OPTIMISATION AND SEISMIC EVALUATION OF AN INNOVATIVE CONNECTION BETWEEN FLAT CONCRETE SLAB AND STEEL COLUMN

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Abstract – *Steel tubular – flat slab system has many advantages but they are not used much for realistic applications, unless the connection is easy to fabricate and have adequate punching shear resistance. The aim of this paper is to develop a new shear connection system between flat slab and steel column which is not only simple and easy to construct, but also able to provide adequate punching shear resistance and lateral resistance. Shear studs, steel plates and steel bars are the three main components in the shear connection system used to improve the performance of structure.*

Key Words: STFSSC system- Steel tubular flat slab shear connection system, Single plate (SP), Double plate (DP), Steel plate with hollows (SP- HOL), Shear studs.

1.INTRODUCTION

Flat slab is supported directly by columns without the use of beams. Due to their flexibility in room layout and for use, they are mostly used in industrial structures, parking garages, ramps, warehouses etc. Nowadays, RC columns and RC slabs are used for construction practices. But steel columns have many specific advantages over RC columns. Like faster construction, reduced size, and superior structural performance. Therefore, the use of steel-tubular columns was considered as a good option. One of the main reason that prevents the usage of steel column is their lack of punching shear resistance. This because of the smooth external finish of the steel column. Therefore, new studies have to be carried out to develop punching shear resistance. The use of innovative connections like shear studs, steel plates and steel rebars used in punching shear resistance and in lateral resistance is studied.

1.1 Shear Connection System

Shear connection system includes shear studs, steel plates and bent up rebars. In stud welding, shear studs are used to transfer force between the steel section and the concrete slab to secure framed buildings by creating a shear connection between steel and concrete. These fasteners secure columns and resist loading between concrete and steel components in a composite construction. The bent-up steel bar system is feasible, but because of the presence of the steel tube, the rebars around the steel tube have to be cut. For the construction to be easy and simple, the bent-up steel bars should not be physically connected to the steel tube. These discontinuous rebars are not able to provide moment of resistance of the slab. Whereas, additional continuous slab rebars can be provided to ensure adequate moment of resistance. Since the tube dimension is negligible compared to the slab width, sufficient space will be available to place the required moment- resisting rebars. So, this can be easily achieved. Furthermore, a thick steel plate can be placed on top of the shear studs to enable all the concrete slab near the steel to be engaged in punching shear and lateral shear.

2. FINITE ELEMENT MODELLING

2.1 General

To investigate punching shear resistance and lateral resistance of shear connection system in flat slab – steel tubular column connection. Finite element model were developed using ANSYS 19.0. Solid 186 elements were used to model slab, Beam 188 elements were used to model reinforcement and stud, 20 node solid 186 elements were used to model plate and column. Solid 65 is used for 3-D modeling of solids with or without reinforcing bars. The element is defined by eight nodes having three degrees of freedom at each node: translations in the nodal x, y, and z directions. BEAM188 is suitable for analyzing slender to moderately stubby/thick beam structures. The element is a linear, quadratic, or cubic two-node beam element in 3-D. BEAM188 has six or seven degrees of freedom at each node. SOLID186 is a higher order 3-D 20-node solid element that exhibits quadratic displacement behaviour. The element is defined by 20 nodes having three degrees of freedom per node: translations in the nodal x, y, and z directions.

2.2 Geometry and material properties

Size of slab is 1300x1300mm and has a thickness of 150mm. The steel tube, which was positioned in one of the slab's corners, was a square hollow portion measuring 200mmx200mmx12mm. shear stud have an overall length of 200mm. Steel plates having 20mm thickness, double plates each having 10mm thickness and steel plate with hollows are selected for modelling. For the most effective depth, a minimum concrete cover of 15mm was chosen. Rebars were 10mm in diameter. Young's modulus of steel plate is 2 x10^5MPa and Poisson's ratio is 0.3. Yield strength and ultimate strength of steel plate is 250 MPa and 460 MPa respectively.

