

AN ANALYTICAL AND EXPERIMENTAL INVESTIGATION OF SHEAR CONNECTORS IN COMPOSITE SECTIONS

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ABSTRACT: Steel-concrete composite beams are used for a considerable time in bridge and building construction. Shear connectors are important for steel concrete composite structures. It is used as a shear resistance in the steel concrete interface. This study presents an evaluation of the structural behaviour of different types of shear connectors in composite beams. It is suitable for transferring shear force in composite structures by both analytical and experimental way. The composite sections are modelled and analysed with the help of ANSYS software, then results are documented for comparison. Once the composite sections casted, it is made to undergo Standard Push-out tests. The test was carried out to analyse various parameters like resistance, strength degradation and ductility and also the failure modes of the different types of Shear connectors used will be detailed. The effective and economical ways of using the shear connectors in Steel-Concrete composite sections are discussed in this paper. For Further studies the comparisons of the results of the different kinds of shear connectors used can be documented.

Key words- shear connectors; push-out test; ductility; finite element modelling; composite beams

1. INTRODUCTION

The component that assures the shear transfer between the steel profile and the concrete slab in steel-concrete composite construction is the shear connector. The transmission of shear forces and the intensity of stress in the steel beam, the weld that connects the shear connector to the flange of the beam, material of connector itself and the surrounding concrete of the slab, which all determines the strength, are highly dependent on the form of the shear connector. There are very different forms of means for composition that are used in practice. Steel-concrete composite beams have been used for a considerable time in bridge and building construction. Composite action can be obtained through mechanical connection commonly provided by headed studs or channel shear connectors. Many experimental push-out tests have been used to evaluate the shear connector's capacity.

There are many types of shear connectors and they are most generally divided into rigid and flexible, according to the distribution of shear forces and functional dependency between strength and deformations.

The rigid shear connectors resist shear forces through the front side by shearing, and they have insignificant deformations in the proximity of ultimate strength. They produce stronger concentrated stress in the surrounding concrete that results either in failure of concrete or in failure of weld.

Flexible shear connectors resist shear forces by bending, tension or shearing in the root, at the connection point of steel beam, where they are subject to plastic deformations when they reach the ultimate strength values. The manner of failure of flexible shear connector is more ductile and is not prompt. They maintain the shearing strength even with a lot of movement between the concrete slab and the steel beam.

In the field of real stress states, that is exploitation load, the slim and rigid shear connectors act similarly, because they have an insignificant deformation that allows for the supposition that there is no moving between the concrete and the steel part of the cross-section. Because of these reasons, there is no difference in the calculation of strength in the elastic area, regardless of the type of shear connectors applied (rigid or elastic), because the cross section may be considered homogenous. However, for the calculation of the limit strength by the plasticity theory, the slim shear connectors have the advantage, because they allow, due to their plastic deformation, for the certain sliding between the

concrete and steel, and thus, for the more favourable distribution of shearing forces. Their behaviour is similar to the behaviour of the basic material (steel beams) in the area of the failure.

2. ANALYTICAL WORK

2.1 GENERAL

Analytical work can be carried out with the help of ANSYS a finite element software package. Finite element analysis is a numerical method of deconstructing a complex system into very small pieces called elements. The software implements equations that govern the behaviour of these elements and solve them all, creating a comprehensive explanation of how the system act as a whole. These results then can be presented in tabulated, or graphical forms. This type of analysis is typically used for the design and optimization of a system far too complex to analyse by hand. Systems that may fit into this category are too complex due to their geometry, scale, or governing equations.

