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ANALYTICAL STUDY OF STEEL CONCRETE COMPOSITE SLAB WITH PROFILED STEEL DECK AND DIFFERENT SHEAR CONNECTOR CONFIGURATIONS

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Abstract - *Steel concrete composite structures consists advantage of two different materials result in reduced size, weight, and less cost of construction. The profiled steel deck, concrete over the deck and embedded shear connector together constitute the composite deck slab. The horizontal slippage between the concrete and the steel deck should be avoided by mechanical shear connectors. The mechanical shear connectors are provided in the form of stud bolts, shear bar, and ribs. The profiled steel deck provided here is of 75 mm depth and over that 75 mm concrete is placed. The different slab cases with different shear connector arrangements considered are normal slab without shear connector(SWOSC),slab with 10 mm diameter bolt as shear connector(SWSC T1), slab with 10 mm steel bar as shear connector(SWSC T2), slab with both 10 mm diameter bolt and bar(SWSC T3), and finally slab with perfobond ribs(SWSC T4). The effectiveness of shear connector configuration in the slab is determined by analyzing these five different shear connector configuration involved slabs under two-point loading in ANSYS Workbench. The effective slab is determined on basis of maximum load carrying capacity of slab, total deformation and slip values.*

***Key Words*: Steel concrete composite slab, Profiled steel deck, Shear connector, Horizontal slippage, Perfobond ribs**.

1. INTRODUCTION

The profiled steel deck performs two major functions that act as a permanent formwork during concrete casting and also as tensile reinforcement after the concrete has hardened. The profiled decking sheet provides the resistance to vertical separation and horizontal slippage between the contact surface of concrete and the steel deck. Additional steel in the form of reinforcing bars or welded wire fabrics needs to be provided for taking care of shrinkage, temperature and negative bending moment at support.

The horizontal slippage between the concrete and the steel deck will also exist due to the longitudinal shear stress when the shear force of the shear connectors reaches its ultimate strength. In order to reduce the slippage steel deck should be properly connected to concrete and also to each other. Mechanical shear connectors including all the types and their combinations are widely adopted in effective way. i.e.; by the combination of steel rod and stud bolt, steel rod and perfobond ribs. The secondary reinforcements in the form of mesh are also provided in the steel deck slabs other than shear connector in order to avoid the slab curling and also to improve strength of slab in shear.

2. METHODOLOGY

The project includes analytical study of steel concrete composite slab with profiled steel deck including different shear connector configurations. The five different slab models were considered and they are analyzed under flexure (two-point loading) for ultimate load, total deformation and slip. The modeling and analysis were done using ANSYS Workbench 15.0

3. FINDINGS

The previously published papers suggest various types of embossments and ribs as shear connector. In a research paper [1] the structural behaviour of orthotropic steel deck slab with normally used stud bolt for bridges was studied. The combined slab of steel plate, concrete and shear connector in bridge deck helps to minimize the stress concentration induced by the vehicles. In another paper [3] ultimate behavior of a steel concrete composite deck slab system with profiled steel sheeting and perfobond rib shear connectors was experimentally investigated. In one of the paper [8], the slab is created by the composite interaction between the concrete and steel deck with embossment to improve their shear bond characteristics. But that fails under longitudinal shear bond due to the complicated phenomenon of shear behavior. Most of the previous research papers explain about the experimental tests to know the behavior of steel plate and shear connector involved slab. The profiled steel sheet involved slab improves the tensile capacity of slab. And also the combined effect of shear connector, steel plate and concrete enhance the slab in terms of shear strength and load carrying capacity. In many cases only one shear connector either stud bolt or embossment or slab is considered. The combination of different shear connector is an effective method to improve the load carrying capacity of slab and also to minimize the deformation. The shear connector combination of stud bolt and steel bar or perfobond sheet and steel bar will reduce the slab deformation. The combination of shear connector will also reduce slip between the steel deck and concrete in span direction.