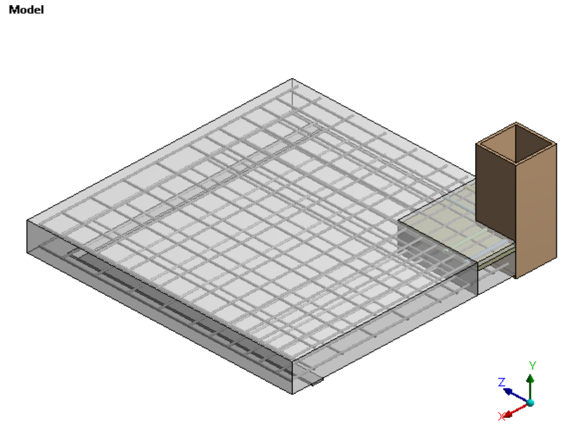

Fig -1: Geometry of STFSSC system with single plate

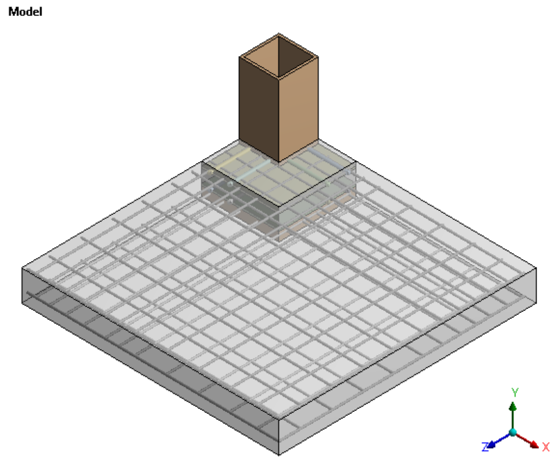

Fig -2: Geometry of STFSSC system with double plate

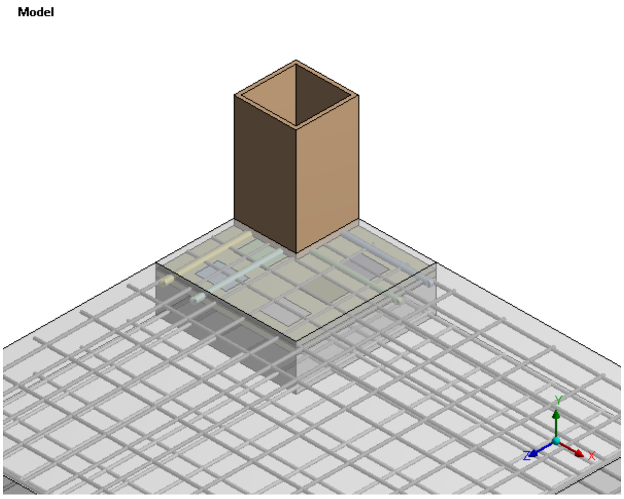

Fig -3: Geometry of STFSSC system with single plate hollows

2.3 Meshing

Selected three-dimensional models of STFSSC system was developed by finite element software to demonstrate behavior property. Figure 4 shows meshing of STFSSC system so that, solid model with given dimensions is formed into a Finite Element Model. Meshing size provided is 50 mm. Element type used is concrete – solid 65, reinforcement, stud – beam 188, plate and column – 20 node solid 186.

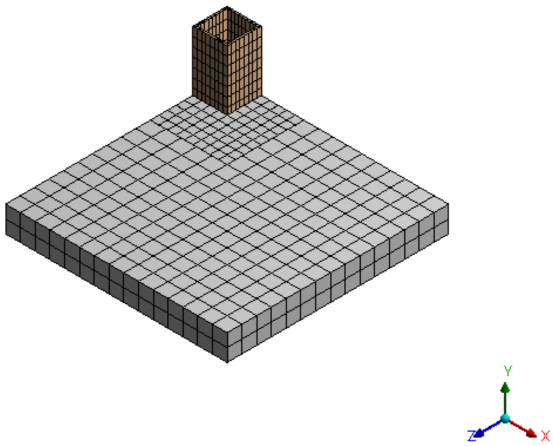

Fig -4: Meshing of STFSSC system

2.4 Boundary conditions

Figure 5 Shows boundary conditions of STFSSC system. To simulate the real condition, boundary conditions of specimens were set to be same as in the test. Both exterior end of slab is fixed and the load is applied gradually from the top of the column. The load was applied through displacement control. Bottom of column was constrained in three (X, Y, and Z) displacement directions; in addition, rotation about Y-axis was constrained. That is, STFSSC system was analyzed with fixed support.

