Numerical Analysis on Different Void Former On ANSYS
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Abstract: The use of construction materials has risen as culture and technology have grown. Concrete is the most often used of all the essential construction materials. To meet structural specifications, traditional architecture approaches include participants with large sizes. These massive structural elements including columns, slabs, beams, footings, partitions, and so on. These massive structural elements have an effect on the volume of concrete used in building around the world. This, in particular, warns us to limit our use of concrete as a building medium because concrete not only adds to the dead load of a house but also produces carbon dioxide as a byproduct, making it detrimental to our climate. This research uses a bi-axial voided slab with various void formers, such as cylindrical, spherical, rectangular, trapezium, and square, spaced at 10mm centre to centre. It removes the concrete from the centre of the slab, resulting in a self-weight reduction of around 6% to 10%. A two bi-axial voided slab functions similarly to a standard slab. The final results met the requirements for strength and serviceability.

Keywords: Bi-axial Voided Slab, Spherical void former, Rectangular void former, Cylindrical void former, Square void former, Trapezium void former.

1. INTRODUCTION

Voided slabs are hollow bi-axial slabs that are hollow on both sides. RCC slabs with separate void former in place of concrete are known as void slabs. Concrete is the most commonly used building material in today's world, but it has a number of drawbacks as well. The self-weight of concrete structures is a major drawback, since it restricts the span and height of the structure. To solve this drawback, Jorgen from Europe developed the Bubble-Deck system, which is a voided slab system.[3].

As a result, we can use a void former in the slab to reduce the weight of the structure without compromising its stability. Partially removing concrete from the zero stress zone and tension zone, which serves no structural function, is part of this procedure. HDPE void former are made of waste plastic and are referred to as such. These are hollow, thin, and long-lasting.

The slabs serve as the primary structural member in superstructures and also serve as a load transfer medium from one structural member to another. We've all learned how concrete functions in the compression field, so we can assume that the concrete in every structural member isn't fully utilized in load bearing. Up to 50% of total concrete volume is idle concrete, or concrete that does not participate in structural performance.

Since the idle concrete cannot be entirely eliminated, a partial removal of concrete volume can be accomplished by employing various void former. Any shape, scale, or waste material may be used as a void former. We may also use waste plastic balls, which aid in the management of solid waste.

2. LITERATURE REVIEW

R Sagadevan, Rao B N (2019) : The researchers conducted an empirical and experimental investigation on three specimen samples and presented their findings at a meeting. The first was a standard slab with a depth of 150mm, the second was a voided slab with a depth of 150mm and 90mm diameter spherical voids spaced at 160mm centre to centre, and the third was a voided slab with a depth of 250mm and 120mm diameter spherical voids spaced at 210mm centre to centre. In his experimental and analytical work, the researcher discovered that both the traditional and voided slabs had the same flexural activity and cracks in the X type as the Yield pattern. The slabs' ultimate load carrying capacity was also the same. The initial stiffness of the voided slab was 37% that of a standard slab.[12].

K. Subramaniam, P.Bhuvaneswari, N.A.Jabez (2017) : Spherically voided Bi-axial slabs were studied. To remove voids in large slab constructions, they used void former. Between the compression and tension layers, three slabs measuring 2900mm*2900mm*100mm were cast. The only difference between such specimens was the gap former pacing, which was 20mm, 30mm, and 50mm. With void former spaced 20mm apart, the concrete reduction was greatest. Instead of using point load research, the testing was performed using area testing. Both strength and serviceability requirements were met in the tests, and the percent reduction in concrete is directly proportional to construction costs. The load is reduced when the amount of concrete in the slab is reduced, resulting in smaller columns and foundations.[14].

R Sagadevan, Rao B N (2017) : The existence of voids decreases the area of concrete, which leads to a reduction in Flexural stiffness and shear resistance, according to a paper presented at a conference. To
determine the Flexural potential of the Bi-axial hollow slab, simulations were performed using the DIANA FEM programme. When compared to Grillage analysis, the findings obtained were satisfactory[13].

Kivanc T., Kerem P. (2014) : The experimental analysis of a solid slab and a Bi-axial voided slab is compared. The researchers in this study used Nautilus as void former, a technology that was first developed in Europe and later adopted by Turkey. Different software was used to create FE models for different span lengths and load intensities. Various void former were used, like Nautilus, Mushrooms, and both. The load intensities ranged from 0.2t/m2 to 1t/m2. Slab lengths ranged from 6m to 18m. For different slab lengths and load intensities, the cost and concrete consumption were compared. Finally, it was determined that the slab with void former Nautilus resulted in a 40% concrete reduction and a 50% cost reduction as compared to the standard slab.[17].

