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ANALYSIS AND DESIGN OF MULTISTOREY BUILDING WITH GRID SLAB

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Abstract - *Civil engineering structural design deals with the critical parameters of economy, durability, and serviceability. It is quite challenging and time-consuming to achieve these objectives through manual methods. This paper studies the use of digital tools in structural design by taking ETABS as a tool for the analysis and design of a residential building. The output obtained from the software is compared with manual calculations to determine their accuracy and practicality. Even though ETABS and other software have gained popularity in the industry, the most appropriate software for any design requirement is still in question. This research thus emphasizes the pros and cons of ETABS, along with the improvement efforts of software developers in trying to bridge the gaps identified. Through its detailed comparison, the research paper serves as a guide for future users to pick suitable tools that can suit particular needs of structural design effectively. It further highlights the importance of using digital tools in improving the efficiency and accuracy of output with proper critical evaluation.*

Key Words: Structural design, civil engineering, ETABS software, digital tools, structural analysis.

1.INTRODUCTION

A reinforced cement concrete-framed structure is an integrated slab, beam, column, and foundation system for efficient transmission of loads to the soil. In comparison with load-bearing wall constructions, RCC framed structures provide 10–12% more floor area and offer better resistance to vibration and seismic forces due to its monolithic construction. The tensile strength of the concrete with the compressive strength is combined with reinforced concrete that ensures stability to the structure under varying load conditions. Designing this effectively involves numerical analysis skills, familiarity with IS codes, and comprehensive knowledge of building loads. Different types of structures exist; they include residential, commercial, industrial, or institutional, and a specific code is followed in each case to ensure safe construction.

1.1 Objective

This research aims to evaluate foundational assumptions in structural design that have often been accepted without systematic testing or empirical validation. By identifying and rigorously testing such unverified assumptions, this study will contribute meaningful insights to the field of structural engineering. The specific objectives include:

Modeling and Analysis: To model and analyze a G+5 RCC framed structure using ETABS, detailing the process with algorithms derived from various design codes for concrete member selection.
Design Optimization: Optimal cross-sections should be assigned, not only to resist applied loads but also satisfy key design criteria such as economy and serviceability.
Comparative Comparison: Storey drift, displacement, base shear, stresses, and deflection among the different building segments with flat slab and grid slab construction would be compared.
These goals can help bridge gaps in existing methodologies and deliver concrete insights to structural design optimization.

1.2 Priorities

This paper prioritizes the functionality of the structure by following design code specifications and making analyses based on established assumptions. Key assumptions are:

- Structural materials are homogeneous throughout.
- All structural elements are monolithic.
- Concrete resists compressive forces, while steel resists tensile forces.
- Applied forces are within the load resistance capacity of the structural members.
- These priorities ensure a comprehensive and standardized approach to the analysis and design process.

2. LITERATURE REVIEW

- Balhar et al. (2019): Analyzed RC buildings, finding increased displacement and varied drift.
- Indrani V et al. (2018): Found higher base shear and differences in axial forces and drift.
- Waghule et al. (2018): Highlighted bubble deck slabs' sustainability.
- Ahmed et al. (2018): Compared material use, finding grid slabs needed more steel and concrete.
- Mahamuni et al. (2018): Recommended optimal analysis techniques for grid slabs.
- More et al. (2015): Found grid slabs reduced drift under dynamic loads.
- Rajkumar et al. (2017): Found maximum shear and twisting moments in grid slabs under spectrum loads.
- Anitha et al. (2017): Studied grid slab performance and beam spacing.
- Patel et al. (2017): Noted grid slabs offer better drift control but at higher costs.
- Bhaduria et al. (2017): Found flat slabs cheaper with lower displacement.
- Harish et al. (2017): Showed grid slabs had better seismic control.
- Sethia et al. (2017): Recommended drop panels in flat slabs for shear strength.
- Khan et al. (2015): Found flat slabs had higher drift, requiring lateral load consideration.
- Sathawane et al. (2012): Found flat slabs with drop panels more economical.
- Arvind et al.: Introduced U-boot beton for eco-friendly slabs.

