85 sq m.
			width 2.75 m
			height 2.40 m
11	Passage		width 1.00 m
12	Doorway with HabiTable room	width 0.80 m.	width 0.90 m
		height 2.00 m.	height 2.20 m
13	For kitchen bath W.C. etc	width 0.75 m	width 0.75 m
		height 2.00 m.	height 2.00 m
14	Staircase	Width 0.75 m.	Width 0.90 m.
		No restriction for internal ladder	

Table 3. 1 - NBC guidelines for space requirement for different parts of building

Notes:

i. *Provided that the minimum clear headway under any beam shall be not less than 2.4 m.*

ii. *The maximum height permissible for all the components of the building mentioned above is 4 m.*

3.2.6.4 HabiTable room size and width for group housing

i. Building requirements in respect of dwelling units up to 45 sq. mt. in size will correspond to Table 3.1 and as applicable to plots up to 50 square meters.

ii. Building requirements in respect of dwelling units above 45sq m. may be referred from Table 3.1 applicable to above 50 square meters. plot size.

iii. Projection into Open Spaces without counting towards FAR.

iv. All open spaces provided either interior or exterior shall be kept free from any erections thereon and shall open to the sky. Nothing except cornice, chhajja, or weather shade (not more than 0.75 m. wide) shall overhang or project over the said open space to reduce the width to less than the minimum required.

   Note: Such projections shall not be allowed at a height less than 2.2 m. from the corresponding finished floor level.

v. One canopy per block on the ground floor not exceeding 4.5 m. in length and 2.4m. in width.

vi. Balcony at roof slab level of 1.2 m. width and area not exceeding 3.5 square metre. per bedroom but not exceeding 3 in number per flat.

vii. Balcony having an entrance from the toilet/bathroom and a width of 1.2 metres for drying clothes.

3.3 Sewage Treatment Plant

STPs are a type of wastewater treatment that removes contamination coming from sewage to generate an effluent for distribution to the surroundings for consumption, reuse, gardening, etc. It is an effective and economic solution to combat water pollution and misuse [29].

3.3.1 Primary Treatment

The primary industrial wastewater treatment plant plans to use screens, grit chambers, and sedimentation tanks to get quality water that is free from waste and bad bacteria. Before ejection of the quality water, the sewage passes through many cleaning processes. When sewage is influent in the plant for treatment, it comes across to a screen for removal of large floating objects that can block or damage pipes or equipment [16].

After completion of the primary screening process, water falls into a grit chamber where small objects are separated from the water. It set cinders, sand, and stones at the bottom.

After the above two applications for the removal of big and small objects, sewage water contains many suspended solids with organic and inorganic materials. For water purification, minute particles are needed to be yet removed. A sedimentation tank is used for this process. In this tank, solids sink to the bottom as and when the flow of water gets reduced. This collection of solid is known as raw primary biosolids formerly sludge that is thrown out of the tank through pumping [16].

Gradually, this primary method was unable to meet the increased quality demands of the community. So, secondary and advanced methods are developed to fulfill the needs of cities and industries.

3.3.2 Secondary Treatment

By using the trickling filter and activated sludge process, this stage throws out around 85% of the organic and inorganic waste material from the water [16].

After completion of the primary stage and when effluent leaves the sedimentation tank, a trickling filter comes into play. The trickling filter is around six feet deep bed of stones through which sewage flows. Partially treated sewage gets transmitted to another sedimentation tank after a trickling filter to remove bacteria [16].

Nowadays, the activated sludge process is used in place of a trickling filter. The process is fast and early result-giving compared to the tricking filter. After the primary stage sedimentation tank, sewage flows into the aeration tank. For a few hours, it is blended with air and sludge loaded with bacteria to break down the organic matter. Like a tricking filter, partially treated sewage is sent to another sedimentation tank for further process [16].

At the end of the stage, the effluent of the sedimentation tank is disinfected with the help of chlorine to remove odour and kill pathogenic bacteria before being discharged to water communities.

The function decomposition of the design of the Sewage Treatment Plant is shown in Fig. 3.1 [25].

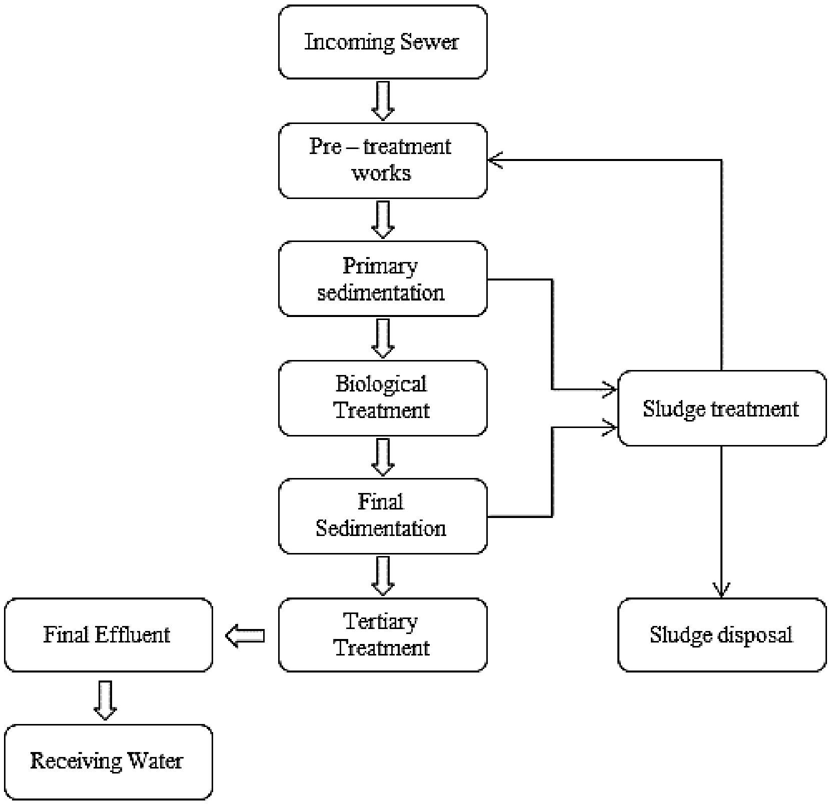


Figure 3. 1 - Function decomposition of design

3.4 Natural Lighting and Ventilation

3.4.1 Lighting & Ventilation

Inside Air Quality (IAQ) represents the quality of air inside and in the surrounding in terms of concentration of pollutants and comfort parameters like thermal condition, whether etc that affects the health and living. Humans spend 60% - 90% of their life indoors, like houses, Schools, Offices, etc., while according to WHO each year 3.7 million people die in the urban area because of pollution [30].

Light and ventilation are one of the major components considered when designing green infrastructure and determining indoor air quality. Indian Green

Building Council (IGBC) has been established for the regulation of Green Building [31].

3.4.2 Light

IGBC Green Homes norms-Reference Guide has been prepared to help the Indian developer and planner in the terms of sustainability in India. The glazing factor is calculated with the help of the area for the window and the room. The minimum limit of the glazing factor for different rooms has been mentioned in Table 3.2 [6].

Type of Regularly Occupied Spaces	**Glazing Factor (GF)**
Living / Bedroom	1
Study room	2
Kitchen	2

Table 3. 2 - Minimum limit of the glazing factor for different rooms

The openable window area to carpet area ratios is determined for daylight analysis.

$$\text{Glazing Factor} = \frac{Window\ area}{Room\ area} * AVTG * constant * 100 \text{ ……. (Equation 3. 1)}$$

Where,

AVTG = Actual Visible Transmittance Glazing

Constant value = 0.2 (for windows in walls)

= 1 (for windows in the roof)

Substrate	**Light Transmission (%)**
2mm clear	91
3mm clear	90
4mm clear	90
5mm clear	90
6mm clear	89
8mm clear	88
10mm clear	87
12mm clear	87
15mm clear	85
19mm clear	84

Table 3. 3 - Light transmission with respect to the thickness of window glass

3.4.3 Ventilation

The openable window + door area to carpet area ratio is determined for ventilation analysis using the formula given. Actual openable area calculation is done using Equations 3.2, 3.3, and 3.4 as given below [31]. Considering two-thirds of windows are openable and doors are openable for only half of the time, the factors ⅔ and ½ are used.

Openable area = Area of doors + Area of windows………(Equation 3. 2)

Actual openable Area = Openable area * 2/3 ………………(Equation 3. 3)

(for kitchen and Living rooms)

= Openable area / 2……………………(Equation 3. 4)

(for Bathroom)

Space Type	Openable area as % of Total Carpet Area
Living Spaces	10%
Kitchens	8%
Bathrooms	4%

Table 3. 4 - Design criteria for openable windows and doors

3.4.4 Light energy

Minimum lighting for a residential building has been provided in NBC (2012) [28] as mentioned in Table 3.5. The limiting value has been provided in luminous per feet square, thus multiplying it by the carpet area, the luminous required for the constructed unit is calculated. Hence, the number of lights with their properties can be determined easily.

Room	lm/ft^2
Living room	80
Family room	80
Dinning	45
Kitchen	80
Bathroom	65
Bedroom	70
Hallway	45
Laundry	70
Workshop	70

Table 3. 5 - Lighting requirements for Residential Building

3.4.5 Solar Setup

The best orientation from a solar point of view requires that the building as a whole should receive the maximum solar radiation in winter and the minimum in summer. The total direct plus diffused diurnal solar loads per unit area on the vertical surface facing different directions are given in Table 3.6 for two days in the year, that is, 22 June and 22 December, representative of summer and winter, for latitudes corresponding to some important cities all over India. From Table 3.6, the total heat intake can be calculated for all possible orientations of the building for these extreme days of summer and winter.

	(1)	(2)	9°N (3)	13°N (4)	17°N (5)	21°N (6)	25°N (7)	29°N (8)
1	North	Summer	1494	1251	2102	1775	2173	1927
2	North	Winter	873	859	840	825	802	765
	North-East	Summer	2836	2717	3144	3092	3294	3189
3	North-East	Winter	1240	1158	1068	1001	912	835
	East	Summer	3344	3361	3475	3598	3703	3794
4	East	Winter	2800	2673	2525	2409	2211	2055
	South-East	Summer	2492	2660	2393	2629	2586	2735
5	South-East	Winter	3936	3980	3980	3995	3892	3818
	South	Summer	1009	1185	1035	1117	1112	1350
6	South	Winter	4674	4847	4958	059	4942	4981
	South-West	Summer	2492	2660	2393	2629	2586	2735
7	South-West	Winter	3936	3980	3980	3995	3892	3 818
	West	Summer	3341	3361	3475	3598	3703	3794
8	West	Winter	2800	2673	2525	2409	2211	2055
	North-West	Summer	2836	2717	3144	3092	3294	3189
9	North-West	Winter	1240	1158	1068	1001	912	835
	Horizontal	Summer	8107	8139	8379	8553	8817	8863
10	Horizontal	Winter	6409	6040	5615	5231	4748	4281

Table 3. 6 - Total Solar Radiation (Direct Plus Diffused) Incident on Various Surfaces of Buildings, in $W/m^2/day$, for Summer and Winter Seasons

NBC – Part 8(2012) (Clause 3.4.1) [28]

3.5 Conclusion

The role of software has eased down human labor to the bare minimum. Some of the software used has been discussed in sections 3.1.1 – 3.1.3. a basic introduction to the theory of RCC structures has been chalked out in section 3.2. Design of important sections, limit state design, limit state of collapse, limit state of serviceability, slabs and their types, and doubly reinforced beams have also been mentioned. Sewage treatment plants and their basic functions are mentioned in section 3.3

Section 3.4 discusses the natural lighting and ventilation plans for the residential buildings. Light and ventilation are one of the major components considered when designing green infrastructure and determining indoor air quality. Adhering to the IGBC guidelines, light and glazing factors are shown in Table 3.2.

The openable window + door area to carpet area ratio is determined for ventilation analysis using the formula given. Design criteria for openable doors and windows are shown in Table 3.4 under section 3.4.3.

Solar setups are discussed in section 3.4.5 which discusses the best possible orientation of solar panels so that they can generate maximum output. Total Solar Radiation (Direct Plus Diffused) Incident on Various Surfaces of Buildings, in W/m2/day, for Summer and Winter Seasons, NBC – Part 8(2012) (Clause 3.4.1) [28] is shown in Table 3.6.

CHAPTER – 4: RESULTS AND DISCUSSIONS

4.1 Design of Sewage Treatment Plant

Before proceeding to the design, the no. of occupants residing in our society is required. Then, the amount of water supply and sewage discharge can be calculated.

4.1.1 Estimation of Population

The total no. of occupants is calculated for the residential spaces including the overall security staff and management staff for the society.

While calculating the no. of occupants for villas and bungalows, no. of staff is also included. The components taken into account are villas, bungalows, and apartments with 3BHK flats.

The calculation summary is shown below in Tables 4.1 & 4.2.

Residential Buildings					
S. No.	**Component**	**Area (ft^2)**	**Total No. of Components**	**No. of Occupants/ Component**	**Total No. of Occupants**
1	Villa	4800	12	12	144
2	Bungalow	3200	6	10	60
3	Flats (3BHK)		48	4	192
4	**Total**				**396**

Table 4. 1 - Estimation of no. of occupants for residential spaces

Staffs		
S. No.	**Category**	**No. of Staffs**
1	Security	30
2	Management	25
3	Others	25
4	**Total**	**80**

Table 4. 2 - Estimation of no. of staff

$\therefore$ Total No. of occupants = 476 ≈ **500**

4.1.2 Water supply and Sewage Discharge per day

4.1.2.1 Water supply

Water supply is the quantity of water that a source must produce to meet all the water requirements of a project.

Water supply depends on various factors such as general domestic purposes and flushing for residences. For the upper-middle class, the value of the water supply can be given as 150 to 200 litres per head per day. A minimum of 70 to 100 litres per head per day may be considered adequate for the domestic needs of urban communities, apart from non-domestic needs such as flushing requirements [32]. Out of the 150 to 200 litres per head per day, 45 litres per head per day may be taken for flushing requirements and the remaining quantity for other domestic purposes [32]. The value of water supply given as 150 to 200 litres per head per day may be reduced to 135 litres per head per day for houses for Lower Income Groups (LIG) and Economically Weaker Section of Society (EWS), depending upon prevailing conditions[32].

The people residing in residential spaces have been considered as upper middle class, taking the average water supply per head per day for them as 200 litres per head per day, and the staff as Lower Income Groups (LIG), taking the average water supply per head per day for them as 150 litres per head per day.

The Calculation of the water supply is shown in Table 4.3.

S. No.	Type of Occupants	No. of Occupants	Water Supply Per Person Per Day (Litres)	Average Water Supplied Per Day (Litres)
1	Villas	144	200	28800
2	Bungalows	60	200	12000
3	3BHK (Flats)	192	200	38400
4	Other Staffs	80	150	12000
5	**Total**	**476**	**750**	**91200**

Table 4. 3 - Average water supplied to residences and staff per day

∴ Average Water supply for Residences comes out to be **91200 Litres/day**.

4.1.2.2 Sewage Discharge

Wastewater discharge means the amount of water or substance added /leached to a water body from a point or a non-point source.

The per capita sewage which is produced in a community can be easily determined by assuming it as 75 to 80 % of the per capita water supplied to the public [33].

Average Sewage discharge is assumed to be 80%.

The average sewage discharge is calculated in Table 4.4.

S. No.	Type of Occupants	Average Water Supplied Per Day (Litres)	Average Sewage Discharge Per Day (Litres)
1	Villas	28800	23040
2	Bungalows	12000	9600
3	3BHK (Flats)	38400	30720
4	Other Staffs	12000	9600
5	**Total**	91200	72960

Table 4. 4 - Average sewage discharge for residences and staffs per day

∴ Average Water discharge for Residences comes out to be **72960 Litres/day**.

4.1.3 Design of STP in Excel

a. Analytical and Numerical Model Solutions

Total Population =	500	
Water Consumed =	**90000**	**LPCD**
	90	KLD
	0.09	MLD
	90	m^3/day
Average Sewage generated =	**76.5**	**KLD**
Average Sewage per hour =	**3.1875**	**m^3/hour**

Peak Factor =	3	
Design Flow Capacity =	**9.5625**	**m^3/hour**
	0.0027	**m^3/sec**

b. Sizing Calculation for Collection Pit

Retention time required =	4	hr
Average Design flow =	3.1875	m^3/hour
Capacity of collection sump =	12.75	m^3
Assume liquid depth =	5	m
Area, required for collection pit =	2.55	m^2

Let us consider it to be a circular tank

Now,

r =	0.9	m

c. Design of Sewer Chamber

Q_{max}	0.0027	m^3/sec
Assumption,		
Shape of Bar	MS FLAT	
Size	10	mm
	50	mm
Clear Spacing between the bars =	20	mm
Inclination of bars =	80	deg
	1.4	radian
Sin 80 =	0.98544973	
Assume avg. velocity to sewer	0.8	m/sec
At peak flow, the net inclined area required =	0.003375	m^2
Gross inclined area =	0.00405	m^2
Gross vertical area required =	0.003991071	m^2
Provide submergence depth =	0.3	m
Width of channel =	0.013303571	m
Assumed Width of channel =	**0.3**	**m**

d. Design of Grit Chamber

Design Flow =	0.225	MLD
	225	m^3/day
Surface Loading =	1100	m^3/m^2/day
To account for turbulence and shortcircuiting,		
Reduced surface loading =	770	m^3/m^2/day
Area required =	0.292207792	m^2
Assumed area required =	0.3	m^2
Provide 0.3 m dia. Chamber (Circular)		
detention time =	60	sec
Volume =	0.15625	m^3
Liquid Depth =	0.53	m
Free Board =	**0.6**	**m**
Size of grit chamber =	**0.3 X [0.53 + 0.6]**	**m**
	0.3 X 1.13 m	**(L X B)**
Dia =	**0.3**	**m**

e. Check for horizontal velocity

Cross-sectional area of grit chamber =	0.159	m^2
Velocity =	0.02	m/sec
	2	cm/sec
Check if velocity is less than 18 cm/sec =	OK	
Grit generation assumed =	0.05 m^3 per 1000 m^3 of sewage flow	
Storage volume required =	0.0051	m^3
Grit storage area =	3.14	m^2
Grit storage depth =	0.0016	m
Total liquid depth =	0.53	m
Provide grit chamber of size =	**2 m X 0.28 m**	

f. Design of Primary Sedimentation Tank

Detention time	2	hour
Volume of Sewage	1.59	m^3
Provide depth	1	m

Surface Area	= Volume/Depth	
	1.59	m^2
d^2	2.02	m
d	**1.42**	**m**

g. Design of Aeration Tank

No. of Tanks	2	
Avg. Flow to each tank	0.1125	MLD
Q	**112.5**	**m^3/day**
Total BOD entering STP	295	mg/L
The BOD of sewage coming to the aeration tank, Y_0	295	mg/L
BOD left in the effluent, Y_E	20	mg/L
BOD removed in the activated plant	275	mg/L
Minimum efficiency required in the activated pant	93	%
	OK	

The volume of the aeration tank can be designed by assuming a suitable value for MLSS and "Q_C" (or F/M ratio). MLSS should be between 3000 - 3500 mg/L and the F/M ratio should be between 0.18 - 0.10.

Assuming,

MLSS, X_T	3000	mg/L
F/M ratio, "q_c"	0.1	
F/M = (Q/V) X (Y_0 / X_T)		
We have, Q =	112.5	m^3/day
Y_0 =	295	mg/L
X_T =	3000	mg/L
F/M ratio, "q_c" =	0.1	
Therefore,		
V =	(Q x Y_0) / (q_C x X_T)	
Hence, V =	**110.625**	**m^3**

Let us adopt an aeration tank of the following dimensions

B =	5	m
D =	2	m
H = V/(BxD)	11.0625	m
Hence, H =	12	m
Volume Provided =	120	**m^3**

Since, Volume provided > Required Volume,

Hence, the adopted tank size is OK.

So, the adopted tank size is (5 + 0.6)m X 2m X 12m .

h. Design of Secondary Clarifiers

No. of Clarifiers =	1	no.
Avg. Flow =	76.5	m^3/day
Reduced flow, say 50 % =	112.5	m^3/day
Total Inflow =	189	m^3/day
Provide hydraulic detention time =	2	hrs
Volume of tank =	15.75	m^3
Assume liquid depth =	**3.5**	**m**
Area =	4.5	m^2
Surface loading area of avg. flow =	15	m^3/m^2/day
Surface area to be provided =	5.1	m^2

Provide area greater of the two.

Hence, Provided Area =	5.1	m^2
Dia. of circular tank (d) =	2.547726259	m
Provided diameter =	**3**	**m**

Hence, provide a clarifier of 10 m dia. Having liquid depth as 3.5 m.

i. Return Sludge Pump House

Total return flow =	112.5	m^3/day
	4.6875	m^3/hour
	0.0781	m^3/min

Detention time =	15	min
Volume of wet well =	1.1715	m^3
	2.5m x 1.5m x	
Provide wet well =	1.8m	
Provide dry well =	2.5m x 2.5m	
Size of annexe control room =	2.5m x 2.5m	

Provide 2nos pumps each of 0.112 MLD capacity in the dry well for returning the sludge to the aeration tank. The return sludge pipeline should be 150 mm.

j. Design of sludge drying beds

Sludge applied for drying beds @100 Kg/MLD		
Sludge applied =	125	Kg/day
Specific gravity =	1.015	
Solid Contents =	1.5	%
Volume of sludge =	8.21	m^3/day
Considering monsoon, etc., total no. of cycle in 1 year =	33	
Period of each cycle =	11	days
Volume of sludge =	90.31	m^3
Spreading a layer of 0.3 m per cycle area of beds required =	302	
Provide 4 beds of 1.2 m X 7 m,		
Thus, provided area =	**336**	**m^2**

4.1.4 Discussion

A successful technical project involves the integration of various knowledge from different fields. The design of STP combines several aspects of environmental, biological, part of chemical, and mostly civil engineering. The Plant is designed perfectly to meet the needs and demands of approximately 500 population for a large period. The design consists of complete STP components starting from receiving chamber, screening, grit chamber, skimming tank, sedimentation tank, secondary clarifier, activated sludge tank, and drying bed for sewage.