2.2 SPECIMEN DETAILS

A composite section is modelled in ANSYS with steel section ISMB 250, M30 grade concrete and different types of shear connectors such as channel shaped, stud shaped and bolt shaped shear connectors. A model is made by keeping steel I section as beam with shear connectors attached to the flanges of beam by welded connection and concrete slab is attached on both flanges of I section of size 300*150*150mm and minimum reinforcement also provided. Reinforcement grade is Fe415. The model of composite section is shown in fig.1

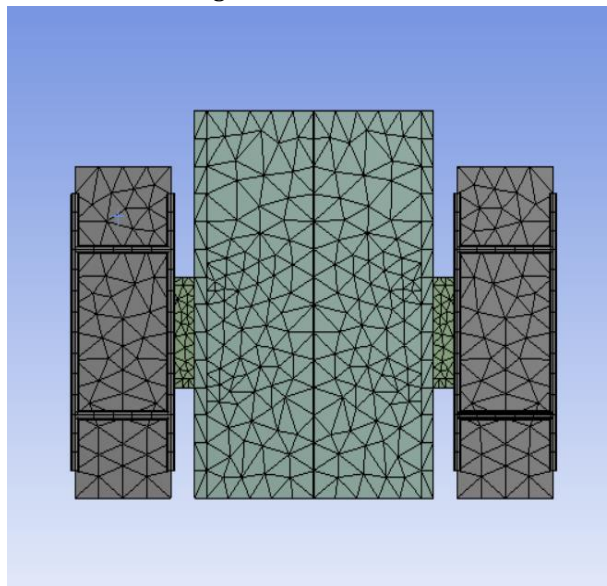


Fig.1 - Composite section model with shear connectors

The size of channel shear connector is ISMC100, stud shear connector is diameter is 19mm, head is 30mm, bolt shear connector is diameter is 19mm where the length of shear connector is common as 100mm in order to compare.

2.3 ANALYTICAL RESULT

After making model in ANSYS load is applied at the web of I section and analyzed with boundary conditions as concrete slab is fixed at bottom. The load slip behaviour of composite section, deformation of connectors, stress distribution in composite section can be obtained after analysing it. The results of analysis can be shown below.

