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A Parametric Study and Analysis of Waffle and Solid Slab

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Abstract—*Reinforced concrete buildings comprises majority of buildings in urban areas. In reinforced concrete slabs the major challenge occurs when high dead-weight of concrete restricts the span length and thus longer spans are not feasible with normal construction practices. It is a known fact that concrete processes excellent molding capability and various innovations over the past few years on maximizing the material utilization led to development of ribbed one way, two way and pre-stressed slabs. In this paper a comparative study of behavior of waffle slabs and solid slabs analytically has been carried out and various parameters affecting the behavior and durability of waffle slabs and solid slabs are investigated. For this purpose slabs are modelled in computer program SAFE V.12 and the output results obtained from the analysis are compared and verified. In this study a square slab panel of 8×8 m is modelled for both waffle and solid slab under the same loading conditions and using the same construction material. The models are used to study parameters like maximum deflection, maximum bending moment, maximum shear force and the amount of reinforcement required in slab. The test results signify the superiority of waffle slab over conventional solid slab and consequently can be employed in various practical applications.*

Keywords: *Waffle slab, analysis, ribs, SAFE V.12*

1. INTRODUCTION

Slab is a structural system consisting of a deck supported on beams and columns which is used to transfer dead and live loads to the supporting vertical members through bending, shearing and torsion. They are used in various places like buildings, bridges, and parking areas. As these places require large column free area with conventional solid slabs it is a major challenge. Since concreting larger area means increased dead weight of the slab thereby resulting to simultaneous heavy structures which in-turn leads to a seismically vulnerable and a costly construction practice. Development in this field can be observed with the usage of waffle slabs which meets the requirement of reduction in dead weight. As the weight of slab decreases, slab moments get reduced and simultaneously material gets reduced, they also exhibit relatively less deformation and possess higher stiffness under heavy loads. Waffle slabs as a structural system comprise of a flat plate or topping slab and a system of equally spaced parallel ribs running in both the directions. The ribs are designed in such a way that that slab does not require any shear reinforcement. Waffle slab are economic in medium size floors ranging from span length of five to ten meters as further increasing their size increases the slab thickness and slab weight is increased. Services can also be easily incorporated without any complications due to uniform soffit, as thin topping within the ribs can be easily cut without the risk of cutting main reinforcement. The various factors which influence the functionality of waffle slabs are rib width, rib depth, rib spacing, distance of ribs from supports, column size and shape, drop panels and column capital, type of beam and rib stiffness. Waffle slabs have different forms as shown in Fig.1. The first system incorporates beams spanning between columns or other supporting systems. In some variants, the beams are constructed in a beam zone as shown in Fig.1 (ii). Beam supported waffle slabs have a superior performance, especially in peripheral shear, and usually result in slabs of minimum thicknesses. They can thus be used in spanning longer distance and for carrying heavier loads. Due to the associated construction and architectural problems, the use of waffle slabs of this from is becoming increasingly unpopular; **Bowden[1]**. The second system shown in Fig.1.(iii) consists of a solid portion around the column having a depth equals the total slab depth, the solid portion is used in the case of heavy loads to satisfy the shear capacity of the slab. The last set of slab shown in Fig.1. (iv) is called a fully ribbed waffle slab as the ribs rested directly on the columns. This system is mostly employed as an analytical model in research areas due to the fact that it is comparatively easier to model and also easier to analyze.

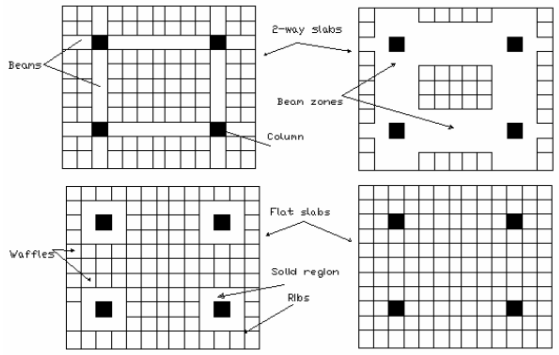

Fig. 1: Different forms of waffle slab

***Economic aspect of the waffle slab*- Selot** [9] reported that savings in material can be achieved up-to 34% in concrete and 18% in steel by proper construction of waffle slabs.

Construction aspect of Waffle slabs- waffle slabs are constructed using following methods:-

- In-situ construction with concrete
- In-situ construction using pre stressing technique

In situ construction using concrete is a general construction practice these days but with pre-stressing longer spans with less slab thickness, less deflection and less construction materials are possible. Though design methods recommended by many design codes such as ACI 318-95 and BS 8110: 1997 Part 1 and IS 456:2000 allow waffle slabs to be designed as solid slabs but the behavior of waffle slabs is significantly different from solid slabs the increased ratio of flexure to torsion rigidity of waffle slab results in less load transfer through torsion in slab. The British and American codes provide specifications regarding the size and spacing of ribs.