4. MODELING

4.1 Dimensions of composite slab

The plain steel sheets are pressed into trough shape with the dimensions of the sheet as determined from IS 277; 2003. The dimensions are; thickness of sheet: 1 mm, length of sheet: 1800 mm, width of sheet 750mm, depth: 75mm, and pitch: 100 mm; shown in Figure-1. The E value for steel is taken as $2x10^5$ and poisons ratio as 0.3.

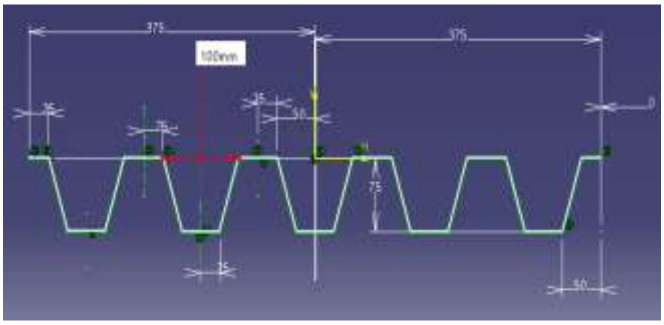

Fig-1: Steel sheet dimensions

The concrete is of grade M20 grade and of depth 75 mm. Thus the overall depth of composite slab is 150 mm. The stress strain values for both steel and concrete are inputted for nonlinear properties as shown in Table 1.The maximum strain in the steel and concrete is taken as 0.0038 and 0.003 respectively.

Table-1: Properties of concrete and steel

Property	Concrete	Steel
Grade	M20	Fe 415
Modulus of elasticity (E)	$0.2828x10^5$ N/mm^2	$2x10^5$ N/mm^2
Poisson's ratio(μ)	0.20	0.3
Maximum strain value	0.003	0.0038

4.2 Shear connector configurations

The shear connectors used are 10 mm diameter stud bolt, 10 mm diameter steel bars and perbond ribs. The perfobond rib is a rectangular sheet of length 1790 mm, width 100 mm and 1mm thick with circular gaps of 25 mm diameter at 150mm c\c on a sheet followed by 10 mm diameter bars along the circular gaps in width direction of slab. In normal slab without shear connector and slab with only 10 mm diameter stud bolts, a secondary reinforcement is provided as 6 mm diameter bars at 250 mm c\c on both ways. Similarly in the case of slab with 10 mm diameter bar only as shear connector, it is followed by 6mm diameter bars at 250 mm c\c on both ways as secondary reinforcement. But in the other two slab cases (SWSC T3 & SWSC T4), secondary reinforcement is not provided since it is shear connector combination of bars, bolts and ribs.

4.3 Modeling of slab

The material property values of steel and concrete were inputted in the respective material sections as per the Table 1. The five different slab cases were modeled as per dimensions and configurations using ANSYS Workbench 15.0., shown in Figures 2 to 6.

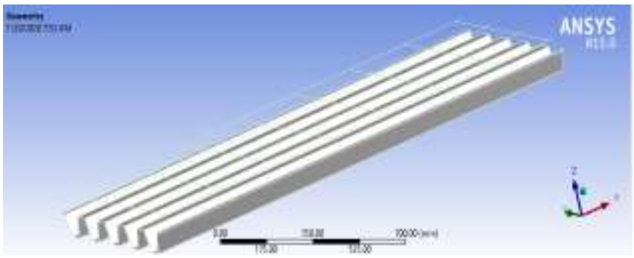

Fig-2: Normal slab without shear connector (SWOSC)

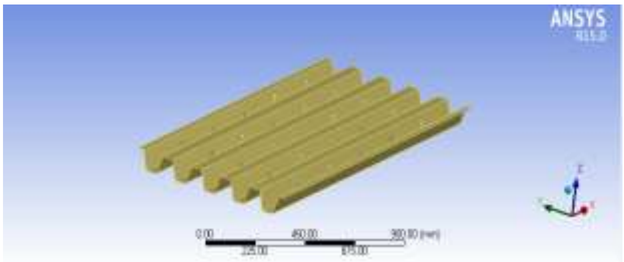

Fig-3: Slab with 10 mm diameterbolt as shear connector (SWSC T1)