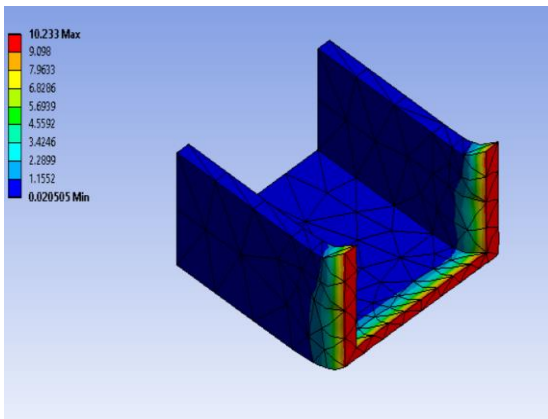


Fig.2 -

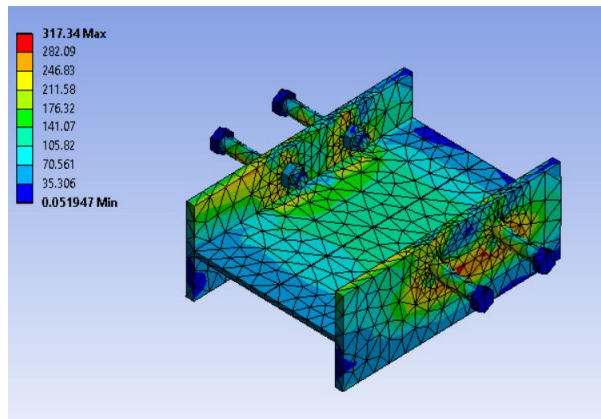


Fig.3.1 - Stress distribution of Stud shaped shear connector

Deformation of Channel shaped shear connector

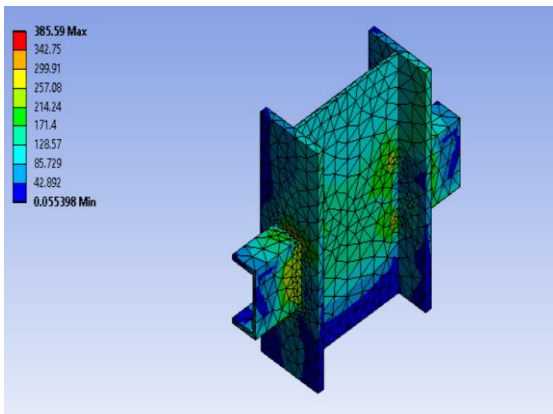


Fig.2.1 - Stress distribution of Channel shaped shear connector

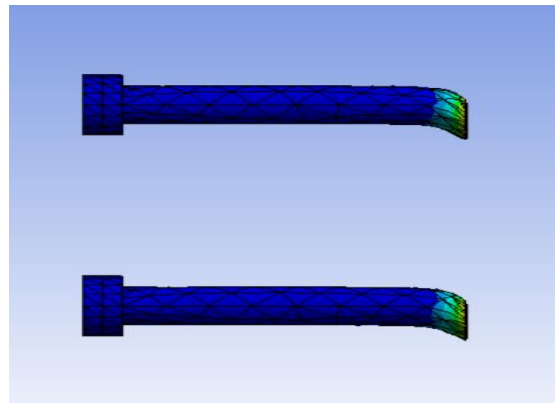


Fig.3 - Deformation of Stud shaped shear connector

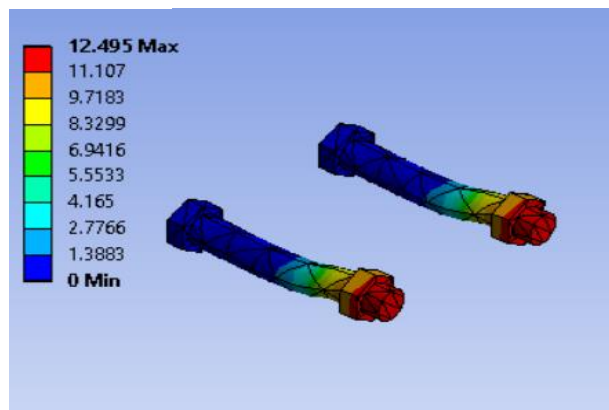


Fig.4 - Deformation of Bolt shaped shear connector

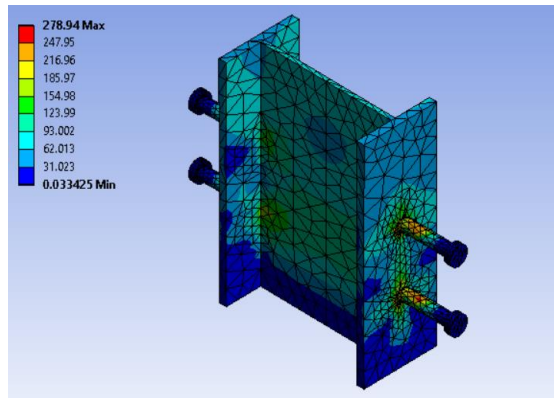


Fig. - 4.1 Stress distribution of Channel shaped shear connector

The above figures shows the stress distribution and deformation of various types of shear connectors.

Table 1 Load carrying capacity and slip of various types of shear connectors

S.N O	TYPE OF CONNECTORS	MAXIMUM LOAD CARRYING CAPACITY IN kN	SLIP IN mm
1.	CHANNEL	211.35	5.11
2.	STUD	144.95	4.907
3.	BOLT	124.49	2.75

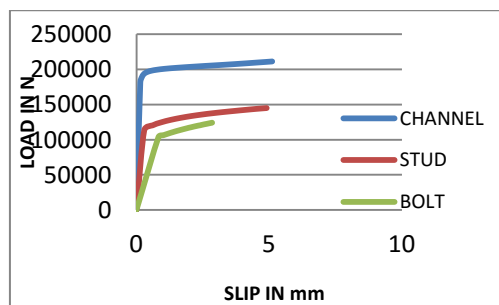


Fig.5 - Comparison of load slip behaviour for various types of shear connectors

Table 1 and Fig.5 represents the behaviour of each shear connector with respect to loading and it clearly shows channel shaped shear connectors have more load carrying capacity when compared with other types of shear connectors.

