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ANALYSIS OF LIGHT WEIGHT FORMERS IN CONCRETE SLABS USING VOIDS

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Abstract — *This paper presents most favorable different hollow slab in a voided slab. To derive most favorable hollow shapes, numerical simulations using nonlinear Finite Element Methods. This paper presents a numerical analysis using ANSYS finite element program to simulate the reinforced concrete slabs with different voids when subjected to five point load. The finite element models represented by this work can be used to take out parametric study for the voided slab example.*
The slab is a very important structure member in the building and slab is one of the largest member consuming concrete. When the load acting on the slab is a large or clear span between columns is more, the slab thickness is on increasing. It leads to consume more material such as concrete and steel, due to that self-weight of the slab is increasing. To avoid these disadvantages various studies carried out and researchers suggest voided flat plate slab system to cut the self-weight of the slab. A voided flat slab system is known as one of the effective slab system, which can reduce the self -weight of the slab.
This report examines a two-way, reinforced concrete slab with plastic voids construction in comparison to traditional different shapes of hollow spheres plate reinforced concrete slab construction. The design process for plastic voided slabs is directly compared with traditional two-way normal plate reinforced concrete slabs through a design comparison of typical bays of different shapes of hollow spheres. The traditional slab was analyzed by using the finite element method program in order to derive optimal hollow sphere shapes. Results of the comparison study are presented.

Keywords*- Voided slab, Solid slab, Recycled plastic bottle, shear, non-linear analyses, Finite element analysis- ANSYS.*

I. INTRODUCTION

In structure, the slab is very important structural member to make a space. And Slab is one of the largest member consuming concrete. In a general way, the slab was designed only to resist vertical load. However, deflection and vibration of slab are also considered recently because people are getting more interest of residential environment. In addition, when span of the building is increasing, deflection of slab is more important. Therefore, the slab thickness is on the increase. The increasing of slab thickness makes slab heavier, and it leads to increase column and base size. Thus, it makes building consume more materials such as concrete and steel. Moreover, the increasing of weight is harmful for building when earthquake occur. To avoid these disadvantages which were caused by increasing of self-weight of slabs, the voided slab system, also known as void slab, was suggested. This slab system could optimize the size of vertical members like walls and columns by lightening the weight of slabs. Therefore, it got attention because it made efficient and economical building design possible. A capacity of voided slab is influenced by hollow sphere shapes and other. However, the researches about voided in slab have been insufficient. So, in this study, several kinds of voided slabs which have different voided sphere shapes were analysed by using finite element method program in order to derive the most favorable voided shapes and to verify.

II. EXPERIMENT PROGRAM

2.1. Materials Properties

A. Concrete idealization:

The solid65 element models the nonlinear response of reinforced concrete. The behaviour of the concrete material is based on a constitutive model for the triaxial behaviour of concrete. Solid65 is capable of plastic deformation, cracking in three orthogonal directions at each integration point. The cracking is modelled through an adjustment of the material properties that is done by changing the element stiffness matrices. If the concrete at an integration point fails in uniaxial, biaxial, or triaxial compression, the concrete is assumed crushed at that point. Crushing is defined as the complete deterioration of the structural integrity of the concrete. Table-1 lists concrete properties within Solid65 element previous to initial yield surface. The solid65 element is capable of cracking in tension and crushing in compression.

B. Steel Reinforcement:

LINK8 is a spar which may be used in a variety of engineering applications and the 3-D spar element LINK8 available in the elements library of the ANSYS program was used. This element can be used to model trusses, sagging cables, links, springs, etc. The 3-D spar element is a uniaxial tension-compression element with three degrees of freedom at each node: translations in the nodal x, y, and z directions. As in a pin-jointed structure, no bending of the element is considered. Plasticity, creep, swelling, stress stiffening and large deflection capabilities are included ANSYS. The geometry, node locations, and the coordinate system for this element are shown in Figure 2.