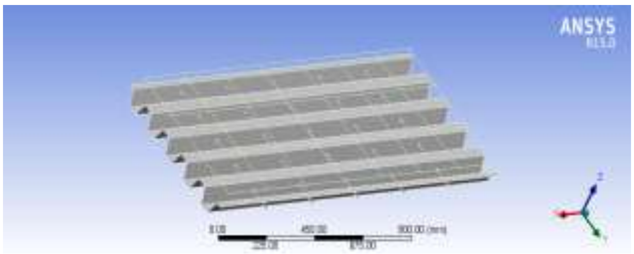

Fig-4: Slab with 10 mm diameter bar as shear connector (SWSC T2)

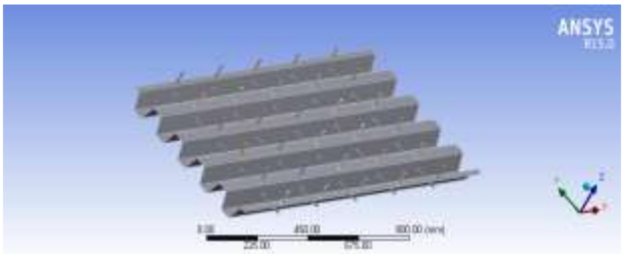

Fig-5: Slab with 10 mm diameter bar and 10mm diamter stud bolt as shear connector (SWSC T3)

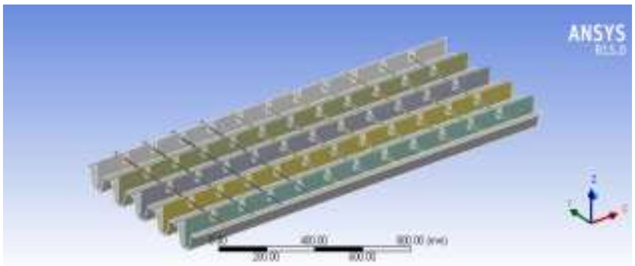

Fig-6: Slab with perfobond rib shear connector (SWSC T4)

Every slab model is of 150 mm overall depth with 75 mm steel deck slab and 75mm concrete over the deck including shear connector arrangements. The modeled slab also includes support and loading points. The support is fixed at 150 mm from each end below the slab. And loading points are fixed at a shear span of 300 mm from each support and these contribute two loading points over the slab; shown in the Figure-7.

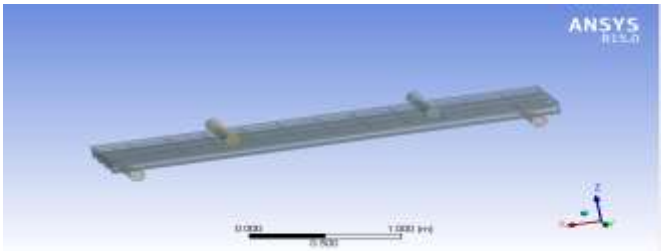

Fig -7: Support and loading conditions

5. ANALYSIS RESULTS

The five different slab cases considered were perfectly modeled in the geometrical part and loaded into analysis part. The support and loading points were fixed at 100 mm from each end and 300 mm from supporting point respectively. Material properties are properly assigned to the solid and surface elements of the model.

