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Comparative Assessment of Different Types of Slabs by Using Software

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A B S T R A C T

In this period of rapidly expanding populations and globally developing industries, the only viable option is to construct big structures. Every structural element counts when creating a tall building such as beams, columns, and mostly the slab systems. These days, several kinds of slab designs are used to construct buildings in order to achieve good views, depending on the circumstances. This study presents a comprehensive analysis of three distinct slab types: Composite, Flat, and Grid Slabs, each with unique characteristics and applications in modern construction. The study focuses on three G + 12 storey buildings, each employing a different slab type, designed to withstand moderate seismic activity in Seismic Zone III. This setup allows for a direct performance comparison under similar conditions. The Composite Slab, known for its efficiency and versatility, is examined against the Flat and Grid Slabs to understand its advantages and potential limitations. The analysis and design of the slabs are performed using both manual calculations and ETABS software, a recognized tool in structural engineering. ETABS provides an integrated environment for modeling, analysis, and design of various slab types, making it an ideal tool for this study. The research findings will contribute to the understanding and application of different slab types in structural engineering, enhancing their use in modern construction.

Keywords: Composite Slab, Flat Slab, Grid Slab, ETABS, Analysis, Design, Comparison

Introduction

General

In the vast domain of **civil engineering and structural design**, the selection and optimization of floor systems are indeed pivotal in the successful realization of architectural visions. Slabs, as fundamental structural elements, bear the weight of structures and facilitate load distribution. They serve as the backbone of any structure, providing stability and strength. The task of choosing the most suitable slab type is a critical endeavor, influenced by a multitude of factors such as load-bearing capacity, cost-effectiveness, durability, and ease of construction. The selection process begins with a comprehensive understanding of the different types of slabs available. These range from **solid slabs**, which are simple and cost-effective, to **ribbed and waffle slabs**, which offer greater strength and flexibility for larger spans. Each slab type has its unique characteristics and applications, making the selection process a complex task that requires a deep understanding of structural dynamics. This study embarks on a rigorous examination of these various slab types, employing advanced software for precise analysis and design. The use of such software enables a more accurate and efficient analysis, allowing for the optimization of the slab design in terms of both performance and cost. Through meticulous scrutiny, this research endeavors to unravel the nuanced intricacies that govern the performance of different slabs under diverse conditions. The performance of a slab is not just about its ability to bear loads but also its response to environmental factors such as temperature changes and moisture content. Therefore, the study also delves into the impact of these factors on the performance of different slab types. By doing so, it aims to provide a holistic view of slab performance, going beyond the *traditional focus on load-bearing capacity. The selection and optimization of slabs play a crucial role in structural design. Through a rigorous examination of various slab types and a comprehensive analysis of their performance under diverse conditions, this study aims to contribute significantly to the field of civil engineering and structural design.*

Objectives

1. To study different types of slabs.
2. Analysis of structures for Zone III for different spans.
3. Analysis of different types of slabs for several parameters – Dead load, Base Shear, Storey Drift.
4. Analysis of Storey deflection, Shear force, Storey Drift, and Bending Moment.
5. To Compare the results and find out the best slab for structures.

Literature Survey

The aim was to study the composite slab and its analysis and design process to compare it with different types of slabs with respect to the ETABS software. Different scholars studied and researched various parameters which are covered below.

1. **Siddhant D. Shirsath and Dr. V. R. Rathi (2022):** The authors used ETABS 2018 Software for modeling both the structures and considered parameters such as Storey Displacement, Storey Drift, Storey Shear, Self-weight, Axial force, Bending moment, and Shear force. The composite structure is quickly gaining acceptance in India's non-residential multi-story building sector. The reason for considering composite construction is simple: Steel is best in tension and concrete is best in compression. Combining these two materials strengthens their structural properties, which can be used to create a highly effective and lightweight design.

