DESIGN AND DEVELOPMENT OF A SUSTAINABLE G+2 RESIDENTIAL BUILDING

A

PROJECT REPORT

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

BACHELOR OF TECHNOLOGY
IN
CIVIL ENGINEERING

Under the supervision of

Dr. Niraj Singh Parihar
(Assistant Professor)

by

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To

JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY WAKNAGHAT,

SOLAN – 173234

HIMACHALPRADESH, INDIA

MAY,2025

DECLARATION

I hereby declare that work presented in this report entitled **“Design and Development of a Sustainable G+2 Residential Building”** in partial fulfillment of the requirement for the requirements for the award of degree in bachelor of Technology in the Department of Civil Engineering from **Jaypee University of Information Technology Waknaghat, Solan, H.P** is original record of my own work carried out under the supervision of **Dr.Niraj Singh Parihar (Assistant Professor)**. This work has not been submitted elsewhere for the award of any other degree/diploma. I am fully responsible for the contents of my project report.

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Date: 14/05/2025

CERTIFICATE

This is to ensure that the work which is being introduced in the venture report named "**Design and Development of a Sustainable G+2 Residential Building**" in partial fulfillment of the requirements for the award of the degree of Bachelor of Technology in Civil Engineering submitted to the Department of Civil Engineering, **Jaypee University of Information Technology, Waknaghat** is an authentic record of work carried out by **Aditya Yadav (211618) & Aryan Thakur (211621)** during a period from August, 2024 to May, 2025 under the supervision of under the management of **Assistant Professor Dr. Niraj Singh Parihar** Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat.

The above statement made is correct to the best of our knowledge.
Date: 14/05/2025

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Thank you.

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ABSTRACT

This project focuses on the design and development of a sustainable G+2 residential building located in Solan, Himachal Pradesh—an area characterized by hilly terrain and moderate seismic activity. The primary goal is to create a structure that minimizes environmental impact while ensuring safety, comfort, and cost-effectiveness. The building integrates several green construction practices and materials to align with modern sustainable development goals.

To reduce the structural load and improve thermal performance, lightweight Expanded Polystyrene (EPS) concrete is used in slabs and other elements. Additional eco-friendly materials such as hempcrete blocks, recycled aggregates, mycelium-based components, and reclaimed wood contribute to lower embodied energy and improved indoor quality. For energy efficiency, the building includes rooftop solar panels to generate clean electricity and reduce reliance on grid power. A rainwater harvesting system is integrated to conserve water and reduce dependence on local water supply. Both systems help the building operate more independently and sustainably. Concealed wiring and standard electrical layouts have also been included in the design.

This project demonstrates how green building principles can be effectively applied in small towns and hilly regions by combining structural reliability with sustainable practices. It offers a practical, scalable model for eco-friendly residential construction in similar geographic and environmental contexts.

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LIST OF ACRONYMS & ABBREVIATIONS

Ast	Area of Steel (Tension Reinforcement)
BM	Bending Moment
c/c	Center to Center
DL	Dead Load
EPS	Expanded Polystyrene
fck	Characteristic Compressive Strength of Concrete
fy	Yield Strength of Steel
IS	Indian Standard
kN	Kilonewton
kNm	Kilonewton Meter
LL	Live Load
M25 / M27	Concrete Mix Grades (25 MPa / 27 MPa)
Mu	Ultimate Moment (Factored Bending Moment)
N/mm^2	Newton per Square Millimeter (Stress Unit)
SBC	Safe Bearing Capacity
SF	Shear Force
τv (Tau v)	Nominal Shear Stress
τc (Tau c)	Design Shear Strength of Concrete
T	Tread (of staircase)
R	Riser (of staircase)
V	Shear Force (Alternative notation)
w	Uniformly Distributed Load (UDL)
γ (Gamma)	Unit Weight / Densit

CHAPTER 1

INTRODUCTION

1.1 Green Building

Green buildings are designed to be both eco-friendly and people-friendly. Their main purpose is to reduce harm to the environment while providing safe, comfortable, and healthy spaces for the people who use them. These buildings are not just about saving energy; they follow sustainable methods from the very beginning—starting with the planning stage, continuing through construction, and lasting all the way to how the building is used and eventually taken down. Green buildings aim to use less electricity, manage water efficiently, reduce waste, and maintain good indoor air quality. They often include solar panels, LED lighting, smart insulation, and environmentally responsible materials like recycled or locally available products. Good design also helps by making better use of sunlight and fresh air, which means less need for artificial lighting or air conditioning.

As the world faces serious issues like climate change, loss of natural resources, and fast-growing cities, green buildings are becoming more important than ever. They help reduce the burden on the environment and also save money in the long run by lowering electricity and water bills. This makes them a practical and responsible choice for homeowners and builders alike.

1.2 Sustainable Design in Solan

Located in Himachal Pradesh, the town of Solan brings its own set of environmental and structural demands. With a temperate climate that includes chilly winters and milder summers, buildings in this region need to be designed to conserve energy—especially for heating. Adding to the complexity, Solan falls under seismic Zone IV, meaning the risk of earthquakes must be factored into every design.

The G+2 residential building project proposed for Solan embraces these realities by combining eco-friendly building methods with earthquake-resistant structural design.

Features like passive solar heating, high-performance insulation, and the use of renewable energy systems will ensure minimal energy usage throughout the year. Meanwhile, the structure itself will be reinforced to meet local seismic codes, ensuring occupant safety during potential earthquakes.

This initiative showcases a tailored, context-sensitive approach to sustainable construction—one that balances energy efficiency, environmental responsibility, and disaster resilience in a single design model.

1.3 Value of This Study

1. Growing Cities in India

With more people moving to urban areas, the demand for housing is rising fast. This study focuses on how to build homes that meet this need while being environmentally responsible, especially in places like Solan.

2. Fighting Climate Change

Climate change is affecting weather patterns everywhere, especially in colder regions. This study looks at how buildings can be designed to use less energy and create a smaller environmental footprint.

3. Saving Energy

Heating buildings in cold areas uses a lot of energy. One of the main goals of this study is to explore ways to reduce that energy use through better design and materials.

4. Healthier Living Spaces

Good building design should also take care of the people inside. By using non-toxic materials, improving ventilation, and keeping indoor temperatures comfortable, this study supports healthier, happier homes.

CHAPTER 2
LITERATURE REVIEW

2.1 Green Building for Sustainable Development in India – Prof. Neeraj Gupta

In this study, Prof. Neeraj Gupta discusses how the rise in urban development has increased the need for construction methods that are both eco-friendly and efficient. He explains that green buildings help reduce environmental damage by using less energy and water, incorporating renewable resources like solar energy, and using sustainable building materials. His work highlights how such practices not only benefit the environment but also improve the overall quality of life for people living in these buildings.

2.2 Sustainable Construction in Hilly Areas – Anil Kumar, Poonam, and Ashok K. Gupta (Jaypee University of Information Technology, Solan)

This research looks into the specific needs and challenges of building sustainably in mountainous regions such as Himachal Pradesh. The authors point out that the terrain, colder climate, and higher earthquake risk in these areas require different construction techniques than those used in flat regions. They suggest the use of local materials, passive design strategies, and structures that can withstand seismic activity to create buildings that are both strong and eco-friendly.

2.3 Lightweight Concrete with EPS Aggregates – J.N. Mwero and V.N. Onchaga

Mwero and Onchaga explored how replacing part of the coarse aggregates in concrete with Expanded Polystyrene (EPS) affects the overall mix. Their study found that using EPS makes the concrete lighter and improves its insulation, which is helpful in colder areas. However, the trade-off is a drop in strength. They also mention that modifying the EPS or adding materials like fly ash can help regain some of that lost strength while keeping the concrete lightweight.

2.4 Design of a G+2 Sustainable Residential Building Using STAAD.Pro – Aakash Sharma (Punjab Technical University)

Aakash Sharma focused on using STAAD.Pro software to design a green residential building with ground plus two floors. His research shows how software tools can help engineers analyze and design buildings that are both safe and sustainable. By applying loads based on IS codes and incorporating seismic considerations, the study demonstrates that it's possible to combine eco-friendly design with structural stability, especially in earthquake-prone areas like Himachal **Pradesh.**

2.5 Sustainable and Eco-Friendly Building Materials – Hosam M. Saleh, Mohamed M. Dawoud, and Amal I. Hassan

As the environmental impact of traditional construction continues to raise concern, there is growing interest in adopting building materials that are both sustainable and less harmful to the environment. Researchers have been actively investigating how industrial waste, natural fibres, and recycled materials can serve as viable substitutes for conventional construction inputs like cement and aggregates. These alternatives not only help in reducing pollution and conserving raw resources but also offer practical benefits such as improved thermal insulation and energy efficiency.

In their review, the authors shed light on how these eco-friendly materials can contribute to greener building practices while also addressing safety concerns—especially radiological safety—when using industrial by-products. Their work emphasizes that sustainable material choices, when properly evaluated for health and environmental risks, can support more responsible and future-ready construction methods.

2.6 Sustainable Architecture for Earthquake-Prone Areas of India – Vasudha A. Gokhale

Vasudha Gokhale's research highlights the importance of designing buildings that are both eco-friendly and safe in earthquake-prone regions of India. She points out that traditional Indian construction methods—using local materials like wood, bamboo, and stone—were naturally suited to handle earthquakes while being sustainable. However, modern buildings often ignore these time-tested techniques.

The study suggests blending traditional design wisdom with modern engineering to create structures that are not only energy-efficient but also resilient during earthquakes. It emphasizes the need to respect local conditions, use available resources wisely, and ensure safety while promoting sustainability.

CHAPTER 3

METHODOLOGY AND MATERIALS

3.1 Methodology

To design a sustainable G+2 residential building that can withstand cold weather and seismic activity, a step-by-step approach was followed. The main goal was to develop a structure that is eco-friendly, energy-efficient, and safe for people living in areas like Solan, where winters are harsh and earthquakes are a real risk. This process involved learning from existing research, selecting the right materials, planning the design, testing it with simulation tools, and refining the final structure for optimal performance.

3.1.1 Learning from Existing Research

The first step was to dive into existing studies and examples of green buildings, especially those built in cold and earthquake-prone areas. This helped us understand which materials and techniques work best in such environments. The performance of materials like hempcrete, engineered bamboo, cross-laminated timber (CLT), and lightweight concrete (using polystyrene or pumice) in terms of keeping buildings warm, staying strong during earthquakes, and being eco-friendly was explored.

3.1.2 Choosing the Right Materials

After reviewing all the information, Materials were carefully selected based on how well they suit cold climates and seismic conditions.

Lightweight Concrete with EPS or Pumice: This was chosen for its ability to keep interiors warm and its reduced weight, which is helpful in earthquakes.

Hempcrete: Used mainly in walls, hempcrete is a breathable and well-insulating material that's also environmentally friendly.

CLT and Engineered Bamboo: These were considered for structural elements due to their light weight and flexibility—important traits in earthquake-resistant construction.

3.1.3 Designing the Building

Once the materials were finalized, the next focus was the actual design of the G+2 building. The layout was designed to make the best possible use of the benefits of these materials.

Smart Layout for Energy Efficiency: The building was designed to let in natural light and air, reducing the need for artificial lighting and heating. Sun-facing windows, proper insulation, and smart room placement helped improve comfort.

Earthquake-Safe Structure: Structural elements were placed and reinforced in a way that could handle seismic activity. Lightweight materials helped reduce overall load while maintaining strength.

Good Insulation: Materials like hempcrete and lightweight concrete were used in the walls and roof to keep indoor temperatures stable and cut down on heating needs.

3.1.4 Simulating the Performance

To see how the building would actually perform, simulations were carried out using software tools.

Thermal Simulation: This helped us check how well the building stays warm and how much energy it might need for heating.

Structural Simulation: Using software like STAAD.ProThe building's strength and stability were tested under earthquake conditions specific to Zone 4 (which includes Solan).These tests gave us real insights into what would work and what needed improvement.

3.1.5 Making Improvements

Based on the results from the simulations, Some changes were made to improve the design. This included tweaking insulation thickness, adjusting the amount of EPS added to the concrete, and rethinking parts of the construction process to make it more practical and cost-effective. These refinements ensured the building was not only strong and energy-efficient but also realistic to build.

3.1.6 Final Documentation

Finally, everything was documented—from why we picked certain materials to how the design evolved after testing. The report explains how combining the right materials with smart design can result in a sustainable, earthquake-safe, and energy-efficient home that's ideal for cold and seismic regions like Solan.

3.2 Selection of Materials

3.2.1 Excavation

The majority of building projects begin with excavation. To prepare the ground for construction, the top layers of dirt, rocks, and trash must be removed. This procedure is done carefully in green building so as not to damage the surrounding environment. In order to minimize long-term ecological harm, efforts are made to control erosion and maintain natural water flow patterns.

3.1.2 Plain Cement Concrete (PCC)

PCC is a basic mixture of cement, sand, and aggregates, used to create a smooth and strong base for laying foundations or floors. In environmentally friendly construction, sustainable alternatives are preferred. These might include replacing part of the cement with fly ash or slag, helping to reduce carbon emissions and make the construction process greener.