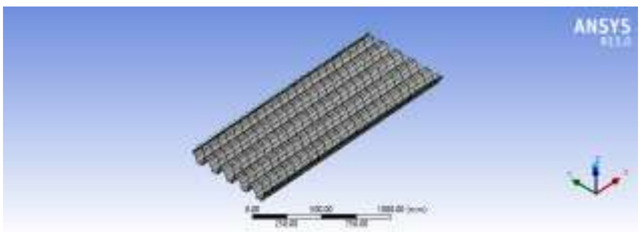

Fig- 8: Meshed steel deck of SWOSC

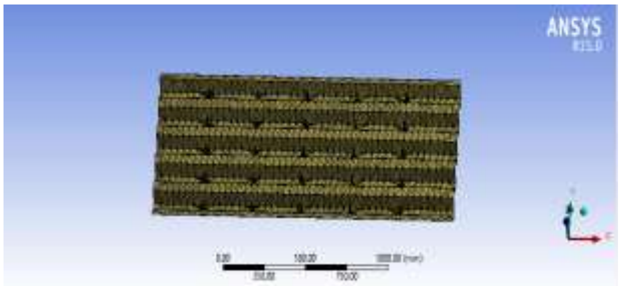

Fig- 9: Meshed steel deck of SWSC T1

Meshing was done for a relevance factor of 80 and with element size of 1mm for both concrete and structural steel elements; Figures 7 to13. The analysis of composite slab cases was done corresponding to the support and loading conditions as given.

