Analysis of Composite Beam with Stiffener using FEA Software

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ABSTRACT

Composite Structures have several advantages over traditional reinforced concrete which incorporate high strength to weight ratios, dimensional stability and structural integrity. Late years have seen a considerable increment in the utilization of composite structures and improved research went for creating new strategies for combining steel and concrete. Composite structures result in efficient design and economy in construction time hence used especially in construction of building floors and bridges. Wide construction practices involve connecting Concrete slab and hot rolled steel beam sections by shear connectors. Shear Connectors are used to enhance proper connection and resist horizontal shear forces. A Composite member has to be designed in such a way that before composite structural element reaches ultimate capacity, shear connectors should not fail due to lack of ductility. This study represents the prediction of Deformation, Stress, Strain and safety factor of a composite member that is embedded with various types of connectors. The results obtained from the Analysis is briefed and the comparative performance of the composites are discussed.

Keywords: Analysis, Composite beams, stiffener, FEA software.

1. INTRODUCTION

a. Overview

Composite steel–concrete construction, particularly for multi-storey steel frames. This is mainly due to a reduction in construction depth, to savings in steel weight and to rapid construction programmers. Composite action enhances structural efficiency by combining the structural elements to create a single composite section. Composite beam designs provide a significant economy through reduced material, more slender floor depths and faster construction. Moreover, this system is well recognized in terms of the stiffness and strength improvements that can be achieved when compared with non-composite solutions. A fundamental point for the structural behaviour and design of composite beams is the level of connection and interaction between the steel section and the concrete slab. The term "full shear connection" relates to the case in which the connection between the components is able to fully resist the forces applied to it. This is possibly the most common situation; however, over the last two decades the use of beams in building construction has led to many instances when the interconnection cannot resist all the forces applied (partial shear connection).

In this case, the connection may fail in shear before either of the other components reaches its own failure state. In the case of the serviceability limit state of composite beams, the condition when the connection between the components is considered as infinitely stiff is said to comprise "full interaction". Whilst this is often assumed in design, it is theoretically impossible and cases where the connection has more limited stiffness (partial interaction) often need to be considered. In this case, the connection itself may deform, resulting in relative movement along the steel–concrete interface and the effect of increased shear deformation in the beam as a whole. Therefore, partial interaction occurs to some extent in all beams whether fully connected or not.

However, studies have shown that any flexibility in the connection may be ignored for beams designed for full connection. The use of partial connection provides the opportunity to achieve a better match of applied and resisting moment and some economy in the provision of connectors. Generally, the effects of partial interaction, which are increased by the use. The composite steel-concrete systems were first used in the middle of the last century. They involve the joint work of concrete elements and steel sections, interacting mechanically by means of connectors, dents or bumps, either by friction or adhesion. Generally, composite beams are made out of a combination of a steel section (commonly "I" shaped), located on predominantly tensioned region, with a concrete slab, positioned in predominantly compressed area.

The mechanical binding is provided by metal devices called shear connectors. The main functions of the shear connectors are to allow for the joint work of the slab-beam new material, restricting longitudinal slip and vertical displacements of the interface elements, and to take shear forces. By combining steel and concrete this way, it is possible to obtain the advantages of both materials working together. Therefore, from the materials strength point of view, it is possible to take advantage of the steel section to take tension stresses and of the concrete in order to withstand compressive stresses. This combination results in high stiffness and smaller structural sections, lighter foundation design, gains in materials performance and reduced costs. In addition, composite systems allow for the occasional elimination of formwork and shoring, and may reduce steel protection against fire and corrosion, due to the presence and adequate behaviour of concrete in the system. The main idea is to make use of the computer program ANSYS, which is based on the Finite Element Methodofpartial shear connection, will result in reduced strength and stiffness, and potentially enhanced ductility of the overallstructural system. It is widely known that laboratory tests require a great amount of time, are very expensive and, in some cases, can even be impractical. On the other hand, the finite element method has become, in recent years, a powerful and useful tool for the analysis of a wide range of engineering problems.

A comprehensive finite element model permits a considerable reduction in the number of experiments. Nevertheless, in a complete investigation of any structural system, the experimental phase is essential. Taking into account that numerical models should be based on reliable test results, experimental and numerical/theoretical analyses complement each other in the investigation of a particular structural phenomenon. Previous numerical studies have been conducted to investigate the behaviour of composite beams. Nevertheless, most of them are based on two-dimensional analytical models and are thus not able to simulate more complex aspects of behaviour, which are intrinsic for three-dimensional studies; for instance: full distribution of stresses and strains over the entire section of the structural components (steel beam and concrete slab), evolution of cracks and local deformations in the concrete slab.

b. Composite Construction

Composite construction consists of providing a monolithic action between prefabricated steel joists and cast- in situ concrete slabs. A sufficient shear connection is provided between the two component construction units so that the two units act as one unitand resist the load by composite action where most of the compression is taken by concrete and the tension by the joist.