4.2 RCC design

The plan consists of villas, Bungalows and Apartments.

Number of Villas = 12

Number of Bungalows = 6

Number of Apartments (3 BHK flats) = 4

Basements of all structures have been made up of steel and Steel design calculations using STAAD.Pro was carried out.

RCC design of elements was carried out for all structures but for the sake of presentation, only components with maximum load have been shown here.

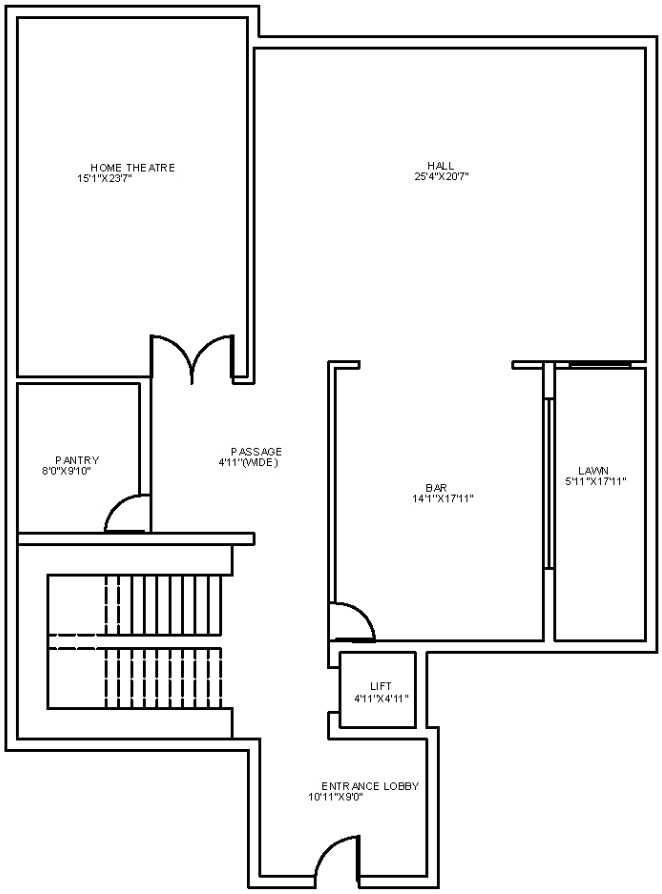
4.2.1 Design of Villa

4.2.1.1 Plan of Villa

Total Area: 4800 ft^2 (60 ft. x 40 ft.)

Carpet Area: 3720 ft^2 (48 ft. x 77 ft.)

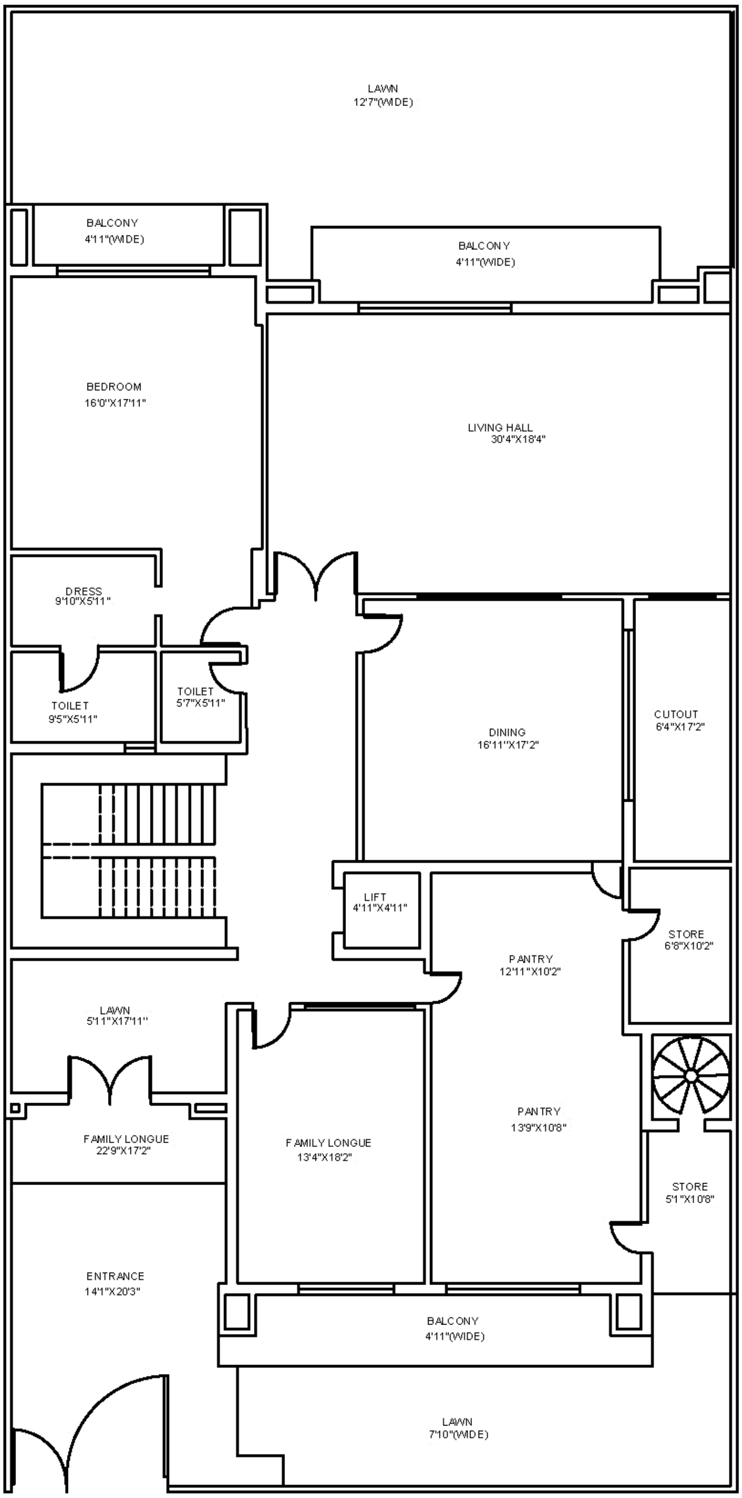
Built-up Area: 3390 ft^2



Scale – 1:150

All dimensions in "feet-inches".

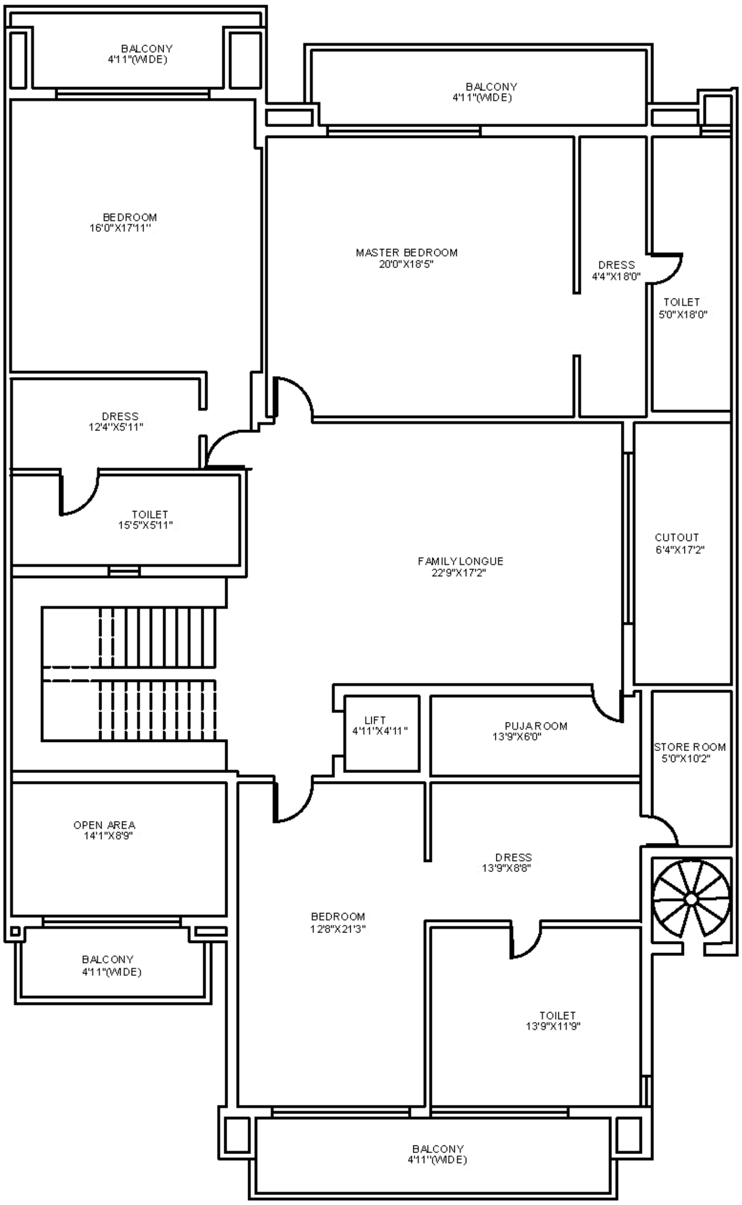
Figure 4. 1 - Plan view of Basement (Villa)



Scale – 1:150

All dimensions in "feet-inches".

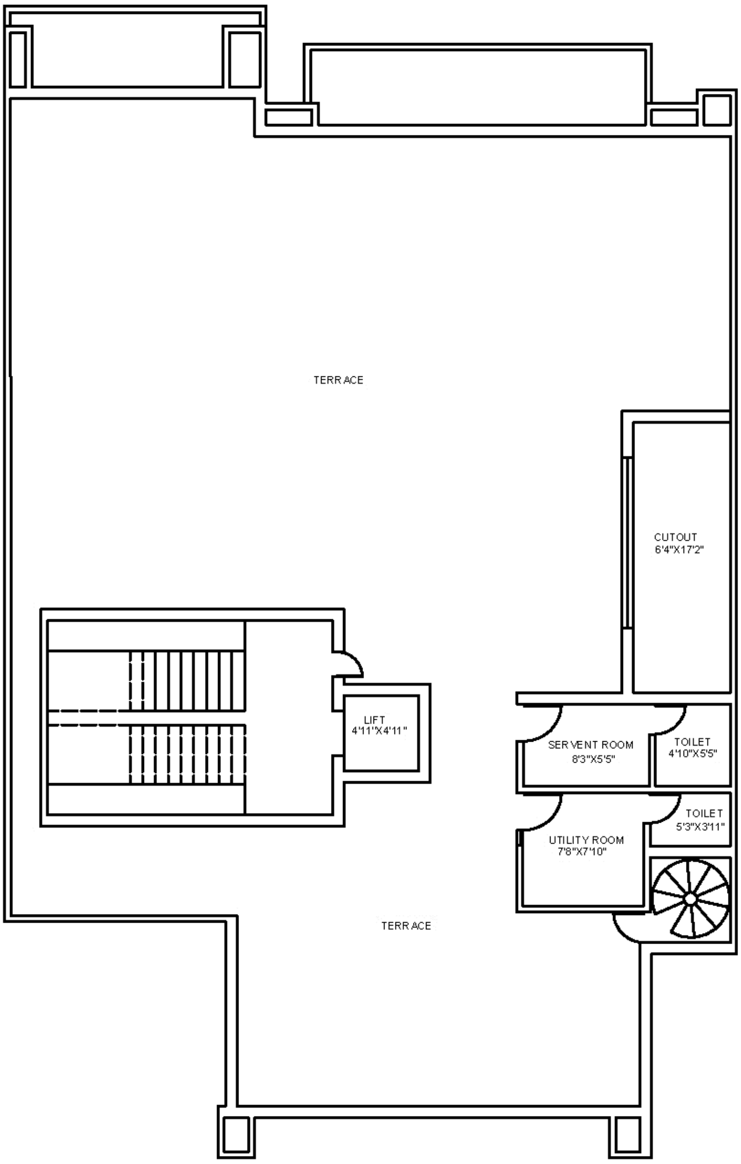
Figure 4. 2 - Plan view of Ground Floor (Villa)



Scale – 1:150

All dimensions in "feet-inches".

Figure 4. 3 - Plan view of First Floor (Villa)



Scale – 1:150

All dimensions in “feet-inches”.

Figure 4. 4 - Plan view of Second Floor (Villa)

4.2.1.2 STAAD Model of Villa

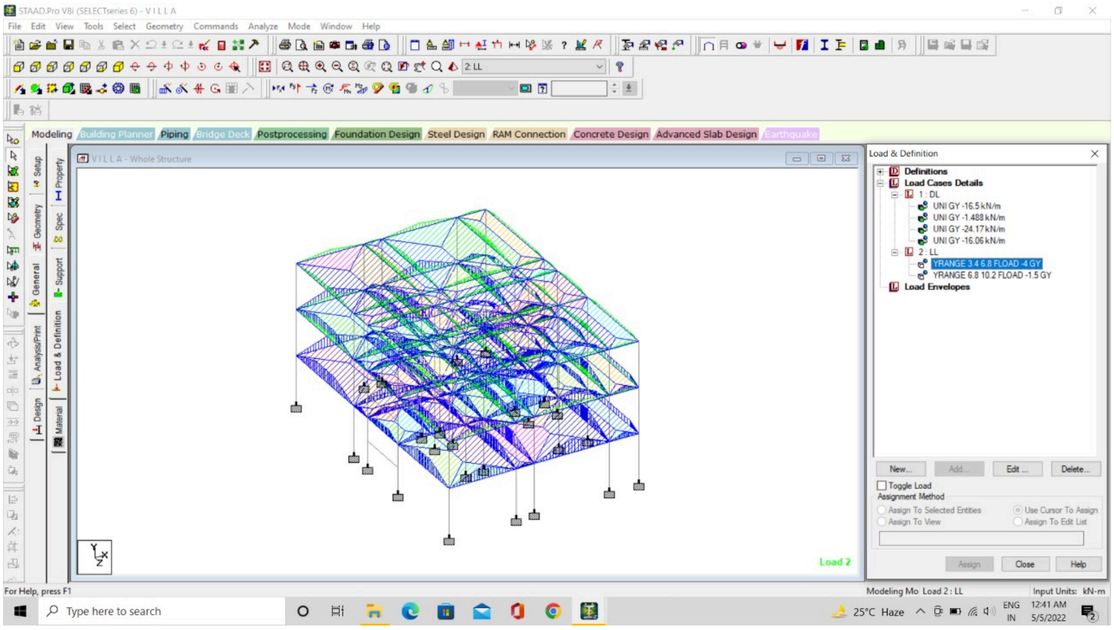


Figure 4. 5 - Live loading on the structure (Villa)

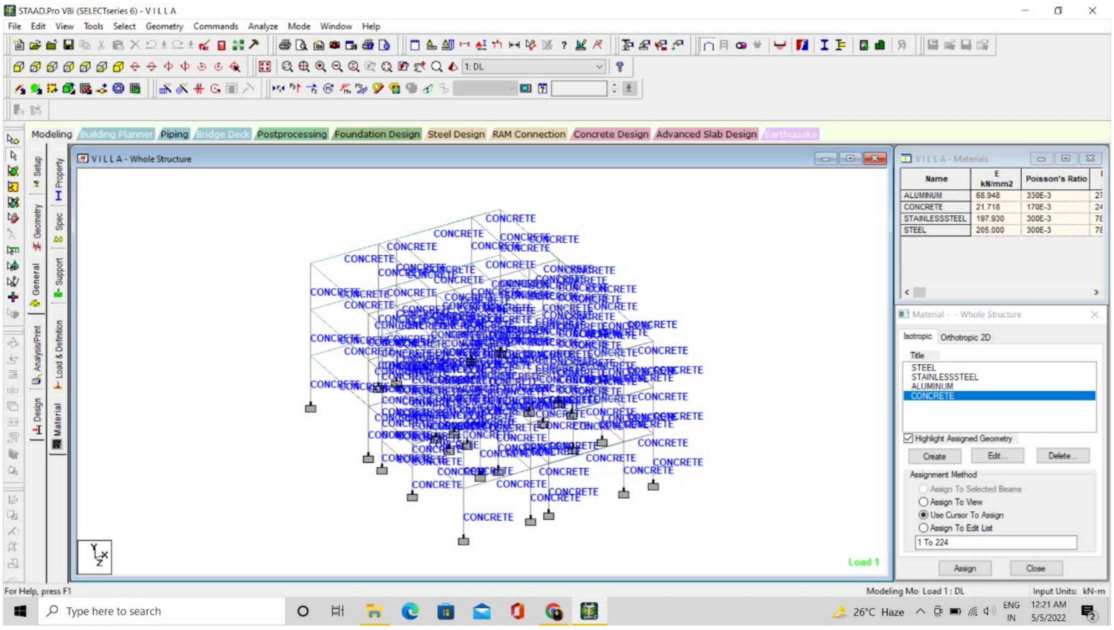


Figure 4. 6 - Material used in the structure (Villa)

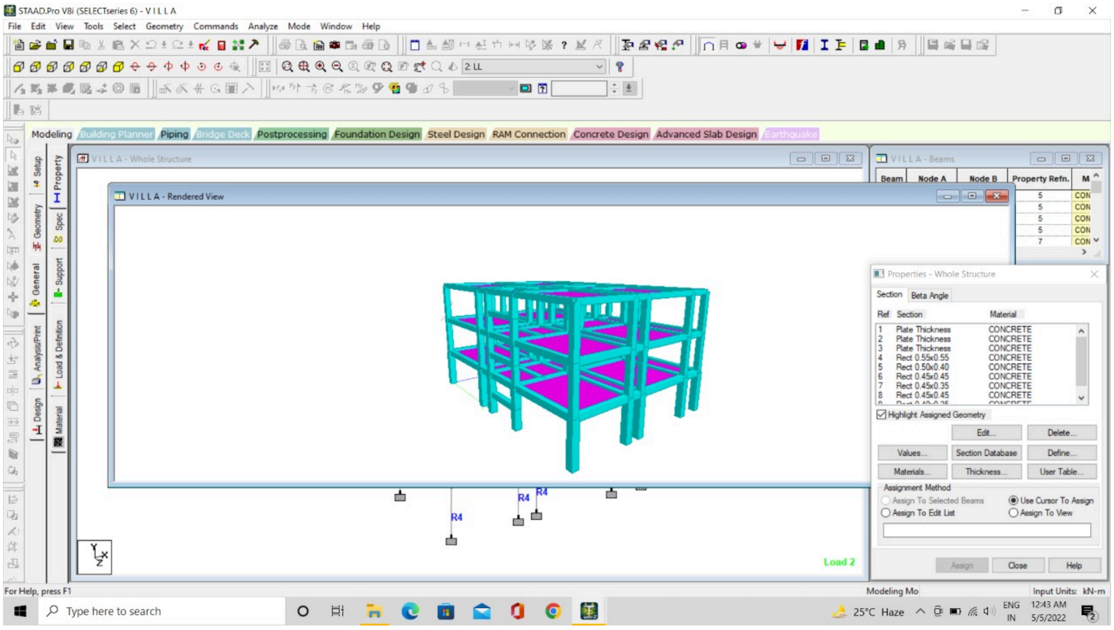


Figure 4. 7 - 3-D view of the structure (villa)

4.2.1.3 RCC design of ground floor of villa

LATERAL BEAM						
BEAM NO. 3 DESIGN RESULTS						
Concrete used M25	FY	550	FC	25MPA		
LENGTH: 5540 mm	SIZE:	400mmX500mm				
LEVEL	HEIGHT	BAR INFO	FROM	TO	ANCHOR	
	(MM)		(MM)	(MM)	START	END
1	57	3-12 MM	952	4358	NO	NO
2	443	3-12 MM	0	1543	YES	NO
3	443	3-12 MM	3766	5540	NO	YES

Table 4. 5 - Design results of Lateral beam (ground floor, Villa)

LONGITUDINAL BEAM						
BEAM NO. 183 DESIGN RESULTS						
Concrete used M25	FY	550	FC	25MPA		
LENGTH: 6480 mm	SIZE:	400mmX500mm				
LEVEL	HEIGHT	BAR INFO	FROM	TO	ANCHOR	
	(MM)		(MM)	(MM)	START	END
1	57	3-12 MM	1152	5058	NO	NO
2	443	3-12 MM	0	1700	YES	NO
3	443	3-12 MM	4510	6480	NO	YES

Table 4. 6 - Design results of Longitudinal beam (ground floor, Villa)

DESIGN RESULTS SHEAR					
at start support	Vu= 38.38 KNS	Vc= 147.33 KNS	Vs= 0.00 KNS		
	Tu = 0.10 KN-MET	Tc= 6.9 KN-MET	Ts= 0.0 KN-MET	LOAD	1
STIRRUPS ARE NOT REQUIRED					
at end support	Vu= 38.62 KNS	Vc= 147.33 KNS	Vs= 0.00 KNS		
	Tu = 0.10 KN-MET	Tc= 6.9 KN-MET	Ts= 0.0 KN-MET	LOAD	1
STIRRUPS ARE NOT REQUIRED					

Table 4. 7 - Design results shear (Lateral beam, ground floor, Villa)

DESIGN RESULTS SHEAR					
at start support	Vu= 4.41 KNS	Vc= 141.38 KNS	Vs= 0.00 KNS		
	Tu = 0.61 KN-MET	Tc= 6.9 KN-MET	Ts= 0.0 KN-MET	LOAD	1
STIRRUPS ARE NOT REQUIRED					
at end support	Vu= 3.93 KNS	Vc= 141.92 KNS	Vs= 0.00 KNS		
	Tu = 0.61 KN-MET	Tc= 6.9 KN-MET	Ts= 0.0 KN-MET	LOAD	1
STIRRUPS ARE NOT REQUIRED					

Table 4. 8 - Design results shear (Longitudinal beam, ground floor, Villa)

COLUMN LOAD				
COLUMN NO. 22				
FY	550	FC	25 MPA	
SIZE	450X450 MMS	TIED		
ONLY MINIMUM STEEL IS REQUIRED				
AREA OF STEEL REQUIRED = 2025.0 MM2				
bar configuration	REINF PCT.	LOAD	LOCATION	PHI
20-12 MM	1.117	1	END	0.65
	(Provide Equal Number Of Bars On Each Face)			
tie bar number	12 Spacing 192.00 MM			

