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Comparative Study On The Dynamic Behaviour Of Grid And Flat Slabs For Long Span Buildings

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ABSTRACT- A strong grasp of numerical problems is essential in design to effectively tackle the various challenges that may arise during the process. While having a comprehensive understanding of both analysis and design allows one to design any structure, it's unrealistic for a single individual to master every area. Therefore, it's important to specialize in a particular field. When it comes to building analysis and design, thorough knowledge of IS Codes and numerical methods is crucial. A designer must also be familiar with the different types of loads considered in building design. Buildings can serve various purposes residential, commercial, industrial, or institutional so different design codes must be consulted accordingly.

Engineers specializing in structural analysis and design are known as Structural Design Engineers. They are proficient in both manual calculations and software-based design methods. However, the challenge lies in selecting the most suitable approach for modern-day design. Structural design is more complex than it appears, requiring extensive mathematical calculations and practical expertise. To excel in this field, one must develop strong numerical skills and gain substantial experience.

II OBJECTIVE OF THE RESEARCH

The central approach to this investigation involves evaluating the major hypotheses employed by others in the field. It is entirely possible for a theory to gain acceptance as established truth simply because it has been repeatedly referenced or quoted by numerous authors, despite never being systematically tested or verified. I have identified one such unverified theory and considered a method to examine its validity, which could bring significant benefits to the field provided the research is conducted meticulously.

Progress is accelerating at an extraordinary pace these days. It is crucial for individuals to stay informed about the latest advancements, as they often simplify life in remarkable ways. Brilliant minds and innovative teams are actively involved in driving these changes, striving to transform complex technologies into solutions that are as simple and practical as possible.

Through this research, I aim to become familiar with the latest advancements and evaluate certain results to determine the extent of improvements achieved and the accuracy of outcomes provided by the technologies used in our field. The key points to be examined during this research are as follows:

- Effective techniques for working with objects that correspond to physical structural members, enabling quicker model construction and clearer interpretation of the resulting effects. These methods can enhance efficiency and accuracy in design processes, making complex tasks more manageable.
- **Concrete Frame Design & Detailing with Flat and Grid Slab**: In this approach, line artifacts are applied to represent structural components. During the process, the system evaluates and determines the most appropriate design method, ensuring precision and compliance with the project requirements. This streamlines the design workflow and facilitates efficient detailing of flat and grid slab structures.
- **Resistance of Grid Slab vs. Flat Slab in Long-Span Buildings**: This point focuses on evaluating the structural resistance and performance of grid slabs in comparison to flat slabs when used in long-span

buildings. By analyzing their respective load-bearing capacities and behavior under various conditions, this approach aims to determine the suitability of grid slabs as an alternative to flat slabs in such constructions.

- **Assigning an Optimal Cross Section**: This involves selecting a cross-sectional shape and size that can effectively resist applied loads while meeting critical design criteria such as economic feasibility and serviceability. The goal is to balance structural performance with cost efficiency and ensure long-term functionality under critical conditions.
- **Harnessing Emerging Technology for Efficiency**: This involves understanding the significance of modern advancements that require minimal effort and time while delivering precise outcomes. The focus is on modeling and analyzing a G+14 reinforced concrete framed structure using ETABS software. The process includes employing diverse design code algorithms for selecting concrete members, conducting stress testing, and optimizing drift to ensure the structure meets design standards effectively.
- **Designing Regular and Irregular Building Plans**: This involves creating structural designs for both regular and irregular building layouts in compliance with Indian standard codes IS-456 and IS-1893:2002. These standards provide guidelines for concrete structure design and seismic analysis, ensuring safety, stability, and adherence to regional building regulations. The process takes into account factors such as load distribution, seismic behavior, and overall structural performance.
- **Stress and Deflection Analysis for Flat and Grid Slab Portions**: This involves calculating the stresses and deflection in the sections of the building featuring flat slabs and those with grid slabs. The results from both portions are then compared and verified to assess their structural behavior and performance. This analysis helps in determining the efficiency, reliability, and suitability of these slab types for the given building structure.
- **Comparative Analysis of Flat and Grid Slab Designs**: This involves comparing the results obtained from the design of flat slabs and grid slabs, alongside updated design result values. The comparison focuses on evaluating factors such as structural efficiency, load distribution, deflection, and overall performance. This analysis aids in determining the advantages and limitations of each slab type, contributing to informed decision-making in structural design.
- **Evaluating Software Accuracy and Compliance**: This involves examining the precision of the results generated by the software and ensuring they fall within the acceptable range defined by design codes.
- **Identifying Necessary Adjustments**: It includes determining the required modifications to rectify the failure of structural members under specific conditions, ensuring their compliance with safety and performance standards.
- **Enhancing Structural Economy**: This aspect focuses on identifying the extent to which the structure can be optimized for cost-effectiveness without compromising safety, serviceability, or code requirements.

