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Analysis and Design of Multi-Storey Apartment Building using STAAD.Pro

B.Vishnuvardhan Nayak, B.Sai Akshay, B.Suresh, Syed Amjad Peer Quadri

U.G. Student, Department of Civil Engineering, Guru Nanak Institutions Technical Campus, Ibrahimpatnam,
Telangana, India

Assistant Professor, Department of Civil Engineering, Guru Nanak Institutions Technical Campus, Ibrahimpatnam,
Telangana, India

ABSTRACT: STAAD or (STAAD.Pro) is a structural analysis and design computer program Originally developed by Research Engineers International in Yorba Linda, CA. In late 2005, Research Engineer International was bought by Bentley Systems.

The collected data is analysed and a 3-D model is generated using STAAD Pro. The various loads acting on the structure is calculated and the structure is analysed for the various load combinations. Design of the building is done. The obtained results are analysed. Manual calculation and design of slabs, beams, staircase and columns are done.

KEY WORDS: Multi storey building, AutoCAD, Staad Pro & Loads combinations

I. INTRODUCTION

1.1 AIMANDSCOPE OF WORK

The structural design for a building must ensure that the building is able to stand safely, to function without excessive deflections or movements which may cause fatigue of structural elements, cracking or failure of fixtures, fittings or partitions, or discomfort for occupants .It must account for movements and forces due to temperature ,creep ,cracking and imposed loads. It must also ensure that the design is practically buildable within acceptable manufacturing tolerances of the materials. It must allow the architecture to work, and the building services to fit with in the building such that it is functionable (air conditioning, ventilation, lighting etc.).

The aim of this project work is to analyse a 5-storeyed hostel building for different load combinations using STAAD Pro software. Based on the analysis, design of the structure is done mainly in accordance with IS specifications.

1.2 DESIGN PHILOSOPHIES

The limit state method is adopted for the analysis and design of the structure.IS codes, SP-16 and SP-32 charts areal so used as an aid for detailing and design purpose.

The major requirements of a properly designed building are:

a) **GOOD STRUCTURAL CONFIGURATION:**

Its size, shape and structural system carrying loads such that they ensure a direct and smooth flow of inertia forces to the ground.

b) **LATERAL STRENGTH:**

The maximum lateral(horizontal) force that it can resist is such that the damage induced in it does not result in collapse.

c) **ADEQUATE STIFFNESS:**

Its lateral load resisting system is such that the earthquake-induced formations in it do not damage its contents under low-to moderate shaking.

1.3 GOOD DUCTILITY:

Its capacity to undergo large deformations under severe earthquake shaking even after yielding is improved by favourable design and detailing strategies.

COMPONENTS OF THE STRUCTURE;

The components of the structure are mainly classified into

- a) Superstructure
- b) Substructure

Superstructure is the part of the building that lies above the ground line. These are subjected to lateral loads like the wind load, earthquake load, and other dead and live loads.

Substructure is the foundation of the building. The type of foundation adopted for the hostel building under consideration is pile foundation.

1.3.1 PILE FOUNDATION

A deep foundation is a type of foundation distinguished by the depth on which they are embedded into the ground. Piles are generally driven into the ground in situ. The types of piling are DMC Piling and rotary piling.

In DMC Pile Foundation the bentonite suspension is pumped into the bottom of the hole through the drill rods and it overflows at the top of the casing. The mud pump should have the capacity to maintain a velocity of 0.41 to 0.76 m/s, to float the cuttings.

The depth of piling was decided by testing the underground soil samples (to obtain level bed). It is not possible in hard rocks. Tremie pipe is inserted into pile holes for pile concreting.