Table 4. 9 - Column Loads (Ground floor, Villa)

4.2.1.4 RCC design of first floor of villa

LATERAL BEAM						
BEAM NO. 7 DESIGN RESULTS						
concrete used m25	FY	550	FC	25MPA		
LENGTH: 5540 mm	SIZE:	350mmX450mm				
LEVEL	height	bar info	from	to	anchor	
	(MM)		(MM)	(MM)	START	END
1	57	3-12 MM	930	4379	NO	NO
2	393	3-12 MM	0	1543	YES	NO
3	393	3-12 MM	3766	5540	NO	YES

Table 4. 10 - Design results of Lateral beam (First floor, Villa)

LONGITUDINAL BEAM						
BEAM NO. 188 DESIGN RESULTS						
concrete used m25	FY	550	FC	25MPA		
LENGTH: 6480 mm	SIZE:	350mmX450mm				
LEVEL	height	bar info	from	to	anchor	
	(MM)		(MM)	(MM)	START	END
1	57	3-12 MM	1035	5175	NO	NO
2	393	4-12 MM	0	1700	YES	NO
3	393	3-12 MM	4510	6480	NO	YES

Table 4. 11 - Design results of Lateral beam (First floor, Villa)

DESIGN RESULTS SHEAR					
at start support	Vu= 39.22 KNS	Vc= 110.54 KNS	Vs= 0.00 KNS		
	Tu = 0.01 KN-MET	Tc= 4.8 KN-MET	Ts= 0.0 KN-MET	LOAD	1
STIRRUPS ARE NOT REQUIRED					
at end support	Vu= 39.44 KNS	Vc= 110.51 KNS	Vs= 0.00 KNS		
	Tu = 0.01 KN-MET	Tc= 4.8 KN-MET	Ts= 0.0 KN-MET	LOAD	1
STIRRUPS ARE NOT REQUIRED					

Table 4. 12 - Design results shear (Lateral beam, first floor, Villa)

DESIGN RESULTS SHEAR					
at start support	Vu= 4.50 KNS	Vc= 114.26 KNS	Vs= 0.00 KNS		
	Tu = 0.51 KN-MET	Tc= 4.8 KN-MET	Ts= 0.0 KN-MET	LOAD	1
STIRRUPS ARE NOT REQUIRED					
at end support	Vu= 4.00 KNS	Vc= 114.26 KNS	Vs= 0.00 KNS		
	Tu = 0.51 KN-MET	Tc= 4.8 KN-MET	Ts= 0.0 KN-MET	LOAD	1
STIRRUPS ARE NOT REQUIRED					

Table 4. 13 - Design results shear (Lateral beam, second floor, Villa)

COLUMN LOAD				
COLUMN NO. 27				
FY	550	FC	25 MPA	
SIZE	450X450 MMS	TIED		
ONLY MINIMUM STEEL IS REQUIRED				
AREA OF STEEL REQUIRED = 2025.0 MM^2				
bar configuration	REINF PCT.	LOAD	LOCATION	PHI
20-12 MM	1.117	1	END	0.65
(Provide Equal Number Of Bars On Each Face)				
tie bar number	12 SPACING 192.00 MM			

Table 4. 14 - Column Loads (First floor, Villa)

4.2.1.5 RCC design of second floor of villa

LATERAL BEAM						
BEAM NO. 3 DESIGN RESULTS						
Concrete used M25	FY	550	FC	25MPA		
LENGTH: 5540 mm	SIZE:	350mmX400mm				
LEVEL	height	bar info	from	to	anchor	
	(MM)		(MM)	(MM)	START	END
1	57	3-12 MM	885	4425	NO	NO
2	343	3-12 MM	0	1543	YES	NO
3	343	3-12 MM	3766	5540	NO	YES

Table 4. 15 - Design results of Lateral beam (Second floor, Villa)

LONGITUDINAL BEAM						
BEAM NO. 193 DESIGN RESULTS						
Concrete used M25	FY	550	FC	25MPA		
LENGTH: 6480 mm	SIZE:	350mmX400mm				
LEVEL	HEIGHT	BAR INFO	FROM	TO	ANCHOR	
	(MM)		(MM)	(MM)	START	END
1	57	3-12 MM	1257	5493	NO	NO
2	343	3-12 MM	0	1700	YES	NO
3	343	3-12 MM	4510	6480	NO	YES

Table 4. 16 - Design results of Longitudinal beam (Second floor, Villa)

DESIGN RESULTS SHEAR					
at start support	Vu= 39.96 KNS	Vc= 96.80 KNS	Vs= 0.00 KNS		
	Tu = 0.24 KN-MET	Tc= 4.1 KN-MET	Ts= 0.0 KN-MET	LOAD	1
STIRRUPS ARE NOT REQUIRED FOR TORSION					
REINFORCEMENT FOR SHEAR IS PER CL. 11.5.5.1					
PROVIDE 12 MM 2- LEGGED STIRRUPS AT 172 MM C/C FOR 2434 MM					
at end support	Vu= 40.34 KNS	Vc= 96.75 KNS	Vs= 0.00 KNS		
	Tu = 0.24 KN-MET	Tc= 4.1 KN-MET	Ts= 0.0 KN-MET	LOAD	1
STIRRUPS ARE NOT REQUIRED FOR TORSION					
REINFORCEMENT FOR SHEAR IS PER CL. 11.5.5.1					
PROVIDE 12 MM 2- LEGGED STIRRUPS AT 172 MM C/C FOR 2434 MM					

Table 4. 17 - Design results shear (Lateral beam, second floor, Villa)

DESIGN RESULTS SHEAR					
at start support	Vu= 4.68 KNS	Vc= 95.40 KNS	Vs= 0.00 KNS		
	Tu = 0.82 KN-MET	Tc= 4.1 KN-MET	Ts= 0.0 KN-MET	LOAD	1
STIRRUPS ARE NOT REQUIRED					
at end support	Vu= 3.97 KNS	Vc= 95.74 KNS	Vs= 0.00 KNS		
	Tu = 0.82 KN-MET	Tc= 4.1 KN-MET	Ts= 0.0 KN-MET	LOAD	1
STIRRUPS ARE NOT REQUIRED					

Table 4. 18 - Design results shear (Lateral beam, second floor, Villa)

COLUMN LOAD				
COLUMN NO. 32				
FY	550	FC	25 MPA	
SIZE	350X450 MMS	TIED		
ONLY MINIMUM STEEL IS REQUIRED				
AREA OF STEEL REQUIRED = 1575.0 MM2				
bar configuration	REINF PCT.	LOAD	LOCATION	PHI
8-16 MM	1.021	1	END	0.9
(PROVIDE EQUAL NUMBER OF BARS ON EACH FACE)				
tie bar number	12 SPACING 256.00 MM			

Table 4. 19 - Column Loads (First floor, Villa)

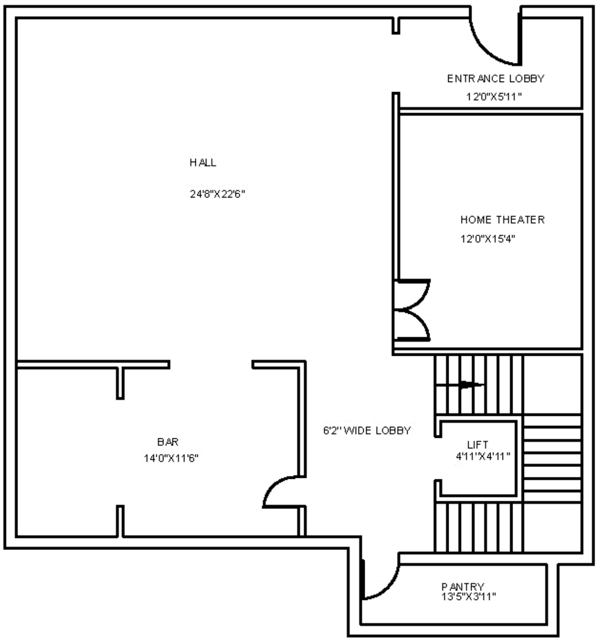
4.2.2 Design of Bungalow

4.2.2.1 Plan of Bungalow

Total Area: 3200 ft^2 (40 ft. x 80 ft.)

Carpet Area: 2736 ft^2 (38 ft. x 72 ft.)

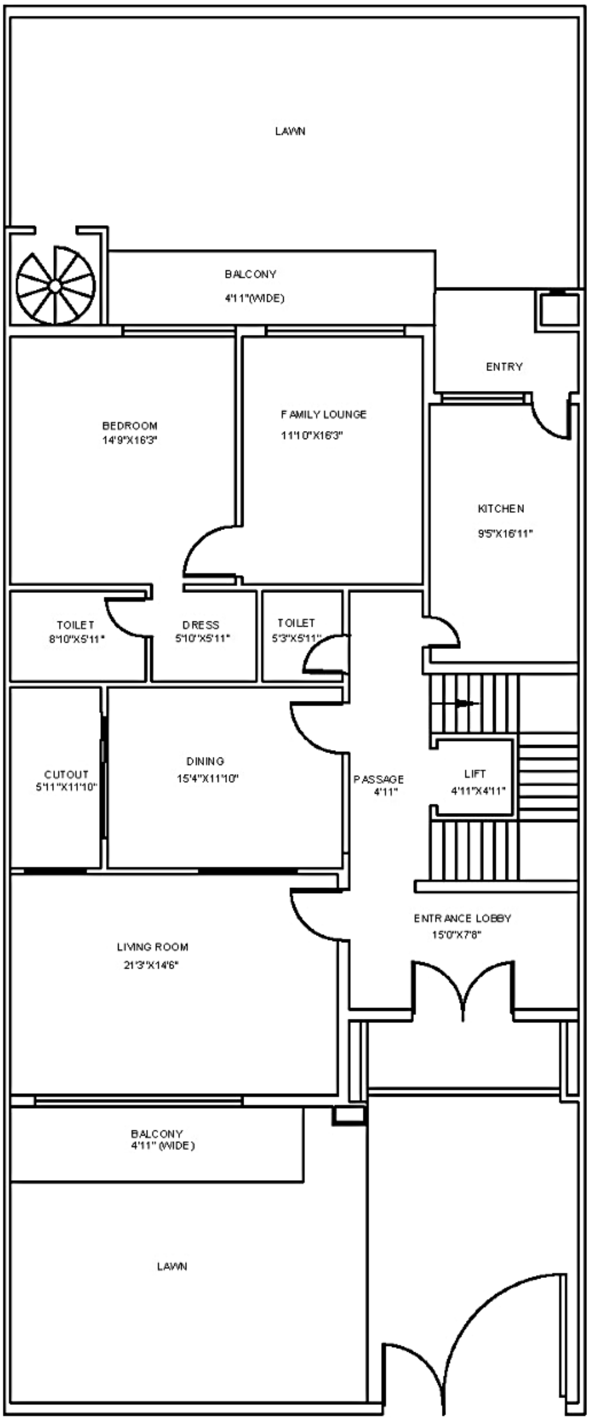
Built-up Area: 2191 ft^2



Scale – 1:150

All dimensions in “feet-inches”.

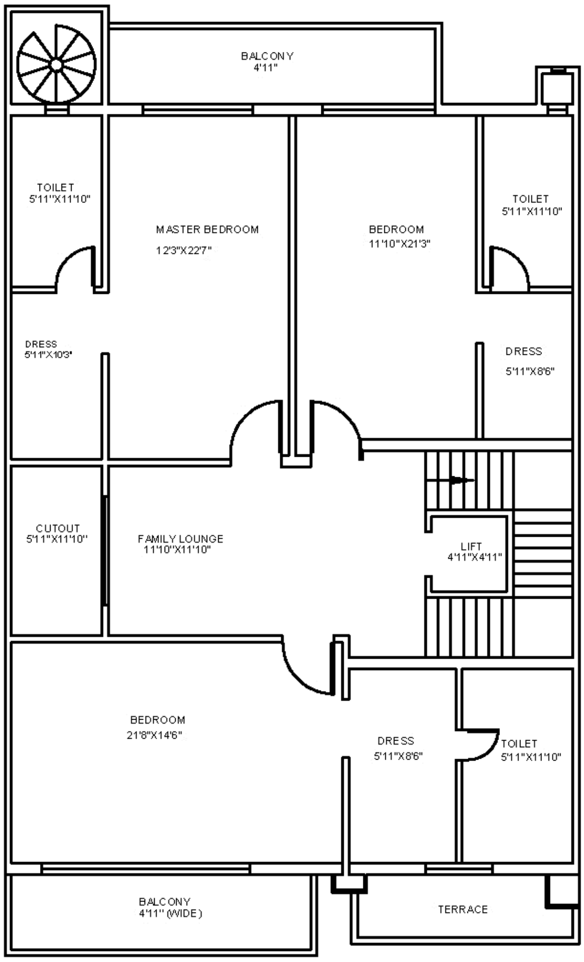
Figure 4. 8 - Plan view of Basement (Bungalow)



Scale – 1:150

All dimensions in “feet-inches”.

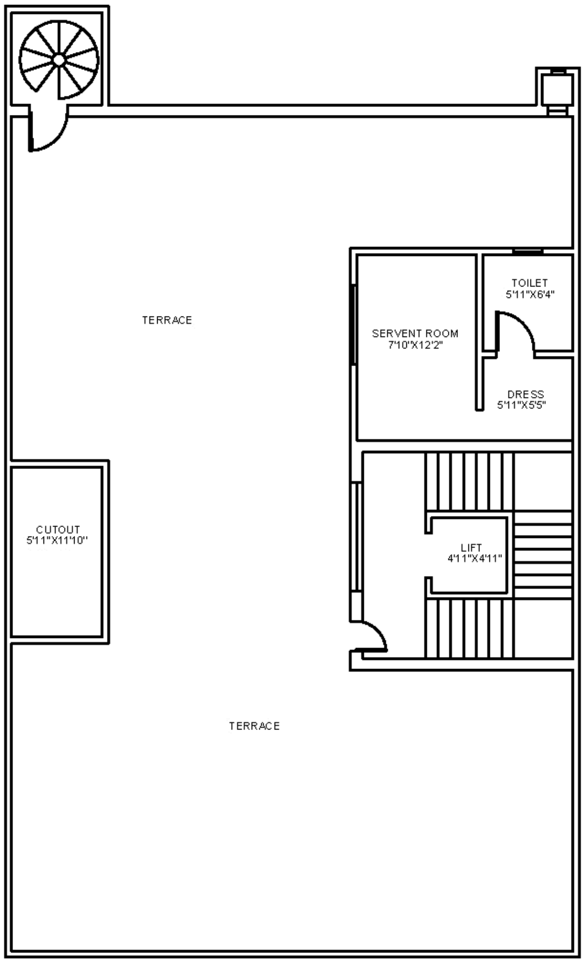
Figure 4. 9 - Plan view of Ground Floor (Bungalow)



Scale – 1:150

All dimensions in "feet-inches".

Figure 4. 10 - Plan view of First Floor (Bungalow)



Scale – 1:150

All dimensions in “feet-inches”.

Figure 4. 11 - Plan view of Second Floor (Bungalow)

4.2.2.2 STAAD Model of Bungalow

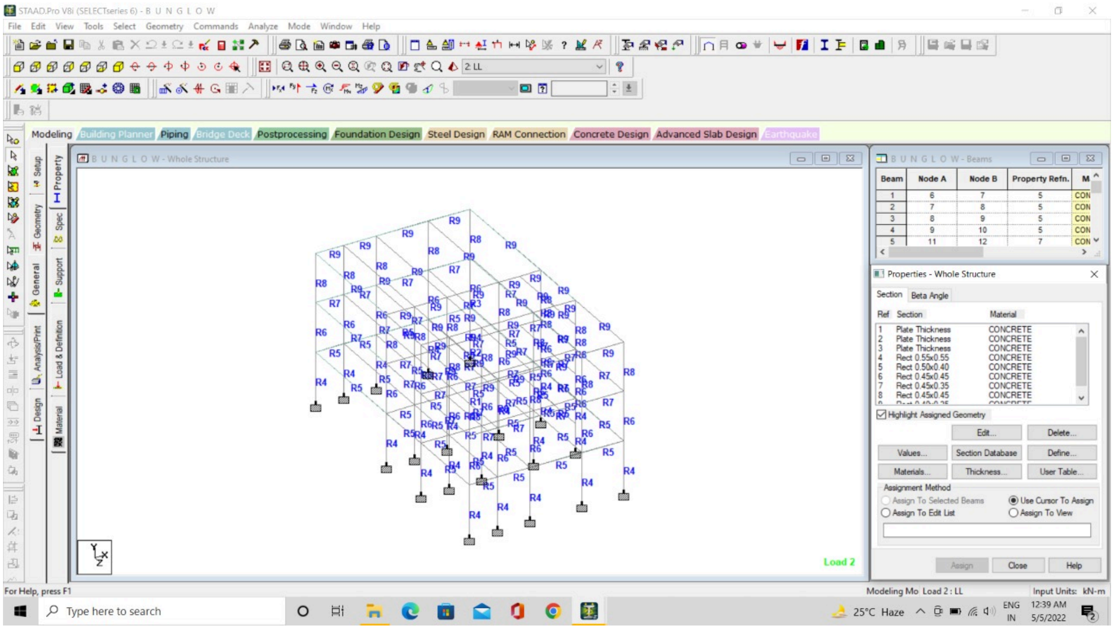


Figure 4. 12 - Live loading on the structure (Bungalow)

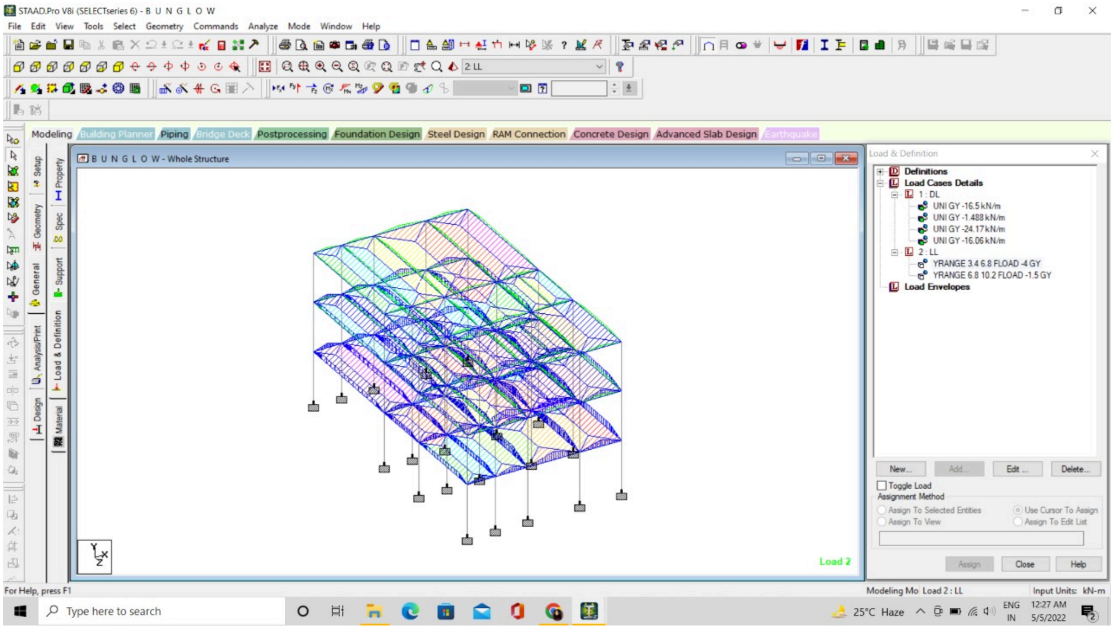


Figure 4. 13 - Material used in the structure (Bungalow)

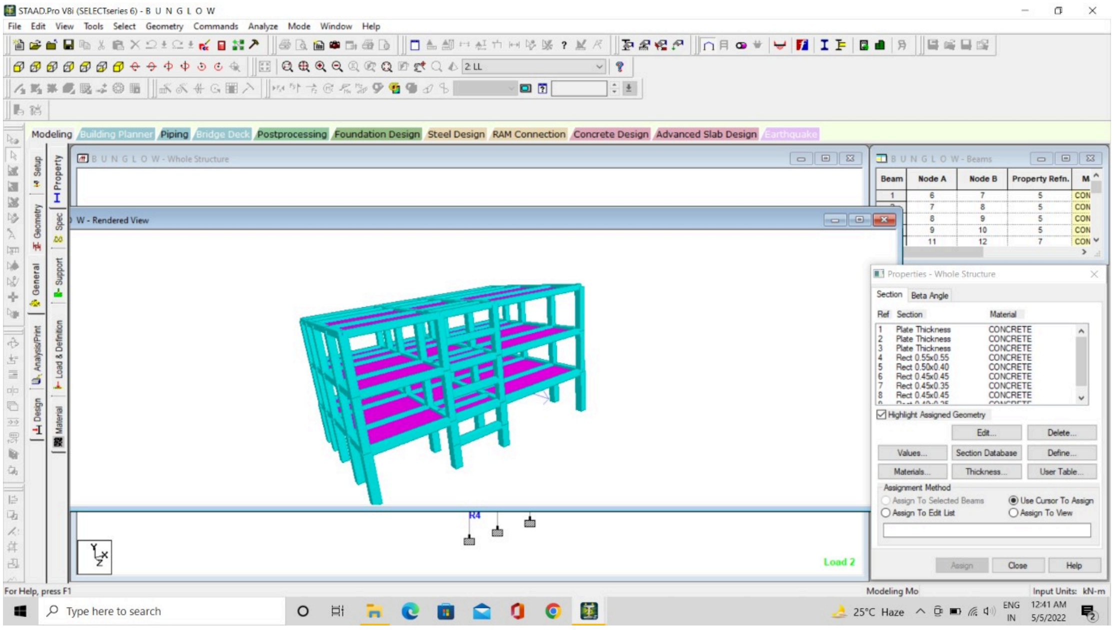


Figure 4. 14 - 3-D view of the structure (Bungalow)