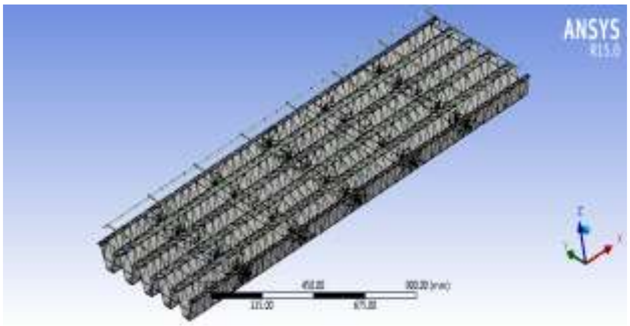

Fig- 10: Meshed steel deck of SWSC T2

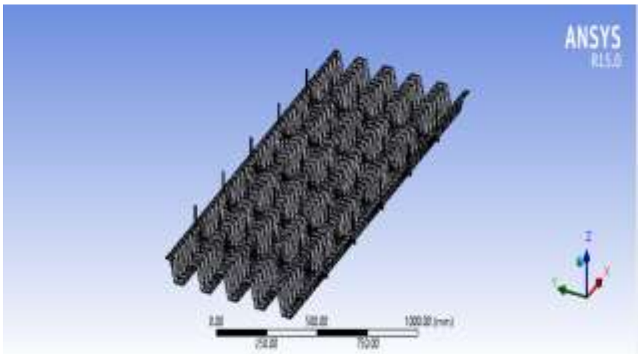

Fig- 11: Meshed steel deck of SWSC T3

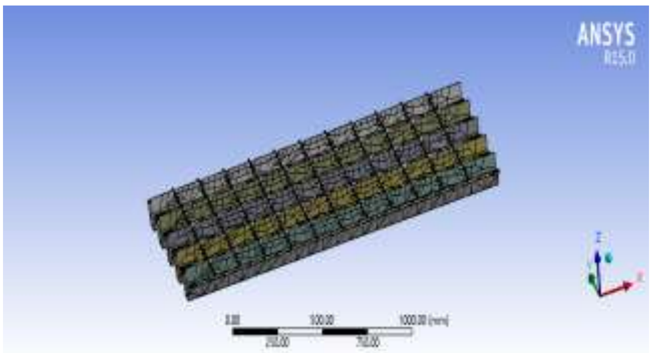

Fig- 12: Meshed steel deck of SWSC T4

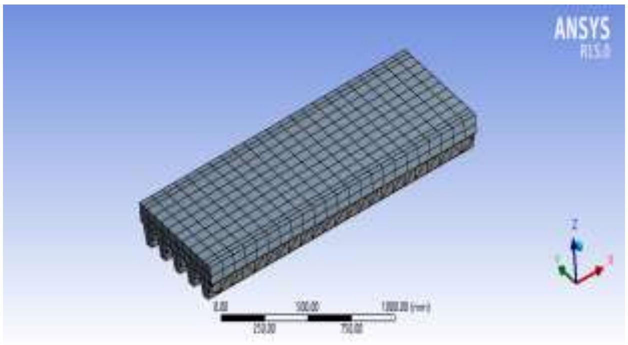

Fig- 13: Meshed whole composite slab

The analysis settings were properly fixed for the analysis. Material failure was allowed in the analysis. The analysis was time controlled including minimum of 10 sub steps and maximum of 50 sub steps. Later fixed supports were assigned to the solid parts by selecting each faces. The load was applied at the two points by inputting the load values in the proper direction corresponding to the co-ordinate system. The maximum load applied is 200 kN. And displacement is limited to span/50 as per ultimate failure criterion [8]. The total deformation was added to the solution part and solved to get the analysis done. After achieving the green tick on solution part, total deformation and slab behavior was observed to achieve the results. The total deformation of each case were checked; shown in Figures 14-18 respectively.

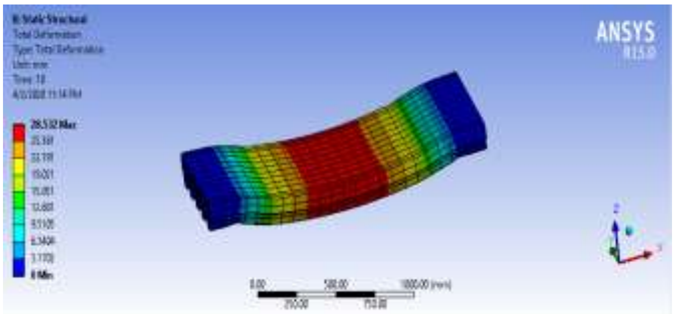

Fig-14 : Total deformation of SWOSC

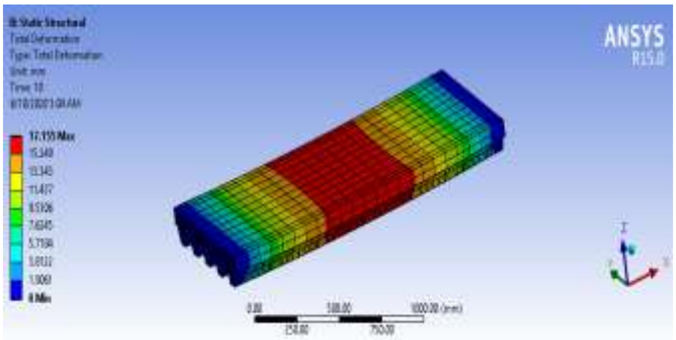

Fig-15 : Total deformation of SWSC T1

Similarly the force reactions corresponding to the deformation were also determined. Slip along span direction is fond out using 'deformation probe' in Ansys. After obtaining values for total deformation, load and slip, load-deformation and load slip curves were drawn. From load deformation curve maximum ultimate load and maximum deformation were determined. Similarly maximum slip value was determined from load slip curve