In these composite sections, the greatest shear stress occurs at the neutral axis which is always near the top flange of the joist. Figure 1 shows the steel joist supporting concrete slab.

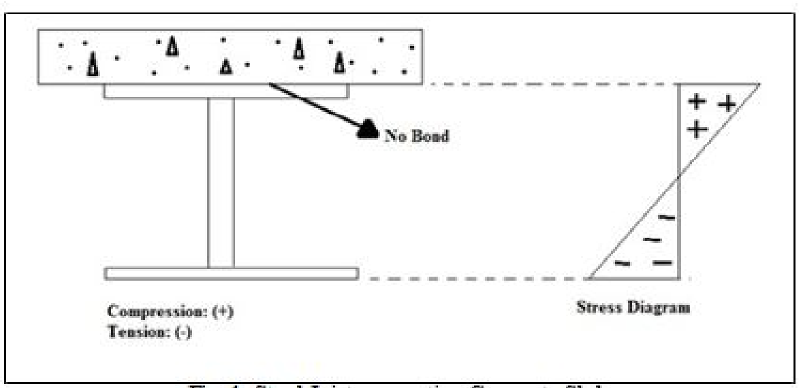

Figure 1 Steel Joist Supporting Concrete Slab

Composite Construction technique is an upcoming solution to achieve structures with high initial stiffness, bearing capacity and ductility.

c. Advantages of Steel-Concrete Compositeconstruction

- Composite Construction will have the advantages of both prefabricated and cast-in situ construction. Firstly, prefabricated units can be used to serve as form work for cast-in situ work.
- Secondly, prefabricated concrete flanges (i) stabilize girders during transportation and construction (ii) do not require stiffeners because of high centre of gravity (iii) avoid the use of braces for concreting of residual in-situ plates (iv) make the task of scaffolding of concrete plated un-required.
- Thirdly, this method leads to the invention of new and economic constructions with high degree prefabrication so that the quality of structure increases substantially.
- Fourthly, light weight cranes instead of heavy ones are required for hauling and lifting of light steel girders.
- Last but not the least, new slender dimensions become superfluous as 1 bay frames can be used to easily substitute 2 bay continuous beams with the same total span but without the provision of any support in the middle.

d. Objective

The objective is to verify the influence of the amount, dimension and height of shear connectors in composite beams. These verifications were made by means of the analysis of longitudinal slip in the slab-beam interface, the vertical displacement at mid-span and the bearing capacity of composite beams. The results were compared to those provided by standards and to other data found in the consulted literature.

2. METHODOLOGY

Figure 2 shows the methodology of the study.

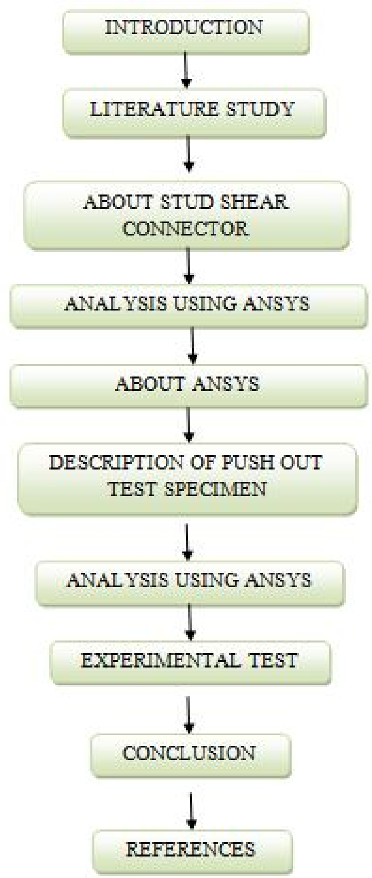

Figure 2 Methodology

3. SHEAR CONNECTORS

a. General

Composite Structures have several advantages over traditional reinforced concrete which incorporate high strength to weight ratios, dimensional stability and structural integrity. Late years have seen a considerable increment in the utilization of composite structures and improved research went for creating new strategies for combining steel and concrete. Composite structures result in efficient design and economy in construction time hence used especially in construction of building floors and bridges. Wide construction practices involve connecting Concrete slab and hot rolled steel beam sections by shear connectors. Shear Connectors are used to enhance proper connection and resist horizontal shear forces. A Composite member has to be designed in such a way that before composite structural element reaches ultimate capacity, shear connectors should not fail due to lack of ductility.