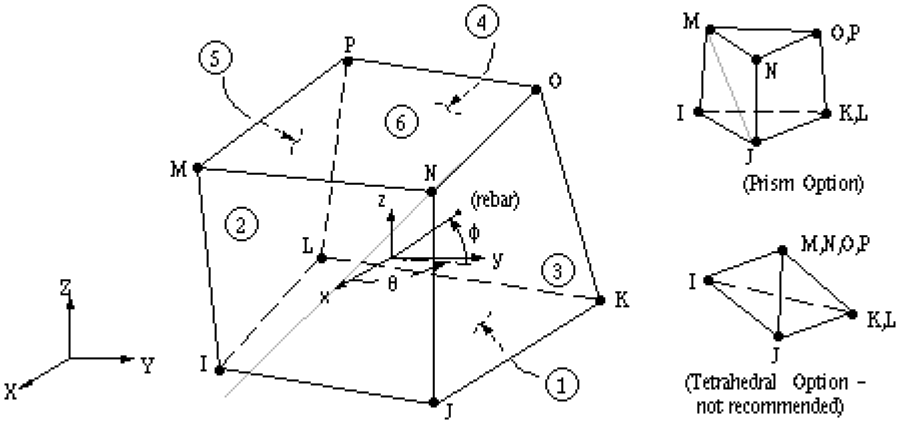

Figure 1. SOLID65 Geometry

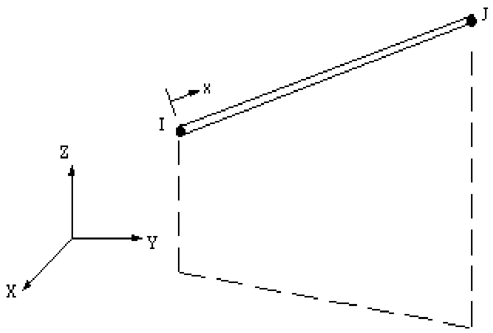

Figure 2. LINK8 Geometry

2.2. Modeling of Material Properties Parameters

A. Concrete Properties

In compression, the stress-strain curve for concrete is linearly elastic up to about 30 percent of the maximum compressive strength. Above this point, the stress increases gradually up to the maximum compressive strength. After it reaches the maximum compressive strength, the curve descends into a softening region, and eventually crushing failure occurs at an ultimate strain. In tension, the stress-strain curve for concrete is approximately linearly elastic up to the maximum tensile strength. After this point, the concrete cracks and the strength decreases gradually to zero. The present study assumed that the concrete is a homogeneous and initially isotropic.

B. Steel

Steel in RC slab is of grade Fy550. The steel for the finite element models has been assumed to be an elastic-perfectly plastic material and identical in tension and compression. Poisson's ratio of γ = 0.3 has been used for the steel in this study. Elastic modulus Es = 200,000 MPa and Poisson's ratio of 0.3 has been used for all the steel bars. Steel plates were provided at support locations and at the loading point in the finite element models to provide a more even stress distribution over the support and loading areas. Same elastic modulus equal to 200,000 MPa and Poisson's ratio of 0.3 were used for the plates. The steel plates were assumed to be linear elastic materials.

Table 1. Material Properties Parameters for Slab Specimens.

Material Type	Element Type	Material Properties	
		Linear Isotropic	
		Es	27163MPa
		Poisson's ratio	0.2
		Multilinear Isotropic	
		Strain	Stress(MPa)

Concrete	Solid65	0	0
		0.00036	10.02
		0.0006	15.28
		0.0009	21.55
		0.0013	27.59
		0.0019	32.31
		0.0024	33.4
		0.003	33.4
Reinforcement	Link8	Linear Isotropic	
		Es	200000MPa
		Poisson's ratio	0.3
		Yield stress	550MPa
Steel Plates	Solid185	Linear Isotropic	
		Es	200000MPa
		Poisson's ratio	0.3

2.2. Test Specimens and Modeling

The finite element method is a numerical analysis technique for getting approximate solutions to a broad variety of engineering problems. ANSYS is a general purpose finite element modeling warp for numerically solving a broad variety of problems which include static structural analysis by nonlinear, The two way solid slabs with tensile and compressive reinforcement slab have been analyzed using a finite element model in ANSYS. Here, a non linear analysis is considered throughout the study by assuming that there is a perfect connecting between concrete and steel reinforcement. Test specimens were designed of seven types of slabs, two were a usual two-way R.C slab and the others were two-way voided slabs. Details and dimensions of the test specimens are illustrated in Table (1 & 2) and Figure (3 & 4). Specimens were tested under a five-point load system using a five hydraulic jack and a five loading plate to satisfy the actual loading condition (Figure (2)). The reasons of using special loading system which has five loading points with bearing were as follows. The loading condition of two-way slabs is UDL in general structure. The deflection of the specimens was measured at their mid-span under the lower face of the tested slabs. The load was increased gradually at increments of to record the deflection up to failure. The slab size of 1100mm x 1100mm x 100mm has been designed for service load of 100 KN. This factored load has been applied in the form of load step and displacement and stresses at each load step has been noted down. Slabs were deferent thickness as 100mm or 125mm. Concrete cover is used 16mm or 20mm and reinforcement adopted is 4mm diameter bar Steel in RC slab is of grade Fy550.