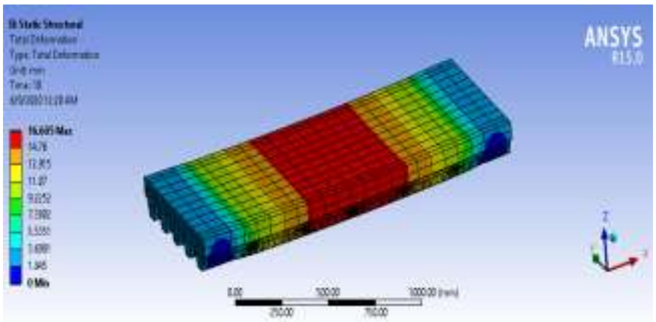

Fig-16 : Total deformation of SWSC T2

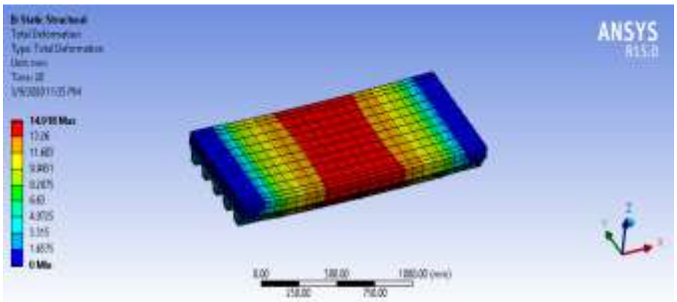

Fig-17 : Total deformation of SWSC T3

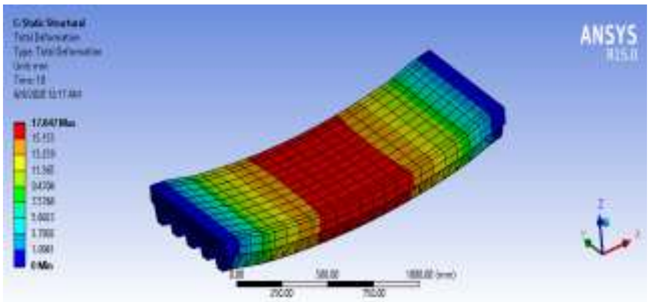

Fig-18 : Total deformation of SWSC T4

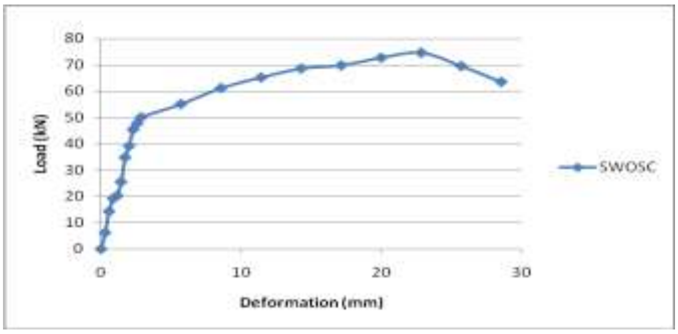

Chart-1: Load-deformation curves for normal slab without shear connector (SWOSC)

Load deformation curves for each slab cases were drawn as shown in Charts 1 and 2 and compared values of ultimate load and deformation.

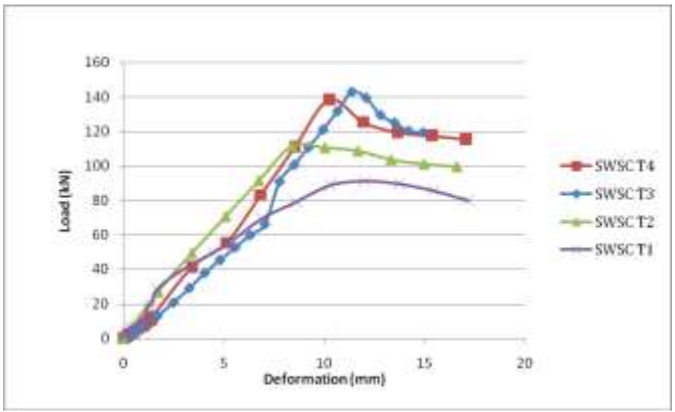

Chart -2: Load-deformation curves for shear connector involved slab cases (SWSC T1, SWSC T2, SWSC T3, and SWSC T4)

Similary comparison was done between slip values from load slip curves of each case as shown in the Charts 3 and 4. . Later comparison table is prepared and studied.

