A Comparative Dynamic Analysis of Voided Slab With Flat Slab

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Abstract- *Slab being the essential part of the structure has to be effectively designed and utilized.*

Concrete slabs tend to use more concrete than requirement, hence has to be optimized. The solution is using void formers, in this case spherical shaped. Finite element analysis is performed using ANSYS software on 6 specimens in which 3 are solid and others voided. In this paper natural frequency and time period are compared for dynamic analysis

Keywords- Flat slab, voided slab, natural frequency, time period, ANSYS

I. INTRODUCTION

Overview

The Bubble Deck slab is a revolutionary biaxial concrete floor system developed in Europe in1990's by Jorgen Breuning. The traditional Bubble Deck technology uses spheres made of recycled industrial plastic to create air voids while providing strength through arch action. This results in a dramatic reduction of dead weight by as much as 35-40% allowing much longer spans and less supporting structure than traditional solutions. Hence, the Bubble Deck has many advantages as compare to traditional concrete slab such as lowered total cost, reduced material use, enhanced structural efficiency, decreased construction time and is a green technology. It gains much of attention from engineers and researchers from the world. But, while designing a reinforced concrete structure, a primary design limitation is the span of the slab between columns. Designing large spans between columns often requires the use of support beams or varies thick slabs thereby increasing the weight of the structure by requiring the use of large amounts of concrete. Heavier structures are less desirable than lighter structures in seismically active regions because a larger dead load for a building increases the magnitude of inertia forces the structure must resist as large dead load contributes to higher seismic weight. Incorporating support beams can also contribute to larger floor-to-floor heights which consequently increases costs for finish materials and cladding. A new solution to reduce the weight of concrete structures and increase the spans of two-way reinforced concrete slab systems was developed in the 1990s in Europe and is gaining popularity and acceptance worldwide. Plastic voided slabs provide similar load carrying capacity to traditional flat plate concrete slabs but weigh significantly less. This weight reduction creates many benefits that should be considered by engineers determining the structural system of the building. Plastic voided slabs remove concrete from non-critical areas and replace the removed concrete with hollow plastic void formers while achieving similar load capacity as solid slabs. The concept of a voided slab is very simple. Void plastic formers are placed between the upper and lower static reinforcement of a concrete slab. They replace concrete in zones where it has no structural benefit. It is possible to create larger spans more open floor layout i.e. uses of fewer columns.Voided slab is a revolutionary method of virtually eliminating concrete from the middle of a floor slab not performing any structural function, thereby dramatically reducing structural dead weight.

Potential Benefits of Voided Slab

a) Saves 30 to 40 % weight compared to a corresponding solid slab of equal stiffness.
b) The reduced weight of the slab will typical result in a change in design to longer spans and reduced deck thickness.
c) It is also seismic friendly as it lowers the total weight of the building.
d) Reduced concrete usage 1 kg recycled plastic replaces 100 kg of concrete.
e) The company estimates that building costs are reduced by 8 to 10 %.

Objectives of Project

a) To study and Design of various parameters like total bay weight, flexural reinforcement, moment capacity, solid perimeter and material-cost analysis of the solid flat slab and voided slab based on design principles.
b) b) To analyze both the slab systems under same loading condition in ANSYS Workbench.16 to find out the total deformation.

c) To check the range of deformation is in the permissible limit as per ACI 318-11.
d) To find the effect on deformation, stress intensity, elastic strain intensity of both the slab systems by varying void diameter dynamic loading condition.
e) To find mode shapes, natural frequency and time period of voided slab and compare with flat slab
f) To perform vibration analysis for both slab systems and compare.

II. METHODOLOGY OF WORK

Methodology of Work

In this study a finite element analysis of the slab panels has been carried out using ANSYS workbench 16. program to find the deformation of both the slab systems under the dynamic loading conditions.

Analytical Methodology of Finite Element Modelling Using ANSYS

To analyse any structure in ANSYS, software required some inputs like material property, element type, boundary conditions, proper meshing, to get the precise results. The requirement of these properties is brief as below

Geometry and Element Type

To analyse and get the precise results, software required some inputs like material property, element type, boundary condition, proper meshing etc.

a) The geometry and the element type have to be considered together.
b) With over 160 element types to choose from, it is not always an easy task to select the most efficient ones for its analysis. Geometry, loading and required results all need to be evaluated as part of the element selection process.
c) Shell element is typically used for structure where thin walled structure having thickness is very less compared to its length and width.
d) Considering above point in the study we considered "SHELL 63" element. It has both bending and membrane capabilities .The element has six degrees of freedom at each node: translations in the nodal x, y, and z directions and rotations about the nodal x, y, and z-axes. Stress stiffening and large deflection capabilities are included.
e) An eight-node solid element, Solid65, was used to model the concrete. The solid element has eight nodes with three degrees of freedom at each node-translation in the nodal x, y and z directions. The element is capable of plastic deformation, cracking in three orthogonal directions, and crushing.
f) A Link 8 was used to model the steel reinforcement. Two nodes are required for this element. Each node has three degrees of freedom, at each node-translation in three nodal x, y and z directions. The element is also capable of plastic deformation.
g) An eight-node solid element, Solid45, was used for the steel plates at the supports and applied load location in the slab models. The element is defined with eight nodes having three degrees of freedom at each node-translation in the nodal x, y and z directions.