III OVERVIEW OF THE METHODOLOGY

This Research involves various factors that have been considered to uncover the reality I was seeking. The approach must be distinctive and practically applicable to ensure relevance. Hence, for this research, I found it suitable to choose ETABS for my reality-discovery process, as it is widely used today. Additionally, experts are available to provide assistance if any technical challenges arise.

STAAD Pro offers versatile interface options that work seamlessly with its cloud services, allowing users to visualize results through straightforward side-by-side graphical comparisons. It supports structural planning for both high seismic regions and everyday environments through Finite Element Analysis, ensuring accuracy and reliability under varying conditions. Additionally, STAAD Pro optimizes BIM workflows for concrete and steel by integrating physical models and environmental factors effectively, streamlining the design and analysis process.

IV STRUCTURAL DESIGNING

Structural engineers possess the technical expertise required to describe, analyze, and evaluate building systems effectively. Their extensive experience in this domain equips them with the ability to design safe and efficient structures. The structural design process undertaken by these engineers includes assessing loads and stresses acting on a building, analyzing the outcomes of the applied loads, and designing structural components that can effectively support these loads. This ensures that the completed structure is capable of safely withstanding the anticipated stresses and environmental conditions.
Structural engineers pay careful attention to selecting materials that are best suited for the specific requirements of a structure. This involves a deep understanding of various construction materials, their properties, and how they perform under current environmental and structural conditions. Engineers must consider factors such as durability, cost-efficiency, sustainability, and the ability of the materials to withstand anticipated loads and stresses. A thorough knowledge of material science is essential to ensure the chosen materials contribute to the safety, longevity, and functionality of the structure.

Structural engineers often assess the quality characteristics of various building materials to determine their suitability for constructing beams, columns, and foundations. This evaluation includes analyzing factors such as strength, durability, resistance to environmental stress, and compatibility with design specifications. By thoroughly examining these materials, engineers ensure that the structural elements can effectively support loads and maintain stability, safety, and performance over time.

Another key area of expertise for a structural designer is structural analysis, which involves assessing the behavior of structures under various loading conditions. Tools like ETABS, STAAD Pro, and SAP2000 are widely utilized for this purpose, offering advanced capabilities to simulate and evaluate structural performance. With technological advancements, new software is continually being developed to analyze structures under diverse conditions, such as wind loads, seismic activity, and other environmental factors. These innovations enhance accuracy, efficiency, and adaptability, ensuring structures meet safety and performance standards in evolving scenarios.

Structural engineers often engage deeply with software tools, gaining insights into both their technical functionalities and programming intricacies. This expertise allows them to leverage software effectively for structural analysis and design. In certain organizations, the responsibility for performing structural analyses might be assigned to a programmer who lacks formal civil engineering qualifications. However, these programmers are typically supported by structural engineers, whose guidance ensures that the analysis aligns with engineering principles and standards, maintaining accuracy and reliability in the results.

Regardless of the analysis method used, it is essential for structural engineers to comprehend and interpret the software outputs to assess the accuracy and reliability of the provided values. Many companies do not rely solely on machine-generated results; they perform independent manual calculations to ensure the correctness and validity of the analysis.