Table 2. Specimens slab dimension

No.	Specimen Name	Length (mm)	Width (mm)	Slab Thickness H (mm)	Bubble Diameter B (mm)	No. of Plastic spheres	Weight (kg)
1.	S_S_100_A	1100	1100	100	--	--	306
2.	B_S_100_64_A				64	144	255
3.	B_S_100_80_A				80	100	238
4.	S_S_125_A			125	--	--	383
5.	B_S_125_64_A				64	144	332
6.	B_S_125_100_A				100	64	298
7.	Bottle_S_100_A			100	D50 L162	B65	269

Table 3. Ball arrangement and Reinforcement detail

Specimen Name	Ball Diametar (mm)	Bottle Size (mm)	c/c Dis (mm)	Clear spacing (mm)	Dis. Froam edge	Ball center from bottom	Reinforcement c/c Dis	Clear cover
B_S_100_64_A	64	-	76	12	110	50	76	16
B_S_100_80_A	80	-	92	15	96	50	92	20
B_S_125_64_A	64	-	76	12	110	62	76	20
B_S_125_100_A	100	-	115	25	98	62	115	24
Bottle_S_100_A	-	L162/D50	70/182	20/20	104/104	50	182/70	16

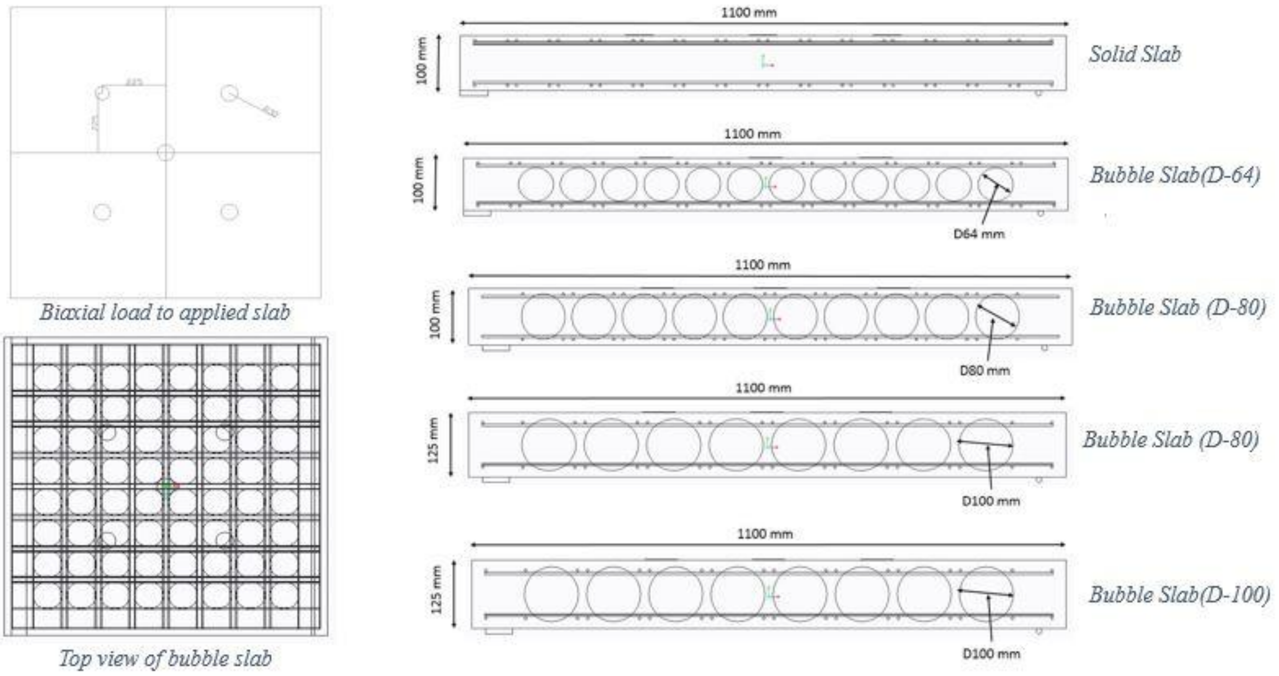

Figure 3. Cross-Section of the slab model

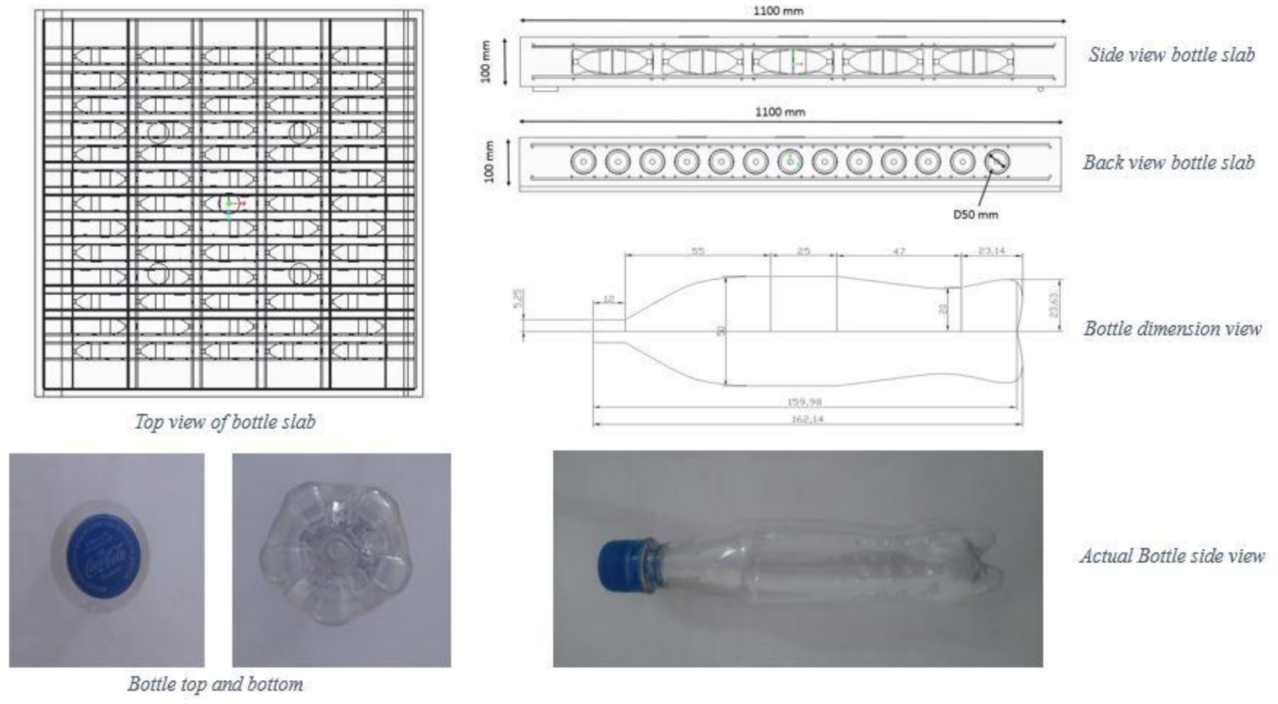

Figure 4. Cross-Section of the bottle use model

A. Loading and Boundary Condition

Boundary conditions are required to get a proper solution for the static structural. Because a accommodate of the entire model slab is used for the model, planes of symmetry are required at the internal faces. The symmetric boundary condition is establish first. The slab model being used is symmetric about two planes is X and Z plane. A accommodate of the full slab was used for modeling by taking advantage of the symmetry of the slab and loadings. Planes of symmetry were required at the internal faces. At a plane of symmetry, the deformation in the direction perpendicular to that plane was held at zero. The force applied at the jack is applied across the entire center line nodes of the plate.

It is type of slab in which one end is simply and another is roller.In that slab parameters to make boundary condition to give support is fixed to six side and roller support is one displacement to a direction. A simply support can resist both vertical and horizontal forces but not a moment. Roller supports are free to rotate and translate along the surface upon which the roller rests. The surface can be horizontal, vertical, or sloped at any angle. The resulting reaction force is always a single force that is perpendicular to, and away from, the surface.

III. ANALYSIS OF SLAB

3.1. Load-Deformation curves

Deformation are measured at mid-span at the center of the bottom face of the slab. Figures (20 & 21) show the load-deformation curves for the solid and voided slabs for analytical results. In general, the load deformation curves for the slabs from the finite element analyses. There are several effects that may cause the higher stiffness in the finite element models. On the other hand, the finite element models do not include the micro-cracks. Next, perfect bond between the concrete and steel reinforcing is assumed in the finite element analyses, but the assumption would not be true for the experimental slabs. The deformation shapes due to applied loads are shown in Figures (5 to 18).