4.2.2.3 RCC design of ground floor of bungalow

LONGITUDINAL BEAM					
BEAM NO. 109					
concrete used m25	Fe 550 (Main)		Fe 550 (Sec)		
LENGTH: 8470.9mm	SIZE:	400mmX500mm		COVER: 25 mm	
REINFORCEMENT AREA (mm^2)					
SECTION	0.0 (mm)	2117.7 (mm)	4235.4 (mm)	6353.2 (mm)	8470.9(mm)
top reinforcement	427.39	0	0	0	455.23
bottom reinforcement	0	290.55	290.55	290.55	0
PROVIDED REINFORCEMENT AREA					
section	0.0 (mm)	2117.7 (mm)	4235.4 (mm)	6353.2 (mm)	8470.9(mm)
top reinforcement	11-10i	4-10i	4-10i	4-10i	11-10i
	1 layer(s)	1 layer(s)	1 layer(s)	1 layer(s)	1 layer(s)
bottom reinforcement	4-10i	11-10i	11-10i	11-10i	4-10i
	1 layer(s)	1 layer(s)	1 layer(s)	1 layer(s)	1 layer(s)
shear reinforcement	2 legged 8i @ 200mm c/c	2 legged 8i @ 200mm c/c	2 legged 8i @ 200mm c/c	2 legged 8i @ 200mm c/c	2 legged 8i @ 200mm c/c

Table 4. 20 - Design results of Longitudinal beam (ground floor, Bungalow)

LATERAL BEAM					
BEAM NO. 57					
Concrete used M25	Fe 550 (Main)		Fe 550 (Sec)		
LENGTH: 3606.8 mm	SIZE:	400mmX500mm		COVER: 25 mm	
REINFORCEMENT AREA (mm2)					
SECTION	0.0 (mm)	901.7 (mm)	1803.4 (mm)	2705.1 (mm)	3606.8 (mm)
top reinforcement	290.55	290.55	0	290.55	290.55
bottom reinforcement	0	290.55	290.55	290.55	0
		PROVIDED REINFORCEMENT AREA			
section	0.0 (mm)	901.7 (mm)	1803.4 (mm)	2705.1 (mm)	3606.8 (mm)
top reinforcement	11-10i	4-10i	4-10i	11-10i	11-10i
	1 layer(s)	1 layer(s)	1layer(s)	1 layer(s)	1 layer(s)
bottom reinforcement	4-10i	11-10i	11-10i	11-10i	4-10i
	1 layer(s)	1 layer(s)	1 layer(s)	1 layer(s)	1 layer(s)
shear reinforcement	2 legged 8i @	2 legged 8i @	2 legged 8i @	2 legged 8i @	2 legged 8i @
	200mm c/c	200mm c/c	200mm c/c	200mm c/c	200mm c/c

Table 4. 21 - Design results of Lateral beam (ground floor, Bungalow)

COLUMN LOAD				
COLUMN NO. 22				
CONCRETE USED M25	Fe 550 (Main)		Fe 550 (Sec)	
LENGTH: 3400.0mm	C/S	450mmX450mm		COVER: 40 mm
GUIDING LOAD CASE:	2 END JOINT 15 SHORT COLUMN			
REQD. STEEL AREA :	149.05 mm2			
REQD. CONCRETE AREA	18631.80 mm2			
MAIN REINFORCEMENT	8-12 dia. (0.45% , 904.78 mm2) Equally Distributed			
TIE REINFORCEMENT	8mm dia. Rectangular ties @190 mm C/C			
SECTION CAPACITY BASED ON REINFORCEMENT REQUIRED (KNS-MET)				
Puz : 2337.93	Muzl : 24.45	Muyl: 24.45		
INTERACTION RATIO: 0.96 (as per Cl. 39.6, IS456: 2000)				
SECTION CAPACITY BASED ON REINFORCEMENT PROVIDED (KNS-MET)				

WORST LOAD CASE: 1				
END JOINT: 15	Puz: 2641.17	Muz: 112.75		
	Muy: 112.75	IR: 0.35		

Table 4. 22 - Column Loads (ground floor, Bungalow)

4.2.2.4 RCC design of first floor of bungalow

LONGITUDINAL BEAM					
BEAM NO. 114					
CONCRETE USED M25	Fe 550 (Main)		Fe 550 (Sec)		
LENGTH: 8470.9mm	SIZE:	350mmX450mm		COVER: 25 mm	
		REINFORCEMENT AREA (mm2)			
SECTION	0.0 (mm)	2117.7 (mm)	4235.4 (mm)	6353.2 (mm)	8470.9 (mm)
TOP REINFORCEMENT	504.24	0	0	0	527.19
BOTTOM REINFORCEMENT	0	227.18	227.18	227.18	0
	PROVIDED REINFORCEMENT AREA				
SECTION	0.0 (mm)	2117.7 (mm)	4235.4 (mm)	6353.2 (mm)	8470.9 (mm)
TOP REINFORCEMENT	10-10i	3-10i	3-10i	3-10i	10-10i
	1 layer (s)	1 layer(s)	1 layer (s)	1 layer(s)	1 layer(s)
BOTTOM REINFORCEMENT	3-10i	10-10i	10-10i	10-10i	3-10i
	1 layer (s)	1 layer(s)	1 layer (s)	1 layer(s)	1 layer(s)
SHEAR REINFORCEMENT	2 legged 8i @	2 legged 8i @	2 legged 8i @	2 legged 8i @	2 legged 8i @
	175mm c/c	175mm c/c	175mm c/c	175mm c/c	175mm c/c

Table 4. 23 - Design results of Longitudinal beam (first floor, Bungalow)

LATERAL BEAM					
BEAM NO. 61					
CONCRETE USED M25	Fe 550 (Main)		Fe 550 (Sec)		
LENGTH: 3606.8 mm	SIZE:	350mmX450mm		COVER 25 mm	
REINFORCEMENT AREA (mm2)					
SECTION	0.0 (mm)	901.7 (mm)	1803.4 (mm)	2705.1 (mm)	3606.8 (mm)
TOP REINFORCEMENT	227.18	227.18	227.18	227.18	227.18
BOTTOM REINFORCEMENT	0	227.18	227.18	227.18	0
PROVIDED REINFORCEMENT AREA					
SECTION	0.0 (mm)	901.7 (mm)	1803.4 (mm)	2705.1 (mm)	3606.8 (mm)
TOP REINFORCEMENT	10-10i	10-10i	10-10i	10-10i	10-10i
	1 layer (s)	1 layer(s)	1 layer (s)	1 layer (s)	1 layer(s)
BOTTOM REINFORCEMENT	3-10i	10-10i	10-10i	10-10i	3-10i
	1 layer (s)	1 layer(s)	1 layer (s)	1 layer (s)	1 layer(s)
SHEAR REINFORCEMENT	2 legged 8i @	2 legged 8i @	2 legged 8i @	2 legged 8i @	2 legged 8i @
	175m m c/c	175mm c/c	175mm c/c	175mm c/c	175mm c/c

Table 4. 24 - Design results of Lateral beam (first floor, Bungalow)

COLUMN LOAD				
COLUMN NO. 27				
CONCRETE USED M25	Fe 550 (Main)		Fe 550 (Sec)	
LENGTH: 3400mm	C/S	450mmX450mm		COVER: 40 mm
GUIDING LOAD CASE:	1 END JOINT 20 SHORT COLUMN			
REQD. STEEL AREA :	738.04 mm2			
REQD. CONCRETE AREA :	92255.30 mm2			
MAIN REINFORCEMENT :	8-12 dia. (0.45% , 904.78 mm2) Equally Distributed			
TIE REINFORCEMENT :	8mm dia. Rectangular ties @190 mm C/C			

SECTION CAPACITY BASED ON REINFORCEMENT REQUIRED (KNS-MET)				
Puz : 2574.26	Muzl: 83.89	Muyl: 83.89		
INTERACTION RATIO : 0.99 (as per Cl. 39.6, IS456: 2000)				
SECTION CAPACITY BASED ON REINFORCEMENT PROVIDED (KNS-MET)				
WORST LOAD CASE: 1				
END JOINT: 20	Puz: 2641.17	Muz: 98.03		
	Muy: 98.03	IR: 0.85		

Table 4. 25 - Column Loads (first floor, Bungalow)

4.2.2.5 RCC design of second floor of bungalow

LONGITUDINAL BEAM					
BEAM NO. 119					
CONCRETE USED M25	Fe 550 (Main)		Fe 550 (Sec)		
LENGTH: 8470.9mm	SIZE:	350mmX450mm		COVER: 25 mm	
		REINFORCEMENT AREA (mm2)			
SECTION	0.0 (mm)	2117.7 (mm)	4235.4 (mm)	6353.2 (mm)	8470.9 (mm)
TOP REINFORCEMENT	557.94	0	0	0	622.13
BOTTOM REINFORCEMENT	0	199.6	199.6	199.6	0
	PROVIDED REINFORCEMENT AREA				
SECTION	0.0 (mm)	2117.7 (mm)	4235.4 (mm)	6353.2 (mm)	8470.9(mm)
TOP REINFORCEMENT	8-20i	2-20i	2-20i	2-20i	8-20i
	1 layer(s)	1 layer(s)	1 layer (s)	1 layer(s)	1 layer(s)
BOTTOM REINFORCEMENT	2-12i	9-12i	9-12i	9-12i	2-12i
	1 layer (s)	1 layer(s)	1 layer (s)	1 layer(s)	1 layer(s)
SHEAR REINFORCEMENT	2 legged 8i @	2 legged 8i @	2 legged 8i @	2 legged 8i @	2 legged 8i @
	165mm c/c	165mm c/c	165mm c/c	165mm c/c	165mm c/c

Table 4. 26 - Design results of Longitudinal beam (second floor, Bungalow)

LATERAL BEAM					
BEAM NO. 65					
CONCRETE USED M25	Fe 550 (Main)		Fe 550 (Sec)		
LENGTH: 3606.8 mm	SIZE:	350mmX400 mm		COVER: 25 mm	
REINFORCEMENT AREA (mm2)					
SECTION	0.0 (mm)	901.7 (mm)	1803.4 (mm)	2705.1 (mm)	3606.8(mm)
TOP REINFORCEMENT	199.6	199.6	199.6	199.6	199.6
BOTTOM REINFORCEMENT	0	199.6	199.6	199.6	0
PROVIDED REINFORCEMENT AREA					
SECTION	0.0 (mm)	901.7 (mm)	1803.4 (mm)	2705.1 (mm)	3606.8(mm)
TOP REINFORCEMENT	9-12i	9-12i	9-12i	9-12i	9-12i
	1 layer (s)	1 layer(s)	1 layer (s)	1 layer(s)	1 layer(s)
BOTTOM REINFORCEMENT	2-12i	9-12i	9-12i	9-12i	2-12i
	1 layer (s)	1 layer(s)	1 layer (s)	1 layer(s)	1 layer(s)
SHEAR REINFORCEMENT	2 legged 8i @	2 legged 8i @	2 legged 8i @	2 legged 8i @	2 legged 8i @
	165mm c/c	165mm c/c	165mm c/c	165mm c/c	165mm c/c

Table 4. 27 - Design results of Lateral beam (second floor, Bungalow)

COLUMN LOAD				
COLUMN NO. 32				
CONCRETE USED M25	Fe 550 (Main)		Fe 550 (Sec)	
LENGTH: 1930.4mm	C/S	350mmX450mm		COVER: 40 mm
GUIDING LOAD CASE:	2 END JOINT 31 TENSION COLUMN			
REQD. STEEL AREA :	1260.00 mm2			
REQD. CONCRETE AREA :	156240.00 mm2			
MAIN REINFORCEMENT :	12-12 dia. (0.86% , 1357.17 mm2) Equally Distributed			

TIE REINFORCEMENT :	8mm dia. Rectangular ties @190 mm C/C			
SECTION CAPACITY BASED ON REINFORCEMENT REQUIRED (KNS-MET)				
Puz : 2277.45	Muzl: 108.37	Muyl: 80.79		
INTERACTION RATIO : 0.04 (as per Cl. 39.6, IS456: 2000)				
SECTION CAPACITY BASED ON REINFORCEMENT PROVIDED (KNS-MET)				
WORST LOAD CASE: 2				
END JOINT: 31	Puz: 2316.44	Muz: 117.45		
	Muy: 87.02	IR: 0.04		

Table 4. 28 - Column Loads (second floor, Bungalow)

4.2.3 Steel Design calculation of Basements of Bungalows and Villas

MEMBER	TABLE	RESULT	FX	CRITICAL LOAD	MY	RATIO	MZ	LOADING	LOCATION
1	PRISMAT	PASS	2.84	IS-7.1.1(A)	0	0.021	5.71	1	0
2	PRISMAT	PASS	23.95	IS-7.1.1(A)	15.95	0.045	5.71	1	3
3	PRISMAT	PASS	23.95	IS-7.1.1(A)	15.95	0.045	-5.71	1	3
4	PRISMAT	PASS	2.84	IS-7.1.1(A)	0	0.021	5.71	1	0
5	PRISMAT	PASS	23.95	IS-7.1.1(A)	-15.95	0.045	5.71	1	3
6	PRISMAT	PASS	23.95	IS-7.1.1(A)	-15.95	0.045	-5.71	1	3
7	PRISMAT	PASS	7.88	IS-7.1.1(A)	0	0.084	15.95	1	0
8	PRISMAT	PASS	7.88	IS-7.1.1(A)	0	0.084	15.95	1	0

Table 4. 29 - Steel Design calculation of Basements of Bungalows and Villas

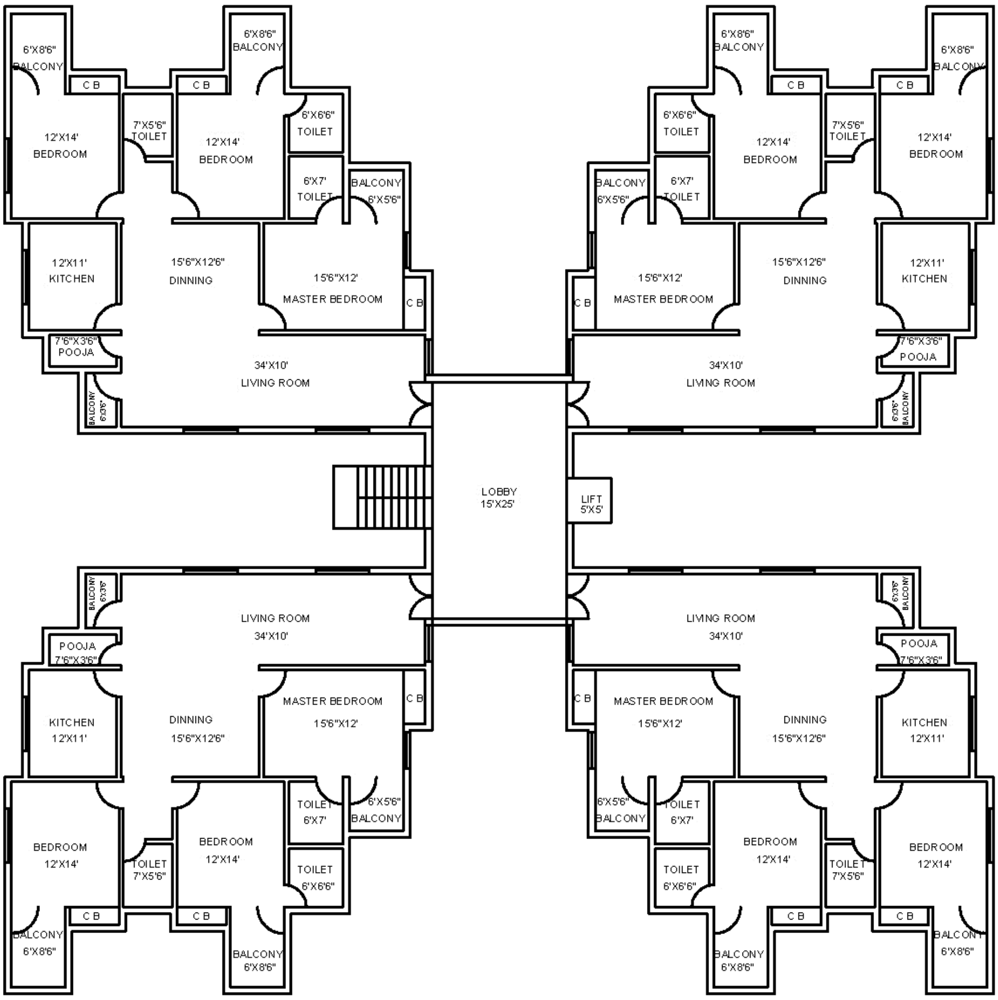
4.2.4 Plan of Apartment and flat

For complete apartment:

Total Area: 13456 ft^2 (116 ft. x 116 ft.)

Carpet Area: 12210 ft^2 (110 ft. 6 in. x 110 ft. 6 in.)

Built-up Area: 10897 ft^2



Scale – 1:250

All dimensions in “feet-inches”.

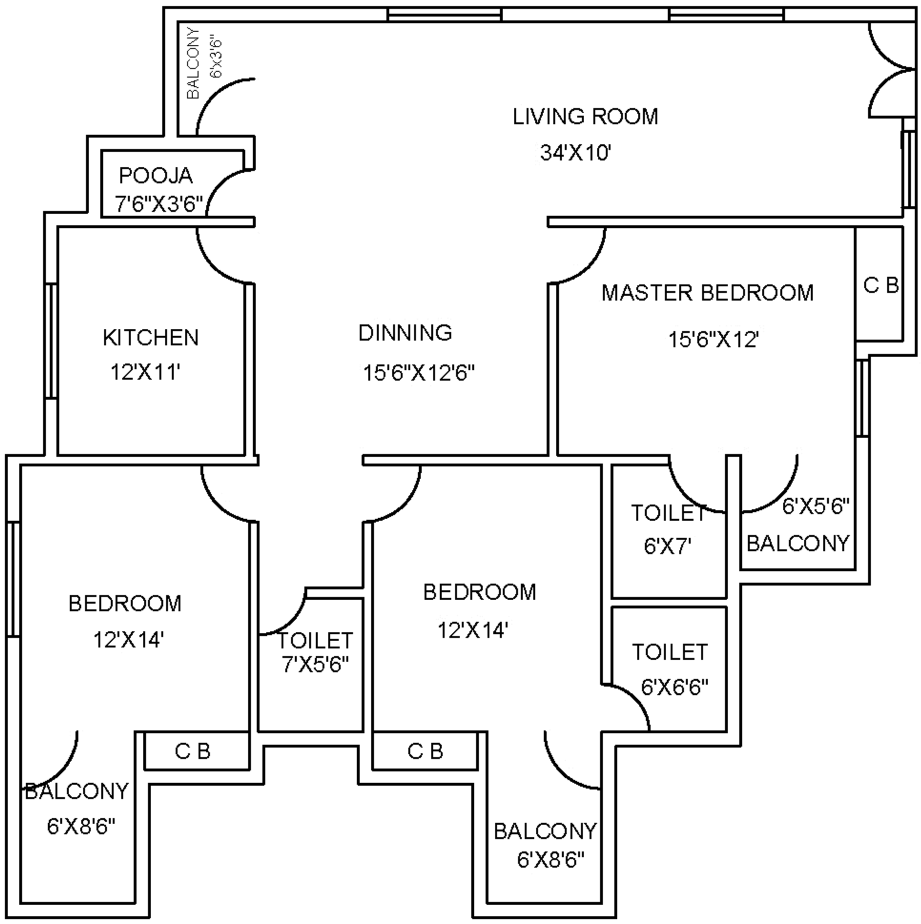
Figure 4. 15 - Plan view of Complete Apartment

For one 3 BHK Flat:

Total Area: 3335 ft^2 (57 ft. 9 in. x 57 ft. 9 in.)

Carpet Area: 2280 ft^2 (47 ft. 9 in. x 47 ft. 9 in.)

Built-up Area: 1800 ft^2



Scale – 1:120

All dimensions in “feet-inches”.

Figure 4. 16 - Plan view of 1 3BHK Flat

4.2.4 Discussion

The RCC design calculation was carried out using STAAD.Pro. The live loadings on villas and the material used are shown in sections 4.2.1 and 4.2.2. Sections 4.4.1 and 4.4.2 discuss the design of all floors of the villa (including lateral and longitudinal beams), bungalows, and steel design of the same.

