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Design of Odd Shape Slab using Yield Line Theory

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Abstract: *This study investigates the mechanical properties of concrete through a series of experimental tests, including cube compressive strength, split tensile strength on cylinders, and slab deflection behavior under loading. Compressive strength tests were conducted on concrete cubes at 3, 7, and 28 days to evaluate the strength gain over time. The results indicated that the average compressive strength at 28 days exceeded the targeted and characteristic strengths, confirming the effectiveness of the mix design. Additionally, indirect split tensile strength tests were performed on cylindrical specimens at 7 and 28 days, revealing a consistent increase in tensile strength with curing age. Further, load-deflection behavior and crack patterns were analyzed on rectangular, square, circular, and triangular slabs to understand structural performance under load. Among the tested slabs, the triangular slab demonstrated the highest load-carrying capacity, while the circular slab exhibited the greatest deflection at failure. The results collectively affirm the strength development and structural adequacy of the concrete mix, providing valuable insights for applications in civil engineering structures*

Keywords: Concrete strength, Compressive test, Split tensile test, Load-deflection behavior, Structural performance

I. INTRODUCTION

Concrete remains the most widely used construction material in the world due to its excellent compressive strength, durability, availability of constituent materials, and flexibility in shaping and usage. Its widespread application in infrastructure, residential, and commercial buildings underscores the importance of continuous research and innovation in concrete technology. The mechanical performance of concrete, especially under different loading conditions, is a critical factor determining its suitability for structural applications. While conventional concrete meets the minimum requirements for many purposes, there is a growing demand for concrete with enhanced mechanical properties, such as higher compressive and tensile strength, improved ductility, and better crack resistance.

Among the fundamental properties of concrete, **compressive strength** is a primary measure of its load-carrying capacity. This strength evolves over time due to the hydration of Portland cement, a process in which water reacts chemically with cement particles to form a hardened paste. This paste comprises calcium-silicate-hydrate (C-S-H) gel, which is the primary binding component that gives concrete its strength. The evaluation of compressive strength at different curing intervals—such as 3, 7, and 28 days—offers valuable insights into the rate of strength development and the eventual structural performance. In this study, compression tests were performed on cube specimens to assess strength development over time.

However, concrete's inherent weakness in tension limits its performance in applications where tensile or flexural stresses are significant. To address this, the **split tensile strength test** on cylindrical specimens is widely adopted to evaluate concrete’s resistance to indirect tension. Although tensile strength is generally only about 10-15% of its compressive strength, this property plays a vital role in the design and analysis of structural elements, particularly in beams, slabs, and pavement applications. This study investigates the split tensile strength of concrete at 7 and 28 days, contributing data necessary for understanding the full mechanical behavior of the material.

In addition to strength properties, **load-deflection behavior and crack patterns** are vital aspects in structural concrete analysis. Structural elements such as slabs are prone to cracking under service and ultimate loads. Understanding the load at which the first crack appears, the progression of cracks, and the deflection at both cracking and failure points provides critical information for durability, safety, and serviceability assessments. In this study, rectangular, square, circular, and triangular concrete slabs were tested to compare their cracking behavior and deflection under load. This comparison aims to identify how geometry affects performance under similar loading conditions.

Overall, the present experimental investigation aims to provide a comprehensive understanding of concrete's mechanical behavior under different testing conditions. By combining data from compressive strength, split tensile strength, and load-deflection characteristics, the study offers an integrated perspective on concrete performance. The findings serve not only to validate existing theoretical assumptions but also to aid in the development of more efficient concrete structural systems. These results can support design engineers in selecting appropriate geometries and evaluating early-age and long-term mechanical properties, ultimately contributing to more resilient and cost-effective construction practices.

II. PROBLEM STATEMENT

Despite concrete's high compressive strength, its low tensile strength and unpredictable cracking behavior under load present significant challenges in structural applications, necessitating a detailed investigation into its mechanical properties and performance across various slab geometries.

III. OBJECTIVE

- To evaluate the compressive strength of concrete cubes at different curing ages.
- To determine the split tensile strength of concrete cylinders at 7 and 28 days.
- To analyze the load-deflection behavior and cracking patterns of different slab shapes.
- To compare experimental results with target and characteristic strength values.
- To assess the influence of slab geometry on structural performance and failure modes.

