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CFRP Strips on Punching Shear Strength Development of Bubble Deck Slab

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Abstract: 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 to improve the load carrying capacity of bubble deck slab. Finite element software ANSYS 14.5 is used for nonlinear analysis of bubble deck slab.

Keywords: Bubble deck slab, Punching shear, CFRP, Finite element modelling, ANSYS 14.5

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. FRP is a composite material, composed of fibres and polymer matrix. FRP has wide range of applicability in civil engineering and other fields. Nowadays FRP is most commonly used material to increase Load carrying capacity, stiffness reduce Deflection etc., one of the promising properties of FRP is its light weight and Reduced cost compared to other strengthening systems. Most commonly used fibres are CFRP and GFRP. In this study bubble deck slab is strengthened with CFRP in different schemes. Compared to GFRP, CFRP have more tensile strength. ANSYS 14.5 is used for modelling and analysis of bubble deck slab.

II. Scope Of The Study

Construction of solid slab is a crucial problem, it require large quantity of money, materials and labours. Bubble deck slab is a light weight structure. Production of one cubic meter of concrete causes CO_2 emission close to 300 kg. But bubble deck slab have less material consumption hence it reduces emission of CO_2 into atmosphere. Thus we can achieve green construction .But studies related to FRP strengthened bubble deck is limited. This study investigates effect of CFRP strips to increase punching shear capacity of bubble deck slab.

III. Specimen Modelling

3.1 Element type and material properties

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Element type used for modelling of bubble deck slab are solid 65 for concrete, link 180 for steel and shell 181 for FRP and HDPE balls. ANSYS 14.5 software was used for modelling of bubble deck slab and dimension of slab specimen was 2500 x 2500 x 230 mm. Dimension of Column stub used was 300 x300 mm. Thickness of HDPE ball is 1 mm. In order to save time only quarter of slab is modelled and symmetrical boundary condition were applied to create full geometry. Load is applied through column as nodal load. Boundary condition used for slab was fixity. In which all degree of freedom were constrained. Material properties and element type used for modelling is shown in Table 3.1

TABLE 3.1
ELEMENT TYPE AND MATERIAL PROPERTIES FOR THE MODELING OF BUBBLE DECK SLAB

Si no:	Element Type Used for modelling	Material Properties	
1	SOLID 65	concrete	
		EX	25000MPa
		PRXY	0.2
		Open Shear Transfer Coefficient	0.2
		Closed Shear Transfer Coefficient	0.8
		Uniaxial Cracking stress	3.5 MPa
		Uniaxial Crushing Stress	-1
2	LINK180	Steel	
		EX	200000 MPa
		PRXY	0.3
		Yield Stress	415
		Tangent Modulus	0
		HDPE balls	
		EX	1030MPa
		PRXY	0.4
3	SHELL 181	CFRP strips	
		EX	259GPa
		PRXY	0.35
		GFRP strips	
		EX	20.23GPa
		PRXY	0.223

3.2. Modelling of solid slab and bubble deck slab

Solid slab and bubble deck slab were modelled using ANSYS 14.5. 8 mm diameter steel reinforcement bars was used and no shear reinforcement is provided. Fig 3.1 shows Modelling of solid slab and bubble deck slab. 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.

