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Punching shear analysis of bubble deck slab with staggered arrangement

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Abstract - *Bubble deck slabs have the unusual property of reducing concrete in the slab's tension zone, lowering slab's weight, which leads to reduction in the size of various elements such as columns, beams, and footings. In this study, punching shear capacity of the slab was estimated using ANSYS WORKBENCH2021. To reduce shear damage, CFS was provided around the vicinity of column and it was evaluated in different arrangements. The balls in the bubble deck slab are made of High-Density Poly Ethylene (HDPE). Bubble deck slab is environmental friendly and reduces carbon-emission. When compared to typical concrete slabs, bubble deck slab provides a number of advantages: low total cost, improved structural efficiency, reduced building time and green technology.*

A Bubble deck slab floor can provide the requisite load-bearing capacity at a small thickness, resulting in saving 40 - 50 % of the material consumption in the floor construction. In this study, the main objective was to analyze the punching shear behavior of the bubble deck slab with staggered arrangement of balls. Also, the staggered bubble deck slab was strengthened by implanting CFS (cold form steel) and estimating its improvement in shear capacity.

Key Words: **Bubble deck slab, Staggered arrangement, Lateral load, HDPE, ANSYS WORKBENCH, CFS.**

1. INTRODUCTION

In building constructions, slab is a very important structural element to make a space and is one of the largest element consuming concrete. When it comes to horizontal slabs, the biggest problem with concrete structures is their hefty weight, which reduces their span [1]. Therefore, we employ bubbles in the slab to reduce its self-weight and increase stability. This is a technique of almost eliminating concrete from the tension zone, which does not play any structural purpose, thus reducing the structural dead weight. Voids are made using balls, which are made of waste plastic material and referred as High-density polyethylene balls. They are hollow and lighter in weight. The concrete in the slab is not completely used as per the research conducted. The concrete which is placed in tension zone is unspecified to carry no load and hence it is idle [2].

Therefore, a portion of this unused concrete can be replaced in any fashion by void formers, which do nothing more than produce voids. The void formers can be of any shape and material. Using recycled plastic as void formers will lessen the impact on the environment. The material does not react chemically with the concrete or the reinforcement, it has no porosity, enough rigidity and strength to take over the loads.

2. OBJECTIVES

- To study the punching shear performance of bubble deck slab in staggered arrangement.
- To strengthen and improve the punching shear capacity of bubble deck slab using CFS implanting and find the effective capacity.

3. METHODOLOGY

In this study, the major goal was to improve the punching shear capacity of the bubble deck slab. The bubble deck slab with rectangular arrangement (RA) and staggered arrangement (SA) was compared to find the effective shear capacity. The bubble deck slab was strengthened by implanting CFS. The CFS was implanted in various arrays and the effective arrangement was estimated. The CFS was implanted near the joint of slab and column. The CFS is a thin plate with provisions on the flat surface to get proper bond with the slab. The complete analysis was performed in ANSYS WORKBENCH.

4. MODELLING

The bubble deck slab was modeled using DESIGN MODELER in ANSYS. The slab size and properties are mentioned in the Table 1 below. The dimension of the bubble deck slab is 2000×2000×230mm and effective span is 1900mm. Only a quarter of the slab has been modeled to take the advantage of symmetry in 'ANSYS'. The employed model is symmetric with respect to two planes. To model the symmetry, face on x and z must be constrained in the perpendicular direction. So, the final load will be multiplied by 4 to get the total load. The dimension of CFS is 600×100×3mm. the properties of CFS is mentioned in the Table 1.

Table -1: Properties of components.

Concrete	Young's modulus = 23734MPa Poisson's ratio = 0.2 Compressive strength = 25.5MPa Tensile strength = 3.11MPa
Steel	12mm dia Young's modulus = 2×10^5MPa Poisson's ratio = 0.3 Yield strength = 568MPa
	16mm dia Young's modulus = 2×10^5MPa Poisson's ratio = 0.3 Yield strength = 569MPa
	6mm dia Young's modulus = 2×10^5MPa Poisson's ratio = 0.3 Yield strength = 466MPa
HDPE	Young's modulus = 1000 MPa Poisson's ratio = 0.3
CFS	Young's modulus = 2×10^5 MPa Poisson's ratio = 0.3 Yield strength = 546 MPa

Fig 1, 2, 3, 4, 5, 6, represents the different model of bubble deck slab in SA with and without CFS arrays. The CFS provided in different arrays like one row in one direction (1R1D), one raw in two directions (1R2D), two rows in one direction (2R1D), two rows in two directions (2R2D).