3.1.3 Laying the Foundation

The foundation carries the weight of the entire structure, so it's essential that it is built to last. In eco-conscious projects, sustainable materials such as hempcrete or geopolymer concrete may be used for their energy efficiency and lighter weight. In areas with seismic activity or extreme cold, special foundation types like insulated slabs or deep footings are used to improve thermal insulation and structural safety.

3.1.4 Types and Grades of Cement (33, 43, 53)

Cement plays a vital role in construction, and its grade represents its compressive strength after 28 days:

- Grade 33 is used for general building needs.
- Grade 43 is suitable for moderate-strength applications like beams and slabs.
- Grade 53 is the strongest and is typically used in heavy-load structures like bridges and towers.

  Green buildings often opt for eco-friendly cements, like low-carbon or geopolymer varieties, to reduce the environmental footprint.

3.1.5 Concrete Reinforcement

While concrete is strong under compression, it lacks tensile strength. To solve this, steel bars or mesh are embedded in the concrete for reinforcement. Steel is the traditional choice, but sustainable options such as Fiber-Reinforced Polymers (FRP) are gaining ground due to their durability, corrosion resistance, and light weight. Additionally, recycled steel is often used in green construction to cut down on energy use and emissions associated with producing new steel.

3.3 Main Features of Eco-Friendly Building Materials

3.3.1. Come from Natural or Reused Sources

Eco-friendly materials are either harvested from nature in a way that allows them to grow back quickly—like bamboo or cork—or they're made from previously used materials, such as reclaimed wood or recycled steel. This helps reduce the need for new raw materials and limits environmental damage.

3.3.2 Use Less Energy from Start to Finish

These materials require less energy during production, transportation, and installation. This means fewer emissions and a smaller carbon footprint throughout the entire building process, making them a smarter choice for the planet.

3.3.3 Safe for People and the Environment

Green materials are chosen not just for the environment, but also for health. They don't release harmful chemicals into the air, helping to maintain clean indoor air and creating a healthier space for occupants.

3.3.4 Strong and Low-Maintenance

Sustainable building materials are made to last. They resist wear and weathering, and often require little upkeep. This means fewer repairs, lower costs over time, and reduced material waste.

3.3.5 Reusable or Earth-Friendly When Disposed

When these materials reach the end of their use, they don't become harmful waste. They can be recycled into other products or naturally break down without polluting the environment, supporting a circular and waste-free building approach.

3.4 Lightweight Concrete Using Expanded Polystyrene (EPS)

Lightweight concrete is specially designed to reduce the weight of the structure while maintaining strength and insulation. EPS beads—tiny, lightweight plastic spheres—are commonly used in place of traditional coarse aggregates. This type of concrete is often used in non-load-bearing walls, insulation layers, or prefabricated components. Though it may have lower compressive strength and weaker bonding with cement, these challenges can be managed with proper mix design.

EPS concrete is a mix of cement, sand, water, and EPS beads. These beads are lightweight and reduce the overall density of the concrete, making it easier to handle and improving thermal insulation. The performance of EPS concrete depends on the proportions used and the mix quality. By tweaking these factors, builders can strike a balance between strength, workability, and insulation.

Materials Used in EPS Concrete

Material	**Purpose**
Cement	Binds all materials together
Sand	Fills gaps and boosts strength
Water	Activates cement and maintains workability
EPS Beads	Replace coarse aggregate to reduce weight
Admixtures (optional)	Improve bonding, durability, and workability

EPS beads are made from polystyrene, a plastic derived from petroleum. Here's how they are produced:

1. Polymerization: Styrene monomers are chemically bonded to create polystyrene granules.
2. Pre-Expansion: These granules are exposed to steam and a blowing agent (like pentane), causing them to expand up to 50 times their original size.
3. Aging & Stabilization: The expanded beads are stored in ventilated containers to stabilize and equalize pressure.
4. Final Shaping: Depending on the use, the beads can be shipped as loose fill or molded into blocks and sheets for construction or insulation.

EPS can be used in two main forms:

- Loose Beads: For lightweight concrete, insulation, packing, and filling.
- Melded Blocks/Sheets: Used in insulation panels, wall systems, and protective packaging.

Mix Ratios and Water-Cement Ratios for EPS Concrete

Cement : Sand : EPS	Use Case
1 : 1.5 : 1	Moderate strength and basic insulation
1 : 2 : 2	Higher insulation, lower strength

Water-Cement Ratio Guidelines:

- 0.35 – 0.40: Suitable for stronger mixes.
- 0.40 – 0.50: Better workability but lower compressive strength.

3.5 Solar Tiles

Solar tiles, also referred to as solar shingles, are an innovative type of roofing material that integrates solar power generation directly into the roofing system. Unlike traditional solar panels that are mounted on top of a roof, solar tiles are designed to replace regular roofing materials while generating electricity. They are made with photovoltaic (PV) cells that capture sunlight and convert it into electrical energy, but they look and function just like traditional tiles or shingles, offering a seamless and aesthetically appealing solution for energy generation.

Solar tiles are crafted by embedding photovoltaic cells into a durable outer layer that can withstand the harsh elements. The outer casing is typically made of materials like tempered glass or composite plastics. These tiles are designed to function just like standard roof shingles but are capable of converting sunlight into electricity when it passes through the outer layer. Each tile is connected to form a network that captures energy, making them an efficient, integrated part of the roof structure.

When sunlight strikes the photovoltaic cells inside the tiles, it excites the electrons, causing them to flow and generate a direct current (DC). This electricity is then converted to alternating current (AC) through an inverter, which is the type of electricity used to power homes. Excess electricity can be stored in batteries or returned to the grid, allowing homeowners to reduce their dependence on traditional power sources.

Solar tiles are ideal for buildings aiming to reduce their environmental impact while maintaining a traditional aesthetic. They are particularly useful in residential and commercial buildings looking to achieve **energy independence** and minimize their reliance on non-renewable energy. Solar tiles can be combined with other sustainable features, such as high-efficiency insulation and energy-efficient windows, to create buildings that produce their own electricity and consume very little energy from external sources.

3.6 Reclaimed Wood

Reclaimed wood is timber that has been salvaged from old buildings, warehouses, barns, or other structures, and is repurposed for new construction projects. Rather than cutting down new trees, reclaimed wood gives previously used timber a second life, helping to conserve forests and reduce the environmental impact associated with the logging industry.

The process of reclaiming wood begins with the careful extraction of timber from old buildings. Once the wood is gathered, it is cleaned to remove any nails, screws, or other metal fasteners. The wood is then dried, and depending on its intended use, it may be sanded or refinished. Sometimes, reclaimed wood is treated to prevent pests, rot, or mold that may have developed over time. This process ensures that the wood is safe, stable, and ready for use in new construction.

Reclaimed wood is an excellent material for sustainable construction because it reduces the need for new lumber, helping to protect forests and decrease the carbon footprint associated with harvesting fresh timber. It's commonly used in flooring, wall cladding, furniture, beam structures, and decorative accents. The unique character of reclaimed wood, including its texture, grain, and natural wear, makes it a popular choice for both functional and decorative elements in green building projects.

Reclaimed wood is also an environmentally responsible choice because it reduces the amount of waste going to landfills. By reusing materials that have already been harvested, this approach promotes a circular economy, where products are reused, repurposed, and recycled rather than disposed of.

3.7 Recycled Aggregates

As the construction industry shifts toward more eco-conscious practices, one material gaining significant attention is **recycled aggregate**. Instead of relying on freshly mined stone, sand, or gravel, recycled aggregates come from old structures — like roads, demolished buildings, and broken pavements — and are given a second purpose in new projects.

Rather than letting this debris become landfill waste, it's collected, processed, and reused — helping both the environment and the budget.

In simple terms, recycled aggregates are crushed pieces of old concrete, bricks, asphalt, or stones that have been cleaned and sorted for reuse. These materials might come from construction debris, road repairs, or even leftover concrete from demolished buildings.

Once collected, this material goes through a cleaning and crushing process to remove contaminants like nails, plastic, or steel. The result is a coarse or fine aggregate that's ready to be used again — often in the very same types of construction tasks it originally came from.

One of the most common uses of recycled aggregate in green building is sooling, also known as subgrade preparation — the foundational step before laying concrete floors or foundations.

In traditional construction, soling involves placing large stones or bricks on compacted soil to create a stable layer. This base supports the building's floor and helps distribute the weight evenly.

Now, instead of fresh stones, recycled aggregates are being used in their place. Crushed bricks or concrete chunks can be spread and compacted just like new materials, offering the same load-bearing strength — but with a much smaller environmental impact.

Using recycled aggregates in sooling makes sense for several reasons:

1. Sustainability First – It prevents waste from piling up in dumping grounds and reduces the demand for new materials.
2. Cost-Saving – Since the material is often locally sourced and readily available, it's cheaper than buying fresh stone.
3. Reduces Resource Mining – No need to quarry new stones when perfectly usable material is already available.
4. Strong and Reliable – After proper grading and processing, recycled aggregates offer good strength and compaction qualities for sub-base use.

Besides sooling, recycled aggregates are used in:

- Base layers for roads and highways
- Pavement foundations
- Non-load-bearing concrete
- Fill material for landscaping or site leveling
- Drainage systems (when properly sized)

3.8 Solar Panels:

Solar panels are devices that capture sunlight and convert it into electricity. They are made of photovoltaic (PV) cells that use the energy from sunlight to generate direct current (DC), which is then converted into alternating current (AC) to power appliances and lights in the building. These panels are typically installed on rooftops, where they can maximize exposure to sunlight.

Importance of Solar Panels in Solan

Solan, being a hill station, enjoys a significant amount of sunlight, especially during the summer months. Solar panels become a highly efficient and practical solution for buildings in such regions. Here's why:

- Renewable Energy Source: Solar energy is an unlimited, renewable resource, making it an ideal power source for green buildings.
- Energy Independence: Solar panels help reduce reliance on the local grid, which can sometimes be unreliable, especially in remote areas.
- Reduction in Utility Bills: By generating electricity on-site, buildings can significantly reduce their energy costs, which is especially useful for long-term savings.
- Environmentally Friendly: Solar panels reduce the building's carbon footprint by minimizing the use of fossil fuels for electricity generation.

In a green building, solar panels contribute to **sustainable energy generation**, making the structure energy-efficient. By generating clean electricity, solar panels help meet a building's energy demand while maintaining environmental responsibility. This is essential for achieving green certifications such as LEED or GRIHA.

The initial cost of installing solar panels can be significant, with expenses typically ranging from ₹30,000 to ₹60,000 per kW depending on the type of panel and installation complexity. However, solar panels have a lifespan of 20-25 years and require minimal maintenance, which makes them a cost-effective solution in the long term.

Return on Investment: In the long run, solar panels can save significant amounts on electricity bills. The payback period for solar panel installation usually ranges from 5 to 7 years, depending on energy consumption, government incentives, and solar panel efficiency.

Government Subsidies: The government offers incentives and subsidies to encourage the use of solar power, which further reduces the upfront cost of installation.

3.9 Rainwater Harvesting:

Rainwater harvesting involves collecting rainwater from rooftops or other surfaces and storing it for future use. This collected water can be used for non-potable purposes like irrigation, flushing toilets, and washing, or it can be filtered and treated for drinking and cooking purposes.

Importance of Rainwater Harvesting in Solan

Given the region's seasonal rainfall patterns, rainwater harvesting is particularly useful in Solan for several reasons:

Water Conservation: Solan, like many hill stations, has a limited and sometimes erratic water supply. By harvesting rainwater, buildings can significantly reduce their reliance on municipal water systems, especially during dry spells.

Reduced Water Bills: By using harvested rainwater for non-potable uses, households and buildings can cut down on their monthly water bills.

Flood Mitigation: Collecting rainwater can reduce runoff, thus helping to prevent flooding and soil erosion, which are common problems in hilly areas after heavy rains.

In a green building, rainwater harvesting integrates seamlessly into sustainable water management systems. The water is typically stored in tanks or underground reservoirs and can be filtered and used for various purposes within the building. This helps reduce the strain on municipal water supply systems and contributes to the overall sustainability of the building.

Cost Over the Lifetime

The initial installation cost of a rainwater harvesting system varies depending on the building's size and the complexity of the system. On average, it can range from **₹30,000 to ₹80,000** for a basic setup that includes a storage tank, filtration system, and plumbing. However, the long-term benefits, especially in a region like Solan, far outweigh the costs.

- Long-Term Savings: By using rainwater for irrigation and non-potable uses, buildings can significantly reduce their water consumption from the local supply, resulting in long-term savings.
- Minimal Maintenance: After installation, the maintenance cost of rainwater harvesting systems is relatively low. Regular cleaning of filters and storage tanks is required to keep the system functioning efficiently, but these costs are manageable over time.