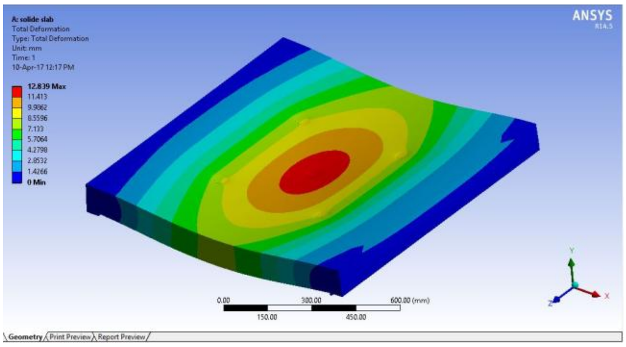

Figure 5. Solid_Slab_100 Deformation

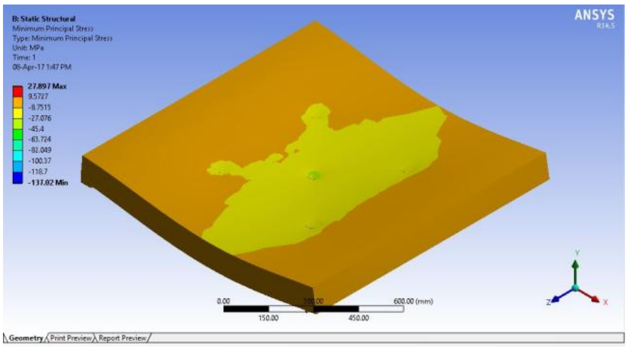

Figure 6. Solid_Slab_100 Stress

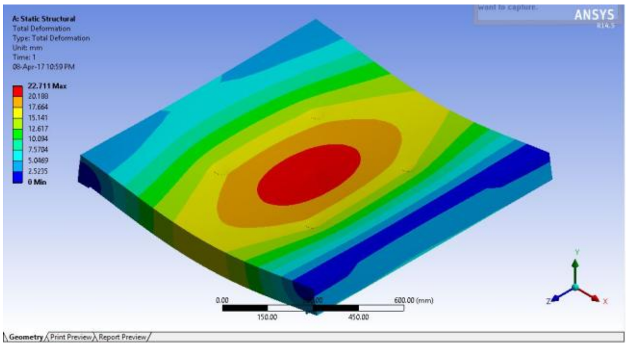

Figure 7. Bubble_Slab_64_100 Deformation

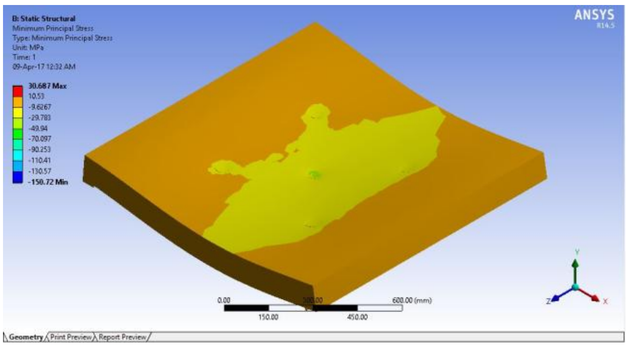

Figure 8. Bubble_Slab_64_100 Stress

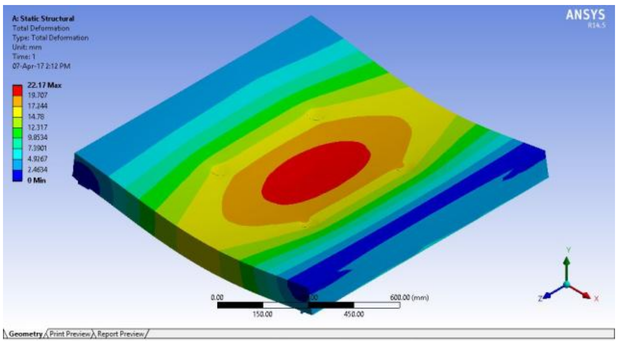

Figure 9. Bubble_Slab_80_100 Deformation

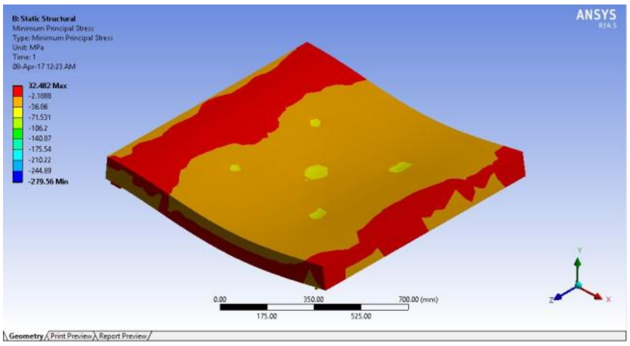

Figure 10. Bubble_Slab_80_100 Stress

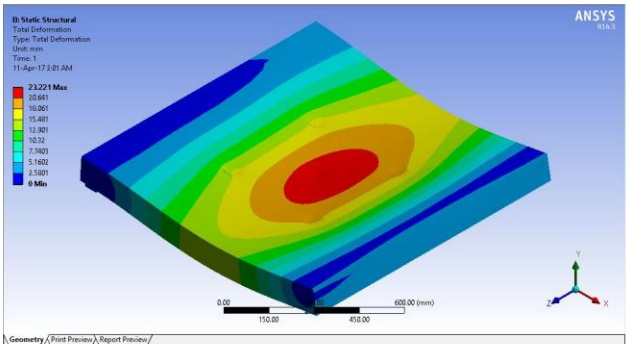

Figure 11. Bottle_Slab_50/162_100 Deformation

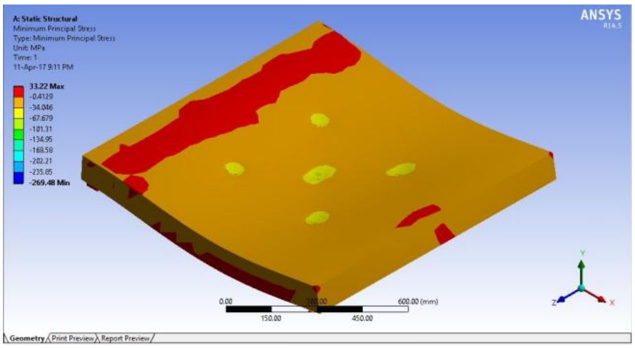

Figure 12. Bottle_Slab_50/162_100 Stress

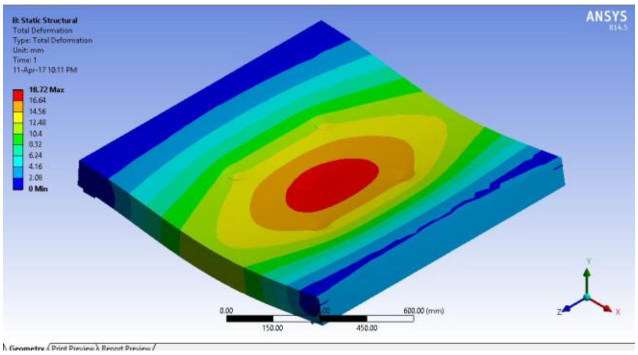

Figure 13. Bottle_Slab_50/162_100 Deformation

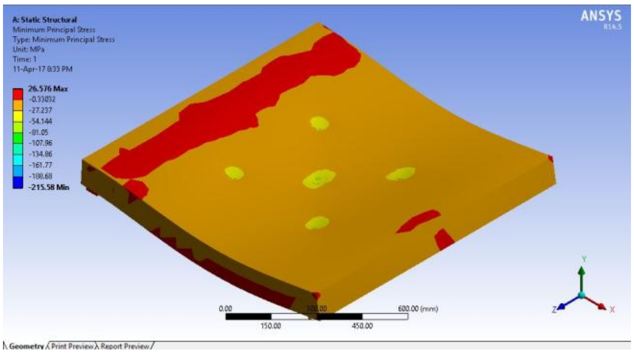

Figure 14. Bottle_Slab_50/162_100 Stress

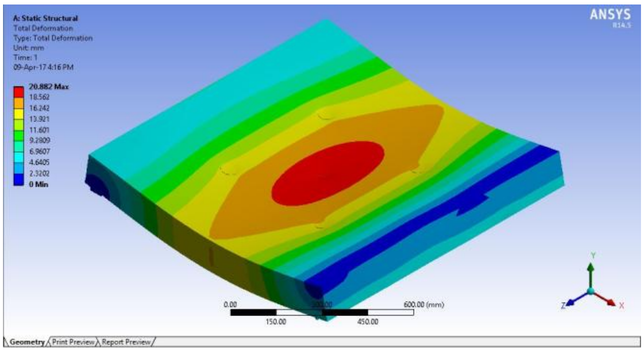

