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International Journal For Research in  
Applied Science and Engineering Technology



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# INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

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**Volume: 7      Issue: V      Month of publication: May 2019**

**DOI: <https://doi.org/10.22214/ijraset.2019.5607>**

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# Punching Shear Strength Development of Bubble Deck Using FRP Stirrups

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**Abstract:** Bubble deck slab is a method of virtually eliminating all concrete from the middle of a floor slab, which is not performing any structural function, thereby dramatically reducing structural dead weight. High density polyethylene hollow spheres replace the in-effective concrete in the centre of the slab, thus decreasing the dead weight and increasing the efficiency of the floor. By introducing the gaps, it leads to 30 to 50% lighter slab which reduces the loads on the columns, walls and foundations, and of course of the entire building. In slabs, thickness of compressed concrete is only a small proportion of the slab depth and this means it involves only the concrete between the surface and ball. So there is no sensible difference between the behaviour of a solid

slab and bubble deck. But weight of bubble deck slab is low compared to solid slab, so punching shear capacity of bubble deck is very low. This study deals with what will be the effect of strengthening system such as CFRP and GFRP to improve the load carrying capacity of bubble deck slab and to find which FRP is better. Finite element software ANSYS 16.0 is used for nonlinear analysis of bubble deck slab.

**Keywords:** Bubble deck slab, Polyethylene, CFRP, GFRP, Punching shear.

## I. INTRODUCTION

The bubble deck slab is a revolutionary biaxial concrete floor system developed in Europe. High-density polyethylene hollow spheres replace the ineffective concrete in the centre of the slab, thus decreasing the dead weight and increasing the efficiency of the floor. For the construction of bubble deck slab it requires three main materials. They are steel, plastic spheres and concrete. This slab have many advantages over a normal solid slab such as lower total cost, reduced material use, improve structural efficiency, construction time decreased, and is a green technology. When the load is act on a structure compressive force is fully taken by concrete above neutral axis and tensile force is taken by steel in tension zone, so there is no sensible difference between flexural strength of solid slab and bubble deck slab. But punching shear capacity of bubble deck slab is a crucial problem. Bubble deck slab have low weight compared to solid slab. Thus punching shear capacity of bubble deck slab is low. Punching shear is a type of failure in flat slabs due to localized forces. In flat slab this occurs at column support points. The failure occurs due to shear. It is a catastrophic failure because no visible signs are shown prior to failure. In this study bubble deck slab is strengthened with CFRP in different schemes. Compared to GFRP, CFRP have more tensile strength. ANSYS 16.0 is used for analysis.

## II. NEED FOR THE STUDY

Bubble deck slab is a revolutionary biaxial concrete floor system, it eliminate concrete in centre of slab which is not performing any structural action. In slabs, thickness of compressed concrete is only a small proportion of the slab depth and this means it involves only the concrete between the surface and ball. So there is no sensible difference between the behaviour of a solid slab and bubble deck. But weight of bubble deck slab is low compared to solid slab, so punching shear capacity of bubble deck is very low. This study deals with what will be the effect of strengthening system such as CFRP and GFRP strips to improve the load carrying capacity of bubble deck slab. Finite element software ANSYS 16.0 is used for nonlinear analysis of bubble deck slab.

## III. SCOPE AND OBJECTIVES

The scope of the study is to investigate the effect of CFRP strips and GFRP strips to increase punching shear capacity of bubble deck slab and their comparison using ANSYS 16.0. The objectives are:

- A. To compare conventional and bubble deck slab using ANSYS workbench 16.0.
- B. To study the punching shear development of bubble deck slab by providing CFRP and GFRP strips in different schemes
- C. A comparative study to determine which FRP is more better.

#### IV.METHODOLOGY

In this study a solid slab and bubble deck slab was modelled. Bubble deck with FRP's in different scheme was also modelled.

##### A. Modelling of Solid and Bubble Deck Slab

Solid slab and bubble deck slab were modelled using ANSYS 16.0. 8 mm diameter steel reinforcement bars was used and no shear reinforcement is provided. Difference between solid and bubble deck slab is that in bubble deck slab concrete in the centre portion is removed and replace with 180 mm diameter HDPE balls were used. Solid slab with one column stub is modelled. Dimension of slab specimen is 2500 x 2500 x 230 mm. A column in structural engineering is a structural element that transmits, through compression, the weight of the structure above to other structural elements below. In other word a column is a compression member. A stub column is a column whose length is sufficiently small to prevent failure as a column, but long enough to contain the same residual stress pattern that exists in the column itself. A stub column is column which does not have any base which provided only for stiffness purpose of the member. Dimension of Column stub used was 300 x300 mm. Modeling of solid and bubble deck slab is shown in Fig. 1 and Fig. 2.