4.3 Natural Lighting and Ventilation

4.3.1 Natural Lighting

4.3.1.1 Apartments (3BHK)

Apartment: 3 BHK							
S. No.	Room	Area (ft^2)	Area (m^2)	Window Area	AVTG	Constant	Glazing Factor
1	Living Room	340	31.62	130	0.89	0.2	6.81
2	Pooja	26.25	2.44	42.5	0.89	0.2	28.82
3	Dining	193.75	18.02	48	0.89	0.2	4.41
4	Kitchen	132	12.28	24	0.89	0.2	3.24
5	Bedroom	168	15.62	90	0.89	0.2	9.54
6	Toilet	38.5	3.58	4	0.89	0.2	1.85
7	Bedroom	168	15.62	66	0.89	0.2	6.99
8	Toilet	39	3.63	4	0.89	0.2	1.83
9	Master Bedroom	186	17.3	82	0.89	0.2	7.85
10	Toilet	42	3.91	4	0.89	0.2	1.70

Table 4. 30 - Calculation for minimum natural lighting (apartment)

4.3.1.2 Villa

Villa: Ground Floor							
S. No.	Room	Area (ft^2)	Area (m^2)	Window Area	AVTG	Constant	Glazing Factor
1	Longue	242.1	22.5	32	0.89	0.2	2.35
2	Pantry	279.76	26	40	0.89	0.2	2.55
3	Store Room	53.8	5	16	0.89	0.2	5.29
4	Store Room	67.68	6.29	16	0.89	0.2	4.21
5	Dining	290.3	26.98	48	0.89	0.2	2.94
6	Toilet	32.93	3.06	4	0.89	0.2	2.16
7	Lawn	105.99	9.85	16	0.89	0.2	2.69
8	Living Hall	555.86	51.66	68	0.89	0.2	2.18
9	Bedroom	286.54	26.63	48	0.89	0.2	2.98
10	Dress	58.1	5.4	12	0.89	0.2	3.68
11	Toilet	55.63	5.17	8	0.89	0.2	2.56

Table 4. 31 - Calculation for minimum natural lighting (ground floor, Villa)

Villa: First Floor							
S. No.	Room	Area (ft^2)	Area (m^2)	Window Area	AVTG	Constant	Glazing Factor
1	Master Bedroom	362.72	33.71	48	0.89	0.2	2.36
2	Toilet	89.95	8.36	8	0.89	0.2	1.58
3	Dress	77.9	7.24	12	0.89	0.2	2.74
4	Bedroom 1	286.54	26.63	44	0.89	0.2	2.73
5	Dress	72.85	6.77	9	0.89	0.2	2.20
6	Toilet	91.14	8.47	8	0.89	0.2	1.56
7	Longue	390.37	36.28	48	0.89	0.2	2.19
8	Puja Room	82.42	7.66	10	0.89	0.2	2.16
9	Bedroom 2	269	25	36	0.89	0.2	2.38
10	Dress	119.11	11.07	12	0.89	0.2	1.79
11	Toilet	161.4	15	13	0.89	0.2	1.43
12	Store Room	50.79	4.72	16	0.89	0.2	5.61

Table 4. 32 - Calculation for minimum natural lighting (first floor, Villa)

Villa: Second Floor							
S. No.	Room	Area (ft^2)	Area (m^2)	Window Area	AVTG	Constant	Glazing Factor
1	Servant Room	93.93	8.73	16	0.89	0.2	3.03
2	Toilet	37.34	3.47	4	0.89	0.2	1.91
3	Utility Room	143.86	13.37	20	0.89	0.2	2.47
4	Toilet	31.96	2.97	4	0.89	0.2	2.23

Table 4. 33 - Calculation for minimum natural lighting (second floor, Villa)

4.3.1.3 Bungalow

Bungalow: Ground Floor							
S. No.	Room	Area (ft^2)	Area (m^2)	Window Area	AVTG	Constant	Glazing Factor
1	Living Room	308.13	28.66	44	0.89	0.2	2.54
2	Dining	181.44	16.87	44	0.89	0.2	4.32
3	Toilet	31.06	2.89	4	0.89	0.2	2.29
4	Kitchen	159.3	14.81	24	0.89	0.2	2.68
5	Longue	92.29	8.58	24	0.89	0.2	4.63
6	Bedroom	239.69	22.29	24	0.89	0.2	1.78
7	Dress	34.51	3.21	4	0.89	0.2	2.06
8	Toilet	52.26	4.86	4	0.89	0.2	1.36

Table 4. 34 - Calculation for minimum natural lighting (ground floor, Bungalow)

Bungalow: First Floor							
S. No.	Room	Area (ft^2)	Area (m^2)	Window Area	AVTG	Constant	Glazing Factor
1	Bedroom 1	276.65	25.73	32	0.89	0.2	2.06
2	Dress	60.65	5.64	15	0.89	0.2	4.40
3	Toilet	70	6.51	8	0.89	0.2	2.03
4	Bedroom 2	251.46	23.39	32	0.89	0.2	2.27
5	Dress	50.29	4.68	15	0.89	0.2	5.31
6	Toilet	70	6.51	8	0.89	0.2	2.03
7	Longue	140	13.02	24	0.89	0.2	3.05
8	Master Bedroom	314.17	29.22	48	0.89	0.2	2.72
9	Dress	50.29	4.68	6	0.89	0.2	2.12
10	Toilet	70	6.51	8	0.89	0.2	2.03

Table 4. 35 - Calculation for minimum natural lighting (first floor, Bungalow)

Bungalow: Second Floor							
S. No.	Room	Area (ft^2)	Area (m^2)	Window Area	AVTG	Constant	Glazing Factor
1	Servant Room	93.93	8.73	16	0.89	0.2	3.03
2	Toilet	37.34	3.47	4	0.89	0.2	1.91
3	Lift Room	143.86	13.37	20	0.89	0.2	2.47
4	Dress	31.96	2.97	9	0.89	0.2	5.01

Table 4. 36 - Calculation for minimum natural lighting (second floor, Bungalow)

4.3.2 Natural Ventilation

4.3.2.1 Apartments

APARTMENT: 3BHK								
Room	Area (ft^2)	Area (m^2)	Window Area	Door area	W&D area	Actual openable Area	% Of Openable Area	Minimum Required
Living Room	340	31.62	64	56	120	80.04	23.54	10%
Pooja	26.25	2.44	4	38.5	42.5	28.35	108	10%
Dining	193.75	18.02	0	153.5	153.5	102.38	52.84	10%
Kitchen	132	12.28	24	45	69	46.02	34.86	8%
Bedroom	168	15.62	24	42	66	44.02	26.2	10%
Toilet	38.5	3.58	4	21	25	16.68	43.32	4%
Bedroom	168	15.62	0	59.5	59.5	39.69	23.63	10%
Toilet	39	3.63	4	17.5	21.5	14.34	36.77	4%

Master Bedroom	186	17.3	16	59.5	75.5	50.36	27.08	10%
Toilet	42	3.91	4	17.5	21.5	14.34	34.14	4%

Table 4. 37 - Calculation for minimum natural ventilation (Apartment)

4.3.2.2 Villa

VILLA: GROUND FLOOR								
Room	Area (ft^2)	Area (m^2)	Window Area	Door area	W&D area	Actual openable Area	% Of Openable Area	Minimum Required
Longue	242.1	22.5	32	21	53	35.35	14.6	10%
Pantry	279.76	26	40	84	124	82.71	29.56	8%
Store Room	53.8	5	16	21	37	24.68	45.87	10%
Store Room	67.68	6.29	16	21	37	24.68	36.47	10%
Dining	290.3	26.98	48	21	69	46.02	15.85	10%
Toilet	32.93	3.06	4	17.5	21.5	14.34	43.55	4%
Lawn	105.99	9.85	16	56	72	48.02	45.31	10%
Living Hall	555.86	51.66	68	49	117	78.04	14.04	10%
Bedroom	286.54	26.63	48	63	111	74.04	25.84	10%
Dress	58.1	5.4	12	17.5	29.5	19.68	33.87	4%
Toilet	55.63	5.17	8	17.5	25.5	17.01	30.58	4%

Table 4. 38 - Calculation for minimum natural ventilation (ground floor, villa)

VILLA: FIRST FLOOR								
Room	Area (ft^2)	Area (m^2)	Window Area	Door area	W&D area	Actual openabl e Area	% of Openabl e Area	Minimu m Required
Master Bedroom	362.72	33.71	48	63	111	74.04	20.41	10%
Toilet	89.95	8.36	8	17.5	25.5	17.01	18.91	4%
Dress	77.9	7.24	12	17.5	29.5	19.68	25.26	4%
Bedroom 1	286.54	26.63	44	63	107	71.37	24.91	10%
Dress	72.85	6.77	9	17.5	26.5	17.68	24.27	4%
Toilet	91.14	8.47	8	17.5	25.5	17.01	18.66	4%

Longue	390.37	36.28	48	63	111	74.04	18.97	10%
Puja Room	82.42	7.66	10	21	31	20.68	25.09	10%
Bedroom 2	269	25	36	42	78	52.03	19.34	10%
Dress	119.11	11.07	12	42	54	36.02	30.24	4%
Toilet	161.4	15	13	17.5	30.5	20.34	12.6	4%
Store Room	50.79	4.72	16	21	37	24.68	48.59	4%

Table 4. 39 - Calculation for minimum natural ventilation (first floor, villa)

VILLA: SECOND FLOOR								
Room	**Area (ft^2)**	**Area (m^2)**	**Window Area**	**Door area**	**W&D area**	**Actual openable Area**	**% of Openable Area**	**Minimum Required**
Servant Room	93.93	8.73	16	21	37	24.68	26.27	10%
Toilet	37.34	3.47	4	17.5	21.5	14.34	38.4	4%
Utility Room	143.86	13.37	20	21	41	27.35	19.01	10%
Toilet	31.96	2.97	4	17.5	21.5	14.34	44.87	4%

Table 4. 40 - Calculation for minimum natural ventilation (second floor, villa)

4.3.2.3 Bungalow

BUNGALOW: GROUND FLOOR								
Room	Area (ft^2)	Area (m^2)	Window Area	Door area	W&D area	Actual openable Area	% Of Openable Area	Minimum Required
Living Room	308.13	28.66	44	21	65	43.36	14.07	10%
Dining	181.44	16.87	44	21	65	43.36	23.9	10%
Toilet	31.06	2.89	4	17.5	21.5	14.34	46.17	4%
Kitchen	159.3	14.81	24	42	66	44.02	27.63	8%
Longue	92.29	8.58	24	55.42	79.42	52.97	57.4	10%
Bedroom	239.69	22.29	24	42	66	44.02	18.37	10%
Dress	34.51	3.21	4	17.5	21.5	14.34	41.55	4%
Toilet	52.26	4.86	4	17.5	21.5	14.34	27.44	4%

Table 4. 41 - Calculation for minimum natural ventilation (ground floor, Bungalow)

BUNGALOW: FIRST FLOOR								
Room	Area (ft^2)	Area (m^2)	Window Area	Door area	W&D area	Actual openable Area	% Of Openable Area	Minimum Required
Bedroom 1	276.65	25.73	32	42	74	49.36	17.84	10%
Dress	60.65	5.64	15	35	50	33.35	54.99	4%
Toilet	70	6.51	8	17.5	25.5	17.01	24.3	4%
Bedroom 2	251.46	23.39	32	42	74	49.36	19.63	10%
Dress	50.29	4.68	15	35	50	33.35	66.32	4%
Toilet	70	6.51	8	17.5	25.5	17.01	24.3	4%
Lounge	140	13.02	24	0	24	16.01	11.44	10%
Master Bedroom	314.17	29.22	48	21	69	46.02	14.65	10%
Dress	50.29	4.68	6	35	41	27.35	54.38	4%
Toilet	70	6.51	8	17.5	25.5	17.01	24.3	4%

Table 4. 42 - Calculation for minimum natural ventilation (first floor, Bungalow)

BUNGALOW: SECOND FLOOR								
Room	Area (ft^2)	Area (m^2)	Window Area	Door area	W&D area	Actual openable Area	% Of Openable Area	Minimum Required
Servant Room	93.93	8.73	16	21	37	24.68	26.27	10%
Toilet	37.34	3.47	4	17.5	21.5	14.34	38.4	4%
Lift Room	143.86	13.37	20	21	41	27.35	19.01	10%
Dress	31.96	2.97	9	35	44	29.35	91.83	4%

Table 4. 43 - Calculation for minimum natural ventilation (second floor, Bungalow)

4.3.3 Calculation of Energy required for lighting

4.3.3.1 Apartment

APARTMENT: 3BHK						
Room	Area (ft^2)	Area (m^2)	lm/ft^2	lm	Components used	watt
Living Room	340	31.62	80	27200	3 Tubes - 45wt	135
Pooja	26.25	2.44	65	1706.25	1 bulb - 20wt	20
Dining	193.75	18.02	45	8718.75	3 bulbs - 20wt	60

Kitchen	132	12.28	80	10560	3 bulbs - 25wt	75
Bedroom	168	15.62	70	11760	2 Tubes - 45wt	90
Toilet	38.5	3.58	65	2502.5	1 bulb - 20wt	20
Bedroom	168	15.62	70	11760	2 Tubes - 45wt	90
Toilet	39	3.63	65	2535	1 bulb - 20wt	20
Master Bedroom	186	17.3	70	13020	2 Tubes - 45wt	90
Toilet	42	3.91	65	2730	1 bulb - 20wt	20
					total	620

Table 4. 44 - Calculation of energy required for lighting (apartment)

Total energy	**Need in a day**	**In this Project**
620	11160	4340

Table 4. 45 - Comparison of energy required with and without natural lighting (apartment)

4.3.3.2 Villa

Villa: Basement						
Room	Area(ft^2)	Area(m^2)	lm/ft^2	lm		watt
Pantry	78.67	7.32	80	6293.6	3 bulbs - 20wt	60
Passage	48.35	4.5	45	2175.75	1 bulb - 20wt	20
Bar	252.33	23.47	65	16401.45	2 Tubes - 45wt	90
Lawn	106	9.86	45	4770	3 bulbs - 20wt	45
Entrance Lobby	98.25	9.14	45	4421.25	3 bulbs - 20wt	45
Hall	521.44	48.49	80	41715.2	6 Tubes - 45wt	270
Home Theatre	355.72	33.08	45	16007.4	3 Tubes - 45wt	135
					total	665

Table 4. 46 - Calculation of energy required for lighting (basement, villa)

Villa: Ground Floor						
Room	Area(ft^2)	Area(m^2)	lm/ft^2	lm		watt
Longue	242.1	22.5	80	19368	2 Tubes - 45wt	90
Pantry	279.76	26	80	22380.8	3 Tubes - 45wt	135
Store Room	53.8	5	45	2421	1 bulb - 20wt	20
Store Room	67.68	6.29	45	3045.6	1 bulb - 20wt	20
Dining	290.3	26.98	45	13063.5	2 Tubes - 45wt	90
Toilet	32.93	3.06	65	2140.45	1 bulb - 20wt	20
Lawn	105.99	9.85	45	4769.55	2 bulbs - 20wt	40
Living Hall	555.86	51.66	80	44468.8	6 Tubes - 45wt	270
Bedroom	286.54	26.63	70	20057.8	2 Tubes - 45wt	90
Dress	58.1	5.4	65	3776.5	2 bulbs - 20wt	40
Toilet	55.63	5.17	65	3615.95	2 bulbs - 20wt	40
					total	855

Table 4. 47 - Calculation of energy required for lighting (ground floor, villa)

Villa: First Floor						
Room	Area(ft^2)	Area(m^2)	lm/ft^2	lm		watt
Master Bedroom	362.72	33.71	70	25390.4	2 Tubes - 45wt	90
Toilet	89.95	8.36	65	5846.75	3 bulbs - 25wt	75
Dress	77.9	7.24	65	5063.5	3 bulbs - 25wt	75
Bedroom 1	286.54	26.63	70	20057.8	2 Tubes - 45wt	90
Dress	72.85	6.77	65	4735.25	2 bulbs - 20wt	40
Toilet	91.14	8.47	65	5924.1	3 bulbs - 25wt	75
Longue	390.37	36.28	80	31229.6	3 Tubes - 45wt	135
Puja Room	82.42	7.66	80	6593.6	3 bulbs - 20wt	60
Bedroom 2	269	25	70	18830	2 Tubes - 45wt	90
Dress	119.11	11.07	65	7742.15	2 bulbs - 25wt	50
Toilet	161.4	15	65	10491	3 bulbs - 25wt	75
Store Room	50.79	4.72	45	2285.55	1 bulb - 20wt	20
					total	875

Table 4. 48 - Calculation of energy required for lighting (first floor, villa)

Villa: Second Floor						
Room	Area(ft^2)	Area(m^2)	lm/ft^2	lm		watt
Servant Room	93.93	8.73	80	7514.4	2 bulbs - 25wt	50
Toilet	37.34	3.47	65	2427.1	1 bulb - 12wt	12
Utility Room	143.86	13.37	80	11508.8	3 bulbs - 25wt	75
Toilet	31.96	2.97	65	2077.4	1 bulb - 12wt	12
					total	149

Table 4. 49 - Calculation of energy required for lighting (second floor, villa)

Total energy	Need in a day	In this Project
2544	45792	17808

Table 4. 50 - Comparison of energy required with and without natural lighting (villa)

4.3.3.3 Bungalow

BUNGALOW: BASEMENT						
Room	Area(ft^2)	Area(m^2)	lm/ft^2	lm		watt
Entrance Lobby	71	6.6	45	3195	1 bulb - 25wt	25
Hall	555	51.62	80	44400	6 Tubes - 45wt	270
Home Theatre	184	17.11	45	8280	3 bulbs - 20wt	60
Bar	161	14.97	45	7245	3 bulbs - 20wt	60
Pantry	186.72	17.36	80	14937.6	4 bulbs - 25wt	100
					total	515

Table 4. 51 - Calculation of energy required for lighting (basement, bungalow)

BUNGALOW: GROUND FLOOR						
Room	Area(ft^2)	Area(m^2)	lm/ft^2	lm		watt
Living Room	308.13	28.66	80	24650.4	2 Tubes - 45wt	90
Dining	181.44	16.87	45	8164.8	3 bulbs - 20wt	60
Toilet	31.06	2.89	65	2018.9	1 bulb - 12wt	12
Kitchen	159.3	14.81	80	12744	2 Tubes - 45wt	90
Longue	92.29	8.58	80	7383.2	3 bulbs - 20wt	60
Bedroom	239.69	22.29	70	16778.3	2 Tubes - 45wt	90
Dress	34.51	3.21	65	2243.15	2 bulbs - 12wt	24
Toilet	52.26	4.86	65	3396.9	2 bulbs - 12wt	24
					total	450

Table 4. 52 - Calculation of energy required for lighting (ground floor, bungalow)

BUNGALOW: FIRST FLOOR						
Room	Area(ft^2)	Area(m^2)	lm/ft^2	lm		watt
Bedroom 1	276.65	25.73	70	19365.5	3 Tubes - 45wt	135
Dress	60.65	5.64	65	3942.25	2 bulbs - 12wt	24
Toilet	70	6.51	65	4550	2 bulbs - 20wt	40
Bedroom 2	251.46	23.39	70	17602.2	2 Tubes - 45wt	90
Dress	50.29	4.68	65	3268.85	2 bulbs - 12wt	24
Toilet	70	6.51	65	4550	2 bulbs - 20wt	40
Longue	140	13.02	80	11200	2 Tubes - 45wt	90
Master Bedroom	314.17	29.22	70	21991.9	3 Tubes - 45wt	135
Dress	50.29	4.68	65	3268.85	2 bulbs - 12wt	24
Toilet	70	6.51	65	4550	2 bulbs - 20wt	40
					total	642

Table 4. 53 - Calculation of energy required for lighting (first floor, bungalow)

BUNGALOW: SECOND FLOOR						
Room	Area(ft^2)	Area(m^2)	lm/ft^2	lm		watt
Servant Room	93.93	8.73	80	7514.4	2 bulbs - 25wt	50
Toilet	37.34	3.47	65	2427.1	1 bulb - 12wt	12
Dress	31.96	2.97	65	2077.4	1 bulb - 12wt	12
					total	74

Table 4. 54 - Calculation of energy required for lighting (second floor, bungalow)

Total energy (wh)	**Need in a day (wh)**	**In this Project (wh)**
1681	30258	11767

Table 4. 55 - Comparison of energy required with and without natural lighting (bungalow)

4.3.4 Discussion

In order to reduce the carbon emissions from the buildings, natural lighting and ventilation have been maximised. For each part of the villa and bungalow, Natural lighting and Ventilation have been calculated in sections 4.3.1 and 4.3.2 respectively.

The total energy required with and without natural ventilation has also been calculated and tabulated for each of the components villa and bungalow in section 4.3.4.