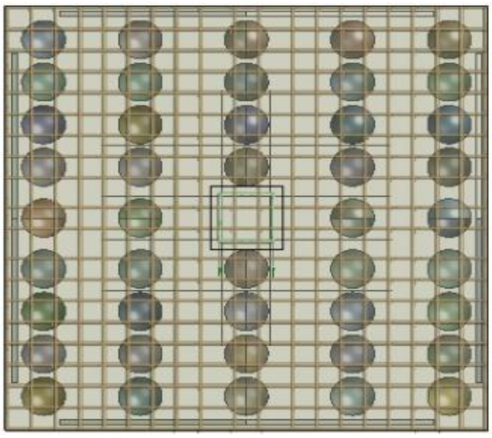

Fig -1: Bubble deck slab in RA

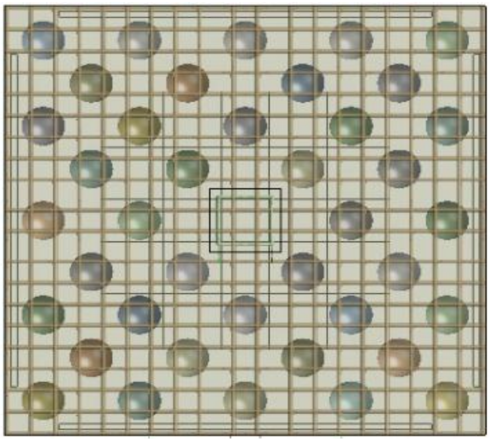

Fig -2: Bubble deck slab in SA

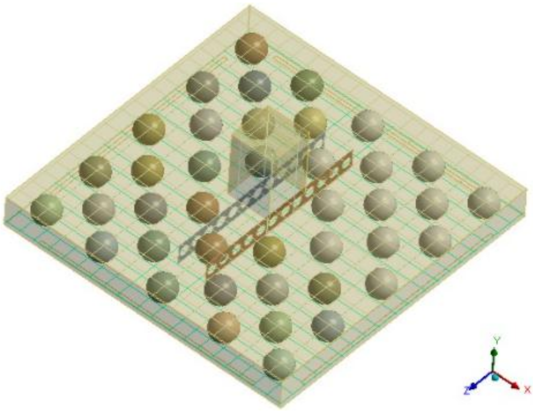

Fig -3: Bubble deck slab in SA with CFS in 1R1D.

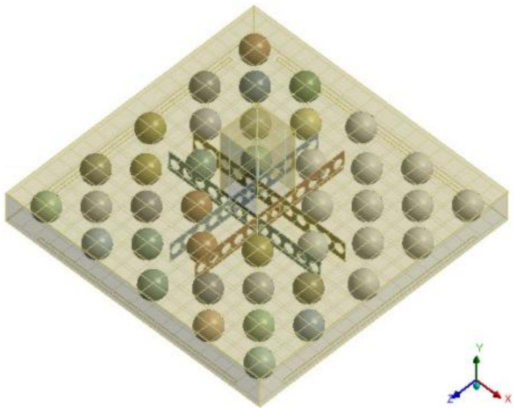

Fig -4: Bubble deck slab in SA with CFS in 1R2D.

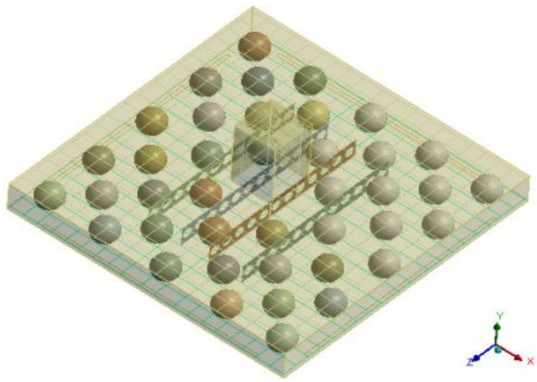

Fig -5: Bubble deck slab in SA with CFS in 2R1D.

