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The Comparative Study of Bubble Deck Voided Slab and Flat Slab

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Abstract: ***In the ever-evolving world of construction, reinforced concrete slab will always remain an important component. Every aspect of engineering is being refined to make construction more feasible, more reliable and more robust to reach new heights. Mostly slabs are designed to take vertical loads but as we look to increase the span of the structures it is accompanied with increase in thickness of the slab thereby increasing the Dead load of the slab, and the need to design a voided slab. It was developed to allow structural concrete slabs, to be lighter in self-weight while maintaining similar load carrying capacity as that of a solid Slab. In order to reduce the self-weight of the Slab, hollow recycled plastic balls are placed within slab thereby reducing the amount of concrete necessary to construct a building by 30 percent or more. This reduction in concrete will help financially, making it more economical as well as increasing the performance of the structure. This dissertation highlights the advantages and applications of bubble deck voided slab system. The comparative study of bubble deck voided slab and conventional flat slab were carried out to study the behavior of bending moments, shear force, deflections and reactions due to change in span for various load conditions. The results evidently show that the bubble deck voided slab is more efficient than conventional flat slab in terms of strength and economy. The finite element models of the bubble deck voided slabs created for this study in SAP2000 verify the prior analysis.***

Keywords: Bubble deck slab, voided slab system, Flat slab comparison, Finite element analysis, Structural performance

1. Introduction

Reinforced concrete slabs are the most well-known structural elements which are thin and flat mainly used for transmitting loads acting normal to their plane. The main disadvantages of concrete construction, in case of horizontal slabs, is the high weight which limits the span, for this reason basic research in the field of reinforced concrete structure have focused on enhancing the span, either by reducing the weight or over natural weakness in tension. Although they are being designed and build in large numbers but the details like elastic and plastic behavior is always been overlooked and carried in most conventional way. The main reason though not the only reason behind this being the mathematical complexities of dealing with elastic equations especially where support conditions occur which is realistically closest to those used in building floor slabs.

Regardless of the design method that are prevailing or new concepts that will overcome with time, the resulting slab must be serviceable at designed working load with its deflection and cracking remaining within allowable limits. The main concern while designing a slab revolves around its flexural properties, but shear force cannot be overlooked as it may also be the limiting factor. Problems arises when designing a beamless slab mainly due to shear, especially when shear is acting in combination with the unbalanced moments which are transferred from slabs to columns. Keeping this in sight a new and innovative type of concrete slab system was developed to allow for lighter self-weight of the structure while maintaining similar load carrying capacity of a solid slab and this was bought with the introduction of plastic voids in reinforced concrete slabs. These slabs are capable of reducing the amount of concrete necessary to construct a building by 30 percent or more.

2. Objectives

This study aims at comparative study of bubble deck voided slab and conventional flat slab. The objectives of the study are as follows:

1) To evaluate the various parameters of bubble deck voided slab such as stiffness multiplication factor, weight reduction, bending strength, punching shear strength.
2) To analysis the single floor slab system of conventional flat slab and bubble deck voided slab by finite element analysis using SAP2000 for grids (6m x 7m), (7m x 8m), (8m x 9m).
3) To analysis the single floor slab system of conventional flat slab and bubble deck voided slab by manual calculation using Direct design method as per IS456 - 2000 for grids (6m x 7m), (7m x 8m), (8m x 9m). conventional flat slab system in terms of bending strength, deflection and shear strength for single floor slab system.
4) To study the comparison between bubble deck voided slab and conventional flat slab system in terms of bending strength, deflection and shear strength for single floor slab system.

3. Scope of Work

The present work aims at comparison of bubble deck voided slab system and conventional flat slab system by finite element analysis using SAP 2000 as well as manual calculation by Direct design method using IS456:2000, in terms of behavior of bending moments, shear force, deflections and reactions due to change in span for same load conditions. The present study is carried out to study the cost reduction effect on overall structure due to use of bubble deck

voided slab system and the seismic behavior of structure due to reduction in dead weight of structure by modelling and analysis of G+12 storey structure for 6m x 7m, 7m x 8m, 8m x 9m grid systems.