4.4 DesignBuilder Simulation results

4.4.1 Villa

4.4.1.1 Model

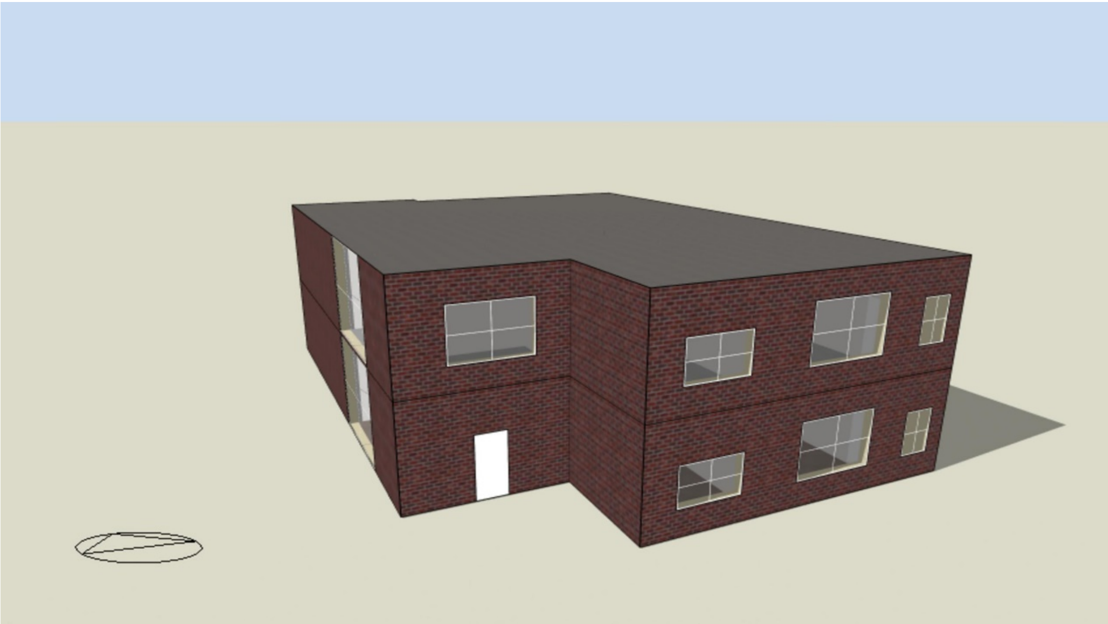


Figure 4. 17 - Model of villa drawn in DesignBuilder

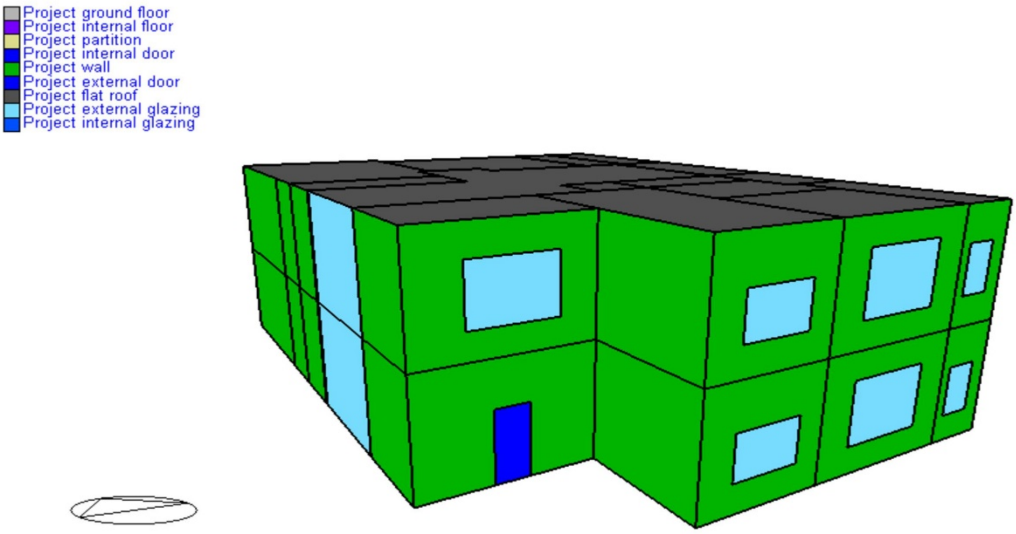


Figure 4. 18 - Model of villa showing various surfaces

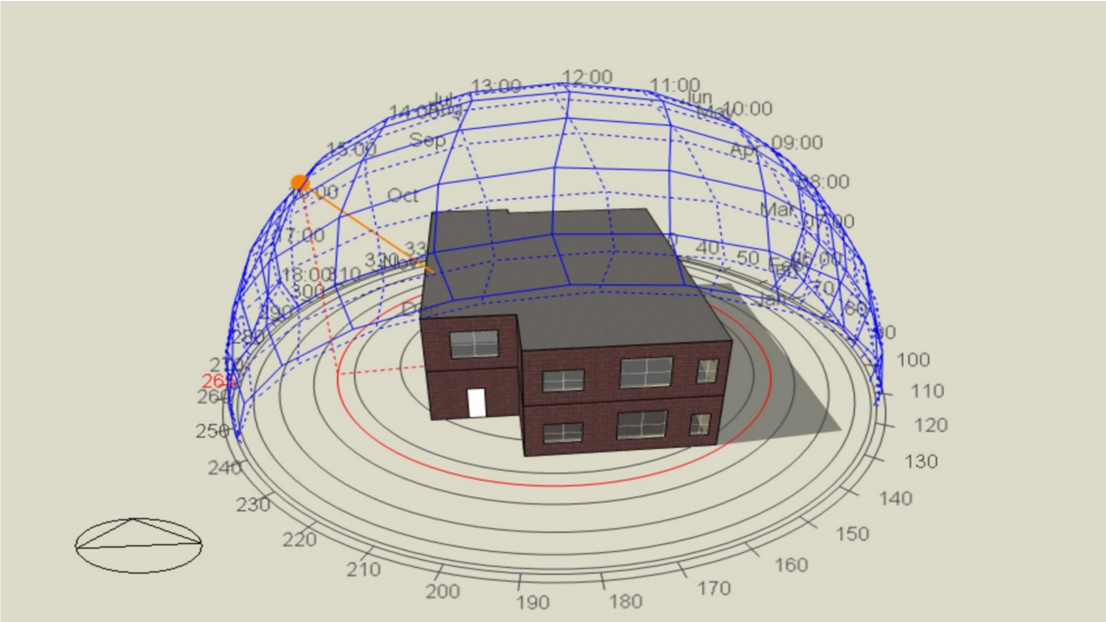


Figure 4. 19 - Model of villa along with sun path diagram

4.4.1.2 Cooling Design of villa

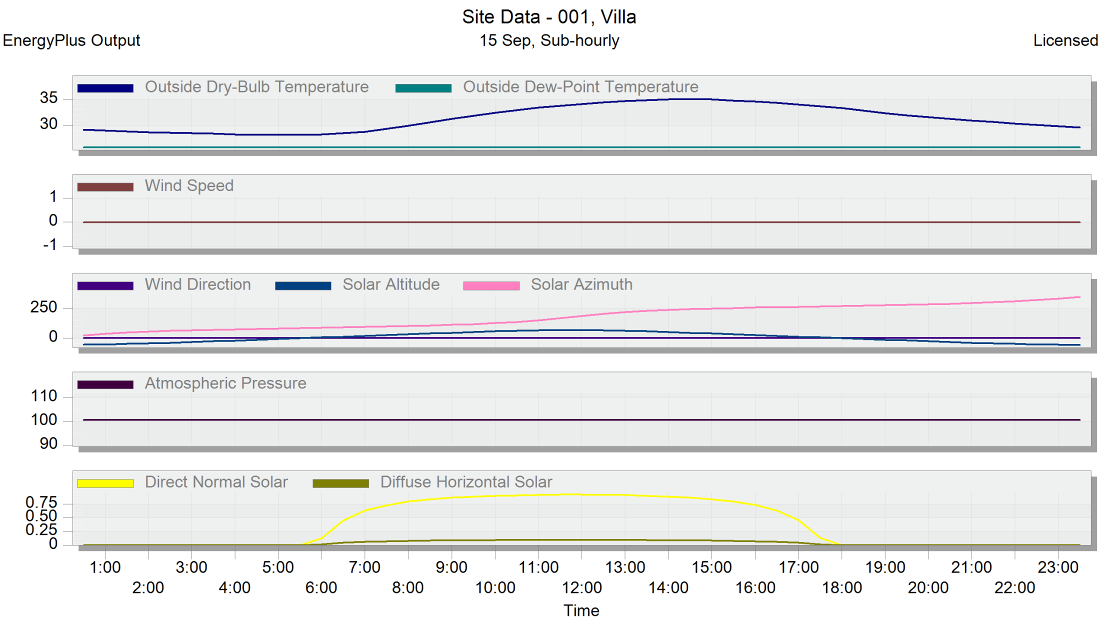


Figure 4. 20 - Site data curves for cooling design of villa

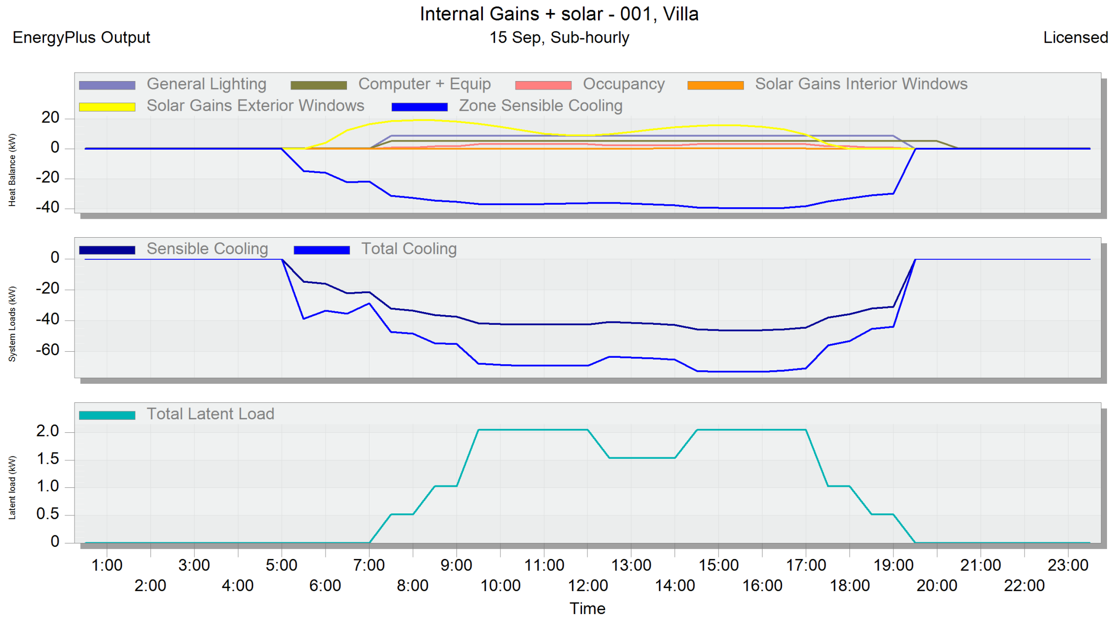


Figure 4. 21 - Internal data + solar curves for heating design of villa

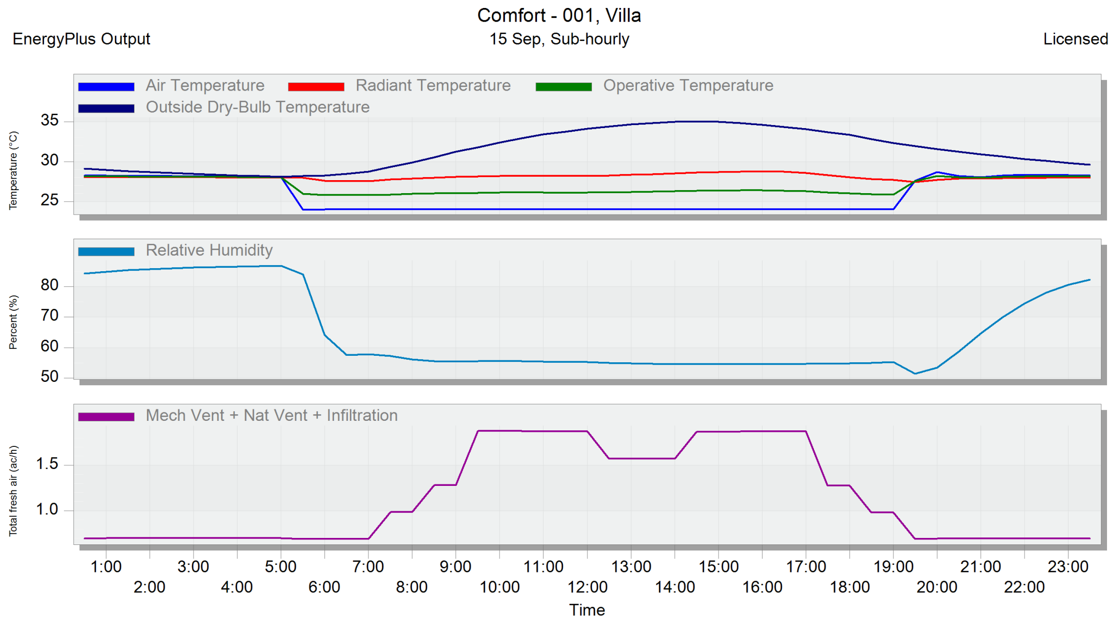


Figure 4. 22 - Comfort curves for villa

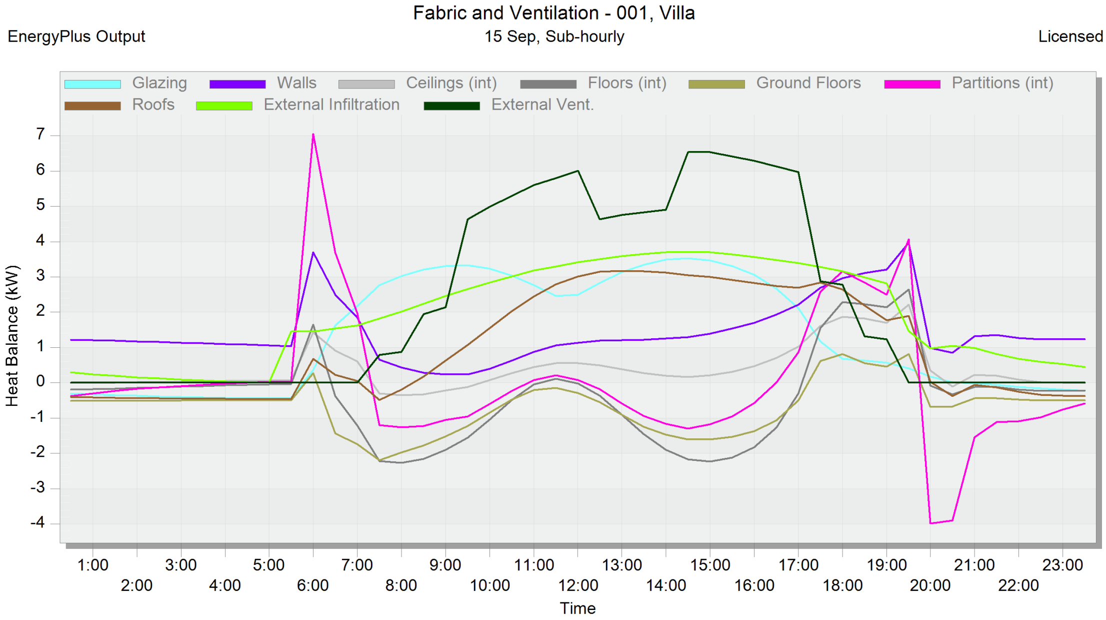


Figure 4. 23 - Heat Balance over fabric and ventilation (villa)

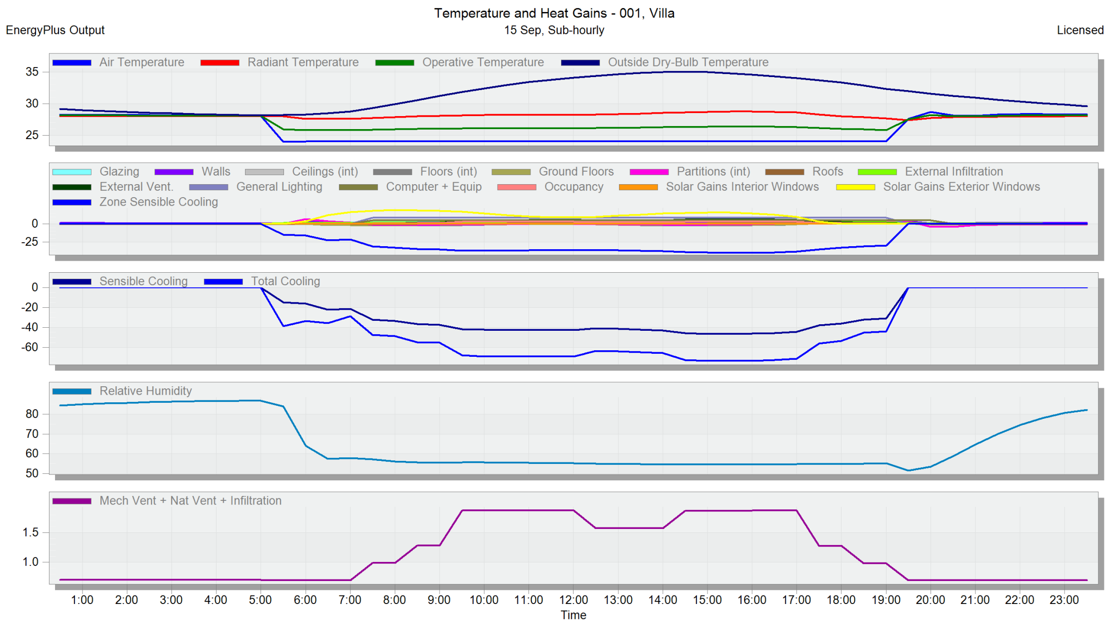


Figure 4. 24 - Sub hourly temperature and heat gains (villa)

4.4.1.3 Heating Design of villa

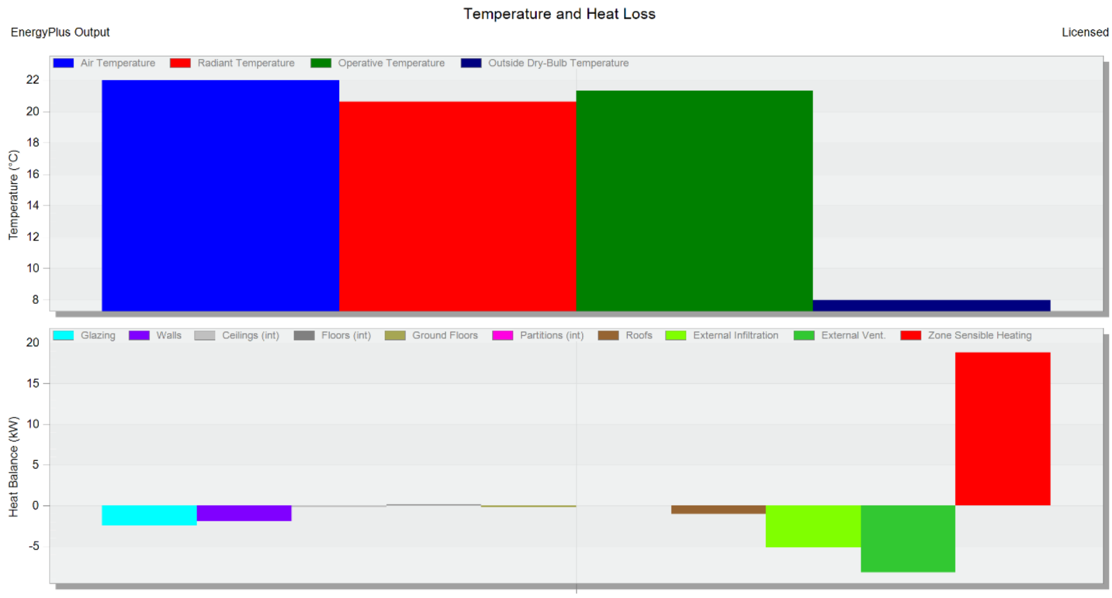


Figure 4. 25 - Temperature and Heat Loss curve obtained from heating design - Villa

Figure 4. 26 - Heating design for Comfort - Villa

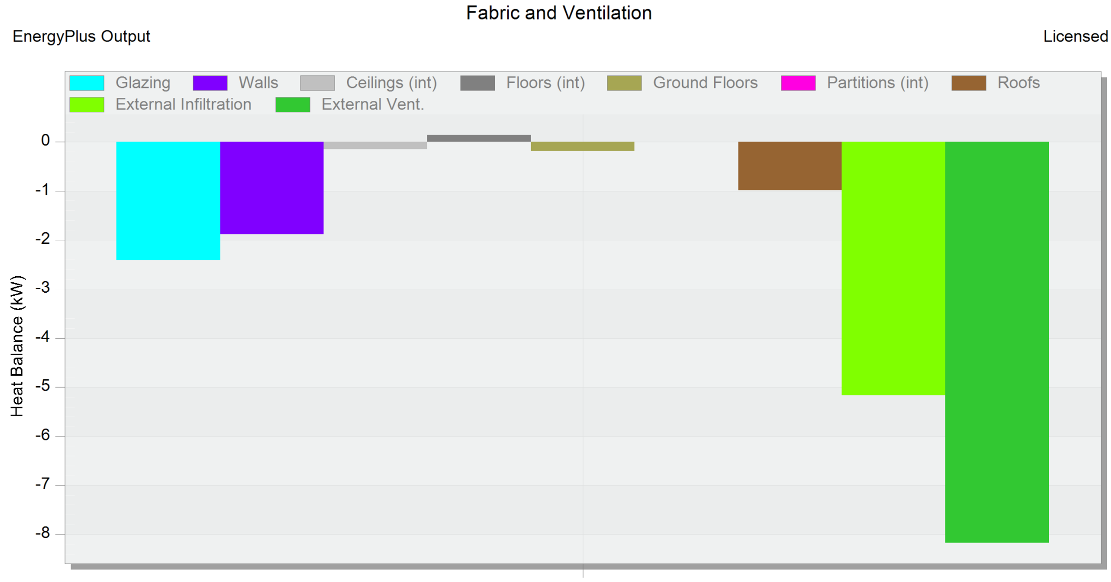


Figure 4. 27 - Heating design for Fabric and ventilation - Villa

Figure 4. 28 - Internal Gains + solar curves for Villa

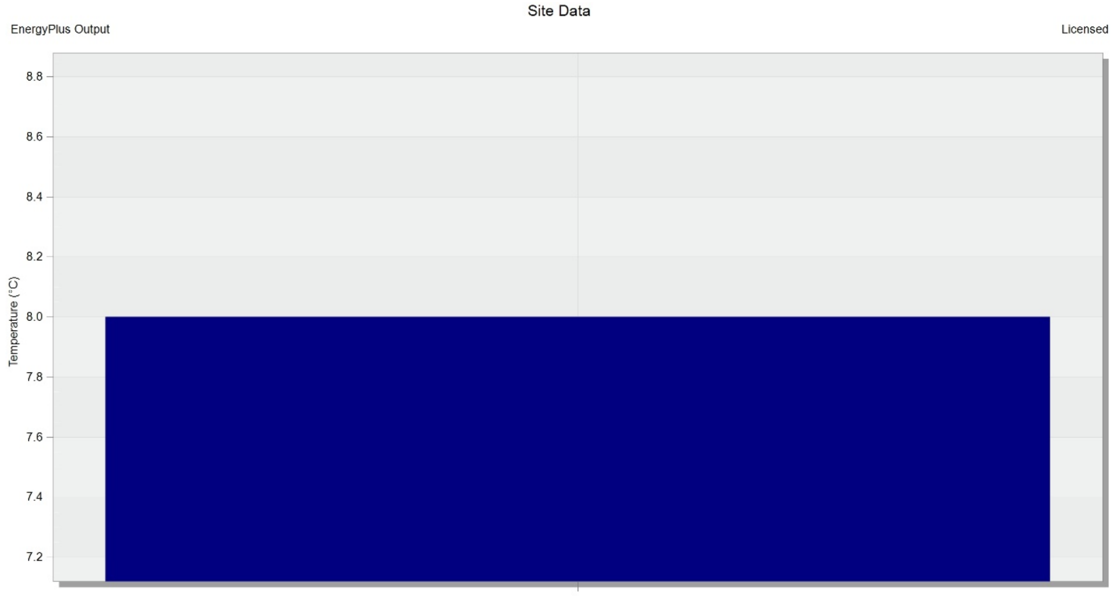


Figure 4. 29 - Site data curves for heating design - Villa

4.4.1.4 Simulation Results

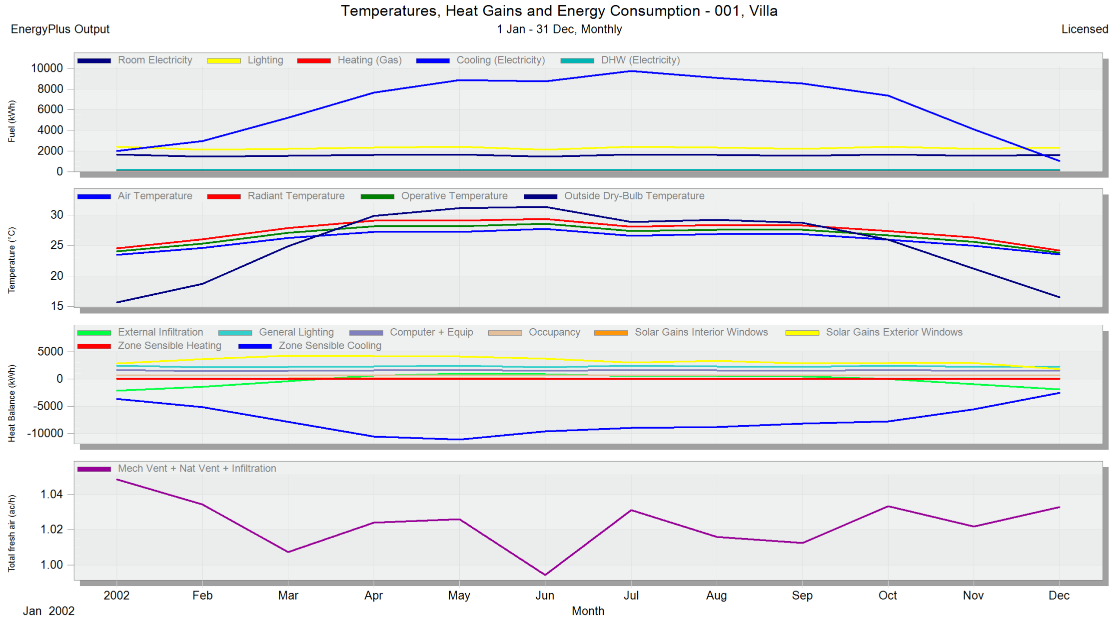


Figure 4. 30 - Monthly temperature, heat gains, and energy consumption curve - Villa