3. EXPERIMENTAL WORK

3.1 PUSHOUT TEST

Strength of shear connector will be determined by using standard push-out test. The strength of stud, channel and bolted shear connector are calculated in this test.

3.2 EXPERIMENTAL SETUP

The experimental setup consists of a loading frame with a hydraulic jack and proving ring with 250kN loading capacity. The composite section is casted and placed in the loading frame by making the concrete slab as fixed and then the load is applied on the web of the I section as shown in fig.6. Before casting composite sections all materials are tested for material properties as per IS code. Six composite sections are casted with different types of shear connectors.

The tests are to be done by using hydraulic jacks. Soft wooden boards were placed between the concrete blocks and the base of the test frame to eliminate undesirable bearing stress concentrations. It was assumed that the shear load per stud was the total load applied to the specimen divided by the total number of studs. This assumption was shown to be reasonable during testing by the very small differences between the two slips gauges readings. In plotting the results, the mean of the two readings was used. All the tests were carried out under the condition of load control. The load level and the corresponding slip were recorded at each increment of loading.

Each test consisted of a push-out specimen which has two identical reinforced concrete slabs attached to the flanges of a steel I-section beam (ISMB 250) by means of shear connectors. The assembly was subjected to a vertical load on the steel beam. The shear load, produced along the interface between the concrete slab and the steel beam flange due to this vertical load, was transferred to the concrete slabs through shear connectors. For shear connectors to develop composite action in girders such that they are a part of the lateral load resisting system, they are expected to undergo load reversals during large seismic events, thus, the specimens are tested under cyclic loading. In the first step of the cyclic loading, the displacement increment was 2mm, followed by an increment of 5 mm for every step after, till a maximum of 45 mm, i.e. a total of 10 cycles. The hydraulic actuator used for testing had a capacity of 50 tons and a stroke length of 500 mm. The loading frame had a capacity of 200 tons and the test floor was 800 mm thick. The specimens were tested until failure. The testing was done in order to obtain the load-slip curve.

The dial gauges were fitted just below the I-section to calculate the deflection and on the concrete top to find the slip.



Fig.6 - Experimental Setup

Experimental results are shown below, the load carrying capacity and load slip behaviour are obtained.

Table 2 Experimental results - Load carrying capacity of various types of shear connector

S.NO	TYPE OF CONNECTORS	MAXIMUM LOAD CARRYING CAPACITY IN kN	SLIP IN mm
1.	CHANNEL	207.95	5.03
2.	STUD	136.71	4.27
3.	BOLT	118.57	2.58

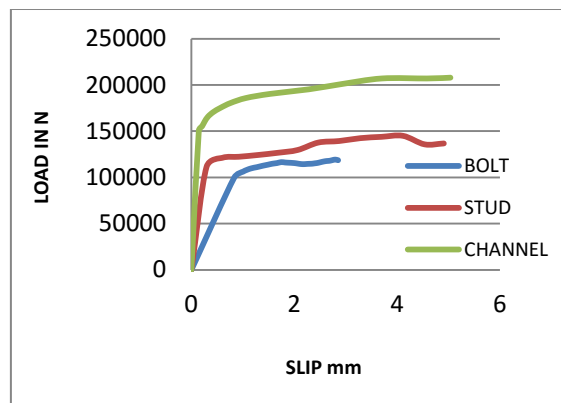


Fig.7 - Comparison of Load slip behaviour for various types of shear connectors after conducting standard push-out test.

From the above Table 2 and Fig.7 the behaviour of all types of shear connectors are obtained and it also shows that the channel shaped shear connector has more loading capacity when compared with other two types of shear connectors.