3.10 SOFTWARE USED

In today's construction and architectural industry, designing a building isn't just about sketching on paper—it requires precision, efficiency, and collaboration. To meet these needs, professionals rely on powerful design software that helps bring their ideas to life while minimizing errors. Two such important tools are **AutoCAD** and **Revit**, both developed by Autodesk.

3.10.1 AutoCAD – The Foundation of Technical Drawing

AutoCAD is one of the oldest and most trusted software tools used in engineering and architecture. It mainly focuses on **2D drafting**, allowing users to create floor plans, elevations, sections, and technical drawings with high precision. Using AutoCAD is like drawing on a digital sheet, but with tools that help you measure, adjust, and edit layouts quickly and accurately.

AutoCAD was used in this project to create detailed 2D drawings of the G+2 residential building. These drawings included the building layout, dimensions, electrical and plumbing plans, and structural detailing. AutoCAD was chosen because it is widely accepted in the construction industry, and the files are easily shared and understood by engineers, consultants, and contractors. It also allows for the maintenance of accuracy and clarity throughout the planning phase.

3.10.2 Revit – Intelligent 3D Modelling and BIM

While AutoCAD focuses on 2D layouts, **Revit** takes things a step further by allowing us to create a **3D model** of the building with real-life components. Revit works using Building Information Modelling (BIM), which means every element you draw—be it a wall, window, door, or roof—is more than just a shape. Each component carries real-world data such as size, material, thickness, cost, and even energy performance.

Revit was used to visualize the building in three dimensions, making it easier to understand how the entire structure would look and function once built. With Revit, sunlight simulations were conducted, space usage was checked, electrical and plumbing systems were coordinated, and potential design issues were detected early in the process. This made the design more efficient and accurate while reducing the chances of error during actual construction.

3.10.3 Explaining the Use of Both Methods

By using both AutoCAD and RevitThe best of both worlds was combined. AutoCAD provided detailed 2D drawings essential for construction and approvals, while Revit helped create a complete digital model of the building, allowing for careful planning of every element. This dual approach helped to:

Visualize the building clearly before construction.

Identify and fix design conflicts early.

Improve energy efficiency through simulation tools in Revit.

Create more accurate estimates of material quantities.

Coordinate architectural, structural, and MEP (Mechanical, Electrical, Plumbing) systems effectively.

3.11 GREEN RESIDENTIAL BUILDING PLANNING

General Description of Building

- Living Room
- Bed Room
- Kitchen and Pantry
- Pooja Room
- Servant Rooms
- Rain Water Tank
- Solar Pannels
- Air-Grow Technology