IV. LITERATURE SURVEY

[1] Yousefzandi et al. (2021):-In the analysis of rectangular reinforced liquid storage tanks, a method assuming linear-elastic behavior for material can be used, i.e., the strip method, the moment coefficient method, the finite element method, etc. In the analysis of these types of tanks, tank walls can be considered as slabs. In this study, tank walls were analyzed as slabs subjected to hydrostatic loading; in the analysis, the yield line theory is used because it is more suitable for the linear inelastic behavior of reinforced concrete slabs than the ones based on the linear elastic theory. An iterative algorithm based on yield line theory is presented for the design of isotropically reinforced rectangular concrete slabs supported along all four edges. A computer program is coded which predicts the location of yield lines for the slabs depending upon certain parameters. As a result of this prediction, the manual design of such slabs can be significantly simplified by the use of the coefficient obtained by using the program. It was shown that the analytical computation of the ultimate moment per unit length requires the solution of a highly nonlinear system of equations. This difficulty was overcome by utilizing an iterative technique within the computer program. It also gives the value of the ultimate moment per unit length of the yield line.

[2] Linwei He et al. (2016):- The well-known yield-line analysis procedure for slabs has recently been systematically automated, enabling the critical yield-line pattern to be identified quickly and easily, whatever the slab geometry. This has been achieved by using the discontinuity layout optimization (DLO) procedure, which involves using optimization to identify the critical layout of yield-line discontinuities interconnecting regularly spaced nodes distributed across a slab. However, whilst highly accurate solutions can be obtained, the corresponding yield-line patterns are often quite complex in form, especially when relatively dense nodal grids are employed. Here a method of rationalizing the DLO-derived yield-line patterns via a geometry optimization post- processing step is described. Geometry optimization involves adjusting the positions of the nodes, thereby simultaneously simplifying and improving the accuracy of the solution. The mathematical expressions involved are derived analytically, and various practical issues are highlighted and addressed. Finally, an interior point optimizer is used to obtain rationalized solutions for a variety of sample slab analysis problems, clearly demonstrating the efficacy of the proposed rationalization technique.

[3] Canh V et al. (2015):- This paper describes a numerical kinematic formulation for yield design of reinforced

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concrete slabs governed by Nielsen yield criterion. The size of the resulting optimization problem is reduced significantly due to the fact that only one integration point is needed per sub-element. The discrete optimization problem was solved using a highly efficient primal-dual interior point algorithm. The proposed numerical procedure is applied to various reinforced concrete slab problems with arbitrary geometries and different boundary conditions.

[4] J.O.Akinyele et al.(2014):- Analysis of precast waffle slabs have concentrated on the rib portions, while the slab portion were left unanalyzed. This has led to cracks or outright failure of the slab portions due to under reinforcement. This paper proposed the use of yield line theory in solving this problem. Yield line theory was adopted to develop a computer program called YLRGT in the analysis of pre-cast waffle slabs. Three panels with dimensions 6m x 6m, 6m x 5m and 5m x 2m were analyzed, and the results were compared with an existing analytical method which was based on the BS 8110 slab coefficient factor. YLRGT analyzed the slab portion effectively, unlike the BS 8110 where approximate values were adopted for the slab portion. The paper concluded that the slab portion of pre-cast waffle slabs can be effectively analyzed using the computer program.

[5] Albert kawan et al. (2013) :- Using the dip and strike angles method of representing the geometry of yield line pattern in terms of the dip and strike angles of the deflected slab segments, the yield line analysis of reinforced concrete slabs had been successfully computerized. In this study, the dip and strike angles method is generalized for applications to slabs with any number of arbitrary-shaped openings subjected to point, line, patch and uniformly distributed loads. As before, the external work done by applied loads and the internal energy dissipation along yield lines are evaluated as functions of the dip and strike angles, but to allow for the presence of openings, the external work done and internal energy dissipation within the openings are discounted. Based on the principle of virtual work, the load factor is evaluated in terms of the dip and strike angles and the yield line pattern is determined by minimizing the load factor with respect to the dip and strike angles. Examples of slabs with openings under various boundary conditions and loading patterns are presented to illustrate the applicability, efficiency and accuracy of the generalized method.

V. METHODOLOGY

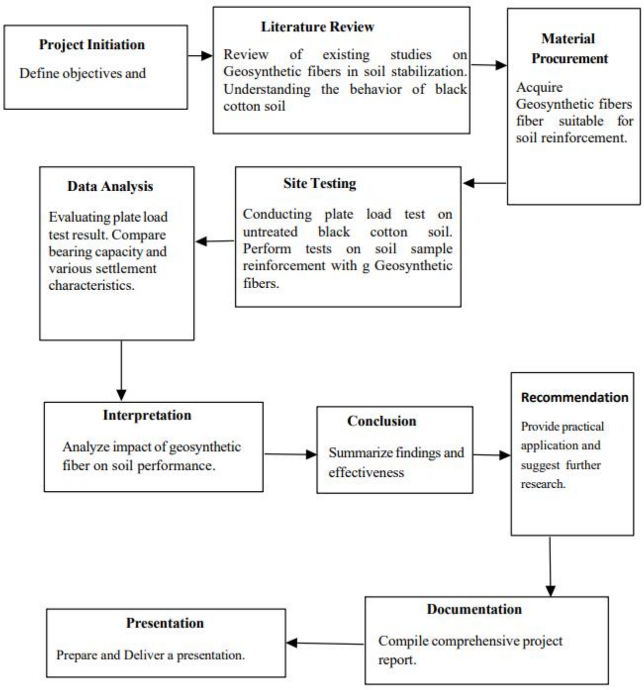

Figure 1: FlowDiagram

The methodology of the present study involves systematic experimental procedures to evaluate the mechanical properties of concrete, focusing on compressive strength, split tensile strength, and slab behavior under load. The

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following steps outline the comprehensive process adopted to conduct the tests and analyze the results.