2. **Namdeo Adkuji Hedaoo et. Al (2012):** The authors carried out an experimental full-size test to investigate the shear bond strength under the bending test by Eurocode 4 - Part 1.1. Eighteen specimens are split into six sets of three specimens each in which all sets are tested for different shear span lengths under static and cyclic loadings on simply supported slabs. The longitudinal shear bond strength between the concrete and steel deck is evaluated analytically using m-k and partial shear connection (PSC) methods and compared the values. The experimental results are verified and compared with the results of both m-k and PSC methods.

3. **Sayli D. Madavi and Prof. Sushant M. Gajbhiye (2020):** The authors used ETABS software for modeling and analyzing the structures considering parameters like shear force, bending moment, deflection, and axial load. The results were obtained in the form of graphs. The study found that the slab is the most important component of the building. In the construction of tall buildings, every component of the structure is important, like columns, beams, and mainly the slab systems. The flat slab and grid slab systems were analyzed for a commercial building of G+20 stories with a floor-to-floor height of 3.5m having the same area as each floor slab. The slab was subjected to dead loading and live loading.

4. **Kedar Lambe and Sharda Siddh (2017):** The authors used ABAQUS 6.13 for finite element analysis and considered a simply supported composite slab for the investigation. Cold-formed deck-profiled steel sheets are widely used for constructing composite slabs. These sheets perform two functions: they act as the formwork during construction and as tension reinforcement in the composite slab. In the case of a continuous slab, for taking care of shrinkage, temperature effect, and a negative bending moment at support, the only additional steel that needs to be provided is reinforcing steel. This kind of flooring system results in faster construction, lighter floors, and rational use of construction materials.

5. **Kamal B. et. Al. (2016):** Composite deck slabs blend the speed and versatility of steel construction with the performance and durability of concrete, enabling a holistic approach to space-efficient structural designs. They are engineered to reduce story height while maximizing ceiling height and address market-specific building requirements. The authors used a profiled steel deck with a concrete topping and light welded mesh reinforcement. Light welded mesh reinforcement acts as tensile reinforcement, controls cracking, and also resists longitudinal shear. In conclusion, the study provides a comprehensive design of a composite deck slab, providing valuable insights for the design and construction of building structures.

Methodology

1. **Study of Different Slabs**
2. **Study of Different Software**
3. **Investigation of Loads**
4. **Examination of Structure**
5. **Manual Calculation**
6. **Analysis of Different Slabs**
7. **Comparison of Results**

Different types of slabs

1. **One-way Slab**: A one-way slab is supported on two opposite sides and carries the load in one direction. It is typically used for shorter spans and is reinforced in one direction only. This type of slab is simpler to design and construct compared to other types, but it may not be as efficient for larger spans.

2. **Two-way Slab**: A two-way slab is supported on all four sides and is designed to carry loads in both directions. It is commonly used for larger spans and requires reinforcement in both directions. This type of slab is more complex to design and construct, but it offers greater load-bearing capacity and flexibility.

3. **Flat Slab**: A flat slab is a type of two-way slab without beams, where the slab directly rests on columns. It offers flexibility in floor layout and provides a flat soffit, making it suitable for architectural purposes. Flat slabs can be more aesthetically pleasing and allow for easier installation of services such as HVAC and lighting.
4. **Ribbed Slab**: A ribbed slab is a two-way spanning system consisting of a series of parallel reinforced concrete ribs. The ribs provide additional strength and stiffness, reducing the volume of concrete and improving the load-carrying capacity. Ribbed slabs are often used in buildings where large open spaces are required.
5. **Waffle Slab**: A waffle slab consists of a series of concrete ribs in both directions, creating a waffle-like pattern. It offers a high strength-to-weight ratio, efficient material usage, and provides a visually distinctive ceiling. Waffle slabs are often used in buildings where a unique aesthetic is desired.
6. **Post-tensioned Slab**: Post-tensioned slabs are constructed using high-strength steel tendons or cables that are tensioned after the concrete has hardened. This technique allows for longer spans and reduced slab thickness, leading to cost savings. Post-tensioned slabs are often used in large buildings and bridges where long spans are required.
7. **Precast Slab**: Precast slabs are manufactured off-site and then transported to the construction site for installation. They can be both one-way or two-way slabs and offer advantages such as faster construction, better quality control, and reduced formwork requirements. Precast slabs are often used in buildings where speed of construction is a priority.
8. **Composite Slab**: A composite slab, also known as a composite deck or composite floor system, is a type of construction method that combines a concrete slab and a steel deck. It offers several advantages in terms of strength, efficiency, and construction speed. Composite slabs are often used in multi-story buildings where a combination of concrete and steel provides the best solution.
9. **Grid Slab**: A grid slab is a type of structural system used in construction where a series of columns and beams form a grid-like pattern to support the weight of the floor above. It provides flexibility in designing spaces and can be used to create unique architectural features.