PLAN – GROUND FLOOR

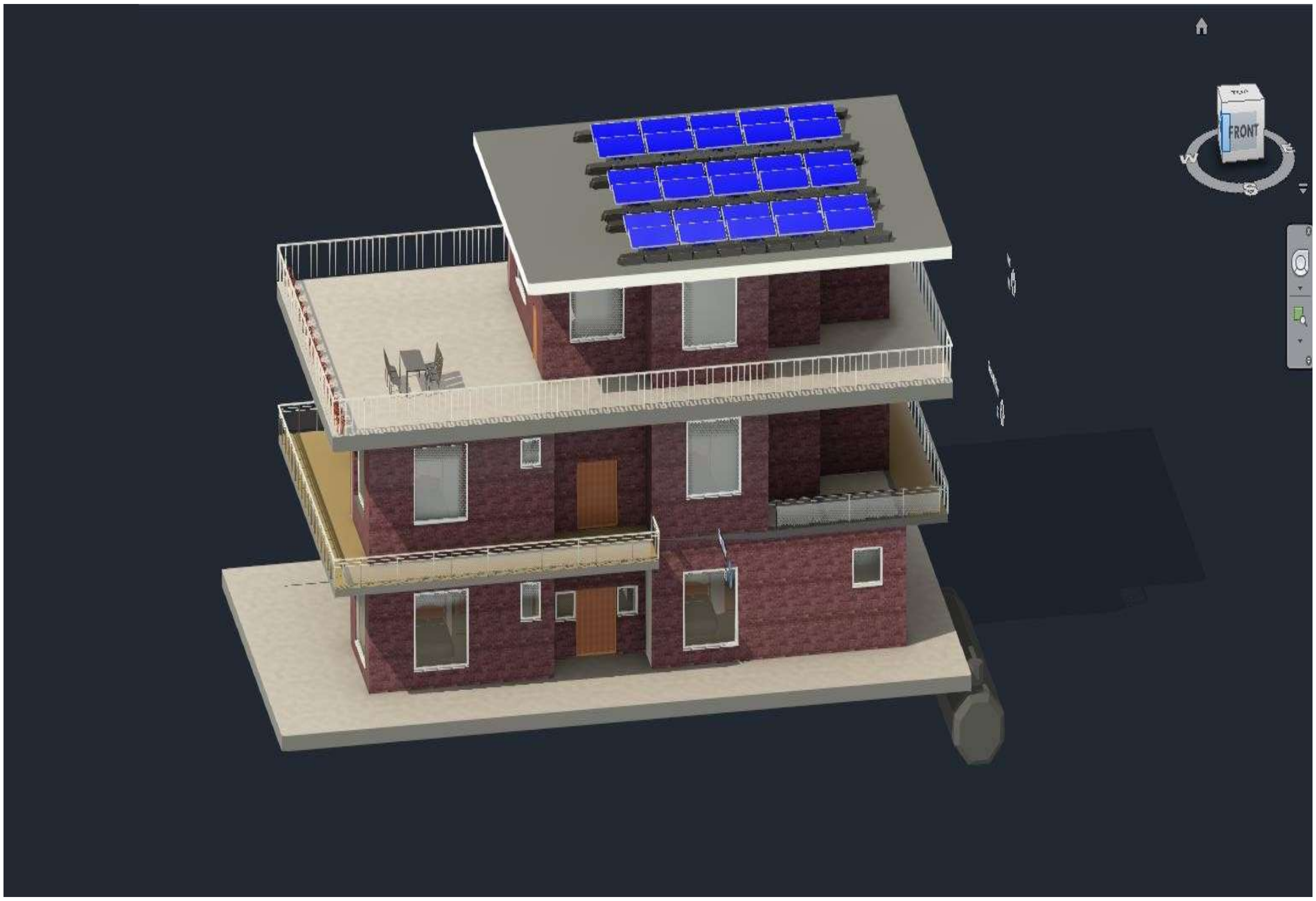

Figure3. 1 Plan – Ground floor

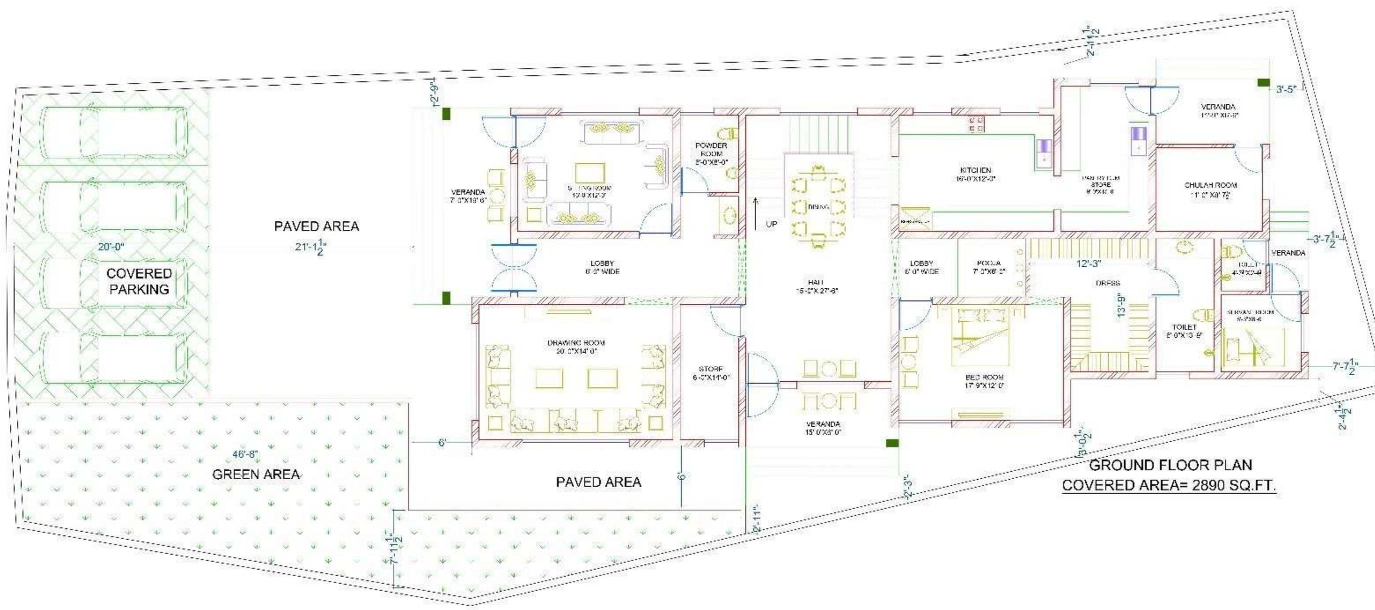

Figure3. 2 GROUND FLOOR

PLAN – FIRST FLOOR

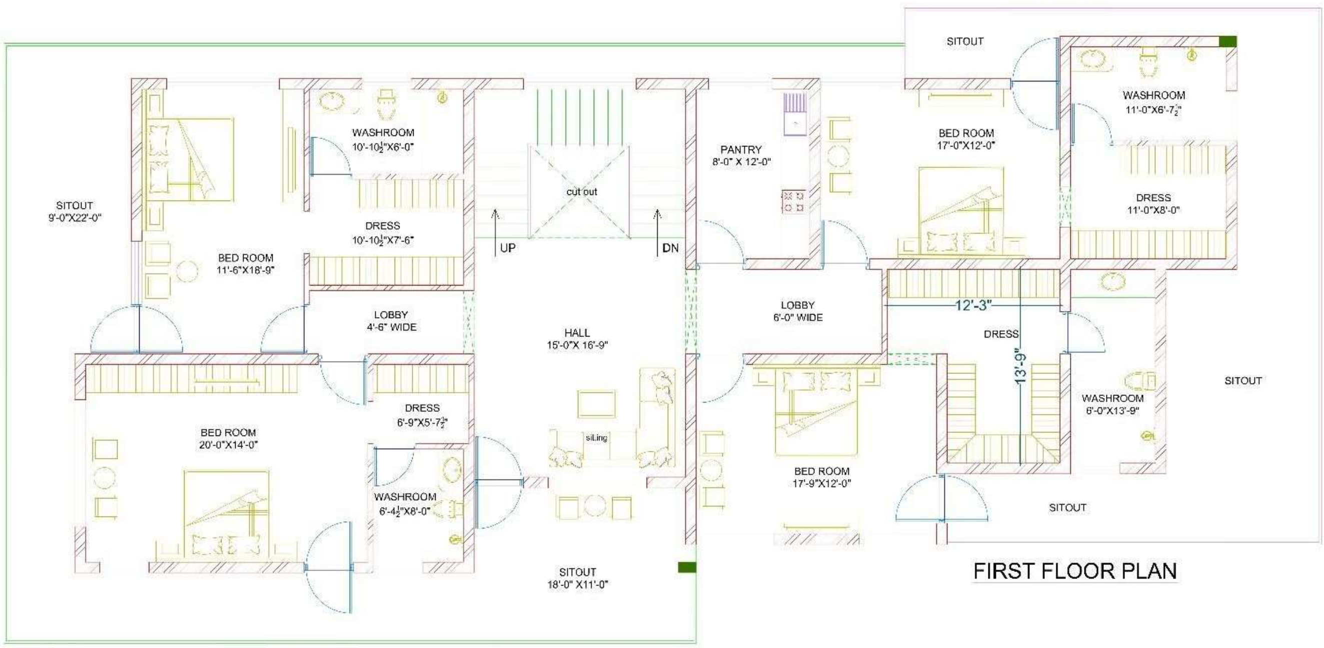

Figure3. 3 First Floor Plan

PLAN – SECOND FLOOR

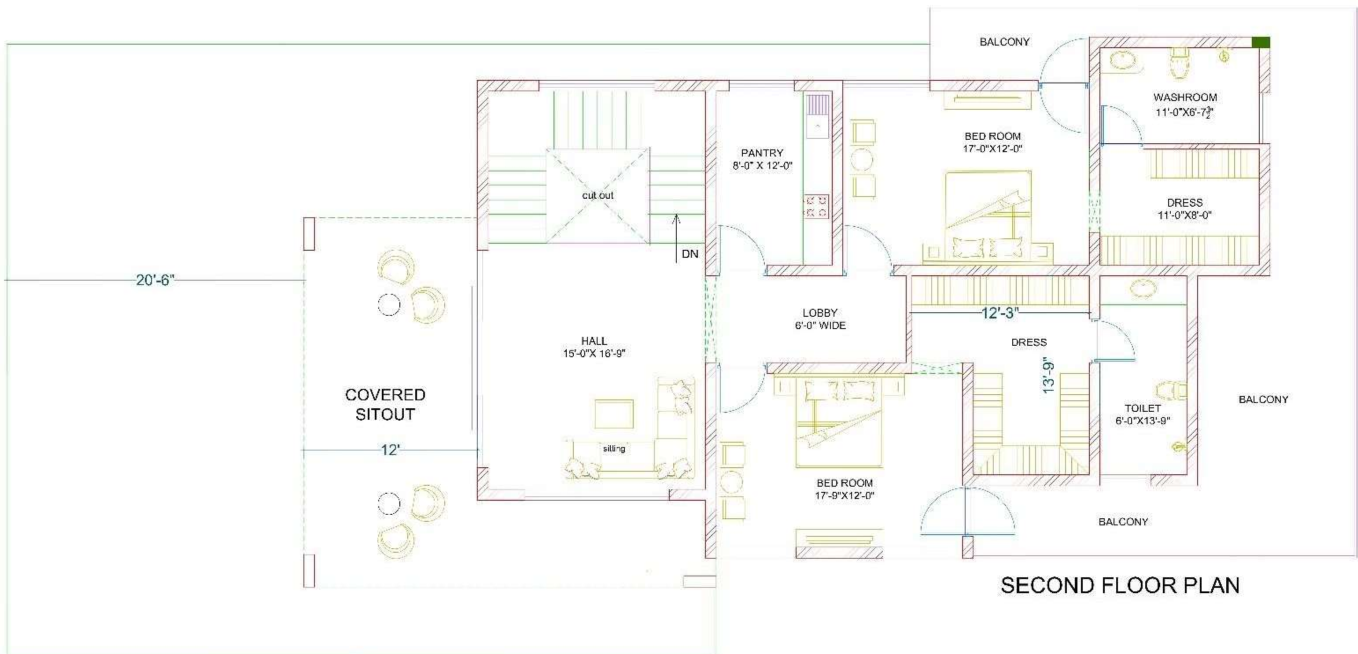

Figure3. 4 Second Floor Plan

Plinth beam Layout

A plinth beam is a horizontal concrete beam that’s placed just above the ground level in a building.

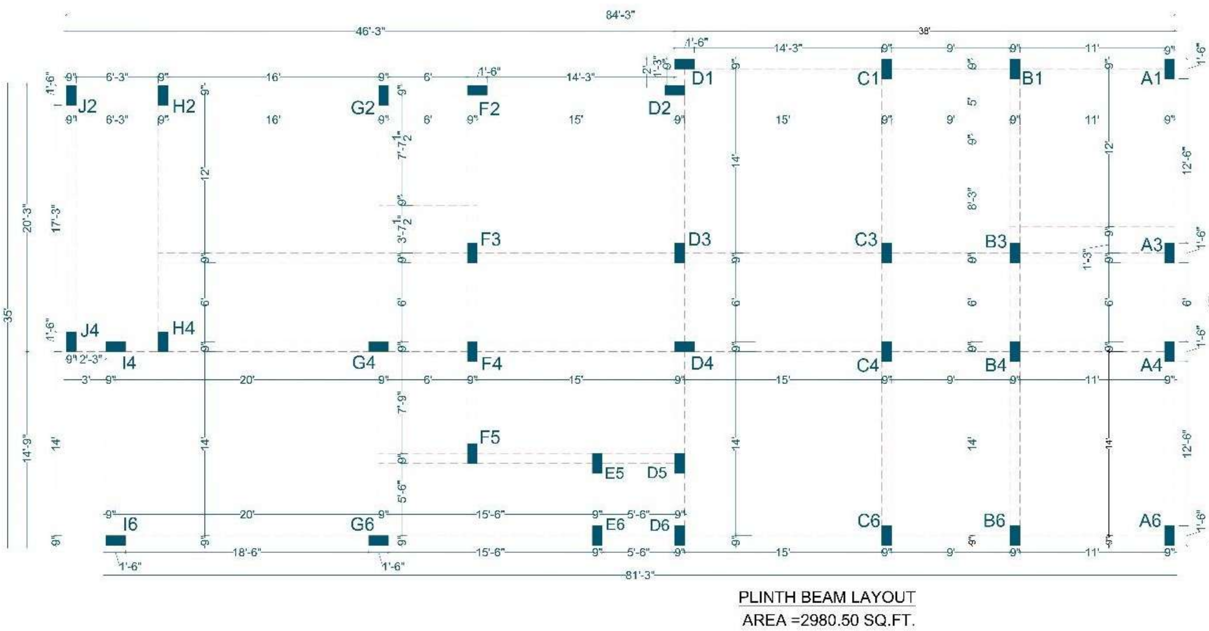

Figure3. 5 Plinth beam Layout

CHAPTER 4
RESULT

4.1 ANALYSIS OF BUILDING USING STAAD PRO SOFTWARE

In modern construction, especially when safety is a top concern, we can't rely only on manual calculations or visual estimations. To ensure our **G+2 green residential building** in **Solan, Himachal Pradesh** is structurally sound, we used **STAAD.Pro**—a powerful structural analysis and design software. It allowed us to simulate how our building would behave under different conditions like earthquakes, wind, and daily use, so we could design a structure that is both safe and efficient.

Since **Solan lies in Seismic Zone 4**, which is known for a relatively high risk of earthquakes, using software like STAAD.Pro was essential. It helped us analyze the building's response to seismic activity, taking into account the materials used, layout, and load distribution. It also ensured that our design complies with **IS codes** (Indian Standards), which are mandatory for safe structural design in India.

4.1.1 Types of Loads Considered

In STAAD.Pro, we applied various loads to simulate real-world conditions. Here's what we included:

1. Dead Load

This is the permanent weight of the building itself—the structural components like walls, columns, beams, slabs, roofing, and finishes. Because we used lightweight concrete with EPS (Expanded Polystyrene), the dead load was lower than usual. This is a good thing, especially in seismic areas, because lighter buildings face less impact during earthquakes.

2. Live Load

Live loads are the temporary or movable forces the building needs to withstand—like people walking around, furniture, household appliances, and daily usage. These loads are dynamic and vary with time, so it's crucial to account for them to ensure the building remains safe in everyday use.

3. Seismic Load

Given Solan's location in Zone 4, earthquake resistance is a major priority. We applied seismic forces using STAAD.Pro as per IS 1893:2016, which defines how to calculate earthquake loads in India. The software helped us model the building's response to these forces, allowing us to adjust the design for greater safety and stability during seismic events.

4. Wind Load

Being in a hilly region, Solan sometimes experiences strong winds. Using IS 875 (Part 3), we calculated wind pressures that act on the building's surfaces and checked whether the structure could resist them. STAAD.Pro made it easy to simulate this and ensure there would be no risk of excessive sway or structural failure during storms.

5. Snow Load

Although Solan doesn't receive heavy snowfall regularly, occasional snow accumulation on rooftops can add extra weight. We included this in our design just to be safe, especially since we're aiming for a sustainable and long-lasting structure.

6. Other Loads (like Impact or Accidental Loads)

We also considered occasional impact forces—like construction activity or vibrations from machinery—to make sure the building stays stable even under unexpected conditions.

4.1.2 Significance of Using STAAD.Pro in Our Project

STAAD.Pro gave us a clear picture of how our building would perform under different stress conditions—before we started actual construction. It helped us experiment with materials, check the building's strength, and make necessary design adjustments to improve safety and reduce costs.

By simulating everything virtually, we avoided potential issues early on. It also helped us optimize the use of eco-friendly materials like EPS concrete and hempcrete, without compromising structural integrity. As a result, we were able to create a building design that's not just environmentally conscious, but also reliable and durable in a region prone to earthquakes and cold weather.

4.1.3 Types of Structures in STAAD.Pro

STAAD.Pro is a powerful software used for analyzing and designing different types of structures. Depending on the nature of the project and how the loads act on the structure, STAAD allows you to model in various ways. Let's break down the main types of structural models you can create using STAAD in a simple and understandable way:

1. Space Structure (3D Model)

This is the most complete and flexible type of structure in STAAD. A space structure is three-dimensional, meaning it can handle loads and movements in all directions—X, Y, and Z. It's perfect for modeling real-world buildings where forces like wind, earthquakes, and gravity act from different angles. Whether it's a house, an office building, or a bridge, space structures allow for a full, realistic analysis.

2. Plane Structure (2D Model)

A plane structure is two-dimensional, which means it's confined to a flat surface—usually the X-Y plane. This model is useful when you're dealing with simpler frames, like a single wall or portal frame, where all loads and structural behaviour happen within one plane. It's commonly used in early design stages or for analyzing walls or simple beam-column systems.

3. Truss Structure

A truss structure is made up of members that can only carry forces along their length—either pulling (tension) or pushing (compression). These members don't bend. Truss models are typically used for things like roof trusses or bridge trusses, where the load is efficiently distributed through axial forces in straight members.

4. Floor Structure

A floor structure is like a simplified version of a space structure, usually used for floor slabs or framing systems that don't move horizontally. In this setup, movement in the X and Z directions is restricted, and it mainly deals with vertical loads. It's useful for modeling individual floor systems in buildings, especially when there's no horizontal loading like wind or seismic forces. However, if horizontal forces are present, it's better to model the system as a space structure for accurate results.

4.2 DETAILED ANALYSIS OF G+2 BUILDING WITH STAAD.PRO

This is a 3D space frame model, likely of a multi-story building (G+2 or more), created in STAAD.Pro .

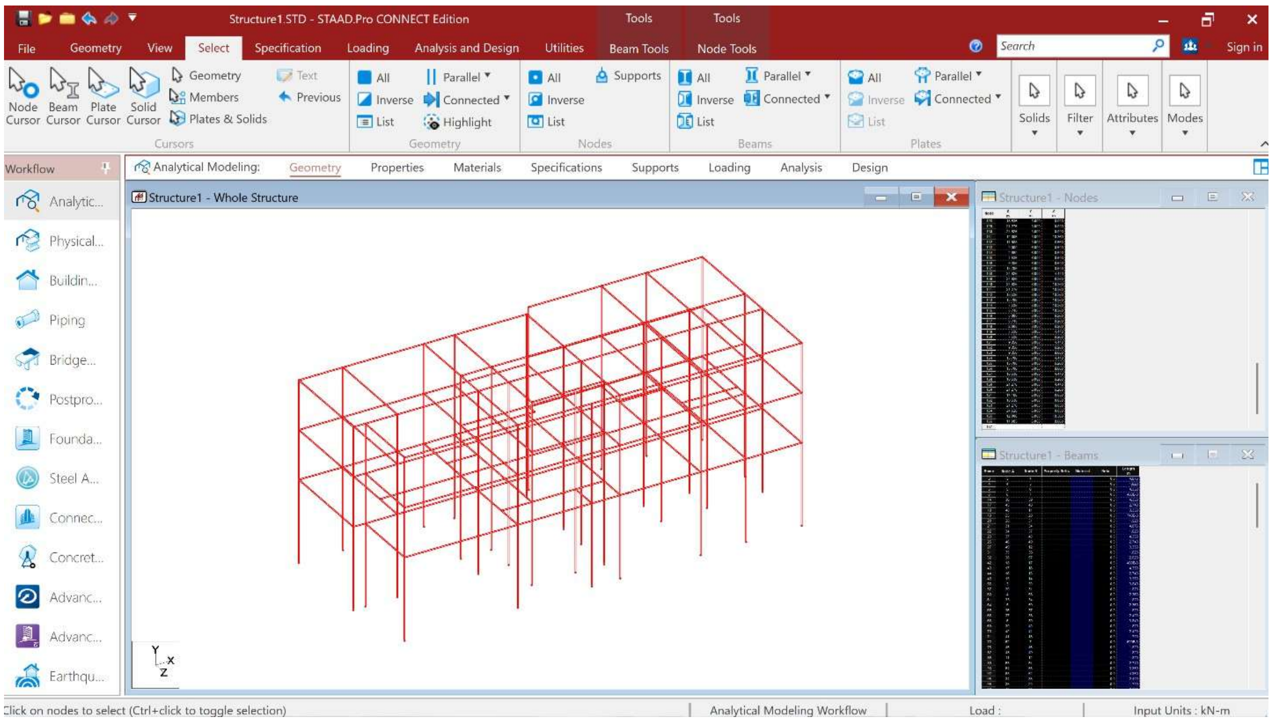

Figure4. 1 3d Frame Model

Data Panels (right side):

Structure1 - Nodes: Lists all the node numbers and their coordinates.

Structure1 - Beams: Shows member details such as beam numbers, node connectivity, etc.

Structure:

The model has multiple bays and floors, with vertical and horizontal members, indicating beams and columns.

No slab or plate elements are shown in the current view—only beam elements.