Fall et.al. (2014) : He concluded that adding steel fibre reinforcement increased the proportion of load borne in the weak direction by monitoring reaction forces in a statically indeterminate and asymmetrically reinforced slab. Furthermore, the inclusion of steel fibre reduced the gap in effective support length found in this analysis. In slabs with only traditional reinforcement, the entire width of the support was used in the strong direction, but only a portion of the support width was used in the weak direction. Neither way was completely exploited in slabs with traditional and steel fibre reinforcement. However, the disparity between the lengths was narrowed. Steel fibre supported a substantial increase in load carrying capacity, according to the findings. Furthermore, the crack pattern followed the planned pattern: additional cracks formed with steel fibre reinforced concrete combined with traditional reinforcement, but with narrower crack widths than slabs reinforced with steel fibre reinforced concrete alone[1].

Amer M. Ibrahim et.al. (2013) : Flexural capacities with two-way reinforced concrete bubble deck slabs of plastic spherical voids were presented. Two-dimensional Flexural tests were performed using a special loading frame to verify the Flexural behaviour of this Bubble Deck slab, including ultimate load, deflection, concrete compressive strain, and crack pattern. Six specimen tests were carried out. Two of the slabs were traditional RC slabs, while the other four were Bubble Deck slabs with void diameter to slab thickness ratios of 0. (0.51, 0.64 and 0.80). It was discovered that the void diameter to slab thickness ratio affects the crack pattern and Flexural nature. The ultimate load capacities of Bubble Deck slabs with bubble diameter to slab thickness of (0.1) and (0.64), respectively, were the same as solid slabs, while when bubble diameter to slab thickness of (0.80), the ultimate load capacities were decreased by around a third (10 percent). The slab was simply balanced on all four sides by four steel beams with a hinge in the upper surface to reduce fixed end moments and other support-related errors during the evaluation. To satisfy the real loading state, this specimen was examined using a five-point load system with a five hydraulic jack and a five loading tray. [5].

Kim et.al (2011) : The Flexural capacities of a one-way hollow slab with a donut style hollow sphere is presented. A Bi-axial hollow slab system is generally recognized as one of the most powerful slab systems for reducing slab self-weight. The hollow slab with donut style hollow sphere had strong Flexural capacities such as pressure, stiffness, and deflection, according to the studies. Flexural experiments on one-way hollow slabs were conducted to validate the Flexural capacities of this hollow slab. For the research parameters, five laboratory specimens were used. One was a standard RC slab, while the others were hollow slabs. Two various shapes and textures of plastic balls were used as test parameters. Donut and non-donut shapes became the shape parameters. General plastic and glass fibre plastic were the content criteria.[6].

Pajari (2004) : Large-scale floor experiments on hollow-core slabs supported on beams were presented. Many of the experiments resulted in web shear collapse of slabs near the beam’s supports. Both of the experiments revealed that deflection of the supporting beams significantly decreased the shear resistance of pre-stressed hollow core slabs.[10].

Khaloo and Mirzabozorg (2003) : Five I-section concrete girders were used to analyse clearly supported bridges. The study’s key parameters were girder spacing ranging from 1.8 to 2.7 metres, span length ranging from 25 to 35 metres, skew angle ranging from 0 to 60 degrees, and various internal transverse diaphragm arrangements[4].

Van Oss and Padovani (2003) : It has been shown that cement processing plants release toxic gases into the air. The study looked at particulate pollution from the industrial sector. He also took into account the gaseous contaminants from the clinker production process, such as Nitrogen Oxide, Sulphur Dioxide, and Carbon Dioxide. Calcination and combustion produce carbon dioxide emissions. He attempted to figure out various solutions for reducing pollution from various sources in the cement manufacturing industry[18].