3.3 FAILURE MODES

When push-out test is conducted the following failure modes of different types of shear connectors are obtained.



Fig.8 - Failure mode of stud shaped shear connector

Fig.8 represents the failure of stud shaped shear connector while conducting standard push-out test, it shows failure occurs in welded portion of connector with steel beam.



Fig.9 - Failure mode of bolt shaped shear connector

From fig.9 it is understood that concrete is separated from I section and no deformations are made in connectors.



Fig.10 - Failure mode of channel shaped shear connector

From the above fig.10 it is clear that the channel shaped shear connector withstand maximum load. Therefore, the channel shear connectors have the ultimate shear capacity.

4. RESULTS AND DISCUSSION

4.1 COMPARISON OF RESULTS

When comparing experimental work and analytical work the behaviour of the test specimens are same. The load carrying capacity, load slip behaviour and stress distribution are nearly same with minimum percentage of error. Therefore, in future analytical work is sufficient in order to study the behaviour of shear connectors of various sizes and shapes if the same analysing procedure is followed which help in economical way by reducing the experimental work.

Table 3 Comparison of Analytical and Experimental results

S.NO	TYPE OF CONNECTORS	MAXIMUM LOAD CARRYING CAPACITY IN kN		SLIP IN mm	
		Experimental	Analytical	Experimental	Analytical
1.	CHANNEL	207.95	211.35	5.03	5.11
2.	STUD	136.71	144.95	4.27	4.907
3.	BOLT	118.57	124.49	2.58	2.75

The maximum percentage of error obtains from the above table 3 on comparing both analytical and experimental is 5.68%.

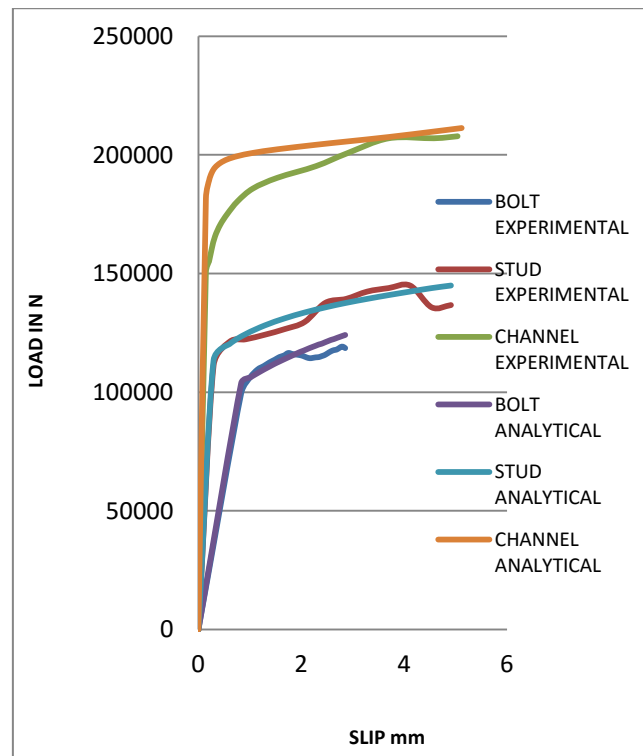


Fig.11 - Comparison graph for both experimental and analytical results

5. CONCLUSION

The bolt and the stud type shear connectors were not that much effective as of the channel shear connectors. Two types of failure are defined in the push out specimens. The first one is the concrete crushing and splitting from the I-section and the second one is the connector fracture type of failure. Cracks are formed when the load is progressed and these cracks showed a quite different behaviour concentrating near the connector along the concrete crushing at the front face of the connector. It is clear that the Channel shear connectors have more load carrying capacity when compared to the Stud type and Bolt type shear connectors. In this study, only the channel shear connectors had withstood the maximum load in both analytical study and experimental study. Therefore, the channel shear connectors have the ultimate shear capacity.

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