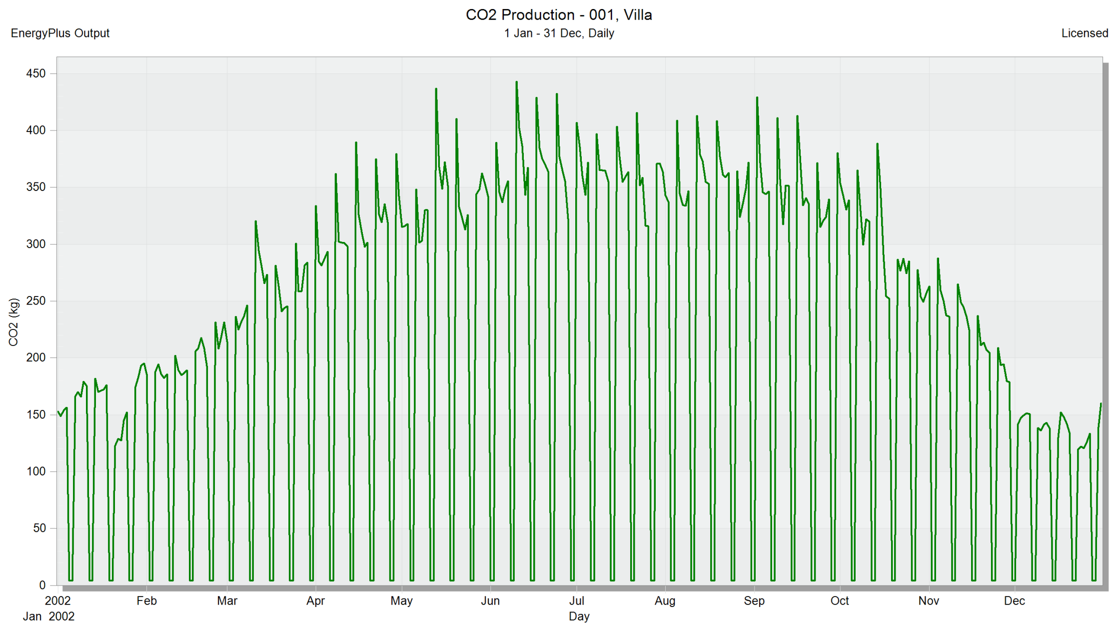


Figure 4. 31 - Daily CO_2 production curve - Villa

4.4.1.5 Daylighting

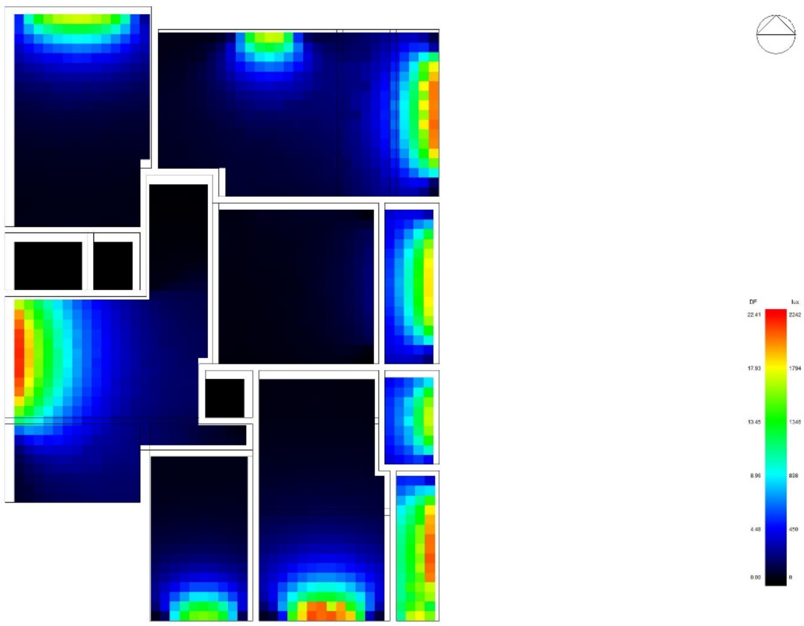


Figure 4. 32 - Daylighting results - villa

4.4.2 Bungalow

4.4.2.1 Model

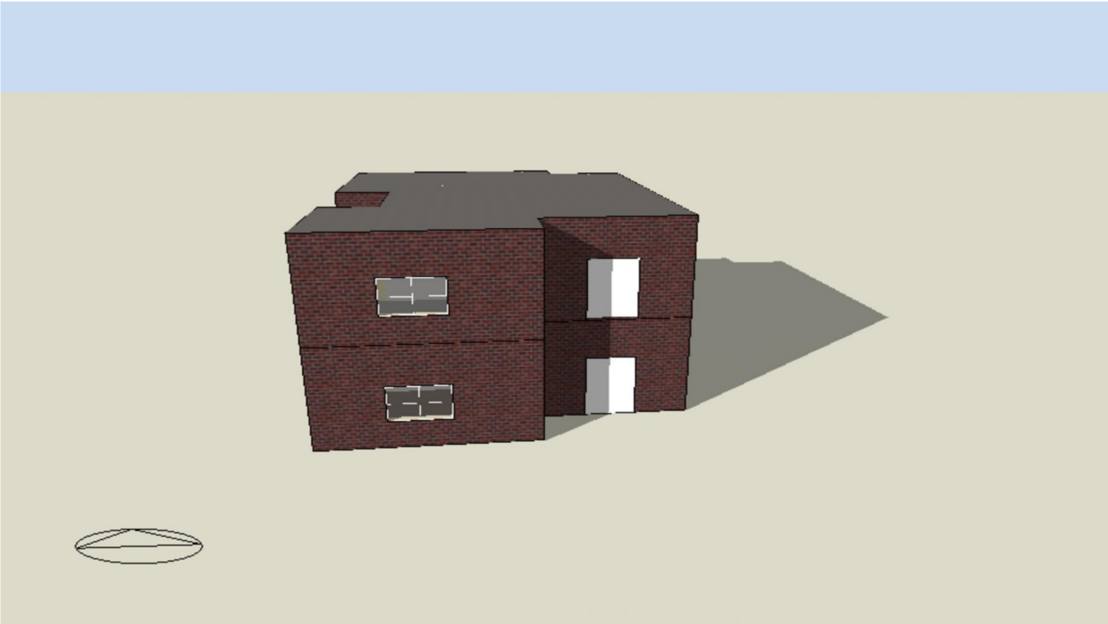


Figure 4. 33 - Model of villa drawn in DesignBuilder

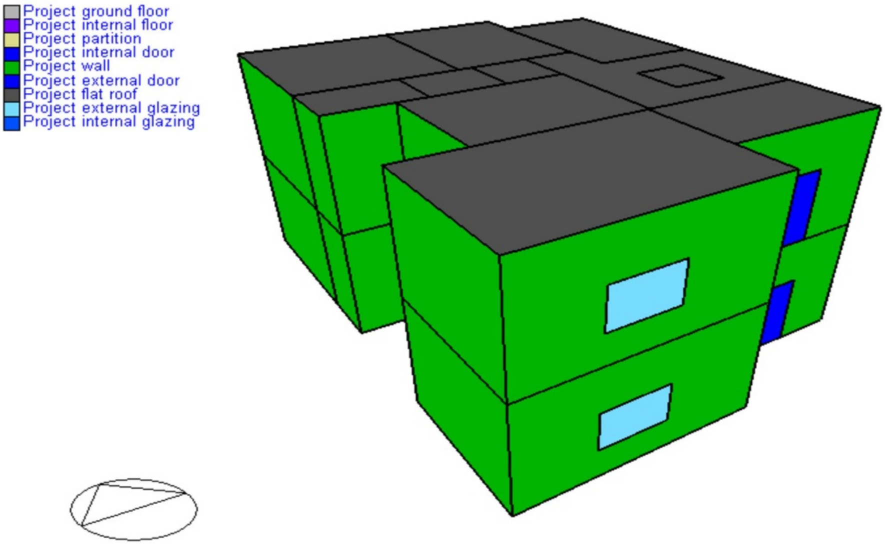


Figure 4. 34 - Model of villa showing various surfaces

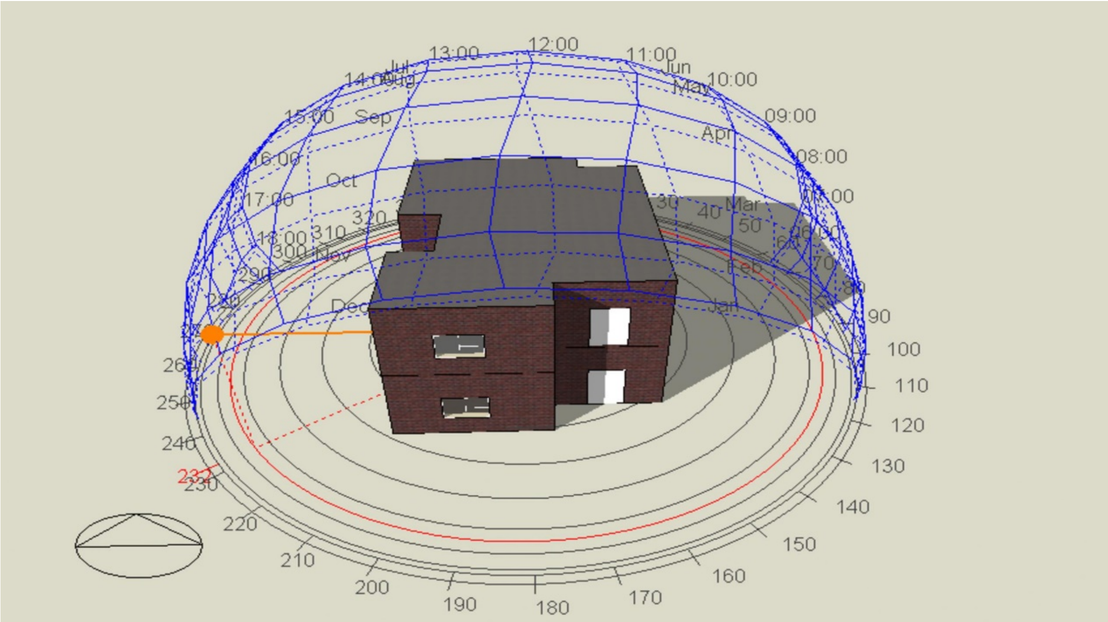


Figure 4. 35 - Model of villa along with sun path diagram

4.4.2.2 Cooling Design of villa

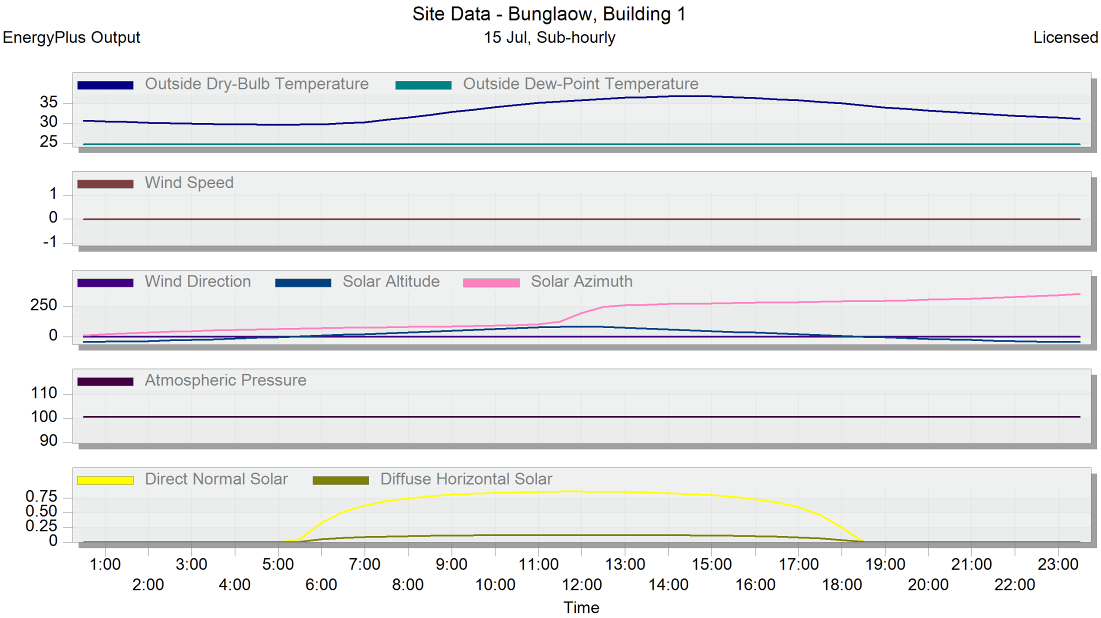


Figure 4. 36 - Site data curves for cooling design of villa

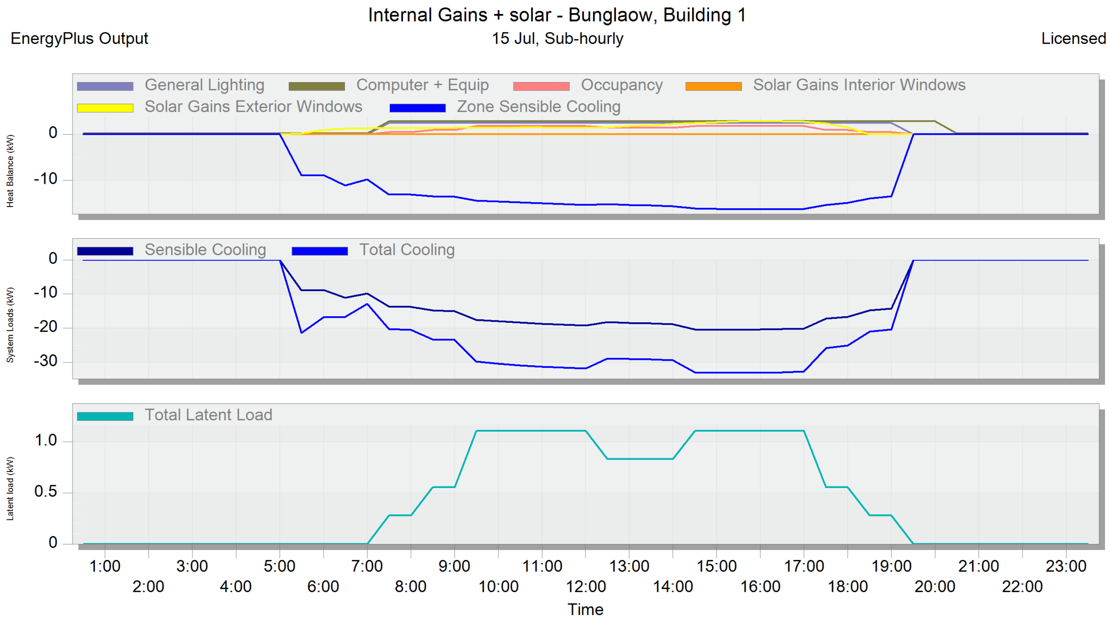


Figure 4. 37 - Internal data + solar curves for heating design of villa

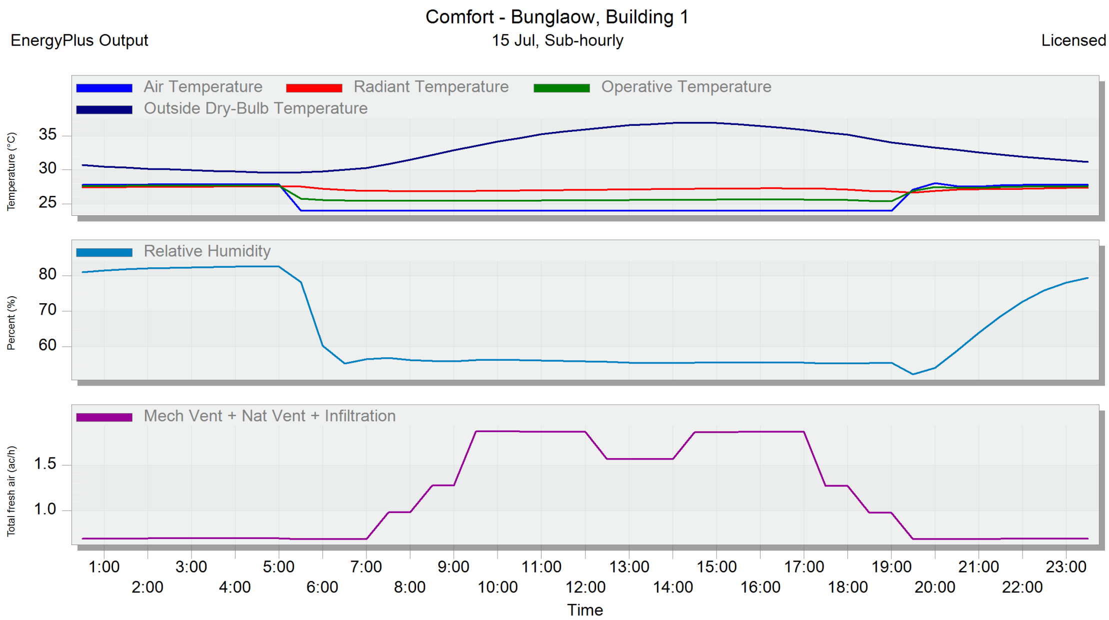


Figure 4. 38 - Comfort curves for villa

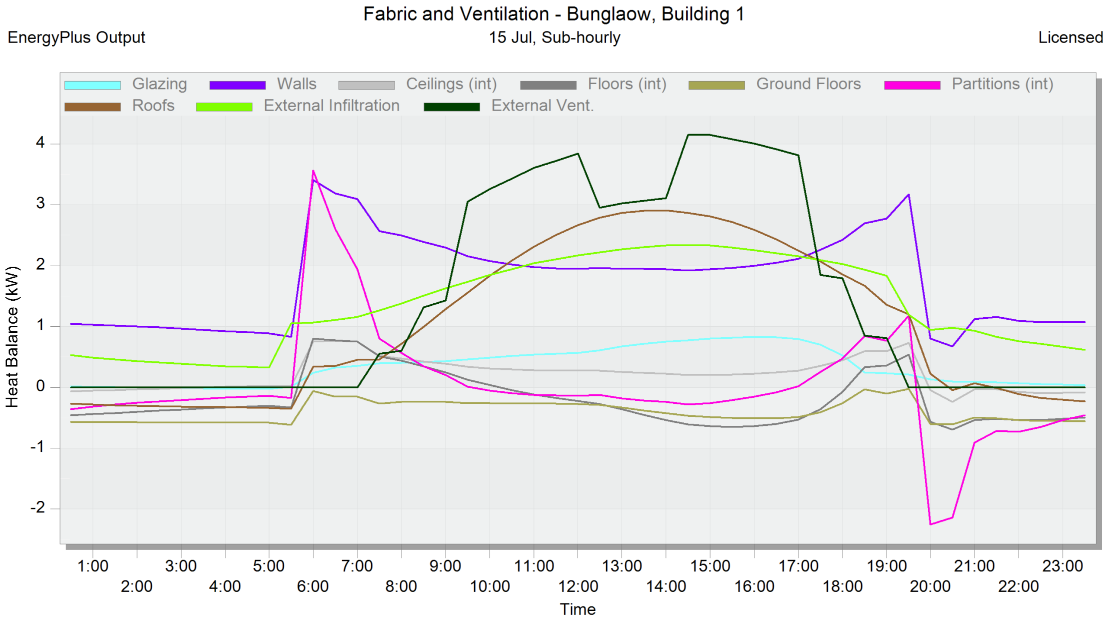


Figure 4. 39 - Heat Balance over fabric and ventilation (villa)