Different types of software

1. **ETABS (Extended 3D Analysis of Building Systems)**: ETABS is a widely used software program for structural analysis and design. It provides an integrated environment for the modeling, analysis, and design of various types of slabs, including one-way, two-way, and composite slabs. ETABS offers unmatched 3D object-based modeling and visualization tools, fast linear and nonlinear analytical power, and sophisticated and comprehensive design capabilities for a wide range of materials.
2. **SAP2000**: SAP2000 is another popular software package for structural analysis and design. It offers a comprehensive set of tools for modeling and analyzing different types of slabs, including the ability to perform advanced analysis techniques such as finite element analysis (FEA). SAP2000 offers a wide range of code-based design features for steel frames, concrete frames, cold-form steel, and aluminum frames.
3. **SAFE (Slab Analysis by Finite Element)**: SAFE is specialized software for the analysis and design of slabs. It offers advanced capabilities for the modeling and analysis of different types of slabs, including one-way, two-way, post-tensioned, and composite slabs. However, the search results seem to be about a different SAFE software, not the one related to slab analysis.
4. **RISA-3D**: RISA-3D is a versatile software program that allows for the analysis and design of a wide range of structural systems, including slabs. It provides powerful tools for modeling, analyzing, and designing different types of slabs, including composite slabs. RISA-3D offers a fresh new take on the most popular 3D general analysis and design software available, with a completely redesigned interface, robust graphical modeling tools, expanded detailed reports, and multi-core processing.
5. **ADAPT-PT/RC**: ADAPT-PT/RC is a software package specifically designed for the analysis and design of post-tensioned slabs and reinforced concrete slabs. It offers a comprehensive set of tools for modeling, analyzing, and designing post-tensioned and composite slabs. Whether investigating beams or designing two-way slabs, ADAPT-PT/RC is the first choice for all post-tensioned projects.

Each of these slab and software types has its advantages and disadvantages, and the choice of software depends on a variety of factors such as the intended use of the building, the architectural design, the load requirements, and the budget. It's important to consider all these factors when choosing the most suitable software for a particular project.

Development of Structural Model

Table 1 – Specification of Building

Specification	**Composite Slab**	**Flat Slab**	**Grid Slab**
Plan Dimension	30m x 40m	30m x 40m	30m x 40m
Length of Grid in X-direction		5m	10m

Length of Grid in Y-direction		5m	10m
Floor to Floor Height		Ground Floor -3.5m Rest of the floor – 3m	Ground Floor -3.5m Rest of the floor – 3m
No. of Stories		G+12	G+12
Slab Thickness		0.2m + Drop 0.2m	0.100m
Size of Beam		--	0.5m x 0.75m
Size of Column		0.75m x 0.75m	1m x 1m
Grade of Concrete	M35	M35	M35
Grade of Steel	Fe-500	Fe-500	Fe-500