II. LITERATURE REVIEW

Chintakrindi V. Kanaka Sarath et. al (2020). focused on the planning, design, and analysis of a multi-story building supported by a single central column, addressing the growing need for innovative construction techniques due to population growth and land scarcity. Located in Chennai, the G+3 building stands 16.5 meters tall and includes essential components such as staircases, dining rooms, restrooms, verandahs, and bathrooms. Designed using M30-grade concrete and HYSD steel with a yield strength of 415 N/mm², the structure adheres to Indian standards (IS 456-2000) for safety and durability. Key dimensions include a 2.5 m × 2.5 m column, 350 mm × 250 mm beams, 230 mm wall thickness, and 0.17 m slab thickness. Advanced structural analysis using STAAD.Pro revealed that seismic loading significantly increases shear forces and bending moments, with bending moments showing a 91% rise compared to non-seismic scenarios. The software also facilitates efficient design, reducing manual effort while providing detailed reinforcement plans for every structural member. The study highlights the importance of combining aesthetic design, structural safety, and economic efficiency, demonstrating the feasibility of constructing such innovative mono-column buildings with adherence to modern standards.

Tarun Kumar Rajak, Girish Joshi, Sandeep Goyal, Mangal Singh Meravi, M. Suresh, D Samuel Abraham et. al (2022). They provided a comprehensive overview of the design and analysis of a G+12 multi-story residential building using STAAD.Pro software. The structure consists of three interconnected apartment blocks with 33 flats, two staircases, and two lifts, designed as an RCC framed structure with brick and block walls. The building's design incorporates M30 grade concrete and Fe415 steel, adhering to IS codes for load considerations, including dead, live, wind, and seismic loads. The study highlights the efficiency of STAAD.Pro in analyzing and designing complex structures, reducing time and effort while ensuring accuracy. Detailed plans, including floor layouts, centerline diagrams, and skeletal models, showcase the arrangement and dimensions of rooms and furniture. The design process involves analyzing the structure for maximum bending moments, shear forces, and stability under varying loads. STAAD.Pro's capabilities extend to foundation analysis, including shallow and deep footings, with precise details on geometry, reinforcement, and manual calculations. Limitations of STAAD.Pro, such as excessive output data and challenges with plinth beam modeling, are also addressed. The report concludes that STAAD.Pro significantly enhances structural design accuracy and efficiency, making it an indispensable tool for high-rise building projects.

Mohd Abdul Majid, Mohammed Shakir Hussain, Mohd Abdul Salman Afridi, Mohd Amer Khan, Amir Sohail, Dr. Aftab Tanveer et. al (2022). They explored the structural planning, analysis, and design of a C+G+6 (cellar + ground floor + 6 stories) commercial building using a combination of manual and software-assisted methods. The

process involves planning with AutoCAD, analysis, and design in STAAD Pro., adhering to the IS: 456-2000 and IS: 875-1987 codes for structural design and load considerations. The building components such as slabs, beams, columns, and staircases are designed using the Limit State Method. STAAD Pro. simplifies structural analysis by calculating reinforcement requirements and verifying the safety of the structure under various loads, including dead load, live load, wind load, and seismic load. The report highlights the significance of multi-story buildings in addressing urbanization challenges and space constraints in cities, emphasizing the role of advanced construction materials, technology, and design codes. References from studies and codes provide context for the methodology and outcomes, showcasing the efficiency of STAAD Pro. in ensuring structural integrity and adherence to standards.

Prof. Jacky Gurnani, Aman Dussawar, Varun Bagade, Syed Faraz Ali et. al (2021).