Figure 15. Bubble_Slab_64_125 Deformation

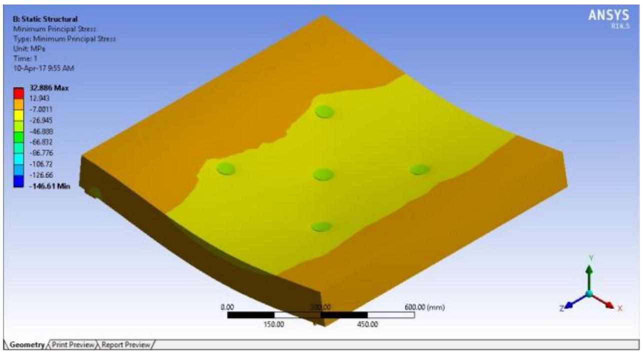

Figure 16. Bubble_Slab_64_125 Stress

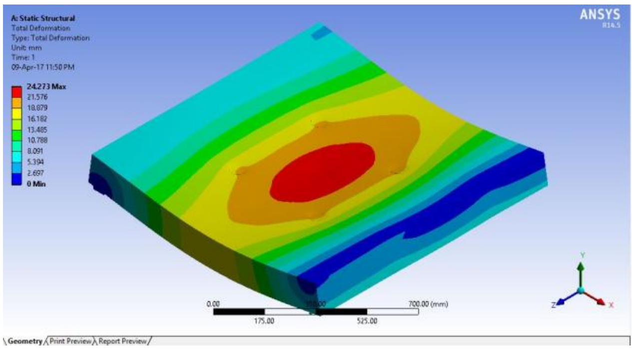

Figure 17. Bubble_Slab_100_125 Deformation

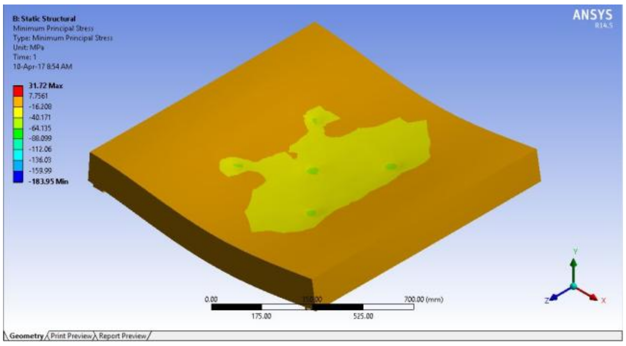

Figure 18. Bubble_Slab_100_125 Stress

The hole of voide sphere functions as preventing a deflection of slab. And as hole diameter of voided sphere was smaller, the deflection of slab was bigger. Finite element analysis (FEA) was carried out by using the ANSYS to study structural behaviour on the slab. The slab of solid and voided slab were subjected to uniformly distributed load. The ultimate load, stress, deformation were measured by analytically. Solid slab carried the stress of applying the udl load of about 500kN and causes deflection in mm.The voide slab carried the stress of the udl load of about 500kN and causes deflection in mm.