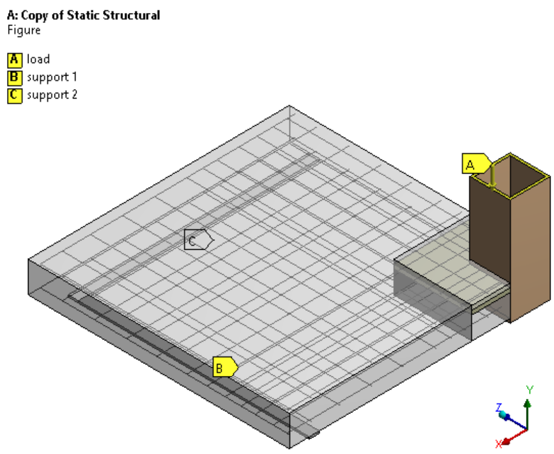

Fig -5: Boundary condition of STFSSC system with single plate

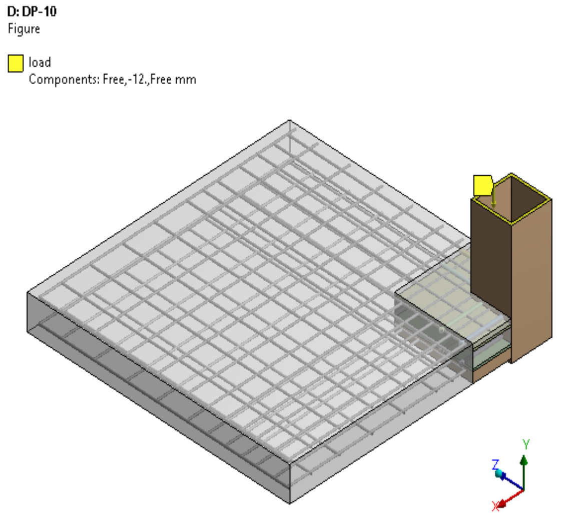

Fig -6: Boundary condition of STFSSC system with double plate

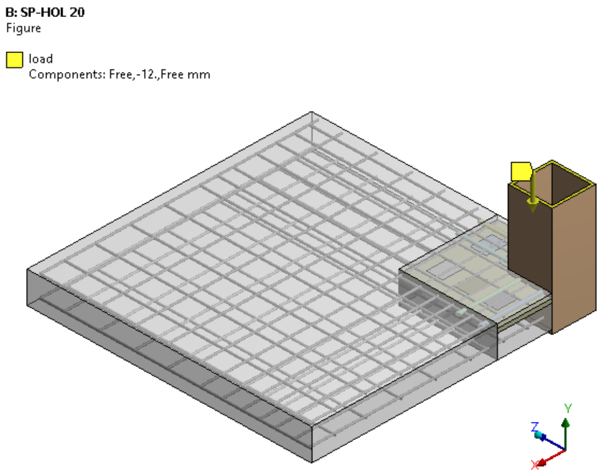

Fig -7: Boundary condition of STFSSC system with single plate hollow

2.4 Analytical results and discussion

Columns were axially loaded. Displacement controlled forces was given in analysis. Total deformation diagrams of connection with single plate, double plate, single plate with holes are shown in below figures. The damages occurred mainly in the tensile surface of the concrete slab. The maximum deformation obtained for connection with single plate is12.363 mm, with double plate is 12.188 mm and with hollowed single plate is 12.232mm.