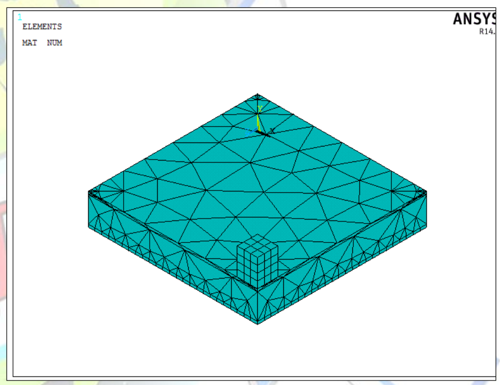

Figure 3.1.Meshed model of solid and bubble deck slab

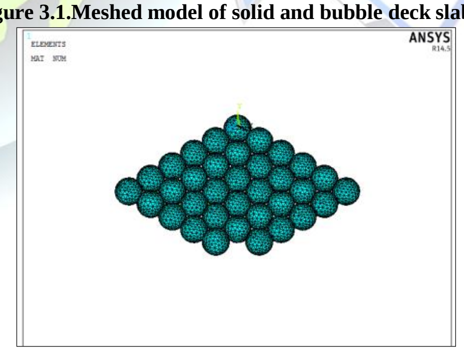

Figure 3.2 Meshed model of HDPE balls

3.3 Modelling of Bubble deck slab with CFRP

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Load carrying capacity of bubble deck slab is low . In order to improve the load carrying capacity of bubble de k slab it is strengthned with CFRP. CFRP arranged in different schemes.figure shows bubble deck slab with different schemes of FRP. Dimensions of FRP used in this study as shown in Table 3.2

TABLE 3.2
DIMENSIONS OF CFRP

	Length of FRP (mm)	Breadth of FRP (mm)	Thickness of FRP (mm)
CFRP	2100	200	2

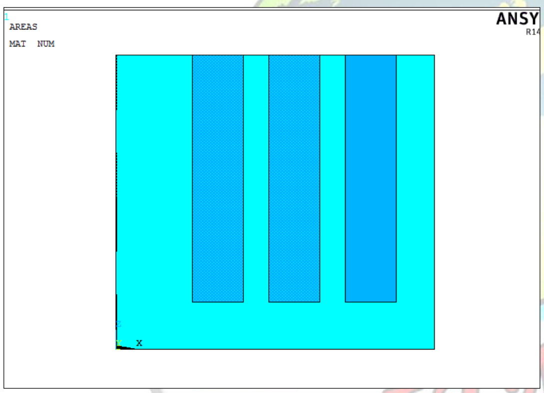

Figure 3.3.Bottom view of one fourth model of bubble deck slab with CFRP scheme 1

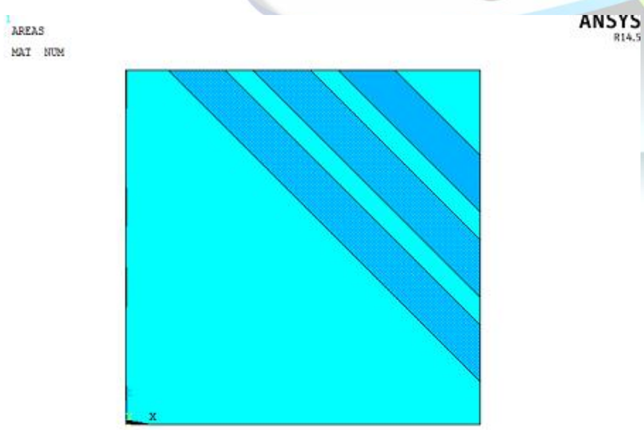

Figure 3.4. Bottom view of one fourth model of bubble deck slab with CFRP scheme 2.

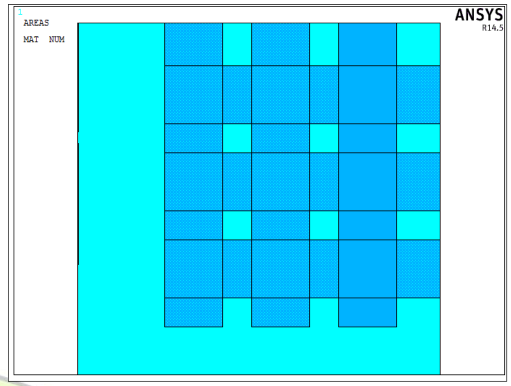

Figure 3.4. Bottom view of one fourth model of bubble deck slab with CFRP scheme 3

IV. RESULTS AND DISCUSSION

4.1. Solid and bubble deck slab

This section deals with result obtained from ANSY 14.5 which include load carrying capacity and displacement diagram of bubble deck slab.