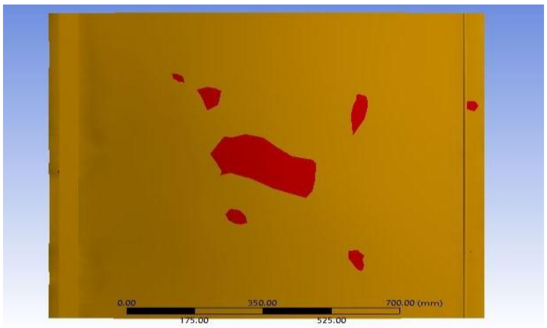

Figure 19. Stress generate bottom of slab

VI. RESULT AN

Table 4. Ultimate load and Deformation of 100 mm thickness to maximum stress

Load (KN)	Specimen Name			
	Solid 100	Bubble 64	Bubble 80	Bottle
100	2.56	2.8	3.3	3.8
200	4.8	5.8	6	6.6
300	6.4	8.3	8.9	10.2
400	9.2	12.3	13	13.2
500	15.8	21.71	22.17	18.72
stress	27.89	30.68	32.48	26.57

Table 5. Ultimate load and Deformation of 125 mm thickness to maximum stress

Load (KN)	Specimen Name			
	Solid 125	Bubble 64	Bubble 100	Bottle
100	2.62	2.98	3.1	3.8
200	4.6	4.99	5.62	6.6
300	6.4	6.9	8.7	10.2
400	9.1	9.3	11.5	13.2
500	12.1	12.59	17	18.72
600	14.9	17.53	21	23.22
stress	30	32.2	31.7	33.22

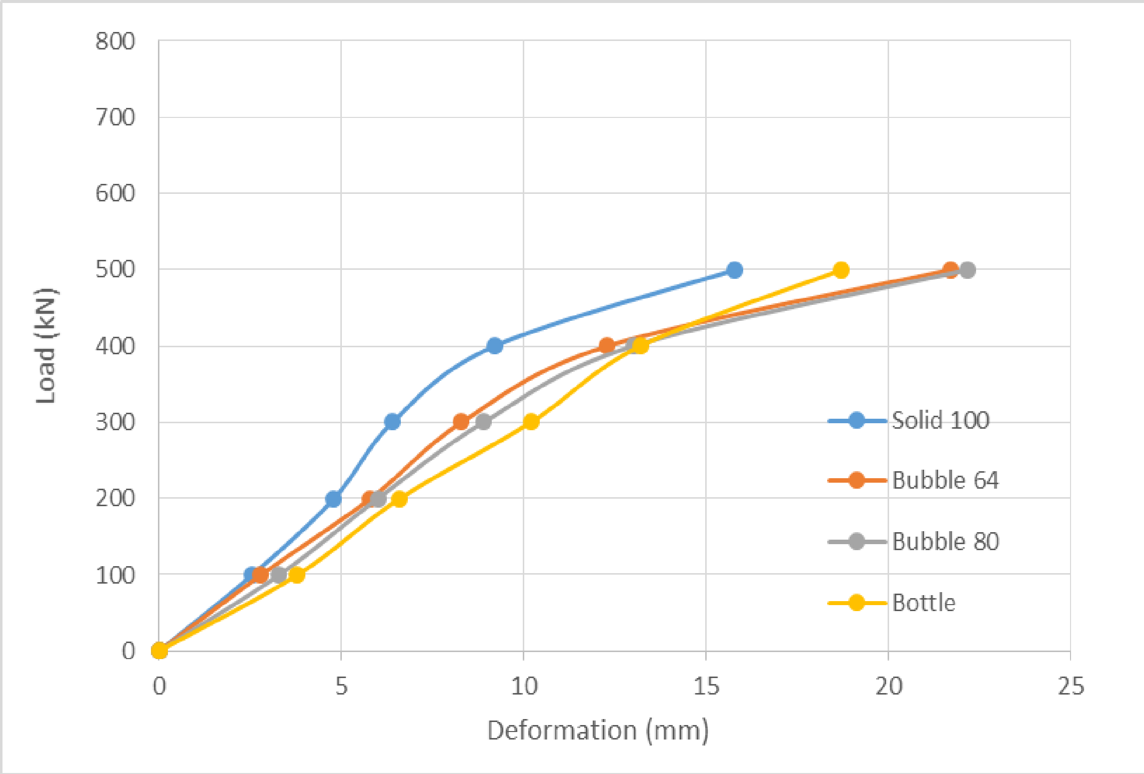

Figure 20. Load versus Deformation Relationship (H=100mm)