Worrell et al. (2001) : CO2 emissions from the cement industry can be minimized by improving the energy performance of the process, switching to a more energy-efficient process (e.g., from wet to dry), replacing high-carbon fossil fuels with low-carbon fossil fuels or alternative fuels, and using a lower C/C ratio in the manufacture of mixed cements, according to a paper presented. Blended cement production appears to be a viable short-term solution for reducing both fuel and process-related CO2 emissions. Long-term, the use of alternative cements (mineral polymers derived from kaolin) or the removal of CO2 from flue gases can help to reduce CO2 emissions even further. To determine their applicability and emission-reduction potential, both
entail significant research and development activities. The most cost-effective steps to minimise CO2 emissions in the near term are energy efficiency improvements, the building of productive new kilns, increased production of mixed cements, and increased usage of waste fuels. The economics of switching to low-carbon fuels is determined by regional fuel prices[19].

Pajari and Koukkari (1998) : Introduced a prestressed hollow core slab construction approach that is based on the true failure mechanisms of prestressed hollow core slabs. 340 full scale load experiments were evaluated and the measured findings were compared to the experimental results to validate the design process and confirm the design parameters. The conclusion was reached that the design against shear compression failure mode should be replaced by a design against anchorage failure mode[8].

Issa et.al. (1994) : Two quarter-scale, continuous, voided slab bridge models, post-tensioned longitudinally and transversely, were tested in the lab to evaluate their operation, post-cracking, and ultimate responses under simulated AASHO truck boarding. The elastic reaction was investigated through eleven experiments. The results of these model tests revealed that the response of continuous, post-tensioned voided slab bridges under duty load is elastic[14].

Pisanty A (1992) : The findings of an experimental and theoretical analysis of hollow core slab shear capability were presented. The aim of this analysis was to look at how these slabs behaved and how certain key parameters affected their behaviour. A total of 120 slab experiments were conducted as part of the full scale tests. This investigation was limited to the issue of principal tensile failure, which was the most common mode of shear failure in these hollow core slabs.[11].

Oduyemi and Clark (1988) : A scale of 1:3.33 was used to test fourteen transverse strips and fifteen longitudinal strips of conventional voided slab bridge sections. Each strip was put through its paces in an upright position before being loaded four times. The proposed method for estimating crack width in such voided slabs due to transverse bending has been shown to be very accurate as compared to test results[7].

Pajari, (1988) : Introduced a prestressed hollow core slab construction approach based on genuine prestressed hollow core slab failure mechanisms. 340 full-scale load measurements were evaluated, and the measured findings were compared to the experimental ones, in order to validate the design process and confirm the design parameters. The conclusion was reached that the design against shear compression failure mode should be replaced by a design against anchorage failure mode[9].

Elliot and Clark (1982) : A system for estimating plate bending stiffness and plate torsional stiffness was presented. To equate experimental findings with the theoretical method, one solid and three voided slabs were tested[2].

3.OBJECTIVES
1. The main aim is to see the deflection behavior of the slab when voids are present is shear zone.
2. To analyse the Slab using ANSYS 2020R1 for Deflection, Equivalent stress, Equivalent strain and Weight.
3. To compare the results obtained from models with different void former (voids in shear zone).

4.METHODOLOGY
To achieve the objectives stated above the following steps were taken:
1. Modelling of Slabs with or without void former using software CREO.
2. Analyzing the prepared models using ANSYS 2020R1.
3. Comparison of results for normal slab and slab with different types of void former.

5.MATERIAL PROPERTIES

| Material       | Properties          | Value    |
|----------------|---------------------|----------|
| Concrete (M20) | Modulus of Elasticity (MPa) | 2500     |
|                | Compressive Strength (MPa)    | 20       |
|                | Poisson’s Ratio        | 0.2      |
| Steel          | Modulus of Elasticity (MPa) | 200000   |
|                | Tensile Strength (MPa)   | 500      |
|                | Poisson’s Ratio        | 0.3      |
| HDPE           | Modulus of Elasticity (MPa) | 1030     |
|                | Density (kg/m³)        | 950      |
6. NUMERICAL ANALYSIS
Slab were modeled in a CAD software named as CREO with Dimension of slab - 300mm x 300mm x 100mm.
- The void so created were of Sphere, Cylinder, Rectangle, Square and Trapezium.
- The voids so created were assumed to be made of HDPE (High Density Polyethylene) material.
- The voids were spaced at 10mm centre to centre.
- The reinforcements were placed in two meshes, one at bottom and one at top.
- The results like Total Deformation, Stress and strain are carried out in FE analysis of Slabs with or without void former.

| Poisson’s Ratio | 0.4 |

Figure 1: Slab modeled using CREO without void former

Figure 2: Slab modeled using CREO Spherical void former.
Figure 3: Slab modeled using CREO Cylindrical void former.