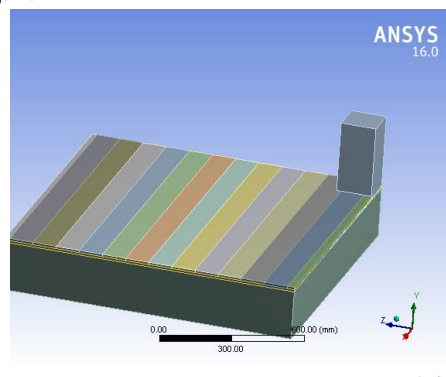


Fig. 1 Model of solid slab

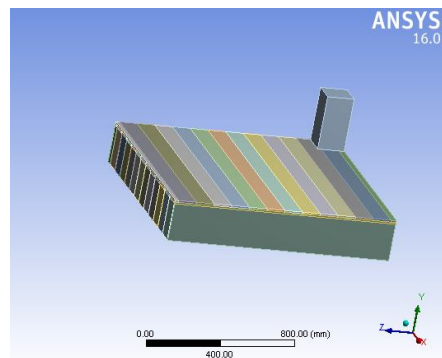


Fig. 1 Model of bubble deck slab

##### B. Modelling of Bubble Deck Slab with CFRP scheme 1 & 2 and with GFRP scheme 1 & 2

CFRP and GFRP having length of 2100mm and breadth 200mm and thickness 2mm was provided. Three layers were provided. Model of the bubble deck slab with CFRP scheme 1 and Scheme 2 is shown in Fig. 3 and Fig. 4.

Bubble deck mainly composed of three main materials Concrete: M25 grade of concrete is used. Modulus of elasticity of concrete used is 25000 MPa. Poisson's ratio is 0.2 .element type used for modeling of concrete is solid 65. Steel: element type used for steel is link 180. Modulus of elasticity  $2 \times 10^5$  ,Poisson's ratio 0.3 ,yield stresses 415 HDPE BALLS: 180 mm diameter balls. Modulus of elasticity 1030 MPa, Poisson's ratio 0.4, and shell 181 element type was used. GFRP STRIPS: Length of GFRP is 2100 mm, width 200mm and thickness is 2 mm. Number of layers used is 3, Modulus of elasticity is 20.23 GPa, Poisons ratio 0.223. CFRP strips: Length of GFRP is 2100 mm, width 200mm and thickness is 2 mm, Number of layers used is 3, Modulus of elasticity is 259 GPa, Poisons ratio 0.35.

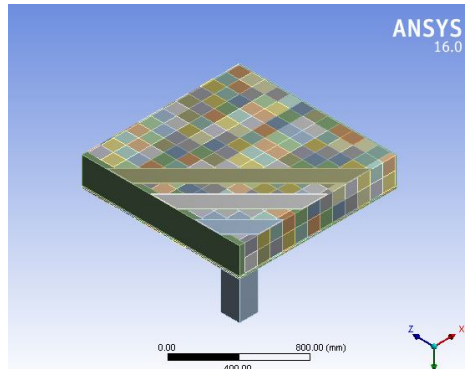


Fig. 3 Model of bubble deck slab with CFRP scheme 1

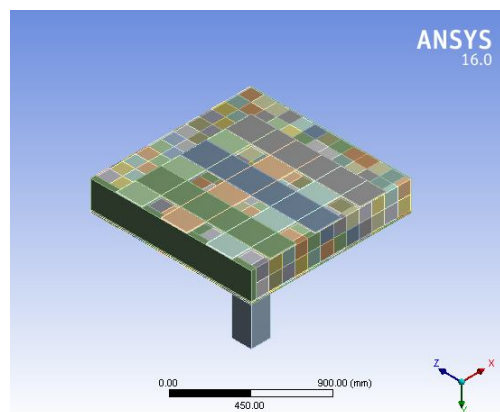


Fig. 4 Model of bubble deck slab with GFRP scheme 1

## V. RESULTS AND DISCUSSION

Bubble deck slab with CFRP and GFRP is modelled and analysed. Non linear static analysis was done using ANSYS 16.

### A. Deformation of Solid Slab, Bubble deck without FRP, with CFRP scheme 1 & 2, and GFRP scheme 1 & 2

Deformation is the change in the shape of a body caused by the application of a force or stress. Deformation obtained for solid slab is low compared to bubble deck slab. Therefore load carrying capacity of solid slab is more for solid slab itself. The deformation values obtained for solid slab, bubble deck slab without FRP, bubble deck slab with CFRP scheme 1 & 2 and with GFRP scheme 1 & 2 is shown in table. 1.. From the table. 1, while comparing the deformation of solid and bubble deck slab without FRP its clear that deformation is more for solid slab. On comparing deformations of bubble deck with CFRP, the deformation is more for CFRP with scheme1. Similarly on comparing GFRP, deformation is more for Scheme 1 itself.