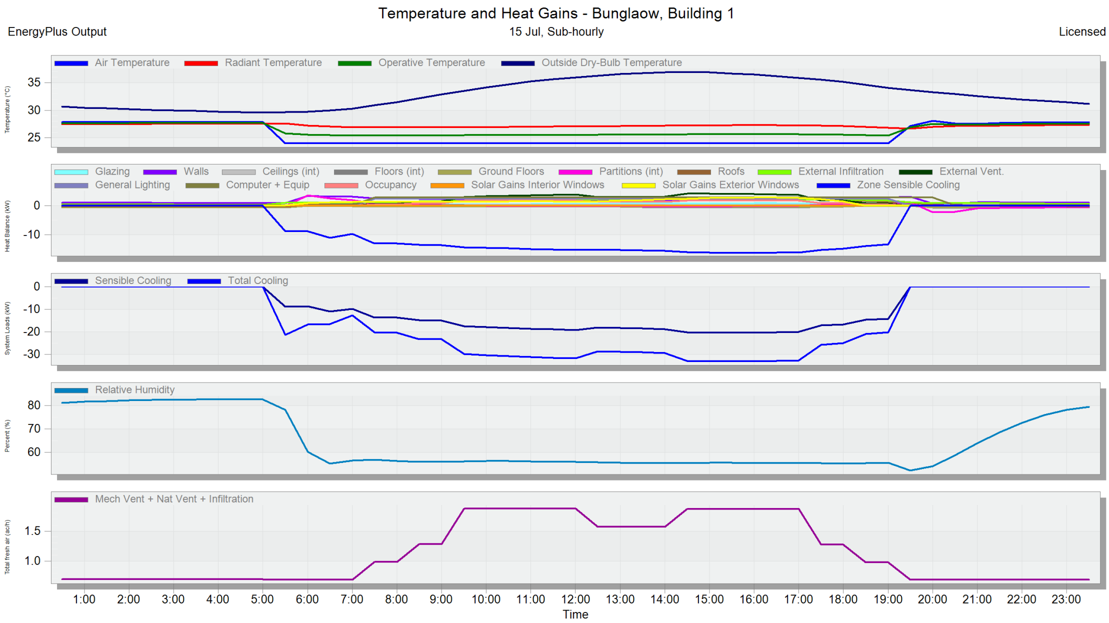


Figure 4. 40 -Sub hourly temperature and heat gains (villa)

4.4.2.3 Heating Design of villa

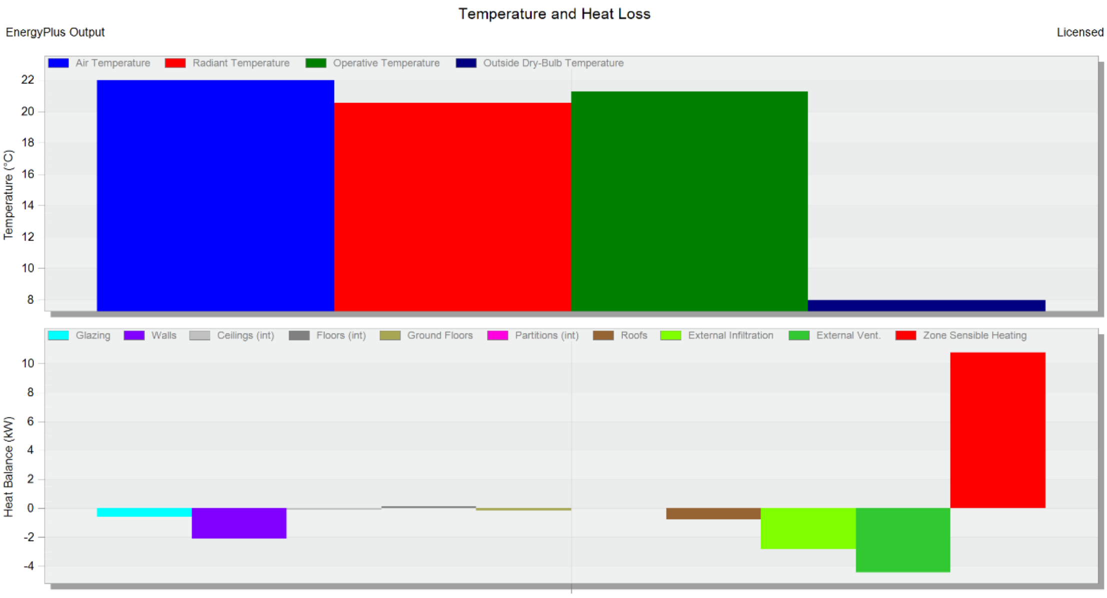


Figure 4. 41 - Temperature and Heat Loss curve obtained from heating design - Villa

Figure 4. 42 - Heating design for Comfort - Villa

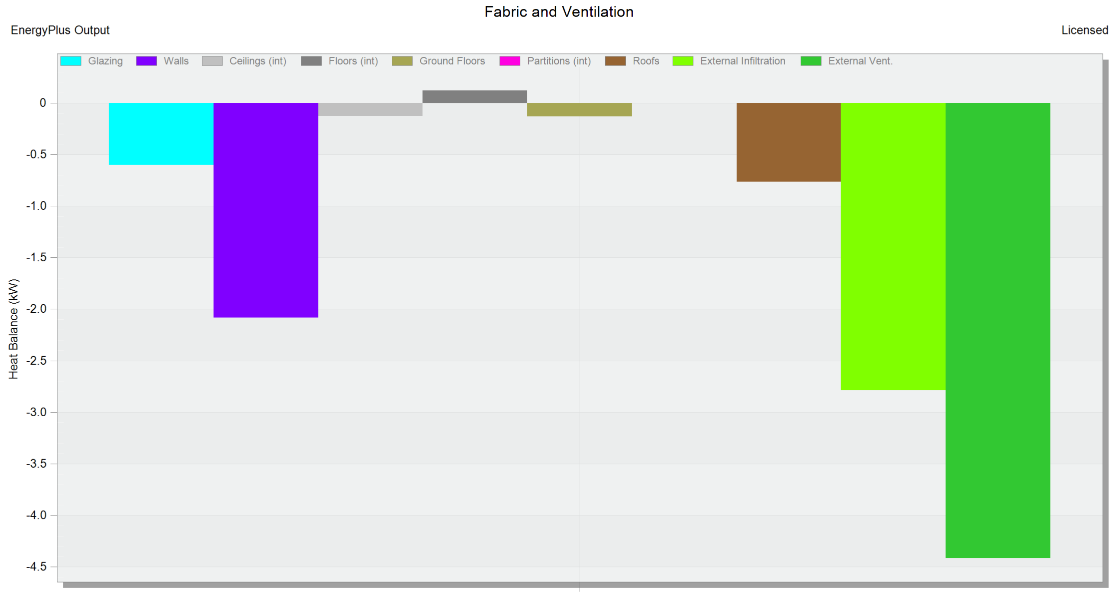


Figure 4. 43 - Heating design for Fabric and ventilation - Villa

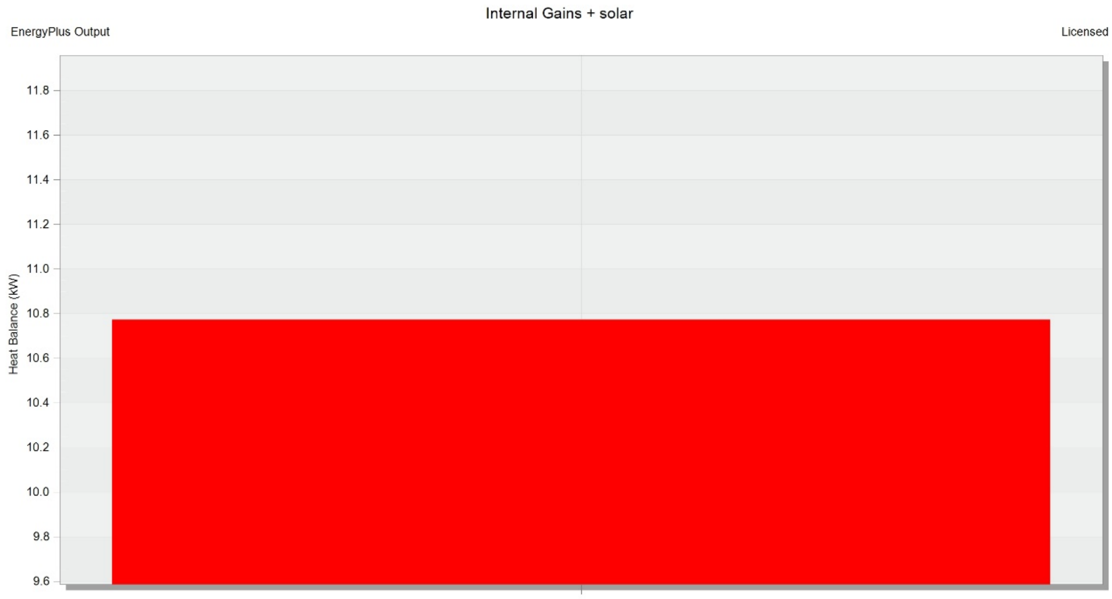


Figure 4. 44 - Internal Gains + solar curves for Villa

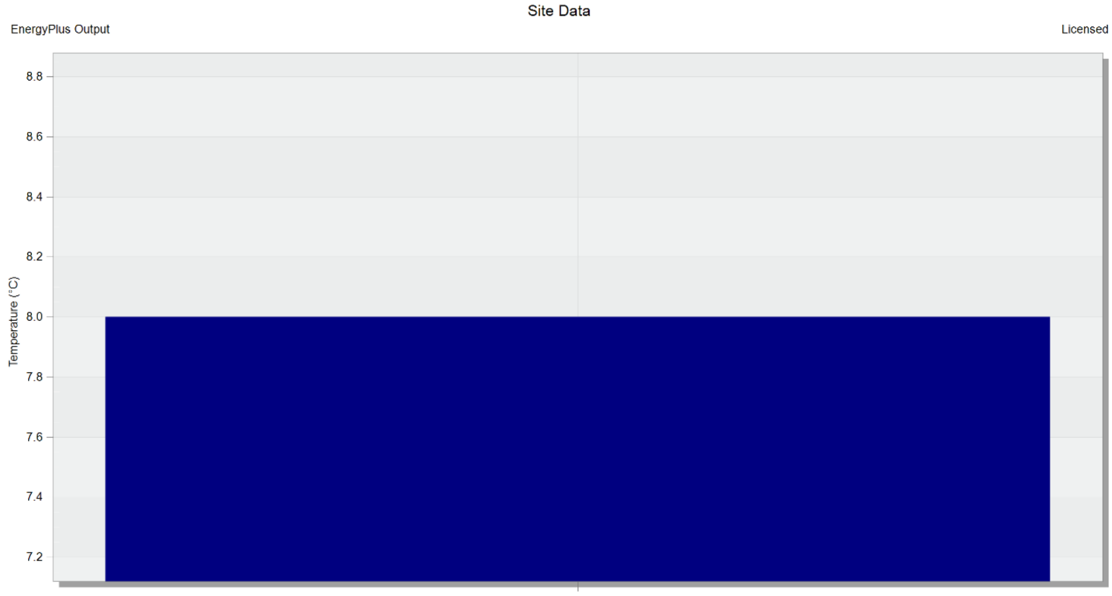


Figure 4. 45 - Site data curves for heating design - Villa

4.4.2.4 Daylighting

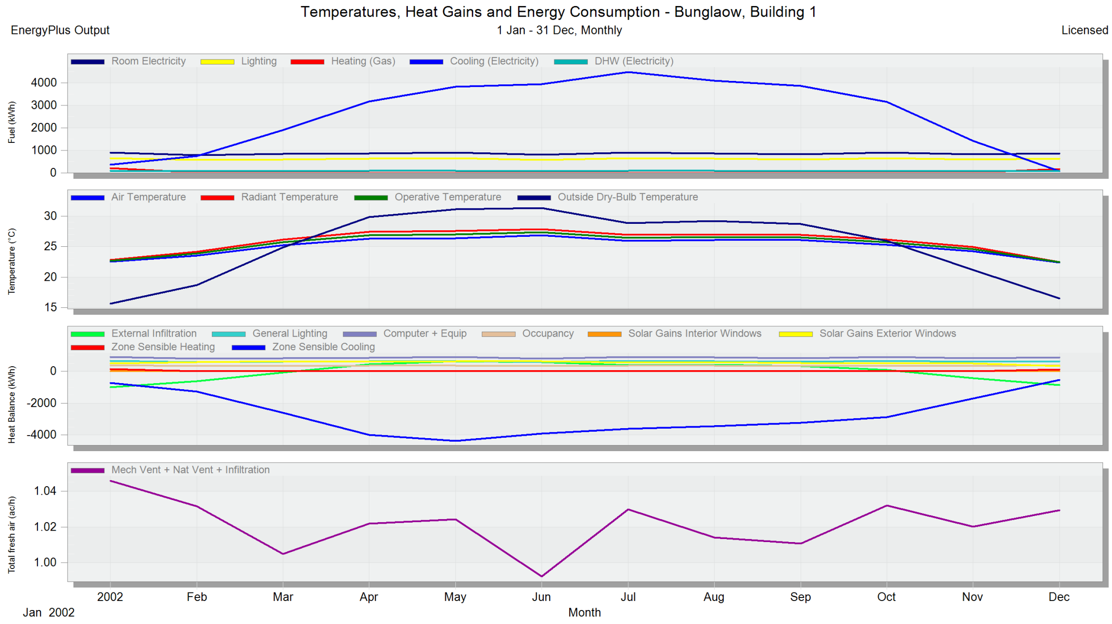


Figure 4. 46 - Monthly temperature, heat gains, and energy consumption curve - Villa

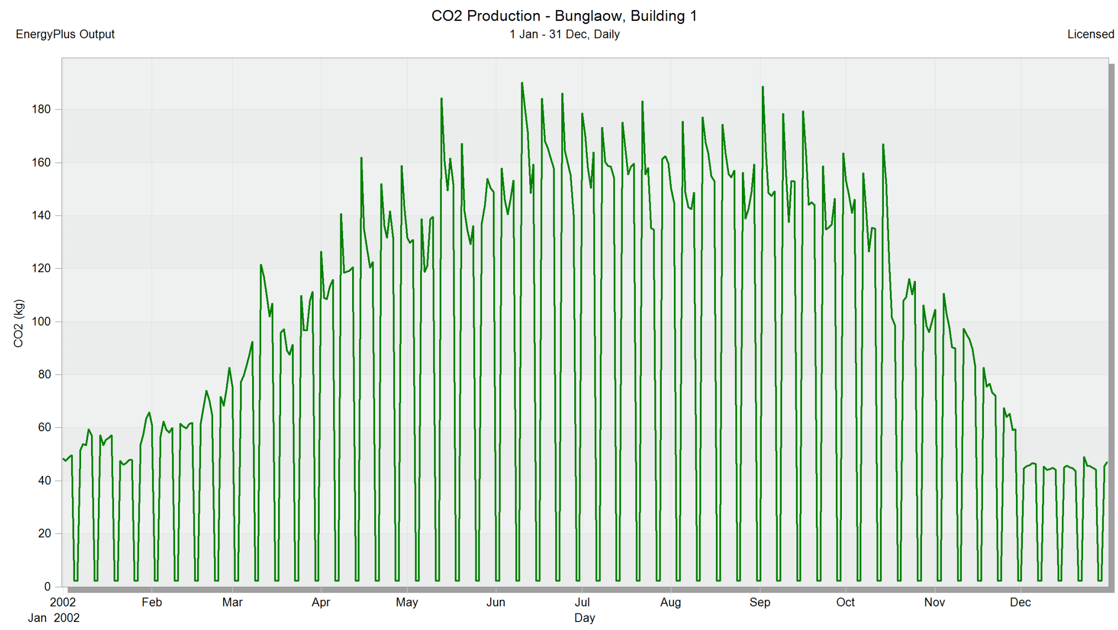


Figure 4. 47 - Daily CO_2 production curve - Villa

4.4.2.5 Daylighting

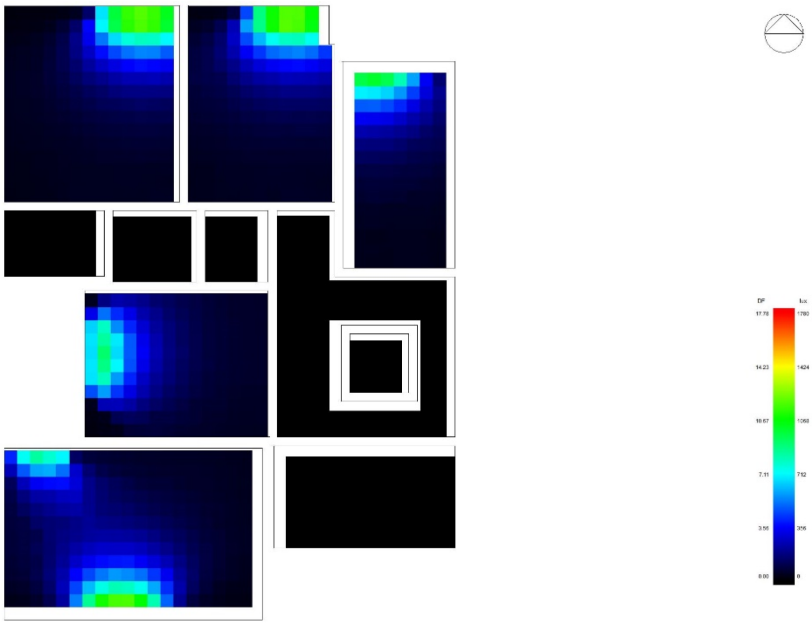


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Figure 4. 48 - Daylighting results - villa

4.4.3 Discussion

To analyse the lighting and ventilation data, **“DesignBuilder”** is used to input the data obtained from the manual calculation done for lighting and ventilation.

Figures 4.20, 2.25, 4.36 & 4.41 represent the curves of the location data file which is saved in DesignBuilder.

Figures 4.21, 2.26, 4.37 & 4.42 represent the Heat Balance, System Load and Latent load for various components with respect to time on a certain day.

Figures 4.22, 2.27, 4.38 & 4.43 represent the temperature, % of relative humidity and total fresh air with respect to time.

Figures 4.23, 2.28, 4.39 & 4.44 represent the heat balance over various surfaces with respect to time.

Figures 4.24, 2.29, 4.40 & 4.45 represent the temperature and heat gains on various surfaces and relative humidity during a sub-hourly period.

Figures 4.31 & 4.47 represent daily CO_2 production over a year.

Figures 4.32 & 4.48 depict the luminescence from the glazed windows.

4.5 Conclusion

Various factors and criteria have been thoroughly designed and calculated here. Starting with section 4.1: estimation of population. The total no. of occupants is calculated for the residential spaces including the overall security staff and management staff for the society and shown in Tables 4.1 and 4.2.

Section 4.2 discusses water supply and sewage discharge per day calculations. Water supply depends on various factors such as general domestic purposes and flushing for residences. For the upper-middle class, the value of the water supply can be given as 150 to 200 litres per head per day. The people residing in residential spaces are considered as upper middle class, taking the average water supply per head per day for them as 200 litres per head per day, and the staff as Lower Income Groups (LIG), taking the average water supply per head per day for them as 150 litres per head per day. The calculated values are discussed in Table 4.3 showing the Average water supplied to residences and staff per day.

The Average Water supply for Residences was calculated as 91200 Litres/day.

Section 4.4.1 and 4.4.2 show various graphs and simulation results obtained for Villa and Bungalow respectively from DesignBuilder.

CHAPTER – 5: CONCLUSION

In this project, a residential society has been tried to be developed which is sustainable in nature as well as eco-friendly by reducing the carbon footprints. The various research methodologies carried out also suggest the design criteria and various other checkpoints to be kept in mind.

i. Natural ventilation and cooling system, solar empowered electrification, and sewage treatment plants are some of the key aspects of this township.

ii. The total energy consumption required for lighting per day in this township was calculated as **87210w**, whereas the net energy requirement in this designed township was only **33915w**. This clearly shows the difference in energy consumption in lighting using natural lighting and artificial lighting.

iii. A net-zero carbon emission society has been tried to be attained through the effective use of the above resources. The entire township has been designed keeping in mind the daily requirements of human beings, recreational purposes, and other needs.

iv. After analysing our lighting energy consumption and comparing it to a government website (www.solarrooftop.gov.in) [34] it was found that our entire lighting energy requirement can be drawn from solar energy alone. This will reduce our effort in making this society a green and low carbon-friendly one. This shall enhance the use of solar panels and shall also encourage others to use so. The solar setup which would help in generating the maximum output is shown in table 3.6.

v. The RCC design (of villas, and bungalows) shows us the reinforcement details of the lateral and longitudinal beam the column load, and reinforcement details.

vi. The average water discharge for residences comes out to be **72960 litres/day**. The average water supply for residences comes out to be **91200 litres/day**. Water supply depends on various factors such as general domestic purposes and flushing for residences.

vii. The STP is designed perfectly to meet the needs and demands of approximately 500 population for a large period. The design consists of complete STP components starting from receiving chamber, screening, grit chamber, skimming tank, sedimentation tank, secondary clarifier, activated sludge tank, and drying bed for sewage.

CHAPTER – 6: FUTURE SCOPE

Initially, this project has been designed for its basic characteristics. Further implementation of green technology and innovation will broaden its scope for further use and implementation. The future scope of work in this project involves:

1. Design of a residential apartment
2. Design and development of commercial places in the township
3. Electricity generation: distribution and supply
4. Mode of transportation in the township (role of an electric vehicle)

These basic features if added to this design of the township will add benefits of low greenhouse gas emission, along with beautification of the project. EVs will play an important role in the near future scope and will enhance the dependency on renewable energy resources.

Commercial places when designed to maximize user output will help in bringing in more human interference in this society. These will also help in generating revenue and penultimate usage of spaces allotted to them.

Electricity generation distribution and supply will require a deep understanding of power distribution and generation causing minimum harm to the environment. NBC guidelines for electrical line supply should be also kept in mind while designing. Furthermore, green energy generation and supply of renewable sources from nature if incorporated in this township will minimise the greenhouse gases effect and increase our reach to net-zero carbon emission.

The material used in construction should also be checked further to decrease the pollution and increase the structure's health. These materials should be eco-friendly and should adhere to all safety norms and sustainability.

The empty spaces left in the plan layout can be used to install windmills. These windmills will also help in generating electricity and decrease the only dependency on solar-powered households. On days when sunlight is low and weather is cloudy and optimum solar power cannot be received, these windmills will help in generating enough power to run the society.

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