3. METHODOLOGY

This paper covers the use of ETABS software in structural analysis and design. This is a widely used software in this field. The software of ETABS along with STAAD PRO, SAP, and SAFE plays a key role in analyzing and designing building structures. The methodology of the research is covered in the following several steps:
Model development
Material property definition
Section property definition and assignment
Assignment of support, loads, and load combinations
Analysis and design

3.1 Overview of ETABS

ETABS is one of the comprehensive building design software that combines structural analysis and design capabilities for various materials. It has advanced 3D object-based modeling with nonlinear analysis and real-time integration of all aspects of the engineering design process. It accommodates large, complex models and integrates design from conception to production, with the ability to create floor and elevation framing quickly and easily.

3.2 Features and Improvements

The latest version of ETABS includes continuous updates, most specifically for Indian IS codes that enhance its efficiency in terms of reinforced concrete design. Seismic analysis, wind load analysis, and optimization is more reliable in ETABS. Whereas STAAD Pro is the best for steel frame analysis, it provides fewer alternatives for reinforced concrete design along with missing dynamic features like in ETABS.

3.3 Structural Design Process

Structural engineers calculate loads, stresses, and material selection in detail to design structures that can withstand anticipated forces. Modern software such as ETABS and STAAD Pro helps in the analysis, but sometimes manual calculations are required for validation. The design process considers load types, material strengths, and structural elements such as beams and columns.

3.4 Model Description

The study focuses on an RCC frame with grid slabs to minimize column use and increase rigidity. Parameters for analysis and design include:

Floors: G+5
Beam Size: 230 mm x 300 mm
Column Sizes: 230 mm x 380 mm, 380 mm x 450 mm
Grid Slab Thickness: 450 mm (waffle slab)
Concrete Grade: M25, Steel Grade: Fe-415
Dead Load: 3 KN/m^2, Live Load: 2 KN/m^2

3.5 Loading Considerations

The design process is also accompanied by the consideration of loading conditions carefully. These include codes like IS-875 (dead, live, and wind loads), IS-1893 (earthquake loads), and IS-456 (concrete design). The distribution of load varies with one-way slabs transferring loads to longer beams and two-way slabs sharing loads.
The methodology ensures that the building is designed to resist the anticipated loads safely and fulfills all the structural requirements.

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4 DESIGN AND ANALYSIS

4.1 Storey Data

The storey data for the building Every storey has a height of 3000 mm, and the elevations start from the base at 0 mm up to 21,000 mm for Storey7. The analysis is based on the master storey and whether it is alike with another, and none of the stories spliced.

Table-1 Storey data

NAME	HEIGHT mm	ELEVATION mm	MASTER STOREY	SIMILAR TO	SPICE STOREY
Storey7	3000	21000	NO	Storey7	NO
Storey 6	3000	18000	NO	Storey6	NO
Storey 5	3000	15000	NO	Storey6	NO
Storey 4	3000	12000	NO	Storey6	NO
Storey 3	3000	9000	NO	Storey6	NO
Storey 2	3000	6000	NO	Storey6	NO
Storey 1	3000	3000	NO	Storey6	NO
Base	0	0	NO	none	NO

4.2 Loads

This part covers load patterns and load cases of the load applied to the structure. The load patterns are as follows: dead, live, masonry, superimposed dead, and earthquake loads Ex and Ey, as depicted. The corresponding load cases cover dead, live, seismic response RS, and directions of earthquake, Eqx, Eqy.

4.3 Earthquake Loadings

Earthquake loading is significant for structures located in seismic zones, especially Zone III, as depicted for Lucknow, UP, India. illustrate earthquake loading along the X and Y axes, where dynamic analysis is required for buildings of five or more stories.

4.4 Response Spectrum Functions

the response spectrum functions as per IS 1893:2002, with different periods and accelerations for soil type III, and damping values of 5%. These values help in estimating the seismic behavior of the building under earthquake loads.