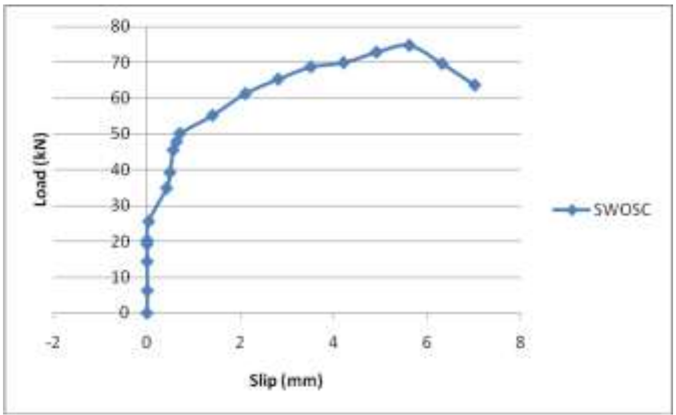

Chart -3: Load-slip curve for normal slab without shear connector (SWOSC)

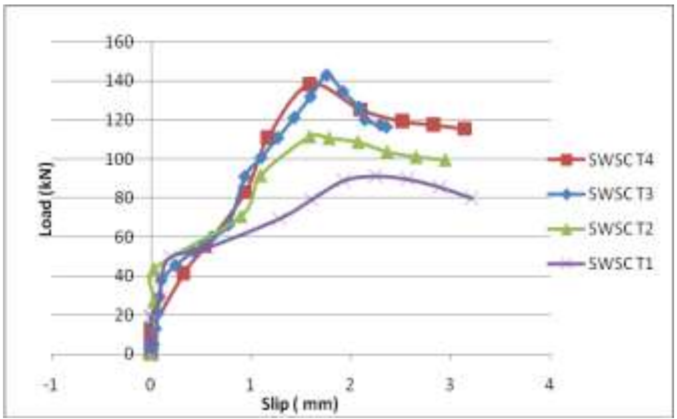

Chart -4: Load-slip curve for slab with shear connectors (SWSC T1, SWSC T2, SWSC T3, SWSC T4)

5.1 Comparison of results

The five different type of composite slab with different shear connector configurations were analyzed and thus obtained total deformation, ultimate load and slip. The five slabs were compared based on these three parameters as given in the Table 2.

Table-2: Comparison of analysis results

Type of shear connector in slab	Total deformation (mm)	Ultimate Load (kN)	Slip in span direction (mm)
SWOSC	28.532	74.656	7.0236
SWSC T1	17.155	91.328	3.21
SWSC T2	16.605	112.022	2.965
SWSC T3	14.918	143.285	2.35
SWSC T4	17.047	138.430	3.139

Among that, slab without shear connector failure at lower load and lower ultimate value. i.e.; 74.656 kN and possess higher deformation and slip. The slab SWSC T3 is found to be the effective slab as compared to the other slab due to their higher ultimate load or load carrying capacity i.e.; 143.28 kN and lower deformation and slip values. The last slab (SWSC T4) also possesses higher load carrying capacity than SWSC T1 and SWSC T2, but lower than SWSC T3. In this case (SWSC T4),the slip value is found to be higher than SWSC T3 and SWSC T2,but lower than SWSC T1.SWSCT1 and SWSC T2 were found to be the slab with lower load carrying capacity.

After comparing and studying these features, it was obtained that the slab with shear connector scheme SWSC T3 (with both 10 mm diameter steel bar and 10 mm diameter bolts) is the effective way to be used; Thus SWSC T3 is the composite slab with effective shear connector configurations.

6. CONCLUSIONS

The paper represents the analytical behavior of steel concrete composite slab with profiled steel deck and different shear connector configurations under two points loading or flexure. The five different slab cases were modeled and analyzed under two-point loading to determine the effective shear connector configuration involved slab. The determination of effective shear connector involved profiled steel deck slab is determined on the basis of maximum load carrying capacity or ultimate load, minimum slip and deformation values. The following findings were made using this study.

- From the four different shear connector configuration involved slabs and a normal slab without shear connector, it is concluded that the slab incorporated with both 10 mm diameter shear bar and 10 mm diameter stud bolt (SWSC T3) is the effective slab.
- The SWSCT3 slab has higher ultimate load value or maximum load carrying capacity; lower deformation and low slip values among the other cases.

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