5.1 Materials Used

- **Cement:** Ordinary Portland Cement (OPC) conforming to relevant standards was used as the primary binder.
- **Aggregates:** Fine aggregates (sand) and coarse aggregates of specified sizes were selected to ensure proper gradation and packing.
- **Water:** Potable water was used for mixing and curing.
- **Admixtures (if any):** Any chemical admixtures used for modifying the workability or strength development were noted.

5.2 Mix Design

The concrete mix proportions were designed to achieve a target compressive strength suitable for the study. The mix ratio was prepared based on standard guidelines, ensuring consistency in material quantities for all specimens. The water-cement ratio was optimized to balance workability and strength development.

5.3 Specimen Preparation

- **Compression Test Cubes:** Standard cubes of size 150 mm × 150 mm × 150 mm were cast. Each cube was thoroughly compacted using a mechanical vibrator to eliminate air voids and ensure uniform density.
- **Split Tensile Test Cylinders:** Cylindrical specimens with standard dimensions (typically 150 mm diameter and 300 mm height) were cast for indirect tensile strength evaluation.
- **Slabs:** Four types of slab specimens (rectangular, square, circular, and triangular) were cast with appropriate dimensions to study deflection and crack behavior under loading.

5.4 Curing

All specimens were demolded after 24 hours and submerged in a curing tank maintained at a temperature of 27 ± 2°C with saturated water conditions. The curing was carried out for 3, 7, and 28 days depending on the test schedule to study the strength gain over time.

5.5 Testing Procedures

5.5.1 Compression Test

- The compression test on cubes was performed using a calibrated compression testing machine.
- Specimens were tested at 3, 7, and 28 days of curing.
- The load was applied gradually until failure, and the maximum load at failure was recorded.
- Compressive strength was calculated by dividing the failure load by the cross-sectional area of the cube.
- Average compressive strength was obtained from three specimens for each curing period.

5.5.2 Split Tensile Test

- The indirect split tensile test on cylindrical specimens was conducted as per ASTM or IS standards.
- Cylinders were placed horizontally in the compression machine with steel loading strips along the length.
- Load was applied diametrically, inducing tensile stresses perpendicular to the applied load until failure occurred.
- The maximum load was recorded, and split tensile strength was calculated using the standard formula.
- Tests were conducted at 7 and 28 days of curing, with results averaged over three specimens.

5.5.3 Slab Testing

- Slabs of different shapes were subjected to incremental loading using a universal testing machine or loading frame.
- The load at which the first visible crack appeared was recorded.
- Deflection at the first crack and at failure was measured using dial gauges or LVDTs placed at critical points.

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- The load was increased until failure, and the ultimate load capacity was noted.
- Observations on crack pattern and propagation were documented to analyze structural behavior.

5.6 Data Analysis

- Test results from compression and split tensile strength were tabulated and statistically analyzed.
- Load-deflection curves for slabs were plotted to assess stiffness and ductility.
- Comparative analysis was performed to evaluate the influence of curing age, slab geometry, and material properties on mechanical behavior.
- The experimental findings were discussed in light of theoretical concepts and existing literature to validate observations.

VI. RESULT AND DISCUSSION

This section presents and discusses the results obtained from the compression tests on concrete cubes, split tensile tests on cylinders, and the deflection and cracking behavior of slabs under load. The findings are analyzed to evaluate the performance of concrete in terms of strength development and structural behavior over time.

6.1 Compression Test Results

The compression tests were conducted on concrete cubes at curing periods of 3, 7, and 28 days. Tables 5.1, 5.2, and 5.3 summarize the maximum compressive loads and calculated compressive strengths for the specimens tested.

- At **3 days**, the average compressive strength was found to be approximately 9.42 MPa, indicating initial strength gain due to early hydration of cement.
- At **7 days**, the average compressive strength increased significantly to around 16.47 MPa, demonstrating continued hydration and strength development.
- At **28 days**, the average compressive strength reached approximately 26.76 MPa, which is above the targeted characteristic strength, indicating good quality concrete and adequate curing conditions.

The variation in compressive strength among specimens at each age could be attributed to slight differences in compaction, curing conditions, or material properties. The increase in compressive strength over time aligns with the typical hydration process of Portland cement, where calcium-silicate-hydrate (C-S-H) gel formation provides the primary binding mechanism contributing to strength.