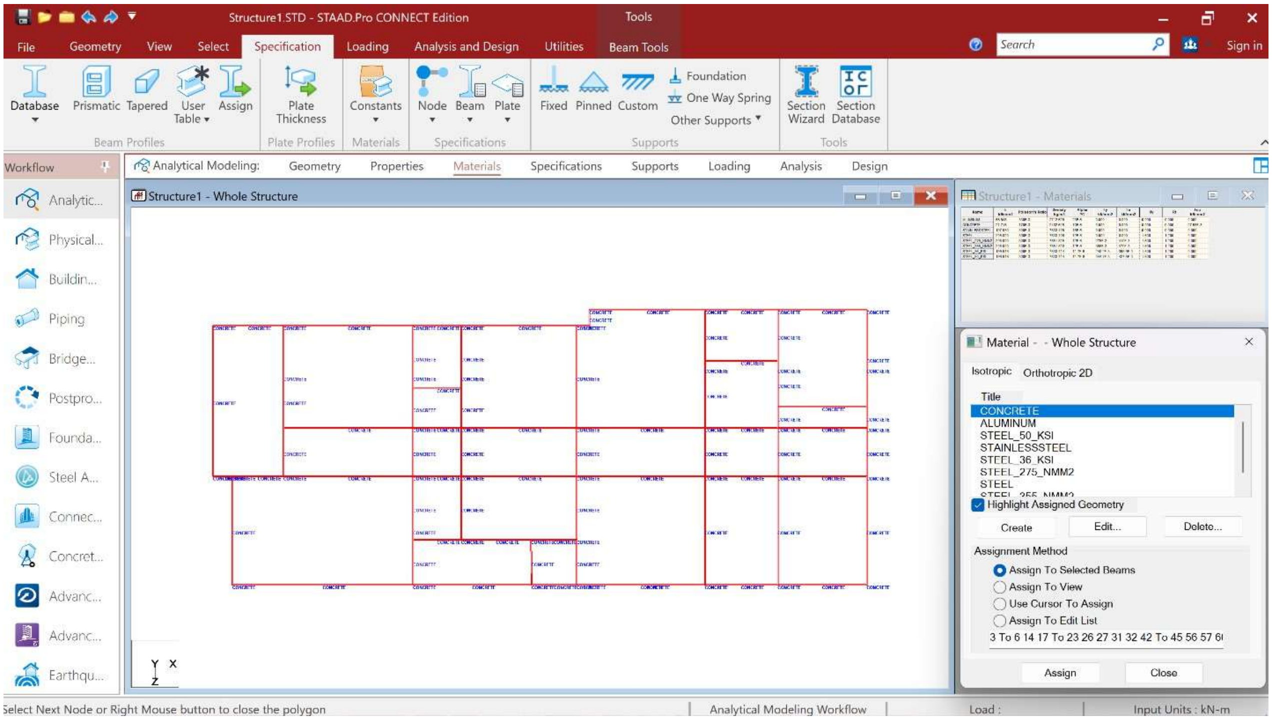

Figure4. 2 Beam Cross-Section Assignment in Analytical Model

STAAD.Pro Beam Layout Summary:

- Plan view shows the beam arrangement for structural analysis.
- Two beam sizes are used:

  0.22 x 0.45 m – Main beams for heavy loads (e.g., corridors).

  0.22 x 0.22 m – Secondary beams for smaller spans.

- All beams are concrete, offering strength and seismic resistance.
- Assigning correct sizes ensures:

  Proper load distribution,

  Accurate stress analysis,

  Safe and cost-effective design.

The structure appears to have full connectivity with no visibly floating or disconnected members.

1. **Node Labels:**

   Node numbers are visible (in blue), meaning node labelling is turned on for easier tracking and connectivity checking.

2. **Beam Elements:**

   Beam lines (red) are shown connecting nodes—these represent your structural elements (columns, beams, etc.).

3. **No Supports Yet:**

   There are no support symbols (like fixed/pinned restraints) visible at the base. This means supports have not yet been defined, or they’re just not shown in this view. This will cause errors during analysis unless defined.

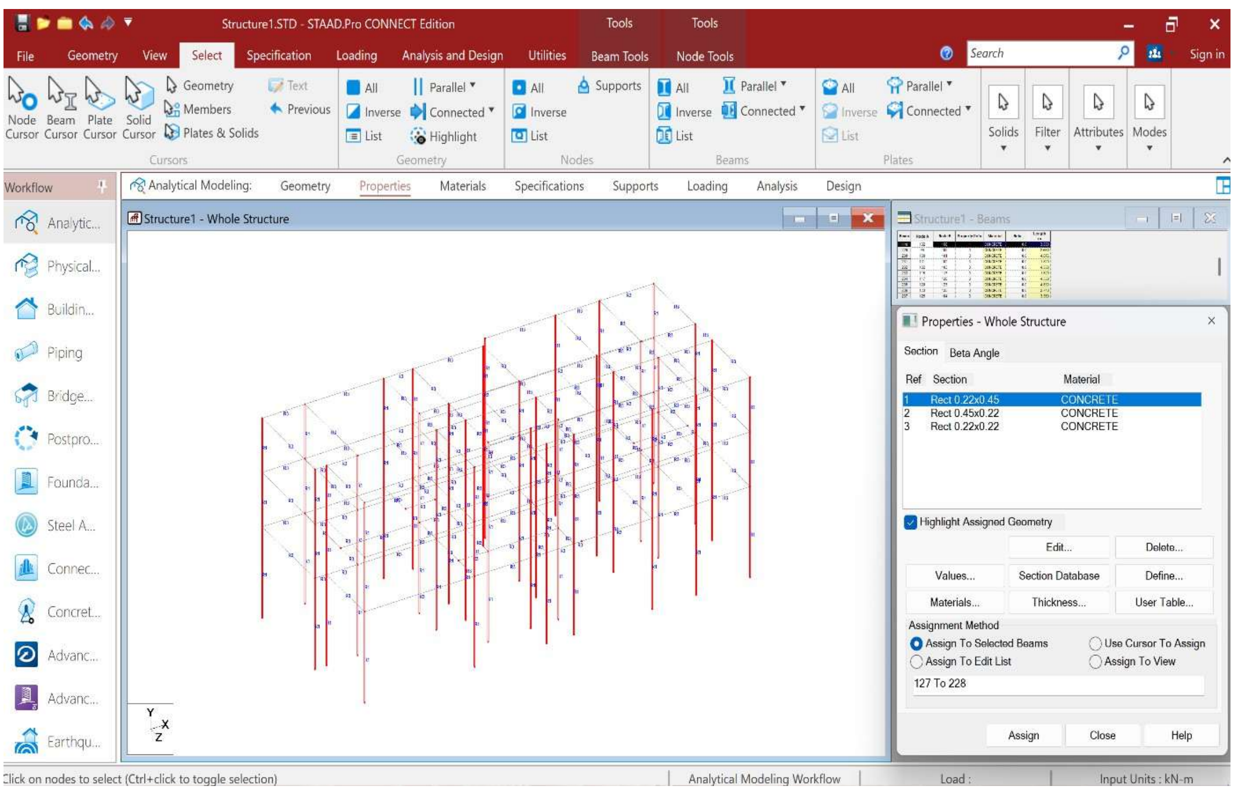

Figure4. 3 3d Model column reactions

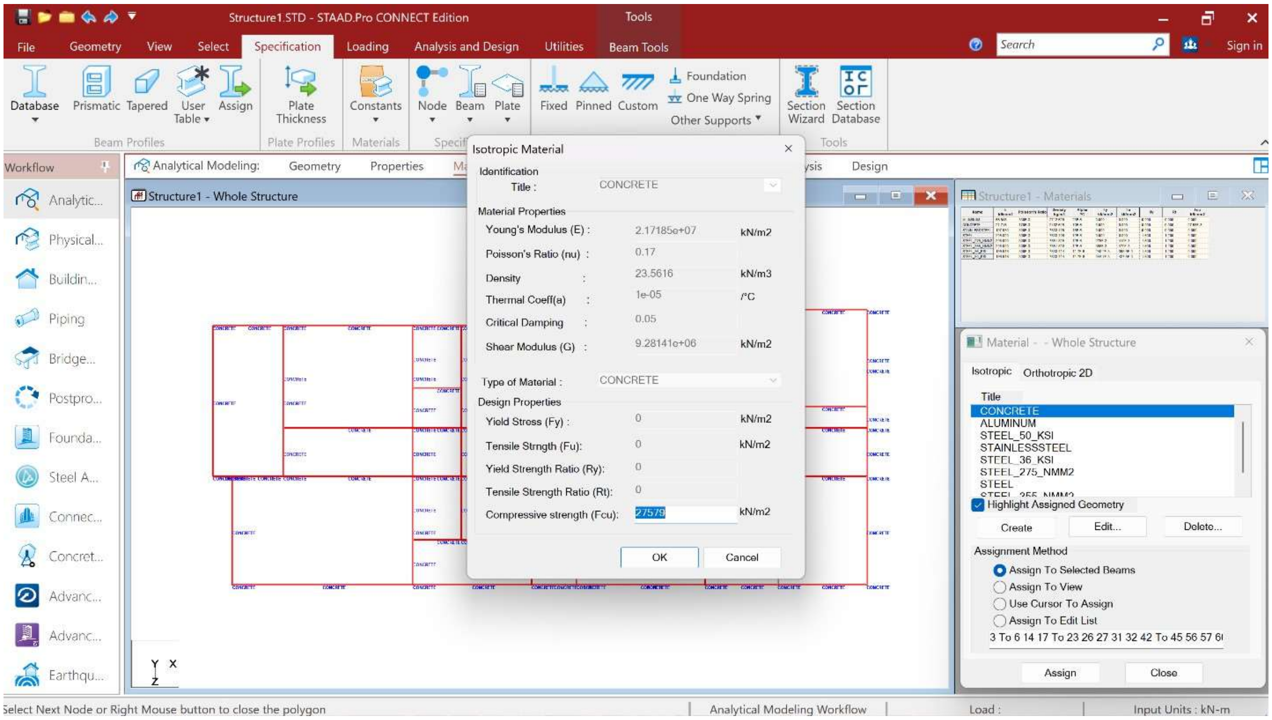

Figure4. 4 Material Property Definition for Concrete

Material Properties in STAAD.Pro:

- Young's Modulus: 2.17×10^7 kN/m² – Controls stiffness and deformation.
- Poisson's Ratio: 0.17 – Typical for concrete, relates lateral to axial strain.
- Density: 23.56 kN/m³ – Used for self-weight calculation.
- Shear Modulus: 9.28×10^6 kN/m² – For shear behaviour analysis.
- Thermal Coefficient: 1e-5 /°C – For thermal expansion.
- Damping Ratio: 0.05 – Used in dynamic (e.g., seismic) analysis.

Dead Load (DL):

- The self-weight of the structure was automatically added using SELFWEIGHT Y -1, which means gravity is acting downward.
- Two uniform loads were also applied on certain beams: one at 4 kN/m and another at 3 kN/m, both acting in the downward direction.

Live Load (LL):

- A floor load of 2 kN/m² was applied using the command YRANGE 0 3 FLOOR -2 GY.
- This applies the load vertically (in the Y direction) across the height range from 0 to 3 meters.

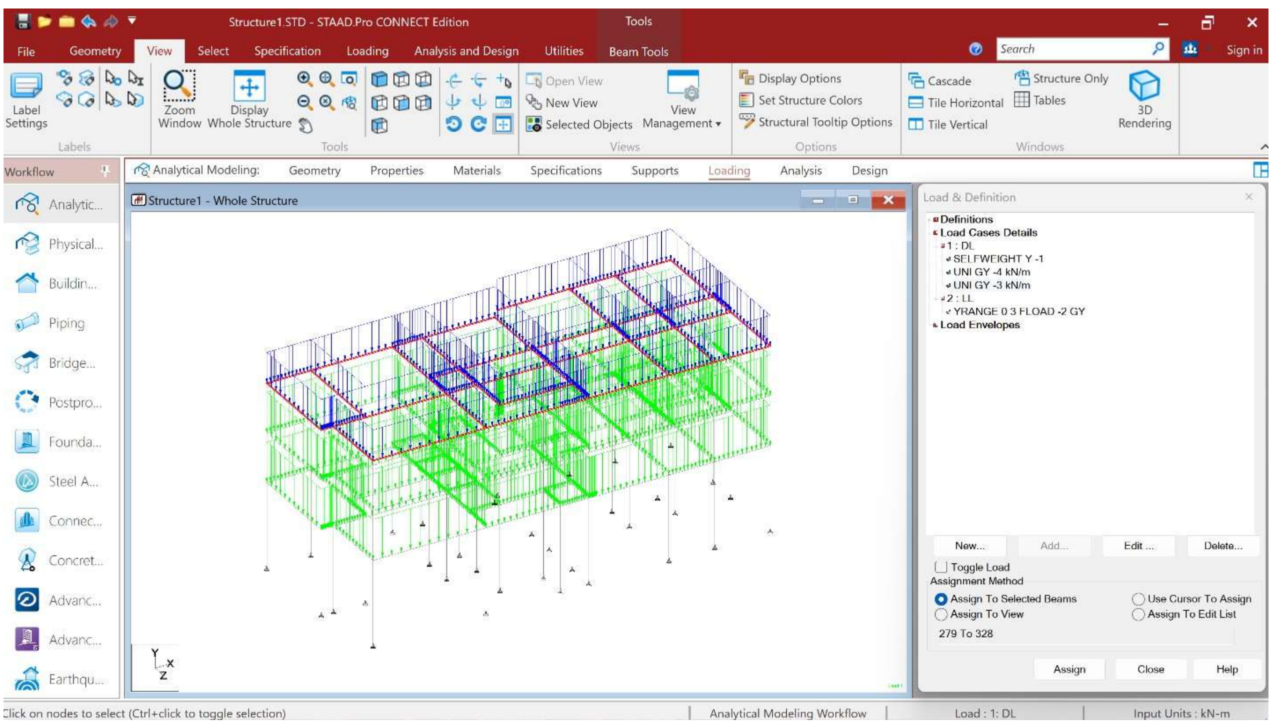

Figure4. 5 Material Property Definition for Concrete

Figure 4.6 shows the beam results view in STAAD.Pro CONNECT Edition after analysis. The red lines on beams represent bending moment distribution—these are BMD contours. The visual confirms:

- Structural deflections and moments are being shown.
- Your model has loads successfully applied and results post-processed.