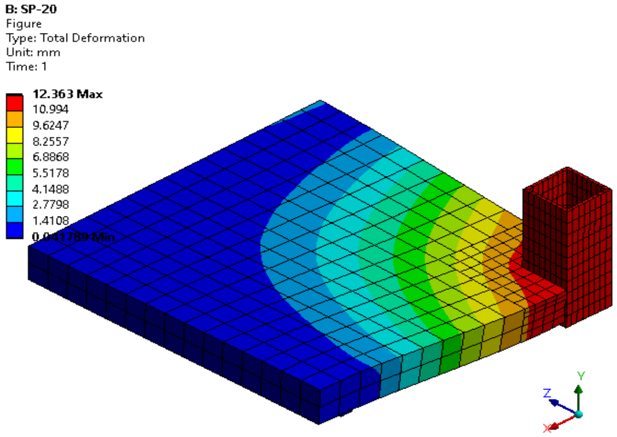

Fig -8: Total deformation of STFSSC system with SP

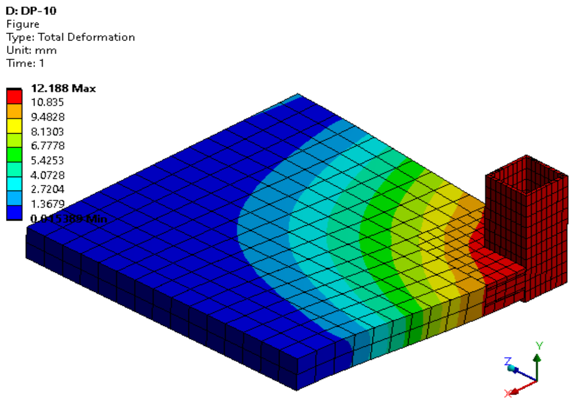

Fig -9: Total deformation of STFSSC system with double plate

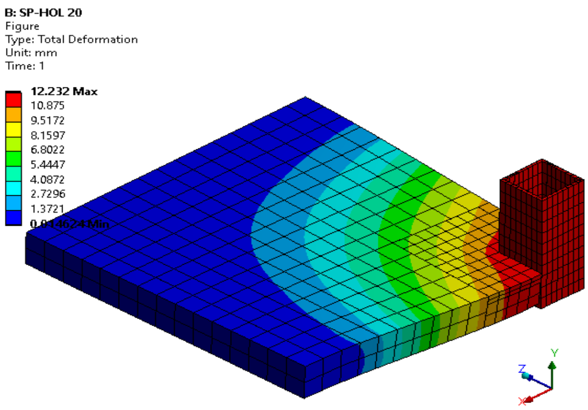

Fig -10: Total deformation of STFSSC system with hollow SP

STFSSC system with single steel plate of 20 mm, double steel plate of 10 mm and single steel plate with hollows are compared first. Load and corresponding displacements of STFSSC system with single steel plate, with single plate having holes and with double plate obtained from finite element model is shown in chart 1. From the table and graph it is clear that, STFSSC connection with double steel plate has better performance than STFSSC connection with single and hollow steel plates.

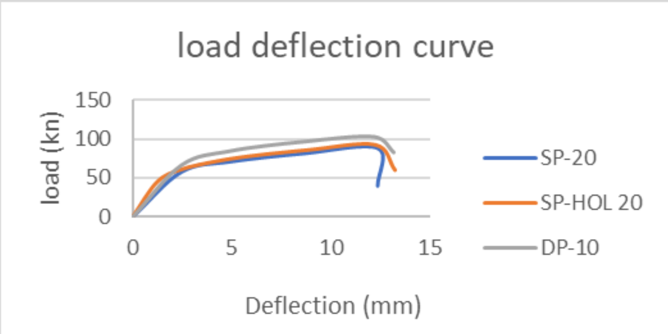

Chart -1: Load deflection curve

Table -1: Comparison of % of increase of load

MODEL	DEFORMATION	LOAD	% OF INCREASE OF LOAD
SP - 20	12.4	88.4	1.0
DP - 10	12.2	92.3	4.4
SP-HOL 20	12.2	103.2	16.7

Table shows the comparison of percentage of increase of load using various steel plates obtained from finite element model. From the above results it is clear that usage of double plates, each having 10 mm thickness have greater load carrying capacity as they have 16.7% of increase in load. Whereas percentage of increase in load of single plate of 20mm thickness and single plate with holes are 1% and 4.4% respectively.

3. CONCLUSIONS

The results shows that the connections with various geometry of plates can increases the punching shear capacity and must be added to ensure the safety and integrity of flat slab. In this study comparison of shear connection system with single plate, double plate and plate with hollows were done. DP-10 models have greater load carrying capacity as they have 16.7 percentage of increase in load and are suitable for resisting axial load. The connection details are simple and are easy to fabricate.

REFERENCES

[1] Yongchang Wang, Junlong Yu , "Punching Shear Behavior Of An Innovative Connection Between Steel-Tubular Column and Flat-Concrete Slab", ASCE, (2020).

[2] Yongchang Wang , Junlong Yu , "Modelling And Design Of A New Connection Between Steel Tubular Column And Flat Concrete Slab", Journal of Constructional Steel Research, Volume 173, (2020).

[3] Joaquim A.O. Barros et.al., "Assessment of the Effectiveness of Steel Fibre Reinforcement for the Punching Resistance of Flat Slabs by Experimental Research and Design Approach", Composite Part B Engineering, Volume 78, (2015), Pages 8-25.

[4] J.M.Russell et.al, "Experimental Investigation on the Dynamic Response of RC Flat Slabs after a Sudden Column Loss", Engineering Structures, Volume 99, (2015), Pages 28-41.

[5] Bompa, D. V., and A. Y. Elghazouli, "Structural performance of RC flat slabs connected to steel columns with shear heads." Engineering Structure (2016).