British code BS 8110:1997 specifies

- The minimum thickness of structural topping should be 75mm for minimum fire resistance of 0.5 hours.
- In-situ ribs should be placed distance not greater than 1.5m.
- The depth of rib excluding any topping should not exceed 4 times its width.
- Minimum value of rib width will be determined by considering minimum cover, bar size and fire resistance.

2. PARAMETRIC STUDY

For carrying out parametric study on waffle slab and solid slab a panel of 8×8 m area is modeled in SAFE V.12 for both the types of slabs, considering office and residential floors.

2.1WAFFLE SLAB DATA - Waffle slab dimensions are taken as per British codal provisions of BS 8110:1997 in accordance to minimum configuration values of fire resistance for top slab and rib dimensions.

***Slab Dimensions* –** Slab span of 8×8 m is taken, slab depth is kept 75mm for fire resistance of 0.5 to 1 hour, rib width is kept 125mm, rib depth has been taken 240mm, spacing is taken 880 mm (max. 1.5m), the total number of rib are 9.

Loading- Only gravity loads are considered, the influence of lateral loads like seismic and wind load has not been taken into account. The loadings are dead load due to floor finishing as 1.5kN/m^2, live load is assumed as 3kN/m^2, and dead load of concrete has been taken 25kN/m^3 for calculating self-weight of slab.

***Support Conditions* –** The slab is assumed to be continuous slab supported on all four edges with column support of size 450mm×450mm.

Construction Material-The material is taken as M20 grade concrete and Fe415 grade steel.

2.2 SOLID SLAB DATA- The solid slab is modelled as per Indian code of practice IS 456: 2000 span area is 8×8 m. Slab depth is taken in accordance to span to depth ratio, slab is designed as two way slab.

Loading- Only gravity loads are considered, the influence of lateral loads like seismic and wind load has not been taken into account. The loadings are dead load due to floor finishing as 1.5kN/m^2, live load is assumed as 3kN/m^2, and dead load of concrete has been taken 25kN/m^3 for calculating self-weight of slab.

***Support conditions* –** The slab is assumed to be continuous slab supported on all four edges with column support of size 450mm×450mm and beam size is 300mm×600mm.

Construction material -The material is taken as M20 grade concrete and Fe415 grade steel.

PARAMETERS FOR STUDY-

i) Bending moment
ii) Shear force
iii) Deflection
iv) Area of steel

Computer Program- Program used for the analysis of slabs is SAFE V.12. This software is used exclusively for the design of footings and slabs. The slabs are modelled for ultimate strength using finite element method for slab moments, shear forces, deflection and area of reinforcement is calculated.

Acceptance criteria- For the acceptance of given dimensions of ribs, codal provisions of British standard and Indian standard has been adopted in general for waffle slab and solid slab respectively. For waffle slab total deflection should be less than span/250 and final deflection after floor finishing is span/500 or 20mm whichever is less for spans up-to spans of 10 m. For solid slabs as per Indian code deflection should be less than span/250 and after application of floor finishes it should not exceed span/350 or 20mm whichever is less.

2.3 OUTPUT RESULT-

Parameters	Solid slab	Waffle slab	% Deviation
Deflection	14mm	19 mm	35.71%
Max B.M.	204 kN –m at middle strip 38 kN-m at column strip	160 kN -m at middle strip 39 kN-m at column strip	21.57%
Shear force	111kN	67kN	39.64%
Area of steel	Middle strip - 2461mm2 Column strip- 684mm2	Middle strip 1621mm2 Column strip 429mm2	34.13% 37.28%

3. RESULT AND DISCUSSION

From the study results it is found that in waffle slabs bending moments reduce up-to 21.57%, shear forces reduce up-to 39.64% and reduction in steel is 34.13% in middle strip and 37.28% in column strip but the deflection limit in waffle slabs exceeds the codal provisions so moving towards higher grade will solve the purpose. Economic aspect is also an important parameter governing the superiority of waffle slab over solid slab which can be inferred from the study results and thus it can be concluded that waffle slabs are clearly a better substitute of solid slabs in near future.

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REFERENCES

[1] Ahmed A.M. B.Sc. Civil Engineering, Zagazig University,2000 “Analysis of waffle slabs with openings”
[2] Bhavikatti S.S. (2005) “Design of R.C.C. structural elements (R.C.C. Volume-1)”.
[3] BS 8110 –97 (1997), “structural use of concrete “ , British Standard Institution , London
[4] Desai S. B., (2000), “Limits on load-carrying capacity of flat slabs”.
[5] IS: 456–2000, “Indian Standard Code of Practice for Plain and Reinforced Concrete”, Bureau of Indian standard, New Delhi
[6] J.Prasad et al (2005)“optimum design of waffle slab for medium size floors”
[7] Selot , R.K , (1966),”A Comparative study of reinforced concrete plain and waffle slabs”,Ph.D Thesis , University of Strathclyde.
[8] SP: 16-1980. “Design Aids for Reinforced Concrete to IS : 456-1978, BIS”, New Delhi, India