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# Punching Shear Study on Composite RC Flat Slab Using Finite Element Method

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## ABSTRACT

In recent decades, there was a significant improvement in utilization of RC composite structural elements as a building member. In particular, the usage of composite steel section at the joint regions of structural members are getting developed. The composite RC structural elements show a noticeable performance in higher structural strength with reduced member size, stability and effectiveness makes the attractiveness in construction field. The present study will primarily aim to provide a suggestion in usage of composite steel section in the application of punching shear resistance in composite RC flat slabs. In this regard, an experimental investigation is going to be done to study the punching shear characteristics of composite RC flat slab. To compare the results obtained from experimental investigation, an analytical investigation is also going to be stimulated using finite element analysis software “ANSYS”. The basic properties of composite steel and reinforcement were done experimentally to model the material properties in “ANSYS” software. The parameter considered in this study is the embedding the additional composite steel member with different sections and shape at the punching failure zone to resist the punching shear force. The punching shear performance in terms of load carrying characteristics, failure modes are going to be examining experimentally and analytically.

Keywords: RC flat slab, punching shear, finite element analysis and ANSYS

## I. INTRODUCTION

Reinforced concrete flat slabs are commonly used in the constructions due to their number of benefits to engineers for design purpose. Theflatslabsarethininsections,whichareallowingforthe greaterroofheights and lighter floors. In the flat slabs, the flexible column arrangements are more difficult to design the slab-column joints. However, the flat slab has a lower stiffnessintheslab-column connectionsofthefloorplanwhichcanleadrelatively largedeflectionandtheshearforcescanbedeveloped.Considеringthefactors, there are main two failure modes occurred in the flat slabs. They are Flexural failure and Punching Shear failure. In the Flexural failure mode is always ductile failure in nature, therefore the larger deflection under the excessive loadingthecrackwillappearsonthebottomsurface.Thiscracksignsindicates the problems to be addressed before the failure occurs. The Punching shear failure is a type of failure in reinforced concrete flat slabs subjected to the high localizedforces.Intheflatslab,thepunchingshearfailureisoccurringattheslab-columnjoints.Thefailureatthisjointisverycriticaldueto highlocalizedshear forces creates sudden failure at this jointposition.

The Finite Element Analysis FEA may be a simulation of any given natural phenomenonemploying a numerictechniquecalledtheFiniteElementMethodFEM. Engineers use it to minimize the number of physical prototypes and tests to refine components in their design process to produce better products, faster while saving on costs. Mathematics must be used to fully explain the measure somephysicalphenomenonsuchasstructuralorfluidbehavior,wave propagation, etc. Most of these processes it is described by using the partial differential equation PDE. However, for a machine to solve these PDE, computationaltechniqueshavebeendevelopedthelastfewdecades,andoneof the most important ones today is the Finite Element Analysis. Differential equations not only explain natural phenomena, but also physical phenomena experienced by engineeringmechanics. ThesepartialdifferentialequationsPDEarecomplexequationsthatneed to be resolved by the size of the structure, such as stress strain, etc. in order to calculate the structural behavior of the load. It is necessary to note that FEA onlyoffersanapproximatesolutiontotheproblemandisa numericalapproach to the actual result of these partial differential equations. Simplified, FEA is a computational tool is used to predict how a component behaves under the certain conditions and helps engineers to identify the weak points, strainzones, etc. in their designs. As the results of simulation based on the FEA method are usually displayed in a colour scale, for example the distribution of the pressure over theobject. The objective of the project is to study the punching shear performance of the Composite RC flat specimens and to find out the effective composite steel sections and shape to resist the Punching shear load.

## II. EXPERIMENTAL PROGRAMME

### Test Programme

Three RC were considered for the study. Slab 1 is Conventional slab (CS). Slab 2 is Non-Conventional Slab 1 (NCS1). Slab 3 is Non-Conventional Slab 2 (NCS2). The dimensions of the slabs were square in size 900mm X 900mm with the thickness of 70mm, and the center column size is 100mm X100mm for both top and bottom. The design of the conventional slab is carried out in accordance with IS 456:2000. In conventional slab (CS), the main Reinforcement was detailed with the diameter of 6mm at 145mm c/c spacing and the secondary reinforcement with the diameter of 6mm at 145mm c/c spacing, and in the column strip a parallel reinforcement pattern is placed at center diameter of 6mm at 72mm c/c spacing. For slab 2 the Zigzag pattern is placed at the column strip same as like as conventional slab. For slab 3 the Diagonal Zigzag pattern is used like as a cross bracing at the column strip. Figure 1, 2 and 3 shows the detailing diagram of the conventional slab (CS), Non-conventional slab1 (NCS 1) and Non-conventional slab 2 (NCS 2).

