ENERGY EFFICIENT COLLEGE BUILDING: INTEGRATING PLANNING, ANALYSIS, DESIGN, ENERGY OPTIMIZATION, AND ESTIMATION

A Project Report

submitted to the APJ Abdul Kalam Technological University

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

Bachelor of Technology

in

Civil Engineering

by

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MATTANNUR

April 2024

DECLARATION

We hereby declare that the project report titled "ENERGY EFFICIENT COLLEGE BUILDING: INTEGRATING PLANNING, ANALYSIS, DESIGN, ENERGY OPTIMIZATION, AND ESTIMATION" submitted for partial fulfillment of the requirements for the award of the degree of Bachelor of Technology of the APJ Abdul Kalam Technological University, Kerala, is a bonafide work conducted by us under the supervision of Dr. ARUN KUMAR S.

This submission represents our ideas in our own words and where ideas or words of others have been included, we have adequately and accurately cited and referenced the original sources.

We also declare that we have adhered to ethics of academic honesty and integrity and have not misrepresented or fabricated any data or idea or fact or source in our submission. We understand that any violation of the above will be a cause for disciplinary action by the institute and/or the university and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been obtained. This report has not previously formed the basis for the award of any degree, diploma or similar title of any other university.

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CERTIFICATE

This is to certify that the report entitled, **"ENERGY EFFICIENT COLLEGE BUILDING: INTEGRATING PLANNING, ANALYSIS, DESIGN, ENERGY OPTIMIZATION, AND ESTIMATION"** submitted by **AFRA FATHIMA** (STM20CE008), **DIYA T M** (STM20CE023), **PRADUL P** (STM20CE037) & **SARIGA JAYARAJ** (STM20CE043) to the APJ Abdul Kalam Technological University in partial fulfillment of the requirements for the award of the Degree of Bachelor of Technology in Civil Engineering is a bonafide record of the Project work carried out by them under our guidance and supervision. This report in any form has not been submitted to any other University or Institute for any purpose.

Internal Supervisor **External Supervisor**

Project Coordinator **Head of Department**

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ABSTRACT

This project outlines a comprehensive approach to focus on achieving energy efficiency in the design of an educational building, by leveraging BIM software tools such as AutoCAD, Revit, Etabs, Forma and other tools like Green Building Studio and Twinmotion. The project encompasses a series of interconnected stages, like site assessment, planning, analysis, design, energy optimization, estimation and 3D visualization. Our project is a proposal of a G+2 educational institution at the college premises. Preliminary survey, planning and designing work were done using Forma, AutoCAD and Revit in accordance with the guidelines from National Building Code, Kerala Municipal Building Rule and others. The structural analysis of various elements has been carried out in ETABS as per relevant IS codes. Green Building Studio was used for energy optimization and Twinmotion for 3D visualization. The estimation is done by using Revit referring to current PWD rates. The success of this endeavor contributes not only to a more sustainable educational building but also to a broader shift towards sustainability in the educational sector.

Keywords: *Energy efficiency, Building Information Modeling, AutoCAD, Revit, ETABS, Green Building Studio, Twinmotion.*

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ABBREVATIONS

AAC	Autoclaved Aerated Concrete
AEC	Architecture, Engineering, and Construction
AICTE	All India Council for Technical Education
BIM	Building Information Modeling
CBOs	Commercial Building Operations
ECBC	Energy Conservation Building Code
ETABS	Extended Three-dimensional Analysis of Building Systems
EUI	Energy Use Intensity
GBS	Green Building Studio
GPS	Global Positioning System
HVAC	Heating, Ventilation, and Air Conditioning
KMBR	Kerala Municipal Building Rules
LED	Light Emitting Diode
NBC	National Building Code
PCM	Phase Change Materials
PWD	Public Works Department
RCDC	Reinforced Concrete Design and Detailing
ROI	Return On Investment
SMRF	Special Moment Resisting Frame
VR	Virtual Reality

NOTATIONS

Vb	Wind speed
k_1	Risk coefficiant
k_3	Topopgraphy
Z	Zone factor
I	Importance factor
R	Response reduction factor
EQ_X	Seismic load In X direction
EQ_Y	Seismic load In X direction
W_X	Wind load in X direction
W_Y	Wind load in Y direction
L	Length of beam
D	Depth of beam or slab
b	Breadth of beam
f_{ck}	Characteristic compressive strength of concrete
f_y	Characteristic yield strength of steel
f_{ys}	Design yield strength of shear rebars
P_u	Design axial load for limit state design
M_u	Design moment of limit state design
K	Constant or factor
V	Shear force
V_u	Shear force dueto factored loads
V_s	Nominal shear strength of reinforcement
V_c	shear force capacity in concrete
A_g	Gross area of sections
A_{sc}	Area of compression of steel
M_a	Moment

CHAPTER 1
INTRODUCTION

1.1 GENERAL

In an era defined by environmental consciousness and resource scarcity, the pursuit of energy efficiency has become a concern across various sectors. Among these, educational institutions stand as a crucial battleground in the fight against energy waste and its associated environmental impact. These buildings are more than just physical spaces for education; they represent a commitment to sustainability, innovation, and the well-being of future generations.

1.2 PROJECT OVERVIEW

This project outlines a comprehensive approach to achieve energy efficiency in the design of an educational building, particularly focusing on leveraging BIM software tools. Throughout the project stages, software such as Revit was pivotal for its comprehensive BIM capabilities, facilitating detailed architectural designs and structural systems. Revit provides a comprehensive platform for linking to and integrating with other software tools for an integrated workflow. AutoCAD played an instrumental role in providing precise drafting and documentation support during the early planning and design stages, ensuring accuracy and efficiency in design development. Autodesk Forma played a crucial role in early-stage planning and design. Forma is a powerful tool that can help planning and design teams make better decisions early in the project lifecycle. ETABS, a pivotal software utilized in the project, offered comprehensive structural analysis and dynamic examination of the proposed building's structural integrity. Green Building Studio was employed for energy modeling and environmental analysis, allowing a comprehensive assessment and optimization of energy performance, aiding in understanding the environmental impact of design choices and facilitating daylighting analysis to enhance the building's energy efficiency. Twinmotion facilitated real-time rendering and high-quality visualization, providing a realistic preview of the building's aesthetic and environmental features. Twinmotion aids in creating compelling presentations, pitch videos, and marketing visuals while streamlining the design process.

Furthermore, the project adheres to a range of Indian Standard Codes to ensure structural integrity and compliance. In addition to the KMBR 2019 and NBC 2016, the project design aligns with codes such as IS 456: 2000 for the design and construction of reinforced concrete structures and IS 875: Part 1 & 3 2015 for the design of loads on buildings and structures. These standards are carefully considered throughout the project, ensuring the building's structural strength and safety measures are in line with the recommended codes. We also integrate other pertinent Indian Standard Codes such as Building Bye-Laws 2016, ECBC 2017 and AICTE Norms and Requirements 2021, reinforcing its compliance with local building regulations and educational institution norms.

By leveraging current PWD rates and proposing a framed structure, with a specific focus on a G+2 building, this project serves as a model for practicality and sustainability within the educational sector.

1.3 OBJECTIVE OF THE PROJECT

The primary objective of this project is to conceive, design, and construct an energy-efficient education building that excels in environmental friendliness, structural integrity, cost-effectiveness, and aesthetic appeal. This undertaking aims to address the prevalent issue of energy inefficiency in educational structures through a multidimensional approach, integrating sustainable design principles, rigorous structural analysis, meticulous cost estimation with a focus on long-term savings, energy modeling and analysis for enhanced efficiency, efficient utilization of BIM software, and advanced 3D visualization techniques. The overarching goal is to create a model engineering college building that not only meets but exceeds local building codes and standards, setting a benchmark for sustainable and efficient educational infrastructure. The project will culminate in comprehensive documentation and reporting, providing a valuable resource for future sustainable building initiatives.

1.4 SCOPE OF PROJECT

In developing our design, we've meticulously considered various factors to ensure optimal energy efficiency and sustainability. Our estimations are rooted in assumed occupant behavior patterns, which serve as a foundation for projecting energy consumption levels accurately. Additionally, we've meticulously analyzed current climate data and energy costs to inform our decision-making process. By incorporating these insights, we aim to create a design that not only meets but exceeds current energy codes and standards. However, we acknowledge the importance of future updates and advancements in energy efficiency regulations. While our focus lies on meeting present requirements, we remain adaptable to potential changes, ensuring that our design remains resilient and future-proof against evolving industry standards and environmental considerations.

CHAPTER 2
LITERATURE REVIEW

2.1 GENERAL

A literature review encompasses an exploration of research, theories and understanding surrounding a specific topic or subject area. Its purpose is to summarize, assess and integrate existing literature providing researchers with a foundation for their studies. The main objectives of conducting a literature review include examining the state of knowledge in a field, identifying gaps or areas of disagreement and situating one's own research within the larger context of scholarly discourse. It plays a role in the research process by enabling researchers to grasp what are already known pinpoint areas, for investigation and elucidate how their work contributes to ongoing academic discussion.

1) E. U. Syed and K. M. Manzoor, "Analysis and design of buildings using Revit and ETABS software," *Mater. Today*, vol. 65, pp. 1478–1485, 2022

The study addresses the crucial aspect of modern construction – the pivotal role of software tools in shaping the future of building design and analysis. In light of a growing population and the increasing shift towards vertical development, the demand for multi-story buildings has surged. This phenomenon highlights the importance of utilizing advanced software applications like Revit and ETABS, which have become central to the design and analysis of such structures, constituting approximately 60-70% of urban infrastructure. The significance of these software tools lies in their ability to streamline the design and analysis process, ultimately impacting the cost-efficiency of construction projects. Through a meticulous comparison, the research uncovers that the choice of software can significantly influence critical parameters, particularly the amount of reinforcement steel. Notably, Revit's Robot Structures often yields higher results, pointing to the potential financial implications of software selection. This highlights a fundamental shift in the construction industry, where software applications have emerged as indispensable allies, saved time and reducing manpower requirements while ensuring precise and cost-effective design solutions. In the ever-evolving landscape of vertical development, the choice of software has become a determining factor in successfully striking the balance between design excellence and affordability.

2) A. S. Shivsharan, D. R. Vaidya, and R. D. Shinde, "3D modeling and energy analysis of a residential building using BIM tools," *Irjet.net*. [Online]. Available: https://www.irjet.net/archives/V4/i7/IRJET-V4I7111.pdf. 2017

This journal discusses the importance of energy analysis in the AEC industry and the use of Autodesk BIM tools, specifically Autodesk Revit and Green Building Studio, for energy analysis of a residential building. The paper emphasizes the need to integrate energy analysis into the design phase of buildings to address global warming and energy crisis concerns. It highlights the functionality of energy balance estimation and the significance of energy modeling in compliance with regulations and project energy use estimation.

The document also provides a step-by-step methodology for conducting energy analysis using Autodesk Revit and Green Building Studio, including creating a 3D model, exporting it to gbXML format, and analyzing the results in the cloud-based Green Building Studio software. Overall, the paper highlights the potential of BIM tools in predicting and tracking energy consumption, optimizing building performance, and supporting sustainable design in the AEC industry.

3) M. U. Deosarkar, D. R. Ballewar, R. R. Chitte, P. B. Swami, and N. S. Shirasath, "Analysis and design of multistoried building by using revit BIM," *Ijirt.org*. [Online]. Available:https://ijirt.org/master/publishedpaper/IJIRT151857_PAPER.pdf. 2021

This case study focuses on the use of BIM software, specifically Revit, in the design, analysis, planning, and clash detection of a residential building in Pune, Maharashtra. The study highlights the creation of an intelligent 3D model, design report, scheduling, estimation, and clash detection capabilities of Revit.

It compares Revit with AutoCAD and emphasizes the advantages of Revit, such as its customization options, time-saving features, and support for parametric engines. The research also explores the concept of families in Revit, which are groups of objects with similar parameters and graphical representation. Overall, the study concludes that Revit is a powerful tool for civil engineers, offering advanced functionalities for architectural design.

4) P. Usta and B. Zengin, "Energy assessment of different building materials in the education building," *Energy Rep.*, vol. 7, pp. 603–608, 2021

This paper investigates the energy efficiency of school buildings using two different building materials, AAC and brick. The authors find that the annual EUI of the two materials is similar, but the AAC material has a lower heating load demand than the brick material. This is because AAC has better thermal properties than brick.

The authors also investigate the effect of reducing interior lighting on energy consumption. They find that reducing interior lighting by 30%, 40%, and 50% can reduce energy consumption by 9.5%, 13.7%, and 15.9%, respectively. Based on their findings, the authors conclude that AAC is a better choice for school buildings than brick in terms of energy efficiency. They also recommend reducing interior lighting to further reduce energy consumption.

5) K. Run, F. Cévaër, and J.-F. Dubé, "Does energy-efficient renovation positively impact thermal comfort and air quality in university buildings?" ***J. Build. Eng.*****, vol. 78, no. 107507, p. 107507, 2023**

This research paper aims to evaluate the energy-efficient renovation performance of the University Institute of Technology buildings in France, particularly regarding thermal comfort and indoor air quality. The authors cite several studies that have shown a correlation between indoor environmental quality and occupants' performance, health, and attitudes. The authors' primary focus is on evaluating thermal comfort and indoor air quality, but they also acknowledge the importance of visual and acoustic comfort.

The authors will be using a variety of data collection methods, including measurements of temperature, humidity, and air quality. They also conducted surveys of occupants to assess their perceptions of thermal comfort and indoor air quality. The study's findings could be used to inform future energy-efficient renovation projects in educational facilities and other types of buildings.

6) Moussa, R. R., Ismaeel, W. S., & Solban, M. M. (2022). Energy generation in public buildings using piezoelectric flooring tiles; A case study of a metro station. Sustainable Cities and Society, 77, 103555.

The study delves into the utilization of piezoelectric flooring tiles as a means to generate clean energy in buildings, particularly focusing on public spaces like transportation hubs. The researchers identified key parameters for selecting suitable piezoelectric tiles and tested their hypotheses in a case study at a busy Metro station in Egypt. Through comparing two types of piezoelectric tiles, the study determined that they could effectively reduce energy consumption and carbon emissions, with the potential for significant savings. The research underscores the importance of integrating clean energy technologies into the building sector, emphasizing their role in fostering environmentally sustainable and socially resilient cities.

Furthermore, the study emphasizes the necessity of ongoing research to advance piezoelectric technology for various building applications, paving the way for cleaner and more sustainable energy solutions. By promoting sustained engagement in this field, the research endeavours to foster wider adoption of piezoelectricity, effectively tackling energy challenges prevalent in urban areas globally.Top of FormThe study concludes that piezoelectricity is a promising solution for reducing energy consumption and carbon emissions in public projects with significant occupation patterns and density.

7) L. A. Fontalvo, S. Martínez-Marín, M. Jiménez-Barros, K. Parra-Negrete, L. Cortabarria-Castañeda, and D. Ovallos-Gazabon, "Modeling energy-efficient policies in educational buildings – A literature review," ***Procedia Comput. Sci.*****, vol. 198, pp. 608–613, 2022**

This study shows the key areas in enhancing energy efficiency within educational buildings. The research focuses on EUI, implementation strategies, and outcomes like reduced energy consumption and carbon dioxide emissions. The findings show that integrating energy efficiency within educational institutions highlights the potential for fostering environmentally conscious practices with significant social impact.

The research advocates to adopt new simulation methodologies to evaluate national energy efficiency policies. Additionally, the review focuses on implementing energy efficiency measures, such as replacing electronic air conditioning, deploying LED-based lighting, harnessing solar power, and retrofitting buildings to attain energy efficiency in educational buildings.

8) L. Chen, M. Ma, and X. Xiang, "Decarbonizing or illusion? How carbon emissions of commercial building operations change worldwide," ***Sustain. Cities Soc.*****, vol. 96, no. 104654, p. 104654, 2023**

Decarbonization efficiency levels across most countries' CBOs are less than 10%, emphasizing the need for concerted efforts. The literature underscores electrification as a pivotal strategy for a low-carbon transition in CBOs. Implementing energy-efficient technologies such as LED lighting, efficient HVAC systems, and adopting renewable sources like photovoltaic, wind, geothermal, and hydrogen energy proves effective in reducing primary energy demand and emissions. However, the review emphasizes that building electrification is just one facet of the decarbonization puzzle.

To deepen the decarbonization of CBOs globally, the literature recommends multifaceted solutions. The promotion of ultralow, near-zero, and zero energy buildings is advocated, along with the endorsement of heat pump technologies, carbon capture, utilization, and storage. Sustainable structure design gains prominence, emphasizing high-performance structures and low-carbon building materials, including innovative walls, energy-saving insulation materials, high-quality cement products, and advanced glass products. Additionally, encouraging sustainable behaviors among building occupants, such as conscientious energy consumption practices, is identified as a crucial component in the overall decarbonization strategy.

9) V. J. L. Gan, M. Deng, Y. Tan, W. Chen, and J. C. P. Cheng, "BIM-based framework to analyze the effect of natural ventilation on thermal comfort and energy performance in buildings," ***Energy Procedia*****, vol. 158, pp. 3319–3324, 2019**

Buildings globally consume a substantial amount of energy, with mechanical air-conditioning systems representing a significant share. Recognizing the potential of natural ventilation to achieve a comfortable indoor thermal environment while reducing energy consumption, this literature review addresses the existing gap in understanding the correlation between thermal comfort and energy performance facilitated by natural ventilation. Previous studies have predominantly focused on either thermal comfort or energy conservation, without thoroughly exploring their interplay. Furthermore, the impact of natural ventilation on buildings, influenced by factors such as geometry, material properties, outdoor conditions, and occupancy, requires a more comprehensive investigation. This paper introduces a novel framework based on BIM to bridge these gaps and enhance the understanding of the intricate relationship between natural ventilation, thermal comfort, and energy performance.

BIM offers a powerful tool for studying the impact of natural ventilation on the correlation between thermal comfort and energy performance in buildings. By providing detailed 3D building models incorporating geometric and material information, as well as data on building location and type, BIM enables a more accurate simulation of outdoor environmental conditions and occupancy factors. This increased accuracy contributes to a more nuanced evaluation of the effectiveness of natural ventilation in achieving thermal comfort while minimizing energy consumption.

10) K. G. Nath and A. M. Thomas, "Analysis of an educational building in ETABS," Ijert.org. [Online]. Available: https://www.ijert.org/research/analysis-of-an-educational-building-in-etabs-IJERTV11IS050103.pdf

The project focused on the meticulous analysis, design, and detailing of an educational building, adhering rigorously to the Kerala Panchayat Building Rules and Indian standard Codes. Tools like AutoCAD for drafting and ETABS 2016 for structural modeling and analysis were used in the study. The project highlighted the advantages of software in producing efficient, accurate, and economical designs for multi-storied structures.

The research also emphasized the software's capability in accounting for diverse loads such as dead loads, live loads, earthquake loads, and wind loads. The software facilitated 3D visualization, precise calculations, and efficient reinforcement determination, highlighting its convenience for multi-storied buildings despite limited use in India. The advantages of software-based design included error avoidance and enhanced accuracy, especially compared to manual design processes prone to mistakes.

CHAPTER 3

METHODOLOGY

3.1 GENERAL

To achieve our study objectives of planning, analyzing, designing, optimizing energy usage, and estimating a G+2 educational building on our college premises while meeting fundamental requirements, we propose a structured methodology. This includes conducting a thorough literature survey to incorporate proven strategies and innovative approaches. A preliminary survey of the site will provide crucial data on environmental conditions and contextual factors. Subsequent phases involve functional planning and architectural design prioritizing user needs and sustainability, structural analysis ensuring safety and resilience, energy modeling to optimize performance, and cost estimation for financial feasibility. Advanced 3D visualization will enhance project communication. By following this structured methodology, we aim to develop a sustainable and energy-efficient educational building that meets the needs of our institution and sets a standard for future construction projects.

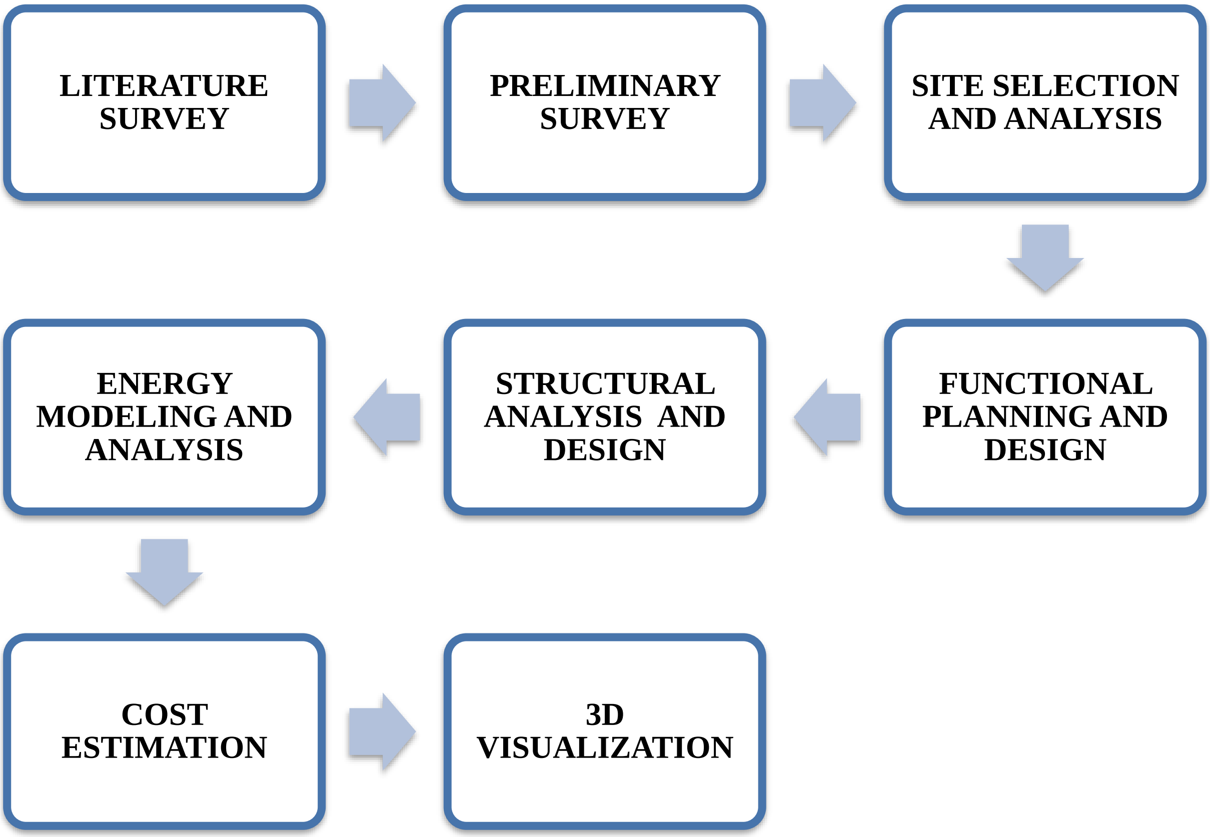


Fig 3.1 Methodology

3.2 LITERATURE SURVEY

The integration of advanced software tools such as ETABS and Revit in structural design processes brings about significant advantages, including a reduction in manpower requirements, time savings, and enhanced accuracy. This streamlined approach not only optimizes the structural design workflow but also contributes to overall project efficiency. Moreover, the utilization of AAC as a building material offers notable benefits, particularly in terms of decreased energy consumption when compared to traditional bricks. This makes AAC a superior choice for sustainable construction practices.

In the realm of architectural design, focusing on energy efficiency becomes paramount. Incorporating energy-efficient windows and shadow screens in educational buildings emerges as a strategic measure to enhance indoor air quality. These features not only contribute to a healthier and more comfortable indoor environment but also align with broader sustainability goals.

Furthermore, for a comprehensive low-carbon transition, it is imperative to embrace energy-efficient technologies such as LEDs and advanced HVAC systems for building electrification. These technologies not only reduce carbon footprints but also contribute to long-term energy savings. In essence, the combination of these efficient technologies ensures a more sustainable and environmentally responsible approach to building design and operation.

3.3 PRELIMINARY SURVEY

The preliminary survey was a comprehensive process that laid the groundwork for an energy-efficient college building. It began by outlining project goals with a strong emphasis on energy efficiency and sustainability. Simultaneously, our team conducted a thorough review of existing structures, site infrastructure, and environmental factors surrounding the potential site. An integral aspect of this phase was the assessment of code compliance, involving an analysis of various Indian standard codes such as the NBC 2016, KMBR 2019, and IS 456 2000. This ensured that the project's early stages aligned with local regulatory requirements.

Software selection was a critical element of this phase. The team deliberated and selected a suite of BIM software that best suited the project requirements. This involved weighing the capabilities of various software like AutoCAD, Revit, Green Building Studio, ETABS, Twinmotion, and Autodesk Forma. The selection aimed to facilitate an integrated approach to planning, analysis, and design for achieving energy-efficient outcomes. The chosen software suite facilitated the analysis of building performance, material selection, and the creation of detailed design models, aligning seamlessly with the energy efficiency goals.

3.4 SITE SELECTION AND ANALYSIS

The site selection process was fundamental in establishing the foundation for our endeavor to create an energy-efficient college building. Our team engaged in a methodical evaluation process, meticulously assessing potential sites based on a range of criteria. Our goal was to identify a location that not only accommodated the building's infrastructure needs but also aligned with our energy efficiency objectives. This involved an in-depth analysis of topographical features, climate considerations, and environmental factors. The site's characteristics, including sun exposure, wind patterns, and natural surroundings, were thoroughly scrutinized to understand their influence on the building's energy requirements. A detailed evaluation of environmental impact and potential sustainability was done to ensure the site was conducive to implementing energy-efficient design elements.

3.5 FUNCTIONAL PLANNING AND DESIGN

The architectural planning and design phase was a pivotal stage where the core concept for an energy-efficient building began to take shape. Initial designs were conceptualized, integrating passive design techniques and sustainability principles. These designs were iterated upon, incorporating efficient spatial planning, optimizing natural lighting, and maximizing ventilation. Material selection was a key focus, emphasizing sustainable and eco-friendly materials that aligned with our energy efficiency goals. Every decision, from the building's orientation to the choice of construction materials, was meticulously planned to harmonize with the overall energy efficiency objectives.

3.6 STRUCTURAL ANALYSIS AND DESIGN

The structural design phase was crucial in ensuring the building's robustness while also adhering to energy-efficient principles. Collaborating closely with the architectural vision, the structural design aimed to optimize energy efficiency without compromising the building's integrity. This phase involved intricate planning of material usage, structural components, and load-bearing elements. The integration of architectural and structural elements was vital to achieving a harmonious balance between aesthetics and energy efficiency. An iterative design process allowed for continuous refinement, enabling us to achieve a design that merged both structural integrity and energy efficiency seamlessly.

3.7 ENERGY MODELING AND ANALYSIS

Sophisticated software and advanced methodologies were employed to conduct detailed energy simulations. These simulations provided critical insights into the building's energy consumption patterns, areas of potential energy loss, and opportunities for optimization. The results of these simulations were analyzed to recommend design modifications that could significantly enhance the building's overall energy efficiency. Strategies for efficient heating, cooling, lighting, and insulation were derived from these simulations, forming the backbone of the energy optimization plan.

3.8 COST ESTIMATION

The cost estimation phase delved into a detailed breakdown of expenses related to energy-efficient features and strategies. It involved a meticulous analysis to ensure that the project aligned with the allocated budget while still achieving optimal energy efficiency. Additionally, a thorough analysis of the long-term ROI was conducted. This assessment aimed to showcase the economic benefits and potential cost savings stemming from investing in an energy-efficient design. It helped in demonstrating the feasibility and long-term sustainability of the proposed design, beyond just energy efficiency.

3.9 3D VISUALIZATION

In this phase, our team developed detailed 3D visual representations and renderings of the proposed design. These visualizations provided a tangible view of how the building design aligned with energy-efficient principles. Through immersive virtual walkthroughs, we can gain a comprehensive understanding of the building's layout, features, and its alignment with energy efficiency goals. This phase significantly aided in communicating the design aspects to the broader team facilitating a clearer vision and understanding of the building's potential upon completion.

CHAPTER 4
SOFTWARES

4.1 GENERAL

BIM software has emerged as a transformative tool in the architecture, engineering, and construction industry. This innovative technology goes beyond traditional 3D modeling, offering a holistic approach to the design, construction, and management of buildings and infrastructure. BIM software allows stakeholders to collaboratively create detailed 3D models enriched with essential information such as time, cost, and materials. One of the key strengths lies in its ability to foster improved collaboration among diverse project teams, enhancing communication and coordination. By facilitating real-time interactions, BIM software minimizes errors through clash detection and streamlines project planning, leading to significant cost and time savings. Ultimately, BIM software not only revolutionizes the design process but also supports the entire lifecycle of a building, making it a cornerstone in modern construction methodologies. We use BIM software like AutoCAD, Revit, ETABS and Forma. Other software like Green Building Studio and Twinmotion are also used.

4.2 AUTODESK FORMA

Autodesk Forma, positioned as the pioneering component of Autodesk's industry cloud for AEC, represents a paradigm shift in early-stage AEC processes. Tailored explicitly for preplanning, Forma introduces a suite of advanced features aimed at elevating decision-making efficiency. Its conceptual design capabilities, encompassing massing models, site analysis tools, and generative design options, empower AEC professionals to rapidly explore and refine design ideas. The integration of predictive analytics, driven by artificial intelligence, provides valuable insights through simulations, spanning sun and wind studies to precise energy analyses and cost estimations. Moreover, automation functionalities, notably in code checking and compliance analysis, not only enhance task efficiency but also contribute to heightened accuracy. Beyond these features, the platform's cloud-based environment fosters seamless collaboration within project teams, facilitating swift idea sharing and decision-making. Autodesk Forma, as a user-friendly and comprehensive solution, sets new benchmarks for the initial phases of AEC projects. Its emphasis on improved decision-making, project outcomes, and collaboration efficiency positions it as an indispensable tool for AEC professionals navigating the complexities of preplanning.

4.3 AUTOCAD

AutoCAD is an essential tool for building planning, offering architects and designers robust 2D drafting and 3D modeling features. With precision tools for creating floor plans and detailed three-dimensional representations, AutoCAD streamlines the planning process. Its layer management system enhances organization, while detailing and annotation features ensure clear communication with construction teams. The software's collaborative capabilities support real-time teamwork and coordination among stakeholders. Compatible file formats and support for parametric design make AutoCAD a versatile asset in creating dynamic and easily modifiable designs during building planning. Overall, AutoCAD significantly contributes to the efficiency and accuracy of architectural drawings, providing a solid foundation for successful construction projects.

4.4 REVIT

Revit, developed by Autodesk, is a pivotal tool in the realm of building planning and cost estimation. Functioning as robust BIM software, Revit extends its capabilities beyond traditional design by incorporating data-rich 3D models that include material, quantity, and cost information. A standout feature is its parametric modeling, establishing a dynamic link between design modifications and associated cost elements, thereby streamlining the estimation process. Through quantification and scheduling tools, Revit allows for the extraction of precise material quantities directly from the 3D model, contributing to detailed and accurate cost estimates. The software facilitates ongoing cost tracking and analysis throughout the project, empowering stakeholders with real-time insights for informed decision-making and cost control. Moreover, Revit's collaborative environment supports concurrent work by architects, engineers, and cost estimators, ensuring that cost estimations align seamlessly with the latest design revisions. Its efficiency is further enhanced by industry-standard templates and libraries, promoting standardized practices and adaptable solutions. In essence, Revit serves as an integrated solution that not only advances building planning but also revolutionizes the accuracy and efficiency of cost estimation processes in the construction industry.

4.5 ETABS

ETABS, developed by Computers and Structures, Inc. (CSI), stands as a cornerstone in structural analysis, providing engineers with a powerful tool for designing and evaluating building systems. Renowned for its advanced three-dimensional analysis capabilities, ETABS allows for the comprehensive modeling of intricate structural systems. Structural engineers leverage its user-friendly interface to define elements such as beams, columns, slabs, and walls, applying diverse material properties and loads. ETABS excels in various analyses, encompassing linear and nonlinear static analyses, dynamic analyses crucial for seismic considerations, and evaluations of the structural response to gravity and lateral loads. The software's dynamic analysis capabilities make it particularly valuable for designing structures that can withstand seismic events. Results from these analyses are visualized through detailed reports, graphs, and animations, aiding engineers in comprehending structural behavior and making informed design decisions. Furthermore, ETABS seamlessly integrates with other CSI software, facilitating the transfer of models and analysis results between different programs. The software's adherence to international design codes ensures that structural designs comply with industry standards. In essence, ETABS emerges as a comprehensive and versatile solution for structural analysis, playing a pivotal role in the efficient and accurate design of complex building and bridge projects.

4.6 GREEN BUILDING STUDIO

Autodesk Green Building Studio is a versatile cloud-based service designed to facilitate building performance simulations, with the overarching goal of optimizing energy efficiency and contributing to early-stage efforts towards carbon neutrality in the design process. This innovative tool offers architects and engineers the capability to design high-performance buildings more efficiently, with significant time and cost savings compared to traditional methods. By harnessing the power of cloud computing, Autodesk Green Building Studio enables users to run simulations without the need for extensive local computing resources. Notably, this service can function as a standalone web service, providing users with the flexibility to access its features independently. Furthermore, it serves as the backbone for Autodesk Revit's whole building energy analysis tools. The integration with Revit enhances the synergy between design and energy analysis, allowing professionals to seamlessly incorporate insights into the energy performance of their building designs. It is essential to stay updated with the latest information through Autodesk's official channels, as software details and features may undergo updates and enhancements over time.

4.7 TWINMOTION

Twinmotion, developed by Epic Games, is a real-time 3D architectural visualization software that empowers architects and designers to swiftly transform 3D models into captivating visualizations. Its strength lies in its seamless ability to swiftly convert 3D models into stunning visual representations. This software boasts an intuitive interface and a powerful rendering engine that facilitates immediate exploration and modification of designs. With an extensive library offering diverse assets such as foliage, furnishings, and weather effects, users can craft vibrant, lifelike scenes. The software's exceptional feature set allows for the simulation of various weather conditions and lighting scenarios, providing a dynamic canvas for experimentation. Furthermore, its compatibility with VR technology elevates the presentation experience, enabling professionals to immerse clients and stakeholders in interactive, immersive environments. Twinmotion serves as a pivotal tool in effectively conveying design visions and ideas, aiding in the seamless communication of architectural concepts.

CHAPTER 5

SITE SELECTION

5.1 STUDY AREA

The selection of the college ground, covering an expansive 6500m^2, as the site for the educational building is a strategic decision aimed at optimizing space utilization and promoting sustainability in construction. This choice not only addresses the immediate infrastructure requirements but also aligns seamlessly with the overarching objectives of energy efficiency.

Fig 5.1 Proposed site

The precise location of the college ground at a latitude of 11° 59' 10.2264" N and a longitude of 75° 22' 50.1996" E provides a specific geographical context for the project. This strategic positioning considers factors such as sunlight exposure, prevailing winds, and overall environmental considerations crucial for sustainable design and construction.

Moreover, the proximity of the chosen site, located approximately 100 meters away from the college's main block, enhances accessibility and connectivity to existing college facilities. This closeness ensures convenience for students, faculty, and staff while fostering a cohesive and integrated campus layout.

In essence, the selection of the college ground as the project site reflects a meticulous approach, considering both functional and sustainable aspects. This decision sets the stage for an educational building that not only meets the immediate needs of the institution but also maximizes energy efficiency and environmental compatibility in its construction and operation.

5.2 SURVEYING

Surveying is a critical process in mapping and measuring the Earth's surface, essential for various fields including construction, engineering, and land development. It involves the collection of accurate spatial data using tools ranging from traditional theodolites to modern technologies like GPS and drones. This data is pivotal in designing and planning projects, setting property boundaries, and ensuring adherence to regulations. Surveying plays a foundational role in the construction industry, aiding tasks such as site analysis and infrastructure planning. Moreover, it is vital for legal purposes, resolving land disputes and maintaining compliance with zoning regulations. Ultimately, surveying provides the crucial spatial information necessary for informed decision-making in diverse fields, contributing to the success and accuracy of projects.

5.2.1 Reconnaissance Survey

The reconnaissance survey at the site has been completed, involving a thorough investigation and the creation of a reference sketch detailing key features such as buildings and roads. Notably, the plot boasts a levelled surface. The precise location of the college ground, coupled with its soil characteristics, offers advantages for sustainable construction practices. The hardness of granite rock can provide a stable base for the building's foundation, reducing the need for extensive excavation and earthworks. Additionally, incorporating sustainable building techniques, such as passive cooling and natural lighting, can further optimize energy efficiency while leveraging the site's natural features. The proposed educational building has been strategically positioned, standing 30 meters away from the existing laboratory building. This deliberate spacing not only adheres to safety and regulatory considerations but also optimizes the functional layout of the campus. The reconnaissance findings serve as a foundational step in the project, offering valuable insights into the site's topography and existing structures, informing subsequent stages of planning and design for the envisioned energy-efficient educational building.

Fig 5.2 Creating reference sketch of the site

5.2.2 Detailed Survey

A comprehensive detailed survey utilizing tape was conducted, establishing boundary points, and accurately measuring the site's area. The meticulous measurements obtained through the tape survey reveal that the total area of the site is 6500 square meters. This detailed survey provides a precise understanding of the site's dimensions, facilitating the next phases of design and construction planning for the energy-efficient educational building. The fixation of boundary points ensures clarity in demarcation, contributing to the accuracy and reliability of the collected data. These survey results serve as a crucial foundation for the project, informing decisions regarding optimal space utilization, sustainable design integration, and adherence to regulatory requirements.

Fig 5.3 The site's dimensions are being assessed using a tape measure

The soil on the site exhibits a unique characteristic of being hard both on the surface and to a significant depth below. This dense and compacted soil profile provides excellent load-bearing capacity, making it suitable for supporting structures without the need for extensive foundation systems. Due to its inherent stability and strength, isolated footings are an ideal choice for constructing buildings on such soil. Isolated footings, also known as pad footings, distribute the structural loads efficiently to the underlying soil, ensuring uniform settlement and minimizing the risk of differential settlement.

Fig 5.4 The area around the site being analyzed

By utilizing isolated footings, construction projects can capitalize on the soil's natural resilience and avoid the complexities and costs associated with deeper foundation systems like pile foundations or raft foundations. This soil condition not only simplifies the foundation design process but also enhances the overall stability and longevity of the building structure.

5.2.3 Digital Survey

In addition to traditional surveying methods, we leveraged advanced digital technologies to enhance the accuracy and efficiency of our data collection process. Utilizing tools such as Google Maps, Google Earth Pro, and Autodesk Forma, we conducted a comprehensive digital survey of the site. These platforms allowed us to precisely measure the land area and identify key geographical features with a high level of detail. By harnessing the power of digital mapping and modeling, we were able to supplement our reconnaissance and detailed surveys, ensuring a thorough understanding of the site's characteristics. This digital approach streamlines the surveying process and provides valuable data for informed decision-making in the project's design and planning phases.

Fig 5.5 Site measurement using Google Earth pro and Forma

5.3 SITE PLAN

A site plan is a visual representation of a project's location, depicting property boundaries, topography, vegetation, existing and proposed structures, easements, wells, and roads. It combines architectural, landscape architecture, and engineering details to illustrate the layout of buildings, parking, landscaping, and other features within a development project. It serves as a blueprint for builders and contractors to guide improvements to a property.

5.3.1 Site Details

Total area of campus	= 4.2563 hectare
	= 42560.79 m^2
Total area selected for the proposed site	= 0.65 hectare
	= 6500 m^2
Total area of the propose building	= 0.2648 hectare
	= 2648 m^2

5.3.2 Site Plan Preparation

The site plan for the given plot underwent a meticulous process from conceptualization to completion. Initially, Autodesk Forma software was employed to outline the layout and key features, including existing buildings, roads, boundaries, drainage areas, and electric lines. Once the initial design was established, it was seamlessly converted into an AutoCAD file, allowing for the integration of detailed data, and enhancing precision. Subsequently, utilizing a variety of tools provided by AutoCAD, the site plan was meticulously drawn to accurately depict the site's layout and infrastructure. Attention to detail ensured clear representation of essential elements such as existing structures, roadways, property boundaries, drainage systems, and utility lines throughout the process.

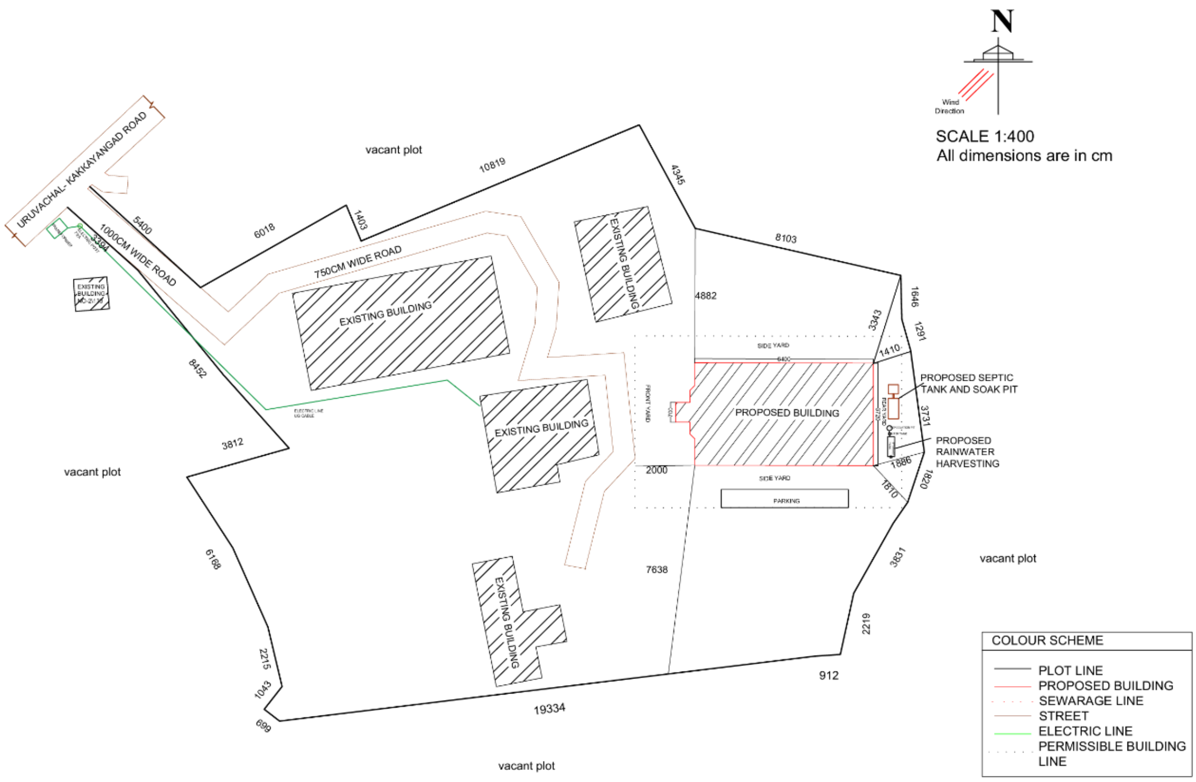


Fig 5.6 Site plan

CHAPTER 6

ANALYSIS USING FORMA

6.1 GENERAL

Utilizing Autodesk Forma, a comprehensive scrutiny of site characteristics was undertaken to gain insightful data crucial for the optimal design of the energy-efficient educational building. The analysis included a meticulous examination of sun exposure, wind patterns, and natural surroundings, recognizing their profound impact on the building's energy requirements. Through these sophisticated analyses facilitated by Autodesk Forma, the project gained valuable insights, ensuring that the energy-efficient educational building will be strategically positioned and designed to maximize sustainability while harmonizing with its natural surroundings. The visualization of daylight potential, in harmony with the surrounding buildings and environment, provided a nuanced understanding of the site's lighting dynamics. The assessment of rooftop solar energy potential, particularly focusing on photovoltaic panel systems, highlighted opportunities for harnessing renewable energy.

Furthermore, a detailed wind analysis was conducted to illustrate how the building and site influence localized air flow patterns, crucial information for optimizing ventilation and energy efficiency. Microclimate analysis was integrated to refine urban site design, enhancing outdoor thermal comfort.

6.2 SUN HOUR ANALYSIS

This report analyzes the variation in sunlight hours recorded for different dates over a year. The dataset encompasses measurements from January to December, categorizing sunlight hours into hourly intervals ranging from 0-1 hour to 9+ hours.

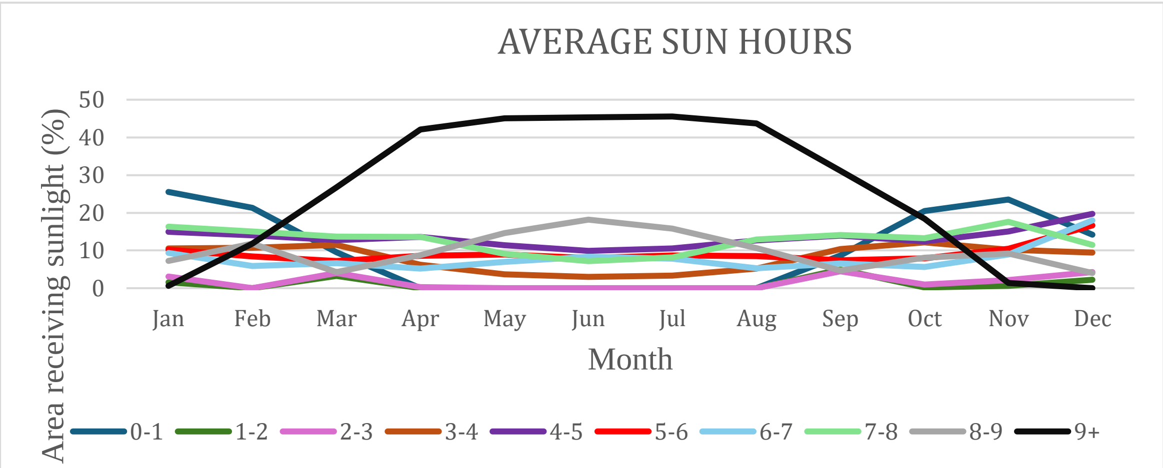


Fig 6.1 Sun hours analysis

The data reveals distinct seasonal trends in sunlight availability. From January to March, sunlight hours gradually increase, reaching their peak in March. April to June experiences the highest average sunlight hours, with June typically recording the maximum. However, from July to September, there's a slight decrease in sunlight hours compared to the peak months, though levels remain relatively high. Finally, from October to December, there's a decline in sunlight hours as the year progresses towards winter.