They analysed that High-rise buildings are essential in urbanized and industrialized areas, providing stability, durability, and serviceability to residents. However, their vulnerability to seismic forces, especially in India's high seismic zones, has highlighted the necessity of designing earthquake-resistant structures. This study focuses on analyzing the behaviour of a G+10 multi-story building with regular configurations (square and rectangular) in seismic zones II (Mumbai) and IV (Nagpur) using STAAD.Pro (V8i) software. Both static (Equivalent Lateral Force Method) and dynamic (Response Spectrum Method) analyses are performed to evaluate parameters such as support reactions, shear forces, bending moments, base shear, and displacements. The findings emphasize that seismic performance varies significantly across zones, with Zone IV structures experiencing higher seismic effects compared to Zone II. Literature reveals that regular structures are more resilient than irregular ones, and seismic performance improves with proper structural configuration, lateral strength, and ductility. Advanced tools like STAAD.Pro streamline structural analysis, ensuring compliance with Indian standards (IS 1893:2002, IS 456:2002, IS 13920:1993) and aiding in the efficient and accurate design of earthquake-resistant buildings. Results consistently show that seismic forces, displacements, and material requirements increase with higher zone factors, making Zone V the most critical for structural safety. Ultimately, STAAD.Pro proves to be a reliable, user-friendly tool for optimizing structural resilience and economic feasibility in varying seismic conditions.

M, Lava Ram Kumar Nayak, K. Roshitha, D. Phanindra Babu, D.Umadevi, A.Nagraju, Eera.Srinivas et. al (2024). They have stated that building construction is an engineering discipline focused on the construction of structures, including residential houses, which serve as essential shelters for human needs such as security, comfort, and privacy. Historically, humans transitioned from living in caves and under trees to constructing huts from timber branches, eventually advancing to modern, sophisticated houses. Rich individuals often reside in luxurious homes, while advancements in technology and software, such as Revit and STAAD.Pro, have revolutionized the planning, analysis, and design of buildings. These tools enable engineers to create 3D models, analyse structural elements, and design buildings efficiently while adhering to codes like IS 456 (2000). STAAD.Pro simplifies tasks like assigning loads, analyzing deflections, and calculating reinforcement, making it invaluable for structural safety and accuracy. Residential buildings, specifically, are designed to provide sleeping accommodations and living spaces, encompassing single-family homes, apartments, and hostels. This evolution of construction practices has enabled the creation of multi-storied, earthquake-resistant, and cost-efficient residential structures to meet societal needs.

III. METHODOLOGY

The various steps involved in the project are:

- Data Collection
- Analysis of the data
- Model generation
- Load calculation
- Building analysis
- Design of building
- Result analysis