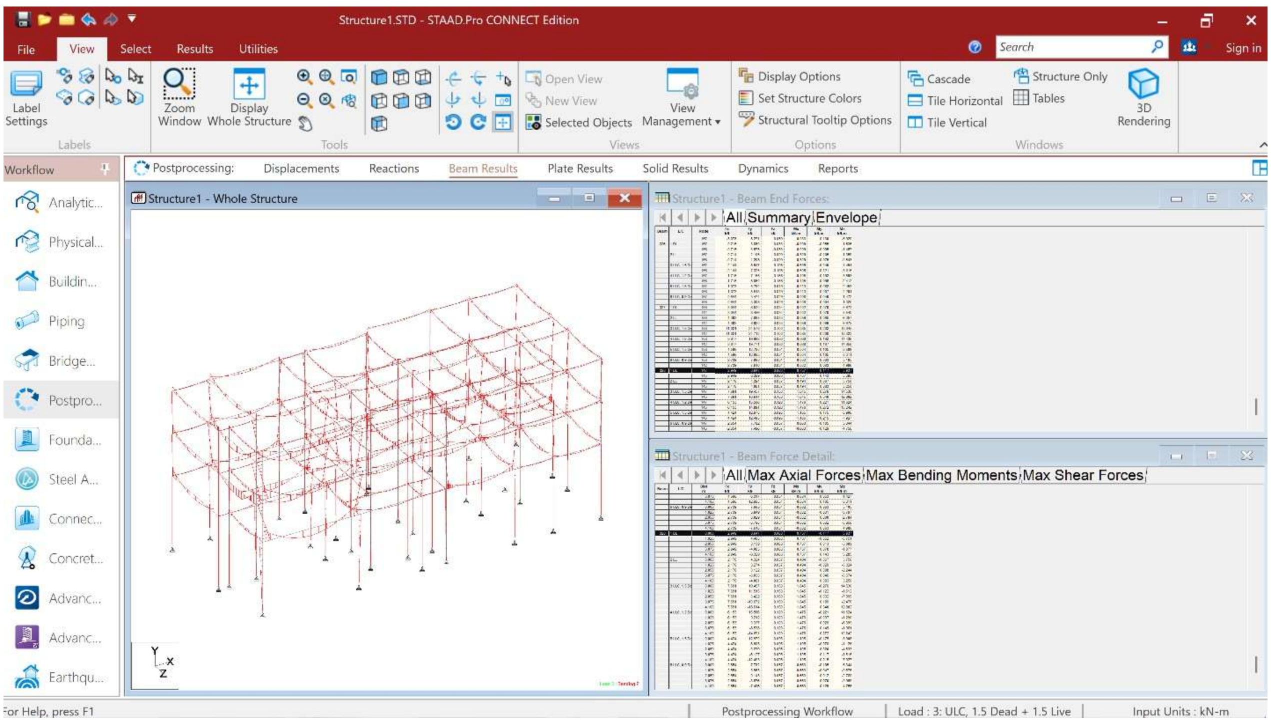

Figure4. 6 Bending moment distribution

Figure 4.7 shows the structural model with vertical reaction forces displayed at the supports using STAAD.Pro CONNECT Edition. The red arrows represent the magnitude and direction of reactions, likely due to gravity loads, and the black labels provide numerical values. This view helps in analyzing support conditions and ensuring load transfer is as per design.

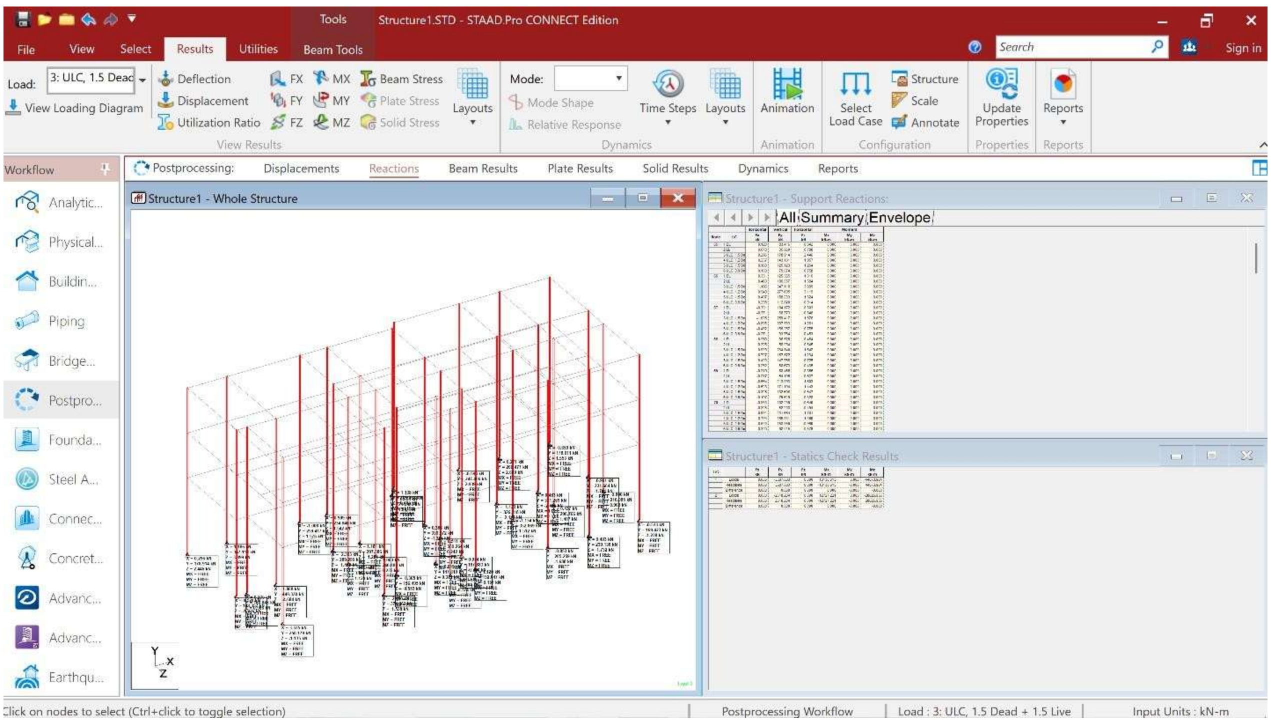

Figure4. 7 7 Reaction Forces Display – Whole Structure

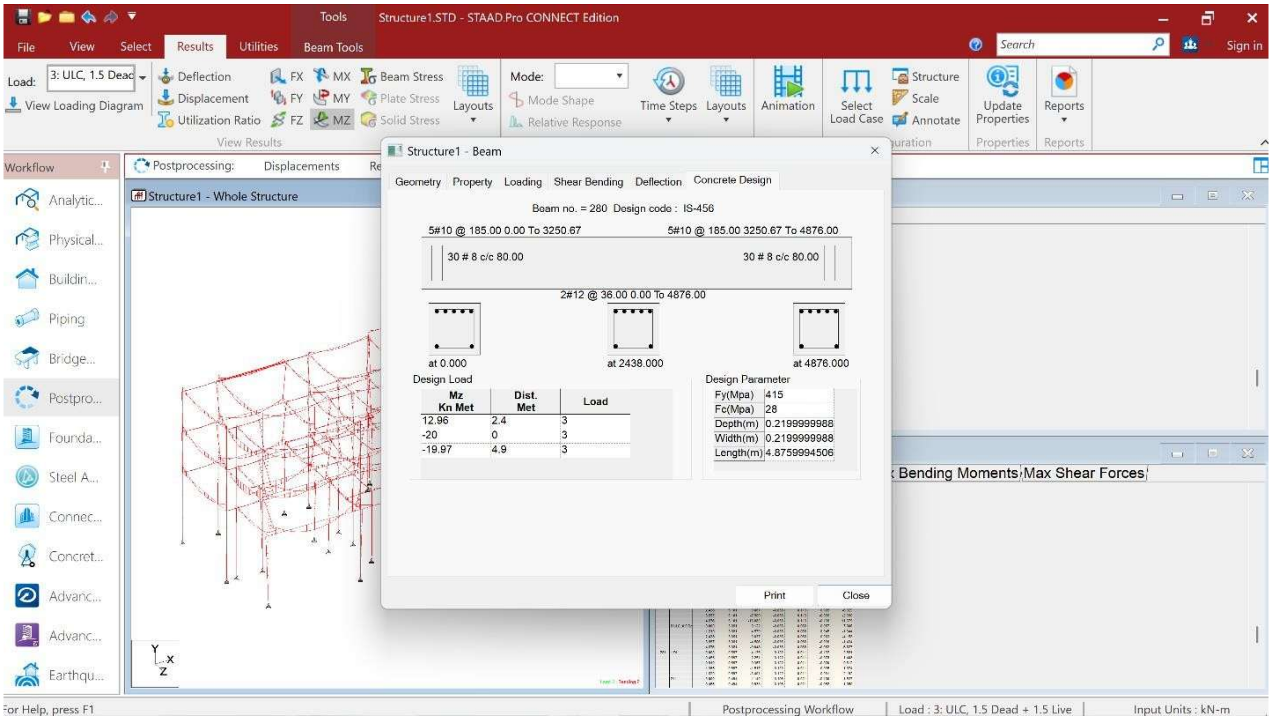

Figure4. 8 Beam Reinforcement and Design Parameters

Beam No. 280 Design Summary (IS 456 - STAAD.Pro)

- Main Bars: 5 bars of 10 mm @ 185 mm c/c on both spans.
- Stirrups: 30 stirrups of 8 mm @ 80 mm c/c.
- Beam Size: 220 mm × 220 mm approx, Length ~4.88 m.
- Material Strengths: Fy = 415 MPa, Fc = 28 MPa.
- Moments (Mz): Max +12.96 kNm, Min -20.0 kNm.

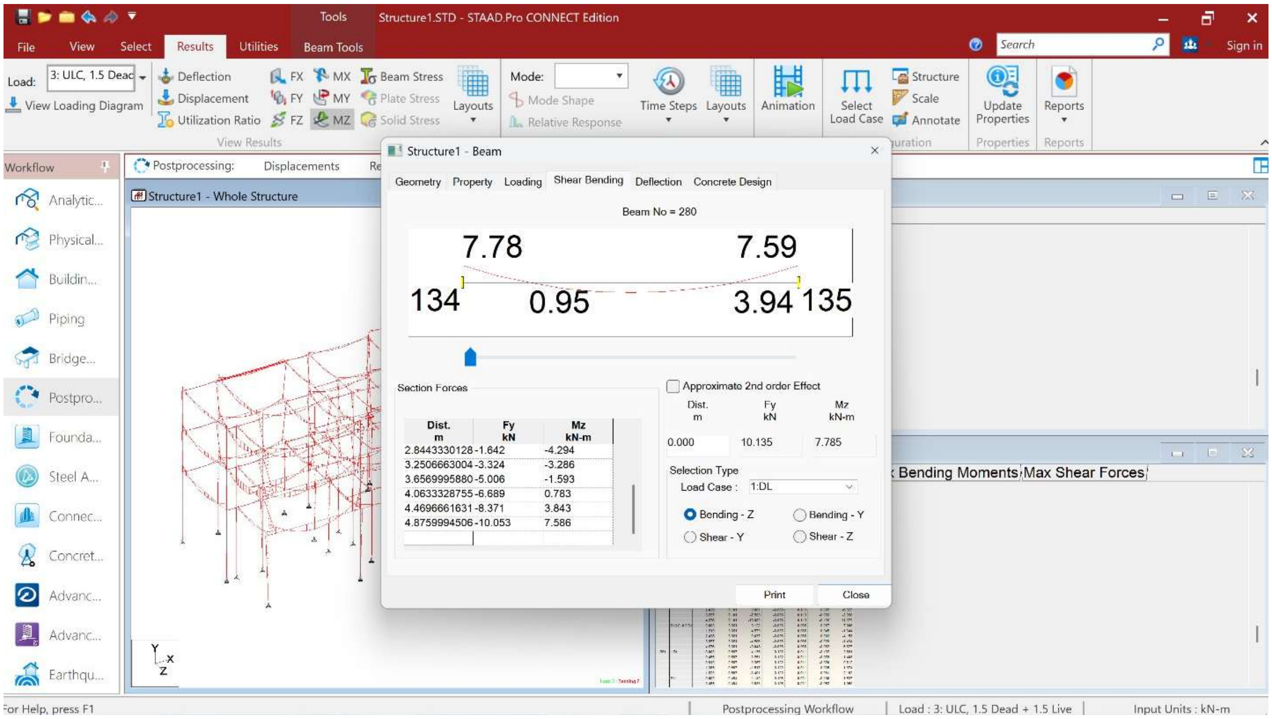

Figure4. 9 Beam Reinforcement and Design Parameters

Beam Ends Uplifted (Support Reactions):

- Left end moment: +7.78 kNm
- Right end moment: +7.59 kNm
- Indicates typical bending for simply supported or partially fixed beams.