Figure 4: Slab modeled using CREO Rectangular void former.

Figure 5: Slab modeled using CREO Square void former.
7. RESULTS

The slab were analyzed on ANSYS 2020R1. The results obtained are shown in Table 2:

| Void former          | Dimension of Void | Placing of Void | Point Load Applied | Weight (kg) | Maximum Total Deformation (m) | Maximum Equivalent Strain (m/m) | Maximum Equivalent Stress (Pa) |
|----------------------|-------------------|-----------------|--------------------|-------------|-------------------------------|---------------------------------|-------------------------------|
| Conventional Slab    | NA                | NA              | 100000 N           | 2.0         | 0.0029                        | 0.96                            | 17.2x10^9                     |
| Slab with spherical voids | Dia = 10mm     | 10mm            | 100000 N           | 1.88        | 0.0029                        | 0.37                            | 21.6x10^9                     |
| Slab with Cylindrical voids | Dia=10mm, Length=10mm | 10mm          | 100000 N           | 1.87        | 0.0031                        | 1.06                            | 22.7x10^9                     |
| Slab with Rectangular voids | Length=10mm, Width=8mm | 10mm         | 100000 N           | 1.85        | 0.0034                        | 0.97                            | 19.1x10^9                     |
| Slab with Square voids | Side = 10mm       | 10mm            | 100000 N           | 1.84        | 0.0035                        | 0.94                            | 18.1x10^9                     |
| Slab with Trapezium voids | A=8mm, B=10mm, C=10mm | 10mm          | 100000 N           | 1.86        | 0.0032                        | 0.62                            | 20.9x10^7                     |
7.1 ANSYS results for No Void Former:

Figure 7: ANSYS Results for Solid Total Deformation

Figure 8: ANSYS Results for Solid Equivalent Strain

Figure 9: ANSYS Results for Solid Equivalent Stress
7.2 ANSYS results for Spherical Void Former:

Figure 10: ANSYS Results for Spherical Total Deformation

Figure 11: ANSYS Results for Spherical Equivalent Strain

Figure 12: ANSYS Results for Spherical Equivalent Stress
7.3 ANSYS results for Cylindrical Void Former:

Figure 13: ANSYS Results for Cylindrical Total Deformation

Figure 14: ANSYS Results for Cylindrical Equivalent Strain

Figure 15: ANSYS Results for Cylindrical Equivalent Stress
7.4 ANSYS results for Rectangular Void Former:

Figure 16: ANSYS Results for Rectangular Total Deformation

![Figure 16: ANSYS Results for Rectangular Total Deformation](image1)

Figure 17: ANSYS Results for Rectangular Equivalent Strain

![Figure 17: ANSYS Results for Rectangular Equivalent Strain](image2)

Figure 18: ANSYS Results for Rectangular Equivalent Stress

![Figure 18: ANSYS Results for Rectangular Equivalent Stress](image3)
7.5 ANSYS results for Square Void Former:

Figure 19: ANSYS Results for Square Total Deformation

Figure 20: ANSYS Results for Square Equivalent Strain

Figure 21: ANSYS Results for Square Equivalent Stress
7.6 ANSYS results for Trapezium Void Former:

Figure 22: ANSYS Results for Trapezium Total Deformation

Figure 23: ANSYS Results for Trapezium Equivalent Strain

Figure 24: ANSYS Results for Trapezium Equivalent Stress
8. Graphical comparison
Where S1 = Conventional Slab
S2 = Spherical voids
S3 = Cylindrical voids
S4 = Rectangular voids
S5 = Square voids
S6 = Trapezium voids

Graph 1: Comparison of Slab for Weight.

Graph 2: Comparison of Slab for Total Deformation.
Graph 3: Comparison of Slab for Equivalent Stress.

Graph 4: Comparison of Slab-Column Connection for Equivalent Strain.
9. CONCLUSION
From the above results we can conclude that:

a) The Weight reduction achieved ranged between 6% -10%.
b) The maximum weight reduction was seen in slab with square voids.
c) The Total Deformation increased by 17%.
d) The maximum Total Deformation was seen in slab with square voids but was zero in spherical voids.
e) The Equivalent stress increased ranged between 5% - 20%.
f) The minimum increase in Equivalent Stress was seen in slab with square voids.
g) The Equivalent strain decreased by 62% and increased by 10%.
h) The Equivalent strain showed maximum reduced in slab with spherical voids.