4. Problem Statement

A comparative study of bubble deck voided flat slab and conventional flat slab in terms of strength and economy has to be analyzed. The Basic parameters for analysis of bubble deck voided slab and conventional flat slab are considered as shown in Table 1.1.

Table 1.1: Design input data

Description	Design data	
	Conventional Flat Slab	Voided Flat Slab
Grade of Concrete	M25	M25
Grade of Steel	Fe415	Fe415
Grid Spacing (m x m)	(6 x 7), (7x 8), (8 x 9)	(6 x 7), (7 x 8), (8 x 9)
Typical column size (m x m)	(0.6 x0.6), (0.7x0.7), (0.8x0.8)	(0.6x0.6), (0.7x0.7), (0.8x0.8)
Floor Finish	1.0KN/m² (IS 875: Part 1-1987)	1.0 KN/m² (IS 875: Part 1-1987)
Live Load	3.0 KN/m² (IS 875: Part 2-1987)	3.0 KN/m² (IS 875: Part 2-1987)
Wall load Intensity	2.0 KN/m² (IS 875: Part 1-1987)	2.0 KN/m² (IS 875: Part 1-1987)
Seismic zone	III (IS 1893: Part 1-2002)	III (IS 1893: Part 1-2002)
Zone factor (Z)	0.16 (IS 1893: Part 1-2002)	0.16 (IS 1893: Part 1-2002)
Response reduction factor(R)	3 (IS 1893: Part 1-2002)	3 (IS 1893: Part 1-2002)
Soil Type	Hard Soil	Hard Soil
Location	Mumbai	Mumbai
Basic wind speed	44 (IS 1893: Part 3-1987)	44 (IS 1893: Part 3-1987)
Risk Coefficient (k1)	1 (IS 1893: Part 3-1987)	1 (IS 1893: Part 3-1987)

5. Results and Discussions

Table 6.1 shows the parametric study of voided flat slab in terms of weight reduction, stiffness multiplication factor, bending strength, punching shear strength to check whether the bubble deck voided slab can be design as conventional flat slab or not.

Table 6.1: Parametric study of bubble deck voided slab

Span Grid (m)	6 x 7	7 x 8	8 x 9
Slab Thickness (mm)	250	280	310
Ball Diameter (mm)	180	180	225
% Weight Saving	30.53%	27.25%	30.77%
Stiffness multiplication Factor	0.802	0.859	0.8
μ ms (Bending Strength check)	0.086 < 0.2	0.0857 < 0.2	0.1 < 02
Nominal Shear Strength VED (N/mm²)	0.972	1.215	1.428

From the above result it may be conclude that the bubble deck voided slabs have lower stiffness than that of conventional flat slabs. The values of stiffness multiplication factor are lies in between 0.8 to 0.85, this means that the reduction of stiffness due to spherical balls are near about 10% to 15%. Once the stiffness multiplication factor has been calculated, structural analysis of bubble deck voided slabs can be performed same as traditional conventional flat slabs. By introducing spherical voids into flat plate slabs, the self-weight of the slabs can be reduced up to 27-30%.

Since the value of μ ms for all cases falls below 0.2 as indicated in table 8.1, the strength calculation of voided flat slabs can be done in the same way as traditional conventional flat slabs with the substitution of modified moment of inertia. From the results of punching shear calculation, it may be concluded that, the calculated perimeter of solid portion around the column is adequate to take applied shear stress as VED < VRD (max).

6. Conclusions

In the present study, the comparative study of bubble deck voided slab and conventional flat slab was carried out. In the first part, the parameters of bubble deck voided slab were studied. In second part, the comparison of deflection, moment and shear force for single floor slab system was studied and in third part, the dynamic analysis was carried out to compare the overall effect on structure due to reduce concrete weight in terms of strength and economy. Some of the conclusions made from the study are as follows:

- From parametric study of bubble deck voided slab, it can be deduced that the bubble deck voided slab has lower stiffness than that of conventional flat slab. The reductions of stiffness due to spherical balls are near about 10 to 15%.
- The ratio of moment resisted by bubble zone to the moment resisted by cross section (μms) for all cases falls below 0.2, the analysis of bubble deck voided slab can be designed using conventional flat slab design principal with substitution of stiffness multiplication factor and weight reduction factor.

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