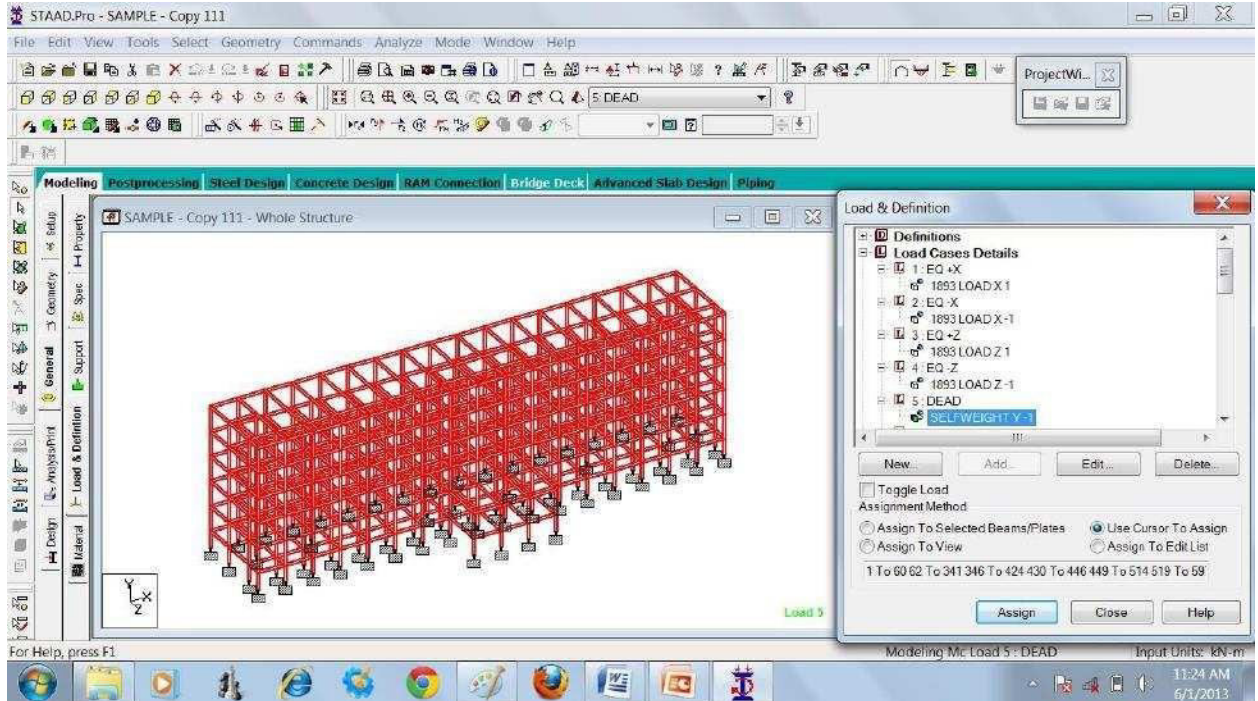


Fig: 1DeadLoad

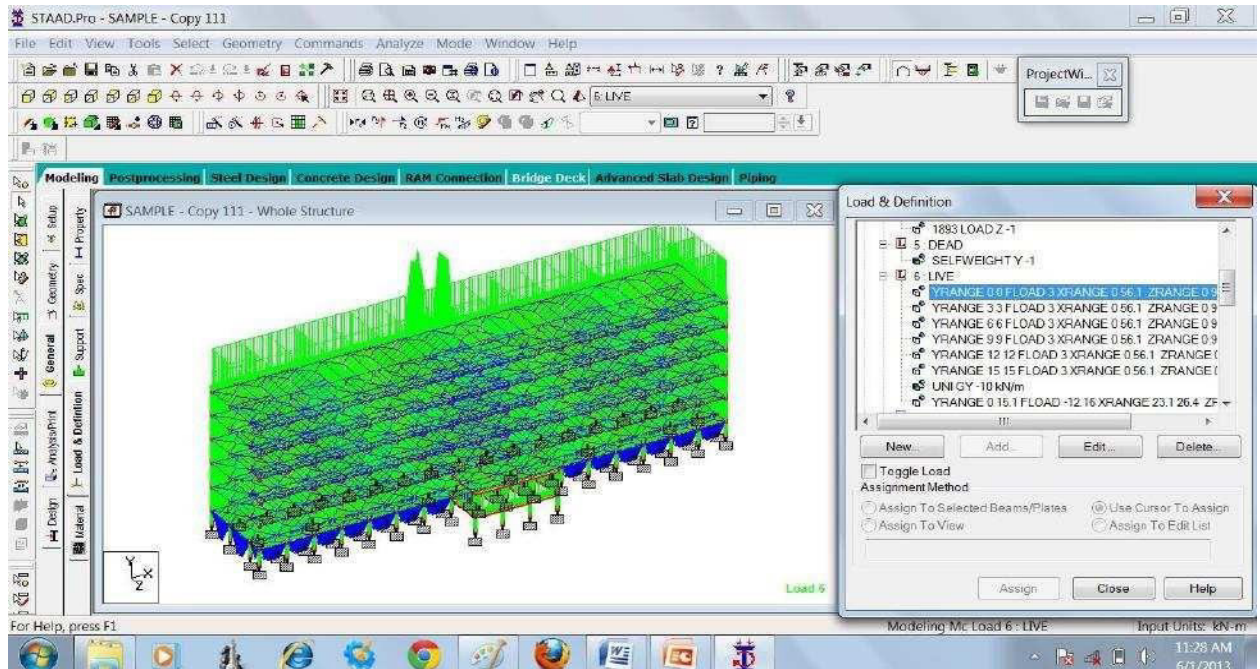


Fig: 2 Live Load

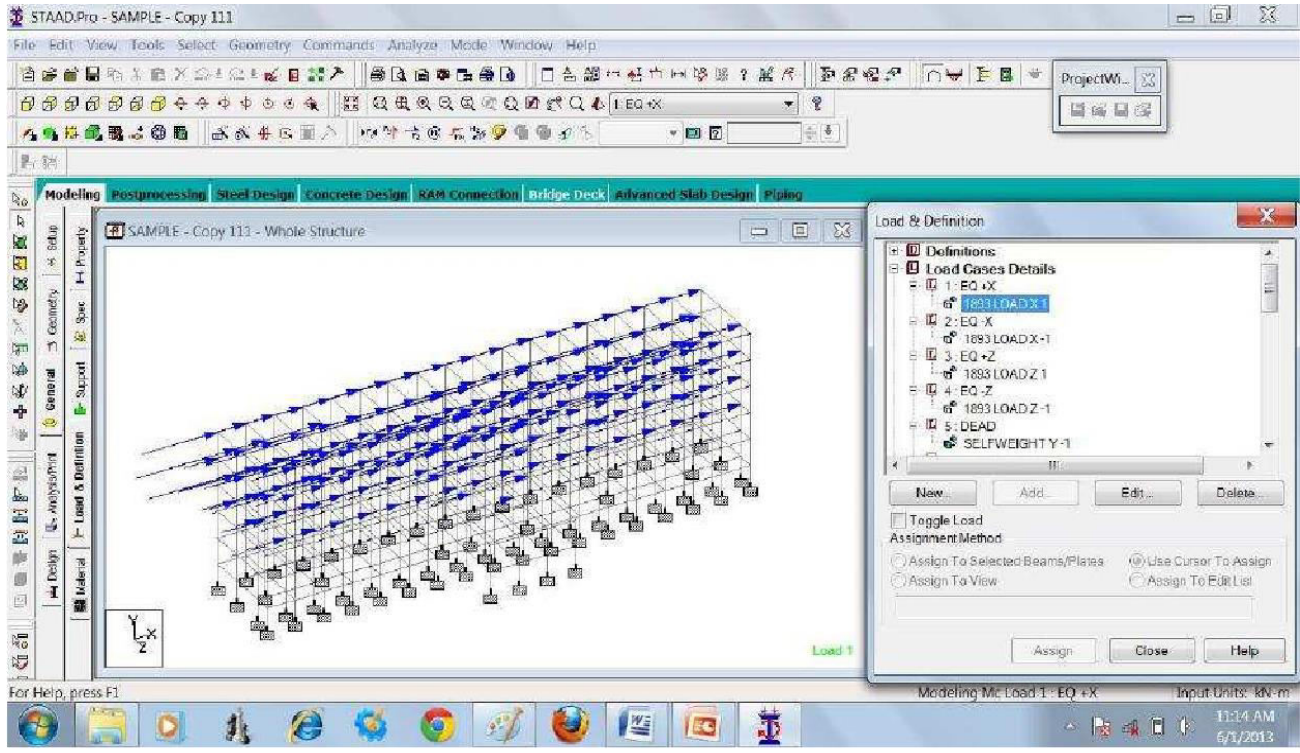


Fig:3 Earthquake Load in +X direction

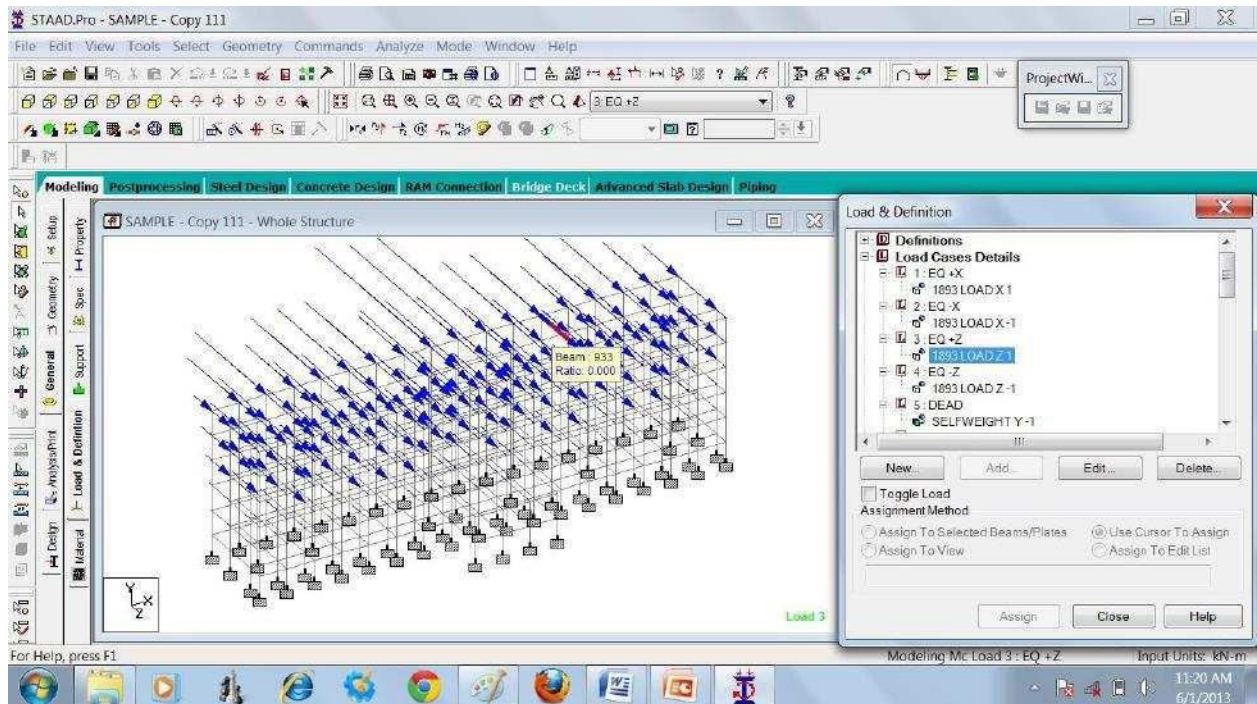


Fig:4 Earthquake Load in +Z direction

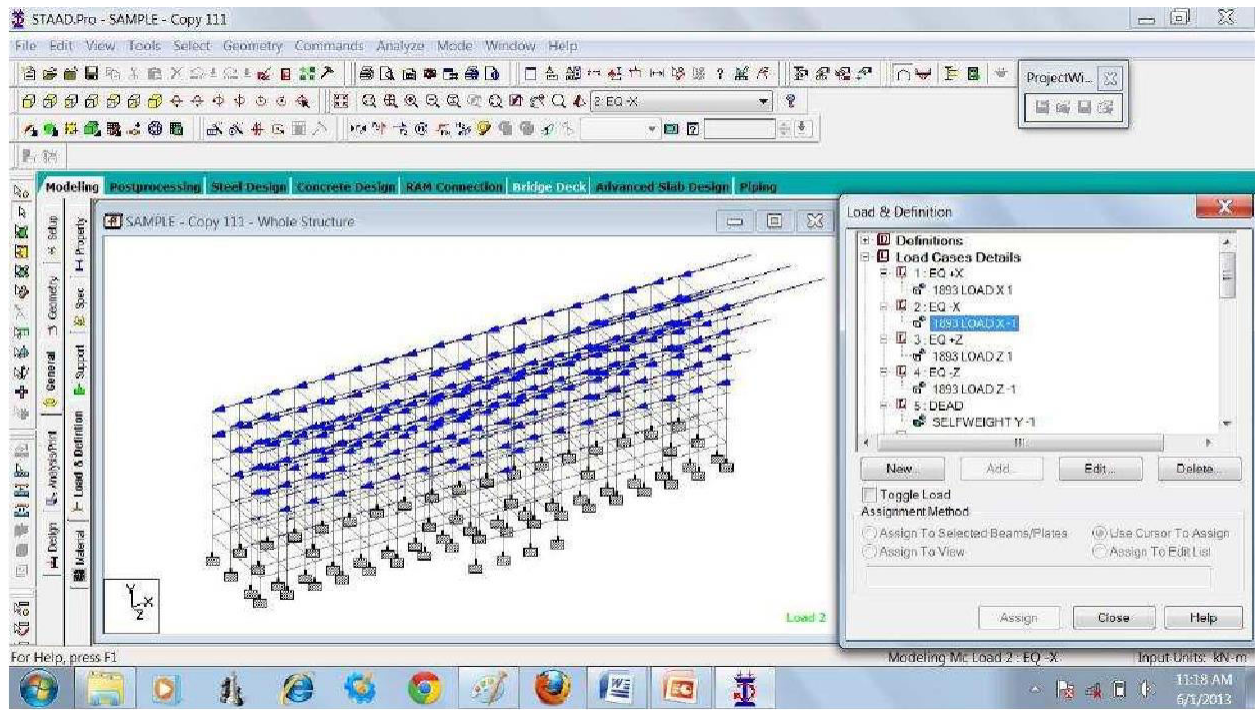


Fig: 5 Earthquake Load in-X direction

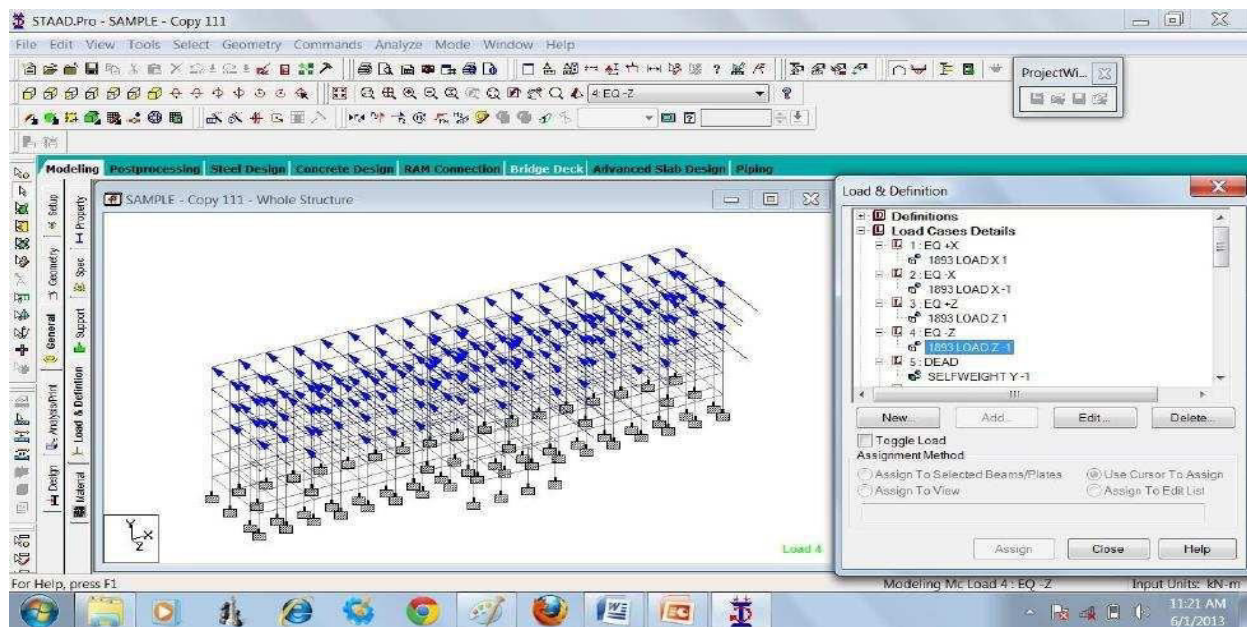


Fig: 6 Earthquake Load in-Z direction

IV. RESULTS AND DISCUSSIONS

Analysis and Design of Multi-storey Apartment Building Using STAAD PRO

The analysis and design of a multi-storey apartment building using STAAD PRO yielded critical insights into the structural behaviour and performance of the building under various loading conditions, including dead loads, live loads, wind loads, and seismic loads. Here are the results and discussions:

4.1. Structural Analysis Results