Composite Slab

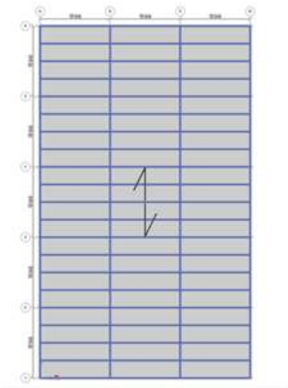

Fig. 1 - 2D view of Composite Slab Model

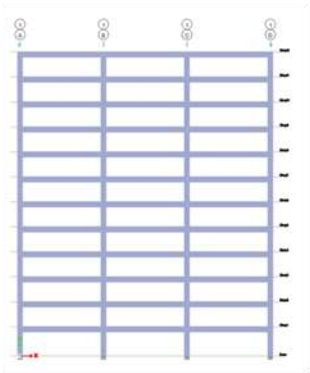

Fig. 2 - Elevation of Composite Slab Model

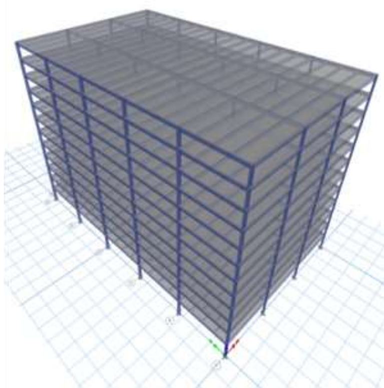

Fig. 3 – 3D View

Flat Slab

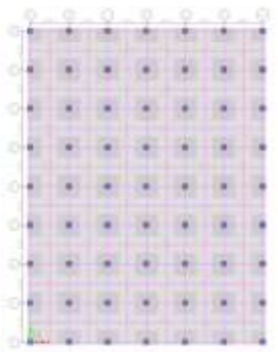

Fig. 4 - 2D view of Flat Slab Model

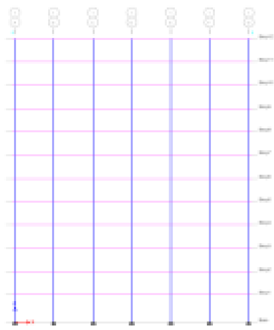

Fig. 5 - Elevation of Flat Slab Model

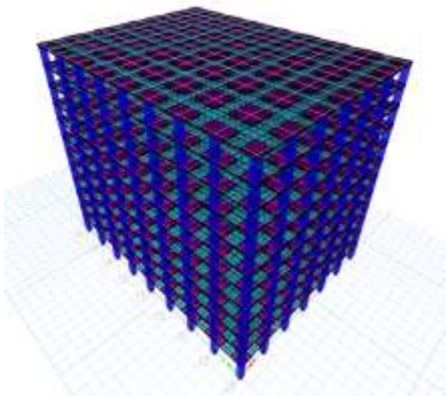

Fig. 6 – 3D View

Grid Slab

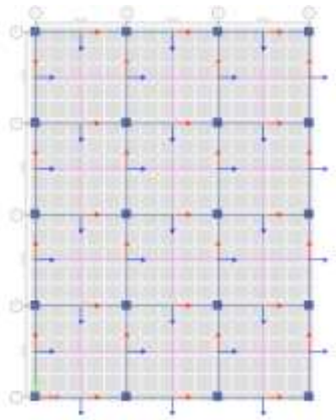

Fig. 7 - 2D View of Grid Slab Model

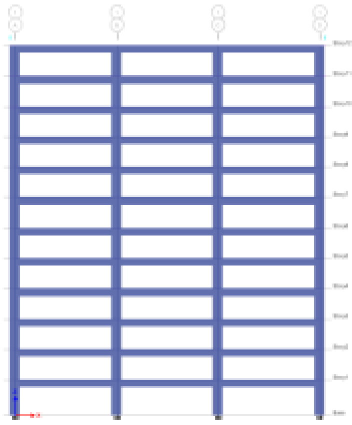

Fig. 8 - Elevation of Grid Slab Model

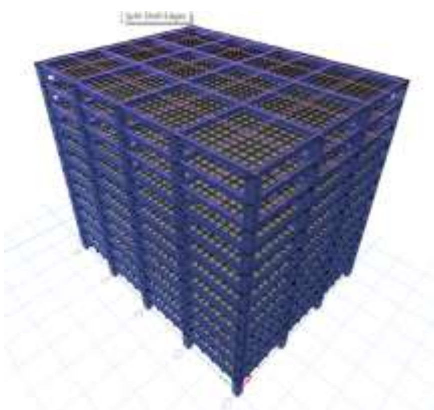

Fig. 9 – 3D View

Manual Calculations:

1. **Composite Slab:**

Panel Size = 10m x 10m having composite beams at 3m distance in X- direction

Load Calculation:

Dead Load:

Assuming Thickness of Slab = 125mm

<u>At floor level</u> -

Load from slab = 3.125 kN/m^2

Partitions = 1.5 kN/m^2

Floor Finishes = 1.2 kN/m^2

Weight of Metal Deck = 0.15 kN/m^2

Weight of duct & Plastering = 0.8 kN/m^2

Total Load = 6.8 kN/m^2

<u>At roof level:</u>

Load from slab = 3.125 kN/m^2

Weight of Metal Deck = 0.15 kN/m^2

Screed concrete 50 mm thick = 1.2 kN/m^2

False ceiling, ducts etc. = 1.0 kN/m^2

Total Load = 5.5 kN/m^2

Live load was taken 4 kN/m^2

2. **Flat Slab:**

Panel Size = 5m x 5m (Considering Interior Panel)

Thickness of Slab = 5000/32 = 160 mm + 40 mm cover = 200 mm

Drop = 1/3 x 5 = 1.67m (consider 3m x 3m drop)

Total Thickness = 200 + 200 = 400mm

Self – weight of Slab = 10 kN/m^2

Live Load = 4 kN/m^2

Floor Finish load = 1 kN/m^2

Total Load= 15 kN/m^2

Design Factored Load = 22.5 kN/m^2, Clear Span = 4.25m

Design Load = 22.5 x 5 x 4.25 = 467.5kN, Mu = 248.36kN

Mu_{lim} = 0.138 x fck x b x d^2= 0.138 x 35 x 5000 x 360^2 = 3129.84 kNm, Mu_{lim} > Mu. Therefore, Safe

Check for Shear: d/2 = 180mm, V = 534.78kN, Nominal Shear = 0.335 N/mm^2 < 1.479 N/mm^2. Hence, Safe

3. **Grid. Slab:**

Panel Size = 10m x 10m

Thickness of Slab = 100 mm

Depth of Ribs: d = 500mm, Width of Ribs = 300 mm. Overall Depth = 600mm, Rib Spacing = 2m x 2m

Loads: Total Load of Slab = 0.1 x 24 x 10 x 10 = 240kN

Total weight of beam (Y – direction) = 259.2 kN, Total weight of beam (X – direction) = 259.2 kN

Total Weight of Floor Finish = 60kN, Total Live Load = 400 kN

Total (Dead + Live Load) = 1218.4kN

Load per meter = 12.184 kN/m^2

Analysis: Central Deflection = 16.2 mm, Long Term Deflection = 32.4 mm < 40 mm. Hence, safe

Analysis and Design of Different Slabs

Analysis and Design of different slabs was done. Following parameters were used-

1. Seismic Zone – III
2. Importance Factor, I – 1.0
3. Response Reduction, R – 3
4. Dead depending on the self weight of Slab
5. Live Load was taken 4 kN/m^2 as per IS codes
6. Size of Bars were calculated from the design in software.

Comparison of Result

Table 2 – Comparison of Shear Force and Bending Moment

Type of Slab	Strip Label	Shear Force	Bending Moment
1. Composite Slab	No Design of Composite Slab	No Design of Composite Slab	No Design of Composite Slab
2. Flat Slab	CSN 5 at 35.8 m	7.0498	12.9337
3. Grid Slab	CSN 105 at 31 m	117.3114	261.3295

Conclusion

As Composite Slab can't be designed in ETABS, no values are taken for comparison. However, it found that during the analysis of the structure, the Shear and Moments on various sections satisfied the Slab type which was better than Flat Slab and Grid Slab. Also, in the Design of Columns, the Composite Slab was far better due to its Composite section. The detailed study of the slab will be executed in the next research paper.

In conclusion, Composite Slab can be used in high-rise structures wherever required.

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