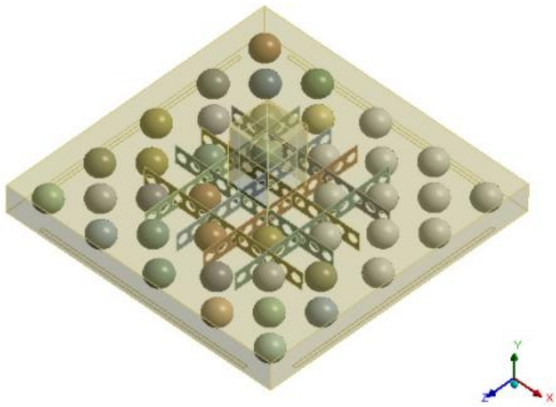

Fig -6: Bubble deck slab in SA with CFS in 2R2D.

5. BOUNDARY CONDITIONS AND LOADING

The slab is simply supported on 4 sides. The external load is applied over the column following the same procedure as used in the experimental work. This load was equally shared by all nodes which are located at the top surface of action of the column. The boundary condition and the loading diagram is same for all models. The Fig 7 represents the loading diagram.

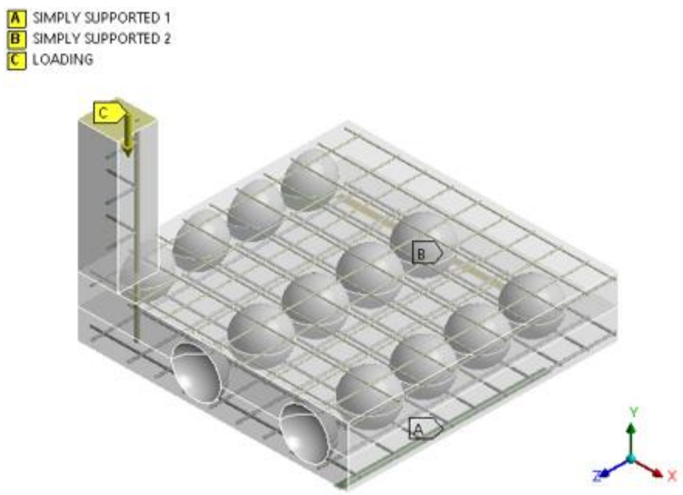

Fig -7: Loading diagram.

6. RESULT AND DISCUSSIONS

All the models were subjected to punching shear analysis. Fig 8, 9, 10, 11, 12, 13 represent the deformation diagram of different bubble deck slab models from ANSYS.

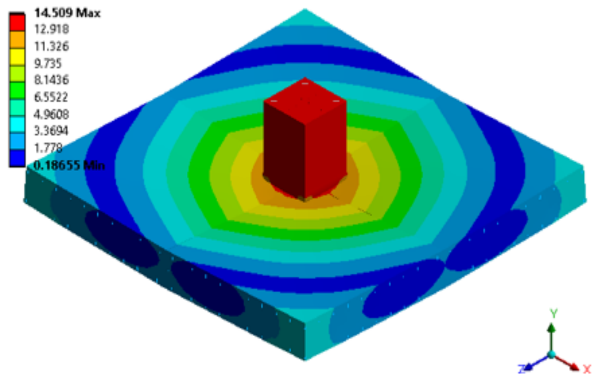

Fig -8: The total deformation of bubble deck slab in RA.

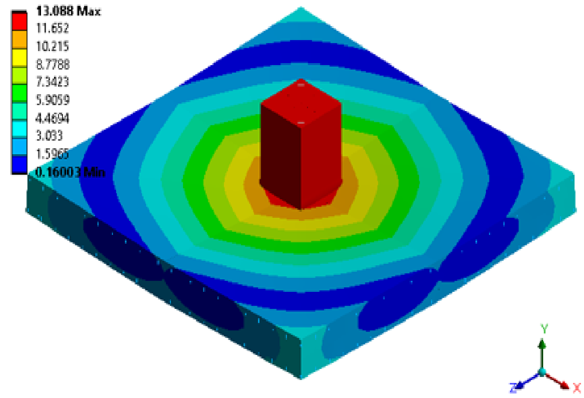

Fig -9: The total deformation of bubble deck slab in SA.