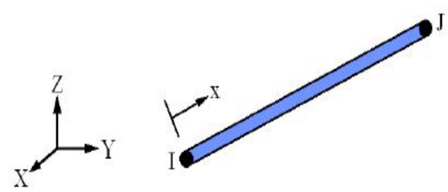

Figure 1. LINK 8 Geometry

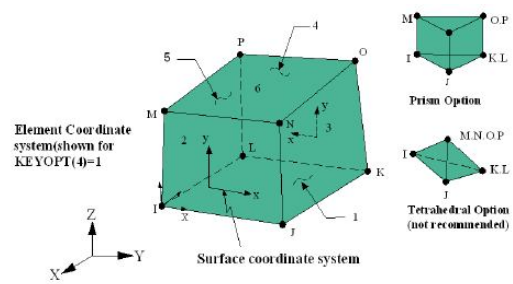

Figure 2. SOLID 45 Geometry

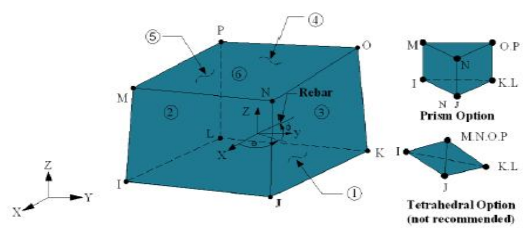

Figure 3. SOLID 65 Geometry

Material Properties

The material properties statements specify intensive properties such as Young's modulus, shear modulus, Poisson's ratio, density, thermal expansion coefficient, thermal conductivity, convection coefficient, and electrical resistivity according to the element type. Most element types require material properties. Depending on the application, material properties may be:

a) Linear or nonlinear

b) Isotropic, orthotropic, or anisotropic.
c) Constant temperature or temperature-dependent.

Meshing

a) Is the process of breaking up the model into smaller pieces that can be solved by using advanced matrix math and then merged together to show the correct result.
b) The goal is to create a mesh that accurately represents the stresses and the displacement meshing that will be present in the real life application of a part without taking of much computing power and time.
c) As the mesh became finer the software generally gives more accurate result.

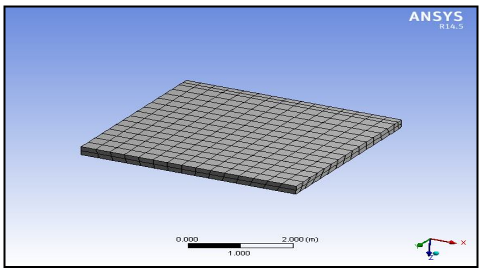

Figure 4. Meshing of Slab

Boundary Condition

a. Boundary conditions are important in determining the mathematical solutions to many physical problems.
b. Different boundary conditions may cause quite different simulation results. Improper sets of boundary conditions may introduce non-physical influences on the simulation system, while a proper set of boundary conditions can avoid that.
c. So arranging the boundary conditions for different problems becomes very important.
d. While at the same time, different variables in the environment may have different boundary conditions according to certain physical problems.

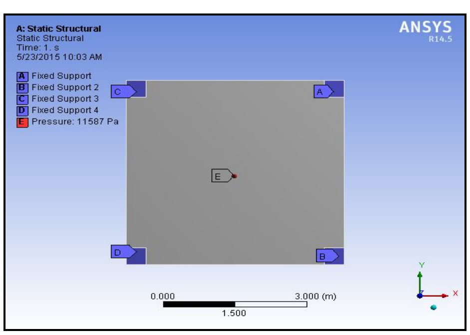

Figure 5. Loading & Boundary Condition

Analysis Type

Static Analysis

a) Structural analysis is the process to analyse a structural system to predict its responses and behaviours by using physical laws and mathematical equation.
b) The main objective of structural analysis is to determine internal forces, stresses and deformation of structures under various load effect.

Buckling analysis

a) Buckling loads are critical loads where certain types of structures become unstable. Each load has an associated buckled mode shape; this is the shape that the structure assumes in a buckled condition.
b) Buckling is depends upon the loading conditions and on its geometrical and material properties.
c) Nonlinear buckling analysis

Linear Eigen value (classical Euler) buckling is a "quick" check on a structure, but the ANSYS Simulation go to considerable pains to point out that in many situations, a Large Displacement solution (geometric nonlinearity) needs to be run also as a check on the buckling adequacy of a design. As with linear buckling, nonlinear buckling may need to be assessed with respect to a number of load cases. In some structures, a diagonal tension field is developed in a web, and elastic buckling failure does not develop at the first Eigen values predicted.

Material Properties Required for Modeling of Slab

a) Steel

Steel was assumed to be an elastic-perfectly plastic material and identical in tension and compression. Poisson's ratio of 0.3 was used for steel reinforcement in this study. The Fe 415 HYSD bars are used for modeling of slabs.

b) Concrete

The present study assumed that the concrete is a homogeneous and initially isotropic.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.