Structural engineers are responsible for developing and detailing the design concepts, and the realization of these designs on-site depends on their accurate execution. For this to happen, other project representatives must share their ideas and perspectives, ensuring collaboration and alignment throughout the process.

Structural engineers actively collaborate and maintain clear communication with various stakeholders, including site engineers, construction engineers, geotechnical engineers, landscape architects, architects, and project managers. This shared awareness ensures that accurate information is conveyed among the team, minimizing misunderstandings and errors, and promoting a harmonious and efficient construction process.

V RESULTS AND DISCUSSIONS

A. INTRODUCTION

The model consists of a reinforced cement concrete (RCC) framework with concrete used as the primary construction material. The structure mainly features a combination of grid slabs and flat slabs at each level. Flat slabs are utilized in the front portion of the building to create a beamless area for aesthetic purposes, while the interior part employs grid slabs to effectively bear loads and enhance the overall rigidity of the structure. The integration of both flat and grid slabs helps reduce the need for closely spaced columns. The various parameters considered for the analysis and design process are outlined below.:

No of Floors = G+14

Height of each Floor = 3m

Beam Size = 300 mm X 250 mm

Column Size's taken = 500mm X 400mm, 350mmX300mm, 450mmX350mm and

Base Column Size: 550mmX500mm.

Flat Slab Thickness = 150 mm

Grid Slab Thickness (Waffle Slab) = 450 (Overall)

Live load on each floor = 3 KN/m^2

Floor Finish = 0.75 KN/m^2

Type of Soil = Medium

Earthquake Zone = III

Concrete Grade = M 25

Grade of Rebar = Fe 415

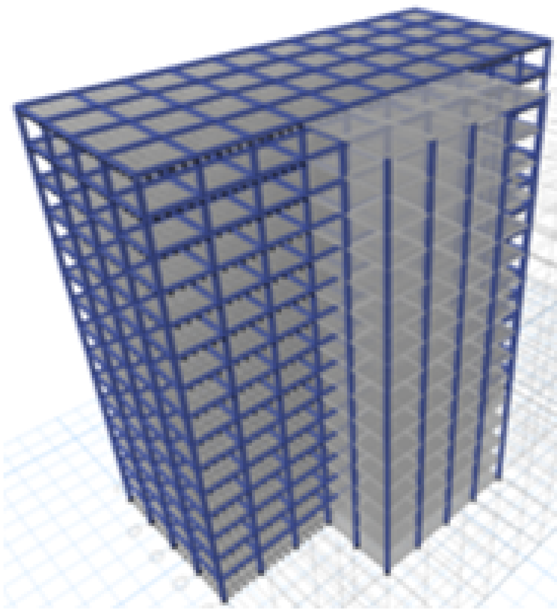

Fig 5.1: 3D Rendered view of building.

The structure incorporates both flat and grid slab systems. The rendered diagram above clearly illustrates this layout. Flat slabs are defined as slabs constructed without the use of beams, meaning the loads acting on the slab are carried directly by the slab and transferred straight to the columns, rather than being passed through beams. In this arrangement, load distribution does not follow the typical one-way or two-way pattern. To safeguard the structure against punching shear failure, drop panels have been incorporated.

B. DISPLACEMENT

Displacement in the structure is caused by external loads, with the maximum displacement occurring in areas where flat slabs are used. The following images provide a visual representation of the displacement caused by dead loads acting on the slabs.