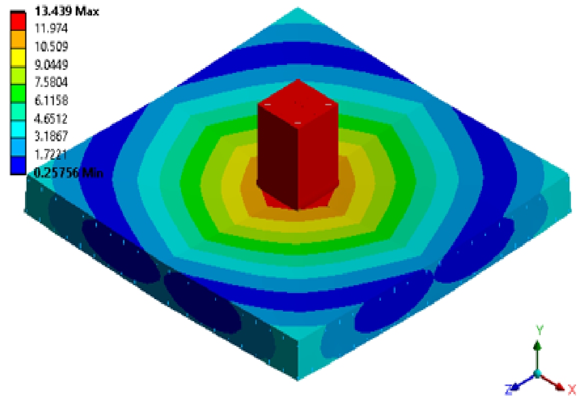

Fig -10: The total deformation of bubble deck slab in SA with CFS in 1R1D.

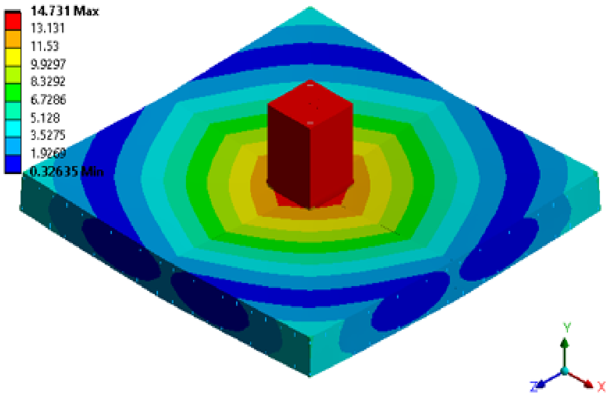

Fig -11: The total deformation of bubble deck slab in SA with CFS in 1R2D.

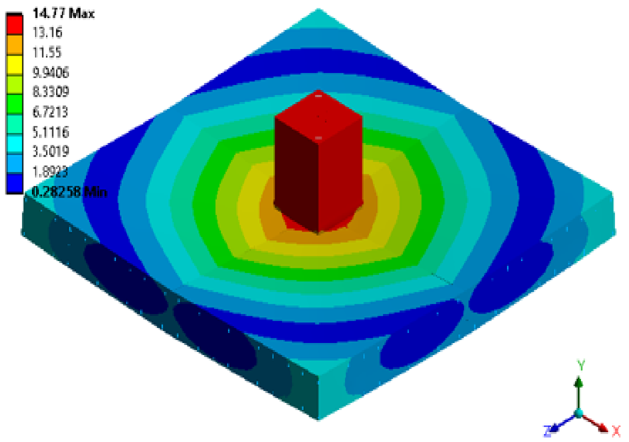

Fig -12: The total deformation of bubble deck slab in SA with CFS in 2R1D.

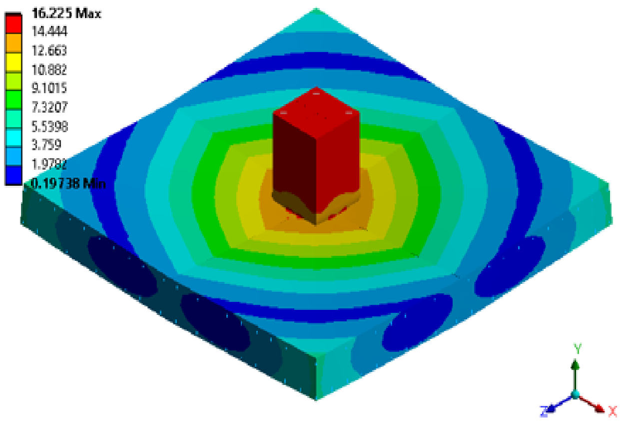

Fig -13: The total deformation of bubble deck slab in SA with CFS in 2R2D.