b. Shear Connector

The latest technology used in construction of buildings and bridges. They are used as a major element in the composite structure. Excellent quality, high load bearing capacity, durability, faster speed of construction, etc. are some of the reasons why it is gaining popularity in the construction industry.
"Shear connector means headed steel studs. These are welded to a structural member for achieving composite action with concrete. Shear connector is one of the major elements in the composite structure.
There are three essential elements used in composite construction. These are:

- Reinforced concrete slab
- Steel beam
- Shear connector

The shear connector is basically used to tie the concrete slab to the steel beam in order to transfer the horizontal shear between the slab and the beam without slip and at the same time to prevent the vertical separation of the slab from the structural steel member at the inner face**.**

i. Types of Shear Connectors

There are many types of shear connectors which are mainly divided into two categories according to the functional dependency between strength and deformations and the distribution of shear forces.

1. Rigid Connectors

Rigid 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.

2. Flexible Connectors

Flexible 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.

3. Headed Studs

Headed stud is a short round piece of cold drawn steel which is welded to the beam at one edge and has a greater diameter head at the other end in to the concrete slab which helps in uplifting of concrete slab from the steel beam. It is the most commonly used connector because of its ease in placing and welding. They prove to be non-ductile connectors and result in large interfacial slip. They go in coherence when used with concrete of low strength. Breakdown of shear connection can occur by stud shearing failure or crushing of concrete.

4. Perfobond Shear Connector

In recent years (1980) a connector called perfobond shear connector was developed by Leonhardt, Andra and partners to overcome the fatigue issues caused by stud connectors when used in bridges. Generally, a steel plate with a number of circular openings welded to beam flange can be called as perfobond connector. The concrete which flows through these connector holes helps in creating a dowel action amongst concrete and connector. Thus, it improves the bondage property and offers good resistance in both horizontal and vertical directions. The structural behaviour of these connectors is highly impacted by its dimensional properties, number of holes, and diameter of holes, thickness, length and height of plate.

5. Channel Connectors

When one flange of rolled Channel, section is welded to steel beam flange, it can be called as Channel connector. Channel connectors are rarely used where field installations are required and are generally shop welded. A very small number of channel connectors can supplant a large number of headed studs because of their expected higher load carrying capacity. Inspection procedures required for channel connectors are low because of high reliable and dependable welding system adopted.

6. I-Shape Shear Connectors

Various reasons like monetary contemplations and strength aspects have persuaded in development of I-shape shear connector. Due to its symmetry in both the axes, it offers more resisting in bending. Similar to channel connector, connection is established by welding one flange of rolled I section to flange of steel beam.

c. Shear Force Distribution Mechanism

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 certain sliding between concrete and steel, causing more favourable distribution of shearing forces.

d. Design Considerations

The Indian Standard Code of Practice for Composite Construction has made the following recommendations.

- The shear connectors should permit a thorough compaction of concrete such that their entire surfaces are in contact with concrete.
- The shear connectors shall be of weld able steel and shall be end welded to the structural members.
- The capacity of the welds at permissible stress shall not be less than the shear resistance of the connectors.
- Studs and channel shear connectors shall not be spaced further apart than 600 mm.
- The clear distance between the edge of a beam flange and the edge of the connectors shall not be less than 25 mm.
- The concrete cover over the shear connectors in all the directions shall not be less than 25 mm.
- In order to ensure that the concrete beam is sufficiently tied down to the steel flange, the overall height of the shear connectors should not be less than 50 mm nor project less than 25 mm into the compression zone of the concrete beam.

e. Advantages of Shear Connector

- Shear Connectors have high load bearing capacity and offer heavy resistance for failure by shearing, in composite structure.
- Very high rate of production can be achieved, during construction.
- Ease of operation, during construction. No specific skill is required for welding.
- Flexibility in design of construction.
- Shear Connectors can be welded through Deck Sheet, to produce concrete beam.
- Size of columns are smaller hence for given built up area we can have larger carpet area
- Strong, durable, stable and seismic resistant.

f. Requirements of Shear Connectors

- The minimum distance between the edge of a shear connector and the edge of a flange plate is 25 mm
- The maximum longitudinal spacing is defined, and is the lower of 800 mm or 4 x concrete beamdepth
- If the plate is subjected to tensile stress or fatigue loading, diameter of the shear stud should not exceed one and a half times the plate thickness,
- Diameter of the shear stud should not exceed 2.5 times the plate thickness in other cases.
- Underside of the head of shear stud should project at least 30 mm above the bottom transverse reinforcement, thus it governs the height of the stud.