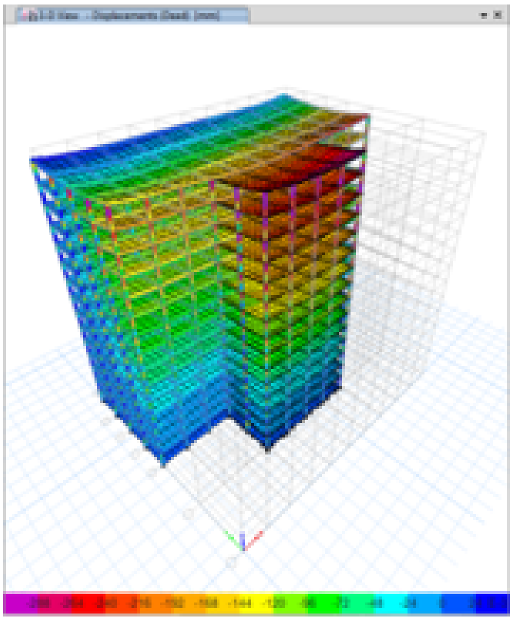

Fig 5.2: Deformation in Building.

Green areas visible near the columns indicate lower stress levels in those regions of the slabs. A detailed stress analysis was carried out to understand the distinct behavior of flat and grid slabs. The images above illustrate the stress distribution at the top storey of the structure.

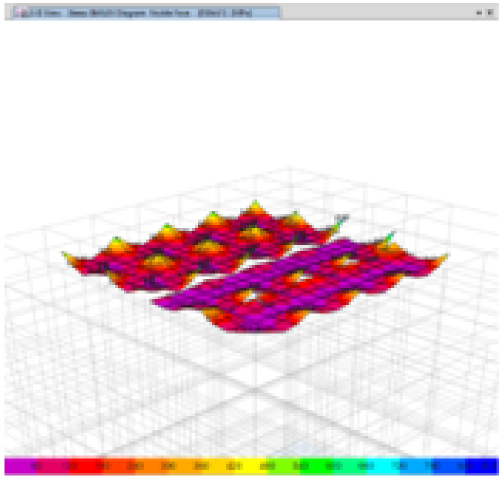

Fig 5.3 Stress Diagram

The image illustrates the stress levels across different zones of the slab. The slabs are displayed separately to enhance clarity. This stress diagram represents the visible surface of the slab.

Region ID	Color	Stress Range (MPa)	Description
R1	Dark Blue	900–960	Highest stress zones
R2	Blue	840–900	Very high stress
R3	Teal	780–840	High stress
R4	Green	660–780	Moderately high stress
R5	Yellow-Green	540–660	Moderate stress
R6	Yellow	420–540	Low to moderate stress
R7	Orange	240–420	Low stress
R8	Red	120–240	Very low stress
R9	Pink-Magenta	60–120	Lowest stress zones (edges/gaps)

Table 5.4: Below table summarize the slab stress distribution based on the color-coded diagram:

C. STOREY DISPLACEMENT.

Displacement was calculated for each structural member, including beams, columns, and slabs. These results help assess the impact of various load combinations on the structure. Evaluating storey displacement is essential to ensure it remains within permissible limits. The graph below illustrates the storey-wise displacement, with the maximum occurring at the top storey, measuring less than 13.5×10^{-3} mm, while the base experiences zero displacement. The red line represents displacement along the Y-axis, and the blue line corresponds to the X-axis. Since the span is larger along the X-axis, the structure exhibits greater stiffness in that direction. Consequently, the displacement is more significant along the Y-axis due to its comparatively shorter span.

Story Level	X-Dir Displacement (mm)	Y-Dir Displacement (mm)
Base	0	0
Story 1	0	0
Story 2	5	1.5
Story 3	10	3
Story 4	20	6.5
Story 5	30	10
Story 6	40	15.5
Story 7	50	20.5
Story 8	60	25
Story 9	70	31
Story 10	80	38
Story 11	90	46
Story 12	100	55
Story 13	110	65
Story 14	120	76
Story 15	130	89

Table 5.5: Storey wise displacement.