The Table 2 represents the comparison of percentage increase in shear capacity of RA and SA bubble deck slab. It shows that SA bubble deck has more shear capacity than RA bubble deck slab. Table 3 represents the comparison of percentage increase in shear capacity of bubble deck slab with and without CFS. It shows that the slab with 2R2D has more shear capacity than other arrays of CFS.

Table -2: Comparison of Percentage increase in shear capacity of bubble deck slab in RA and SA.

Components	Deformation (mm)	Load (kN)	% of increase
SA	13.09	525.29	4.48
RA	14.51	503.36	1.00

Table -3: Comparison of Percentage increase in shear capacity of bubble deck in SA with and without CFS.

Components	Deformation (mm)	Load (kN)	% of increase
SA	13.09	525.92	4.48
1R1D	13.44	571.64	8.69
1R2D	14.73	619.64	17.82
2R1D	14.77	587.52	11.71
2R2D	16.23	635.64	20.86

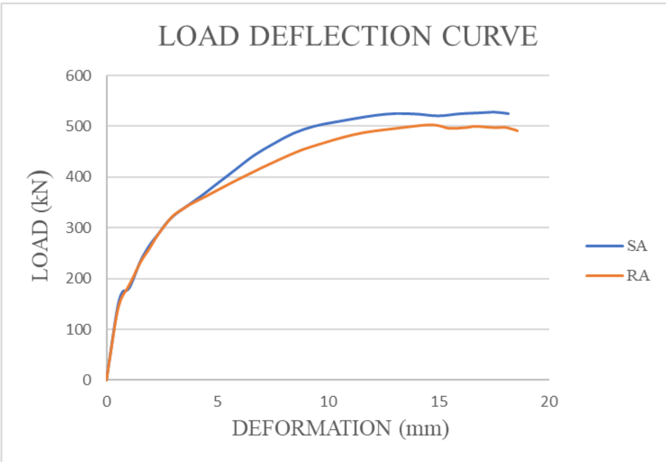

Chart -1: Load deflection graph of SA and RA bubble deck slab.

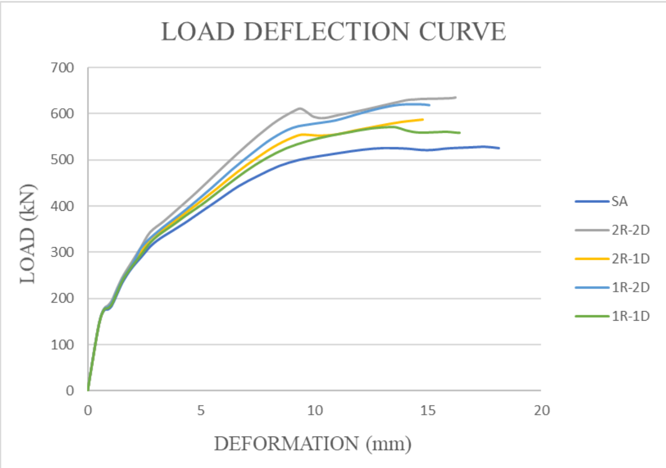

Chart -2: Load deflection graph of bubble deck slab with and without CFS.

The Chart 1 represents the load deflection curve of bubble deck slab in RA and SA. The Chart 2 represents the load deflection curve of bubble deck slab in SA with and without CFS.

7. CONCLUSIONS

In this study, the arrangement of bubble deck slab is changed to staggered arrangement, and the punching shear capacity is estimated. Now to check the performance of bubble deck slab in staggered arrangement in punching shear, need to perform the same in a bubble deck slab in rectangular arrangement with minimum numbers of balls. Also analyzing the staggered bubble deck slab with and without CFS, and then identifying the arrangement with effective shear capacity.

The conclusions are as follows:

- The bubble deck slab in staggered arrangement has 4% increase in shear capacity and bubble deck slab in rectangular arrangement has only 1% increase in shear capacity.
- The difference in CFS arrangement gives different results:

  The slab with 1R1D has 8.69% increment in shear capacity, the slab with 1R2D has 17.82% increment in shear capacity, the slab with 2R1D has 11.71% increment in shear capacity, the slab with 2R2D has 20.86% increment in the shear capacity.
- The bubble deck slab in staggered arrangement with CFS has more shear capacity than those without CFS.

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