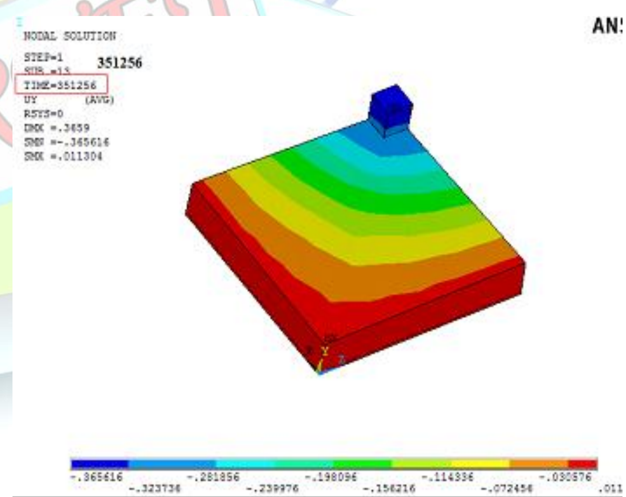

Figure 4.1. Displacement diagram of solid slab

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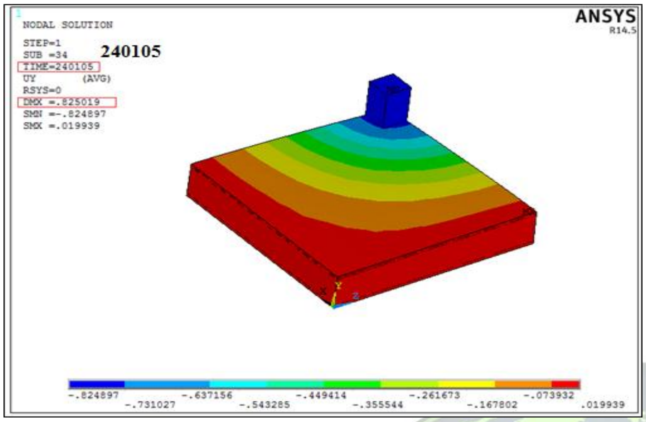

Figure 4.2. Displacement diagram of bubble deck slab

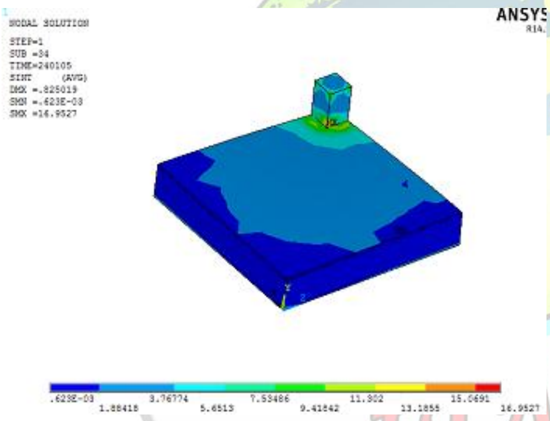

Figure 4.3. Stress diagram of bubble deck slab

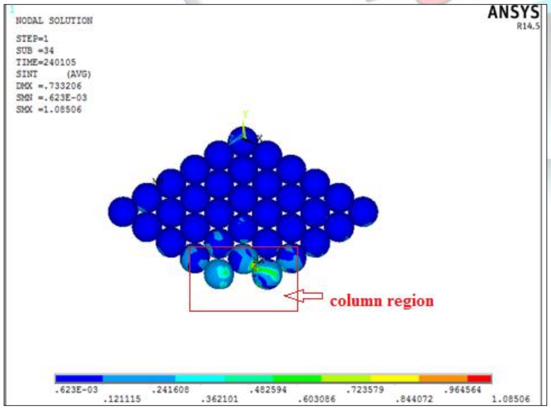

Figure 4.4. stress diagram of HDPE balls

TABLE 4.1
COMPARISON OF SOLID AND BUBLE DECK SLAB

	Solid slab	Bubble deck slab
load carrying capacity of slab (kN)	351.256	240.105
Percentage decreased compared to solid slab	70 %	

4.2. Bubble deck slab strengthened with CFRP

Figure 4.5,4.6,4.7 shows stess diagram of bubble deck slab with CFRP scheme 1,scheme 2,scheme3