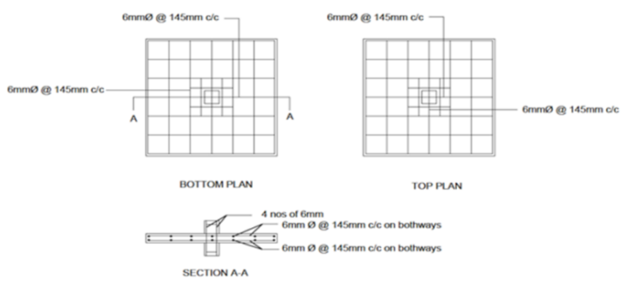


Figure 1: conventional slab (CS)

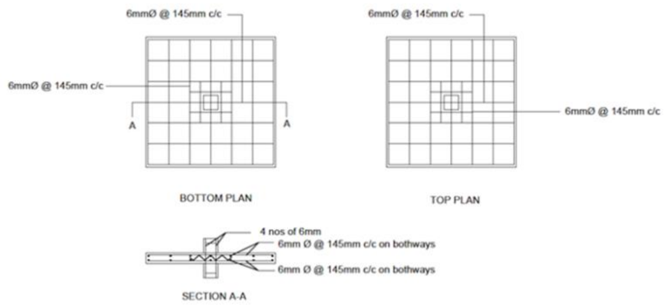


Figure 2: Non-conventional slab1 (NCS 1)

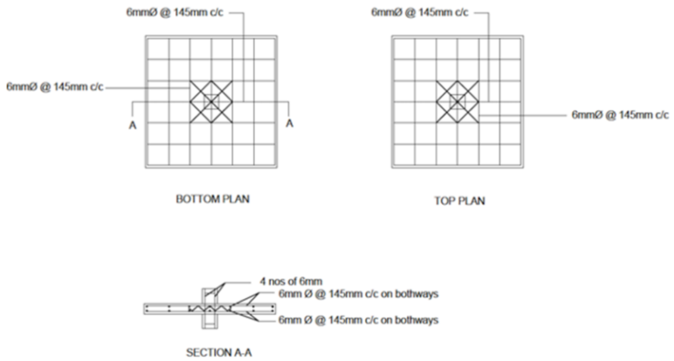


Figure 3: Non-conventional slab2 (NCS 2)

The Slab was cast and tested under the center point load at the column strip using a 500KN hydraulic load cell. The slab was supported along the short side distance of 150 mm from both the ends. The clear span of the slab was kept at 600mm. The deflection at the center of the slab was measured using linear voltage differential transducer. The steel mould was used to cast the slab specimen and the gunny bag method of curing was implemented. Figure 4 shows the casting of RC slabs using steel mould.

Figure 4: RC Slab Specimen

## III. FINITE ELEMENT ANALYSIS PROGRAMME

ANSYS is a Finite Element Analysis software that is used forcomplex analysis of structures in civil engineering. This is particularly used for modelling reinforced concrete structures with their predicted nonlinear property.The FINITE ELEMENT ANALYSIS simulation carried in ANSYS provides the nonlinear behaviour of the element. These problems include static or dynamic structural analysis (both linear and nonlinear). ANSYS consists of two working platform called APDL and workbench. ANSYS offers an easy and flexible platform for performing finite element analysis of structures or models with great accuracy.

### A. Material Property

**CONCRETE**

| | |
|---|---|
| GRADE | M25 |
| POISSON'S RATIO | 0.15 |
| ELASTIC MODULUS (Mpa) | EC = 5000√fck |
| DENSITY (Kg/m3) | 2400 |
| COMPRESSIVE STRENGTH | 43 |

**STEEL**

| | |
|---|---|
| GRADE | FE415 |
| POISSON'S RATIO | 0.3 |
| ELASTIC MODULUS (Mpa) | 200000 Mpa |
| DENSITY (Kg/m3) | 7860 |
| TENSILE STRENGTH (Mpa) | 1110 |

Figure 5 Shows the Assigning of Material Properties

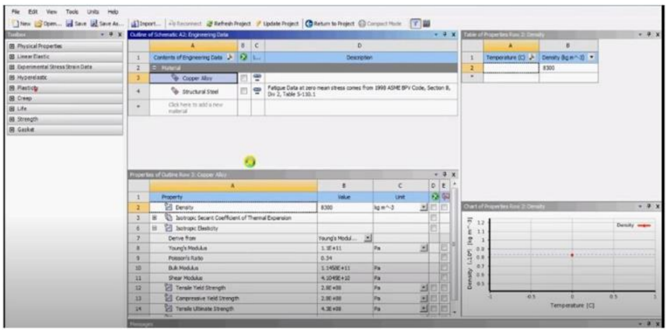

Figure 5: Material Properties

### B. Modelling

Building a finite element model requires a moreANSYS users time than any other part of the analysis. Then, define the element, types real constants and followed by model geometry. The ANSYS version 12 has been used to model and the analysis part also has been conducted in ANSYS. Figure 6 shows the Modelling in ANSYS.