- Shear Force and Bending Moment: The software provided precise calculations for shear forces and bending moments for beams and columns at various nodes and spans. The results revealed that the structural elements were safe under applied loads, with values well within the permissible limits as per IS 456:2000.
- Deflection: The analysis showed that the deflections of beams and slabs were within the allowable range (maximum deflection $< \text{span}/250$), ensuring serviceability and occupant comfort.
- Reinforcement Requirements: STAAD PRO effectively calculated the reinforcement required for all structural components. The reinforcement provided for beams, columns, slabs, and footings complied with IS 456:2000 standards and ensured structural safety under ultimate and service load conditions.

4.2. Load Combination Results

- The analysis incorporated various load combinations, such as $(1.5DL + 1.5LL)$, $(1.2DL + 1.2LL + 1.2WL)$, and $(1.5DL + 1.5EQ)$, to simulate realistic scenarios. The results indicated that the structure could safely withstand these combinations without any overstressing of elements.

4.3. Stability of the Building

- Base Shear and Seismic Resistance: The seismic analysis showed that the base shear was appropriately distributed among the structural members. The lateral displacements due to seismic forces were within acceptable limits, ensuring stability and earthquake resistance.
- Wind Load Analysis: The wind load analysis indicated that the building had adequate strength and stiffness to resist lateral forces caused by wind pressures.

4.4. Advantages of Using STAAD PRO

- The use of STAAD PRO significantly reduced the time required for structural analysis and design compared to traditional manual calculations.
- The software provided 3D visualization of the structure, enhancing understanding of the building's behavior under loads.
- STAAD PRO minimized errors through automated calculations and adherence to codal provisions, leading to more reliable and accurate designs.