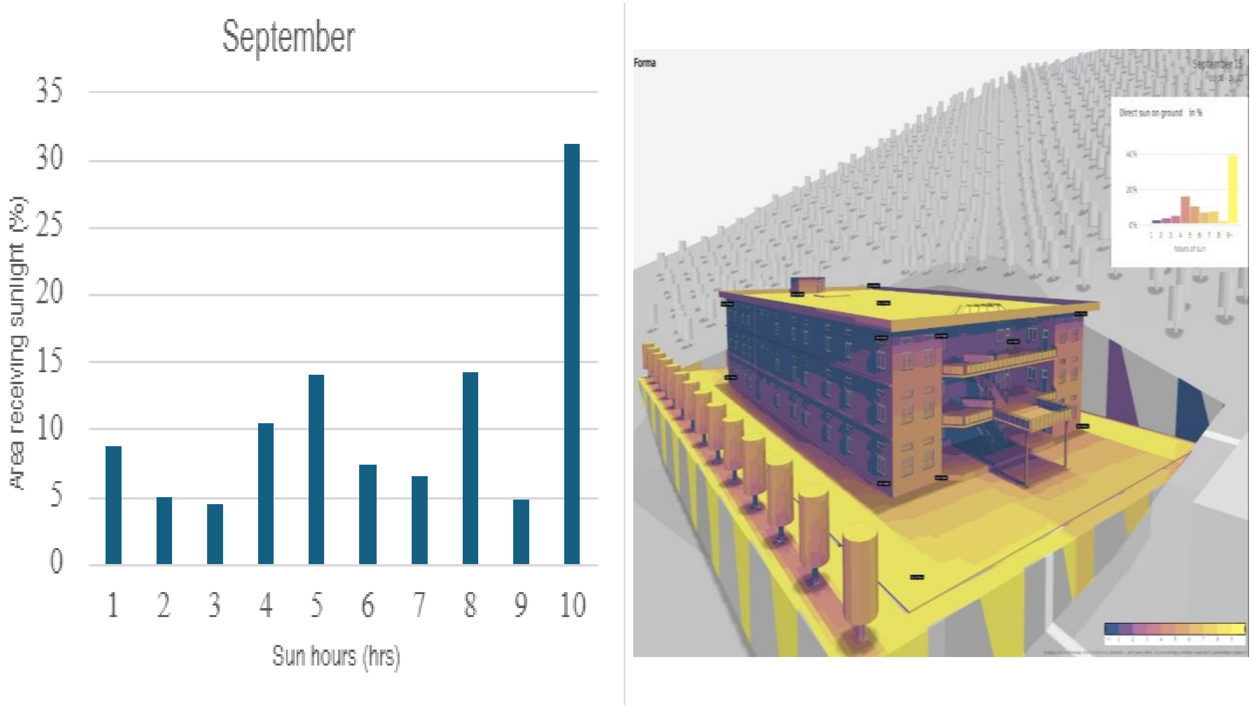


Fig 6.2 Graph showing sun hours of month September

6.3 DAYLIGHT POTENTIAL ANALYSIS

The data, representing daylight factors measured in lux, illustrates variations in natural light penetration from different directions and floors. The orientations studied include west, north, east, and south, while the floors analyzed range from ground floor to terrace floor. Understanding daylight potential is crucial for architects, engineers, and building designers to optimize building layouts, window placements, and shading strategies for enhanced occupant comfort, energy efficiency, and overall building performance.

Across the various orientations and floors, the data indicates fluctuations in daylight potential. The highest average daylight potential is observed on the terrace floor, with lux values ranging from 96 to 98 across all orientations. Conversely, the ground floor generally exhibits lower daylight potential compared to higher floors, with lux values ranging from 16 to 36.

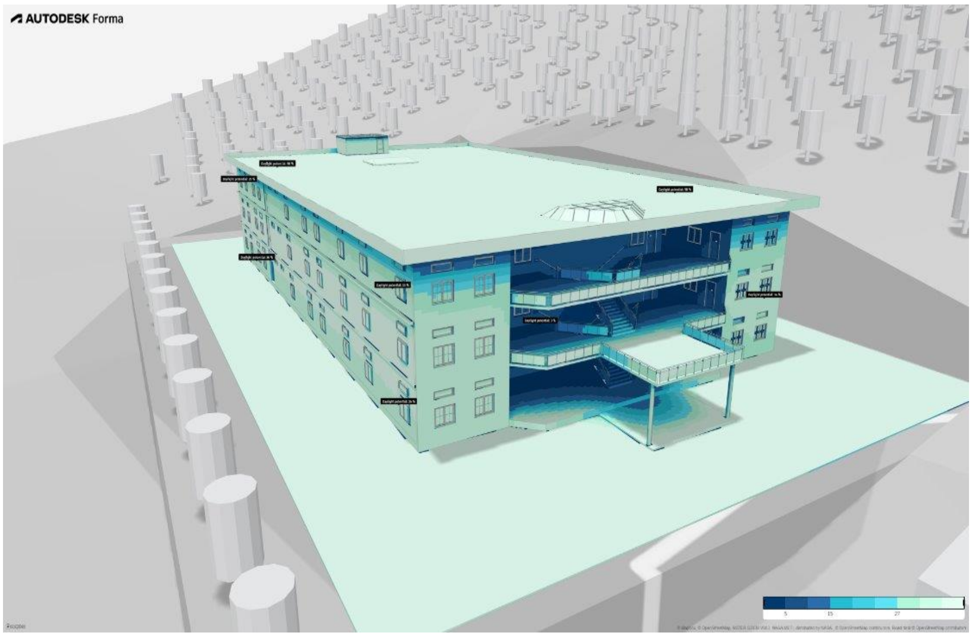


Fig 6.3 Daylight potential analysis

Among orientations, the north orientation consistently shows higher average daylight potential compared to west, east, and south orientations across all floors.

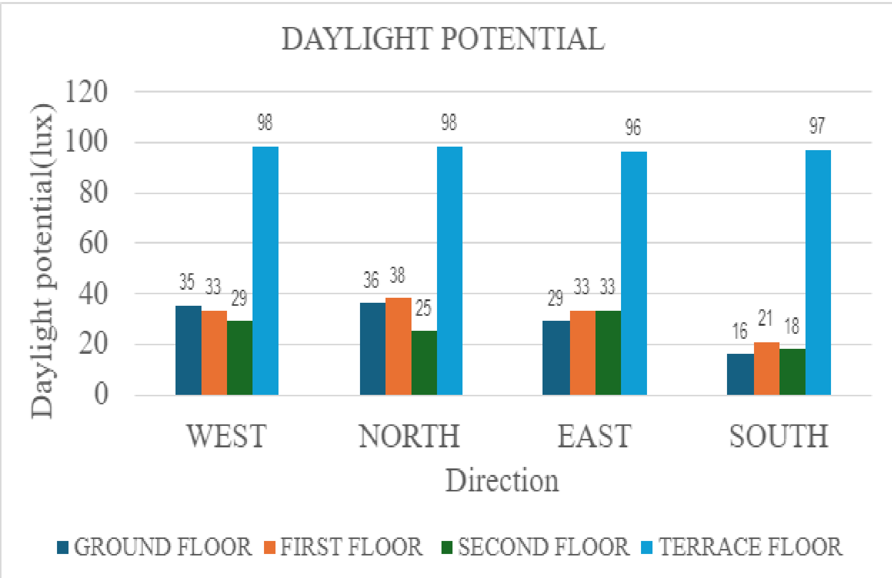


Fig 6.4 Graph showing daylight potential in each floor in different directions

6.4 SOLAR PANEL ANALYSIS

It presents an analysis of solar panel efficiency across various surface coverage percentages and panel placement areas, focusing on annual electrical output measured in kilowatt-hours (kWh). The data encompasses multiple scenarios with different panel efficiencies ranging from 10% to 100%, along with corresponding surface coverage percentages and placement areas.

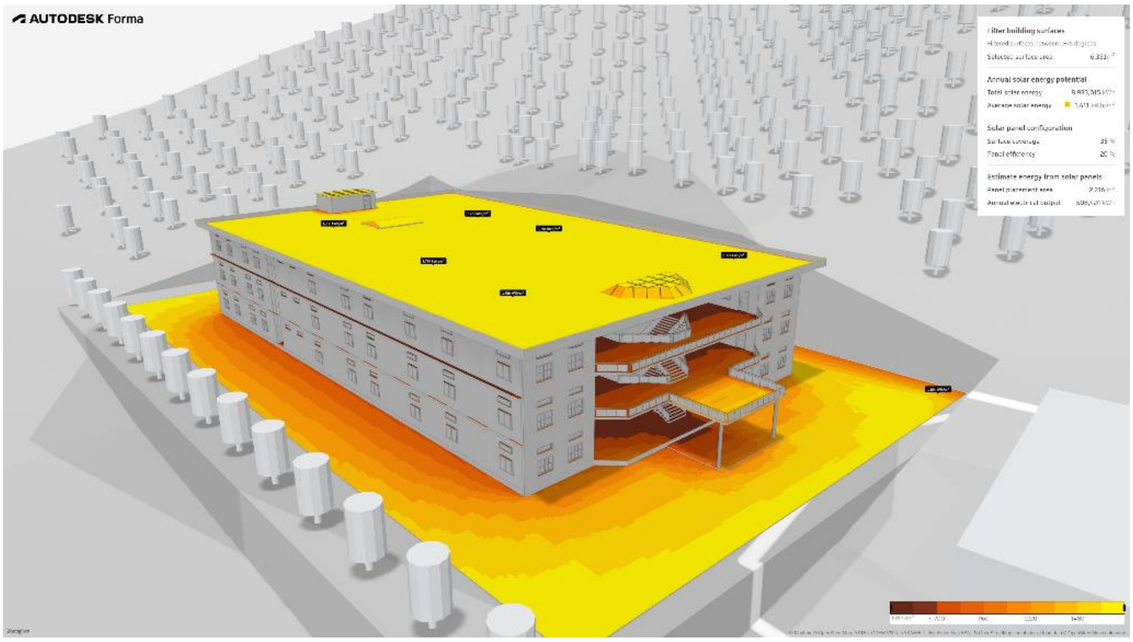


Fig 6.5 Solar energy analysis

The analysis indicates an expected average annual electrical output of 4,35,792 kWh for 30% surface coverage by using solar panel with 20% panel efficiency, underscoring the potential for a sustainable and energy-efficient design.

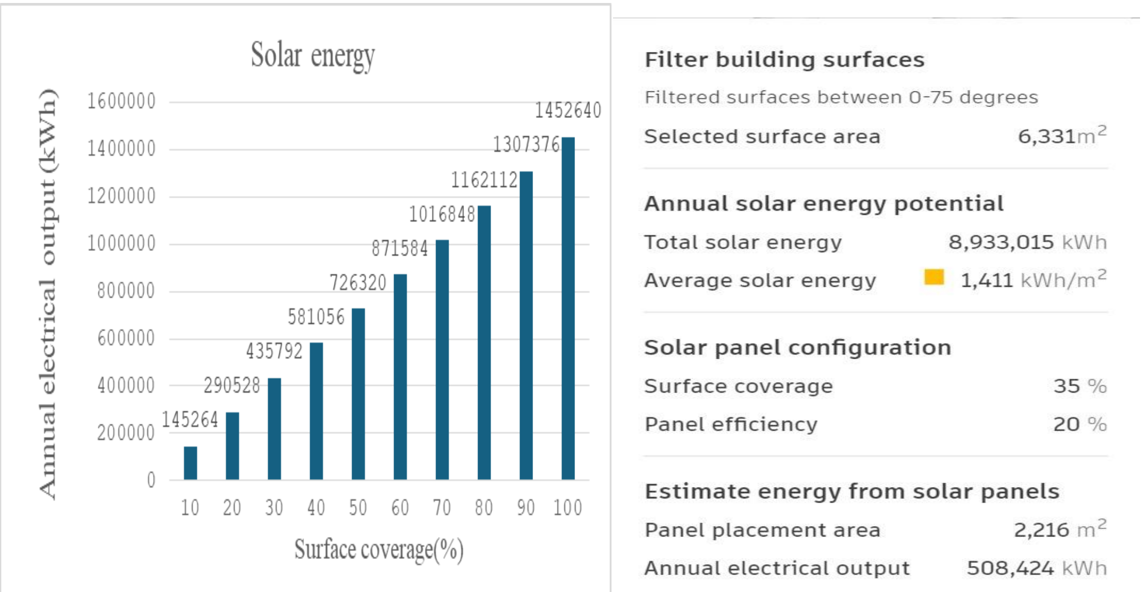


Fig 6.6 Graph showing the annual electrical output when panel efficiency is 20%

6.5 WIND ANALYSIS

The relationship between wind direction and comfort levels, along with corresponding wind speeds were examined. The data encompasses comfort ratings assigned to different wind directions, ranging from North (N) to Northwest (NW), as well as corresponding wind speeds measured in meters per second (m/s).

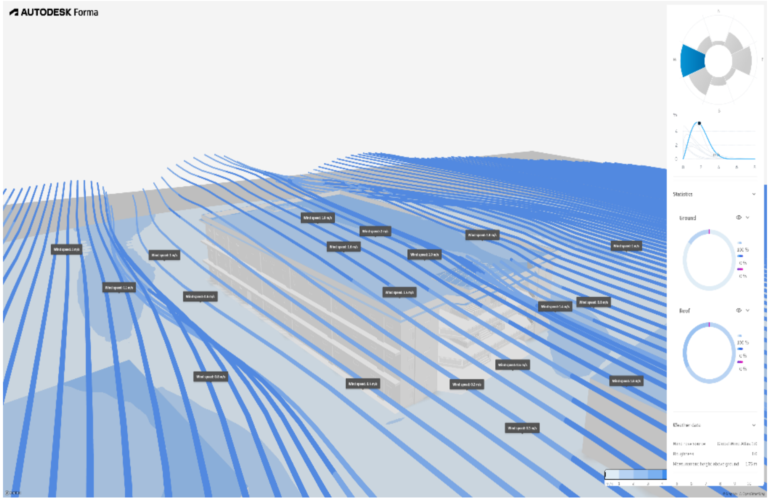


Fig 6.7 Wind analysis

The analysis reveals varying comfort levels associated with different wind directions. Winds from the west (W) are rated the most comfortable with a score of 24, followed closely by winds from the east (E) with a rating of 19. Conversely, winds from the north (N) and southeast (SE) are associated with lower comfort ratings, scoring 3 and 5, respectively. Additionally, the corresponding wind speeds align with comfort ratings, with higher wind speeds generally associated with lower comfort levels. Winds from the west (W) and southwest (SW) exhibit the highest wind speeds at 1.8 m/s and 1.6 m/s, respectively. Conversely, winds from the north (N) and northeast (NE) have the lowest wind speeds at 0.7 m/s and 1.1 m/s, respectively.

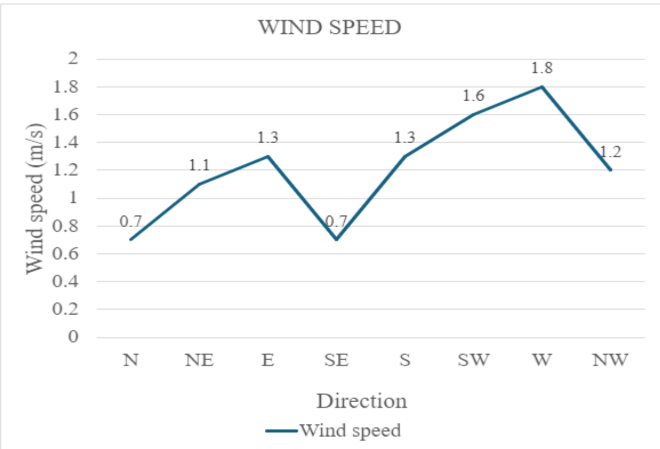


Fig 6.8 Graph showing wind speed in different direction

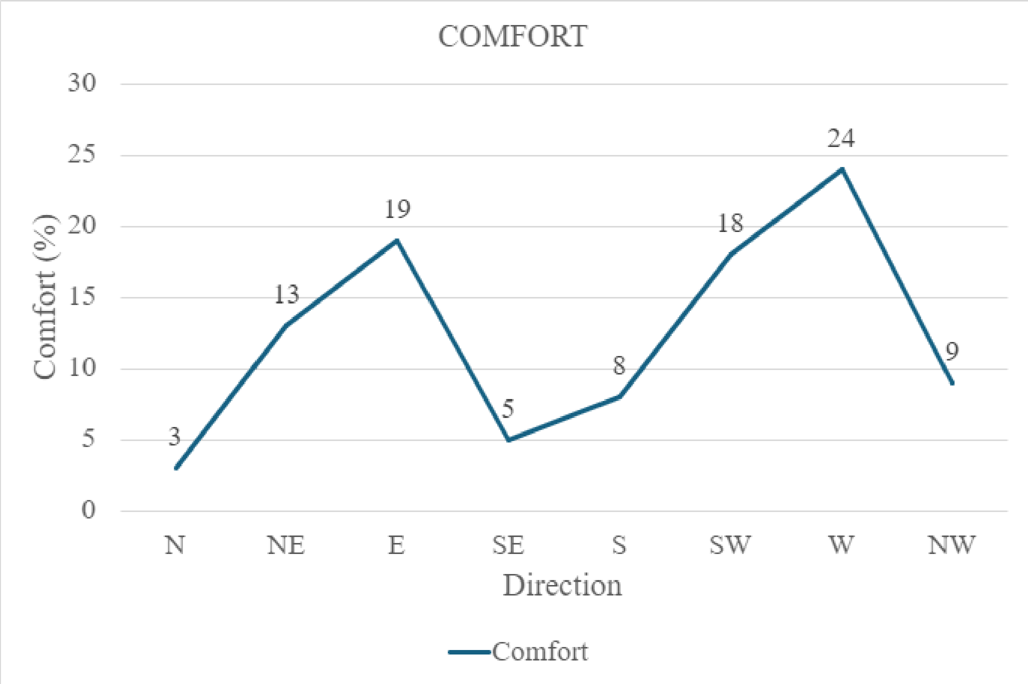


Fig 6.9 Graph showing comfort in different directions

6.6 MICROCLIMATE ANALYSIS

The analysis gives a report of climate data including air temperature, humidity, cloud cover, and direct solar radiation across the year. The data, spanning from January to December, offers insights into seasonal variations and climatic trends.

Monthly Trends:

Air temperature remains relatively high in January and February, peaking at 32-33°C, before gradually decreasing towards June and July, where temperatures reach 26°C. Humidity levels show a general trend of increase from January to June, with a peak of 88% in June, before slightly decreasing in the following months. Cloud cover percentage steadily rises from January to May, reaching its peak of 100% in June and July, indicating overcast conditions during these months. Cloud cover then gradually decreases towards December. Direct solar radiation follows an inverse trend to cloud cover, with higher radiation levels recorded during months with lower cloud cover. January and February exhibit the highest direct solar radiation values, while June and July record the lowest.

Annual Average:

The annual average air temperature is 29°C, indicating a warm climate throughout the year. Humidity averages approximately 67.58%, suggesting a moderately humid climate.

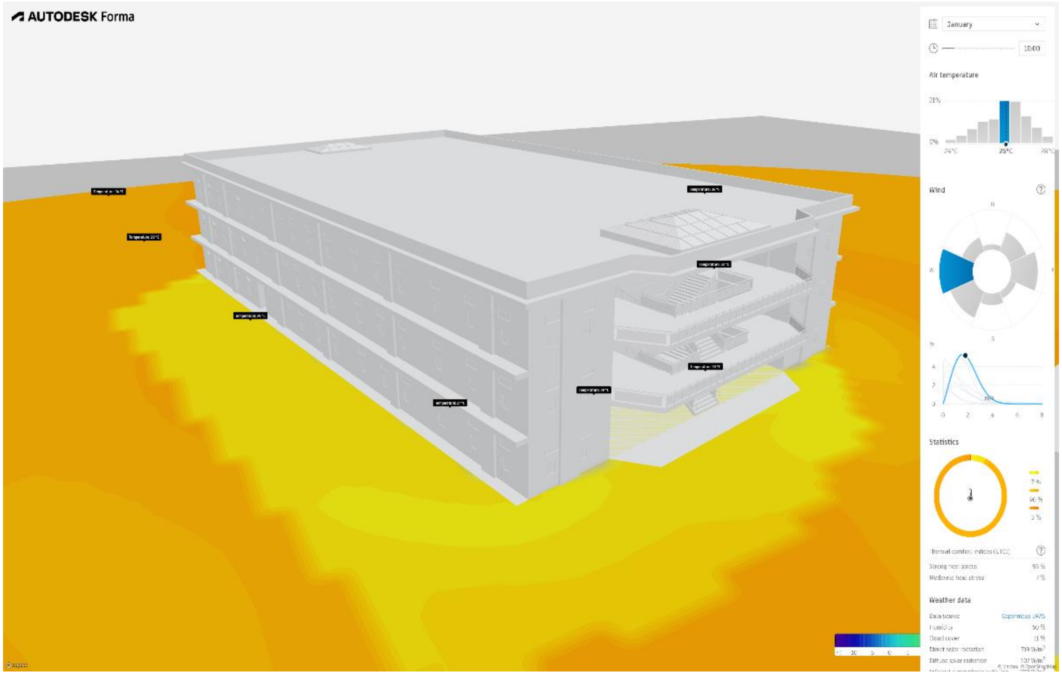


Fig 6.10 Microclimate analysis

Cloud cover averages around 65.92%, with variations across different months. The average direct solar radiation is 562.25 W/m², highlighting the solar energy potential in the region. Additionally, the assessment of outdoor thermal comfort ranging from 25% to 35% further informs the design approach.

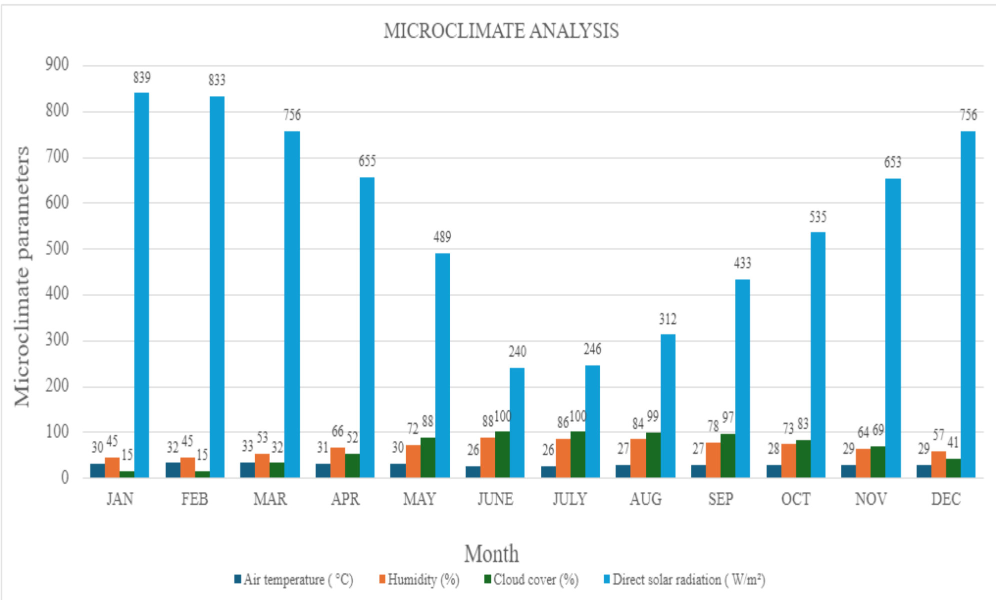


Fig 6.11 Graph showing microclimate parameters

CHAPTER 7

MATERIALS USED

7.1 AUTOCLAVED AERATED CONCRETE (AAC)

AAC is a lightweight precast concrete material that contains numerous small air pockets uniformly distributed throughout its volume. It is also known as autoclaved cellular concrete or autoclaved lightweight concrete. AAC is composed of a precise mixture of sand, cement, lime, water, and a small proportion of aluminum powder. During the manufacturing process, these ingredients undergo a chemical reaction that releases hydrogen gas, creating numerous tiny air pores throughout the material. This cellular structure gives AAC its distinctive lightweight properties while maintaining strength and durability.

It has excellent thermal insulation properties and low thermal conductivity. Its production process generates minimal waste, and it can be recycled or reused at the end of its lifecycle. The porous structure of AAC effectively absorbs sound waves, making it an excellent choice for enhancing acoustic comfort in buildings. When used in walls, AAC can significantly reduce noise transmission between rooms and from external sources, creating quieter and more comfortable indoor environments for occupants.

Fig 7.1 Autoclaved aerated concrete

7.2 UNPLASTICIZED POLYVINYL CHLORIDE (uPVC)

uPVC is a type of rigid, durable plastic widely used in construction for applications such as doors, windows, and piping. Unlike traditional PVC, uPVC is unplasticized, meaning it does not contain added plasticizers, resulting in a stiffer and more durable material suitable for structural applications. uPVC exhibits excellent thermal insulation properties, effectively reducing heat transfer through windows and doors. This helps maintain comfortable indoor temperatures and can contribute to energy savings by reducing the need for heating and cooling.

uPVC windows and doors are designed to fit tightly within their frames, minimizing air leakage. Properly installed uPVC frames contribute to a more airtight building envelope, enhancing overall building performance. uPVC requires minimal maintenance compared to other materials such as wood or aluminum. It is resistant to rot, corrosion, and insect damage, making it suitable for long-term use in various climates. Additionally, uPVC is recyclable at the end of its lifecycle, making it an eco-friendly choice for construction projects and contributing to sustainable building practices.

Fig 7.2 Unplasticized polyvinyl chloride

7.3 KINETIC TILES

Kinetic tiles, also known as energy-harvesting tiles or piezoelectric tiles, are innovative flooring technologies designed to generate electricity through mechanical pressure, typically generated by footsteps. These tiles are integrated with piezoelectric materials that can convert mechanical energy into electrical energy. When individuals walk or move across the surface of kinetic tiles, they apply pressure, causing the piezoelectric materials within the tiles to deform. This deformation generates electric voltage because of the piezoelectric effect, where certain materials produce an electric charge in response to applied mechanical stress.

The electric voltage generated by the kinetic tiles can be harvested using built-in mechanisms such as wires or conductive pathways. This harvested electricity can then be stored in batteries, capacitors, or other energy storage devices for later use. Kinetic tiles provide a renewable energy source that can be utilized to power various applications. The electricity generated by these tiles can be harnessed for lighting systems, signage, sensors, or other electronic devices, offering a sustainable and environmentally friendly energy solution. Kinetic tiles are often installed in areas with high foot traffic, such as staircases or pedestrian walkways, to maximize energy generation potential. By placing them in strategic locations where people frequently walk or move, such as steps or entryways, kinetic tiles can effectively capture mechanical energy and convert it into usable electricity.


Fig 7.3 Kinetic tiles

7.4 LOW-E GLASS

Low emissivity glass is a type of energy-efficient glass featuring a specialized coating designed to minimize heat transfer through windows. Low-E glass is engineered to reduce the emissivity of the glass surface. Emissivity refers to the ability of a material to emit thermal radiation. By minimizing emissivity, low-E glass inhibits heat transfer, preventing warmth from escaping in cold climates and reducing heat gain in hot climates. Despite its insulating properties, low-E glass still allows visible light to pass through, maintaining natural daylighting within indoor spaces.

By minimizing heat loss or gain through windows, low-E glass contributes to overall energy efficiency in buildings, leading to potential cost savings and reduced environmental impact. Low-E glass is commonly used for window glasses in various building projects. Whether in residential, commercial, or institutional settings, low-E glass contributes to creating comfortable, sustainable, and visually pleasing indoor environments.

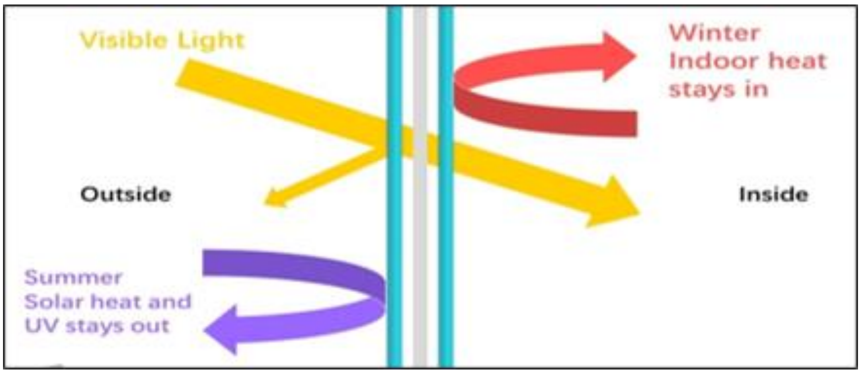


Fig 7.4 Low-E glass

CHAPTER 8

FUNCTIONAL PLANNING AND DESIGN

8.1 GENERAL

When considering energy-efficient design for a Group B educational building in accordance with NBC, KMBR, and AICTE norms, special attention should be given to major rooms like laboratories and lecture halls. Utilizing advanced design software such as Revit and AutoCAD become instrumental in optimizing spatial layouts and ensuring efficient use of resources.

By leveraging Revit and AutoCAD, architects and engineers can employ BIM to streamline the planning process. This technology allows for a more accurate visualization of major rooms, facilitating effective placement of energy-efficient features such as lighting, ventilation, and equipment. The integration of these software tools enhances collaboration, reduces design errors, and contributes to the overall energy efficiency of the educational facility. Incorporating cutting-edge software into the design process not only aligns with modern technological trends but also ensures the practical implementation of energy-efficient principles in the construction of laboratories and lecture halls.

8.2 PLANNING USING AICTE 2021

As per Appendix 4 of AICTE Norms for Land requirement and Building Space for Technical Institution Carpet Area in sqm per room:

Table 8.1 Room area as per AICTE

Room	Area as per AICTE
Lecture hall	66m^2
Laboratory	66m^2
Seminar hall	132m^2
Drawing hall	132m^2
Principal/Director office	30m^2
Central store	30m^2

Board room	$20m^2$
Department offices	$20m^2$
Cabins for head of departments	$10m^2$
Faculty rooms	$5m^2$
Stationery store & reprography	$10m^2$
Housekeeping	$10m^2$
First aid cum Sick room	$10m^2$

8.3 PLANNING USING KMBR 2019

KMBR 2019 is a set of regulations and guidelines governing the planning and construction of buildings within municipalities in Kerala. These rules are formulated to ensure safe, sustainable, and aesthetically pleasing urban development while also addressing the needs of the growing population and urban infrastructure requirements.

8.3.1 Occupancy of the buildings

As per chapter IV our building is classified under Group B – Educational. These shall include any building or part thereof, exceeding $200m^2$ of built-up area, used for school, college, day-care purposes, other institutions for education or research, libraries incidental to educational buildings, religious educational building such as madrassa, Sunday schools & the like and appurtenant assembly buildings having capacity not exceeding 200 persons.

8.3.2 Exterior and interior open air spaces

The minimum yards for buildings in Group B of built-up area above $500m^2$ upto 10m in height shall be:

Front yard – 7.5m

Rear yard – 3m

Side yard – 3 and 5m

For buildings above 10m in height, in addition to the minimum front, rear and side yards and the minimum width of interior open space required for height upto 10m, there shall be provided increase in such minimum yard at the rate of 0.5m per every 3m height or fraction thereof exceeding 10m at the ground level itself, until the total width of yard reaches 16m and no further additional setback is required for additional height above this.

8.3.3 Coverage and floor area ratio

The maximum percentage of coverage permissible for each occupancy shall limit the footprint of a building. The Floor Space Index value shall limit the maximum buildable area. Floor Space Index i.e., F.S.I. shall be calculated as shown below:

$$F.S.I = \frac{Total\ built\ up\ area\ on\ all\ floors}{Plot\ area}$$

Table 8.2 Coverage and floor space index (F.S.I)

Sl. No	Occupancy	Maximum permissible coverage	Maximum permissible F.S.I (Without additional fee)
1	Educational B	50	2.5

8.3.4 Parts of building

As per Chapter V the parts of the building shall be:

Height of room:

The height of room intended for human entry in a building other than residential occupancy and livestock/poultry farm shall not be less than 3m, provided that in the case of air-conditioned rooms it shall not be less than 2.4m.

Sanitation requirements:

(1) Size of bathroom and latrine -

1) The area of bathroom shall not be less than 1.50m^2 with either side not less than 1.1m, area of a latrine shall not be less than 1.10m^2 with one side not less than 1m, provided that the area of combined bathroom and latrine shall be not less than 2.2m^2 with one side not less than 1.1m.

2) The height of the bathroom or latrine shall be not less than 2.20m.

(2) Water closet - Every building above 50m^2 of the buildup area shall be provided with at least one water closet.

Table 8.3 Sanitation requirements

Sl. No	Fitments	Requirements
1	Water closet	1 per every 40 boys and 1 per every 25 girls
2	Urinals	1 per every 50 boys
3	Wash basin	1 per every 40 boys and 1 per every 40 girls

Staircases:

Any building having more than one floor shall be provided with a staircase unless each such floor is independently accessible from the ground. The minimum width of stairs, tread, riser, and handrail shall be 120cm, 30cm, 15cm, and 90cm respectively. Escalators can be provided instead of staircases (width of escalators shall not be less than 1m).

Corridor, verandahs and passageways:

The clear width of any corridor, verandah or passageway in any building shall be not less than 1m at any point.

8.4 PLANNING AS PER NBC 2016

As per Cl.12 of NBC (part 3) the parts of the building shall be:

Plinth:

The plinth or any part of a building or outhouse shall be so located with respect to the surrounding ground level that adequate drainage of the site is assured. The height of the plinth shall be not less than 450mm from the surrounding ground level.

Height:

Educational buildings - Ceiling height 3.6m for all regions; in cold regions, 3m.

Parapet:

Parapet walls and handrails provided on the edges of roof terraces, balcony, verandah, etc. shall not be less than 1m and not more than 1.2m in height from the finished floor level.

As per Annex B of NBC (part 3) the parts of the building shall be:

Entrance/Exit Door:

Minimum width of entrance/exit door: 900mm.

Ramps:

A ramp is a sloping pathway leading from one level to another. Ramps allow persons with reduced mobility to move from one level to another. However, many ambulant persons with disabilities negotiate steps more easily and safely. Hence it is preferable to provide accessibility by both steps and ramps.

Table 10 Requirements for Ramp

(*Clause* B-6.2.2)

Sl No.	Level Difference	Maximum Gradient of Ramp	Ramp Width mm	Handrail on Both Sides	Other Requirements
(1)	(2)	(3)	(4)	(5)	(6)
i)	150 mm to 300 mm	1:12	1 200	√	—
ii)	301 mm to 750 mm	1:12	1 500	√	Landings after every 5 m of ramp run
iii)	751 mm to 3 000mm	1:15	1 800	√	Landings after every 9 m of ramp run
iv)	More than 3 000 mm	1:20	1 800	√	Landings after every 9 m of ramp run

Fig 8.1 Requirements for ramp as per NBC

Handrails for ramps - A ramp run with a vertical rise greater than 150mm shall have handrails that are on both the sides and comply with B-5.5.2.

Lifts:

Lift size - The minimum size of the lift shall be 1500mm wide by 1500mm deep that allows easy maneuverability of wheelchair users.

Lift door - The clear opening of entrance to the lift car shall be at least 900mm. The doors shall be constructed as automatic horizontal sliding doors.

Wheelchair user accessible toilet rooms:

Toilet or sanitary room doors - Toilet or sanitary room doors shall comply with B-5.3. The toilet door shall either be an outward opening door or two-way opening door or a sliding type and shall provide an unobstructed and clear opening width of at least 900mm; it shall be easy to open and close. There should be no openings under or above the door that compromises privacy. Doors should be positioned so as not to constitute a hazard.

As per Annex F (Cl.17) of NBC (part 3) the parts of the building shall be:

Special requirements for development planning in hilly areas:

Appropriate solar passive methods, such as orientation, double-glazing, trombe walls and solar collectors, shall be adopted to achieve climatic comfort with little use of conventional energy. The maximum height of plinth level shall be 2m.

8.5 BUILDING DETAILS

The college building is a three-story structure, standing at a height of 3.6m from floor to floor. Emphasizing both functionality and accessibility, the building incorporates spacious elements such as corridors, verandas, and passageways, each with a minimum width of 2m. This design ensures free movement and promotes a comfortable and well-connected environment within the premises. Furthermore, to enhance accessibility and convenience, a lift has been thoughtfully integrated, adding an additional layer of inclusivity to the overall architectural layout. Together, these features contribute to a well-designed and accommodating educational space, meeting both practical and regulatory requirements.

Ground Floor:

- Built up area : 2456m²
- Floor area :2306.6m²

Table 8.4 Ground floor room details

Sl. No	Room	Size (m)	Area (m^2)	No of Rooms
1	Lecture hall	7m x 12m	84	6
2	Laboratory	15m x 18m	270	2
3	Laboratory	15.2m x 17.4m	264.5	2
4	Administrative room	8.9m x 7m	62.3	1
5	Conference room	8.9m x 7m	62.3	1
6	Sick room	3.8m x 3 m	11.4	2
7	Housekeeping room	2.8m x 3.8m	10.64	1
8	Toilet staff & differently abled students	7m x 3.5m	24.5	2
9	Toilet students	7m x 3.2m	22.4	2
10	Lift	1.8m x 2.2m	3.96	2
11	Stair room (2.5m wide)	9.5m x 6m	57	1
12	Emergency stair (1.5m wide) room	6m x 3.5m	21	1

First Floor:

- Built up area : $2456m^2$
- Floor area : $2306.6m^2$

Table 8.5 First floor room details

Sl. No	Room	Size (m)	Area (m^2)	No of Rooms
1	Lecture hall	7m x 12m	84	6
2	Laboratory	15m x 18m	270	1
3	Laboratory	15.2m x 17.4m	264.5	2
4	Library	15m x 18m	270	1
5	Faculty room	8.9m x 7m	62.3	2
6	Sick room	3.8m x 3 m	11.4	2
7	Store room	2.8m x 3.8m	10.64	1
8	Toilet staff & differently abled students	7m x 3.5m	24.5	2
9	Toilet students	7m x 3.2m	22.4	2

10	Lift	1.8m x 2.2m	3.96	2
11	Stair room (2.5m wide)	9.5m x 6m	57	1
12	Emergency stair (1.5m wide) room	6m x 3.5m	21	1

Second Floor:

- Built up area : 2414m²
- Floor area :2300.6m²

Table 8.6 Second floor room details

Sl. No	Room	Size (m)	Area (m^2)	No of Rooms
1	Lecture hall	7m x 12m	84	6
2	Laboratory	15m x 18m	270	1
3	Laboratory	15.2m x 17.4m	264.5	2
4	Library	15m x 18m	270	1
5	Faculty room	8.9m x 7m	62.3	1
6	Sports room	8.9m x 7m	62.3	1
7	Drawing hall	8.9m x15m	133.5	1
8	Seminar hall	8.9m x15m	133.5	1
9	Prayer room	3.8m x 3 m	11.4	2
10	Store room	2.8m x 3.8m	10.64	1
11	Toilet staff & differently abled students	7m x 3.5m	24.5	2
12	Toilet students	7m x 3.2m	22.4	2
13	Lift	1.8m x 2.2m	3.96	2
14	Stair room (2.5m wide)	9.5m x 6m	57	1
15	Emergency stair (1.5m wide) room	6m x 3.5m	21	1

8.6 BIM TECHNOLOGY FOR FUNCTIONAL PLANNING AND DESIGN

The utilization of BIM technology has revolutionized our approach to architectural planning in our educational building project. By leveraging advanced digital tools such as AutoCAD and Revit, we've optimized spatial layouts, ensured compliance with regulatory requirements, and streamlined the design process for improved efficiency and accuracy. AutoCAD provided a robust platform for creating initial drawings with precision and flexibility, setting the foundation for detailed modeling in Revit. The seamless transition to Revit allowed us to harness its advanced features and three-dimensional modeling capabilities, enabling us to create comprehensive digital representations of the building. The collaboration fosters a more cohesive and informed design process. Additionally, the ability to visualize and simulate different design scenarios in a virtual environment has empowered us to make informed decisions that optimize both functionality and aesthetics.

8.6.1 Initial Drawing in AutoCAD

The planning process commenced with the creation of initial sketches of our educational building using AutoCAD, meticulously considering specific details, and adhering to relevant codal provisions. During this phase, we carefully outlined the basic layout and dimensions of the building, with a focus on major rooms such as lecture halls, laboratories, administrative spaces, and other essential areas. AutoCAD served as an instrumental tool, offering a flexible and intuitive platform for generating precise floor plans and architectural drawings. Importantly, we ensured that our initial drawings aligned with codal provisions and regulatory requirements applicable to educational buildings, incorporating specified dimensions, room sizes, clearances, and other essential parameters mandated by codes such as NBC, KMBR, and AICTE norms. After creating detailed sketches in AutoCAD, we conducted thorough reviews to verify compliance with all relevant regulations and standards, ensuring that our design met functional needs while upholding safety and quality standards essential for educational environments. Further development and modeling work in Revit. further development and modeling work in Revit.

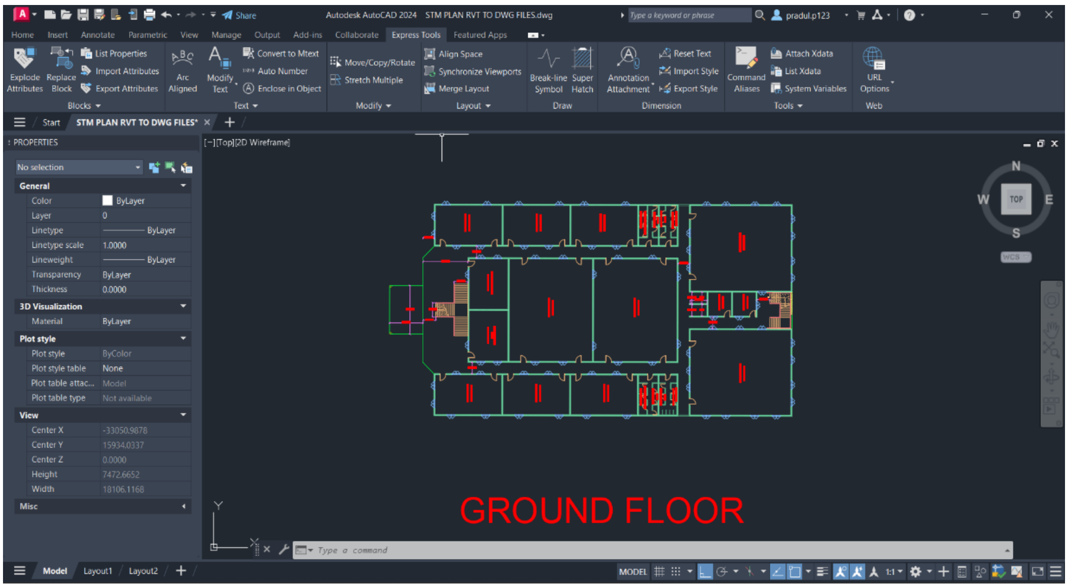


Fig 8.2 Drawing in AutoCAD

8.6.2 Design and Modeling Using Revit

In the realm of modern building design and development, Revit emerges as a pivotal BIM tool, revolutionizing the way architectural projects are conceptualized, modeled, and executed at LOD 400. Leveraging its advanced capabilities, professionals can efficiently navigate through various stages of design and modeling, ensuring precision, collaboration, and adherence to industry standards. Let's delve into the step-by-step process of harnessing Revit for comprehensive building development.

1. Importing the initially crafted 2D CAD sketch into Revit. This serves as the starting point for further design development.

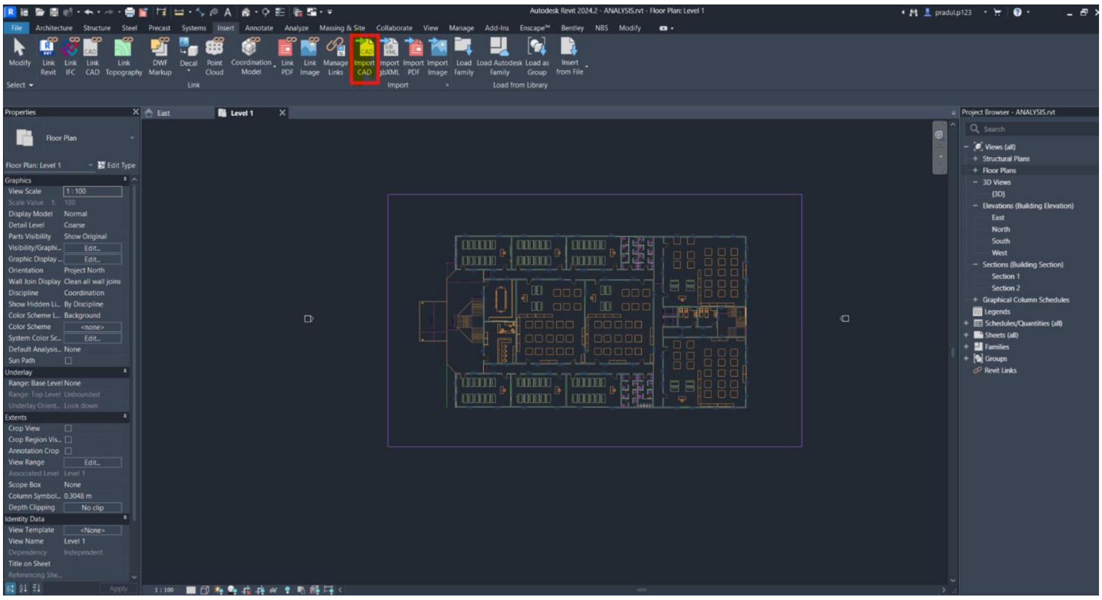


Fig 8.3 Importing the initial CAD sketch

2. Create a central model of the building in Revit. This serves as the core collaborative platform for the design team, ensuring all members work with the most up-to-date version of the design.

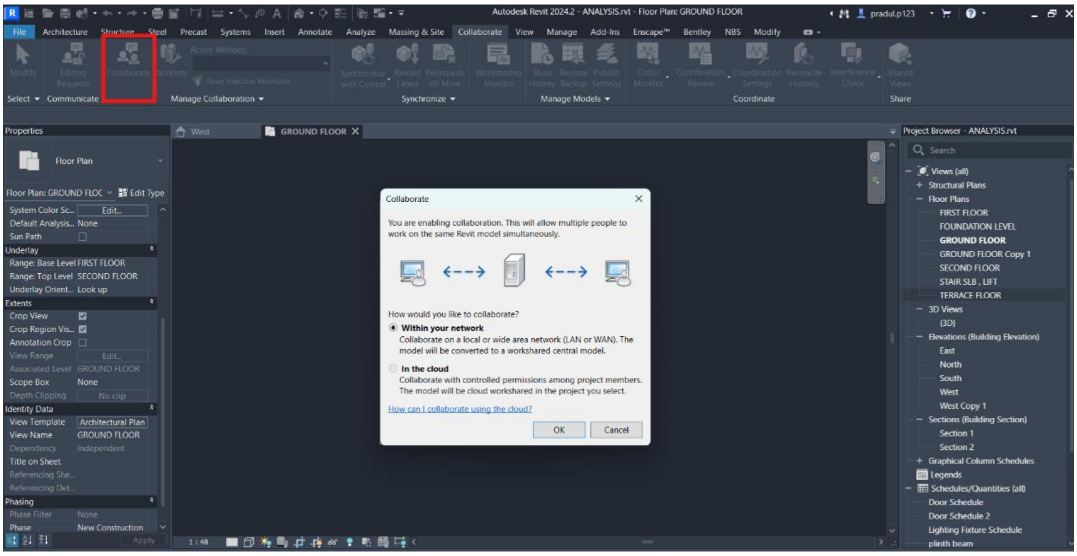


Fig 8.4 Establishing a central model

3. Assign levels to different floors of the building within the Revit model. This allows for an accurate representation of the building's vertical layout and facilitates coordination between disciplines. Additionally, add grid lines to provide reference points for spatial coordination and alignment of building elements.