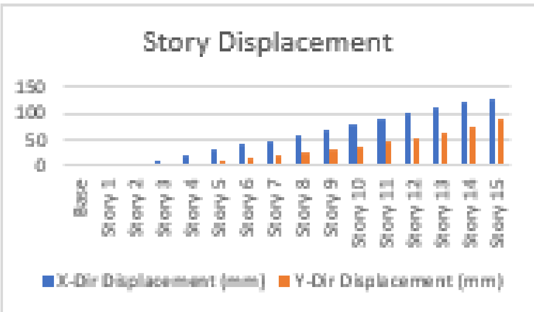

Fig 5.6: Values displayed in the graph, showing a steady increase in displacement as the story level rises.

D. MAXIMUM STORY DISPLACEMENT

This represents the storey response output for a specified range of storeys under a particular load case or a combination of load cases.

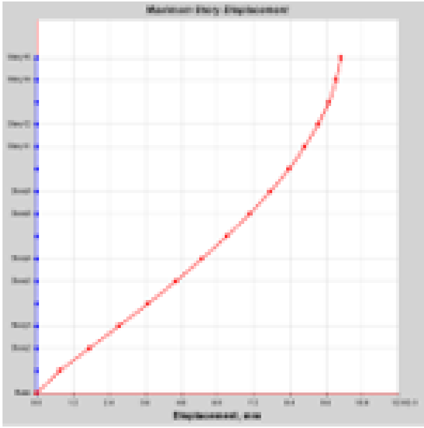

FIG 5.7: Storey Displacement (Response Spectrum)

Graph shown above depicts below points:

- The **blue line** represents the **base displacement**, which remains at **0 mm.** Since the base is fixed, it doesn't move.
- The **red line** illustrates how displacement increases with height. At the **12th story**, the maximum displacement reaches **approximately 10.8 mm**, showing that upper floors experience the most movement.
- The general trend indicates a **gradual increase in displacement as you move higher up the building.** This behavior is expected in tall structures under lateral loads, such as those from wind or earthquakes.

Story	Elevation	Location	X-Dir	Y-Dir
	M		mm	mm
Story 8	24	Top	3.285E-07	0.007
Story 7	21	Top	3.112E-07	0.006
Story 6	18	Top	2.926E-07	0.005
Story 5	15	Top	2.728E-07	0.005
Story 4	12	Top	2.332E-07	0.004
Story 3	9	Top	2.25E-07	0.003
Story 2	6	Top	2.893E-07	0.002
Story 1	3	Top	2.083E-06	0.001
Base	0	Top	0	0

Table 5.8: Story Response Values

Fig 5.9: X-Direction Displacement Distribution.

This chart visualizes the relative contribution of each story's X-Direction displacement to the total displacement across the entire structure.

Key Observations: Story 1 is the dominant contributor in X-Dir displacement, making up a very large portion (~70%) of the total. This is because its value (2.083E-06 mm) is significantly higher than the other stories, which are all in the range of ~2E-07 mm to 3E-07 mm.

Stories 2 to 8 each contribute only a small fraction (between 3% to 5%) to the total X-Dir displacement.

Base contributes 0% as its displacement is zero.

This distribution suggests that maximum horizontal displacement in the X-direction occurs near the base of the structure, specifically at Story 1 (3 m elevation). It may indicate a potential flexibility or a concentrated response in this region, likely due to structural or loading characteristics.

Fig 5.10: Y-Direction Displacement Distribution.

This chart shows the proportion of total Y-Direction displacement attributed to each story.

Key Observations: The distribution is more gradual and even compared to the X-Dir chart.

Story 8 (at the top) contributes the largest share (~25%) of Y-Dir displacement.

Stories 7 through 2 show a descending trend in displacement as elevation decreases, each contributing a smaller portion as we go lower in the structure.

Story 1 and Base have minimal to no contribution.

This smoother gradient suggests a more typical displacement profile for lateral loading, where the top stories experience greater lateral movement (like sway under wind or seismic force). It aligns with expected behavior in tall structures, where displacement often accumulates toward the top due to cumulative flexibility. Along x-direction it shows localized flexibility near base whereas Y-direction pie chart shows typical top-sway lateral behavior.

E. STOREY DRIFT:

Storey drift is defined as the relative lateral displacement between two adjacent storeys. The graph below illustrates the building's behavior under external loading, providing insight into its storey drift performance.