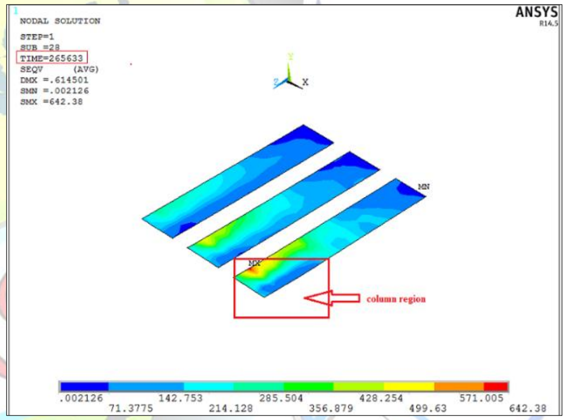

Figure 4.5.Stress diagram of bubble deck slab with CFRP scheme 1

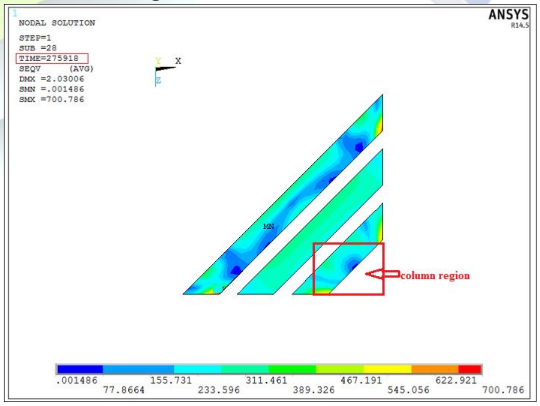

Figure 4.6. Stress diagram of bubble deck slab with CFRP scheme 2

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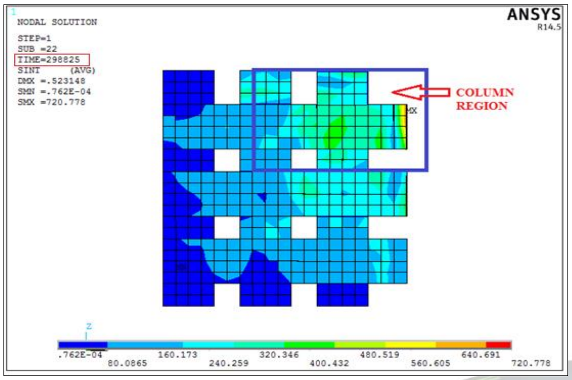

Figure 4.7. Stress diagram of bubble deck slab with CFRP scheme 3

TABLE 4.2
COMPARISON OF RESULTS

	Solid slab	Bubble deck slab without strengthening	Bubble deck with scheme1	Buble deck with scheme 2	Bubble deck with scheme 3
Load carrying capacity of slab	351.256	240.105	265.633	275.918	298.825
Percentage increase in load carrying capacity (%)					
CFRP			10	15	25

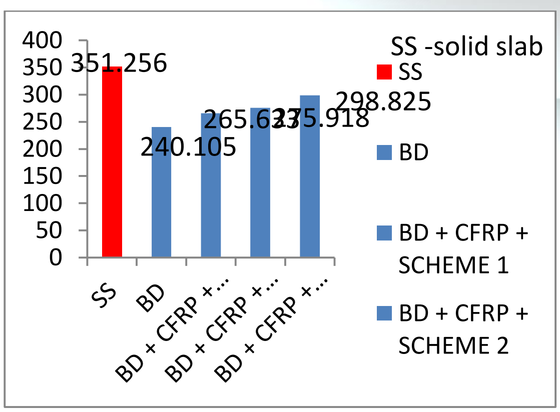

Figure 4.8. Comparison of solid slab ,bubble deck slab and bubble deck slab with different schemes.

V. CONCLUSION

Punching shear capacity of bubble deck slab is low.compared to solid slab bubble deck can achieve only 70 % load carrying capacity.Strengthening bubble deck slab using CFRP is an effective method for improving load carriying capacity. Bubble deck with CFRP scheme 3 can achieve more than 25 % load carrying capacity compared to bubble deck slab without strengthening system.

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