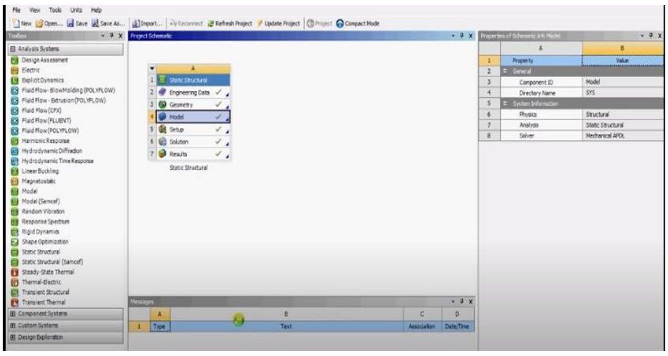

Figure 6: Modelling in ANSYS

### C. Meshing

In order to obtain the actual results from the Solid65 element, a mesh was recommended. The meshing of the reinforcement was a special case compared to volumes. The necessary mesh attributes were set before the volume was meshed. The merging of nodes and key points were carried out to avoid errors due to multiple nodes at the same location.

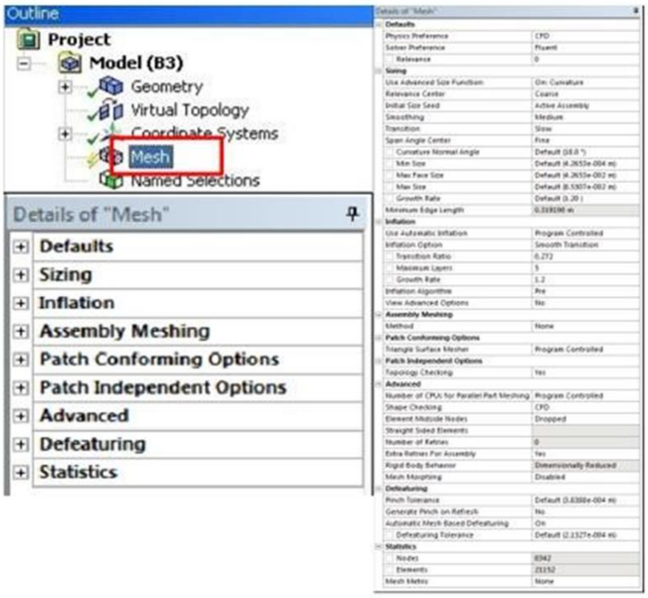


Figure 7: Meshing in ANSYS

### D. Boundary Condition and Loads

The word loads as used in ANSYS as boundary conditions (constraints, supports, or boundary field specifications) as well as other externally and internally applied loads. This project been used with fixed support on the plate given below, in above plate load been applied on range 1000N to 5000N shown in Figure 8.

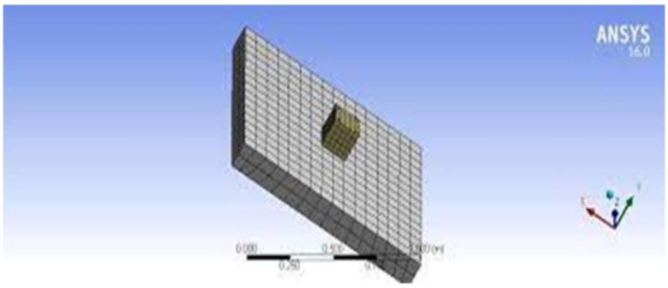


Figure 8: Boundary Conditions and Loads in ANSYS

## IV. RESULTS AND DISCUSSION

### A. RC Slab with size (900mm x 900mm x 70mm)

Analysis of reinforced concrete Flat Slab were carried out on specimens with loading variations between 1000 N and 5000 N. With Beam sizes (900mm x 900mm x 70mm).