High Density Poly-Ethylene (HDPE)

The spherical voids of HDPE were used in modeling of slabs. The number of voids variesaccording to the span of slab. The 180mm diameter void used for all bay sizes. The thickness and size of void diameter is kept constant for all typical bay sizes. The modules of elasticity and density of HDPE voids is maximum as compared to the Poly Vinyl Chloride (PVC) hence HDPE balls are used in this study.

Table 1. Material properties of slab models

Name of Material	Property	Value
Steel	Modulus of Elasticity (E)	200000 MPa
	Density(ρ)	7850 Kg/m^3
	Poisson's Ratio(μ)	0.3
Concrete	Modulus of Elasticity (E)	25000 MPa
	Density(ρ)	2460 Kg/m^3
	Poisson's Ratio(μ)	0.18
Plastic HDPE Balls	Modulus of Elasticity (E)	1035 MPa
	Density(ρ)	970 Kg/m^3
	Poisson's Ratio(μ)	0.4

III. PROBLEM STATEMENTS

Modal Analysis of Solid Flat Slab

Flat slab of dimensions 5.6 m x 6.6 m
Depth of slab 190 mm
Size of drop panel 2.2 m x 2.2 m
Live load on slab 7.75 kN/m2
Design load on slab 18.1 kN/m2
Flat Slab Modeling

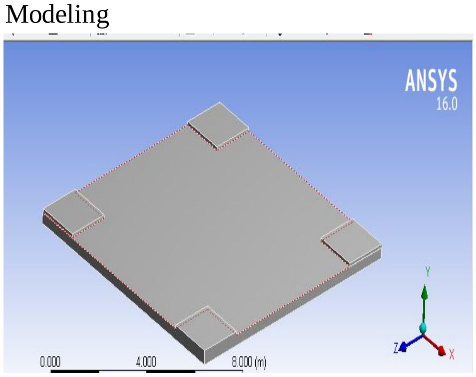

Figure 6. Flat Slab Modeling

Voided Slab Modeling

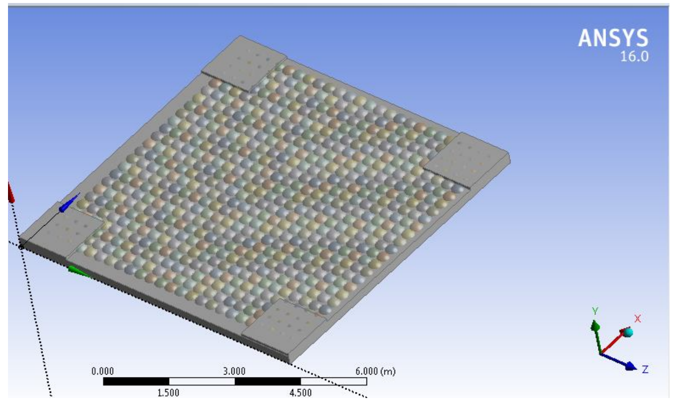

Figure 7. Voided Slab Modeling

IV. RESULTS AND DISCUSSIONS

Modal analysis results in ANSYS workbench 16.

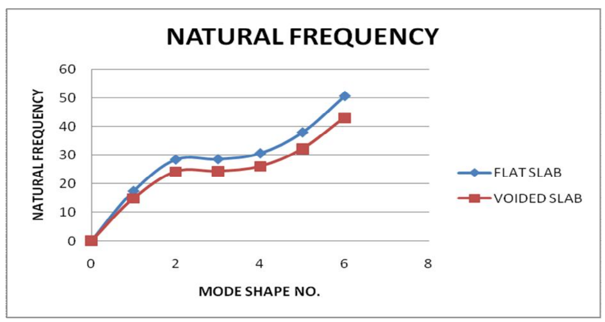

Figure 8.

GRAPH.1NATURAL FREQUENCY VS MODE SHAPE NO.

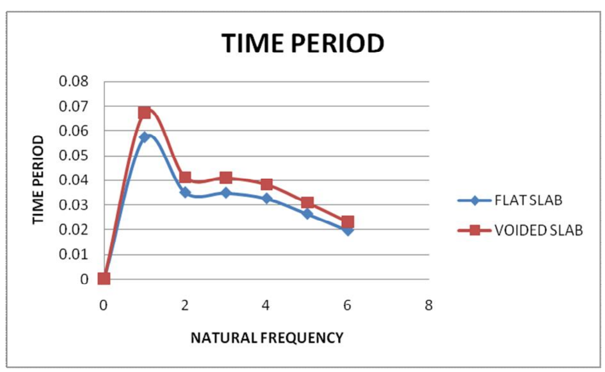

Figure 9.

GRAPH. 2TIME PERIOD VS NATURAL FREQUENCY

V. CONCLUSION

a) The above finite element study was performed on the voided slab of thickness 100 mm and flat slab. The results have concluded that voided slabs performed similar to that of flat slab in static condition
b) Later part includes natural frequency and time period comparison as follows:
c) Natural frequency observed 25% more in flat slab as compared to voided slab
d) Natural frequency observed 15% more in voided slab for mode shape 2 and 3 as compared to flat slab.

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