g. Advantages of Shear Studs

The advantages of shear studs over other forms of connectors are that the

- Installation and welding process is quick and simple;
- Provides little obstruction to the slab reinforcement;
- Allows more satisfactory compaction of the concrete around the connectors;
- It provides equal shear strength in all directions.The advantages of headed stud connectors can be summarized as follows: fast welding, good anchor inconcrete, the arrangement of reinforcement through the slab is easy, production of large-scale size is easy, the standard dimensioned head is a resistance factor for slab uplift and they are practical for use in steel deckslabs.Four portions that are considered for load bearing of studs as suggested by include the concrete behind the weld collar, bending and sharingload-bearing capacity in the lower area of the connector shaft, tensile force in the connector shaft and the frictionforces in the composite interface. There are almost no tensile forces acting on the shank in high strengthconcrete.

h. Role of Shear Connector in Composite Structure

- A Shear connector belongs to a steel projection to be applied on the top flange of steel composite bridge girders to transmit required shear among the steel girder and composite slab to facilitate composite action.
- The headed stud is mostly recognized form of shear connector, or shear stud. Other forms of shear connector range from block and hoop, and channel connectors. Block and hoop, and channel connectors are mainly applied for transmission of large shear. These are good substitute to narrowly spaced shear studs.
- Shear flows are measured at supports, at mid-span, and at quarter points, with the intension of planning a shear flow profile along a girder. Shear Connectors or studs are placed to withstand shear at the relevant locations.
- Standard sizes for shear studs, which are generally utilized in steel composite bridge decks and quickly obtainable from suppliers, are of heights (in mm) 125, 150, 175, 200, 250 and diameters (in mm) 16 19 22 25. Normally, a welding gun is used to connect the shear studs to the top flanges of girders. The stud is kept in the welding gun and an arc is attached between stud and the flange plate. Arc combines a section of both the stud and the plate in a pre-arranged time.

i. Benefits of Shear Studs

The following are the benefits of shear studs over other forms of connectors.

- Set up and welding method is easy and quick;
- Offers least obstacle to the slab reinforcement;
- Facilitates more reasonable compaction of the concrete all over the connectors;
- Offers identical shear strength in all directions. Prerequisites of Shear Connectors
- The lowest distance among the edge of a shear connector and the edge of a flange plate should be 25 mm
- When the plate is dependent on tensile stress or fatigue loading, diameter of the shear stud must not surpass one and a half times the plate thickness,
- Diameter of the shear stud must not surpass 2.5 times the plate thickness in other cases.
- Foundation of the head of shear stud should be minimum 30 mm above the bottom transverse reinforcement, so that it manages the height of the stud.

4. ABOUT SOFTWARE

a. What is Ansys

ANSYS is a general-purpose software, used to simulate interactions of all disciplines of physics, structural, vibration, fluid dynamics, heat transfer and electromagnetic for engineers.So ANSYS, which enables to simulate tests or working conditions, enables to test in virtual environment before manufacturing prototypes of products. Furthermore, determining and improving weak points, computing life and foreseeing probable problems are possible by 3D simulations in virtual environment.ANSYS software with its modular structure as seen in the figure below gives an opportunity for taking only needed features. ANSYS can work integrated with other used engineering software on desktop by adding CAD and FEA connection modules.

b. Finite Element Method

The basic concept in this method is that a body or a structure may be divided into smaller elements of finite dimensions called „Finite Elements". The original body or the structure is then considered as an assemblage of these elements connected at a finite number of joints called „Nodes" or „Nodal Points". The properties of the elements are formulated and combined to obtain the solution for the entire body or structure. The finite element procedure reduced the unknown infinite numbers by dividing into small elements and by expressing the unknown field variables in terms of assumed approximating functions such as shape functions.

- Selection of field variables and the elements.
- Discretization of structure.
- Finding the element properties
- Assembling element stiffness matrix
- Solution of nodal unknown

5. ANALYSIS USING ANSYS

a. Analytical Study

Ductility, bondage and shear strength of a connector can be discovered from the push-out test. Properties of connector like height of connector, embedded depth of connector, modulus of elasticity etc., influences itsbehaviour under load. Behaviour of Shear connectors is also influenced by grade of concrete and the reinforcement provided in the concrete slab.

b. Finite Element Analysis in Ansys

Push-out test specimen is modelled in ANSYS. Concrete is modelled using SOLID element and BEAM 189 element is used for modelling Steel. SOLID is a eight node element withsix degrees of freedom at each node. This element is used for Reinforced or plain concrete models. When considered in structural analysis point of view, this element has large deflection and stress stiffening capabilities.

6. ANALYSIS OF I SECTION CONNECTOR

The FEM is a mathematical performance for outcome nearby experimental solutions to various computational domains. Numerical analysis done using FEM is commonly mentioned as a finite element analysis (FEA). Typical FEA applications consist of structural, thermal, electromagnetic and fluid field problems. Engineers' usage it to decrease the several physical models & tests & optimize components in their design segment to improve better products, quicker. Table 1 shows the stud connector analysis result.