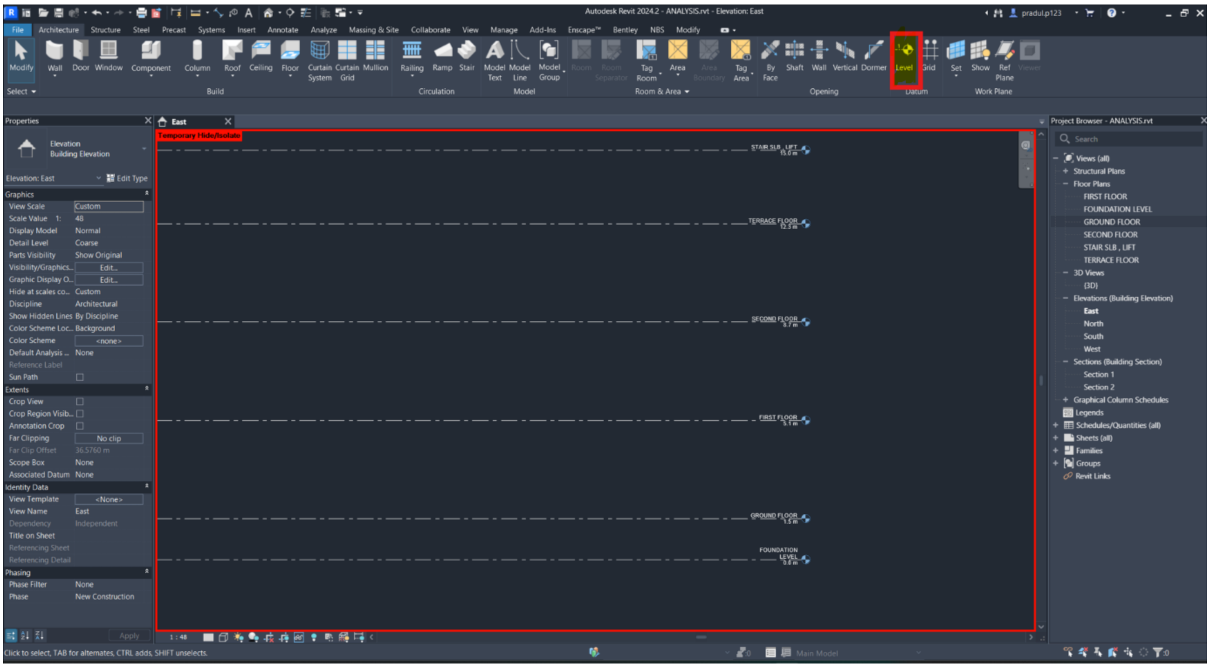


Fig 8.5 Assigning levels and grid lines

4. Add various building components such as walls, doors, windows, and other elements to the central model in Revit. Draw detailed configurations of these components to ensure they meet design specifications and regulatory requirements.

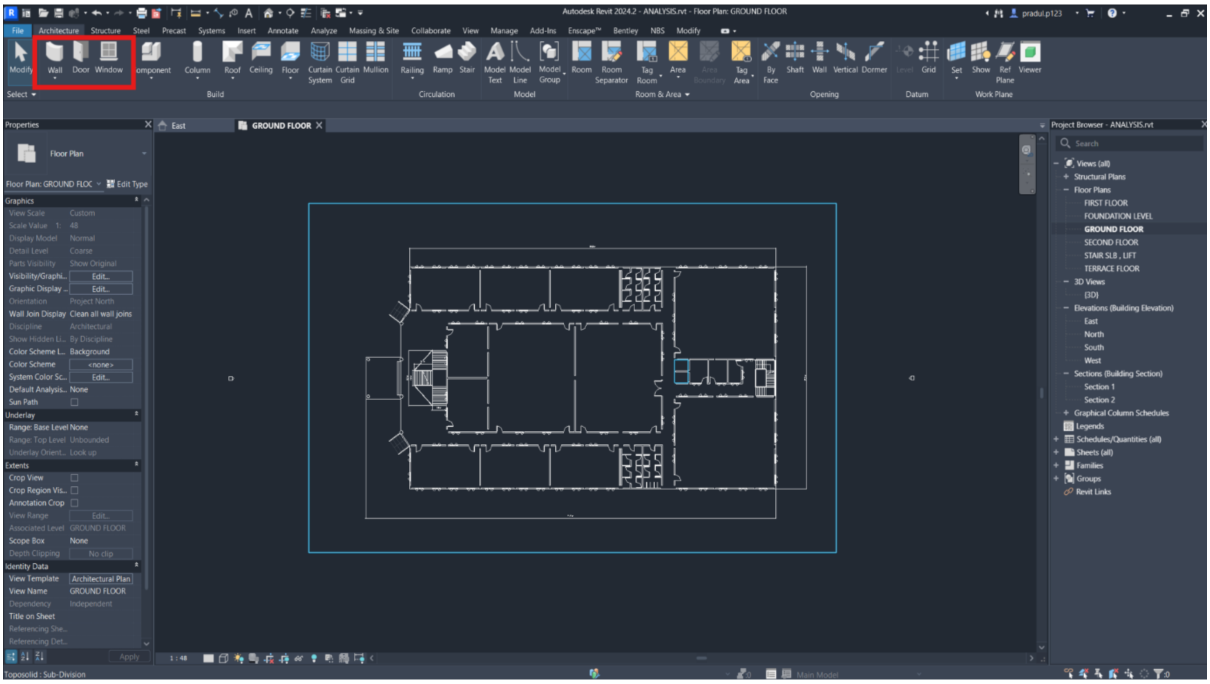


Fig 8.6 Adding building components and detailing

5. Add structural elements such as beams, columns, footings, and other structural components to the Revit model. This accurately represents the building's structural framework.

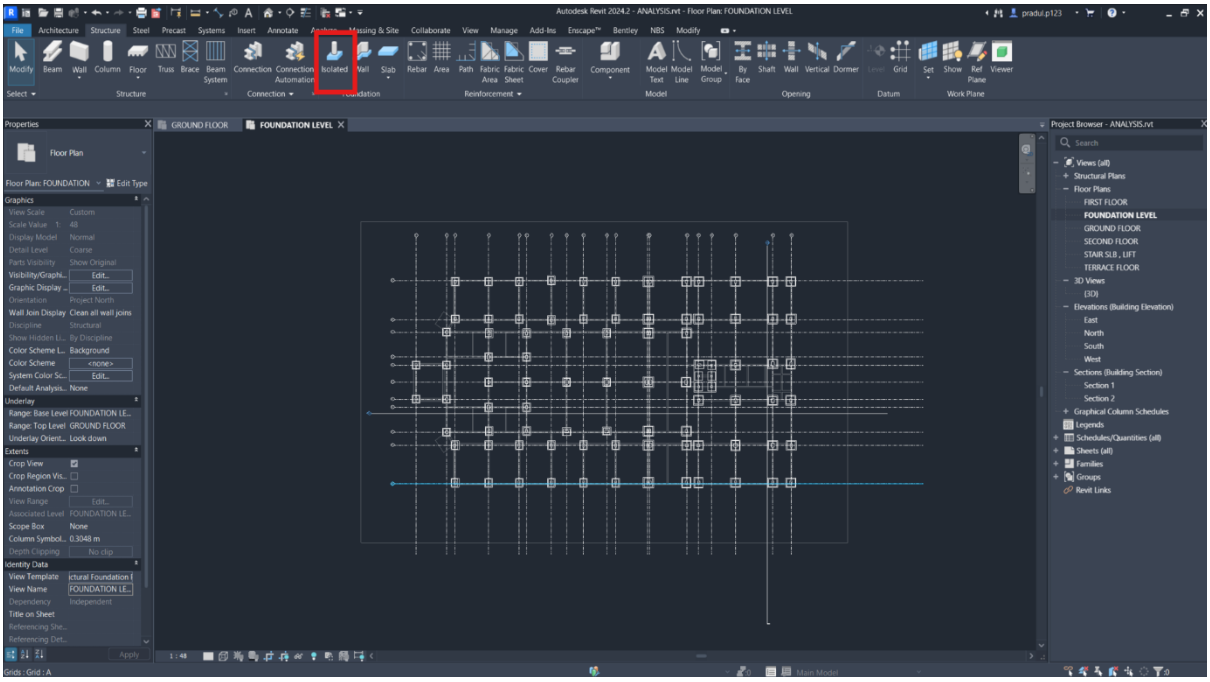


Fig 8.7 Incorporating structural elements

6. Add families for interior designing, including furniture, fixtures, and equipment, to enhance the visual representation of interior spaces.

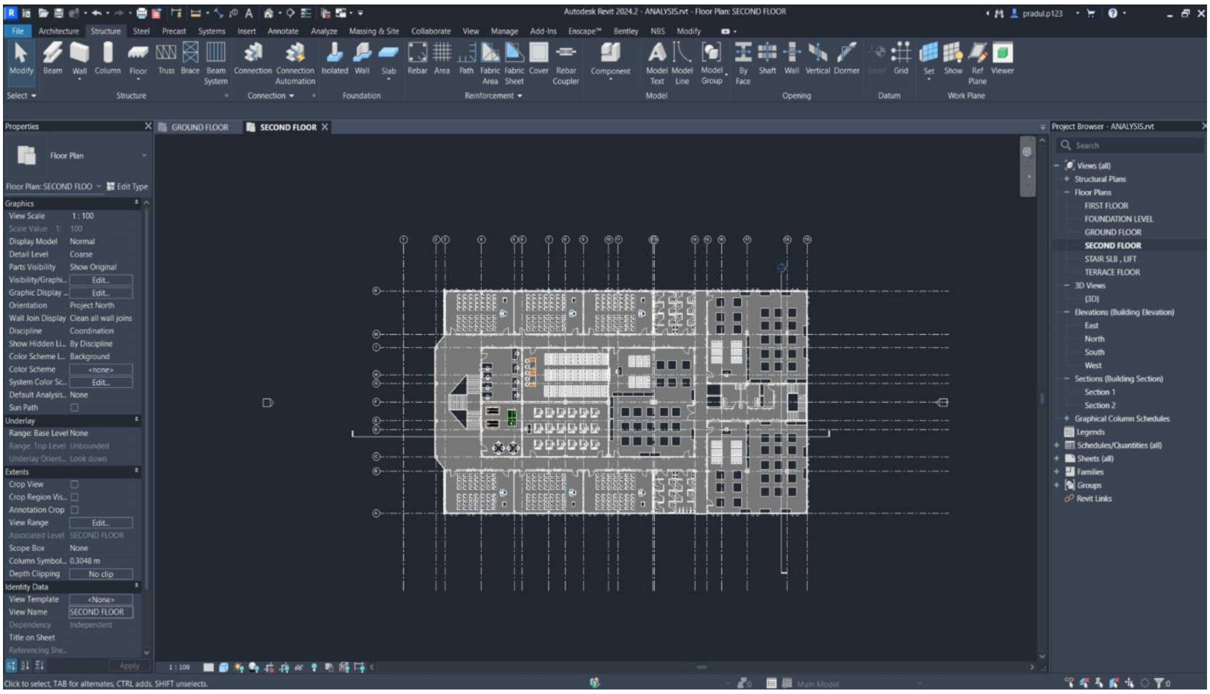


Fig 8.8 Integrating interior design elements

7. Analyze the site and incorporate contextual elements into the Revit model. This includes surrounding buildings, topography, vegetation, and other site features.

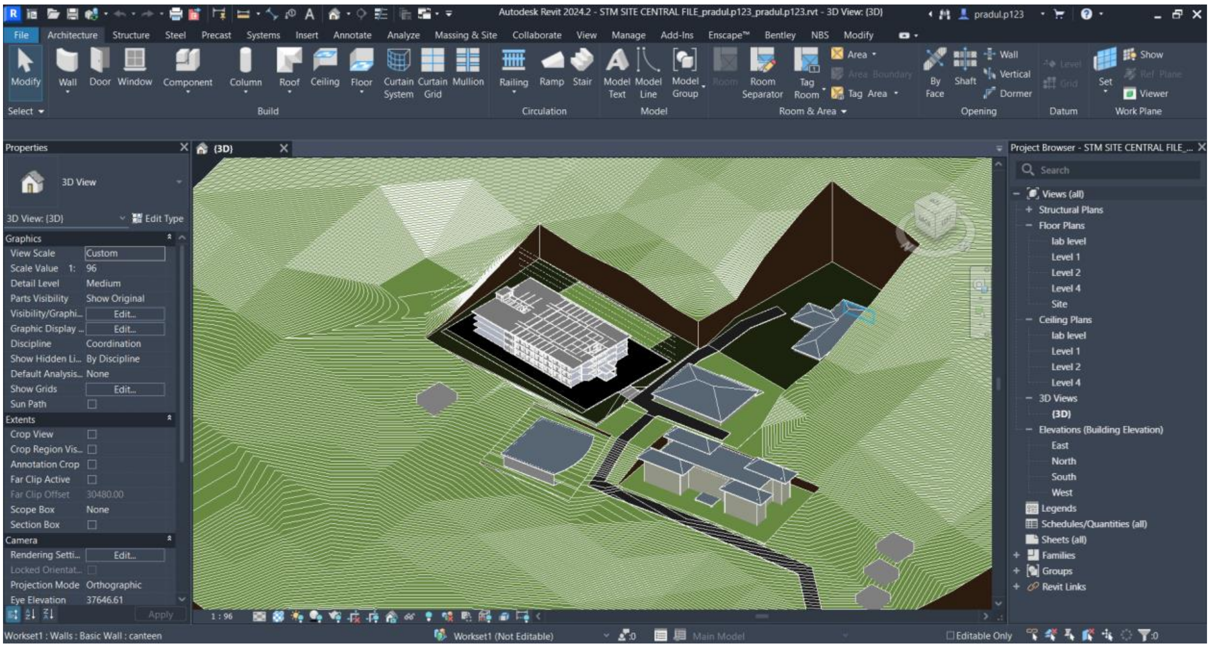


Fig 8.9 Site analysis and contextual modeling

8. Perform clash detection analysis within the Revit 3D model to identify and resolve potential conflicts between building components, ensuring constructability and coordination between disciplines.

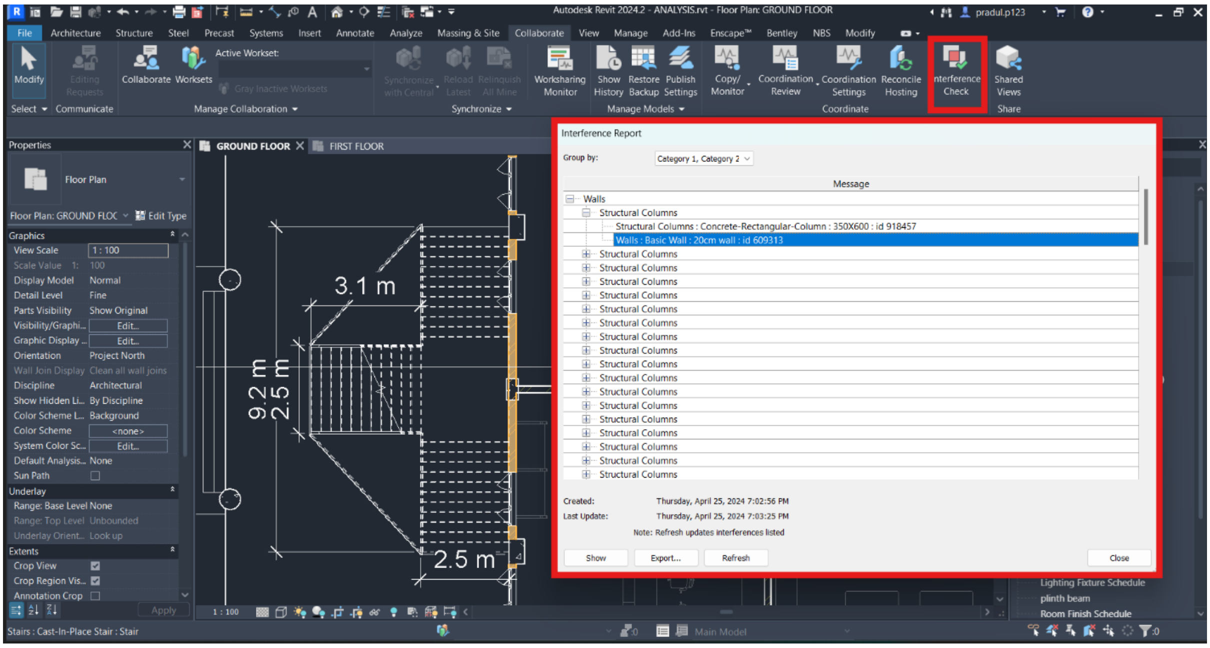


Fig 8.10 Clash detection and clash resolution

9. Prepare schedules and documentation within Revit to communicate key project information, including material quantities, equipment schedules, and construction specifications.

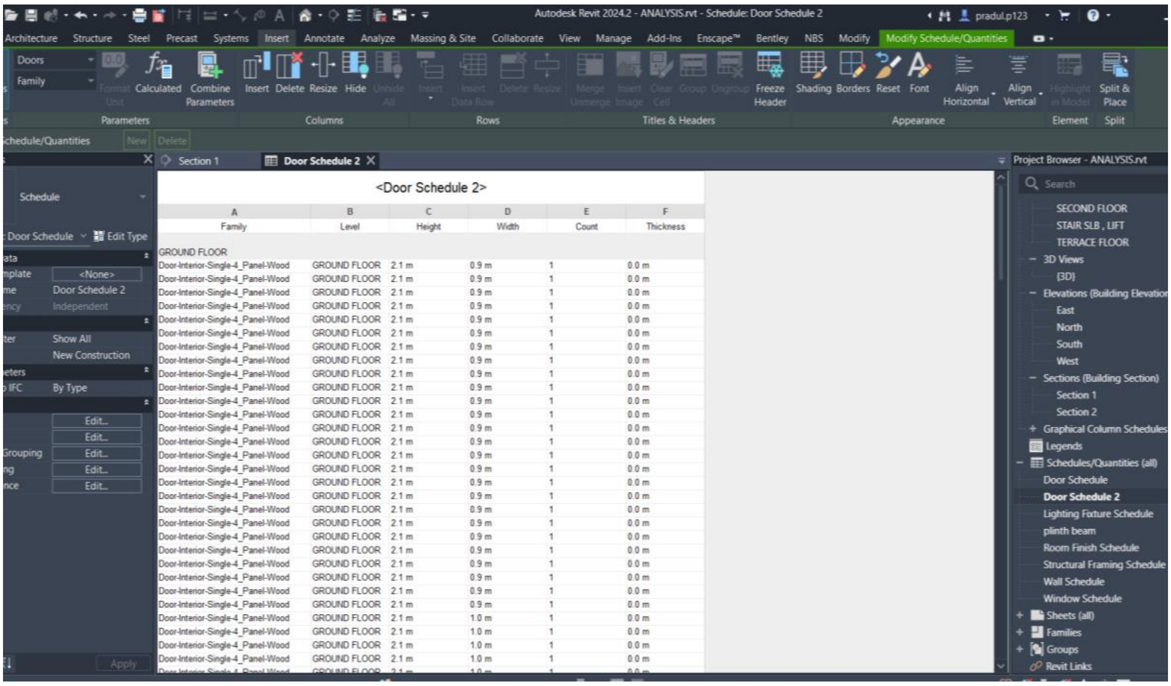


Fig 8.11 Schedule preparation and documentation

10.Integrate lighting design elements into the Revit model to accurately represent the illumination of interior and exterior spaces. This includes placing light fixtures, adjusting light levels, and simulating natural lighting conditions. By incorporating lighting design early in the process, designers can achieve optimal lighting performance and energy efficiency.

11. Utilize building performance simulation tools within Revit to evaluate the thermal, structural, and acoustic performance of the building. This includes simulating heat transfer, airflow, structural loads, and sound transmission to assess the building's overall performance under various conditions. By performing comprehensive performance simulations, designers can optimize the building's design to meet performance objectives and regulatory requirements.

12.Utilize building performance simulation tools within Revit to evaluate the thermal, structural, and acoustic performance of the building. This includes simulating heat transfer, airflow, structural loads, and sound transmission to assess the building's overall performance under various conditions. By performing comprehensive performance simulations, designers can optimize the building's design to meet performance objectives and regulatory requirements.

8.7 BUILDING PLAN

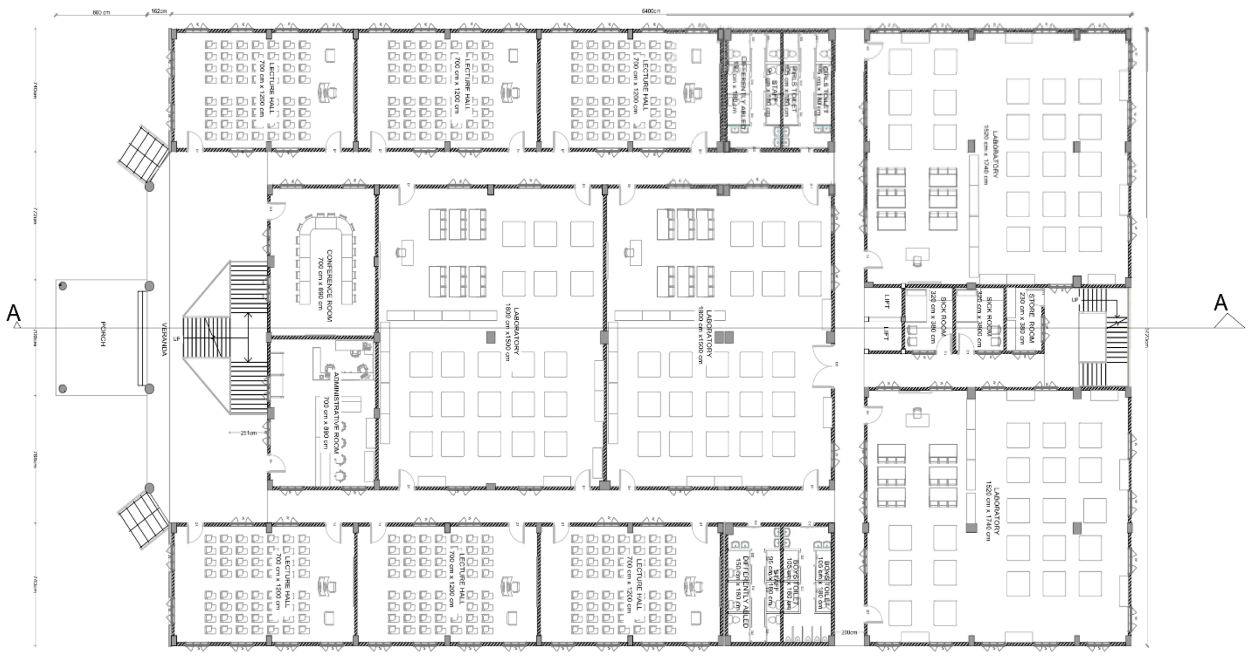


Fig 8.12 Ground floor plan

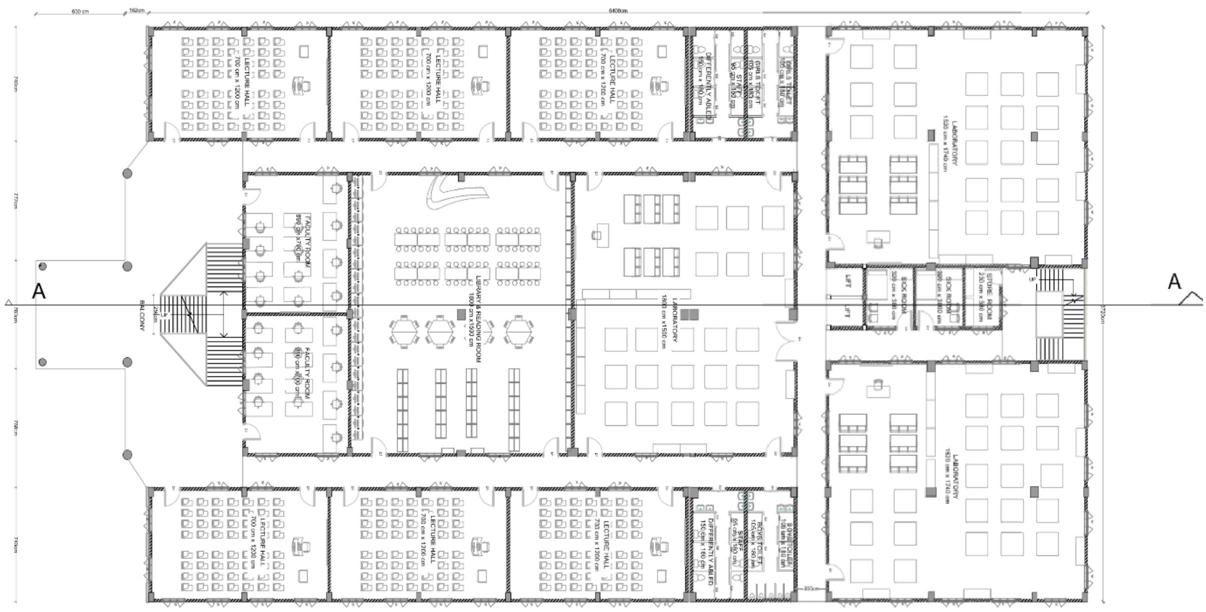


Fig 8.13 First floor plan

Fig 8.14 Second floor plan

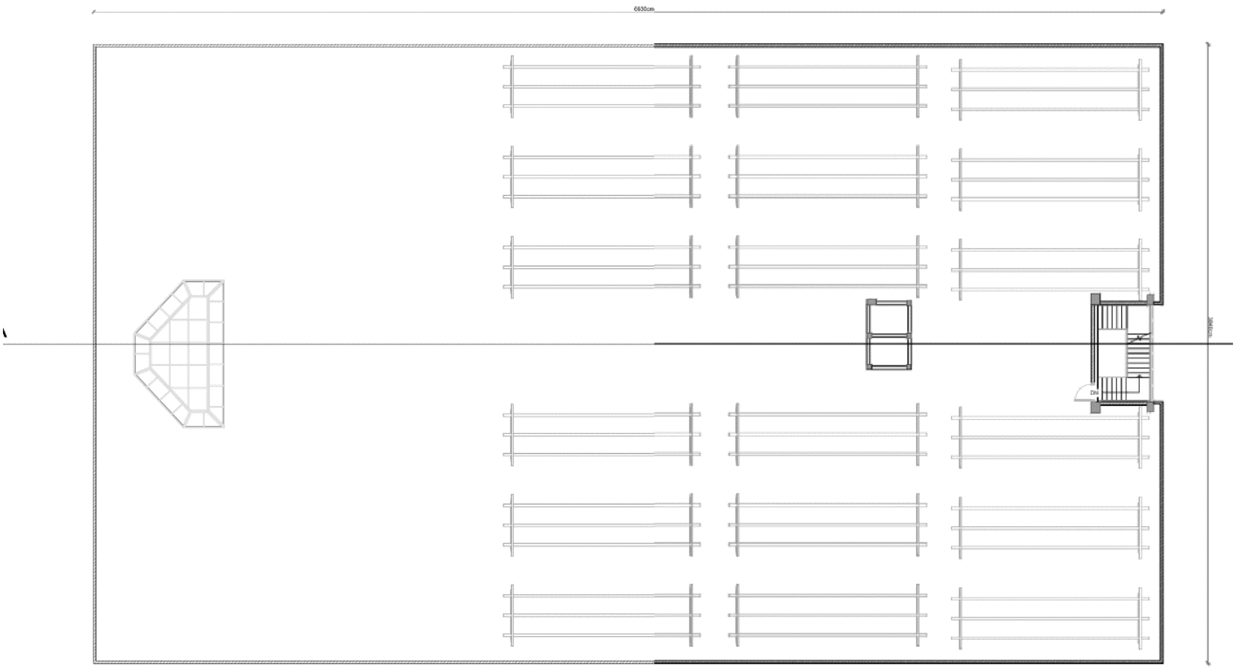


Fig 8.15 Terrace floor plan

Fig 8.16 Elevation view west

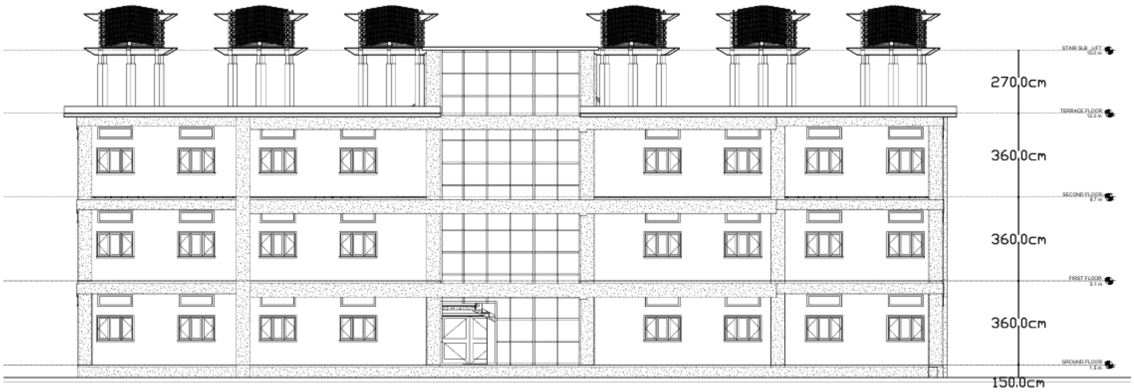


Fig 8.17 Elevation view east

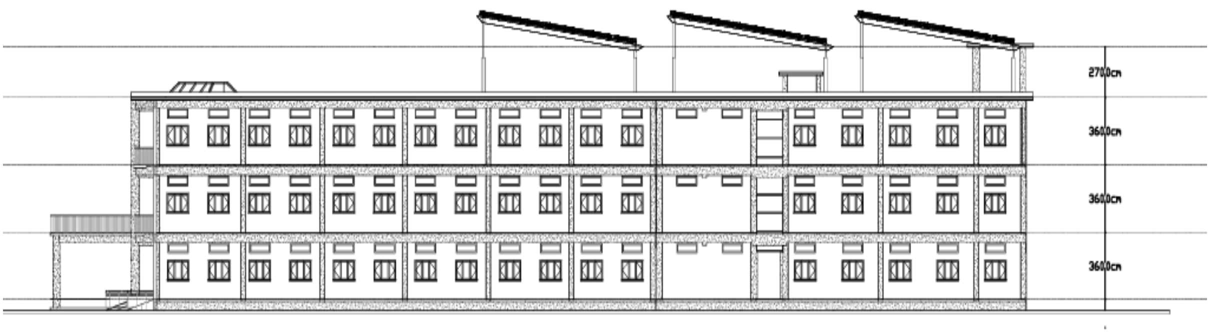


Fig 8.18 Elevation view south

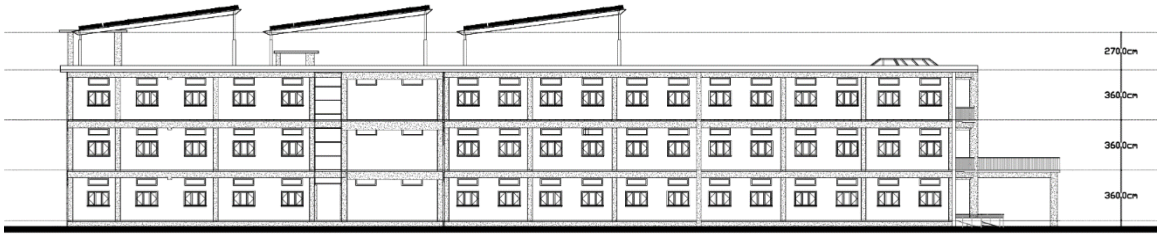


Fig 8.19 Elevation view north

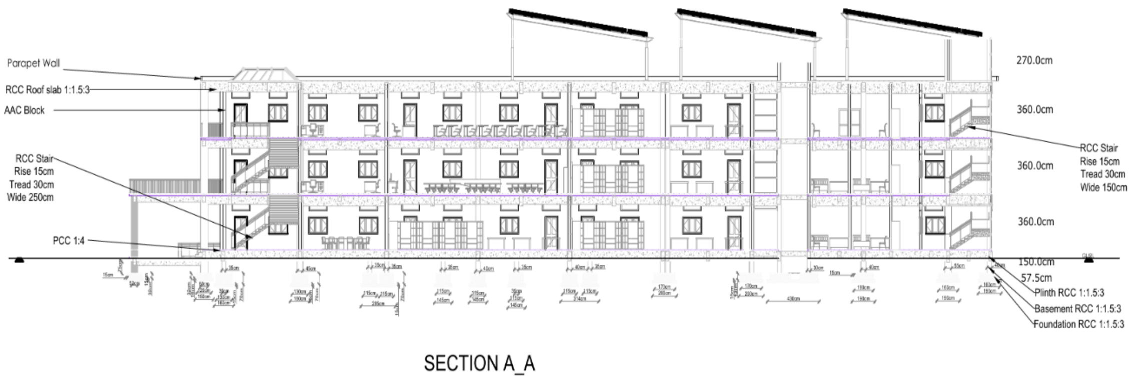


Fig 8.20 Section view

8.8 JOINERY DETAILS

Windows and doors specifications

Table 8.7 Joinery details

D1	Door	100 x 210cm
D2	Door	90 x 210cm
D3	Door	250 x 210cm
W	Window	150 x 100cm
V	Ventilator	150 x 50cm

CHAPTER 9
LOAD CALCULATIONS

9.1 LOADS AND CODAL PROVISION

Structural loads or actions are forces, deformations, or accelerations applied to a structure or its components. Loads cause stress, deformations, and displacements in structures. Assessment of their effects is done by structural analysis. Excess load or overloading may cause structural failure, and hence such possibilities should be either considered in the design or strictly controlled. Different types of loads on the structures are;

- Dead load
- Live load
- Wind load
- Seismic load

9.1.1 Dead Load

Dead loads are permanent or stationary loads which are transferred to the structure throughout their life span. It is primarily due to self-weight of structural members, permanent partition walls, fixed permanent equipment and weights of different materials. Dead load shall be calculated based on unit weight which shall be established taking into consideration the material specified for construction. Dead load may be calculated based on unit weight of material given in IS 875(Part1):2015. The unit weight of reinforced concrete is taken as 25kN/m^3.

9.1.2 Live Load

Live load or movable loads without any acceleration or impact included any external loads imposed upon the structure when it is serving its normal purpose. Live load is exposed and uniformly distributed static load. These are assumed to be produced by the intended use or occupancy of the building including weight of material stored, furniture and movable equipment. Alternatively live load may be calculated based on values given in IS 875(Part 2):2015.

9.1.3 Wind Load

When the structures block the flow of wind, wind's kinetic energy is converted into potential energy of pressure, which causes wind loading. The effect of wind on a structure depends on the air's velocity, the wind's angle of incidence, its shape and stiffness, and its surface roughness. Wind load is calculated using datas given in IS 875(Part 3):2015.

9.1.4 Seismic Load

Seismic loads are lateral exceptional loads which induced due to earthquake. Seismic load should be calculated based on IS 1893(Part 1):2016. The seismic loads are assigned in both the building directions.

9.2 LOAD CALCULATION

Load calculation is a critical aspect of structural engineering and building design, involving the determination of various forces and loads acting on a structure to ensure its safety and stability.

9.2.1 Slab Load Calculation

The loads on the slabs are primarily calculated for preliminary design of columns and beams. The loads coming on the slabs are mainly dead weight the slab, live load on the slab and floor finish on the slab. The dead load of slab is calculated by multiplying the volume of slab per square meter area with the density of concrete. The density of concrete is taken as 25kN/m^3. The live load on slab is taken from IS 875(Part 2):2015 and the weight of floor finish is taken from IS 875(Part 1).

Self-weight of slab = 0.125×25 = 3.125kN/m^2

Floor finish = 0.05×20 = 1kN/m^2

Partition load = 1kN/m^2 (For office and residential building)

Total dead load on slab = 5.125kN/m^2

9.2.2 Load Calculation on Beam

The distribution of gravity loads to various secondary or primary beams and columns may be done by considering the tributary areas. The loads coming on beams are self-weights of beams, load from slab or adjoining structure and the load from walls.

Size of beam = 230×300mm

Self wt. of the beam = 0.23×0.30×25 = 1.725kN/m^2

Self wt. of wall = 0.2×4.5×3.1= 3kN/m^2

Partition wall load = 0.15×4.5×3.1 = 2kN/m^2

Parapet wall load = 0.15×4.5×1.2 = 0.7kN/m^2

9.2.3 Calculation on Column Load

Size of the column = 30×40mm

Self wt. of column = 0.30×0.40×3.3×25 = 9.9kN/m^2

9.2.4 Live Load Calculation

Live loads are calculated considering the IS 875(Part 2):2015. Different rooms have different live loads acting on it.

Table 9.1 Live loads acting on different rooms

Rooms	Live Load (kN/m^2)
Lecture Hall	3
Drawing Hall	
Laboratory	
Sports Room	
Staff Room	2.5
Administrative Room	
Conference Room	
Sick Room	2
Toilet	
Stair	4
Passage	
Library	
Balcony	
Seminar Hall	5
Store	

9.2.5 Wind Load Calculation

Wind speed, V_b (m/s) : 39 (Cl. 6.2, pg. no. 51 of IS 875(Part 3):2015)

Terrain category : 2 (Cl. 6.3.2.1, pg. no. 6 of IS 875(Part 3):2015)

Importance factor : 1.3 (Cl. 6.3.4, pg. no. 19 of IS 875(Part 3):2015)

Risk coefficient (k_1 factor) : 1 (Table 1, pg. no. 7 of IS 875(Part 3):2015)

Topography (k_3 factor) : 1 (Cl. 6.3.3, pg. no. 8 of IS 875:2015)

9.2.6 Earthquake Load Calculation

Seismic zone : Zone 3

Zone factor (Z) : 0.16 (Table 3, pg. no. 10 of IS 1893:2016)

Site type : Type 1 (Cl. 6.4.2.1, pg. no. 9 of IS 1893:2016)

Importance factor (I) : 1.5 (Table 8, pg. no. 19 of IS 1893:2016)

System : SMRF

Response reduction factor (R) : 5 (Table 9, pg. no. 20 of IS 1893:2016)

9.2.7 Load Combinations

Analysis and design of frames were carried out for different load combinations. The load combination, which produced the maximum bending moment, was chosen for the design of beams and columns using appropriate factors of safety.

Various load cases and load combinations used in analysis: -

Load cases:

1. Seismic load In X direction ($EQ_{X)}$
2. Seismic load In X direction (EQ_Y)
3. Wind load in X direction (W_X)
4. Wind load in Y direction (W_Y)
5. Dead Loads (DL)
6. Live Loads (LL)

Load combinations:

Design of structures would have become highly expensive to maintain serviceability and safety, if all types of forces would have always acted on all structures. Accordingly, the concept of characteristic loads has been accepted to ensure at least 95 percent of the case, the characteristic loads considered will be higher than the actual loads on the structure. However, the characteristic loads are to be calculated based on average or mean load of some logical combinations of all loads mentioned below. IS 456: 2000, IS 1893(Part I): 2016 and IS 875(Part 3) stipulates the combination of the loads to be considered in the design of the structures. The different load combinations used were:

1. 1.5 DL
2. 1.5 (DL+LL)
3. 1.2 (DL+LL+EQ_X)
4. 1.2 (DL+LL+EQ-X)
5. 1.2 (DL+LL+EQ_Y)

6. 1.2 (DL+LL+EQ-Y)
7. 1.5 ($DL+EQ_X$)
8. 1.5 (DL+EQ-X)
9. 1.5 ($DL+EQ_Y$)
10. 1.5 (DL+EQ-Y)
11. $0.9DL+1.5EQ_X$
13. 0.9DL+1.5EQ-X
13. $0.9DL+1.5EQ_Y$
14. 0.9DL+1.5EQ-Y
15. $0.9DL+1.5WL_X$
16. 0.9DL+1.5WL-X
17. 0.9DL+1.5WL-Y
18. 0.9DL+1.5EWL-Z
19. 1.5 (DL+WLX)
20. 1.5 (DL+W-X)
21. 1.5 (DL+WLZ)
22. 1.5 (DL+WL-Z)
23. 1.2 (DL+LL+WLX)
24. 1.2 (DL+LL+WL-X)
25. 1.2 (DL+LL+WLZ)
26. 1.2 (DL+LL+WL-Z)

All these combinations are built in the ETABS. Analysis results from the critical load combinations are used for the design of the structural members.

CHAPTER 10

STRUCTURAL ANALYSIS AND DESIGN

10.1 GENERAL

In ETABS, modeling is the crucial process of digitally representing a structure, encompassing its geometry, materials, supports, and loads. It involves defining structural elements like beams, columns, slabs, and walls, and assigning properties such as material types, section sizes, and connectivity. Boundary conditions, like fixed supports or hinges, are specified to replicate real-world constraints. Finally, loads such as gravity, seismic, and wind forces are applied for accurate structural analysis, ensuring designs meet safety and performance standards. Efficient modeling in ETABS enables engineers to evaluate design alternatives, optimize performance, and ensure structural integrity. Detailing is done using RCDC software.

10.2 MODELING IN ETABS

1. The first step is to create a center line diagram of the building that was created in AutoCAD in .dxf format.

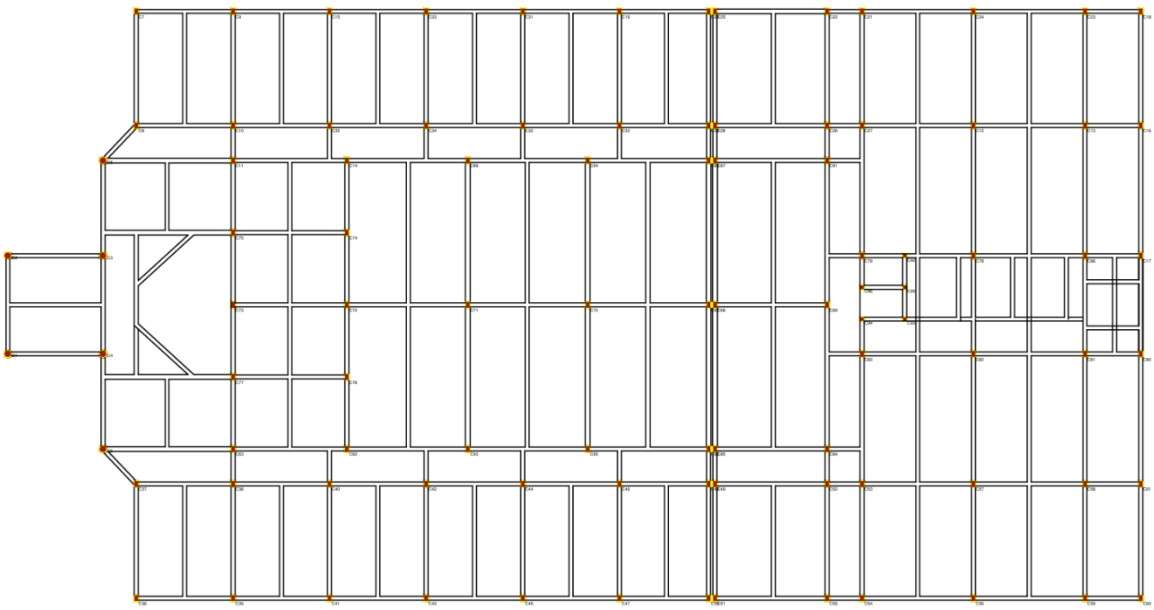


Fig 10.1 Beam Column Slab Layout

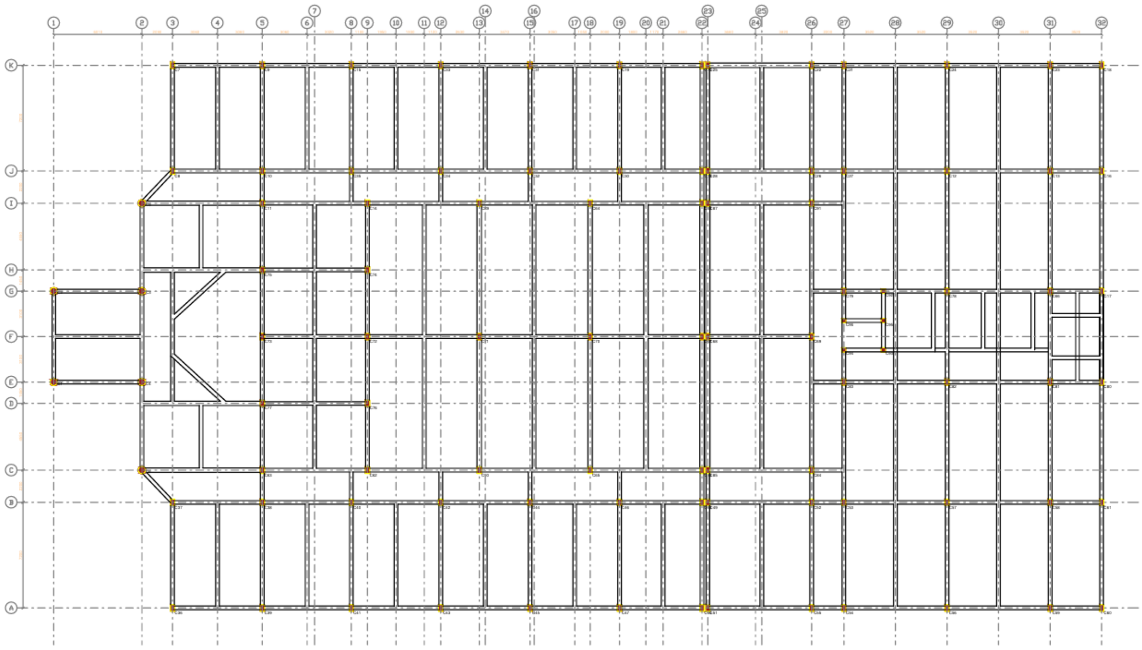


Fig 10.2 Beam Column Slab layout with center line and grids

2. Open a new model in ETABS.

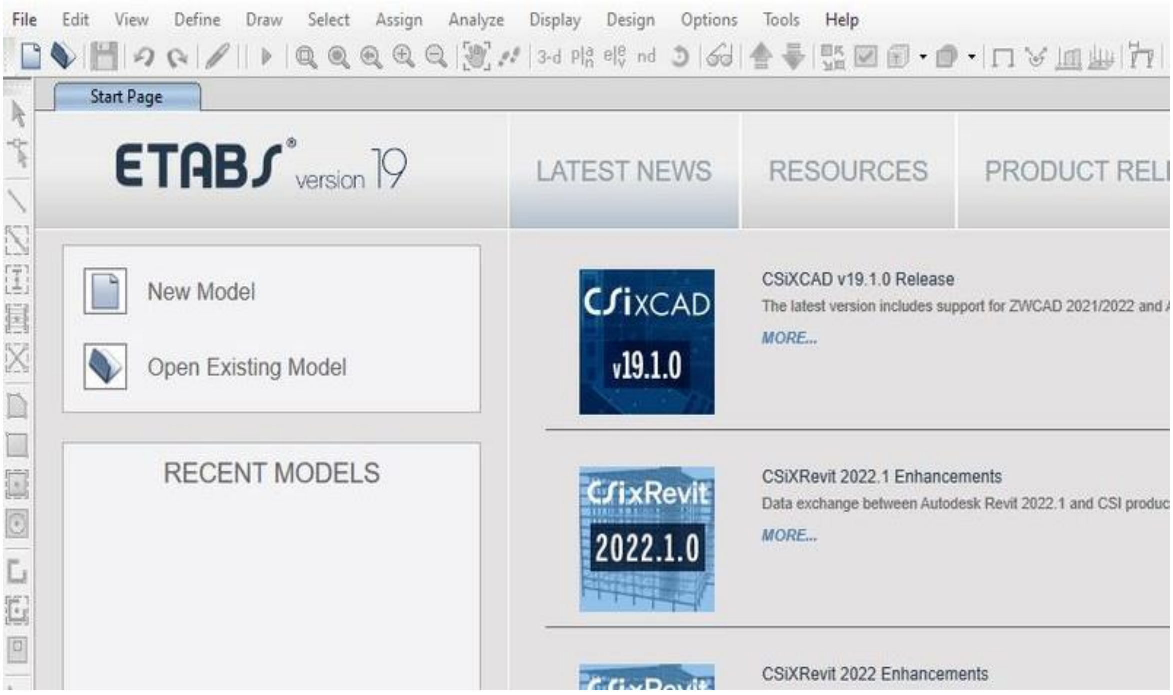


Fig 10.3 Welcome screen

Many Indian Standard (IS) codes are available that are meant for virtually every aspect of civil engineers in their educational or professional life. Similarly, ETABS software also provided with all such codes and gives the analysis results as per the Indian Code.