Story	X-Direction (Blue)	Y-Direction (Red)
Base	0	0
Story 1	0.1	0.15
Story 2	0.2	0.3
Story 3	0.3	0.45
Story 4	0.4	0.6
Story 5	0.5	0.75
Story 6	0.6	0.9
Story 7	0.7	1.05
Story 8	0.8	1.2

Table 5.10: Tabulated data of Storey drift due to Response Spectrum.

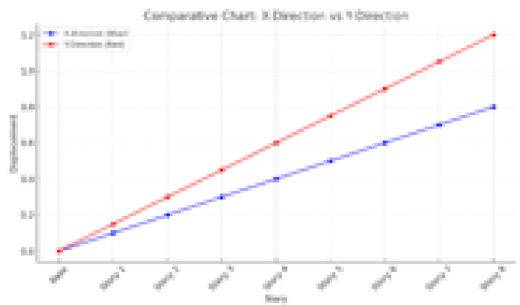

Fig 5.12: Storey drift due to Response Spectrum.

It is observed that storey drift along the X-axis is lower compared to the Y-axis, primarily because displacement is greater in the Y-direction. This behavior largely depends on the building's orientation. In cases where the building is symmetrically aligned along both axes, the storey drift would be approximately equal in both directions.

VI CONCLUSION

Although the methods for evaluating the effects of different structural elements within a single building may vary, the main focus remains the same: assessing their structural effectiveness. Both static and dynamic analyses are performed to understand the overall response of columns and beams to external loads. The conservative design of sections is examined under various load conditions. Storey drift is controlled by the arrangement of grid columns. After reviewing multiple studies, I concluded that, from a practical perspective, grid slabs may not be necessary. However, in the design of large structures requiring expansive spaces, grid slabs play a crucial role. Some structural engineers recommend using floating columns in areas like parking lots and open spaces; however, this requires additional reinforcement for adjacent beams and columns to accommodate the loads transferred by those columns.

To understand the relationship between the grid slab and the flat slab, and their interaction with adjacent beams, as well as to evaluate the impact on reinforcement and section detailing, I reviewed several prior studies. Based on this analysis, I reached the following conclusion:

1. From an economic perspective, flat slabs are more advantageous for design purposes compared to grid slabs.
2. The reinforcement required for flat slabs is minimal compared to that of grid slabs.
3. Grid slabs help reduce the number of columns required, as they are more rigid and can accommodate longer spans. In contrast, flat slabs cannot support as much load, as they lack beam support.
4. The stress in flat slabs is found to be higher compared to grid slabs, which increases the likelihood of cracks forming in flat slabs.
5. According to the analysis results, stress is minimal at the column joints in both cases. However, in the case of flat slabs, drop panels are used to reduce stress on the columns. These drop panels help distribute the load uniformly from all sides.
6. Deflection is generally higher in flat slabs, as they lack beam support, whereas grid slabs exhibit better resistance to deflection.
7. Based on this research, I concluded that for important structures, such as public buildings, it is essential to use grid slabs to enhance the rigidity of the frame. Although this approach may be more costly, it provides greater durability and safety compared to flat slabs. Flat slabs, on the other hand, are typically used when the aesthetic appearance of the building is a priority or when a unique architectural look is desired.
8. When designing a long-span building with flat slabs and grid slabs using ETABS, it is evident that ETABS provides the most accurate reinforcement data. This was a key finding during my research. Additionally, ETABS offers reinforcement detailing in the form of clear, distinct tables along with accompanying drawings.
9. In ETABS, failed members can be easily identified and addressed after the design step. By selecting the "Check Failed Members" option in the design section, the Design Engineer can isolate those members and modify their sections using the "View Selected Objects Only" feature. This allows for adjustments to the sections to ensure they pass under the given loading conditions. ETABS involves multiple steps in the design process, assigning each design parameter, which is why the results obtained through this software were used in the analysis.

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