Table 1: Stud Connector Analysis Result

Load	Deformation	Stress	Strain	Safety Factor
0	0	0	0	0
5	0.002352	3.1551	1.8384e-005	9.1693
10	0.004703	6.3102	3.6768e-005	4.5846
15	0.007055	9.4653	5.5152e-005	3.0564
20	0.009407	12.620	7.3536e-005	2.2923
25	0.011760	15.775	9.1920e-005	1.8339
30	0.014112	18.931	1.1030e-004	1.5282
35	0.016464	22.086	1.2869e-004	1.3099
40	0.018816	25.241	1.4707e-004	1.1462
45	0.021168	28.396	1.6546e-004	1.0188
50	0.023520	31.551	1.8384e-004	0.9169

The Stud connector is analysis based on the gradually load increased 5kN and predict the deformation, stress & strain. The Stud connector model is fine mesh creating the number of nodes and elements generated and gradually increased in all the result, so its mention the table 1. The maximum load of 50kN obtained (deformation – 0.023520mm, stress – 31.551Mpa & Safety - 0.9169) and result image is mention in the below.

a. Model

Figure 3 shows the stud connector model mesh.

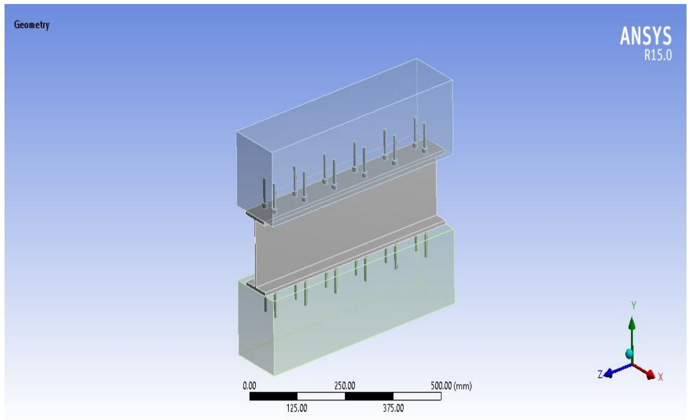

Figure 3 Stud connector model Mesh

Figure 4 shows the stud connector mesh deformation

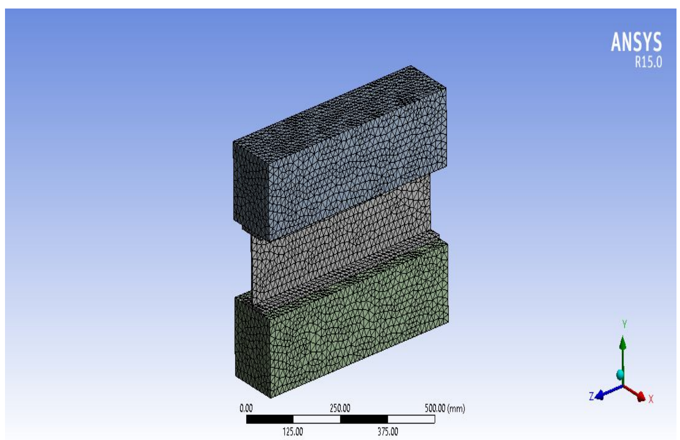

Figure 4 Stud connector mesh deformation

Figure 5 shows the stud connector – deformation stress.

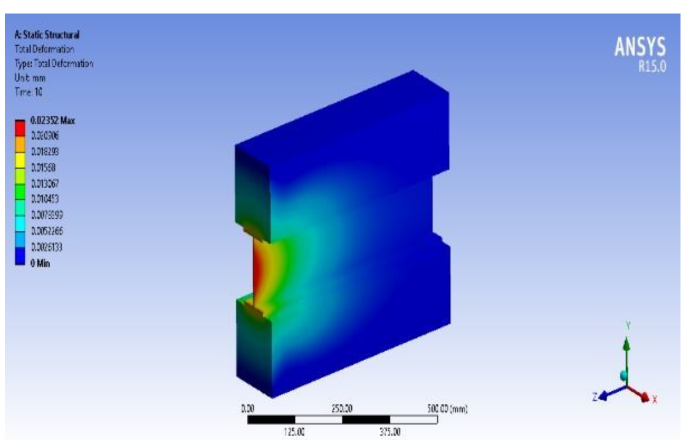

Figure 5 Stud connector - deformation Stress

Figure 6 shows the stud connector – stress strain.