3. Next step is to finalize the IS codes.

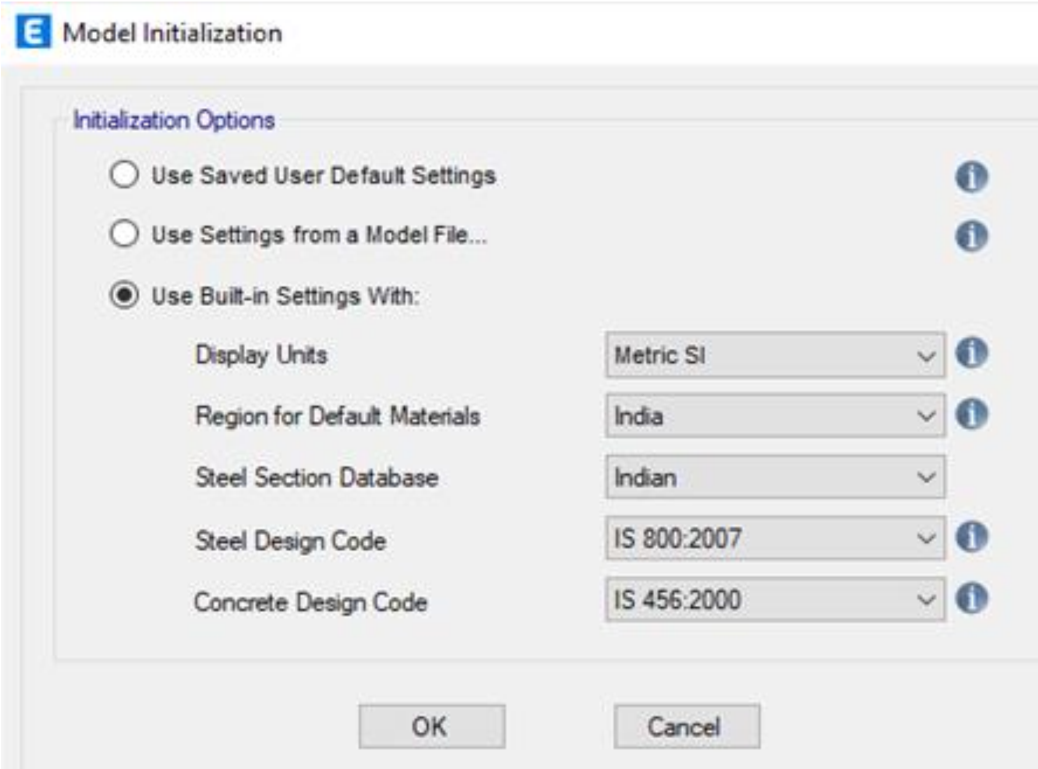


Fig 10.4 Model initialization

4. Selecting the templates

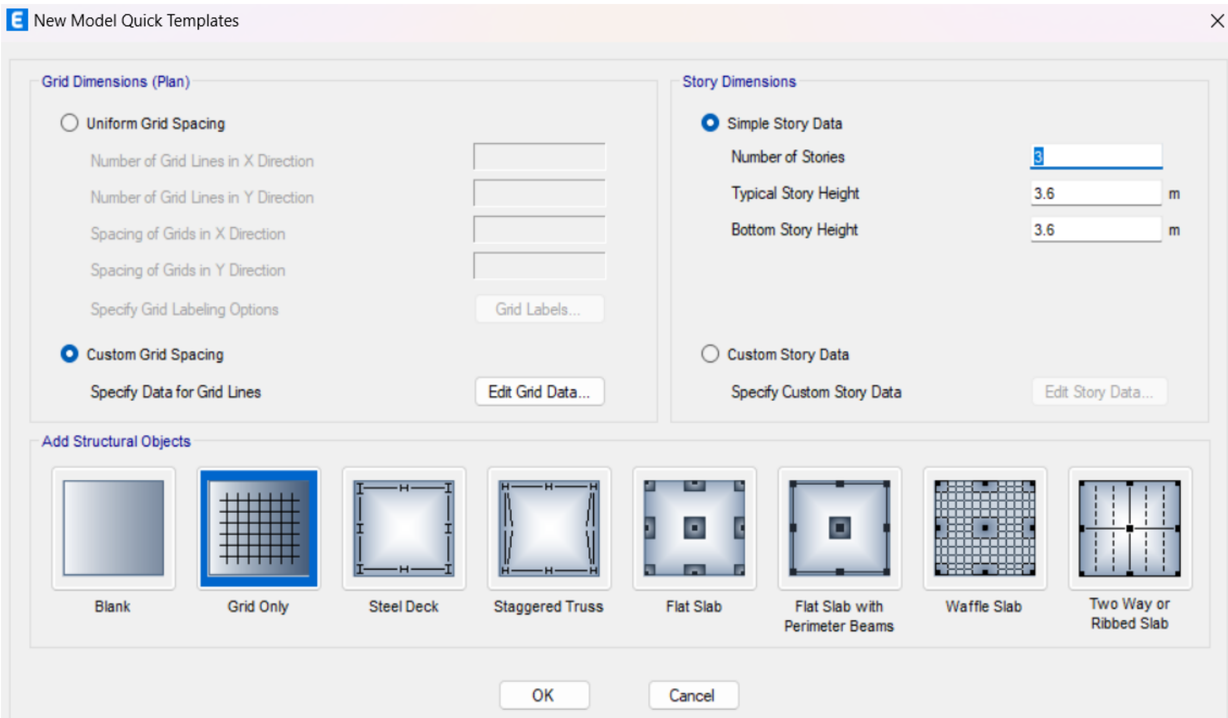


Fig 10.5 Selecting grid and story data

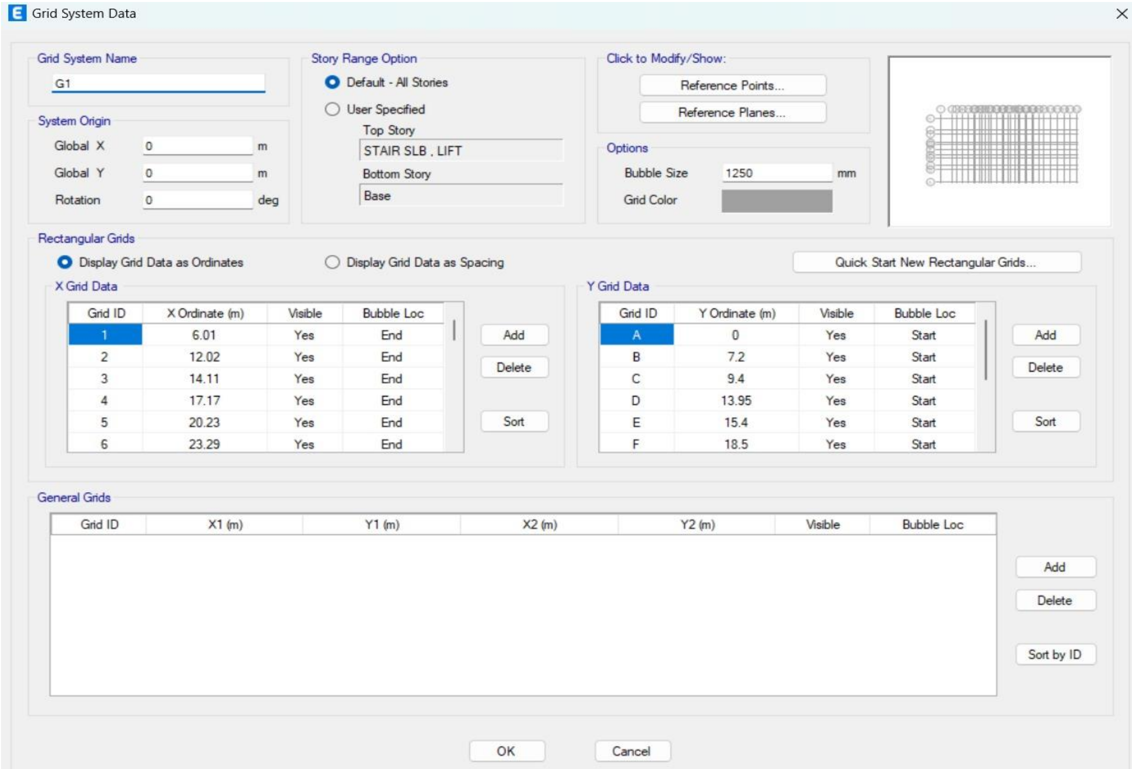


Fig 10.6 Editing grid data

5. The .dxf file is imported into ETABS as floor plans and is replicated to different stories. Stories are replicated into different storey levels.

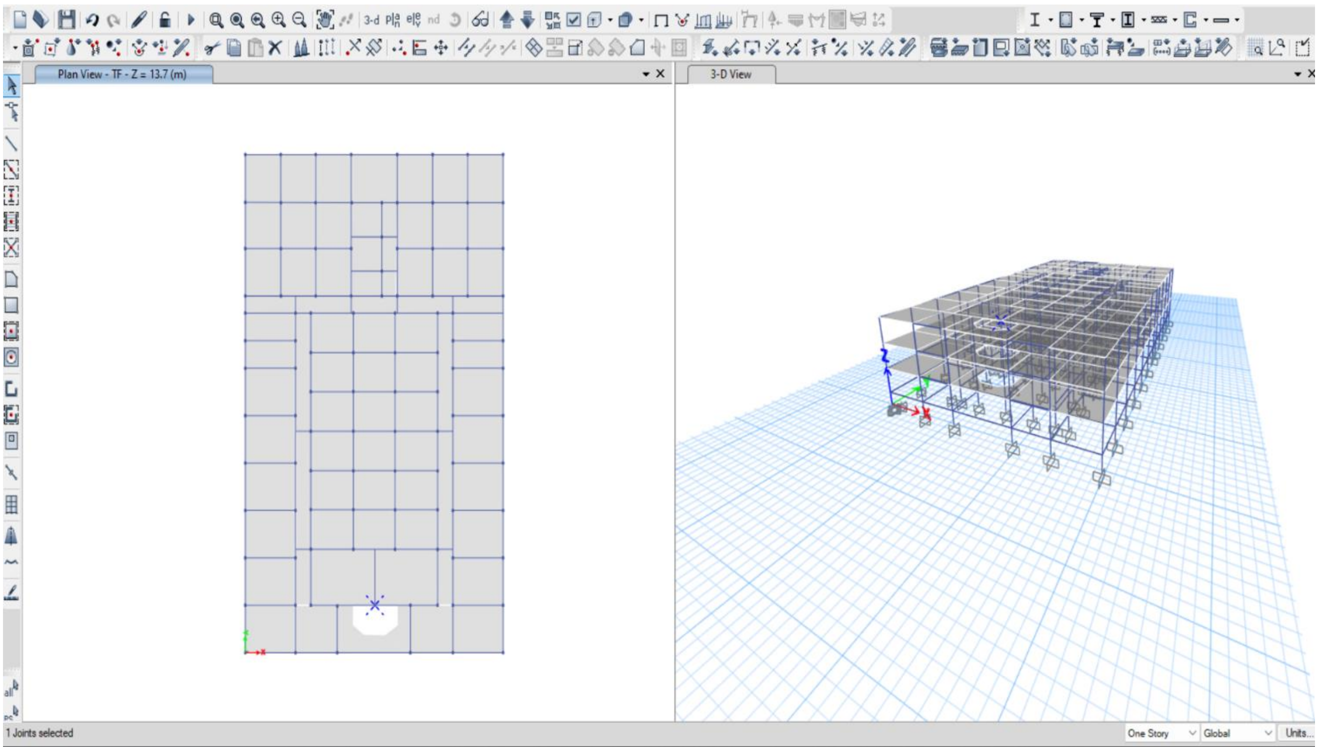


Fig 10.7 Importing BC layout into ETABS

6. Defining materials

➢ Define materials- add new materials-material type (concrete) material name (concrete)-Tick the switch to advanced property display option- material property -v material properties - material property data-material property - ok. Options displays material name (concrete) -material type (concrete) -modify/show

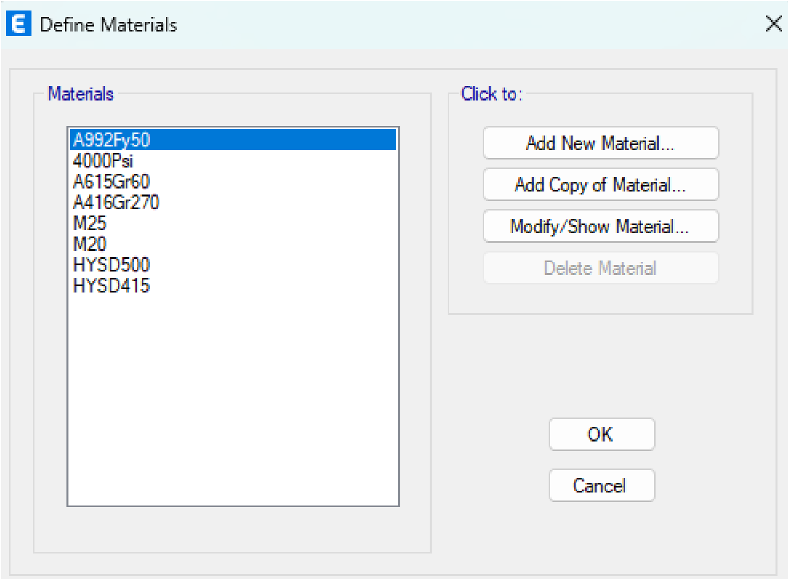


Fig 10.8 Defining materials

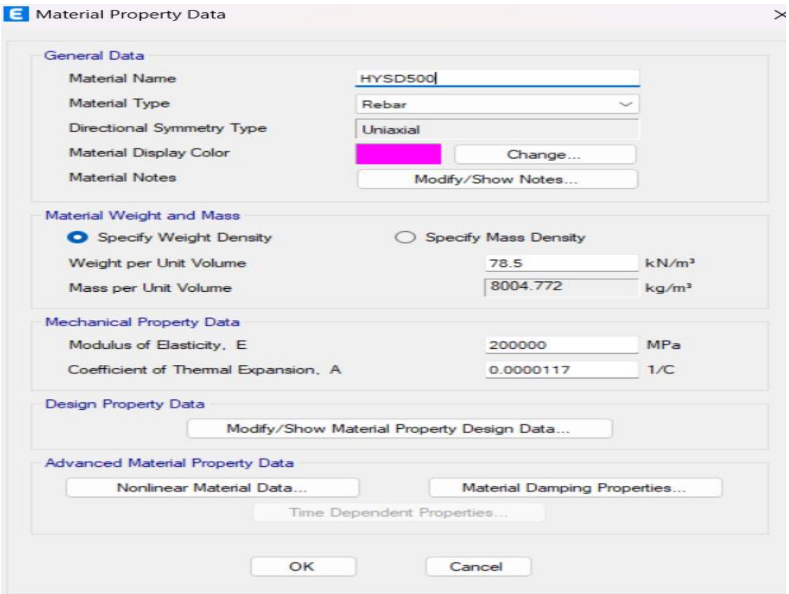


Fig 10.9 Defining material properties

Figs 10.8 and 10.9 show defining the material property of the concrete used for analysis. The grid used for the concrete is M25. The steel is known as rebars in etabs and HYSD500 is defined.

7. Defining section properties

- Section properties →frame sections →add new properties →frame section → property type→ (concrete)-select→ rectangular section→ name (beam)-depth=400, width=300 -material (concrete) concrete reinforcement →select beam →ok
- Frame section → property type→ (concrete)-select→ rectangular section→ name (secondary beam)- depth=300, width=300 -material(concrete)concrete reinforcement →select beam →ok
- Add new property→ frame section →property type (concrete) →select rectangular-section →name (column)- →material (column) 400 x500 →concrete reinforcement →select column →ok

According to **IS 456:2000**, cl. 23.2.1, pg. no. 37

- L/d ratio =26 or
- Beam depth =L/16
- Breadth = D/1.5

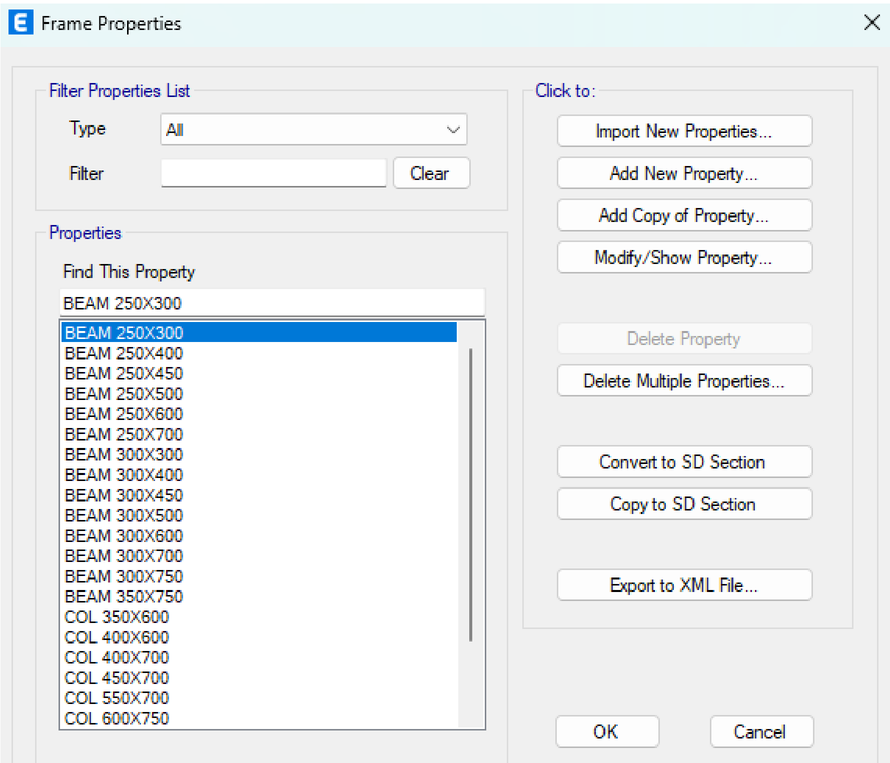


Fig 10.10 Defining various properties such as beams and columns

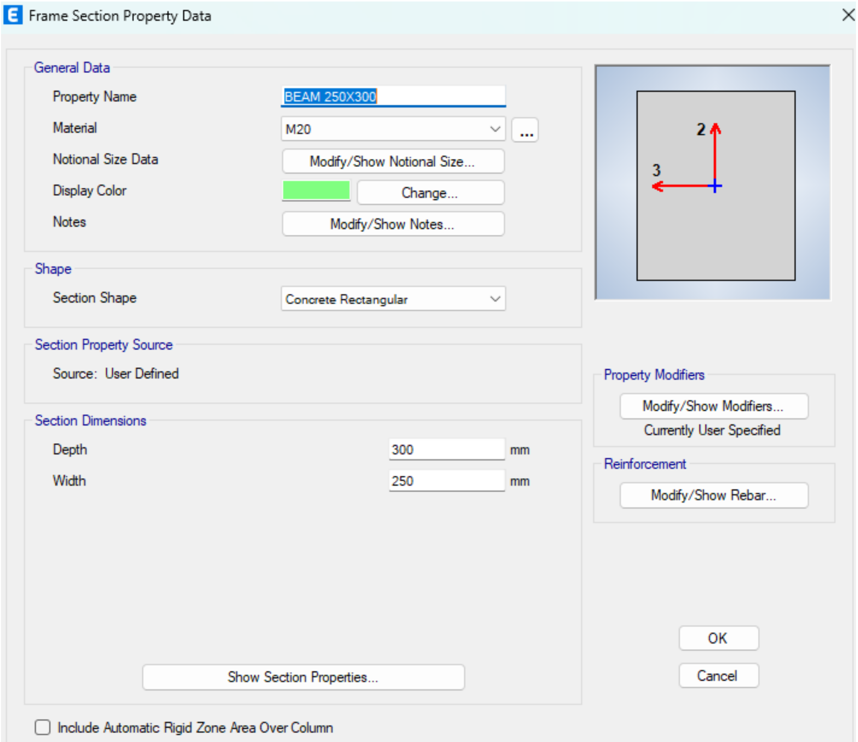


Fig 10.11 Defining section properties of beam

- ➢ Define → section properties →area sections →add new section→ section name (slab) →material name (concrete) →thickness = 120 →ok

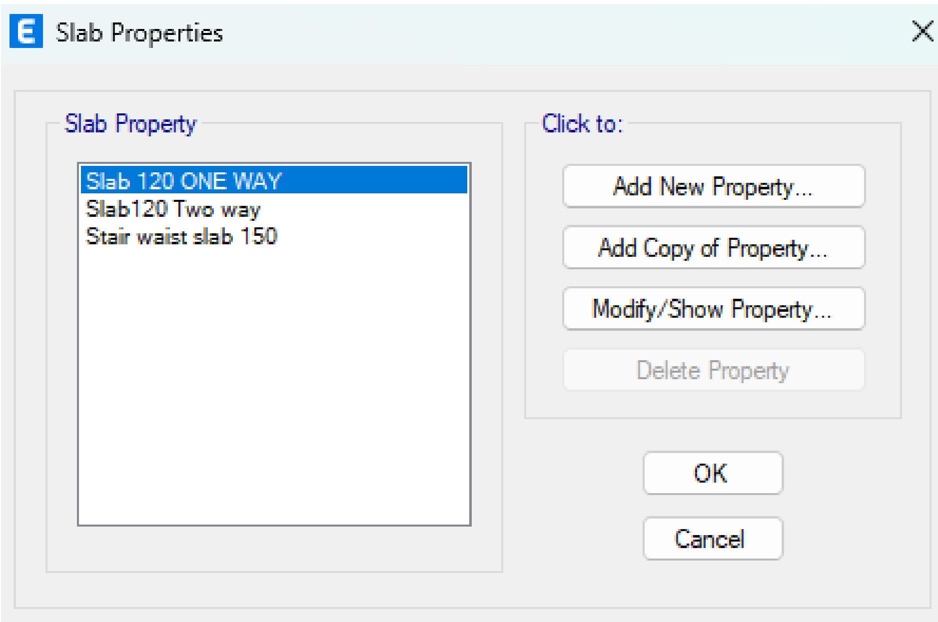


Fig 10.12 Defining slabs

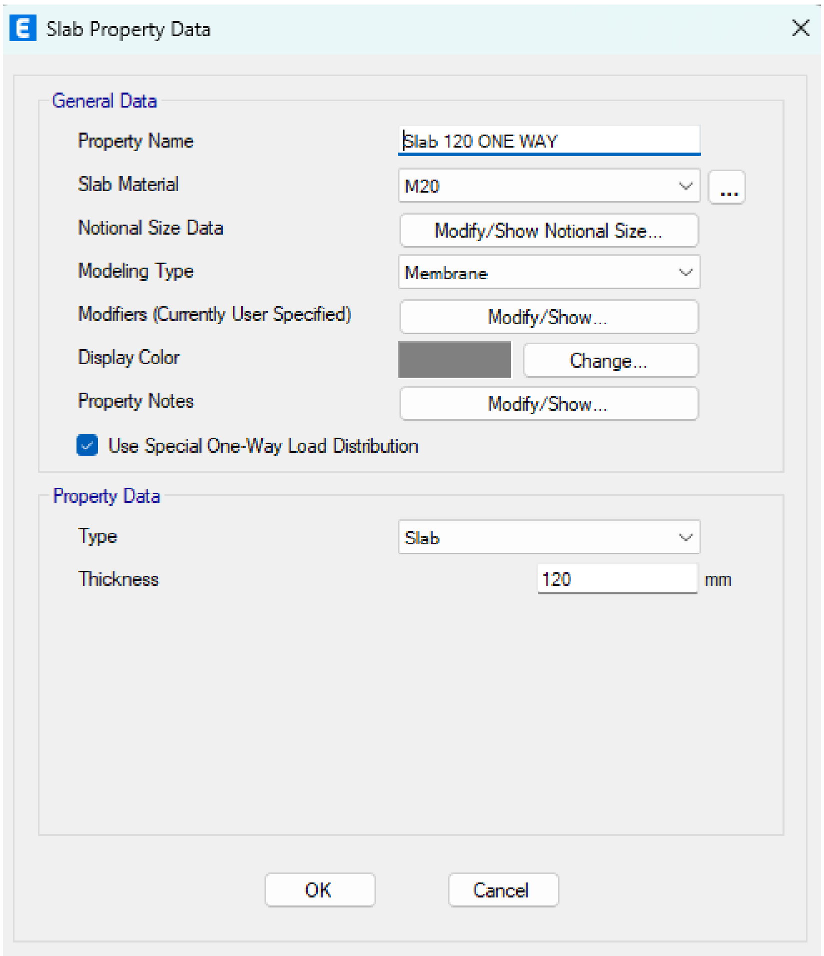


Fig 10.13 Defining slab properties

8. Assigning frame sections

- ➢ Select the entire support grid points → assign→ joint- restraints → fixed →ok
- ➢ Select → select →select lines parallel to → coordinate axes or planes →Z-axis-ok-assign-→frame-→frame sections →columns →ok
- ➢ Select →select lines parallel to-coordinates axes or planes-X-axis and Y-axis →ok →assign frame→ -frame sections →beam →ok
- ➢ Select quick draw floor-properties of object →-slab-select all elements and assign.
- ➢ Set display options- tick extrude view →ok

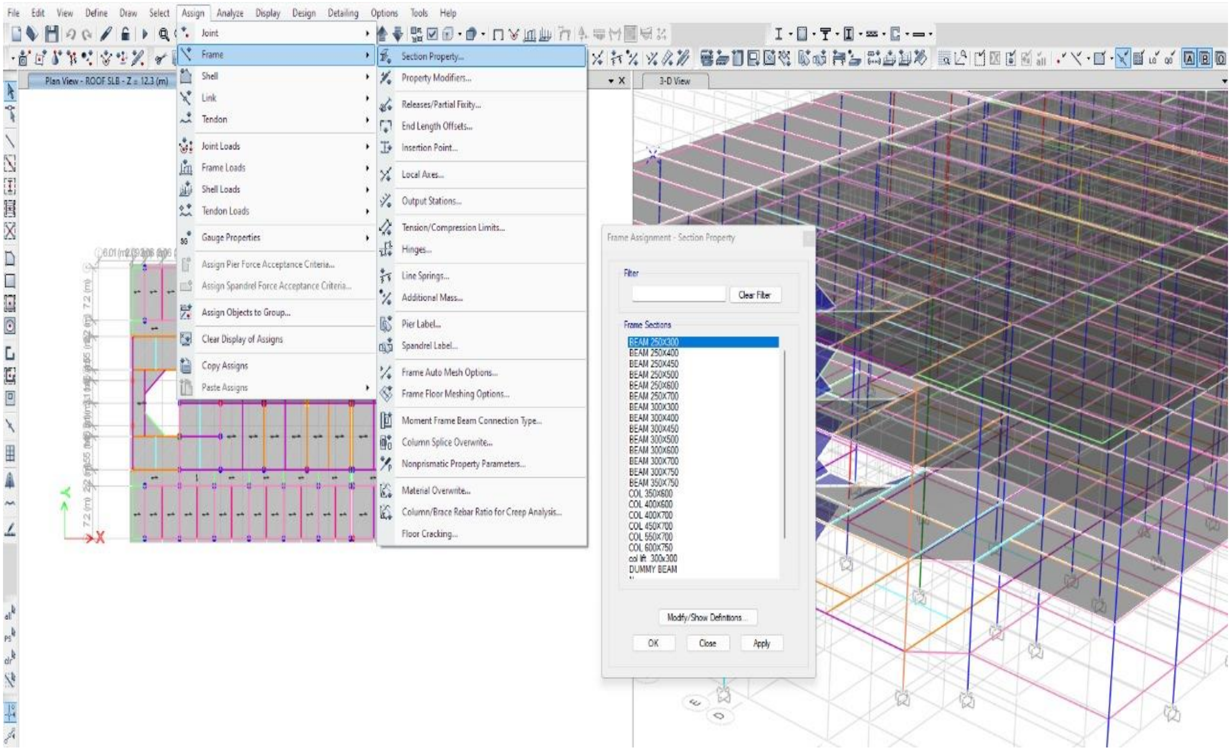


Fig 10.14 Assigning beams

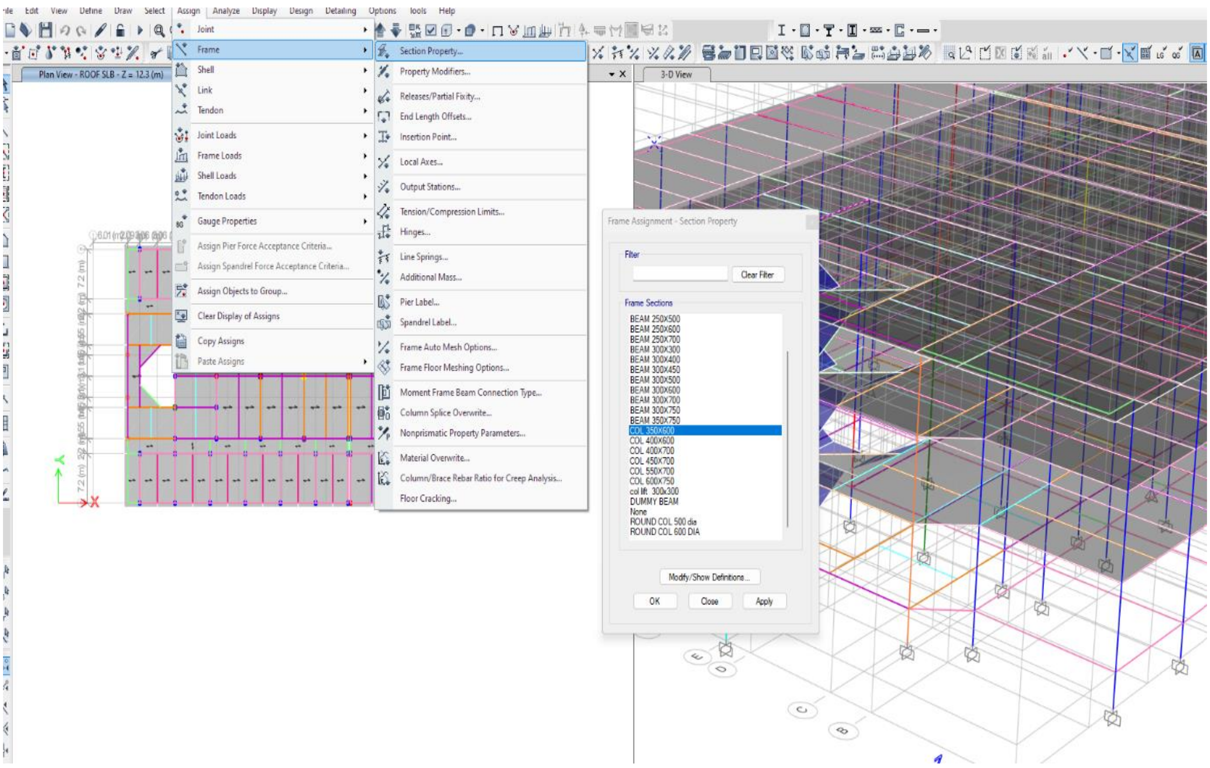


Fig 10.15 Assigning columns

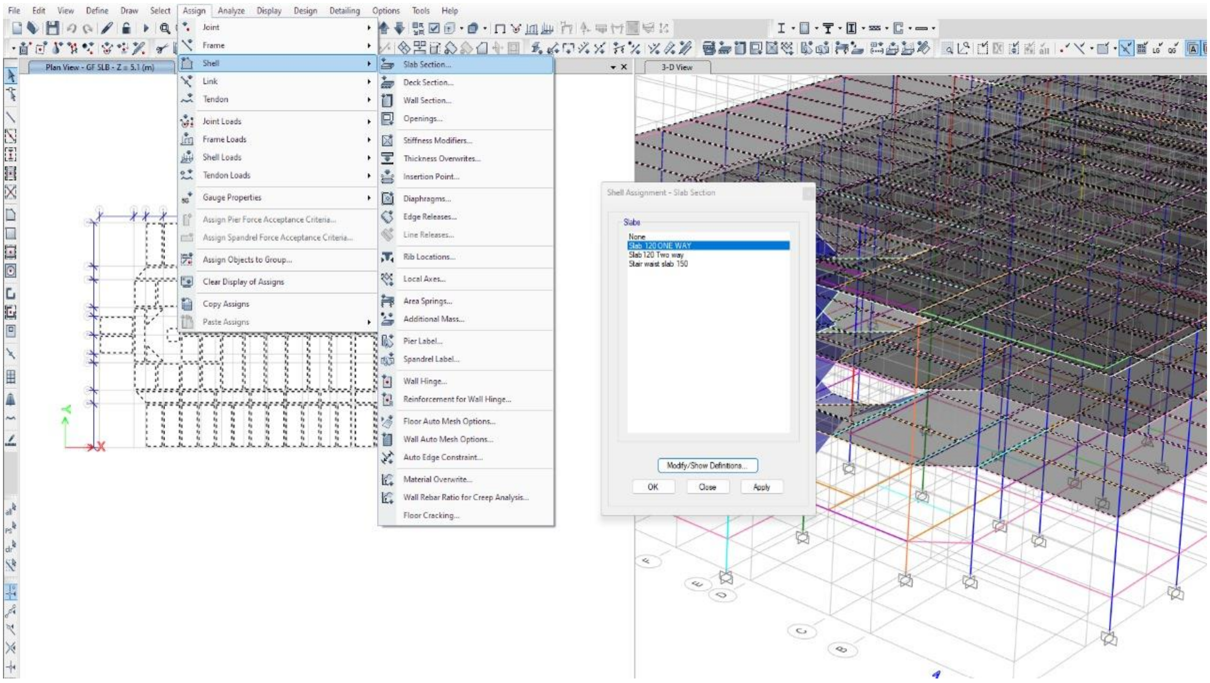


Fig 10.16 Assigning slabs

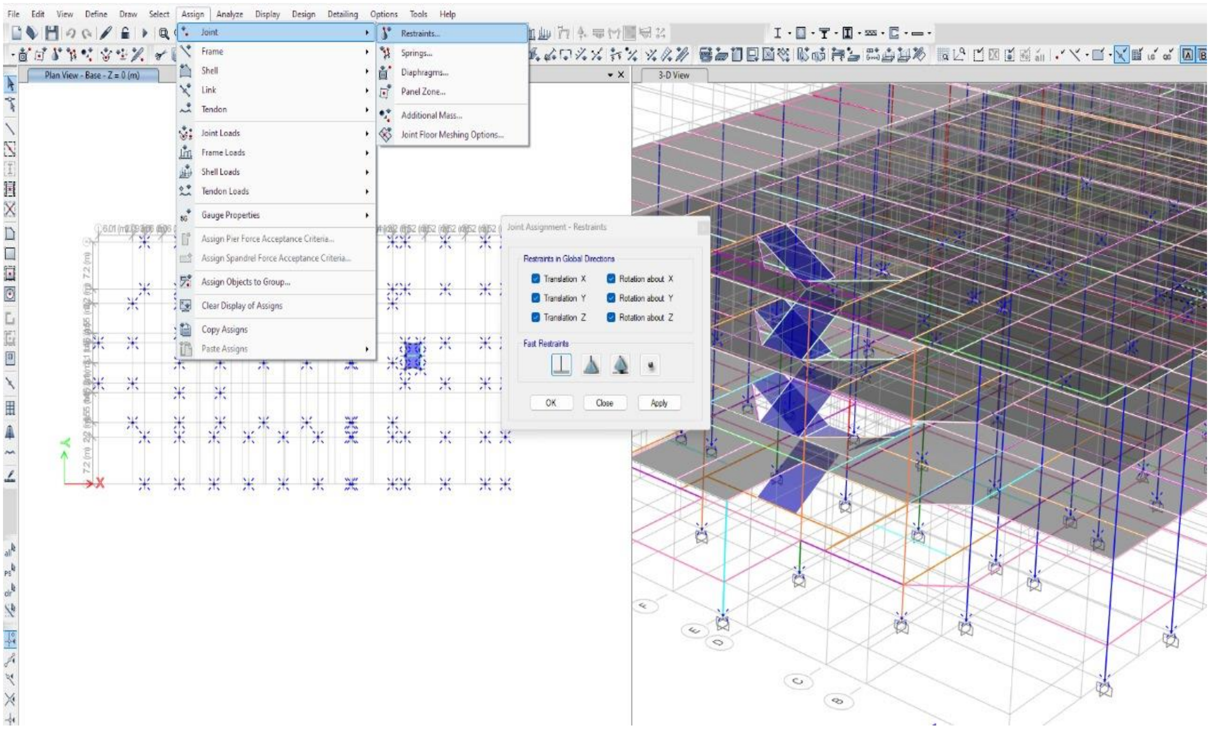


Fig 10.17 Assigning joints

9. Shear wall designing (Lift wall)

➢ Define →section property→ wall reaction →add shear wall →draw shear wall in plan using draw walls tool

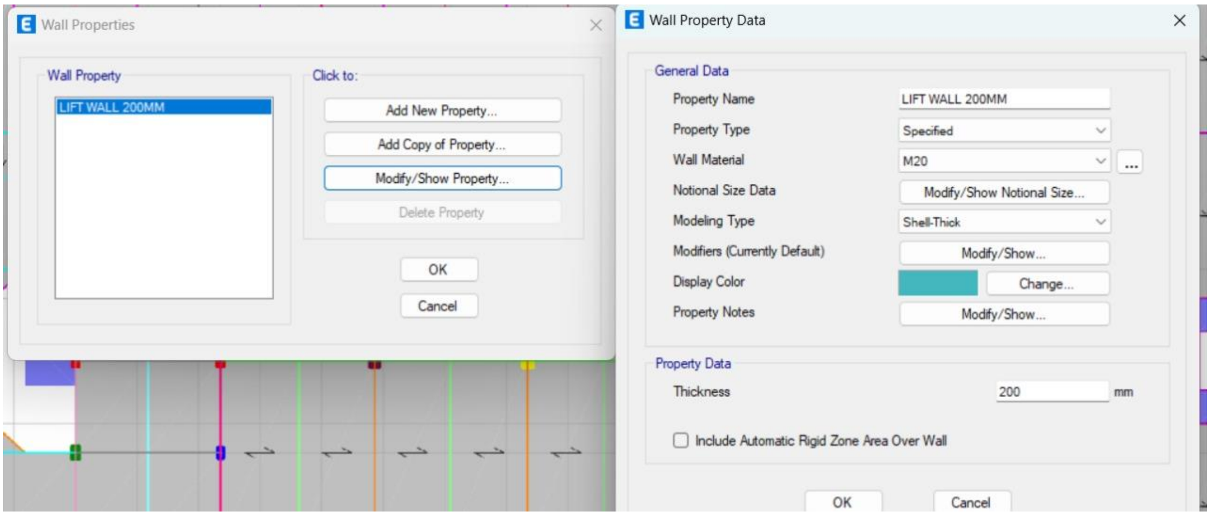


Fig 10.18 Shear wall property

➢ Define →pier/spandrel labels→ add pier /spandrel names→ assign→ shell pier label →apply

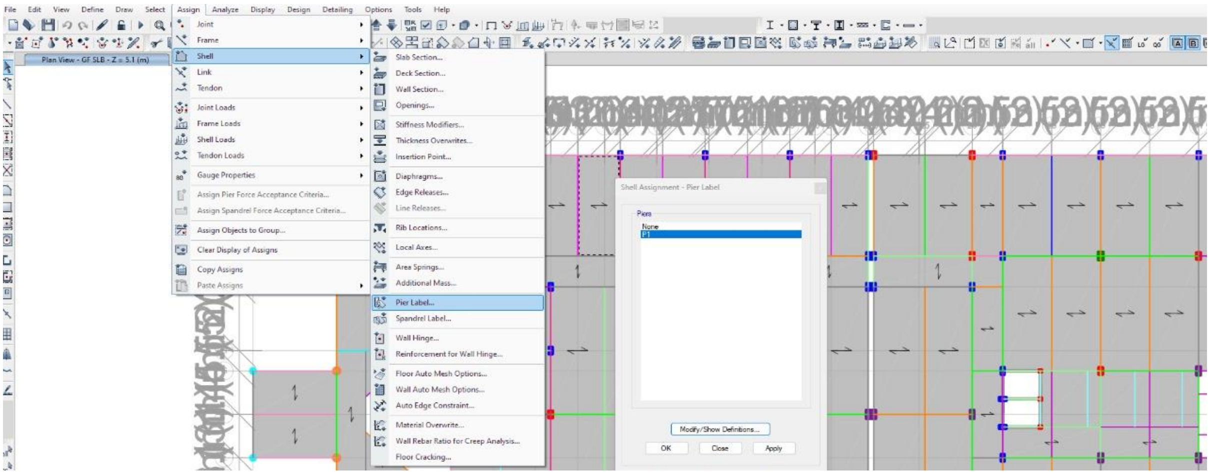


Fig 10.19 Pier defining

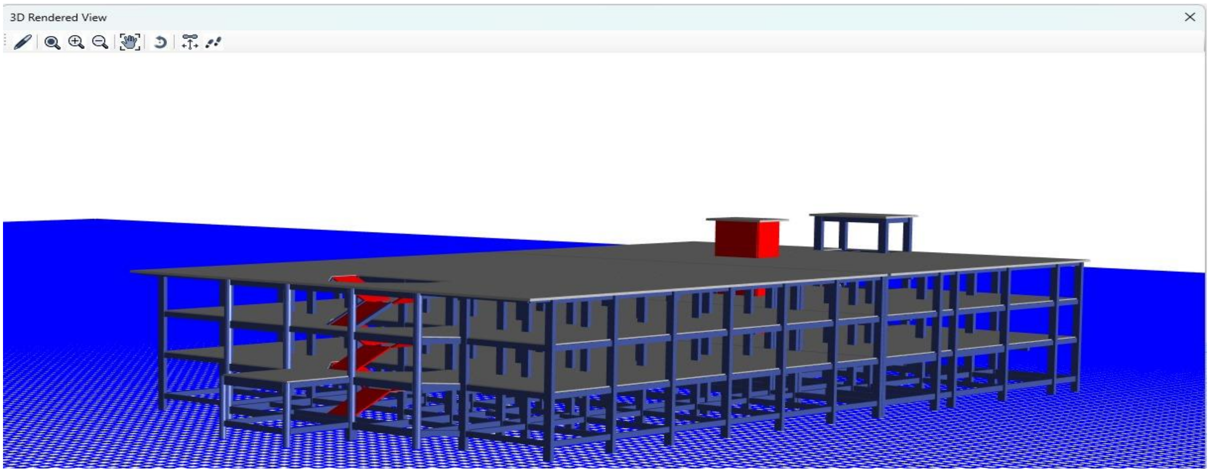


Fig 10.20 3D rendered view

10. Defining various load patterns

- Define →load patterns →load pattern (dead)-name type (dead)-multiplier (1) →load patterns →load pattern (live)-name type (live)-add →load pattern (wind load)
- Select- properties →frame sections →select beams and columns →ok →assign-frame loads gravity →load pattern name (dead) -Global Z=1 →ok
- Select →select properties →area sections →slab →ok →assign →area loads →self weight →load pattern name (dead)-Global Z=1 →ok
- Select →properties→-frame sections-beam→ ok→ assign → frame loads
- →distributed →load pattern name (live)-uniform load 2 →ok
- Define →load combinations →add new combo →load combination (comb1)-load case name (dead and live) →load case type (linear static) →scale factor (1.5)-add →ok