Midspan Deflection:

- Peak deflection around mid-span: ~0.95 mm, showing minor downward bend under load.

Shear Forces (Fyy):

- Varies from -1.64 kN to -10.05 kN, increasing toward supports.

Bending Moments (Mz):

- Negative at mid-span (-4.29 kNm to +7.59 kNm), showing sagging and hogging zones.

Load Case Applied:

- 1-DL selected – only dead load is being considered here.

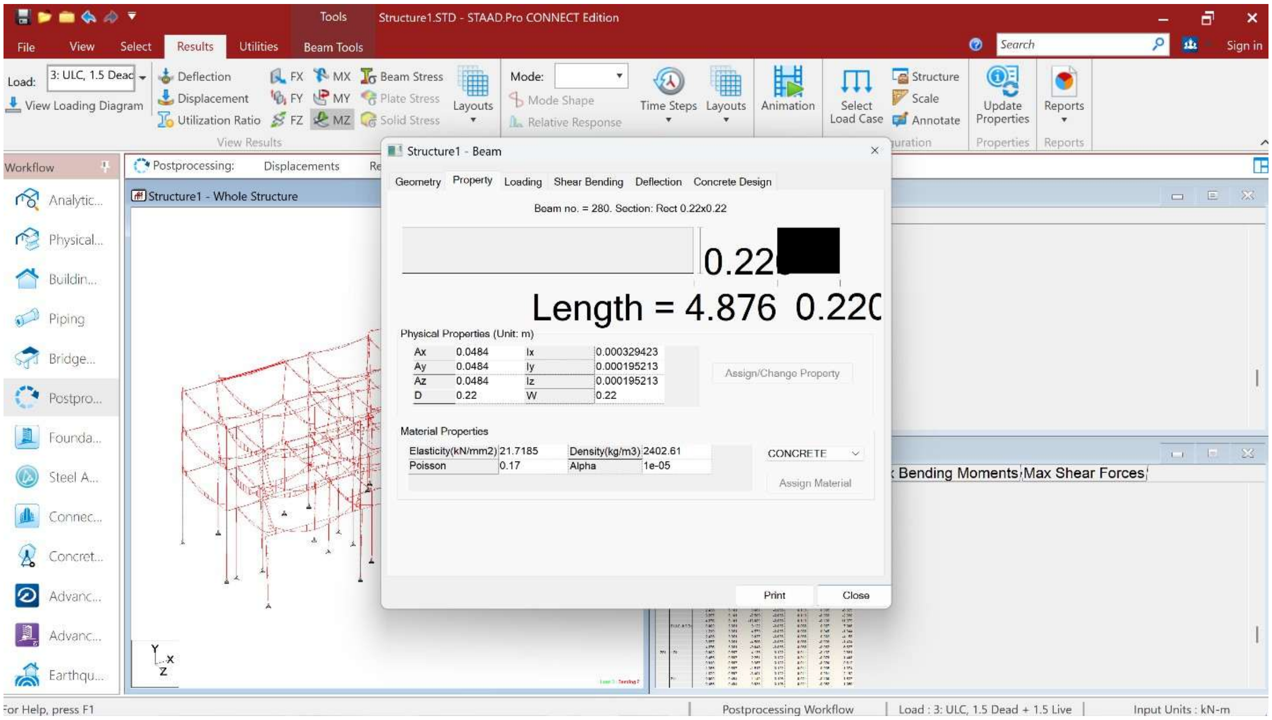

Figure4. 10 Beam Property and Material Assignment

Section & Material Overview

Dimensions: Rectangular section of 0.22 m × 0.22 m

Span: Beam length is 4.876 meters

Section Details:

Area: 0.0484 m²

Inertia (Ix): 0.000329 m⁴, (Iy/Iz): 0.000195 m⁴

Material Info:

Type: Concrete

Elastic Modulus: 21,718.5 kN/m²

Density: 2402.61 kg/m³

Poisson Ratio: 0.17, Alpha: 1e-05

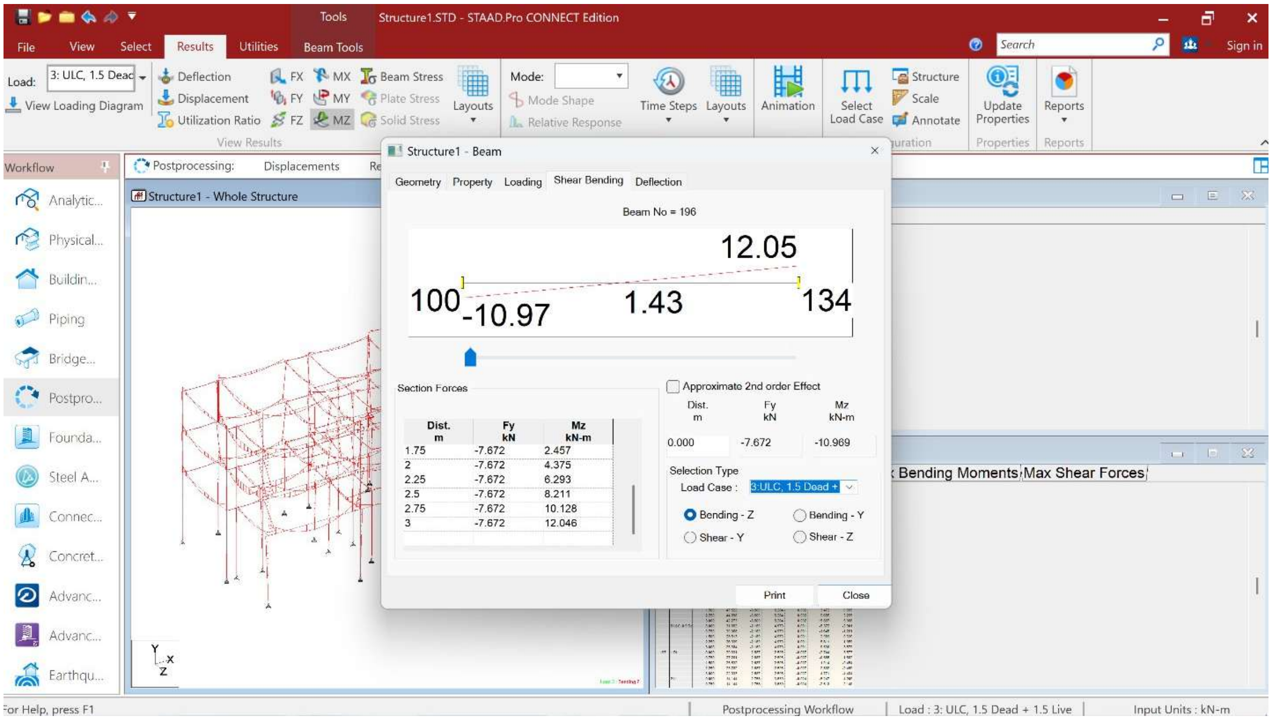

Figure4. 11 Shear and Bending Analysis

Analysis

1. Length: 12.05 m
2. Load Case: Ultimate (1.5 × Dead Load)
3. Shear Force (Fy): Constant at -7.672 kN
4. Bending Moment (Mz): Starts at -10.97 kNm, peaks at 12.05 kNm
5. Type of Load: Likely uniform (UDL) – steady shear, rising moment
6. Direction:
    - Shear in Y-axis
    - Bending around Z-axis

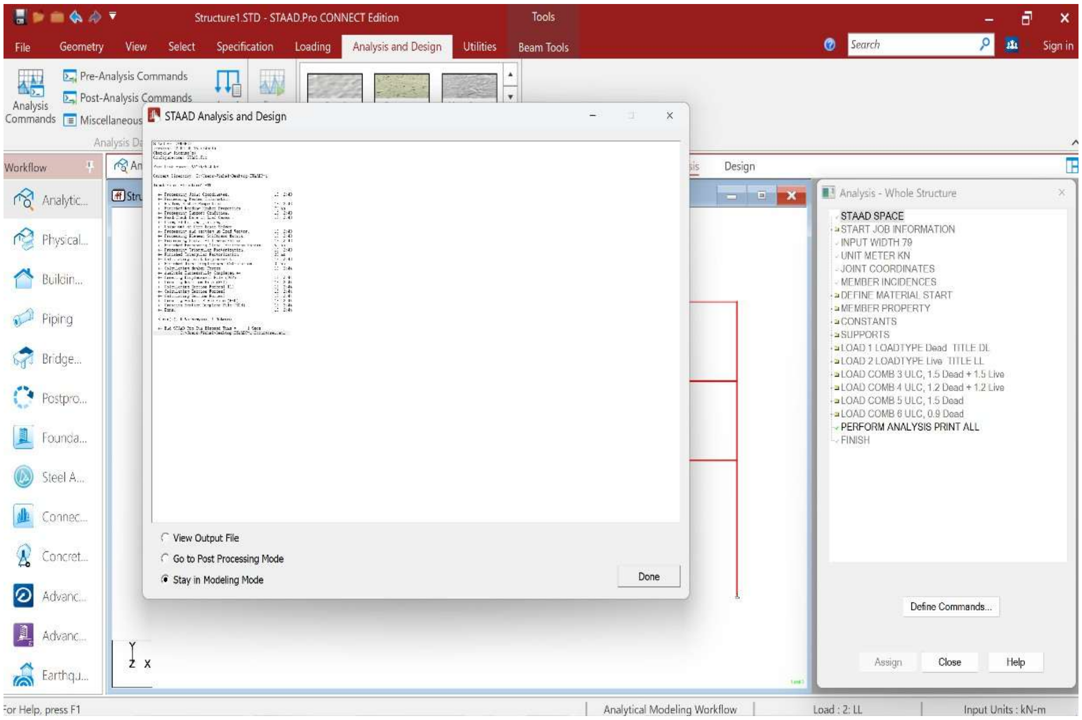

Figure4. 12 STAAD.Pro Structural Analysis Summary

STAAD Analysis Summary (Point-wise):

- **J**oint coordinates, member details, and material properties were successfully defined.
- Support conditions and loading data were correctly read and processed.
- The stiffness matrix was generated without any errors.
- Structural analysis was completed successfully.
- Member displacements and internal forces were calculated accurately.
- All included design checks were performed with no issues.

4.3 Manual Calculations

Initial Assumptions:

Unit Weight of EPS Concrete: 20 kN/m³

Live Load Considered: 2 kN/m²

Wall Specifications:

- Wall Thickness = 230 mm
- Height Above Plinth = 3 m
- Density of Brick Masonry = 20 kN/m³
- Wall Load = 0.23 × 3 × 20 = 13.8 kN/m (Running meter)

Beam Details:

- Beam Length = 3 meters
- Cross-Section = 230 mm × 300 mm
- Concrete Grade = M25
- Steel = Fe500
- Beam Self-weight = 0.23 × 0.3 × 20 = 1.38 kN/m

1. **Load Applied on Beam:**

Total Load per meter (w) = Self-weight + Masonry Load + Live Load

= 1.38 + 13.8 + 2 = 17.18 kN/m

2. **Bending Moment (BM):**

For a simply supported beam:

$BM = (w \times L^2) / 8$

$= (17.18 \times 3^2) / 8 = 19.33$ kNm

3. **Shear Force (SF):**

SF at Supports = (w × L) / 2

= (17.18 × 3) / 2 = 25.77 kN

4. **Reinforcement Calculation:**

Main Reinforcement (Bottom Steel):

Using limit state method:

$Mu = 0.87 \times fy \times Ast \times d$

Assume effective depth (d) = 300 – (cover + ½ dia of bar) = 270 mm

Now,

$19.33 \times 10^6 = 0.87 \times 500 \times Ast \times 270$

$\longrightarrow Ast \approx 159.4\ mm^2$

Shear Reinforcement (Stirrups):

$\tau v = V / (b \times d) = 25.77 \times 10^3 / (230 \times 270) = 0.414$ MPa

Permissible τc for M25 = 0.48 MPa → Safe

Use 8 mm dia, 2-legged stirrups spaced at 150 mm c/c

5. **Load Assessment on Column:**

Let's evaluate the total axial force carried by a typical column in the building:

Slab Load (Dead Load + Finishes):

- Slab Thickness = 125 mm → Load = 0.125 × 25 = 3.125 kN/m^2
- Add 1 kN/m^2 for finishes = 4.125 kN/m^2
- For 3 floors → 4.125 × 3 = 12.375 kN/m^2

Beam Contribution:

- Beam Size = 230 × 450 mm = 0.1035 m^2
- Self-weight = 0.1035 × 25 = 2.59 kN/m
- Assume 6 meters of beam = 2.59 × 6 = 15.54 kN

Masonry Load from Wall:

- Wall per floor = 0.23 × 3 × 19 × 3 = 39.33 kN
- For 3 floors = 118 kN

Self-Weight of Column:

- Column Size = 0.3 × 0.45 = 0.135 m^2
- Volume for 1 floor = 0.135 × 3 = 0.405 m^3

- Load per floor = 0.405 × 25 = 10.125 kN
- Total (3 floors) = 30.375 kN

Total Load on Column =

= 12.375 (Slab) + 15.54 (Beam) + 118 (Wall) + 30.375 (Column)

→ 176.29 kN (approx.)