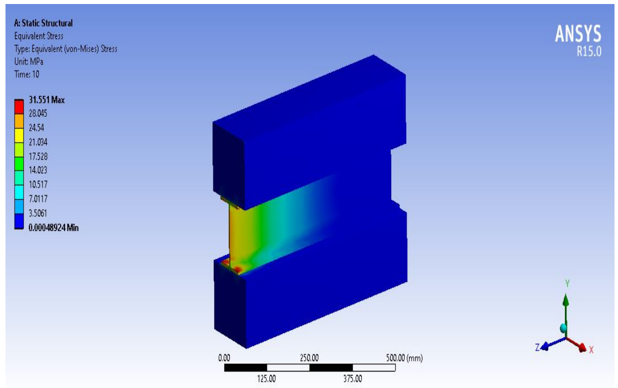

Figure 6 Stud connector – stress strain

Figure 7 shows the stud connector – stress strain safety factor.

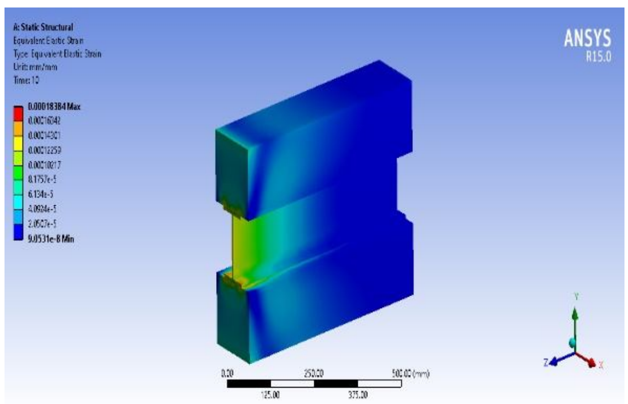

Figure 7 Stud connector - strain Safety Factor

Figure 8 shows the stud connector – safety factor channel.

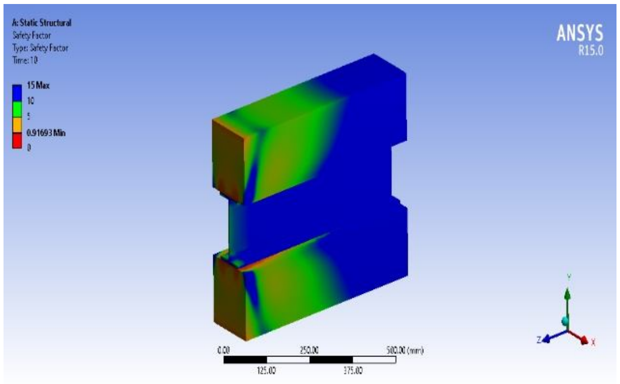

Figure 8 Stud connector – safety factor Channel

b. Connector

Table 2 shows the channel connector analysis result.

Table 2: Channel Connector Analysis Result

Load	Deformation	Stress	Strain	Safety Factor
5	0.002298	2.9962	1.5034e-005	11.402
10	0.004596	5.9924	3.0069e-005	5.7012
15	0.006895	8.9886	4.5103e-005	3.8008
20	0.009193	11.985	6.0137e-005	2.8506
25	0.011492	14.981	7.5172e-005	2.2805
30	0.013790	17.977	9.0206e-005	1.9004
35	0.016088	20.973	1.0524e-004	1.6289
40	0.018387	23.970	1.2027e-004	1.4253
45	0.020685	26.966	1.3531e-004	1.2669
50	0.022983	29.962	1.5034e-004	1.1402
55	0.025282	32.958	1.6538e-004	1.0366
60	0.027580	35.955	1.8041e-004	0.9501

The channel connector is analysis based on the gradually load increased 5kN and predict the deformation, stress & strain. The channel connector model is fine mesh creating the number of nodes and elements generated and gradually increased in all the result, so its mention the table 2. The maximum load of 60kN obtained (deformation – 0.027580mm, stress – 35.955Mpa, & safety – 0.9501).

i. Model

Figure 9 shows the channel connector model mesh.

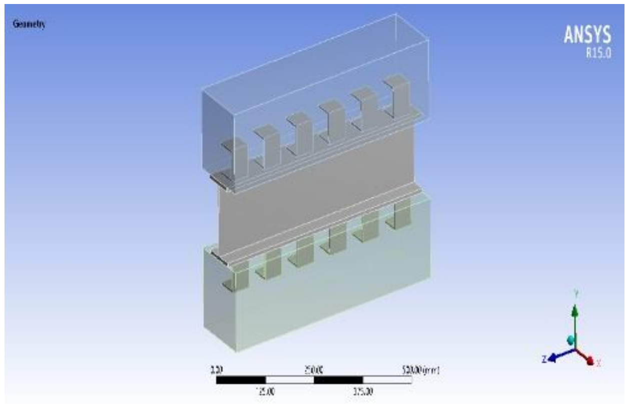

Figure 9 Channel connector model Mesh

ii. Mesh

Figure 10 shows the channel connector mesh.