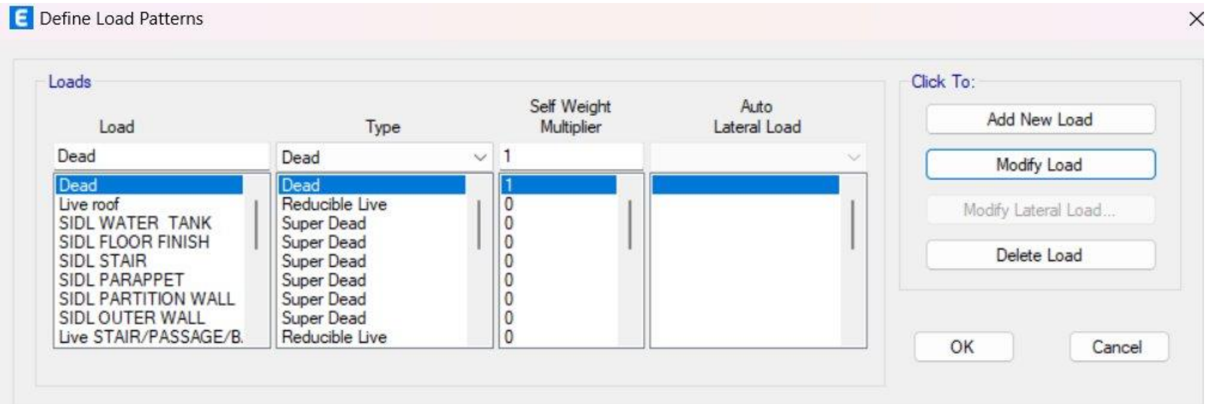


Fig 10.21 Defining various load patterns

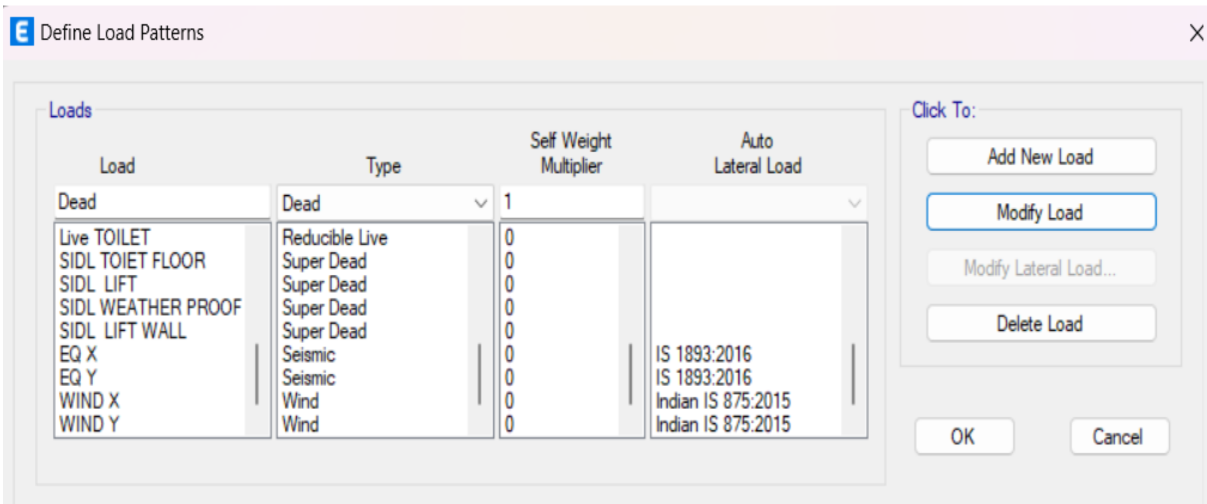


Fig 10.22 Defining various load patterns

➢ Defining earthquake loads in both X and Y direction

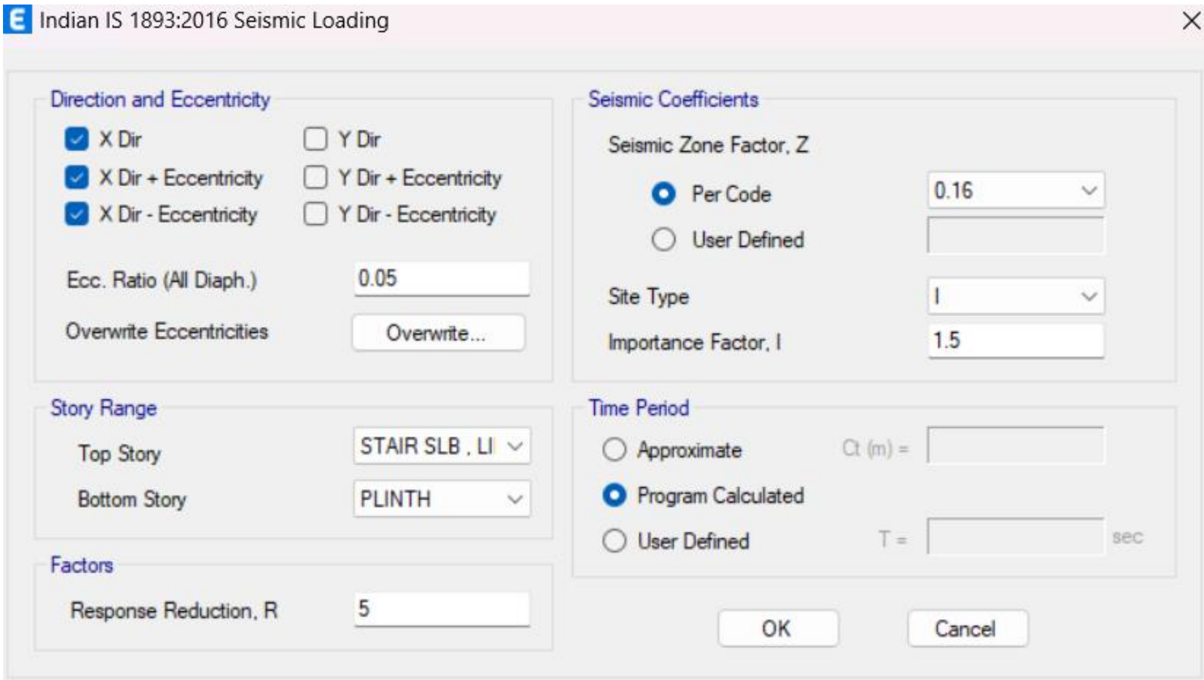


Fig 10.23 Defining Earthquake loads in both X and Y direction

➢ Defining wind loads in both X and Y direction

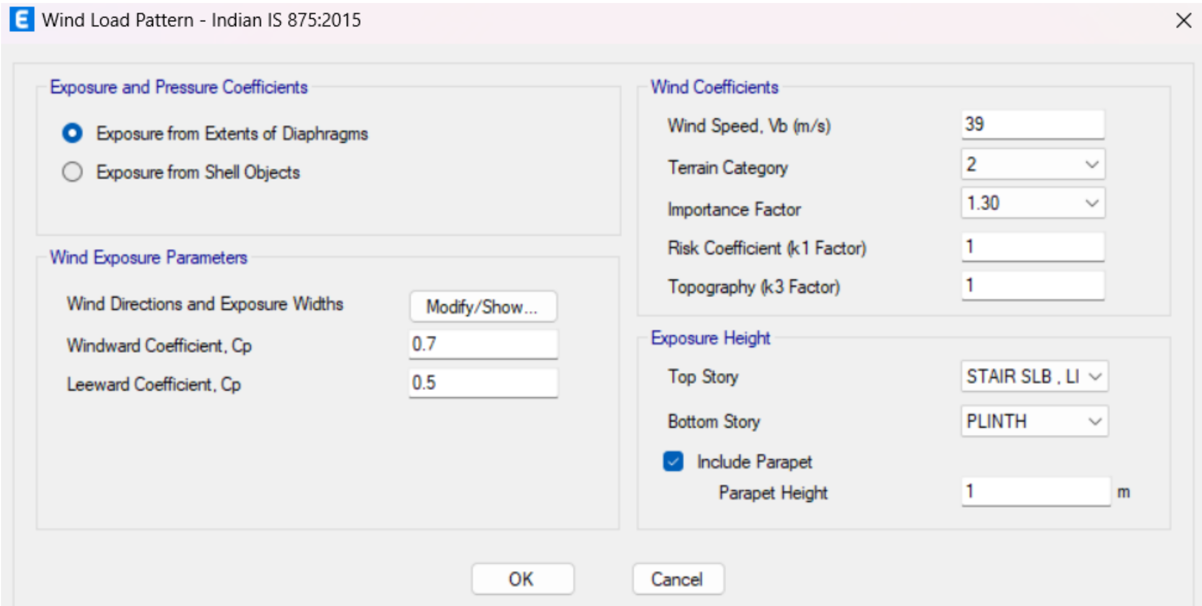


Fig 10.24 Defining wind loads in both X and Y direction

Fig 10.22 shows assigning the frame loads like wall loads and partition wall loads as super dead load and adding the other loads and their corresponding IS codes. Fig 10.23 shows defining the various seismic factors like direction, response and importance factor and other according to IS 1893 2016. Fig 10.24 shows defining the wind load patterns and factors according to the IS 875 2015 (part 3).

11. Live load reduction

Load reduction is a technique used in structural design to reduce the size of columns in mid- to high-rise buildings. The technique reduces the design load for the supports that carry the load vertically from one floor to the next.

From IS 1893 Cl.7.3.2, live load below 3 kN/m^2 load should have 25% reduction and live load above 3 kN/m^2 should have 50% reduction.

Table 10 Percentage of Imposed Load to be Considered in Calculation of Seismic Weight
(*Clause* 7.3.1)

Sl No.	Imposed Uniformity Distributed Floor Loads kN/m^2	Percentage of Imposed Load
(1)	(2)	(3)
i)	Up to and including 3.0	25
ii)	Above 3.0	50

Fig 10.25 IS 1893 Cl.7.3.2 showing percentage of load reduction

➢ Define →load cases →modify →scale factor = 0.25

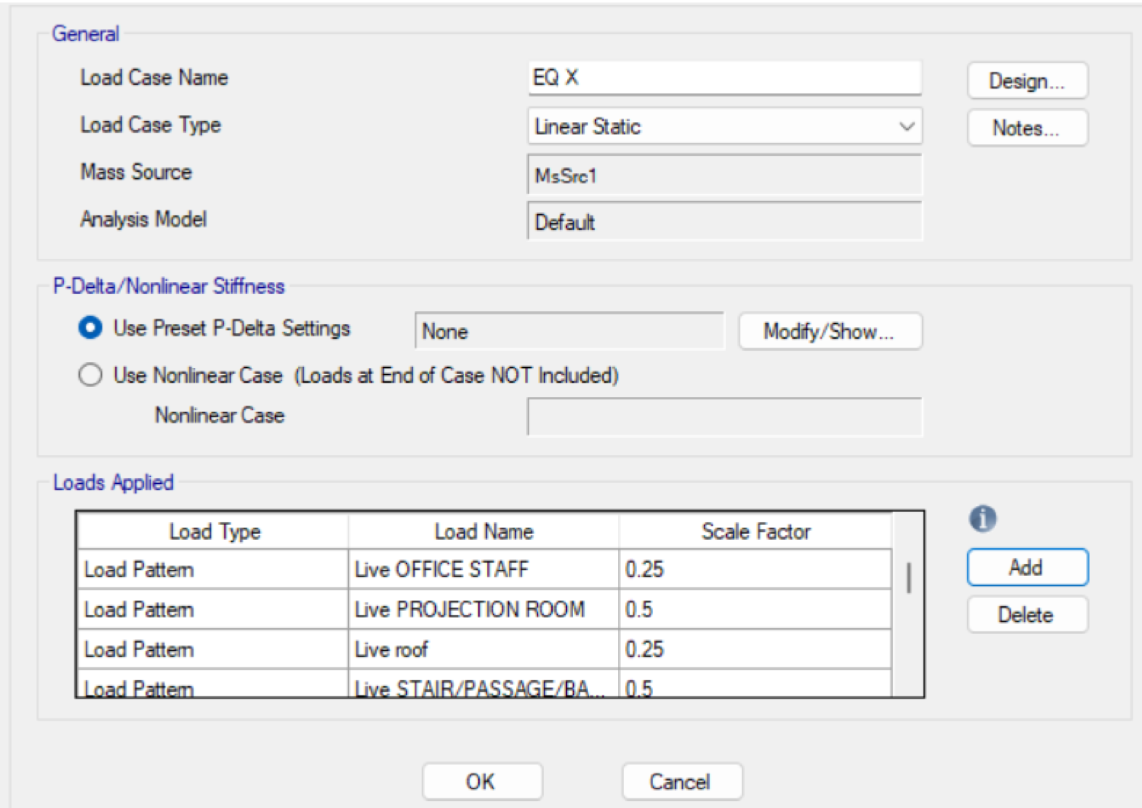


Fig 10.26 Load reduction for earthquake load in X direction

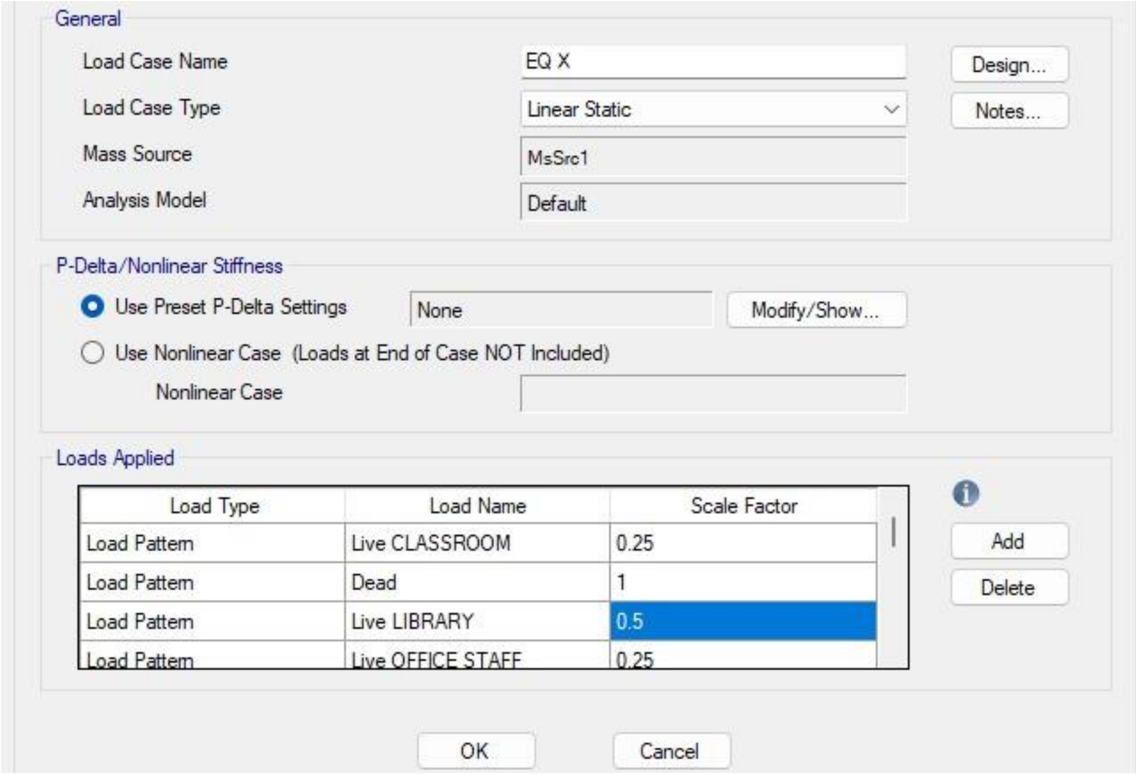


Fig 10.27 Load reduction for earthquake load in X direction

13. Defining various load combination

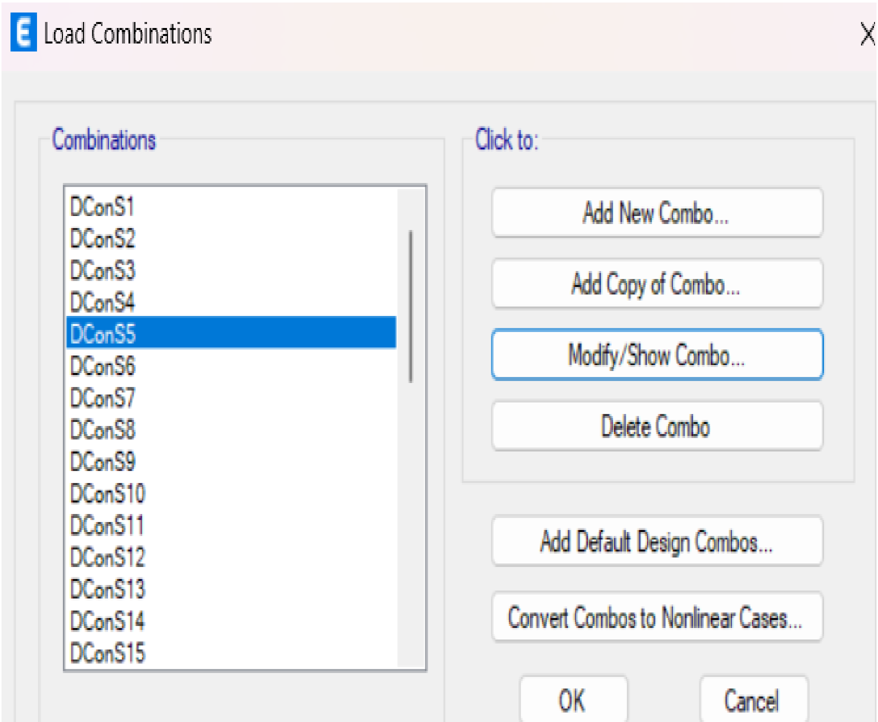


Fig 10.28 Defining various load combination

Fig 10.28 shows the given load combinations in ETABS software after specifying concrete frame.

14. Assigning various loads

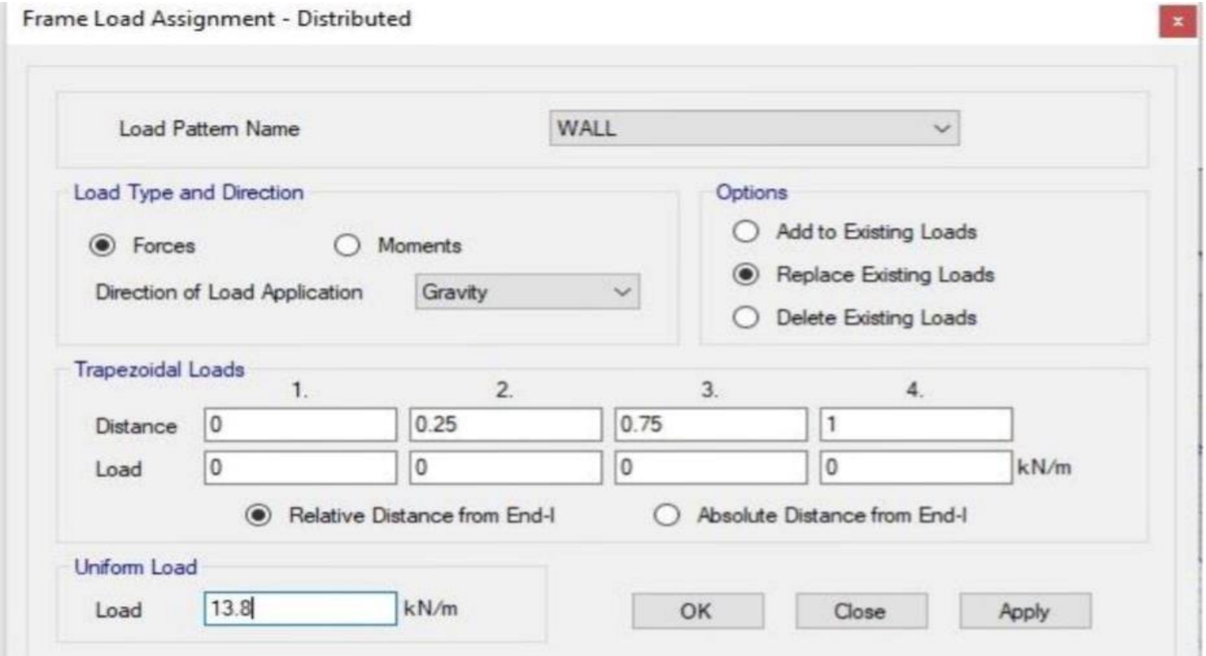


Fig 10.29 Assigning wall load

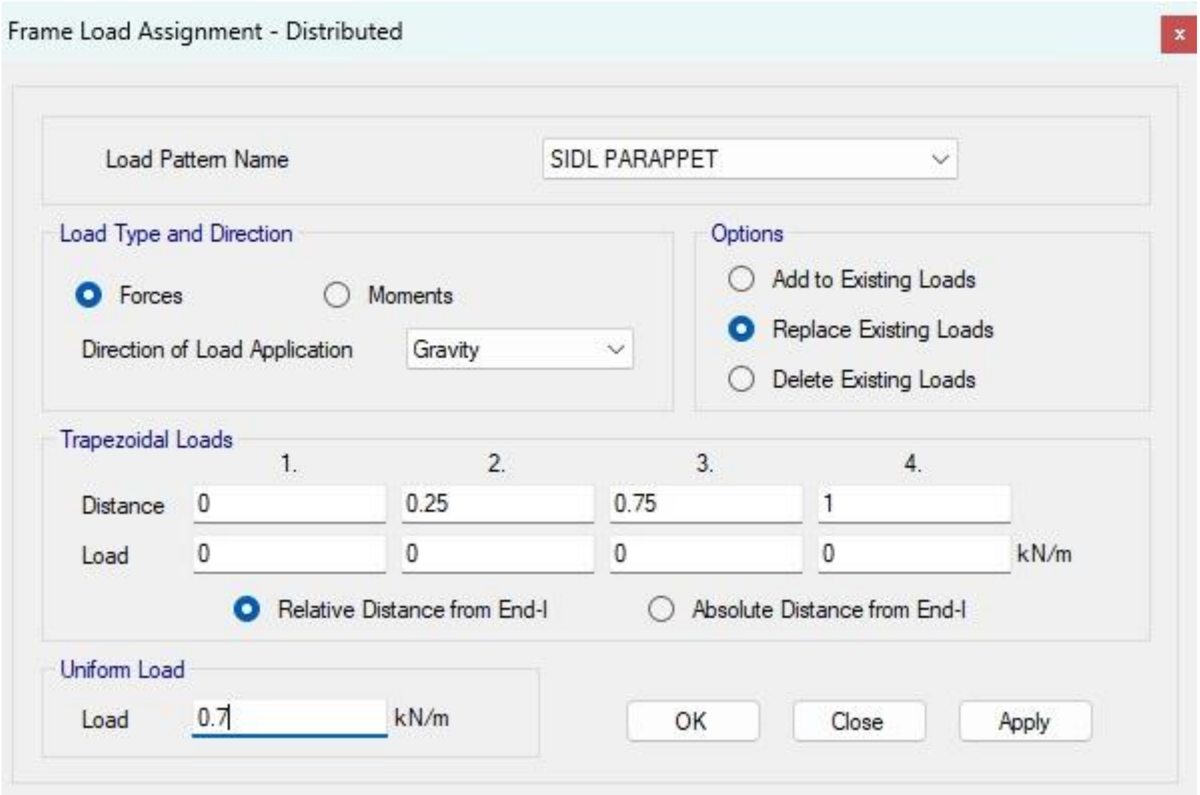


Fig 10.30 Assigning parapet load

Fig 10.31 Assigning live load

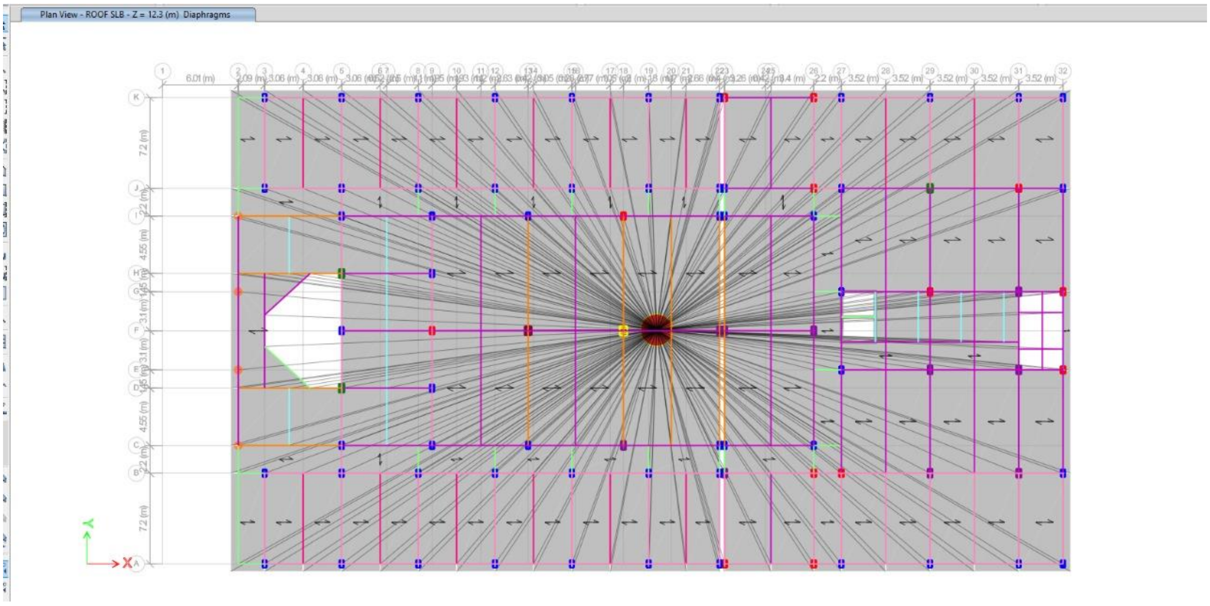


Fig 10.32 Assigning diaphragm

Diaphragms represent rigid horizontal or vertical planes that transfer lateral loads to the lateral force-resisting elements (such as walls, frames, or braces). Assign each horizontal and vertical structural element (such as slabs, beams, or walls) to appropriate diaphragm. Once diaphragms are defined and assigned, apply lateral loads (such as wind or seismic loads) to the diaphragms. ETABS distributes these loads to the connected lateral force-resisting elements based on their stiffness.

15. Analyzing the structure

- ➢ Analyze →set analysis options →ok →analyze →run analysis →run now
- ➢ Go to design →concrete frame design →start design/check →view all members are passed

10.3 ANALYSIS RESULT

Analysis results can be obtained in the graphical as well as in the tabular form, from which the maximum bending moment values are obtained for each member. Concrete dimension and reinforcement quantities are designed from these quantities appropriately.

10.3.1 Displacement

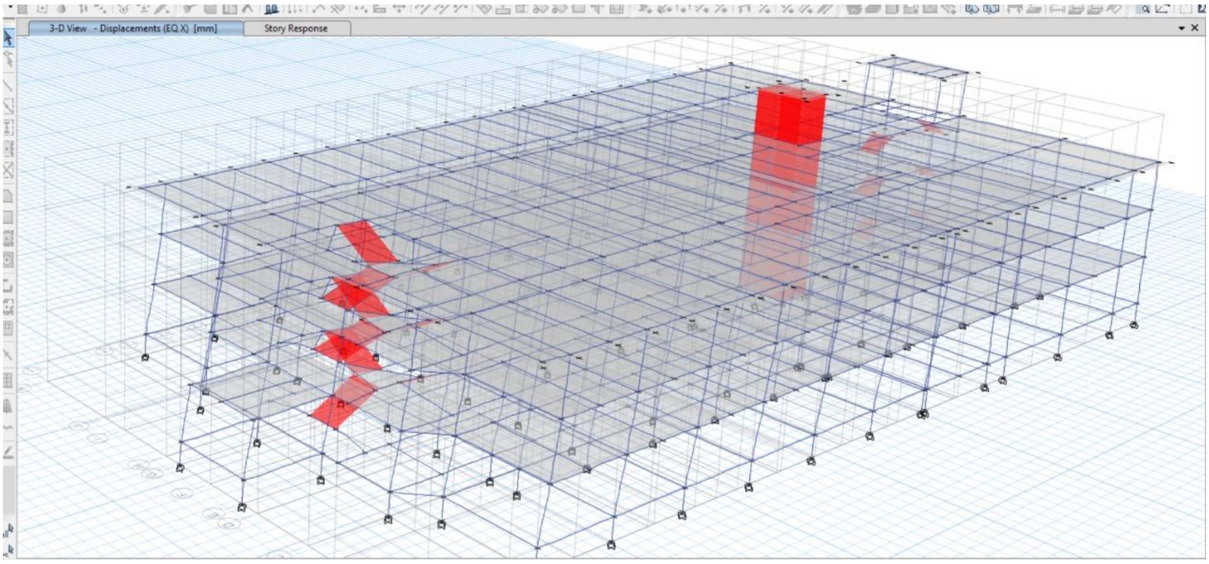


Fig 10.33 Displacement diagram

10.3.2 Storey response spectrum plot

Storey displacement is the total displacement of storey with respect to ground. According to IS 1893 2016 maximum storey displacement is 0.004 times the height of a building. The total height of our building is 14 m. Thus, the maximum storey displacement of the building is 56mm. Here through analyzing we got the value as 8.714mm which is much less than 56mm.

7.11 Deformation

Deformation of RC buildings shall be obtained from structural analysis using a structural model based on section properties given in **6.4.3**.

7.11.1 *Storey Drift Limitation*

7.11.1.1 Storey drift in any storey shall not exceed 0.004 times the storey height, under the action of design base of shear V_B with no load factors mentioned in **6.3**, that is, with partial safety factor for all loads taken as 1.0.

Fig 10.34 IS 1893:2016 Cl.7.11 – drift reference

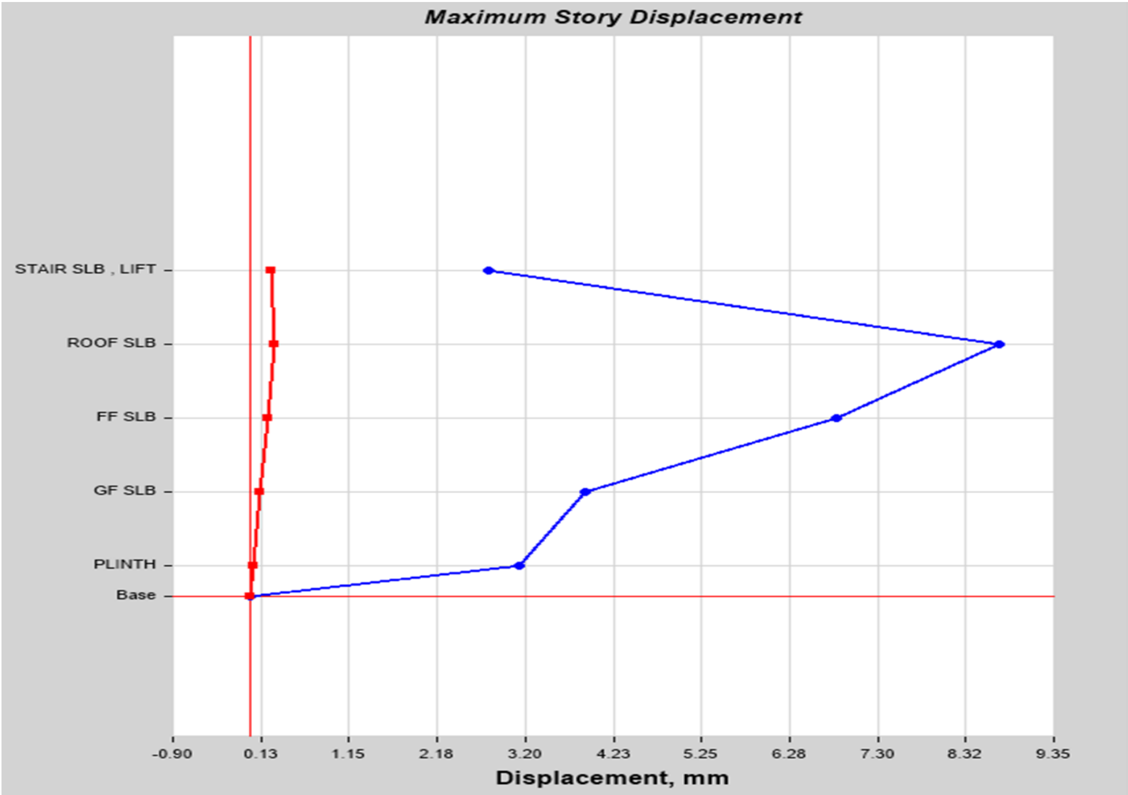


Fig 10.35 Maximum storey displacement

10.3.3 Beam analysis result

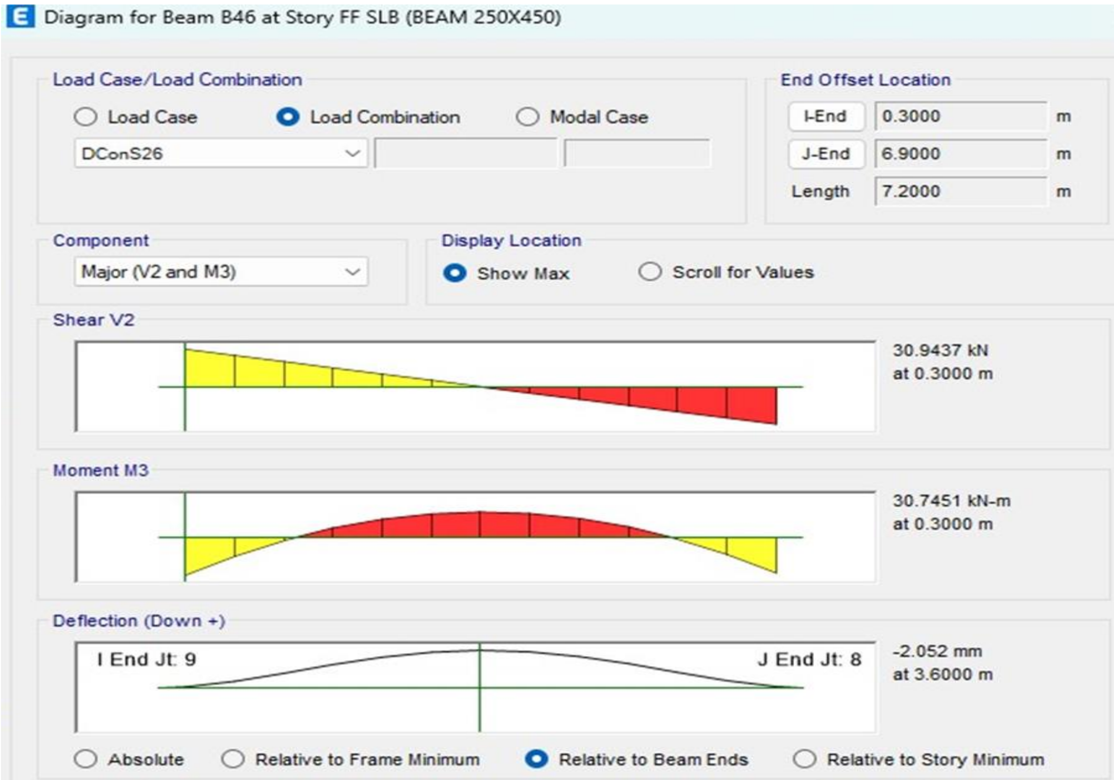


Fig 10.36 Shear force and bending moment of beam

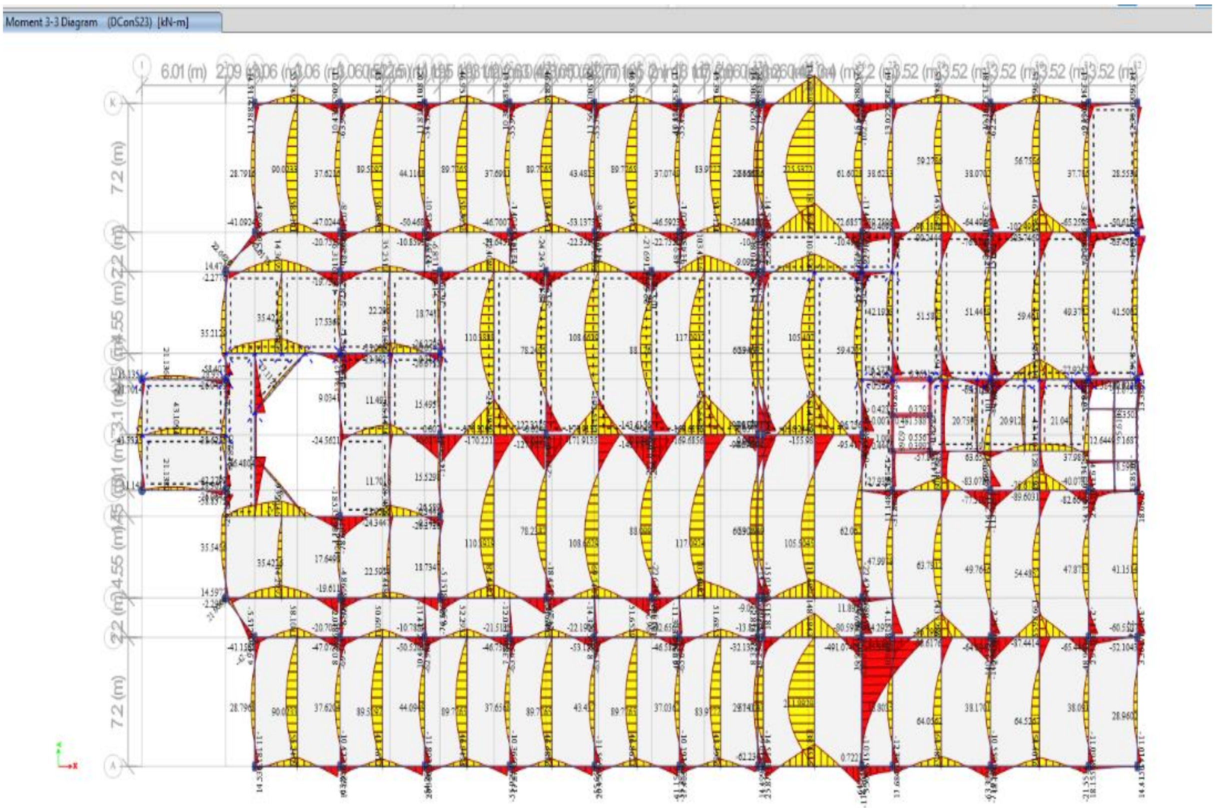


Fig 10.37 Bending moment of beam

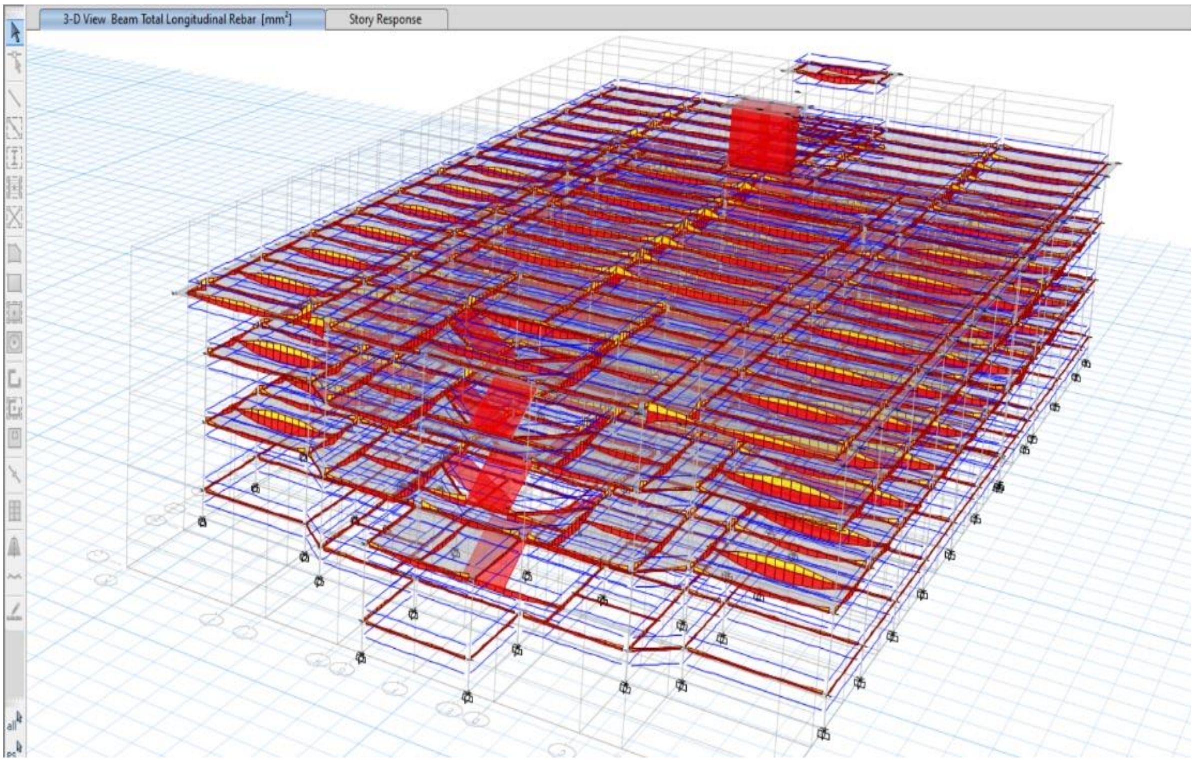


Fig 10.38 Longitudinal rebars in beam

ETABS beam design details

IS 456:2000 Concrete Beam Design

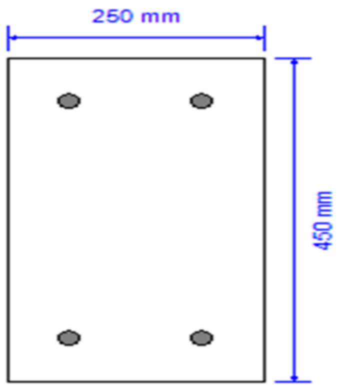


Fig 10.39 250 X 450mm beam

Table 10.1 Geometric properties of beam

Beam Label	Section Property	Length	Section Width	Section Depth	Distance to Top Rebar Center
234	BEAM 250X450	7.2 m	250 mm	450 mm	60 mm

Table 10.2 Material properties of beam

Concrete Comp. Strength	Concrete Modulus	Longitudinal Rebar Yield	Shear Rebar Yield
20 MPa	22360.68 MPa	500 MPa	415 MPa

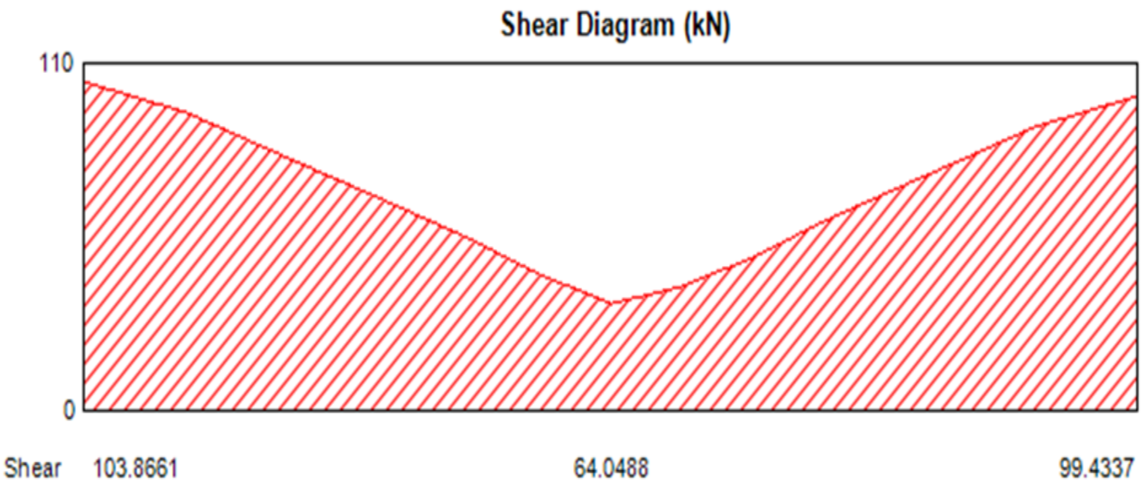


Fig 10.40 Shear force diagram

10.3.4 Column analysis result

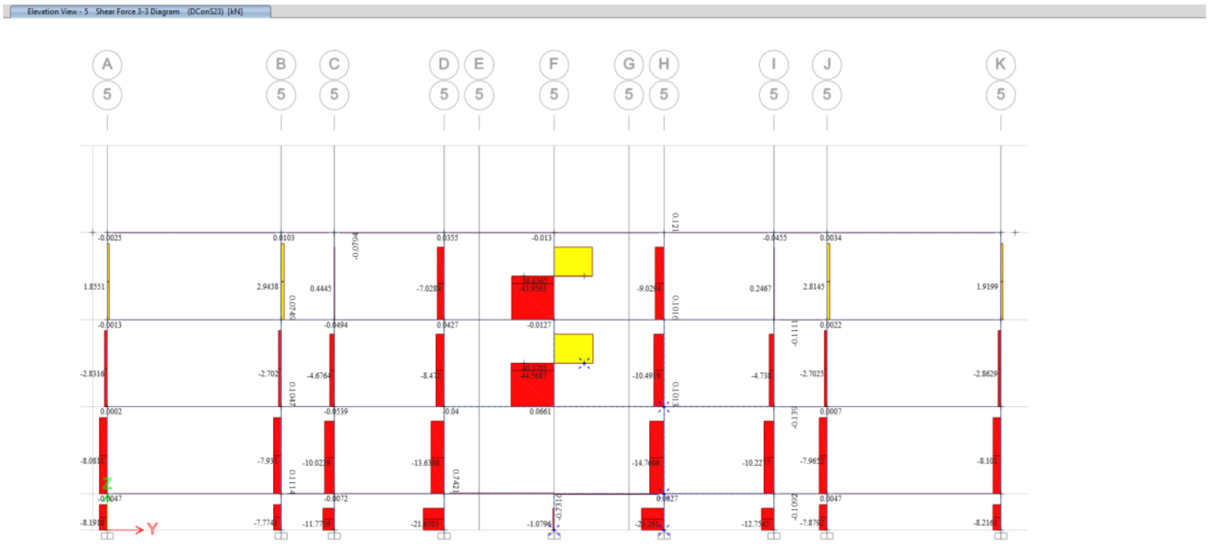


Fig 10.41 Shear force diagram

ETABS column design details

IS 456:2000 + IS 13920:2016 Column Section Design (Summary)

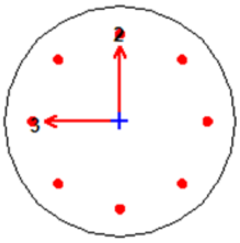


Fig 10.42 Round column of 500 dia.