4.5 Bending Moment

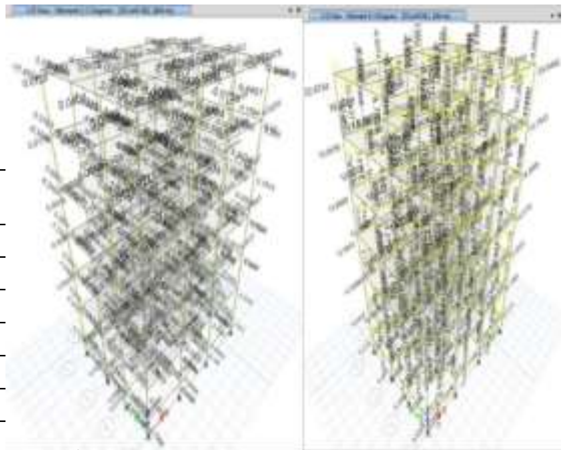
Bending moment diagrams show the moments across the structure. The bending moments are greater at the bottom than at the top; hence, there is more need for reinforcement in the lower floors and grid slabs compared to flat slabs.

4.6 Shear Force

Shear force diagrams present the forces at various sections that are vital in designing shear reinforcement to avoid cracking

4.7 Displacement

Displacement due to external loads, especially in flat slabs. Maximum displacement is about 240x10-3 mm. There is a need for more reinforcement in the most affected areas.



4.8 Stress in Slab

Mid-span is the region with higher stress, while column proximities have lower stresses. Grid slab has smaller stresses compared to the flat slab.

4.9 Storey Displacement

storey displacement results show that maximum displacement occurs at the top of the storey along the Y axis because it has a greater length.

4.10 Storey Response – Maximum Displacement

list the displacement values for each storey, with the top stories experiencing greater displacement in the Y-direction compared to the X-direction.

4.11 Storey Drift

Storey drift analysis shows that the building experiences more drift along the Y-axis, influenced by its orientation. For symmetrical buildings, drift would be similar along both axes.

4.12 Storey Shear

Shear force due to earthquake loading along the X and Y axes. Shear is maximum at the base and decreases upwards in the building.

4.13 Storey Stiffness

Storey stiffness, , is calculated along both the X and Y axes, where the stiffness behavior is higher in the X-axis direction due to a longer span. The graph of response spectrum in represents the stiffness values further.

4.14 Storey Overturning Moment

The overturning moment due to earthquake loading, which is maximum at the base. Shear at the base is similarly high and decreases upwards.

Table-2 Storey response value

STOREY	ELVATION In m	LOCATION	DIRECTION-X In mm	DIRECTION-Y In mm
7	19.5	Top	0.002	0.063
6	16.5	Top	0.002	0.06
5	13.5	Top	0.002	0.054
4	10.5	Top	0.001	0.046
3	7.5	Top	0.001	0.036
2	4.5	Top	0.001	0.024
1	1.5	Top	2.955E-04	0.009
base	0	Top	0	0

4.15 Base Reactions

Base reactions under different load cases are, which provides information on forces and moments at the base of the building.

4.16 Design Results

The results of design from the analysis will include selecting appropriate member sections and details of reinforcement. Iterations of the design process will ensure that the beams and columns have achieved the desired strength. sshow iterations of the design process as adjustments are made for members that failed until optimal sections are chosen for construction.

5. CONCLUSION

This research examines the structural efficiency of different slab types, particularly focusing on their external load behavior under static and dynamic analysis. It explains that grid slabs contribute to the minimization of storey drift, but may not always be the most economic option unless the structure involves large open spaces. A large section of floating columns is frequently used in parking lots or open areas, which often require additional reinforcement of surrounding beams and columns to counteract the load transfer occurring from the column. It takes ETABS software to model, design, and detail for both flat and grid slabs in long-span structures as it provides reinforcement details but even allows easy identification and editing of failed members. Economically, grid slabs need not always be used. However, they are really important when large open space or important structural requirements must be met. Another ability of ETABS is adjustment and optimization of reinforcement after some of the members fail. Another area of future work should be the exploration of the use of other materials along with strengthening techniques to achieve yet more cost-effective and efficient design. This research may contribute to the understanding of slab design in various conditions and provide a basis for further investigations into optimization of slab types and materials for other construction requirements.

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