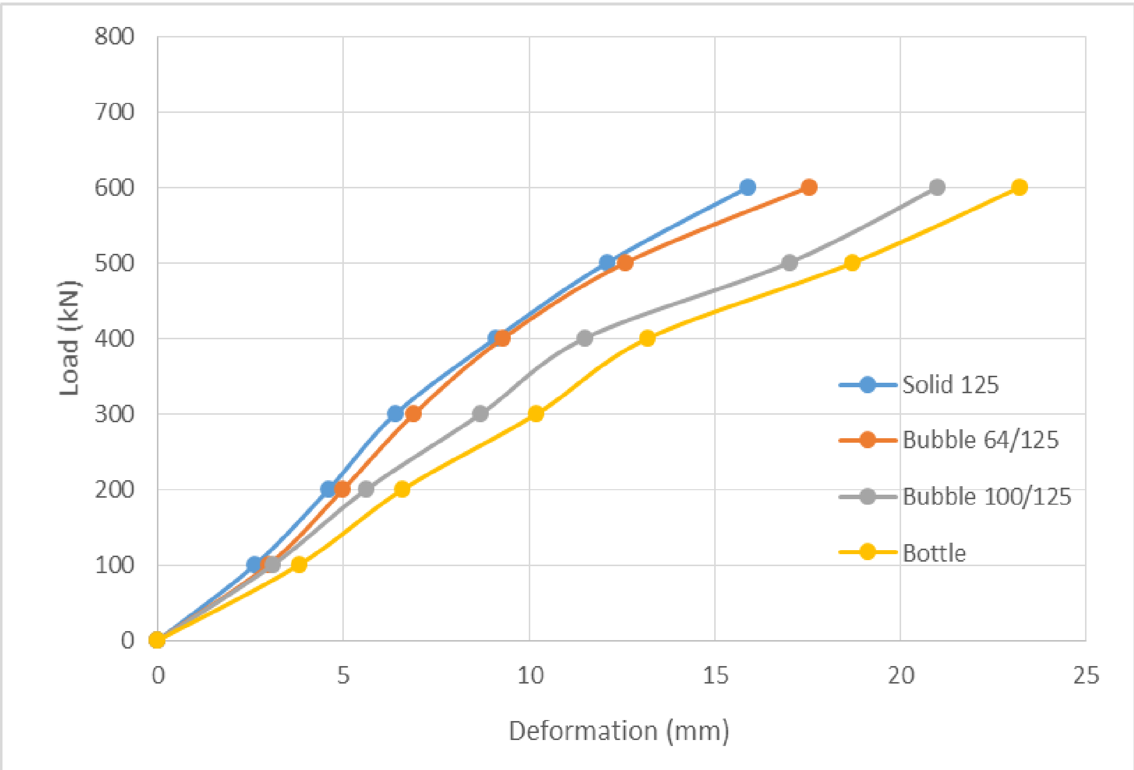

Figure 21. Load versus Deformation Relationship (H=125mm)

CONCLUSION

- In this study, several voided slabs which had different voided shapes were analyzed to compare with structure capacity and failure mode by using finite element method program. Based on the results of numerical simulation, the impacts of voided sphere
- The use of voided slabs (B_S_64,B_S_80), had a result in comparison with reference recommendation solid slabs (without voided), voided slab has (90%) of the ultimate load of a similar reference solid slab but only (90%) of the concrete volume due to plastic spheres, respectively.
- The deflections under service load of voided specimens were a little higher than those of a solid slab.
- The concrete compressive stress of voided specimens is greater than that of a solid specimen.
- As used of bottle voided is corner increase of voided slab and voided sphere was smaller crack, crack caused by concentrated stress was developed earlier.
- The bottle of voided functions as preventing a deflection of slab. And as bottle diameter of the voided slab was smaller, the deflection of slab was bigger.
- The voided slab having most favourable voided, Rect donuts(D=64mm), that show in this study showed more than 90% of load resisting capacity and less than 72% deflection at design load which compared normal slab.

FUTURE SCOPE OF WORK

- Bottle and balls also can be used as bubble in single span of slab.
- Two or more shape of bubble can be used for whole shape.
- It can be applying on Building structure.
- The deferent type of voided can also be used in RCC wall.

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