Table 10.3 Column element details

Level	Element	Unique Name	Section ID	Combo ID	Station Loc	Length (mm)	LLRF	Type
GF SLB	C2	3	ROUND COL 500 DIA	DConS16	3150	3600	1	Ductile Frame

Table 10.4 Section properties

d (mm)	h_0 (mm)	dc (mm)	Cover (Torsion) (mm)
500	440	60	30

Table 10.5 Material properties

E_c (MPa)	f_{ck} (MPa)	Lt. Wt. Factor (Unitless)	f_y (MPa)	f_{ys} (MPa)
25000	25	1	413.69	413.69

Table 10.6 Design code parameters

γ_C	γ_S
1.5	1.15

Table 10.7 Axial force and biaxial moment design for P_u , M_{u2} , M_{u3}

Design P_u kN	Design M_{u2} kN-m	Design M_{u3} kN-m	Minimum M_2 kN-m	Minimum M_3 kN-m	Rebar Area mm²	Rebar % %	Capacity Ratio Unitless
116.1676	-143.7711	69.5875	2.668	2.668	2813	1.43	1

Table 10.8 Axial force and biaxial foment factor

	K Factor Unitless	Length mm	Initial Moment kN-m	Additional Moment kN-m	Minimum Moment kN-m
Major Bend(M3)	2.07509	3150	25.8497	4.9634	2.668
Minor Bend(M2)	0.818564	3150	-16.8915	0	2.668

Table 10.9 Axial compression check for seismic design per IS 13920:2016 section 7.1

Limit Compression Factor Unitless	Limit Compression Strength kN	Compression D/C Ratio Unitless	Status
0.4	1963.4954	0.059164	OK

Table 10.10 Shear design for V_{u2} , V_{u3}

	Shear V_u kN	Shear V_c kN	Shear V_s kN	Shear V_p kN	Rebar A_{sv} /s mm²/m
Major, V_{u2}	48.5898	112.7418	73.2015	48.5898	555.98
Minor, V_{u3}	79.8728	112.7418	73.2015	79.8728	555.98

Table 10.11 Joint shear check/design

	Joint Shear Force kN	Shear V_{Top} kN	Shear $V_{u,Tot}$ kN	Shear V_c kN	Joint Area cm²	Shear Ratio Unitless
Major Shear, V_{u2}	0	0	171.9838	1250	2500	0.138
Minor Shear, V_{u3}	0	0	298.9678	1250	2500	0.239

Table 10.12 Beam/column capacity ratio

Major Ratio	Minor Ratio
0.499	0.82

Table 10.13 Additional moment reduction factor k (IS 39.7.1.1)

A_g cm²	A_{sc} cm²	P_{uz} kN	P_b kN	P_u kN	k Unitless
1963.5	28	3062.0462	1136.3592	116.1676	1

Table 10.14 Additional moment (IS 39.7.1)

	Consider M_a	Length Factor	Section Depth (mm)	KL/Depth Ratio	KL/Depth Limit	KL/Depth Exceeded	M_a Moment (kN-m)
Major Bending (M_3)	Yes	0.875	500	13.073	12	Yes	4.9634
Minor Bending (M_2)	Yes	0.875	500	5.157	12	No	0

10.3.5 Support reactions

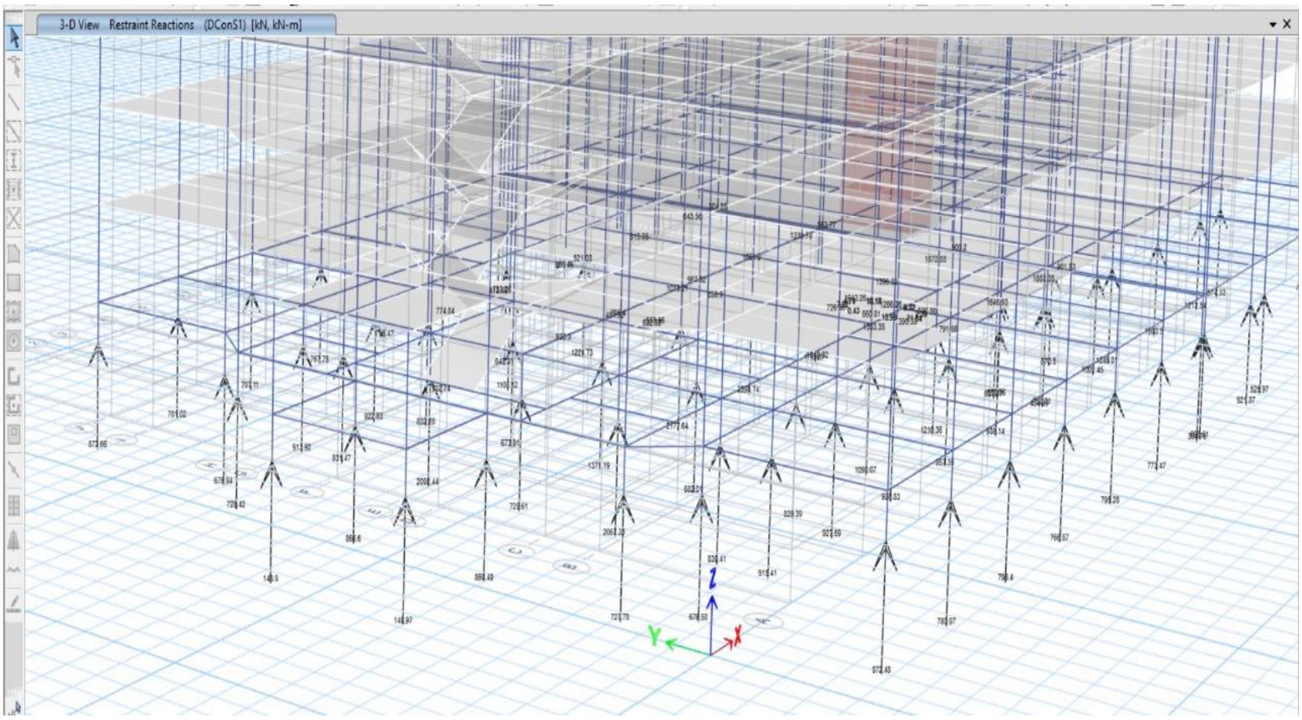


Fig 10.43 Restraint reactions

10.3.6 Shear wall analysis

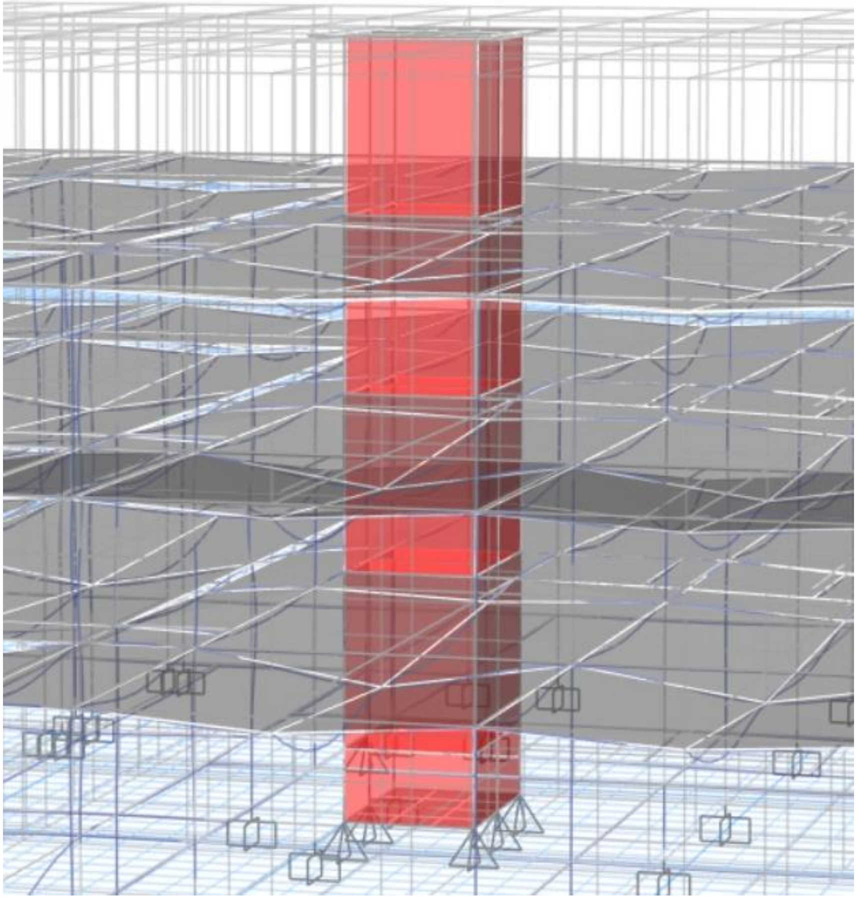


Fig 10.44 Shear wall

ETABS shear wall design details

IS 456:2000 Pier Design

Table 10.15 Pier details

Story ID	Pier ID	Centroid X (mm)	Centroid Y (mm)	Length (mm)	Thickness (mm)	LLRF
FF SLB	P5	61716.3	19600	12100	200	0.598

Table 10.16 Material properties

E_c (MPa)	f_{ck} (MPa)	Lt. Wt. Factor (Unitless)	f_y (MPa)	f_{ys} (MPa)
25000	25	1	415	415

Table 10.17 Design code parameters

Γ_S	Γ_C	IP_{MAX}	IP_{MIN}	P_{MAX}	Min Ecc Major	Min Ecc Minor
1.15	1.5	0.04	0.0025	0.8	Yes	Yes

Table 10.18 Pier leg location, length and thickness

Station Location	ID	Left X_1 mm	Left Y_1 mm	Right X_2 mm	Right Y_2 mm	Length mm	Thickness mm
Top	Leg 1	59920	21600	62620	21600	2700	200
Top	Leg 2	62620	17600	62620	21600	4000	200
Top	Leg 3	59920	19600	62620	19600	2700	200
Top	Leg 4	59920	17600	62620	17600	2700	200
Bottom	Leg 1	59920	21600	62620	21600	2700	200
Bottom	Leg 2	62620	17600	62620	21600	4000	200
Bottom	Leg 3	59920	19600	62620	19600	2700	200
Bottom	Leg 4	59920	17600	62620	17600	2700	200

Table 10.19 Flexural design for P_u, M_{u2} and M_{u3}

Station Location	Required Rebar Area (mm²)	Required Reinf Ratio	Current Reinf Ratio	Flexural Combo	P_u kN	M_{u2} kN-m	M_{u3} kN-m	Pier A_g mm²
Top	6000	0.0025	0.0085	DWalS14	3585.1565	-316.3697	723.8302	2400000
Bottom	6000	0.0025	0.0085	DWalS14	4410.6374	-1010.8119	-786.8162	2400000

Table 10.20 Shear design

Station Location	ID	Rebar mm²/m	Shear Combo	P_u kN	M_u kN-m	V_u kN	V_c kN	$V_c + V_s$ kN
Top	Leg 1	400	DWalS10	1454.0228	-343.8753	205.4867	680.4	992.1913
Top	Leg 2	400	DWalS9	2423.5559	-295.5309	452.6882	1344	1805.913
Top	Leg 3	400	DWalS9	1039.8419	243.0107	106.9229	680.4	992.1913
Top	Leg 4	400	DWalS9	759.7623	-401.0278	286.2604	680.4	992.1913
Bottom	Leg 1	400	DWalS10	1543.0453	651.6938	207.1297	680.4	992.1913
Bottom	Leg 2	400	DWalS9	2828.5559	1334.1464	452.6882	1344	1805.913
Bottom	Leg 3	400	DWalS9	1582.5454	259.2555	105.7552	680.4	992.1913
Bottom	Leg 4	400	DWalS9	962.1291	730.0815	287.0219	680.4	992.1913

10.4 DETAILING USING RCDC

Detailing structural elements like columns, beams, slabs, and others using software like RCDC (Reinforced Concrete Design and Detailing) offers precise and efficient solutions in construction engineering

10.4.1 Detailing

With RCDC software, engineers can meticulously design and specify the reinforcement details for each structural element, ensuring compliance with relevant design codes and standards while optimizing material usage. For columns, the software facilitates the selection of appropriate reinforcement sizes, spacing, and configurations based on the applied loads and column dimensions. Similarly, for beams, RCDC aids in determining reinforcement arrangements, including stirrup spacing and bar sizes, to guarantee adequate strength and ductility. Slab detailing involves specifying reinforcement layout, bar sizes, distribution, and detailing of openings and edge conditions, all of which are efficiently handled by RCDC software. By automating these processes, RCDC not only enhances accuracy but also expedites the design and detailing phases, ultimately contributing to smoother construction workflows and ensuring structural integrity and safety.

10.4.2 Procedure

1. The first step is to export the ETABS file for access to RCDC.

➢ Click File →Export →ETABS Database Tables to Access

➢ Choose tables for export to access – choose the tables →Ok

➢ Select consistent units for export – choose the unit →Ok

➢ Now save the file

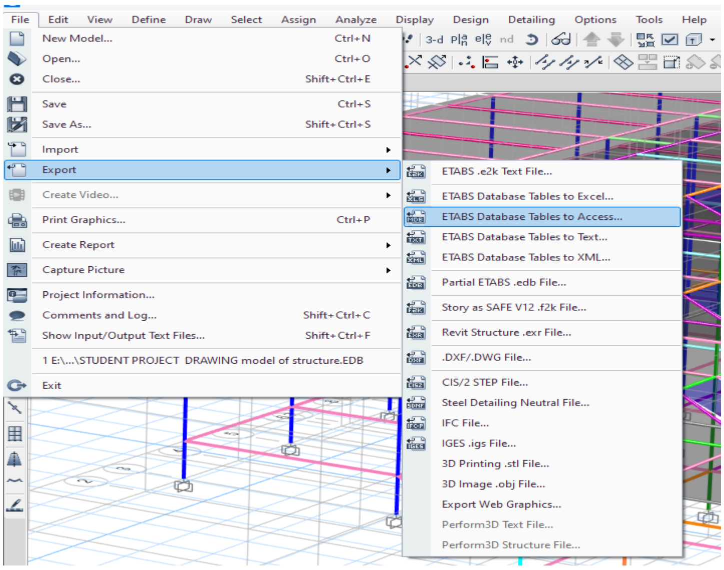


Fig 10.45 Exporting the ETABS file

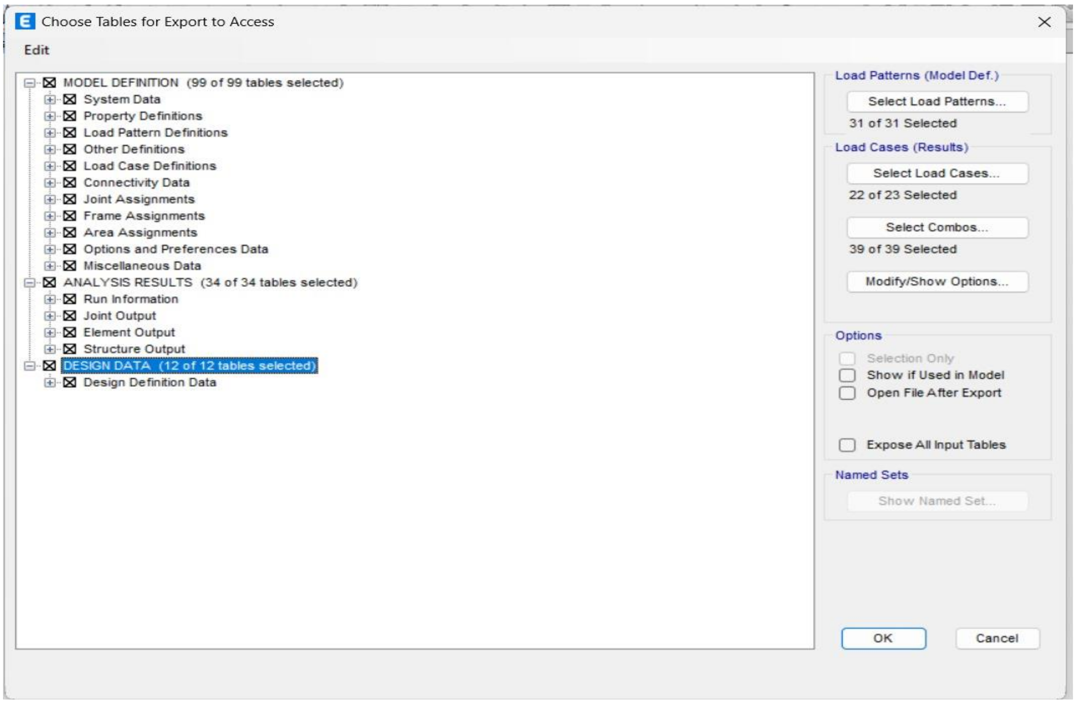


Fig 10.46 Tables required to be exported are selected

2. Creating a new project and importing ETABS file.

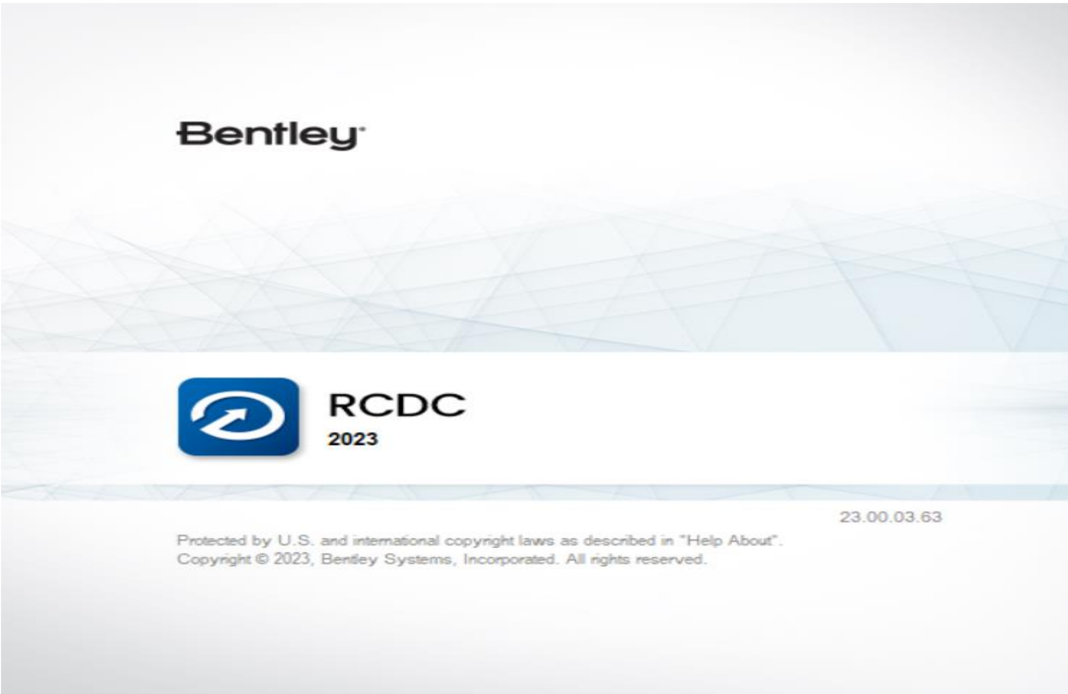


Fig 10.47 RCDC welcome page

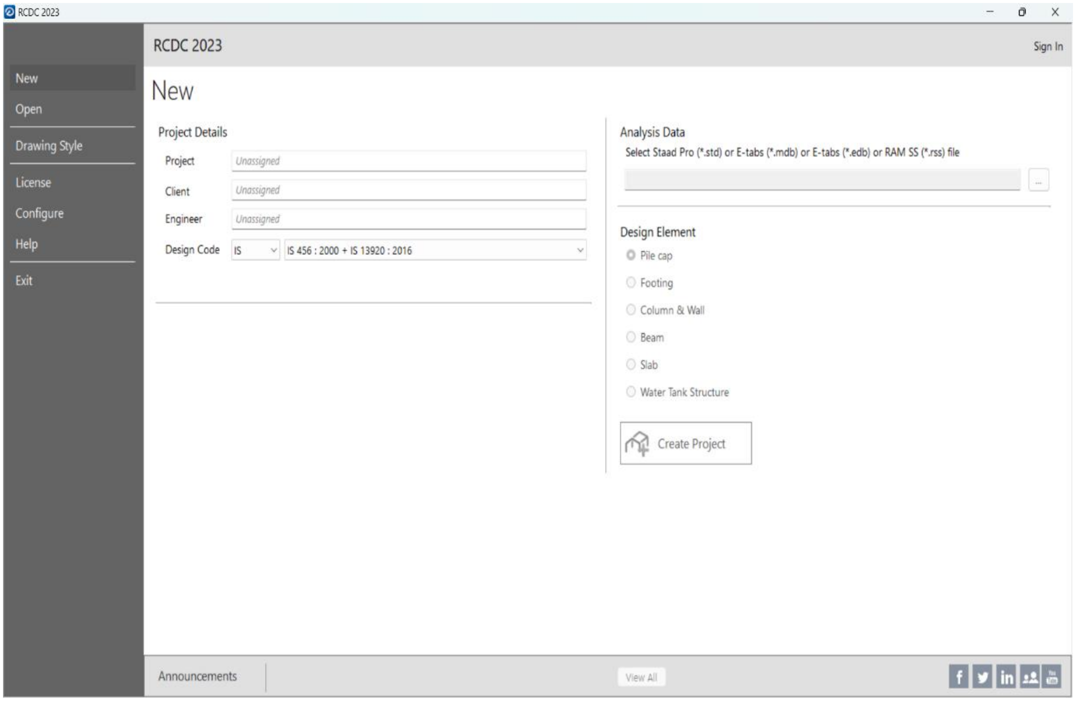


Fig 10.48 Creating a new project

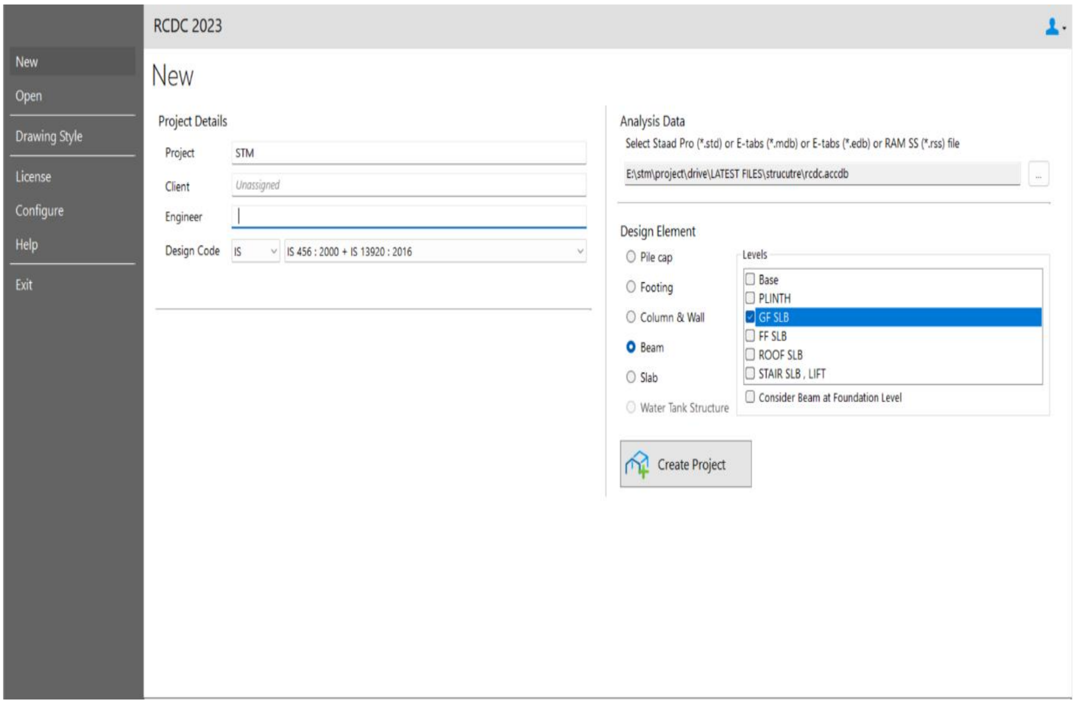


Fig 10.49 The design element is selected

- Details like the project name, design code, ETABS access file, design element, etc. are added. The design codes used are IS456:2000 + IS13920:2016 and the design element is taken as beam. Finally, the project is created. An interface showing the plan and beam continuum opens. Now save the file.

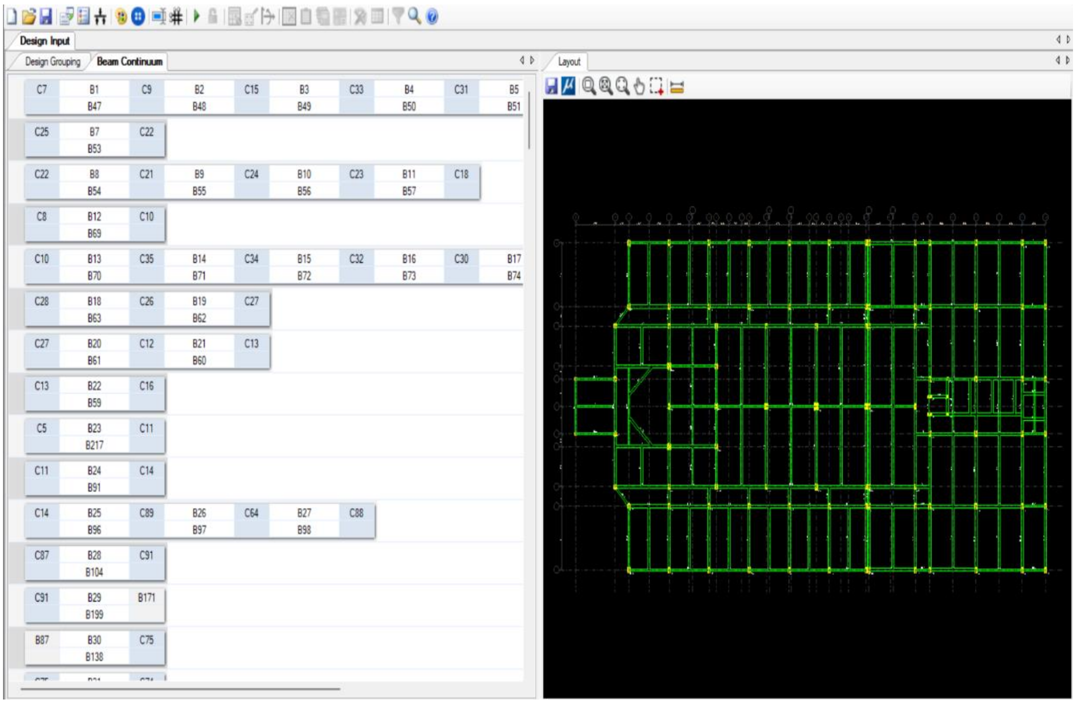


Fig 10.50 Opened interface showing plan and beam continuum

3. Details like design, reinforcement, detailing, curtailment, etc. are added.

- ➢ Main menu →Settings →General and Reinforcement Settings – enter the details →Ok

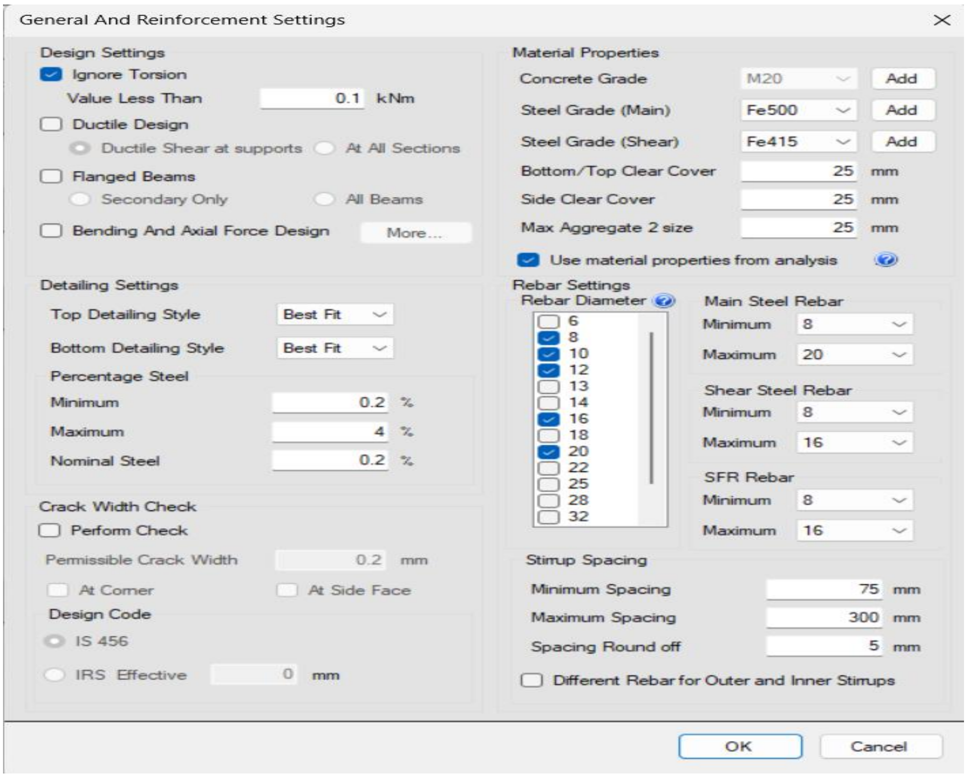


Fig 10.51 General and reinforcement details being added

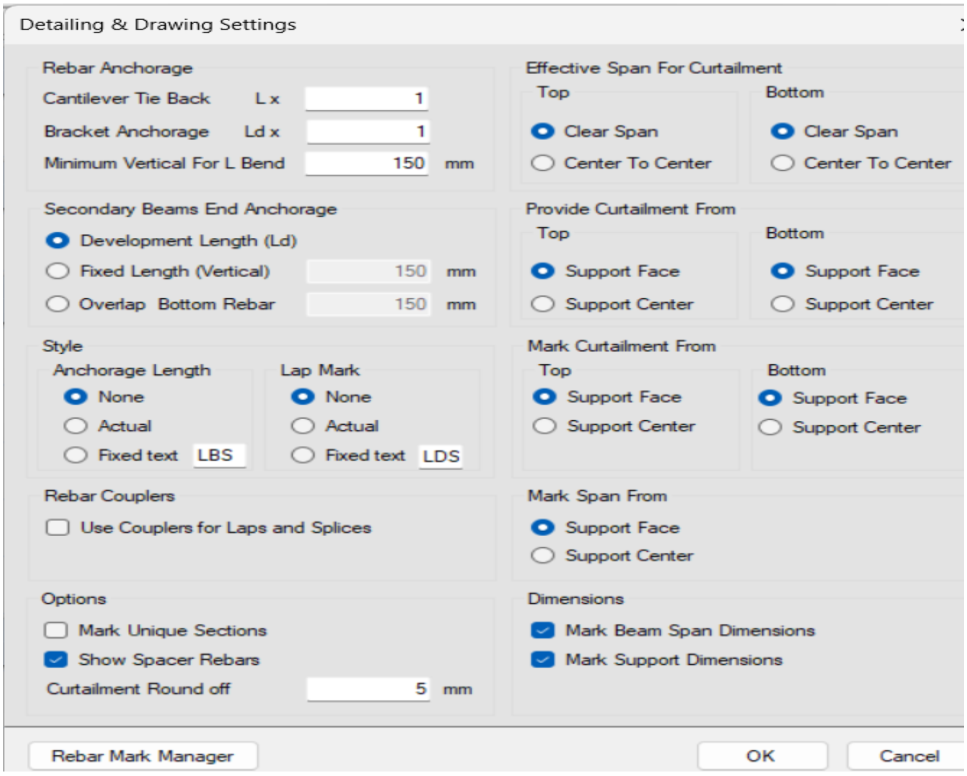


Fig 10.52 Detailing and drawing details being added

- ➢ Main menu →Settings →Rebar curtailment →Ok
- ➢ Main menu →Settings →Basic Load cases

For Analysis Load cases select the appropriate load cases from the drop-down menu and send the selected Load cases to the right side by selecting >> button and then click Ok.

- ➢ Now click the Load Combination Dialog box. Click "Add from Analysis" button of the box. Choose the load combinations. Click OK to accept.

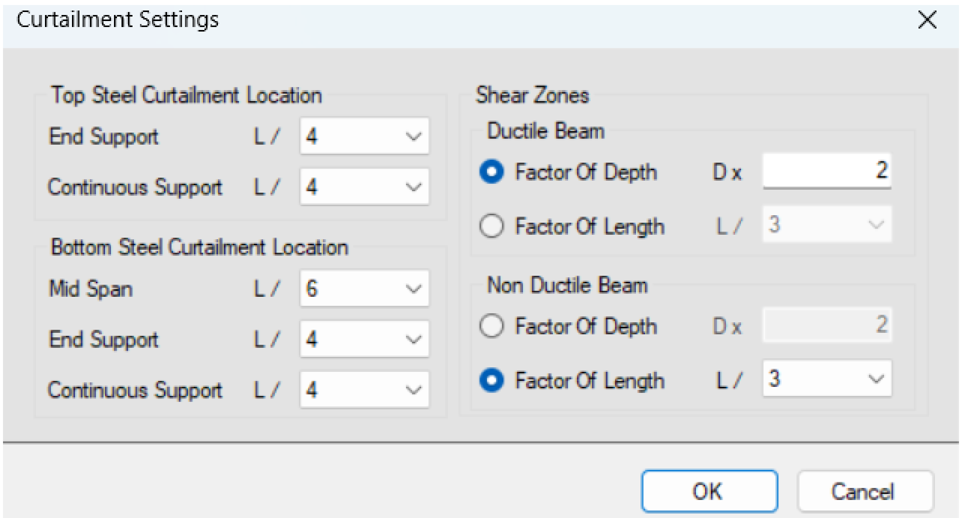


Fig 10.53 Adding Curtailment details

5. The design and report are generated.

➢ Main menu →Design →Auto Design

Top and Bottom layer Reinforcement details like diameter and number of bars, Shear Reinforcement details like diameter and spacing of stirrups will be visible.

➢ Main menu →Report →Elevation and Section

Select required Beam numbers, Elevation, Cross Section and Curtailment detail, Click OK.

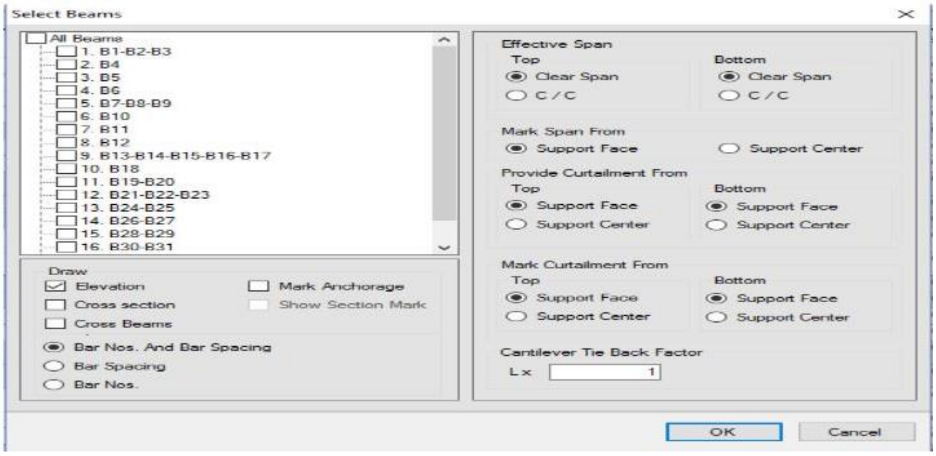


Fig 10.54 Generating Report

The reinforcement details for all Beams in the structure can be viewed in AutoCAD drawing format.

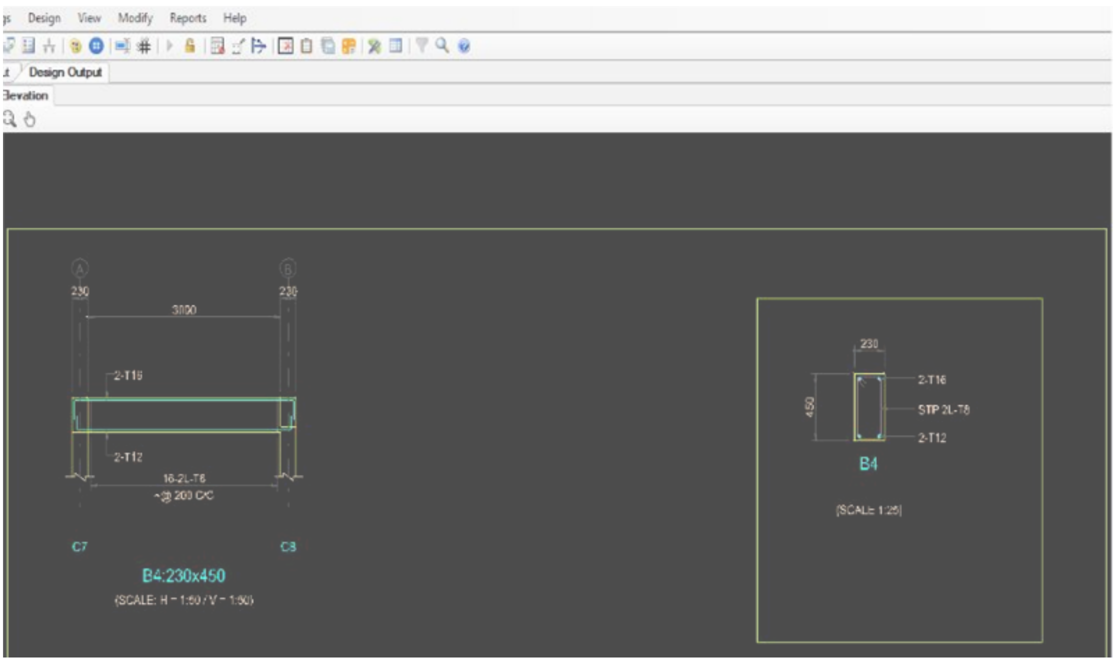


Fig 10.55 Report generated

6. Similarly, the detailing of column, slab and footing are obtained.

10.4.3 Results

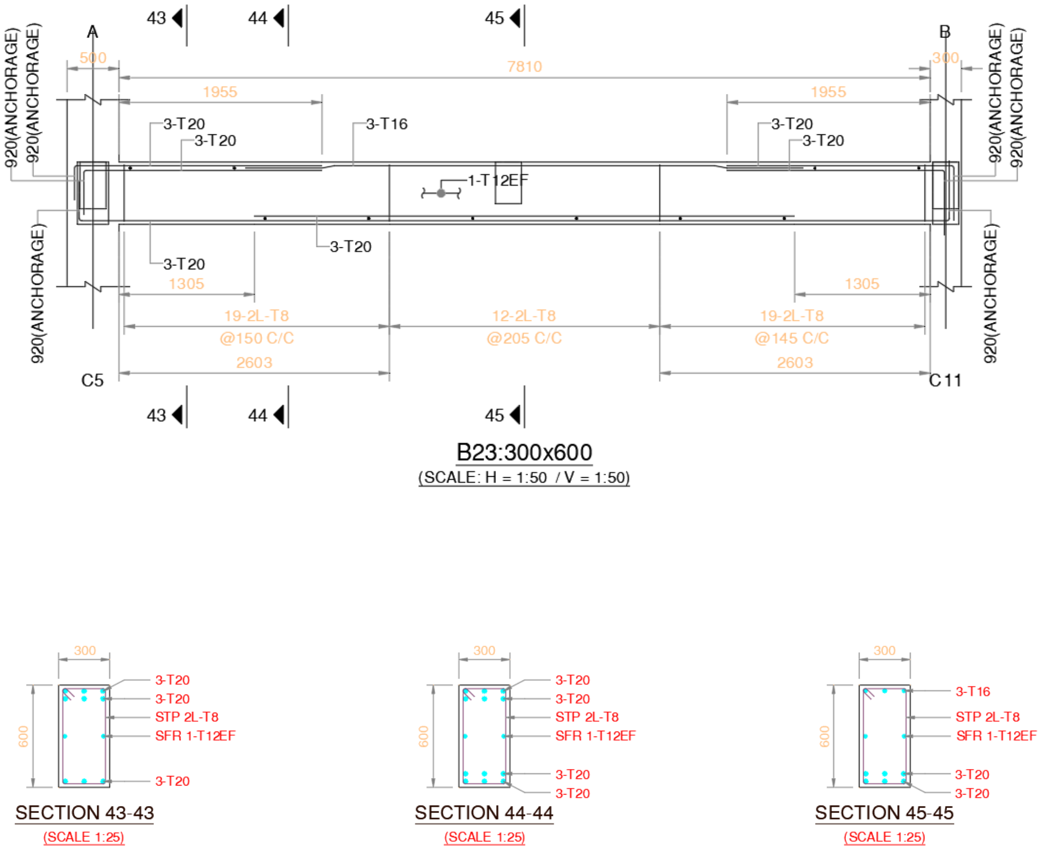


Fig 10.56 RCDC Beam design

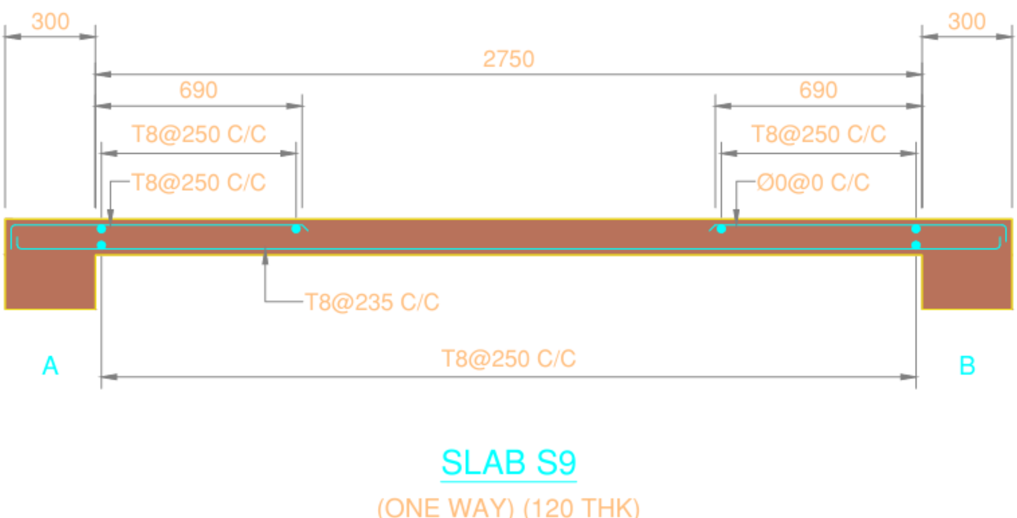


Fig 10.57 RCDC Slab design

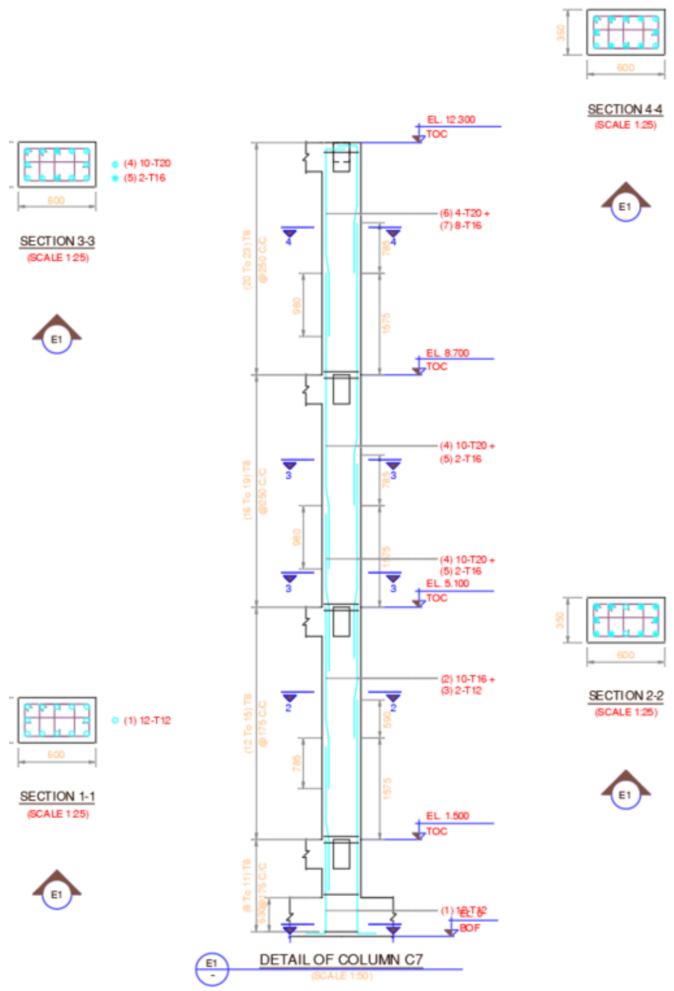


Fig 10.58 RCDC Column design

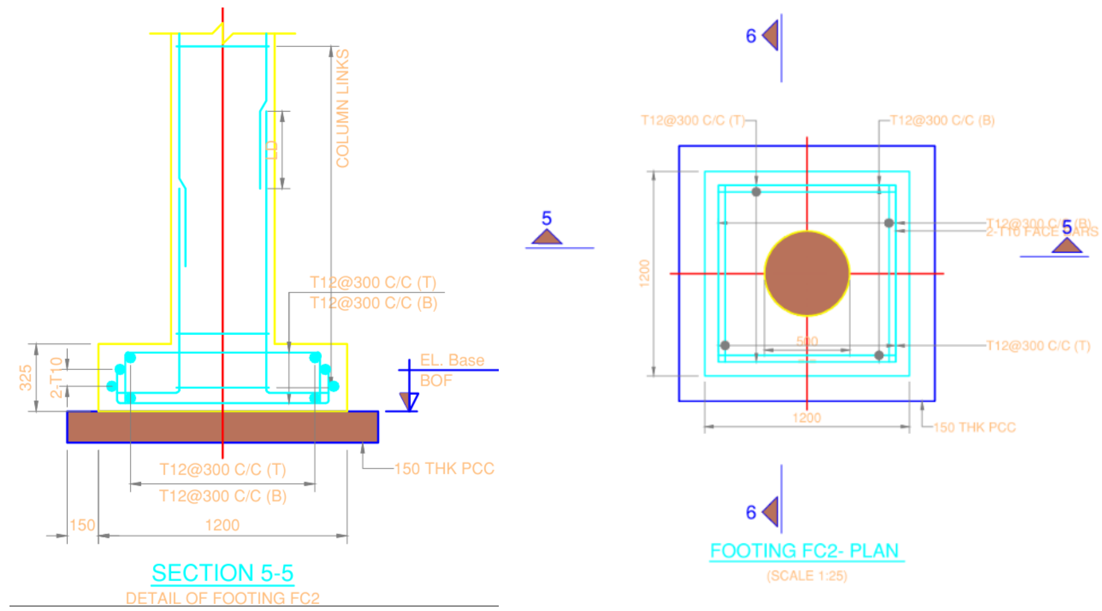


Fig 10.59 RCDC Footing design

10.5 DETAILED STRUCTURAL DRAWINGS

After obtaining the results from the RCDC software, the next step involves the creation of detailed drawings for each structural element using AutoCAD. This process is crucial as it translates the design calculations and specifications into precise visual representations. Utilizing AutoCAD allows for the generation of accurate and standardized drawings, ensuring adherence to industry standards and project requirements. Each element, such as beams, columns, slabs, and footings, is meticulously drafted with attention to detail, dimensions, reinforcement bars layout, and connection details. Detailed drawing of stairs is also created.