### B. Conventional Slab

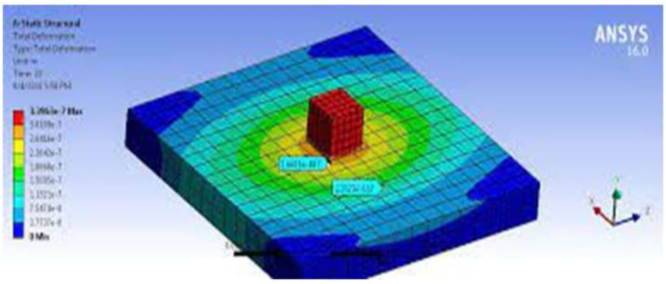


Figure 9: Deformation of CS Slab in ANSYS

### C. Non-Conventional Slab - 1

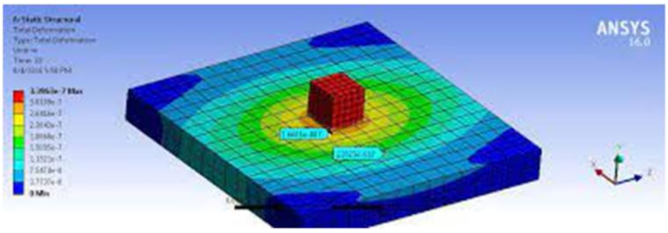


Figure 10: Deformation of NCS Slab 1 in ANSYS

### D. Non-Conventional Slab - 2

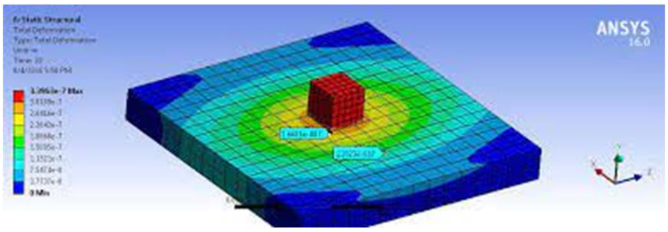

Figure 11: Deformation of NCS Slab 2 in ANSYS

Table -1 Results of Load and Displacement for Experimental Work

| CONVENTIONAL SLAB | |
|---|---|
| LOAD (KN) | DISPLACEMENT (mm) |
| 0 | 78.6 |
| 10 | 80.2 |
| 20 | 81.3 |
| 30 | 84.5 |
| 36 | 88.2 |
| 38 | 93.3 |

| NON-CONVENTIONAL SLAB - 1 | |
|---|---|
| LOAD(KN) | DISPLACEMENT (mm) |
| 0 | 79.2 |
| 10 | 80.6 |
| 20 | 83.1 |
| 30 | 84.8 |
| 35 | 87.2 |
| 38 | 90.3 |
| 42 | 91.5 |

| NON-CONVENTIONAL SLAB - 2 | |
|---|---|
| LOAD(KN) | DISPLACEMENT (mm) |
| 0 | 80.1 |
| 10 | 81.3 |
| 20 | 82.7 |
| 30 | 85.9 |
| 35 | 88.2 |
| 40 | 91.9 |
| 45 | 94.8 |

Table -2 Results of Load and Displacement for Analytical Work

| CONVENTIONAL SLAB | |
|---|---|
| LOAD (KN) | DISPLACEMENT (mm) |
| 0 | 70.6 |
| 10 | 76.6 |
| 20 | 85.3 |
| 30 | 88.9 |
| 36 | 90.1 |
| 38 | 93.3 |

| NON-CONVENTIONAL SLAB - 1 | |
|---|---|
| LOAD(KN) | DISPLACEMENT (mm) |
| 0 | 73.2 |
| 10 | 78.8 |
| 20 | 80.0 |
| 30 | 82.9 |
| 35 | 87.1 |
| 38 | 91.3 |
| 42 | 94.5 |

| NON-CONVENTIONAL SLAB - 2 | |
|---|---|
| LOAD(KN) | DISPLACEMENT (mm) |
| 0 | 76.0 |
| 10 | 80.4 |
| 20 | 82.2 |
| 30 | 84.3 |
| 35 | 86.6 |
| 40 | 92.8 |
| 45 | 95.3 |

## V. CONCLUSION

Punching Shear loading tests on three RC slab specimens were carried out and presented in this paper. In order to validate the experimental results, a finite element analysis was performed using ANSYS software to predict the load displacement response of the RC slab specimens. The following conclusion was drawn on the basis of experimental and analytical results.

1. Modelled the material properties in FEA and sensitivity analysed.
2. Simulated the identical experimental test procedure through FEA.
3. The results of the finite element analysis showed considerable agreement with the experimental results.
4. There was a greater discrepancy in deflection was found than the loading properties.
5. Comparison of the results has been obtained through FEA and Experimental investigation.

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