So from the above results we can conclude that the voided slab with Square void former showed maximum weight reduction. There was increase in Total Deformation, within limits. There was increase in Equivalent Stress & strain in considerable amount.

REFERENCES
1. Fall D, Shu J, Rempling R, Lundgren K, Zandi K (2014) Two-way slabs: Experimental investigation of load re-distributions in steel fibre reinforced concrete. Engineering Structures 80:61-74, DOI: 10.1016/j.engstruct.2014.08.033.
2. Elliot G, Clark L A (1982) Circular Voided Concrete Slab Stiffnesses. Journal of Structural Engineering 108(11):2379-2393, DOI: 10.1061/JSEDEAG.0006070.
3. https://bbdna.com/index.php
4. Khaloo A R, Mirzabozorg H (2003) Load Distribution Factors in Simply Supported Skew Bridges. Journal of Bridge Engineering 8(4):241-244, DOI: 10.1061/(ASCE)1084-0702(2003)8:4(241).
5. Ibrahim A, Ali N K, Salman W D (2013) Flexural Capacities of Reinforced Concrete Two-Way Bubbleded Slabs of Plastic Spherical Voids. Diyala Journal of Engineering Sciences 6(2):9-20, DOI: 10.1002/djes.201300973.
6. Kim B H, Chung J H, Choi H K, Lee S C, Choi C S (2011) Flexural Capacities of One-Way Hollow Slab with Donut Type Hollow Sphere. Key Engineering Masters 453:773.
7. Oduyemi T O S, Clark L A (1988) Prediction of Crack Widths in Circular-Voided Reinforced Concrete Slabs Subjected to Transfer to Bending. Magazine of Concrete Research 39(140):124-132, DOI: 10.1680/macr.1987.39.140.124.
8. Pajari M, Koukkari Heli (1998) Shear Resistance of PHC Slabs Supported on Beams: I Tests. Journal of Structural Engineering 124(9):1050-1061, DOI: 10.1061/(ASCE)0733-9445(1998)124:9(1050).
9. Pajari, M. (1988),"Load-Carrying Capacity of Prestressed Hollow Core Slabs," Journal of Nordic concrete research, No. 7, 233-249.
10. Pajari M (2004) Pure Torsion Test on Single Hollow Core Slabs. VTT Building and Transport Research Notes 2273, DOI: 10.4467/2353737XCT.15.160.4335.
11. Pisanty A (1992) The shear strength of extruded hollow-core slabs. Materials and Structures 25:224-230, DOI: 10.1007/BF02473067.
12. Sagadevan R, Rao B N (2019) Experimental and Analytical Investigations on Two-way Flexural Capacity of Bi-axial Voided Slab. Proceedings of National Conference on Advances in Structural Technologies (CoAST-2019), DOI: 10.1016/j.istruc.2019.03.013.
13. Sagadevan R, Rao B N (2017) Analytical Studies on Flexural Capacity of Bi-axial Hollow Slab. Proceedings of the International Conference on Composite Materials and Structures (ICCMS), DOI: 10.1080/978-981-3-0362-3_8.
14. Sen R, Issa M, Sun X, Gergess A (1994) Finite Element Modeling of Continuous Post tensioned Voided Slab Bridges. Journal of Structural Engineering 120(2):651-667, DOI: 10.12989/sem.2012.4.3.4.4.459.
15. Subramaniam K, Bhuvneshwar P (2017) Finite Element Analysis of Voided Slab with HDPE Void former. IJCTR: 746-753, DOI: 10.1088/1757-899X/872/1/012124.
16. Van O H G, Padovani A C (2003) Carbon dioxide emissions from the global cement industry. Annual Review of Energy and the Environment 26:303-329, DOI: 10.5194/esd-11-1675-2003.
17. Taskin K, Peker K (2014) Design Factors and the Economical Application of Spherical Type Voids in RC Slabs. International Scientific Conference People, Buildings and Environment 2014, An International Scientific Conference ; 448-458, DOI: 10.1109/tvcg.2007.70405.
18. Van Oss H. G., Padovani A. C. (2003) Cement manufacture and the environment, Part II: Environmental challenges and opportunities, Vol. 7. Pp. 93-126.
19. Worrell E, Price L, Martin N, Hendriks C, Meida L O (2001) Carbon dioxide emissions from the global cement industry. Annual Review of Energy and Environment 26:303-329, DOI: 10.1146/annurev.energy.26.1.303.