Considering safety margin, rounding off:

→ Design Load = 224.16 kN

6. Footing Design:

Required Footing Area:

Assume SBC of soil = 150 kN/m²

Required area = 224.16 / 150 = 1.49 m²

Depth of Foundation:Use formula: D = (γ × K) / qnet

Here: γ = 20, K = 0.5

→ D = (20 × 0.5) / 150 = 1.5 meters

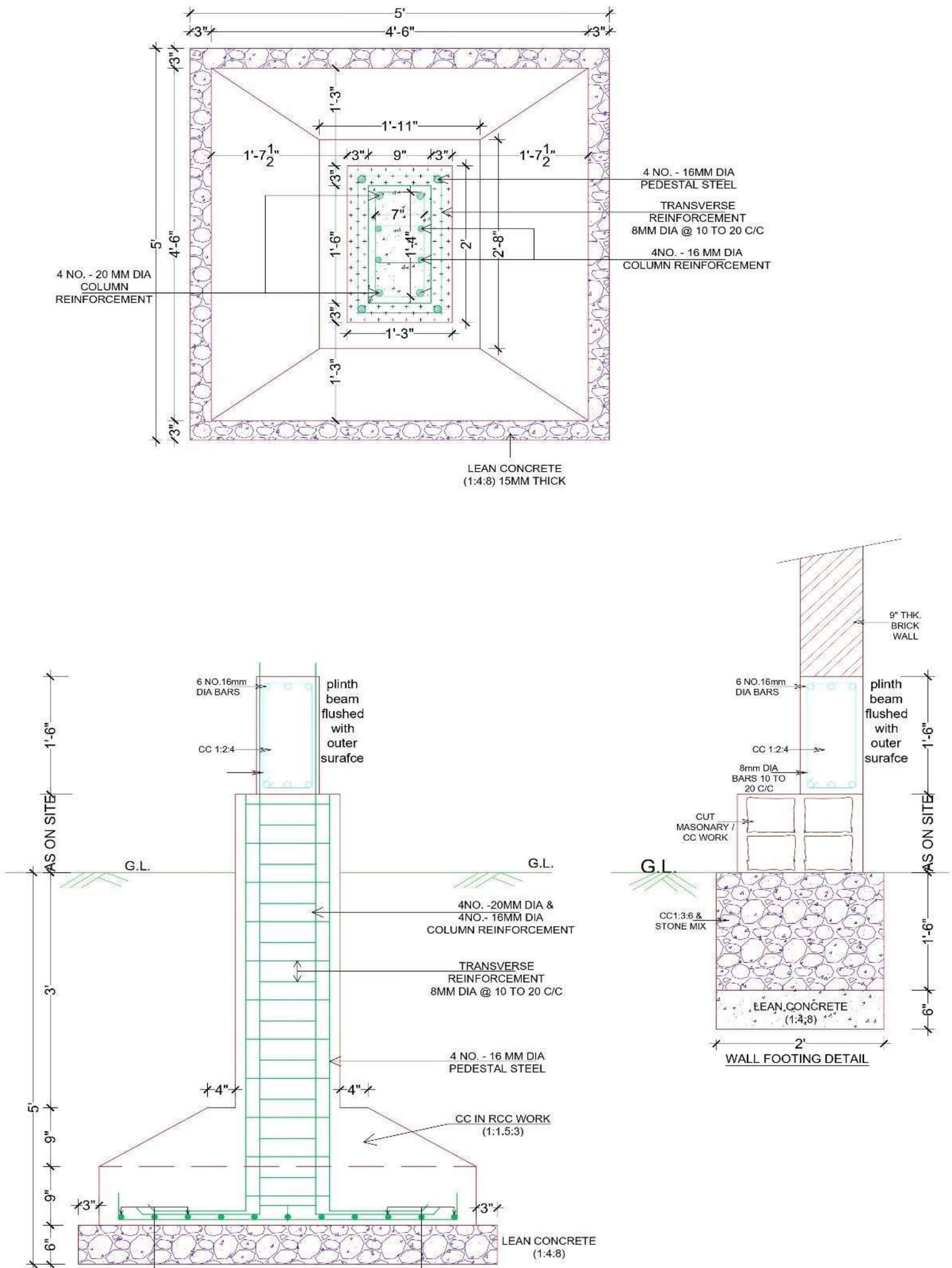

Figure4. 13 Footing and reinforcement detail of column

7. **U-Shaped Staircase Design:**

Total Riser Height = 3 meters

No. of risers = 18 (6 per flight)

→ Riser = 3000 / 18 = 167 mm

Tread Calculation:

Use standard comfort rule: 2R + T ≈ 630 mm

→ T = 630 – 2 × 167 = 296 mm (Rounded to 300 mm)

Nosing = Extend tread by 25–30 mm

Inclination Angle = $\tan^{-1}$ (Rise/Run)

→ $\tan^{-1}$ (1.5 / 1.002) ≈ 33.74°

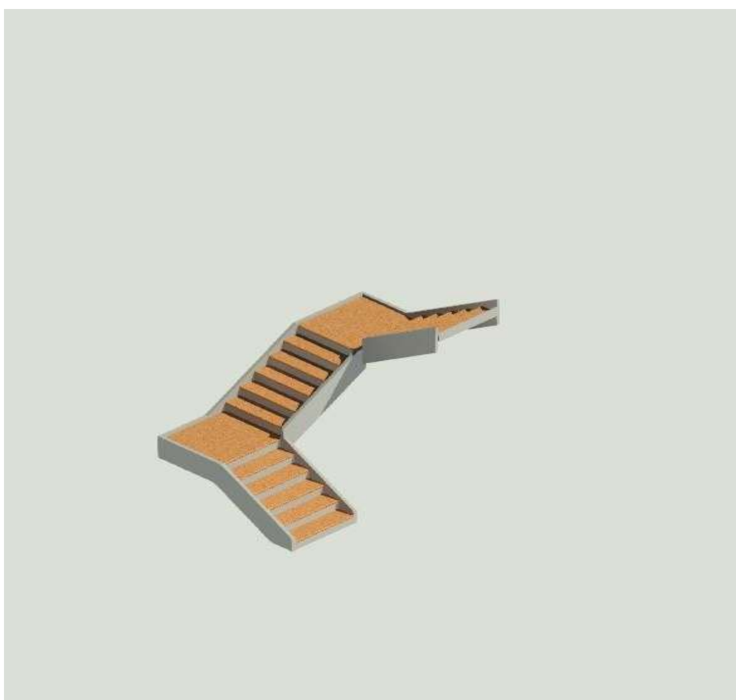

Figure4. 14 3d Model of Stairs

8. **Lintel Thickness Calculation (Precise)**

Clear span of the lintel (L) = 1.5 meters

Factored uniformly distributed load (w) = 26.14 kN/m

To calculate the maximum bending moment (Mu) for a simply supported beam:

Mu= (w * L^2)/ 8 = (26.14 x (1.5)^2)/8

Mu = 7.35kNm

Converting it into N-mm

$$Mu = 7.35 \times 10^6 \text{ N/mm}$$

Now, using the bending strength formula to determine effective depth (d):

d=√(Mu /(0.138×fck×b)

Substitute values:

- fck = 27 MPa (M27 grade concrete)
- b = 230 mm (width of lintel)

d= 93mm

Add effective cover (assumed 30 mm) to get the total depth:

Total depth (D)=93+30=123 mm

Conclusion

The design and analysis journey of a G+2 green building in Solan was carried out successfully and yielded valuable insights. From the outset, the project was envisioned as a structure that would ensure safety, stability, and environmental responsibility. STAAD.Pro was utilized to evaluate the building's response to various realistic load conditions, including dead, live, wind, and seismic loads—particularly important as Solan is located in Earthquake Zone IV. Load combinations based on IS codes were applied to ensure that the structure would perform reliably in real-world conditions.

Sustainability was prioritized throughout the project. Traditional construction materials were partially replaced with eco-friendly alternatives to minimize environmental impact. EPS beads concrete was selected for structural elements like slabs due to its lightweight yet strong properties, which contributed to reducing the building's dead load—a critical factor for seismic safety.

Solar tiles were incorporated into the roof design, enabling renewable energy generation while lowering reliance on grid electricity. Over time, this integration is expected to reduce both energy costs and carbon emissions. Reclaimed wood was used for interior finishes, offering an environmentally responsible option that preserved material quality and added aesthetic value.

Mycelium, a biodegradable fungi-based material, was employed for non-structural internal panels. Though relatively new in the construction field, it contributed positively to insulation and sustainability goals. Additionally, recycled aggregates were incorporated into concrete and pavement layers, helping conserve natural resources and limit construction waste.

Architectural planning emphasized environmental considerations. The building was oriented to maximize solar gain in winter and minimize overheating in summer. Southfacing windows were enlarged, and shading devices were added. Ventilation was optimized through open layouts, balconies, and internal courtyards to support passive cooling and reduce the need for mechanical ventilation.

Structural behavior was simulated using STAAD.Pro, where parameters like load distribution, lateral displacements, and support reactions were closely analyzed. The structure was found to remain within safety limits under all loading conditions, including the combination of seismic and wind forces. The reduced dead weight, achieved by using EPS concrete, was noted to enhance the building's seismic performance.

The overall project demonstrated how civil engineering can be aligned with sustainability goals. The integrated use of reclaimed materials, lightweight concrete, renewable energy systems, and passive architectural strategies showcased a practical model for eco-friendly construction. These approaches are especially relevant for environmentally sensitive regions like Himachal Pradesh.

In conclusion, the project represents more than a structural analysis—it reflects a responsible approach to building design. By combining modern engineering tools with sustainable materials and techniques, a structure was created that meets safety standards while minimizing its environmental footprint. It is hoped that such projects will serve as a blueprint for future green construction efforts.

REFERENCES

Kumar, R., Goel, R., Singh, T., Priyadarshi, N., & Twala, B. (2024). Incentivizing green building technology: A financial perspective on sustainable development in India. *F1000Research*, *13*, 924.

Gupta, A. K., Shukla, S. K., & Azamathulla, H. (2022). *Advances in Construction Materials and Sustainable Environment*. Springer Singapore.

Mwero, J. N., & Onchaga, V. N. Experimental Study On Behavior of Lightweight Concrete with Partial Replacement Of Coarse Aggregates With Expanded Polystyrene.

Kumar, K. S., Lingeshwaran, N., & Jeelani, S. H. (2020). Analysis of residential building with STAAD. Pro & ETABS. *Materials Today: Proceedings*, *33*, 1221-1228.

Saleh, H. M., Dawoud, M. M., & Hassan, A. I. (2023). Sustainable and eco-friendly building materials. *Frontiers in Built Environment*, *9*, 1160556.

Standard, I. (2000). Code of practice for plain and reinforced concrete. *Bureau of Indian Standard, New Delhi, India*.

IS, I. S. C. (1893). 2002 Criteria for earthquake resistant design of structure. *Bureau of Indian Standards, New Delhi*.

BIS, I. S. (1993). 13920 ductile detailing of reinforced concrete structures subjected to seismic forces– code of practice. *New Delhi (India): Bureau of Indian Standards*.

Yu, S., Evans, M., & Delgado, A. (2014). *Building energy efficiency in India: Compliance evaluation of energy conservation building code* (No. PNNL-23217). Pacific Northwest National Laboratory (PNNL), Richland, WA (United States).

Gowda, M. B. G. (2023). An Influence of Recycled Concrete Aggregate and Treated Waste Water Containing 50% GGBS Content in Light weight Concrete Mixes. *International Journal of Engineering and Applied Physics*, *4*(1), 919-929.

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