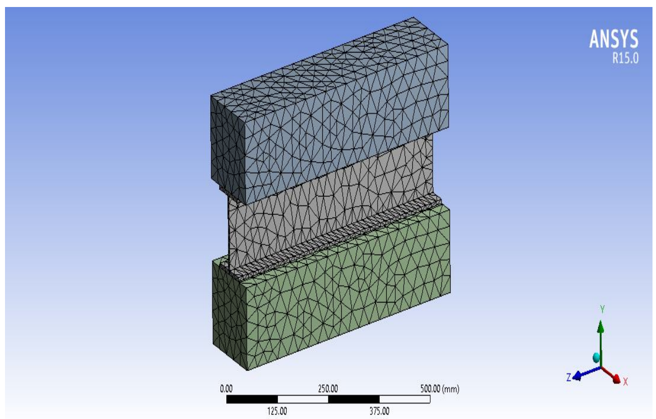

Figure 10 Channel connector mesh

iii. Deformation

Figure 11 shows the channel connector – deformation.

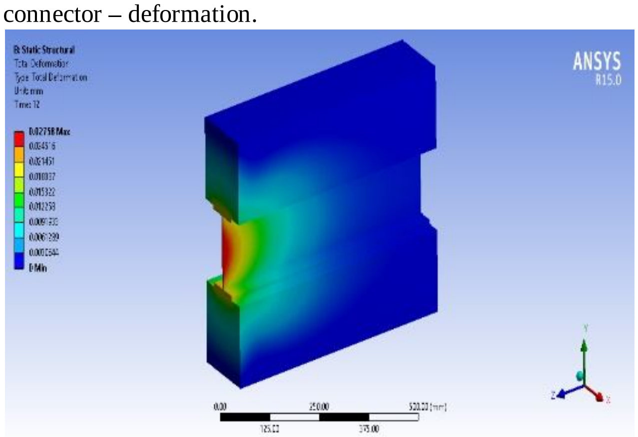

Figure 11 Channel connector - deformation

iv. Stress

Figure 12 shows the channel connector - stress.

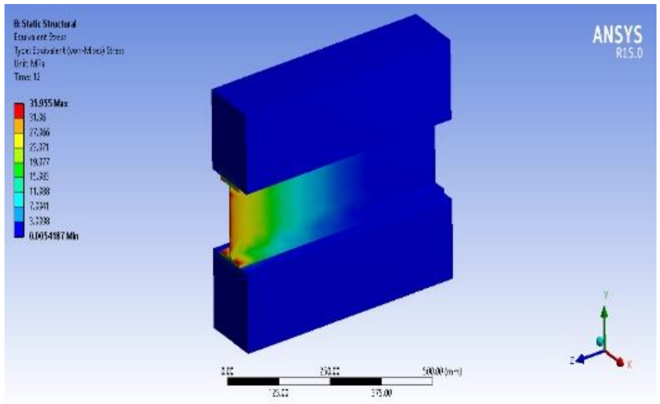

Figure 12 Channel connector - stress

v. Strain

Figure 13 shows the channel connector – strain.

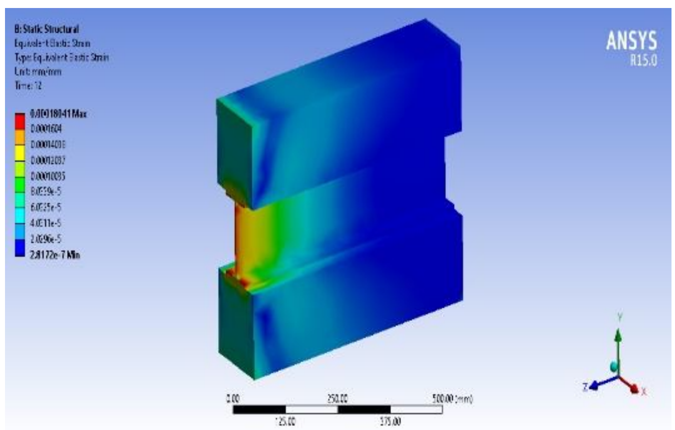

Figure 13 Channel connector - strain

vi. Safety Factor

Figure 14 shows the channel connector – safety factor.