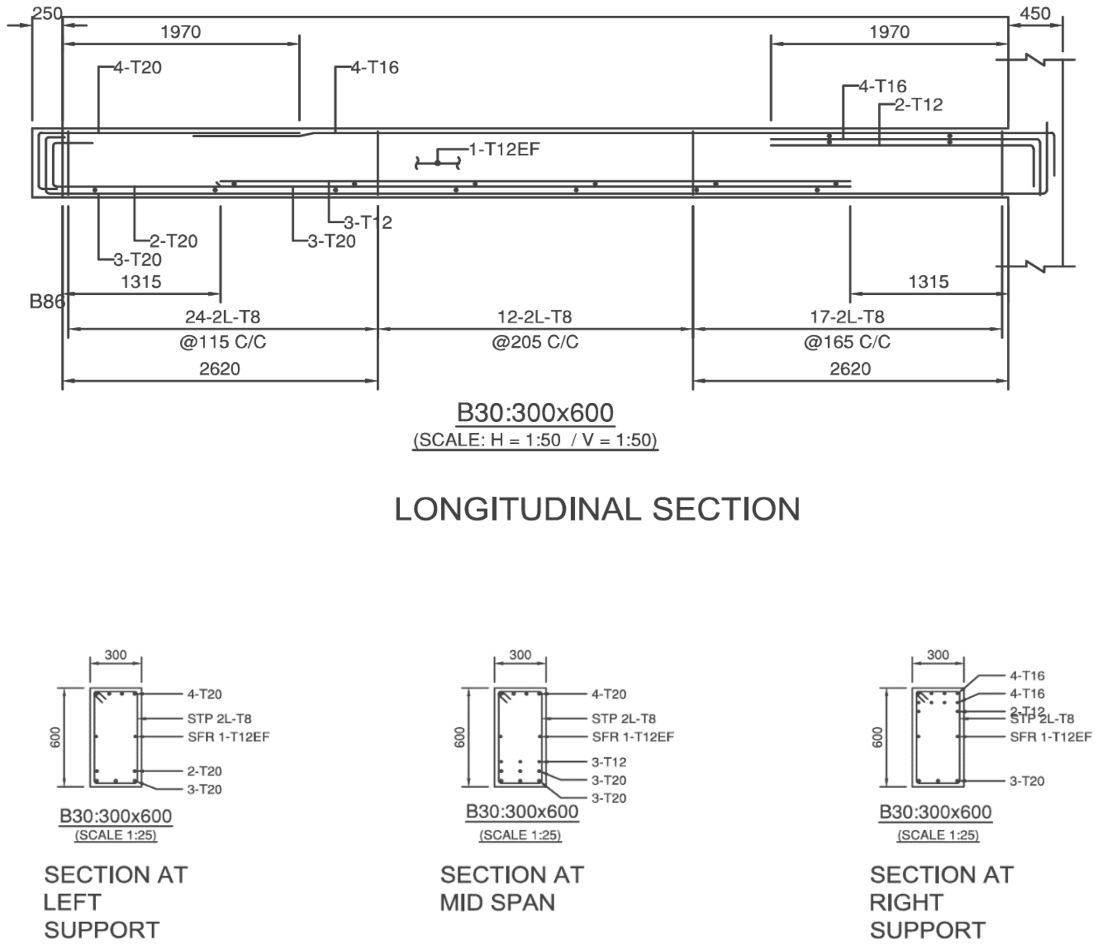


Fig 10.60 Beam design

Fig 10.60 represents detailed drawing of a beam illustrating dimensions, reinforcement layout, and connection details.

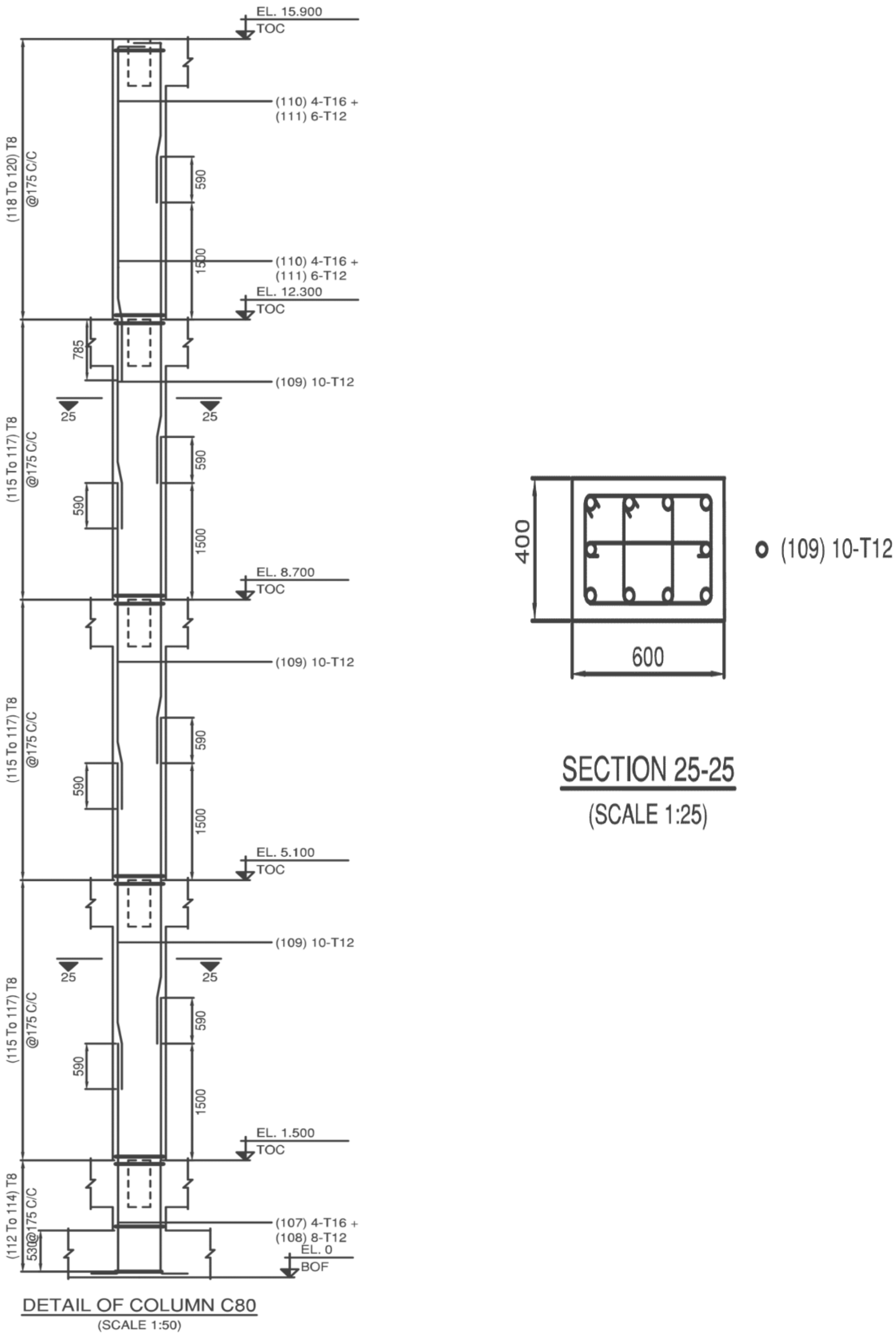
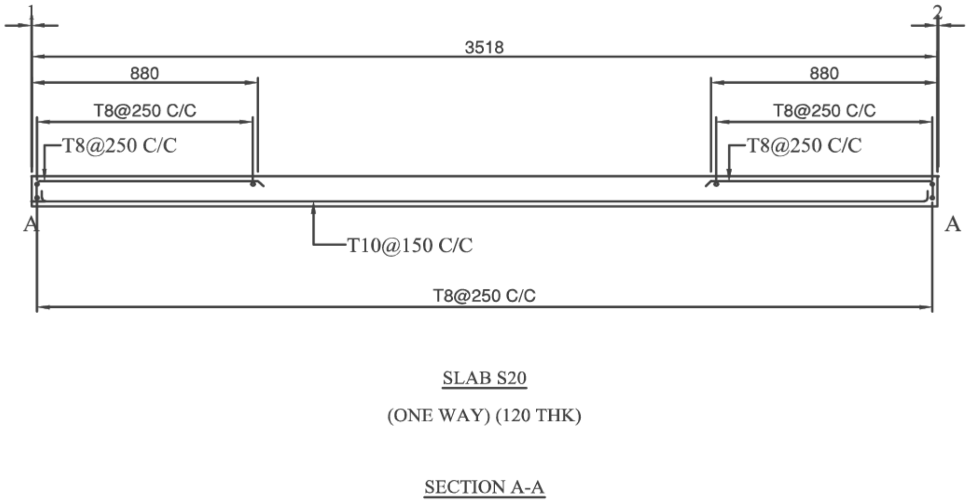


Fig 10.61 Column design

Fig 10.61 shows a detailed drawing of a column with precise visual representation and dimensions of the column's geometry, reinforcement layout, and connection details.



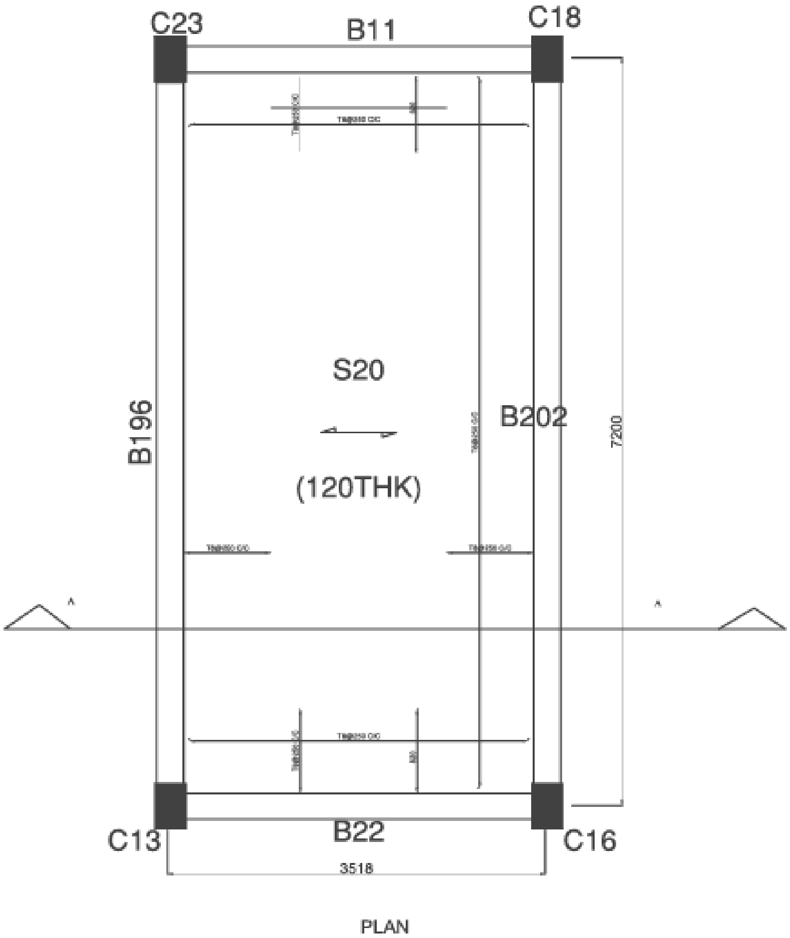


Fig 10.62 Slab design

Fig 10.62 represents detailed drawing of a slab depicting reinforcement layout, dimensions, and connection details.

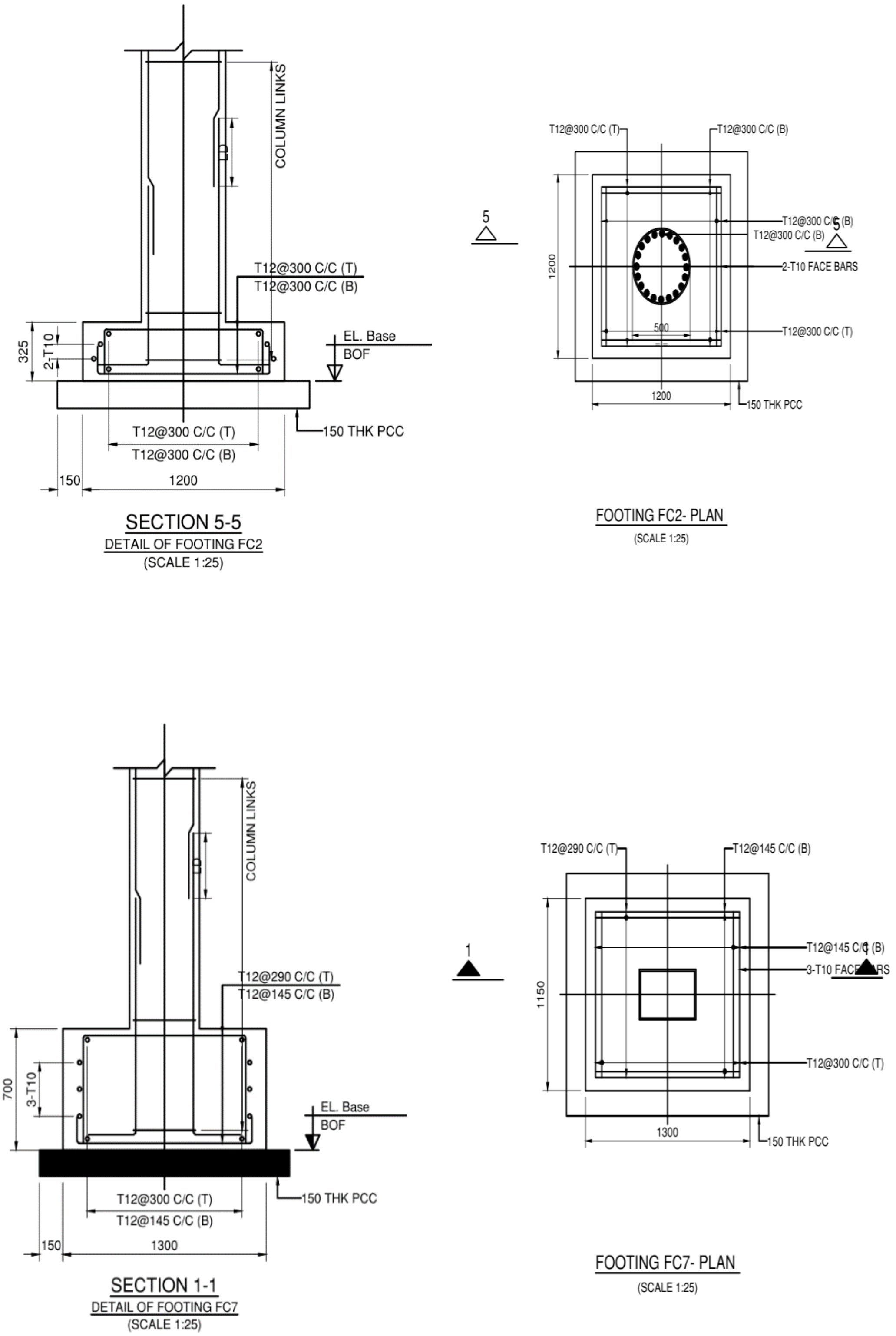


Fig 10.63 Footing design

Fig 10.63 depicts a detailed drawing of a footing illustrating dimensions, reinforcement layout, and connection details for structural stability.

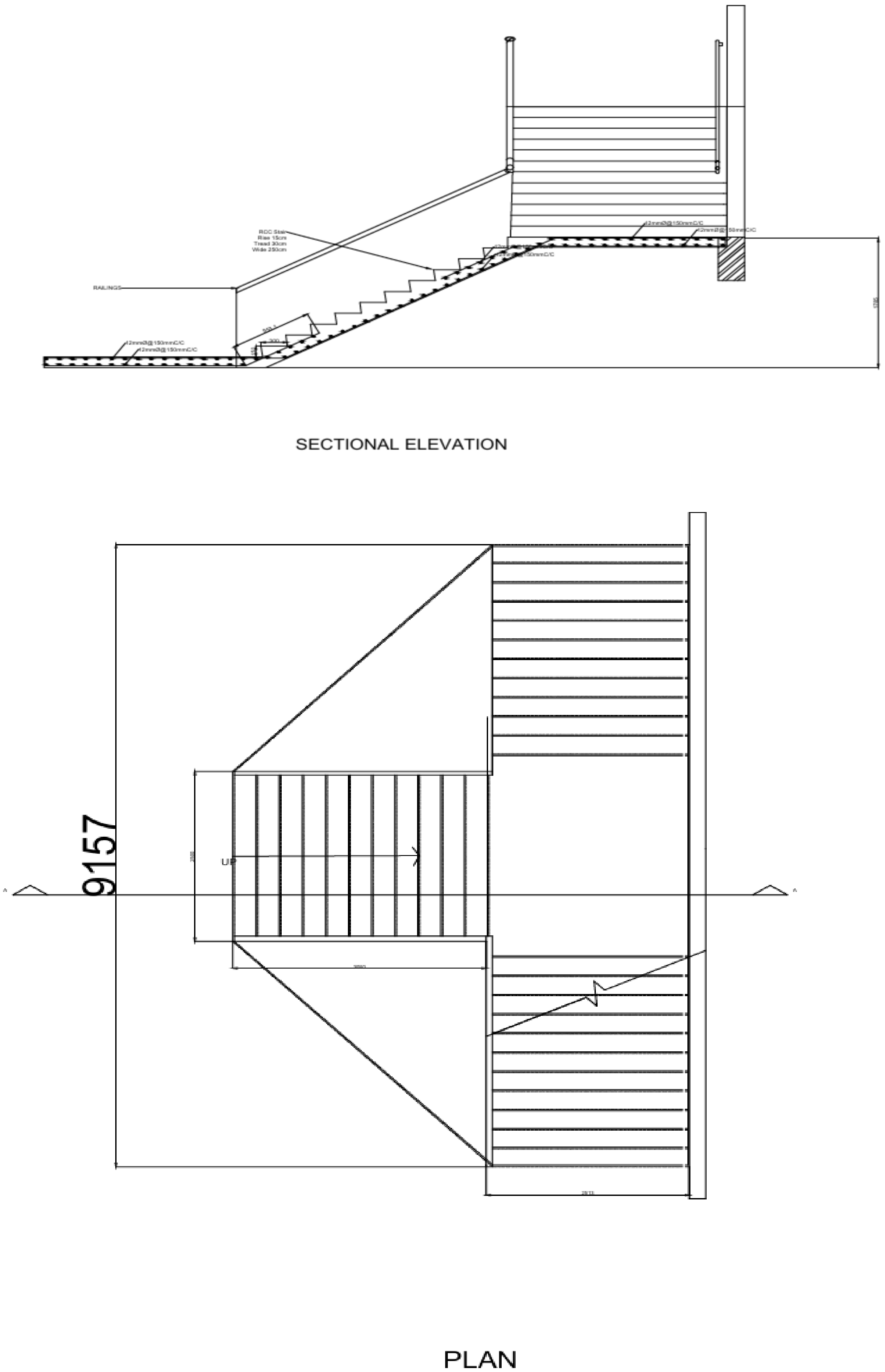


Fig 10.64 Stair design

Fig 10.64 depicts a detailed drawing of a stair, including dimensions.

CHAPTER 11

ENERGY MODELING AND ANALYSIS

11.1 GENERAL

GBS is a cloud-based analysis service by Autodesk, revolutionizing the way architects and engineers evaluate building designs for environmental performance. By leveraging advanced simulation algorithms and cloud computing infrastructure, GBS allows users to seamlessly import building models and define detailed properties such as materials, occupancy schedules, and HVAC systems. Through comprehensive simulation capabilities, users can assess energy consumption, lighting levels, solar radiation, and other key performance metrics, enabling informed design decisions. GBS supports iterative design optimization by facilitating the quick evaluation of design alternatives and the identification of areas for improvement. Its intuitive interface and robust reporting tools streamline the analysis process, empowering users to generate detailed reports and share results with project stakeholders for collaboration and decision-making. With GBS, sustainable design practices are not only achievable but also integrated seamlessly into the design workflow, fostering the creation of environmentally responsible buildings.

Fig 11.1 Welcome page

11.2 ENERGY MODELLING

1. The first step is accessing GBS. Visit the Autodesk website and log in to your account. Navigate to the GBS web portal.

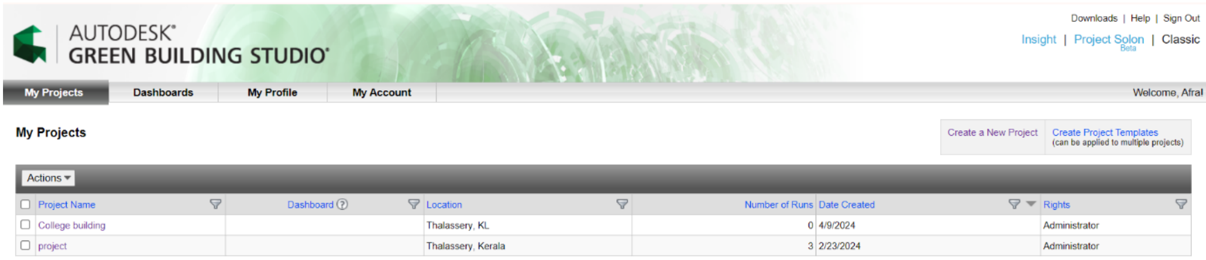


Fig 11.2 Interface of GBS

2. Click on the "Create New Project" button to initiate a new analysis.

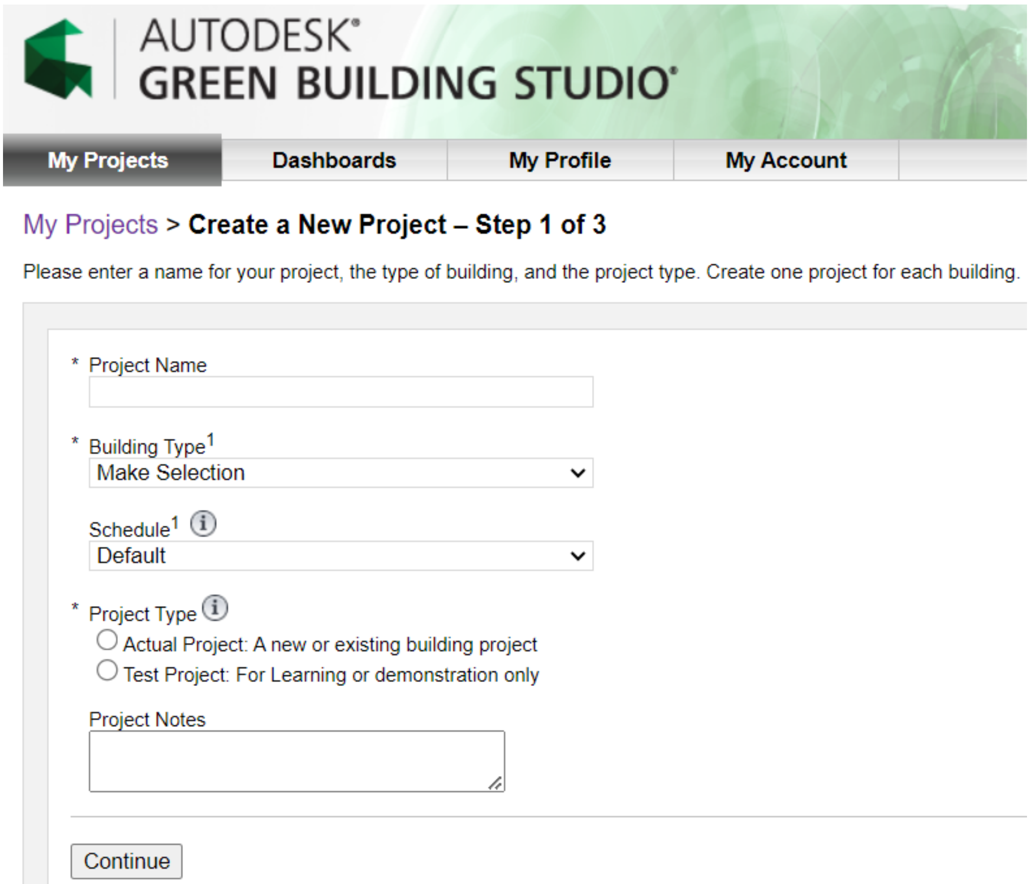


Fig 11.3 Project details

3. Enter the project details such as project name, location, building type (commercial, residential, educational, etc.), schedule of the building and a brief project description outlining its goals and scope.

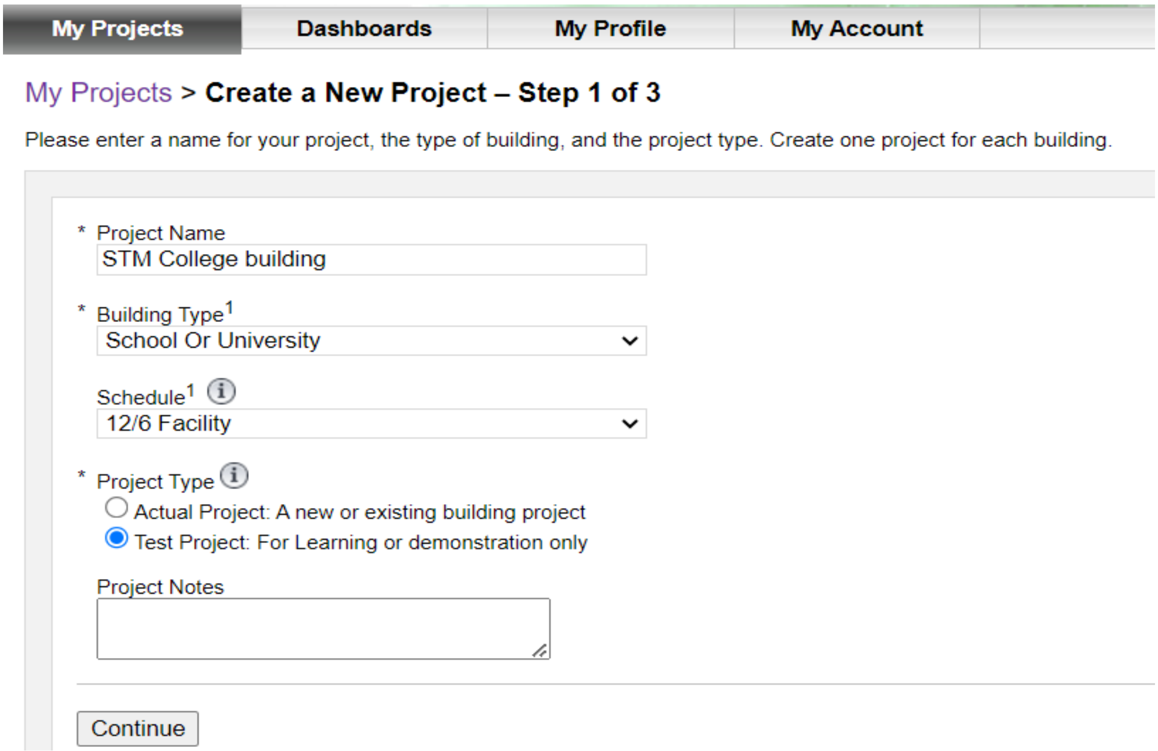


Fig 11.4 Assigning project details

4. Enter the precise location of the building and move the building icon to the site.

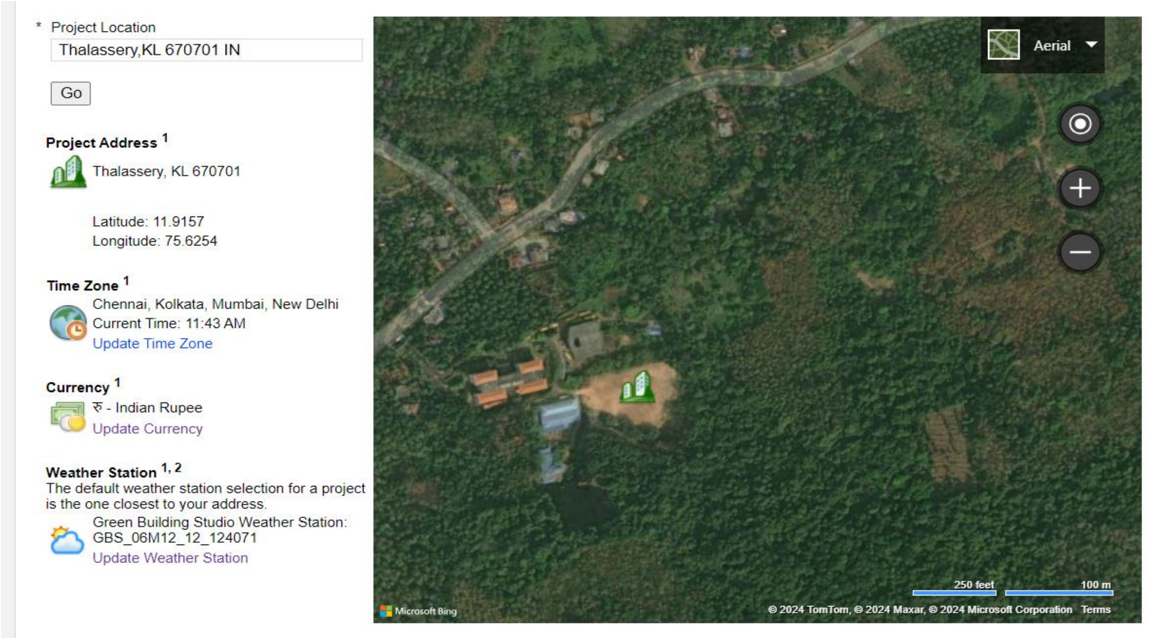


Fig 11.5 Choosing the location

5. The project is now created and ready for energy modelling. Go to project defaults for selecting building properties including construction materials for walls, roofs, floors, and glazing, etc.

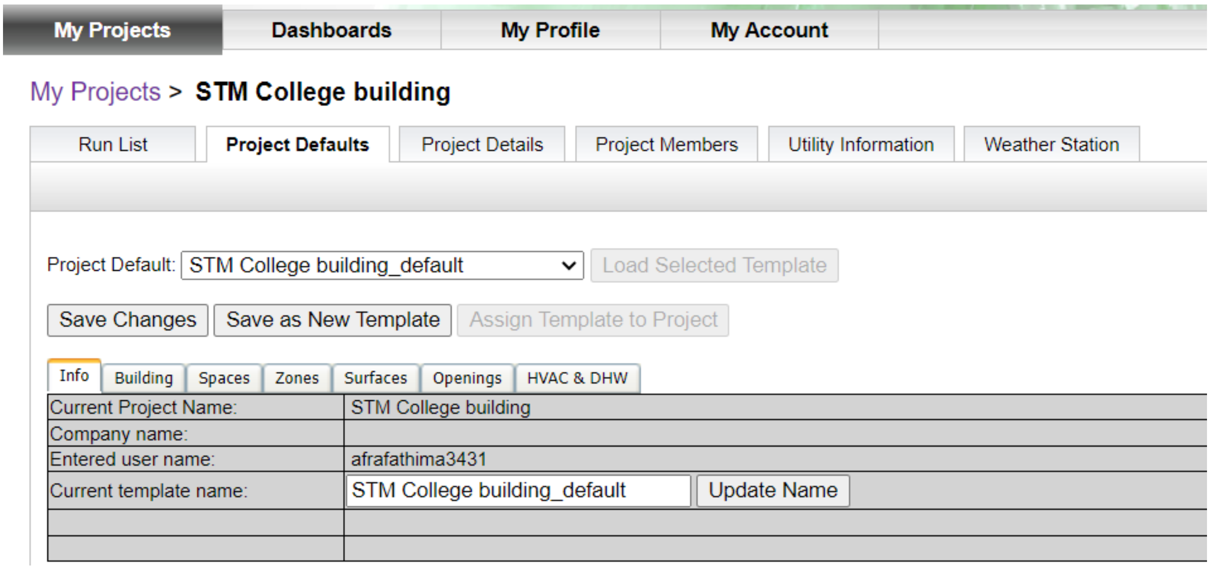


Fig 11.6 Project defaults

6. Selecting condition and space type from spaces.

Condition type: Naturally vented only

Space type: Classroom or lecture or training

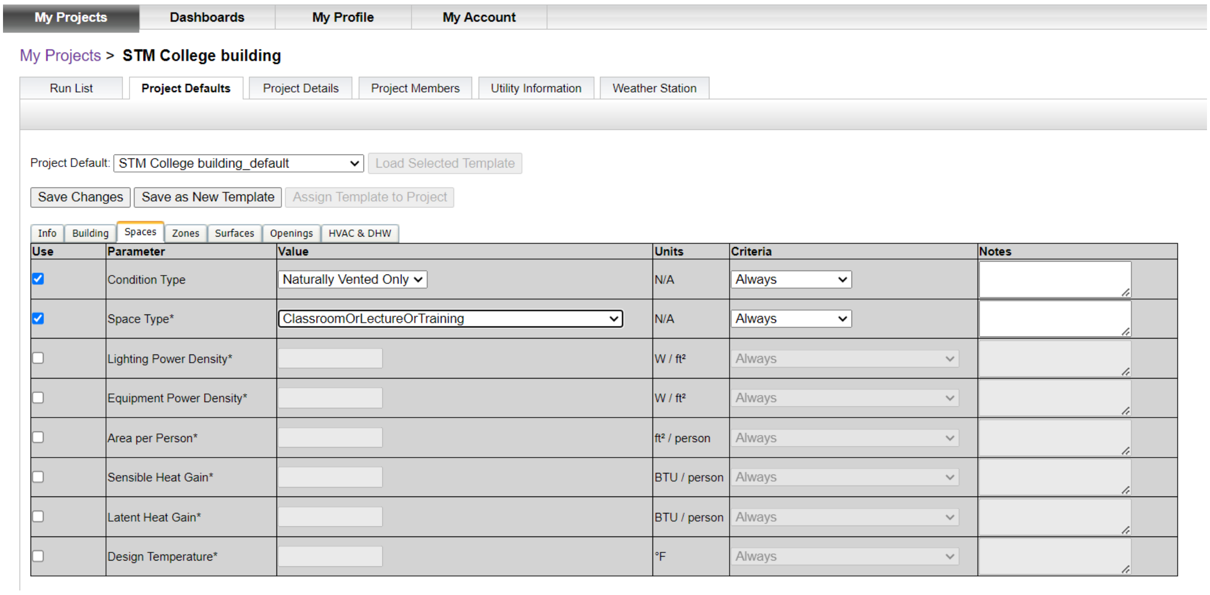


Fig 11.7: Selecting condition and space type

7. Assigning cooling and heating setpoints.

Cooling and heating setpoints refer to the desired temperature ranges at which a building's cooling and heating systems are activated to maintain thermal comfort for occupants. These setpoints are crucial parameters in building energy management, as they directly impact energy consumption and occupant comfort.

Cooling on setpoint: 77

Cooling off setpoint: 77

Heating on setpoint: 70

Heating off setpoint: 70

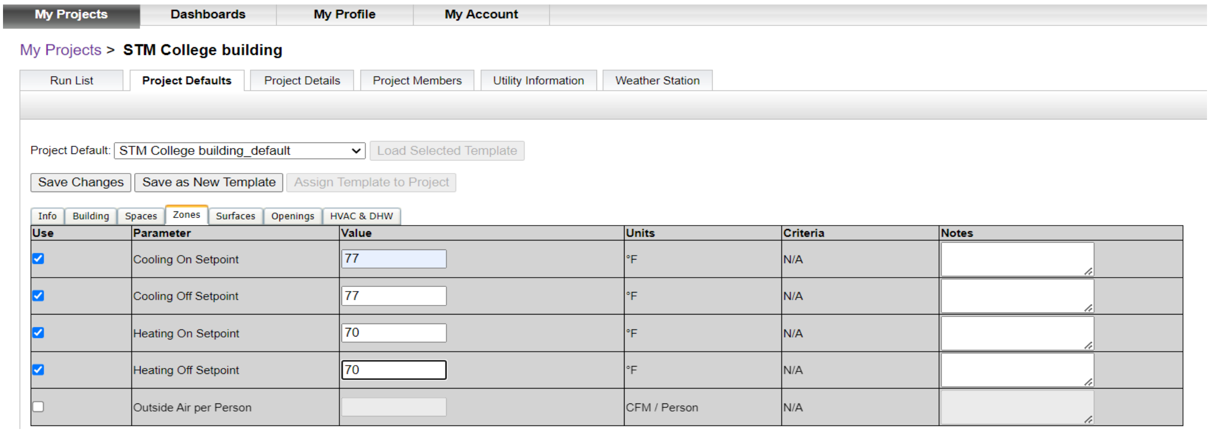


Fig 11.8 Assigning setpoints

8. Assigning construction materials for exterior and interior walls, roof, floors, ceiling and door.

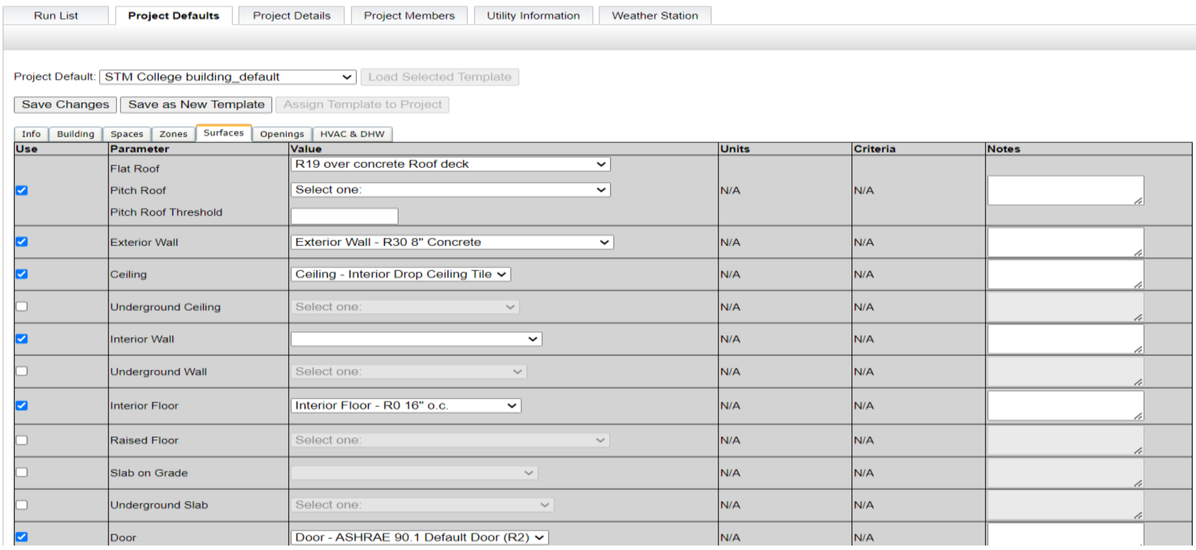


Fig 11.9 Assigning construction materials

9. Assign the opening properties for North glaze, non-north glaze and skylight glaze.

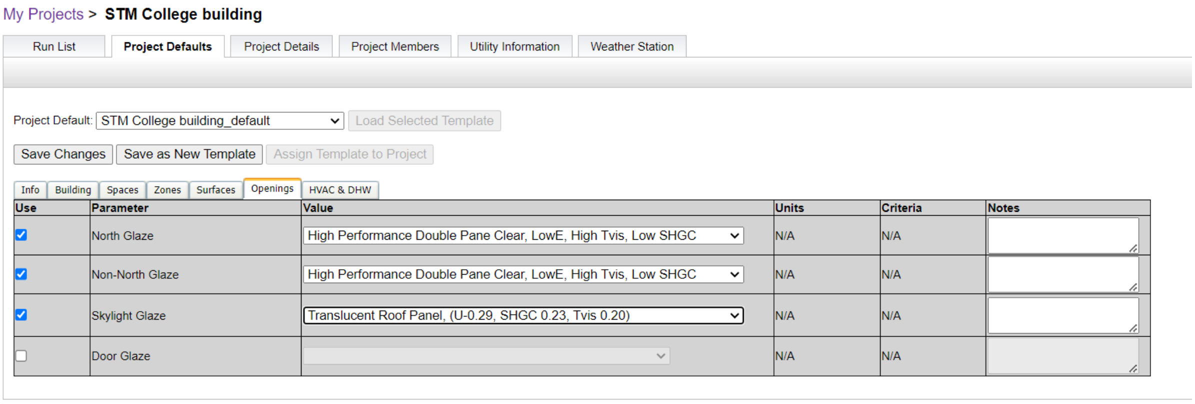


Fig 11.10 Glazing details

10. Save the parameters defined and go to run list. Go to actions and upload the gbXML file of the building from Revit.

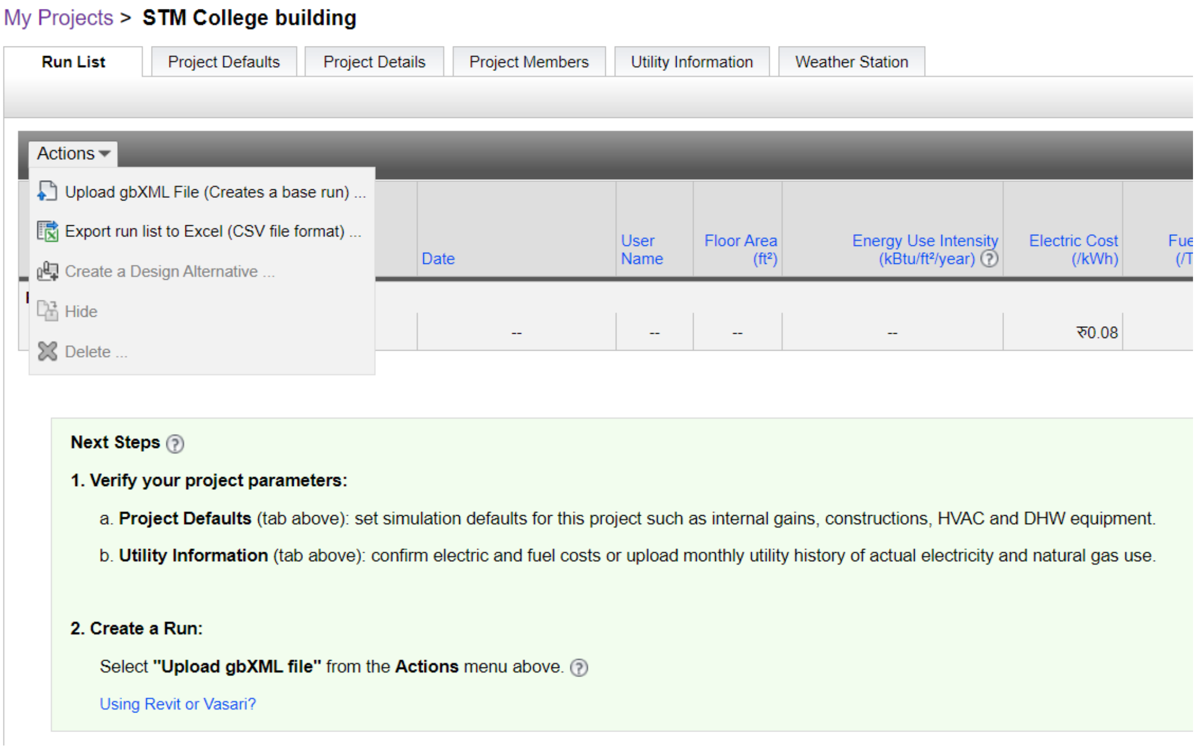


Fig 11.11 Uploading the gbXML file from revit

11. GBS will automatically run the building after uploading.

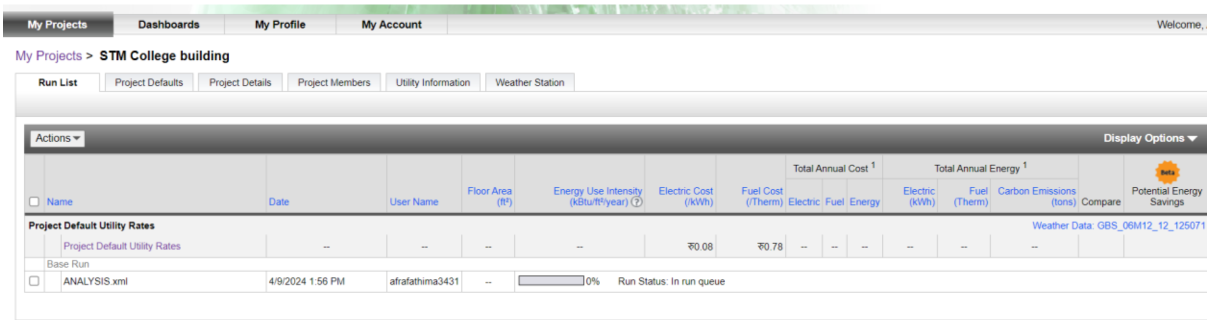


Fig 11.12 Base run

11.3 MODELLING RESULTS

1. Base run details including annual energy cost, annual energy used and lifecycle cost.

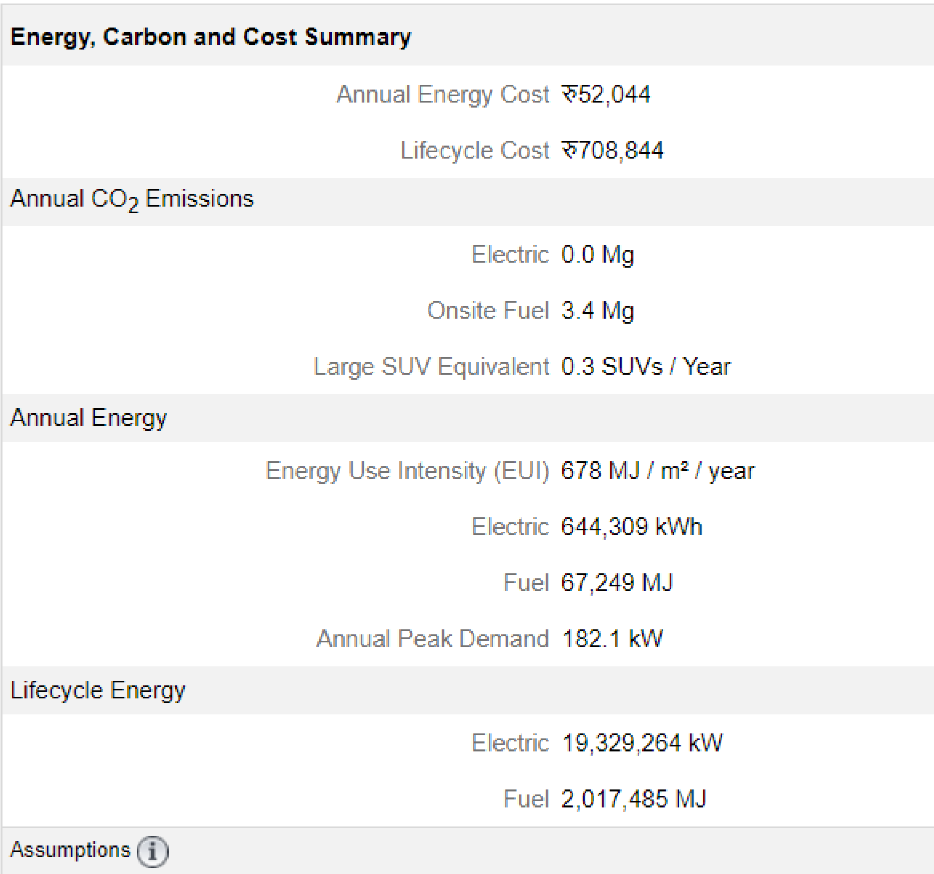


Fig 11.13 Base run results

2. Natural ventilation potential

Natural Ventilation Potential	
Total Hours Mechanical Cooling Required:	4,242 Hours
Possible Natural Ventilation Hours:	19 Hours
Possible Annual Electric Energy Savings:	1,347 kWh
Possible Annual Electric Cost Savings:	₹108
Net Hours Mechanical Cooling Required:	4,223 Hours

Fig 11.14 Ventilation potential

3. Water usage and cost

Water Usage and Costs

Total:	**4,862,806 L / yr**	**₹86,339 / yr**
Indoor:	4,562,181 L / yr	₹78,824 / yr
Outdoor:	300,625 L / yr	₹7,516 / yr
Net Utility:	**3,330,006 L / yr**	₹84,929 / yr

Source: AWWA Research Foundation 2000 Residential / Commercial and Institutional End Uses of Water.