### B. Load carrying capacity of slabs

The load carrying capacity of solid slab is more compared to bubble deck slab without FRP. The stress strain theory is used to determine the load carrying capacity of slab. The time corresponding to the permissible equivalent strain (0.003) is noted and force corresponding to that time is taken as the load carrying capacity of slab. Load carrying capacity of solid and bubble deck slab is shown in table 2.

By comparing the load carrying capacity of bubble deck slab, we can find out which FRP is more better in developing the punching shear strength of the slab. The comparison of result is shown in Fig. 5. From the Fig. 5 the load carrying capacity of bubble deck slab is increased by providing FRP. Therefore the punching shear capacity is also increased for the bubble deck slab. The load carrying capacity is more for FRP with scheme 2 arrangement compared to scheme 1. Also the load carrying capacity is more for CFRP compared to GFRP. In total, the bubble deck slab with CFRP scheme 2 has more load carrying capacity. Hence the punching shear strength development of slab can be obtained by providing CFRP scheme 2 arrangements in the slab.

TABLE I  
DEFORMATIONS OF SLAB

Deformation (mm)	Solid slab	Bubble deck slab without strengthening	Bubble deck with CFRP scheme 1	Bubble deck with CFRP scheme 2	Bubble deck with GFRP scheme 1	Bubble deck with GFRP scheme 2
	2.17	2.39	2.34	2.25	1.87	1.74

TABLE II  
LOAD CARRYING CAPACITY OF SLABS

	Solid slab	Bubble deck slab without strengthening	Bubble deck with CFRP scheme 1	Bubble deck with CFRP scheme 2	Bubble deck with GFRP scheme 1	Bubble deck with GFRP scheme 2
Load carrying capacity of slab	260	190	230	250	210	240
% increase in the load carrying capacity			21%	31%	10%	26%

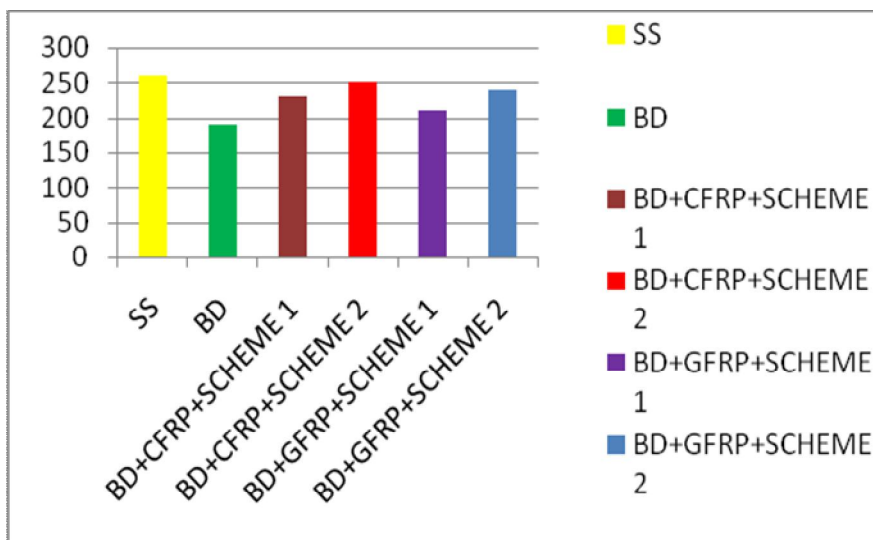


Fig. 5 Comparison of results

**VI. CONCLUSIONS**

Bubble deck slab and solid slab without FRP was compared. Also bubble deck with CFRP and GFRP in different schemes were also compared using the load carrying capacity of slab.

- A. On comparing the load carrying capacity of bubble deck slab and solid slab, solid slab have more load carrying capacity.
- B. The bubble deck with CFRP scheme 2 is more better compared to scheme 1, since the load carrying capacity of scheme 1 is low compared to scheme 2. Similarly GFRP with scheme 2 is more better.
- C. On comparing the FRP's CFRP is more better. SO we can conclude that for developing punching shear strength of bubble deck slabs, CFRP with scheme 2 is better.

**VII. ACKNOWLEDGMENT**

We are really thankful to all the teaching and non-teaching staff of Sri Vellapally Natesan College of Engineering for supporting us throughout this work.



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