4.5. Discussion

The analysis highlights the efficiency of STAAD PRO in handling complex multi-storey designs. The ability to simulate real-life conditions, such as wind and seismic loads, ensures that the design adheres to safety and serviceability criteria.

V. CONCLUSIONS

The analysis and design of multi-storey buildings using advanced tools like STAAD.Pro have revolutionized construction practices, enabling efficient, accurate, and code-compliant designs to meet modern engineering challenges. Various studies highlight the versatility of STAAD.Pro in handling complex structural requirements, such as the design of residential and commercial buildings, multi-storey apartments, and high-rise structures. STAAD.Pro's ability to simulate and analyze critical factors, including seismic forces, wind loads, and load combinations, ensures that structures are safe, durable, and serviceable under varying conditions. The integration of software like Revit further enhances project efficiency by facilitating 3D modeling and visualization. Research emphasizes the growing importance of innovative construction techniques, including mono-column designs and earthquake-resistant structures, to address urbanization challenges, land scarcity, and increasing safety standards. STAAD.Pro simplifies traditionally tedious manual calculations, enabling engineers to optimize material use and design time while providing detailed reinforcement and stability analyses. Overall, STAAD.Pro and similar tools serve as indispensable assets in modern construction, ensuring that buildings are not only structurally sound but also aesthetically appealing, cost-efficient, and environmentally sustainable. This evolution in design methodologies continues to drive advancements in the construction industry, enabling the creation of sophisticated multi-storey buildings that meet diverse societal needs.

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