6.2 Split Tensile Strength Results

Split tensile strength tests on cylinders were carried out at 7 and 28 days, with results presented in Tables 5.4 and 5.5.

- At **7 days**, the average split tensile strength was 3.05 MPa.
- At **28 days**, the average split tensile strength increased to 3.78 MPa.

The tensile strength, although lower than compressive strength, shows a consistent increase with curing age. This reflects the development of tensile resistance due to the cement matrix and aggregate interlock. The indirect split tensile test results correlate well with the compressive strength trend, indicating overall improvement in concrete integrity with age.

6.3 Deflection and Cracking Behavior of Slabs

The deflection and cracking behavior of different slab shapes (rectangular, square, circular, and triangular) were evaluated under increasing load as shown in Table 5.6.

- The **triangular slab** exhibited the highest load capacity at first crack (33 kN) and failure load (42.83 kN), indicating better load distribution and stiffness characteristics.
- The **rectangular slab** also showed high strength, with a failure load of 40.33 kN and significant deflection at failure (7.66 mm).
- The **circular slab** had the lowest load at failure (29.58 kN), but interestingly showed the highest deflection at failure (8.31 mm), suggesting higher ductility but lower ultimate strength.

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- The **square slab** demonstrated moderate performance with failure load of 34.16 kN and deflection at failure of 6.83 mm.

The deflection data reveal that slabs with different geometries respond differently under loading. Slabs with sharper corners such as rectangular and triangular shapes showed higher load capacities, while the circular slab demonstrated greater flexibility. This can be attributed to the stress distribution and moment of inertia variations inherent to each shape.

6.4 Discussion

The experimental results confirm that the concrete mix design and curing regime used in this study effectively enhanced the mechanical properties of concrete. The compressive strength values exceed the targeted strengths, suggesting that the mix proportions and curing were optimized for strength gain. The split tensile strength results support the understanding that tensile properties improve with age but remain significantly lower than compressive strength, necessitating reinforcement in structural applications where tension is critical.

Slab testing revealed that geometry plays a crucial role in structural performance, with triangular slabs providing superior load-carrying capacity and rectangular slabs offering a balance between strength and deflection. Circular slabs, while less strong, showed higher ductility, which might be beneficial in applications requiring energy absorption.

Overall, the results align well with the theoretical principles of concrete behavior and provide valuable insights for practical design and application, emphasizing the importance of curing, mix design, and structural geometry.

VII. CONCLUSION

The experimental study demonstrated that the concrete mix and curing process used resulted in compressive and tensile strengths exceeding the targeted values, confirming the effectiveness of the mix design. The compressive strength showed significant improvement from 3 to 28 days, highlighting the importance of adequate curing. Split tensile strength results aligned with expected trends, reinforcing the need for reinforcement in tension-critical areas. The slab tests revealed that geometry significantly influences load capacity and deflection behavior, with triangular slabs exhibiting the highest load resistance and circular slabs showing greater ductility. These findings provide valuable insights for optimizing concrete mix design and structural element shapes to enhance performance and durability in construction applications.

REFERENCES

[1]. A. Neville, Properties of Concrete, 5th ed. Harlow, UK: Pearson Education Limited, 2012.

[2]. M. S. Shetty, Concrete Technology: Theory and Practice, 7th ed. New Delhi, India: S. Chand Publishing.

[3]. P. Kumar and R. Singh, “Effect of curing on compressive strength of concrete,” International Journal of Civil Engineering and Technology, vol. 8, no. 3, pp. 123–130, Mar. 2017.

[4]. S. Mehta and P. Monteiro, Concrete: Microstructure, Properties, and Materials, 4th ed. New York, NY, USA: McGraw-Hill Education, 2014.

[5]. K. H. Khayat, “Split tensile strength of high-performance concrete,” ACI Materials Journal, vol. 89, no. 5, pp. 473–479, Sep.-Oct. 1992.

[6]. J. K. Lee and T. T. Ngo, “Experimental study on slab geometry and load capacity,” Journal of Structural Engineering, vol. 145, no. 7, pp. 04019106, Jul. 2019.

[7]. IS 516:1959, “Methods of Tests for Strength of Concrete,” Bureau of Indian Standards, New Delhi, India, 1959.

[8]. ASTM C496 / C496M-17, “Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens,” ASTM International, West Conshohocken, PA, 2017.

[9]. M. M. A. Ismail and E. T. Shaaban, “Effect of slab shapes on flexural behavior of concrete slabs,” Construction and Building Materials, vol. 212, pp. 513–523, Oct. 2019.

[10]. P. S. Rao, “Influence of curing methods on compressive strength of concrete,” International Journal of Advanced Engineering Research and Studies, vol. 3, no. 2, pp. 143–147, Apr.-Jun. 2014.