Fig 11.15 Water usage

4. Annual energy end use charts

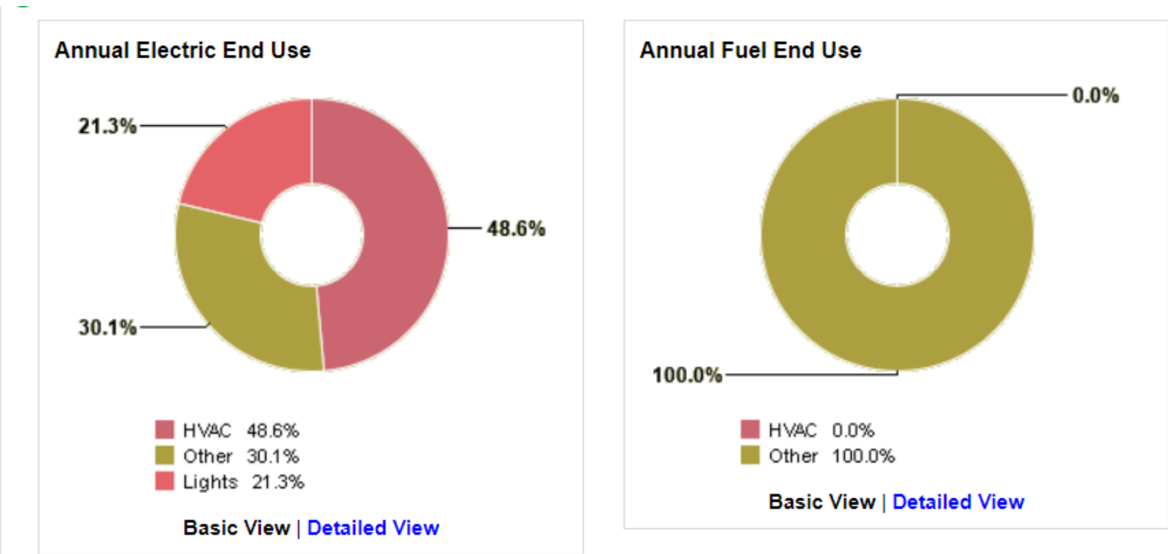


Fig 11.16 Energy end use charts

11.4 RESULTS

1. Base run details: The annual energy cost and lifecycle cost are provided, with a significant portion attributed to HVAC operations. The annual CO_2 emissions indicate a relatively low environmental impact from electric usage but a noticeable impact from onsite fuel usage.
2. Natural ventilation potential: The building has a limited capacity for natural ventilation, with only 19 out of 4,242 total hours suitable for it. This results in minimal annual electric energy savings and cost savings. However, there is still potential to optimize ventilation strategies to reduce mechanical cooling requirements further.
3. Water usage and costs: The total water usage is significant, with the majority being consumed indoors. There's a noticeable net utility cost associated with water usage, indicating potential for efficiency improvements or conservation measures, particularly in indoor water usage.
4. Annual electric end use and annual fuel end use: HVAC accounts for a significant portion of both annual electric and fuel end use. This highlights the importance of optimizing HVAC systems for energy efficiency to reduce overall energy consumption and costs.

CHAPTER 12

COST ESTIMATION

12.1 GENERAL

Cost estimation is the process of predicting the expenses for a project by evaluating factors like materials, labor, and overhead costs. It's crucial for project planning, budgeting, and control, providing stakeholders with accurate forecasts to make informed decisions and optimize resource allocation. Effective cost estimation minimizes financial risks and helps ensure projects stay within budgetary limits.

The estimate may be prepared approximately as a preliminary estimate by various methods without going into details of the different items of work, to know the approximate cost or rough cost. Accurate estimate is prepared in detail item wise by detailed estimate. The work is divided into different items of work and the quantities under each item are taken out and then an ‘Abstract of estimated cost is prepared at suitable rates,

From the detailed estimate the quantities of various materials and labour required may also be calculated. It also gives an idea of the time required for the completion of the work. The estimate is also required for inviting tenders and to arrange contracts and to control the expenditure during the execution.

12.2 DATA FOR ESTIMATE

To make out an estimate for a work the following data are necessary

1. Drawing (plans, section, etc.)
2. Specifications
3. Rates

12.3 ESTIMATION TYPE

Detailed Estimate or Item Rate Estimate- Detailed estimate is an accurate estimate and consists of working out the quantities of each item of work and working the cost. The dimensions, length, breadth and height of each item are taken out, correctly froes drawing, and quantity of each item are calculated and obstructing and billing are done.

The detailed estimate is prepared in two stages: -

1) Details of measurement and calculation of Quantities -

The whole work is divided into different items of work as earthwork, concrete, brick work etc. and the items are classified and grouped under different sub heads, and details of measurement of each item of work are taken out and quantities under each item are computed in prescribed forma Details of Measurement Form.

Table 12.1 Detailed estimate sample

Item no	Description/ Particulars	No.	Length	Breadth	Height/Depth	Quantity

2. Abstract of estimated cost -

The cost under the item of work is calculated from the quantities already computed at a workable rate and the total cost is worked out in a prescribed form, Abstract of Estimate Form. A percentage of 3 to 5% is added for contingencies, to allow for petty contingent expenditures, changes in design, change in rates etc. which may occur during the execution of the work. The grand total thus obtained is the estimated cost of the work.

Abstract of Estimate Form-

Table 12.2 Abstract sample

Item no	Description/ Particulars	Quantity	Unit	Rate	Amount

12.4 PREPARATION OF ESTIMATION

The estimation phase of our project stands as a pivotal pillar, guiding the entirety of our endeavor towards success. Through meticulous analysis of drawings, specifications, and rates sourced from reputable standards such as CPWD DSR, we meticulously quantify and evaluate each aspect of the project. With the help of user-friendly tools such as Microsoft Excel, we ensured our calculations are accurate. Our aim is to provide clear and reliable estimates that empower all involved parties to make informed decisions.

12.5 QUANTITY ESTIMATION

Table 12.3 Detailed estimation

Item No	Description	No	Length	Breadth	Depth	Quantity
1	Excavation work by mechanical means in foundation trenches or drains (not exceeding 1.5m in width or $10m^2$ on plan), including dressing of sides and ramming of bottoms, lift to 1.5m, including getting out the excavated soil and disposal of surplus excavated soils as directed, within a lead of 50m.					
	F1	6	1.5	1.5	2	27.00
	F2	40	1.6	1.45	2	185.60
	F3	7	2	1.85	2	51.80
	F4	30	1.9	1.75	2	199.50
	F5	1	5.9	4.2	2	49.56
	GRAND TOTAL FOR EXCAVATION WORK	513.46				
2	PCC 1:4:8 (1 Cement: 4 coarse sand (zone-III) derived from natural sources: 8 graded stone aggregate 40mm nominal size derived from natural sources).					
	F1	6	1.5	1.5	0.15	2.03
	F2	40	1.6	1.45	0.15	13.92
	F3	7	2	1.85	0.15	3.89
	F4	30	1.9	1.75	0.15	14.96
	F5	1	5.9	4.2	0.15	3.72
	GRAND TOTAL FOR PCC	38.51				
3	RCC 1:1.5:3 using 20mm broken stone for footing, beam, column, lintel etc. Including formwork, watering, curing, cost of conveyance and all labour charges, etc. complete.					
	Column footing					
	F1	6	1.2	1.2	0.325	2.81
	F2	40	1.3	1.15	0.7	41.86
	F3	7	1.7	1.55	0.475	8.76
	F4	36	1.6	1.45	0.425	35.50
	Total for footing	88.93				
	Column					

	Column up to plinth					
	Circular column					
	500 dia.	2	0.5	0.5	1.5	2.35
	600 dia.	4	0.6	0.6	1.5	6.78
	Rectangular column					
	350 X 600	55	0.35	0.6	1.5	17.33
	400 X 600	15	0.4	0.6	1.5	5.40
	450 X 700	3	0.45	0.7	1.5	1.42
	400 X 700	10	0.4	0.7	1.5	4.20
	300 X 300	5	0.3	0.3	1.5	0.68
	550 X 700	1	0.55	0.7	1.5	0.58
	600 X 750	1	0.6	0.75	1.5	0.68
	Ground floor column					
	Circular column					
	500 dia.	2	0.5	0.5	3.6	5.65
	600 dia.	4	0.6	0.6	3.6	16.28
	Rectangular column					
	350 X 600	55	0.35	0.6	3.6	41.58
	400 X 600	15	0.4	0.6	3.6	13.96
	450 X 700	3	0.45	0.7	3.6	3.40
	400 X 700	10	0.4	0.7	3.6	10.08
	300 X 300	5	0.3	0.3	3.6	1.62
	550 X 700	1	0.55	0.7	3.6	1.39
	600 X 750	1	0.6	0.75	3.6	1.62
	First floor column					
	Circular column					
	600 dia.	4	0.6	0.6	3.6	16.28
	Rectangular column					
	350 X 600	55	0.35	0.6	3.6	41.58
	400 X 600	15	0.4	0.6	3.6	13.96
	450 X 700	3	0.45	0.7	3.6	3.40
	400 X 700	10	0.4	0.7	3.6	10.08
	300 X 300	5	0.3	0.3	3.6	1.62
	550 X 700	1	0.55	0.7	3.6	1.39
	600 X 750	1	0.6	0.75	3.6	1.62
	Second floor column					
	Circular column					
	600 dia.	4	0.6	0.6	3.6	16.28
	Rectangular column					
	350 X 600	55	0.35	0.6	3.6	41.58
	400 X 600	15	0.4	0.6	3.6	13.96
	450 X 700	3	0.45	0.7	3.6	3.40
	400 X 700	10	0.4	0.7	3.6	10.08

	300 X 300	5	0.3	0.3	3.6	1.62
	550 X 700	1	0.55	0.7	3.6	1.39
	600 X 750	1	0.6	0.75	3.6	1.62
	Total for column	311.83				
	Slab					
	First floor slab					
	S1	1	64	37.2	0.12	285.70
	S2 (Veranda)	1	34.68		0.12	4.16
	S3 (Porch)	1	6	7	0.12	5.04
	Deduction					
	Main stair	1	40.576		0.12	4.87
	Emergency stair	1	3.5	6	0.12	2.52
	Lift	1	3.8	2.5	0.12	1.14
	Total	286.37				
	Second floor slab					
	S1	1	64	37.2	0.12	285.70
	S2 (Veranda)	1	34.68		0.12	4.16
	Deduction					
	Main stair	1	40.576		0.12	4.87
	Emergency stair	1	3.5	6	0.12	2.52
	Lift	1	3.8	2.5	0.12	1.14
	Total	281.33				
	Third floor slab					
	S1	1.00	66.1	38.4	0.12	304.589
	S2 (Veranda)	1	34.68		0.12	4.16
	Deduction					
	Main stair	1	40.576		0.12	4.87
	Emergency stair	1	3.5	6	0.12	2.52
	Lift	1	3.8	2.5	0.12	1.14
	Total	300.22				
	Total for slab	867.92				
	Beam					
	Plinth beam					
	250 X 300	1	36.1	0.25	0.3	2.71
	250 X 400	1	34	0.25	0.4	3.40
	250 X 450	1	440.9	0.25	0.45	49.60
	250 X 500	1	53.9	0.25	0.5	6.74
	250 X 600	1	356.7	0.25	0.6	53.51
	250 X 700	1	6.4	0.25	0.7	1.12
	300 X 600	1	113.3	0.3	0.6	20.39
	Total plinth beam	137.47				
	Ground floor beam					
	250 X 300	1	9.1	0.25	0.18	0.41

	250 X 400	1	38.6	0.25	0.28	2.70
	250 X 450	1	268.9	0.25	0.33	22.18
	250 X 600	1	148.5	0.25	0.48	17.82
	300 X 300	1	20.2	0.3	0.18	1.09
	300 X 400	1	93.4	0.3	0.28	7.85
	300 X 450	1	207.2	0.3	0.33	20.51
	300 X 500	1	13.6	0.3	0.38	1.55
	300 X 600	1	302.6	0.3	0.38	34.50
	300 X 700	1	108.6	0.3	0.58	18.90
	300 X 750	1	29.3	0.3	0.63	5.54
	Total ground floor beam	133.05				
	First floor beam					
	250 X 300	1	9.1	0.25	0.18	0.41
	250 X 400	1	38.6	0.25	0.28	2.70
	250 X 450	1	268.9	0.25	0.33	22.18
	250 X 600	1	148.5	0.25	0.48	17.82
	300 X 300	1	20.2	0.3	0.18	1.09
	300 X 400	1	93.4	0.3	0.28	7.85
	300 X 450	1	207.2	0.3	0.33	20.51
	300 X 500	1	13.6	0.3	0.38	1.55
	300 X 600	1	302.6	0.3	0.38	34.50
	300 X 700	1	108.6	0.3	0.58	18.90
	300 X 750	1	29.3	0.3	0.63	5.54
	Total first floor beam	133.05				
	Second floor beam					
	250 X 300	1	9.1	0.25	0.18	0.41
	250 X 400	1	38.6	0.25	0.28	2.70
	250 X 450	1	243.3	0.25	0.33	20.07
	250 X 600	1	148.5	0.25	0.48	17.82
	300 X 300	1	20.2	0.3	0.18	1.09
	300 X 400	1	93.4	0.3	0.28	7.85
	300 X 450	1	207.2	0.3	0.33	20.51
	300X 500	1	13.6	0.3	0.38	1.55
	300X 600	1	334.6	0.3	0.38	38.14
	300X 700	1	108.6	0.3	0.58	18.90
	300X 750	1	29.3	0.3	0.63	5.54
	Total second floor beam	134.58				
	Terrace floor beam					
	300 X 600	1	33	0.3	0.6	5.94
	Total terrace floor beam	5.94				
	Total for beam	409.50				
	lintels					
	Ground floor	1	340	0.2	0.15	10.20

	First floor	1	340	0.2	0.15	10.20
	Second floor	1	340	0.2	0.15	10.20
	Total for lintel	30.60				
	Total for beam and lintel	440.10				
	Stair					
	Waist slab	3	10.8	2.5	0.15	13.15
	Landing	3	3	2.5	0.15	3.38
	Steps	36	2.5	0.3	0.15	4.05
	Total for steps in 3 floors	19.58				
	Emergency Stair					
	Waist slab	3.00	7.46	1.5	0.15	5.0355
	Landing	6.00	1.5	1.5	0.15	2.025
	Steps	36.00	1.5	0.3	0.15	2.43
	Total for emergency steps in 3 floors	9.49				
	Total stair and slab	896.98				
4	Earth filling of inside portion of basement including all cost of conveyance, labour charges, ramming, watering etc. Complete					
	Lecture hall	6	7	12	0.45	226.80
	Laboratory 1	2	18	15	0.45	243.00
	Laboratory 2	2	15.2	17.4	0.45	238.03
	Administrative room	1	8.9	7	0.45	28.04
	Conference room	1	8.9	7	0.45	28.04
	Sick room	2	3.8	3.2	0.45	10.94
	Toilet	2	7	6.9	0.45	43.47
	Store	1	3.8	2.3	0.45	3.93
	GRAND TOTAL FOR EARTH FILLING	822.25				
5	AAC nearly dressed stone in cement mortar 1:6 including cost of conveyance, all labour charges etc. complete.					
	Ground floor					
	Super structure wall 20cm	1	603	0.2	3.1	373.86
	Super structure wall 10cm	1	72.7	0.1	2.5	18.18
	Front verandah step					
	Step 1	1	2	0.3	0.15	0.09
	step 2	1	3.2	0.3	0.15	0.14
	Total	392.27				
	Deduction					
	D1	29	1	0.2	2.1	13.18

	D2	26	0.9	0.2	2.1	9.83
	D3	1	2.5	0.2	2.1	1.05
	For window W	92	1.5	0.2	1	27.60
	For ventilator V	128	1.5	0.2	0.5	19.20
	Total	69.86				
	AAC work for ground floor	322.41				
	First Floor					
	Super structure wall 20cm	1	603	0.2	3.1	373.86
	Super structure wall 10cm	1	72.7	0.1	2.5	18.18
	Total	392.04				
	Deduction					
	D1	29	1	0.2	2.1	13.18
	D2	26	0.9	0.2	2.1	9.83
	D3	1	2.5	0.2	2.1	1.05
	For window W	92	1.5	0.2	1	27.60
	For ventilator V	128	1.5	0.2	0.5	19.20
	Total	69.86				
	AAC work for first floor	322.177				
	Second Floor					
	Super structure wall 20cm	1	603	0.2	3.1	373.86
	Super structure wall 10cm	1	72.7	0.1	2.5	18.18
	Total	392.04				
	Deduction					
	D1	29	1	0.2	2.1	13.18
	D2	26	0.9	0.2	2.1	9.83
	D3	1	2.5	0.2	2.1	1.05
	For window W	92	1.5	0.2	1	27.60
	For ventilator V	128	1.5	0.2	0.5	19.20
	Total	69.86				
	AAC work for second floor	322.177				
	GRAND TOTAL FOR AAC WORK	966.77				
6	Providing and laying vitrified floor tiles laid on 20mm thick cement mortar 1:4 (1 cement: 4 coarse sand), jointing with grey cement slurry @ 3.3 kg/sqm including grouting the joints with white cement and matching pigments etc. including the subbase of cement concrete 1:4:8 50mm thick, complete.					
	Ground floor	1	2400			2400.00

7	Providing and laying vitrified floor tiles laid on 20mm thick cement mortar 1:4 (1 cement: 4 coarse sand), jointing with grey cement slurry @ 3.3 kg/sqm including grouting the joints with white cement and matching pigments etc., complete.					
	First Floor	1	2500			2400.00
	Second floor	1	2400			2400.00
	TOTAL FOR FLOORING first and second floor	4800.00				
8	Plastering with C.M 1:4, 12mm thick one coat loathed hard and trowel led smooth including cost of conveyance and all labour charges etc. complete.					
	Ground floor					
	Lecture hall	6	38		3.6	820.80
	Laboratory 1	2	66		3.6	475.20
	Laboratory 2	2	65.2		3.6	469.44
	Administrative room	1	31.8		3.6	114.48
	Conference room	1	31.8		3.6	114.48
	Sick room	2	14		3.6	100.80
	Toilet	2	27.8		3.6	200.16
	Passage	1	213.6		3.6	768.96
	Store	1	13.2		3.6	43.92
	Outer wall	1	190		3	570.00
	Verandah column	4	3.14	5*5	3.6	1130.40
	Car porch column	2	3.14	6*6	3.6	813.88
	Front verandah step					
	Step 1	1	2	0.3	0.15	0.09
	step 2	1	3.2	0.3	0.15	0.14
	Stair					
	Waist slab	3	10.8	0.25	0.15	1.22
	Landing	3	3	2.5	0.15	3.38
	Steps	108	2.5	0.3		81.00
	Total	5708.34				
	Deduction					
	D1	29	1		2.1	60.90
	D2	26	0.9		2.1	49.14
	D3	1	2.5		2.1	5.25
	For window W	92	1.5		1	138.00
	For ventilator V	128	1.5		0.5	96.00

	Total	349.29				
	Plastering for ground floor	5359.05				
	First floor					
	Lecture hall	6	38		3.6	820.80
	Laboratory 1	2	66		3.6	475.20
	Laboratory 2	2	65.2		3.6	469.44
	Staff room	1	31.8		3.6	114.48
	Staff room	1	31.8		3.6	114.48
	Sick room	2	14		3.6	100.80
	Toilet	2	27.8		3.6	200.16
	Passage	1	213.6		3.6	768.96
	Store	1	13.2		3.6	43.92
	Outer wall	1	190		3.6	684.00
	Verandah column	4	3.14	5*5	3.6	1130.40
	Stair					
	Waist slab	3	10.8	0.25	0.15	1.22
	Landing	3	3	2.5	0.15	3.38
	Steps	108	2.5	0.3		81.00
	Total	5008.23				
	Deduction					
	D1	29	1		2.1	60.90
	D2	26	0.9		2.1	49.14
	D3	1	2.5		2.1	5.25
	For window W	92	1.5		1	138.00
	For ventilator V	128	1.5		0.5	96.00
	Total	349.29				
	Plastering for first floor	4658.94				
	Second floor					
	Lecture hall	6	38		3.6	820.80
	Laboratory 1	1	66		3.6	237.60
	Laboratory 2	2	65.2		3.6	469.44
	Staff room	1	31.8		3.6	114.48
	Sports room	1	31.8		3.6	114.48
	Sick room	2	14		3.6	100.80
	Toilet	2	27.8		3.6	200.16
	Passage	1	213.6		3.6	768.96
	Store	1	13.2		3.6	43.92
	Outer wall	1	190		3.6	684.00
	Verandah column	4	3.14	5*5	3.6	45.22
	Drawing hall	1	47.8		3.6	172.08
	Seminar hall	1	47.8		3.6	172.08
	Stair					
	Waist slab	3	10.8	0.25	0.15	1.22

	Landing	3	3	2.5	0.15	3.38
	Steps	108	2.5	0.3		81.00
	Total	4029.61				
	Deduction					
	D1	29	1		2.1	60.90
	D2	26	0.9		2.1	49.14
	D3	1	2.5		2.1	5.25
	For window W	92	1.5		1	138.00
	For ventilator V	128	1.5		0.5	96.00
	Total	349.29				
	Plastering for second floor	3680.32				
	GRAND TOTAL FOR PLASTERING	13698.31				
9	6mm cement plaster 1:3 (1 cement: 3 fine sand) finished with a floating coat of neat cement and thick coat of Lime wash on top of walls when dry for bearing of R.C.C. slabs and beams.					
	Ceiling					
	Ground floor	1	2400			2400.00
	First floor	1	2400			2400.00
	Second floor	1	2600			2400.00
	GRAND TOTAL FOR CEILING	7200.00				
10	Supplying and fixing steel doors and pvc windows including all hardware fittings.					
	D1	88				88
	D2	78				78
	D3	3				3
	For window W	276				276
	For ventilator V	384				384

12.6 ABSTRACT

Table 12.4 Abstract

Item No	DESCRIPTION	QUANTITY	UNIT	RATE	PER	AMOUNT
1	Excavation work by mechanical means in foundation trenches or drains (not exceeding 1.5m in width or 10 sqm on plan), including dressing of sides and ramming of bottoms, lift up to 1.5 m, including getting out the excavated soil and disposal of surplus excavated soils as directed, within a lead of 50 m.	513.46	cum	632.95	cum	324994.51
2	P.C.C 1:4:8 using 40mm nominal size hard granite stone including cost of conveyance and all labour charge, etc. complete for foundation.	38.51	cum	6812	cum	262326.71
3	R.C.C 1:1.5:3 using 20mm broken stone for column footing, including formwork, watering, curing, cost of conveyance, and all labour charges, etc. complete.	88.93	cum	10065	cum	895033.90
4	R.C.C 1:1.5:3 using 20mm broken stone for column, etc. including formwork, watering, curing, cost of conveyance, and all labour charges, etc. complete.	311.83	cum	19503.95	cum	6081902.69
5	R.C.C 1:1.5:3 using 20mm broken stone for lintel, beam, etc. including formwork, watering, curing, cost of	440.10	cum	19237.20	cum	8466233.05

	conveyance, and all labour charges, etc. complete.					
6	R.C.C 1:1.5:3 using 20mm broken stone for slab, stair, etc. including formwork, watering, curing, cost of conveyance, and all labour charges, etc. complete.	896.98	cum	19199.00	cum	17221190.82
7	Reinforcement for RCC work	145440.00	kg	107.85	kg	15685704.00
8	Earth filling of inside portion of basement including all cost of conveyance, labour charges, ramming, watering, etc. complete.	822.25	cum	650.00	cum	534461.85
9	AAC in cement mortar 1:6 including cost of conveyance, all labour charges, etc. complete.	966.77	cum	10195.45	cum	9856604.22
10	Providing and laying vitrified floor tiles laid on 20 mm thick cement mortar 1:4 (1 cement: 4 coarse sand), jointing with grey cement slurry @ 3.3 kg/ sqm including grouting the joints with white cement and matching pigments etc. including the subbase of cement concrete 1:4:8 50mm thick., complete.	2400.00	sqm	2389.00	sqm	5733600.00
11	Providing and laying vitrified floor tiles laid on 20mm thick cement mortar 1:4 (1 cement: 4 coarse sand), jointing with grey cement slurry @ 3.3 kg/ sqm including grouting the joints with white cement and matching	4800.00	sqm	2089.65	sqm	10030320.00

	pigments etc., complete.					
12	Plastering with C.M 1:4, 12mm thick one coat floated hard and trowel led smooth including all cost and conveyance and all labour charges etc. complete.	13698.31	sqm	347.05	sqm	4753998.486
13	6mm cement plaster 1:3 (1 cement: 3 fine sand) finished with a floating coat of neat cement and thick coat of Lime wash on top of walls when dry for bearing of R.C.C. slabs and beams.	7200.00	sqm	396.65	sqm	2855880
14	Supplying and fixing steel doors and pvc windows including all hardware fittings					
	D1	88	nos	14000	nos	1232000
	D2	78	nos	6000	nos	468000
	D3	3	nos	8000	nos	24000
	For window W	276	nos	12000	nos	3312000
	For ventilator V	384	nos	4000	nos	1536000
15	Finishing walls with 100% Premium acrylic emulsion paint having VOC less than 50 gm/litre and UV resistance	20898.31	sqm	146.2	sqm	3055332.922
	Steel	60.52	kg	117.35	kg	7102.022
	Wood	4.38	sqm	3747.3	sqm	16413.174
16	Provision for lift and accessories					4000000.00
17	Provision for solar panel					2000000.00
	Total	₹ 9,83,53,098.35				
	Cost of architectural work 1%					9,39,670.98
	Cost of water supply work 5 %					46,98,354.92

	Cost of sanitary work 5%					46,98,354.92
	Cost of electrification work 6%					56,38,025.90
	Unforeseen item					20,58,494.93
	GRAND TOTAL	**₹ 11,70,00,000.00**				

The construction project encompasses a comprehensive scope, meticulously detailed across various activities and materials. Excavation work, crucial for laying the foundation, is priced at ₹324,994.51 for 513.46 cubic meters, with meticulous attention to dressing sides and ramming bottoms. Concrete works are itemized, from P.C.C to R.C.C mixes for footings, columns, lintels, beams, slabs, and stairs, each meticulously costed, totaling ₹30,433,065.36. Reinforcement for R.C.C work adds further detail, with 145,440kg priced at ₹10,785 per kg, amounting to ₹15,685,704. Earth filling, AAC, and vitrified floor tiling follow suit, ensuring a comprehensive approach to every aspect of construction. The inclusion of plastering, steel doors, PVC windows, and finishing walls with premium acrylic emulsion paint demonstrates attention to both structural integrity and aesthetic appeal. Moreover, provisions for lift installation and solar panels anticipate future needs. Factoring in costs for architectural, water supply, sanitary, and electrification works, alongside an allowance for unforeseen items, the grand total amounts to a substantial ₹117,000,000.00, reflecting the thoroughness and foresight embedded within this construction endeavor.

CHAPTER 13

3D VISUALIZATION

13.1 GENERAL

3D visualization stands as a transformative tool in modern architectural practice, revolutionizing the way we conceptualize and communicate designs. By translating abstract ideas into vivid, immersive representations, it bridges the gap between imagination and reality, offering a tangible preview of proposed structures. Through the utilization of sophisticated software tools like Twinmotion, architects can seamlessly transform 3D models into dynamic visualizations, immersive VR experiences, and captivating visualization videos, ultimately enriching the understanding and appreciation of architectural designs.

13.2 TWINMOTION VISUALIZATION

Twinmotion serves as a real-time visualization tool, empowering users to generate high-quality images, panoramas, standard or 360° VR videos, and interactive presentations directly from design data. Notably, any modifications made in Twinmotion reflect in real-time, ensuring a fluid design process.

1. Export from Revit: Open a 3D view of the Revit model you wish to export to Twinmotion.

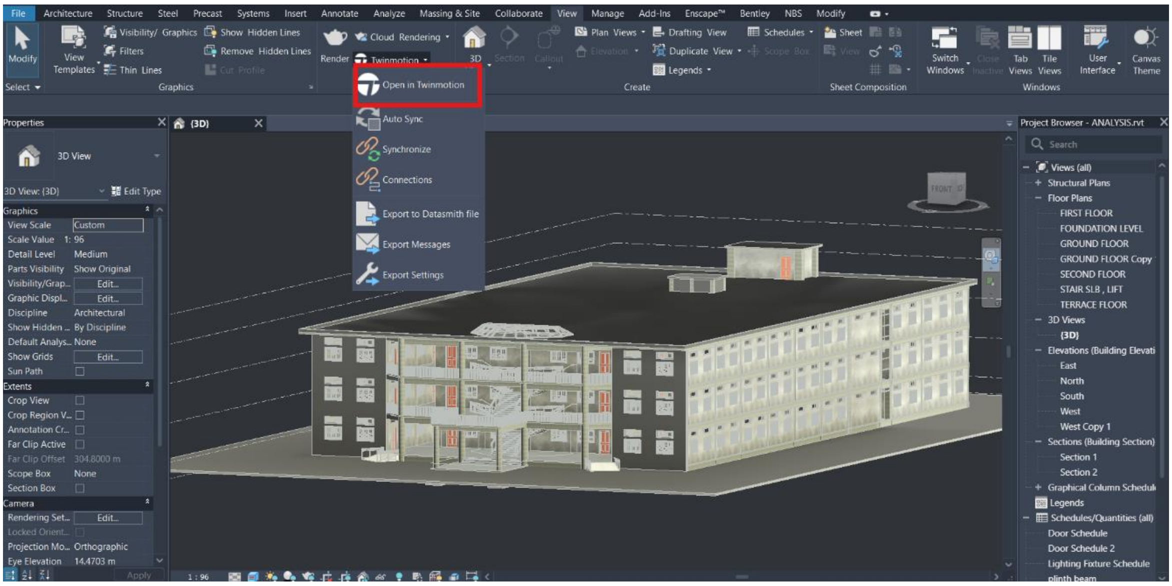


Fig 13.1 Exporting of 3D to twinmotion

2. Launch Twinmotion: Click "View Twinmotion Open in Twinmotion" within the Revit interface to launch Twinmotion.

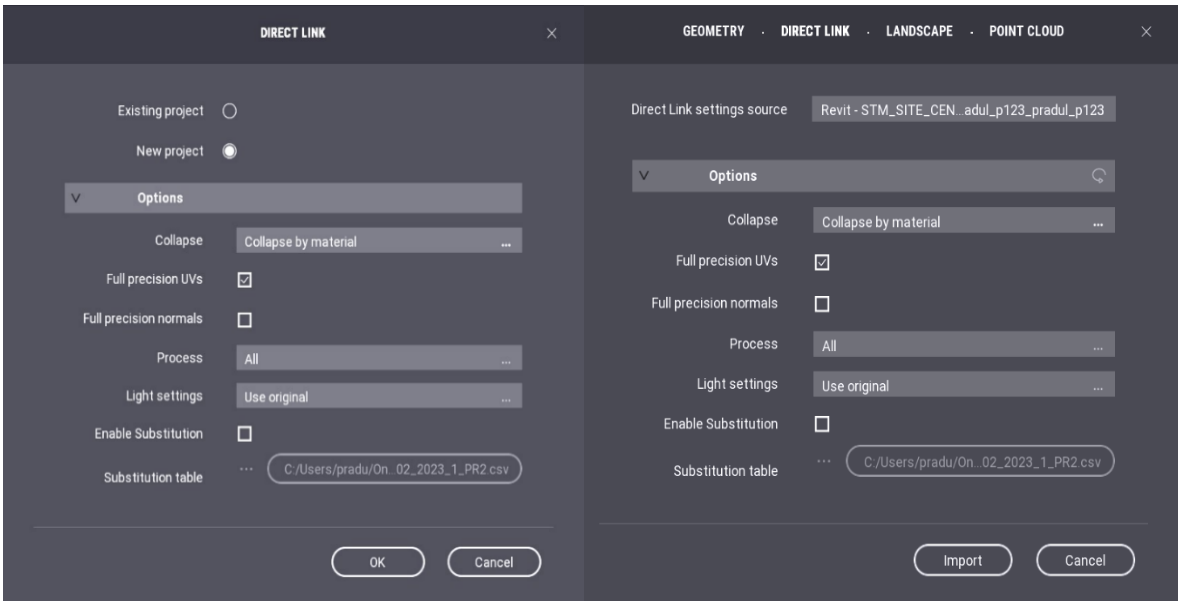


Fig 13.2 Creating a new project

3. Create New Project: Twinmotion will present options for creating a new project or accessing an existing one. Select "New project" to establish a direct link connection with the current Revit model.

4. Initial Synchronization: Upon selecting "New project," Twinmotion performs an initial synchronization, transferring the geometry visible in the active Revit 3D view to the Twinmotion project.

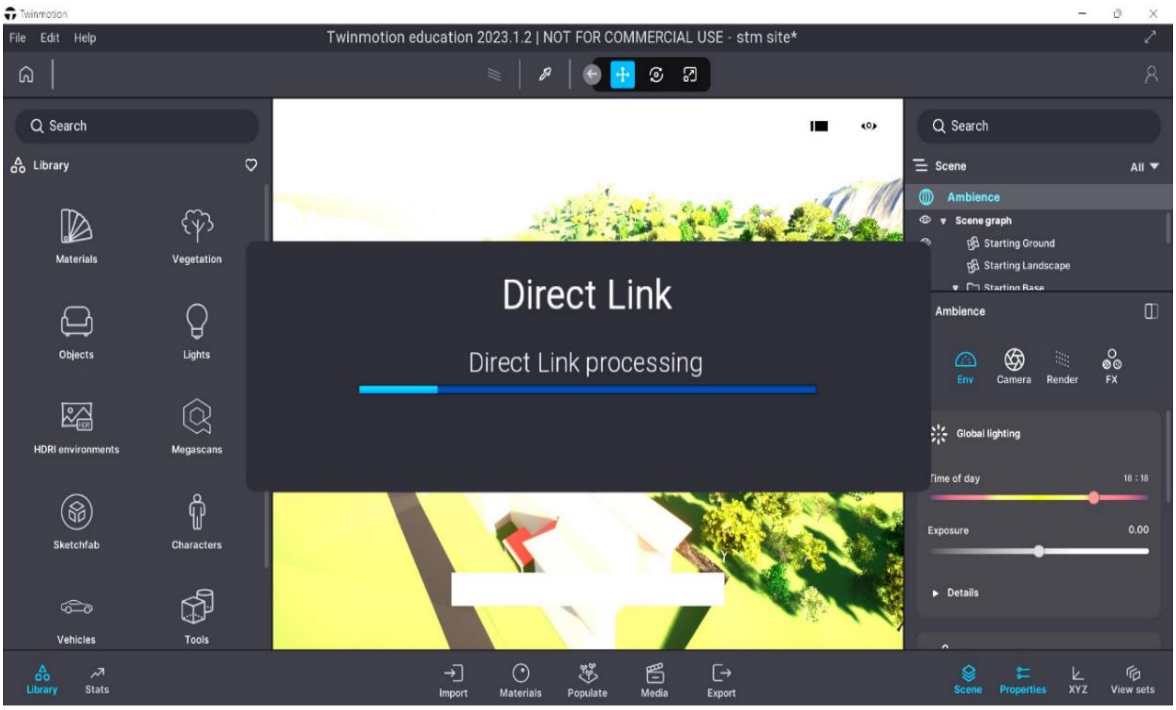


Fig 13.3 Initial synchronization

5. Refine and Enhance: Once in Twinmotion, continue the design and visualization journey by refining and enhancing the project with Twinmotion's tools and features.

Fig 13.4 The building is enhanced using different features

6. Export Rendered Files: Twinmotion offers the capability to export rendered files to various formats including images, videos, panoramas, and 360° videos. Choose the desired format and settings to export high-quality imagery and experiences.

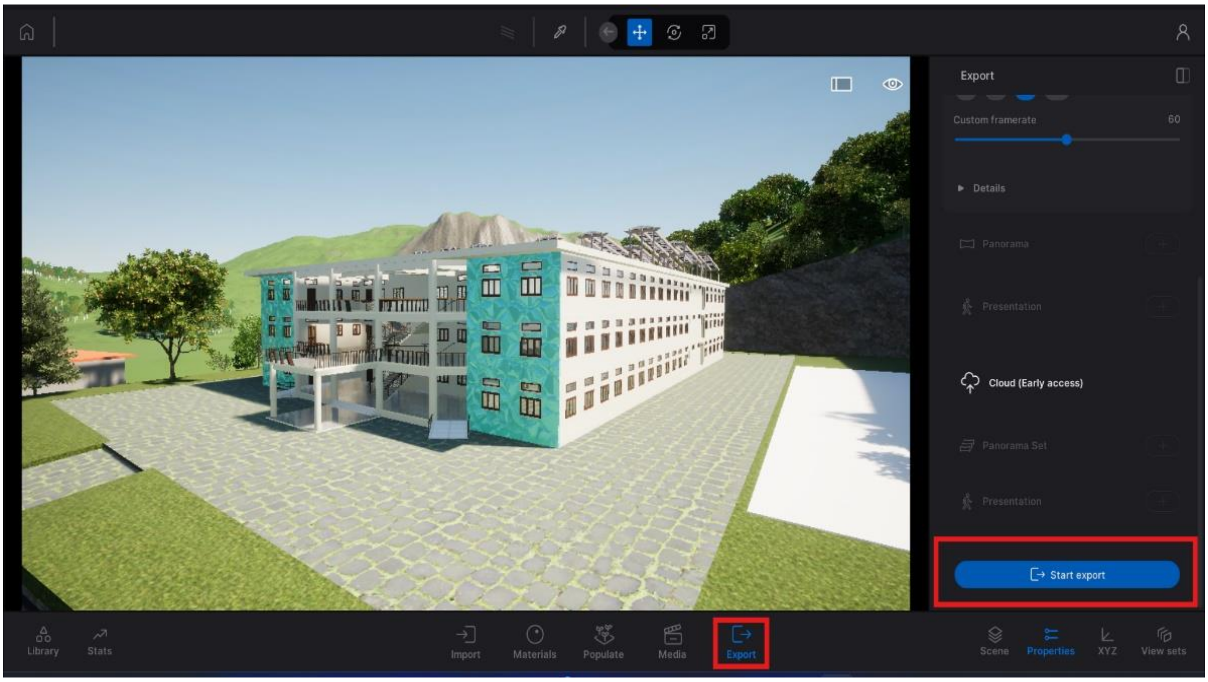


Fig 13.5 Rendered files are exported

13.3 3D RENDERED VIEWS

Fig 13.6 Front View

Fig 13.7 Side View

Fig 13.8 Rear View

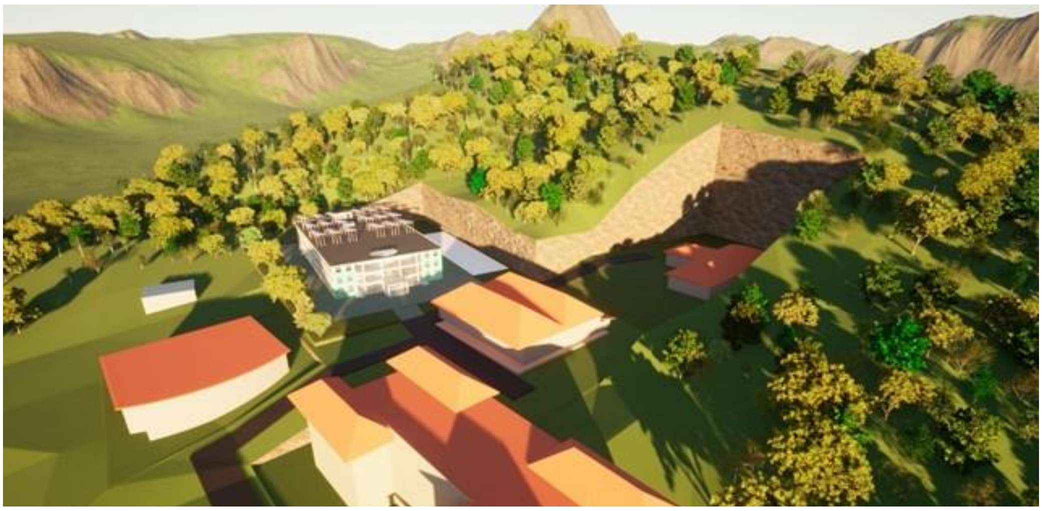


Fig 13.9 Site view

Fig 13.10 Lecture hall

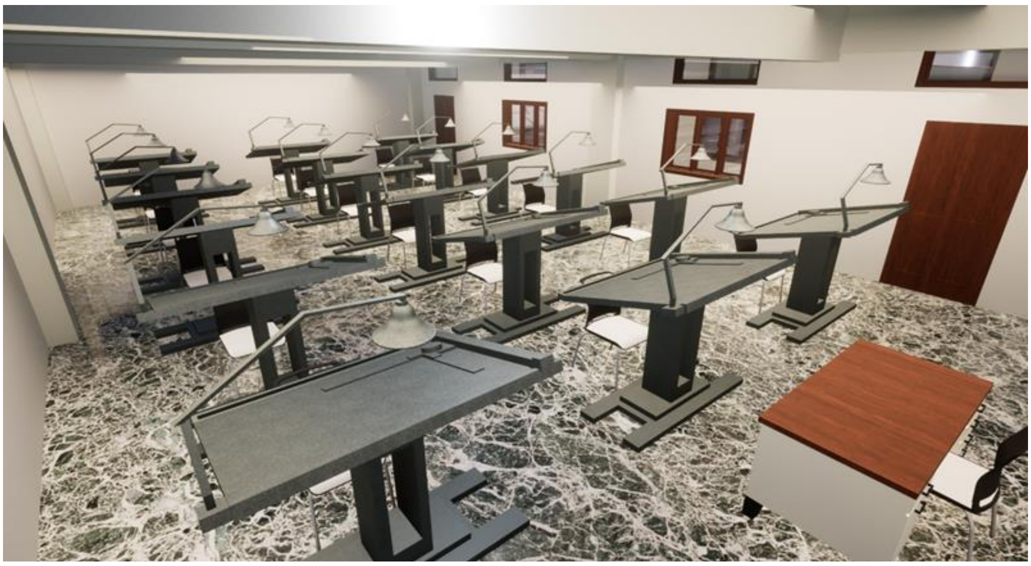


Fig 13.11 Drawing hall

Fig 13.12 Laboratory

Fig 13.13 Seminar Hall

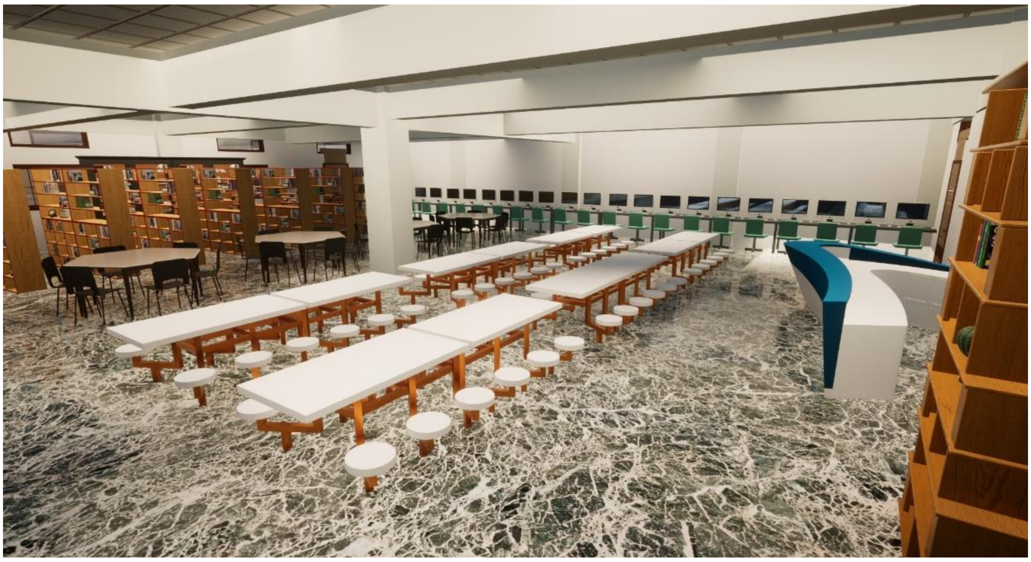


Fig 13.14 Library

Fig 13.15 Faculty room

Fig 13.16 Conference room

Fig 13.17 Administrative room

Fig 13.18 Sports room

13.4 3D RENDERED VISUALIZATIONS

Videos

https://youtube.com/playlist?list=PLBip7ccTVcvewoYcRrg2QGc7Ix3mKT8O&si=sie4pRguIptcUqhV

Other views

https://project-dasp.github.io/

Live walk though

https://api2.enscape3d.com/v1/view/link/0a18fc78-7246-4ce7-86aa-390808cc9470/edacc547-7751-402e-b104-6a4bed7d5fec

CHAPTER 14
CONCLUSIONS

The project demonstrates a meticulous integration of planning, analysis, design, energy optimization, and estimation to create a sustainable and comfortable environment for occupants. Through the detailed utilization of different software, the project adhered closely to local and national building codes, ensuring both safety and compliance. By incorporating energy-efficient materials such as AAC, uPVC, and Low e glass, the building not only maintains comfortable indoor temperatures but also enhances the well-being of its occupants. The comprehensive energy analysis reveals a promising balance, with an estimated electricity consumption of 6,44,309 kWh per year and an impressive estimated electrical output from solar panels of 5,08,424 kWh annually, showcasing the project's commitment to renewable energy sources. Despite the significant construction cost of ₹11,70,00,000.00, the long-term benefits of reduced energy consumption and lower operational costs make it a financially prudent investment. However, it's important to acknowledge that the estimations are based on assumed occupant behavior patterns regarding energy consumption, indicating a potential area for further refinement. Moreover, while the design meets current energy codes and standards, it may benefit from considering future updates to ensure ongoing efficiency and sustainability. The project also underscores the importance of leveraging software tools to streamline processes, reduce manpower, save time, and achieve greater accuracy, highlighting a forward-thinking approach to construction and design in the pursuit of energy efficiency and environmental stewardship.

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