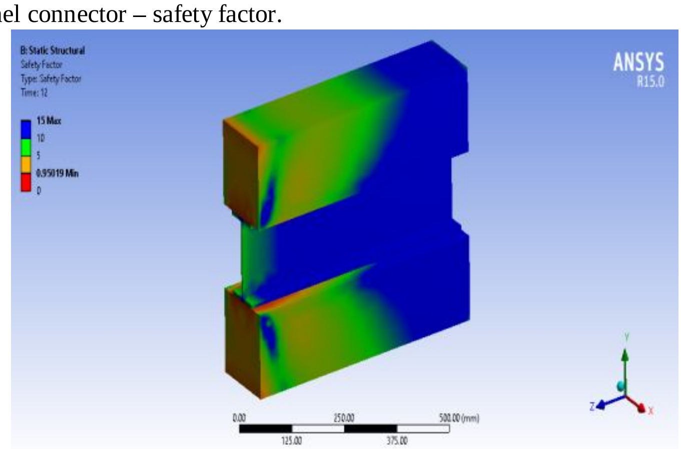

Figure 14 Channel connector – safety factor

c. Tee Connector

Table 3 shows the Tee connector analysis result.

Table 3: Tee Connector Analysis Result

Load	Deformation	Stress	Strain	Safety Factor
5	0.002302	3.1067	1.8338e-005	10.280
10	0.004605	6.2135	3.6676e-005	5.1401
15	0.006907	9.3202	5.5014e-005	3.4267
20	0.009210	12.427	7.3352e-005	2.5700
25	0.011513	15.534	9.1690e-005	2.0560
30	0.013815	18.640	1.1003e-004	1.7134
35	0.016118	21.747	1.2837e-004	1.4686
40	0.018420	24.854	1.4671e-004	1.2850
45	0.020723	27.961	1.6504e-004	1.1422
50	0.023025	31.067	1.8338e-004	1.0280
55	0.025328	34.174	2.0172e-004	0.9345

The tee connector is analysis based on the gradually load increased 5kN and predict the deformation, stress & strain. The tee connector model is fine mesh creating the number of nodes and elements generated and gradually increased in all the result, so its mention the table 3. The maximum load of 55kN obtained (deformation – 0.025328mm, stress – 34.174Mpa, & safety – 0.9345) and result image is mention in the below.

i. Model

Figure 15 shows the Tee connector model mesh.

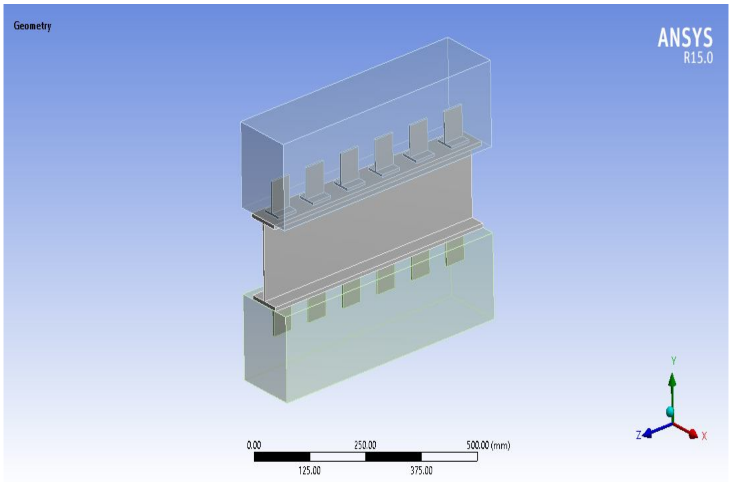

Figure 15 Tee connector model Mesh

ii. Mesh

Figure 16 shows the Tee connector mesh.

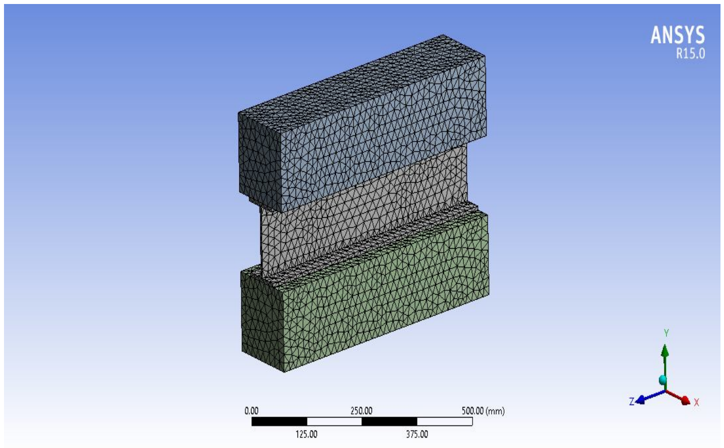

Figure 16 Tee connector mesh

iii. Deformation

Figure 17 shows the channel connector – deformation.

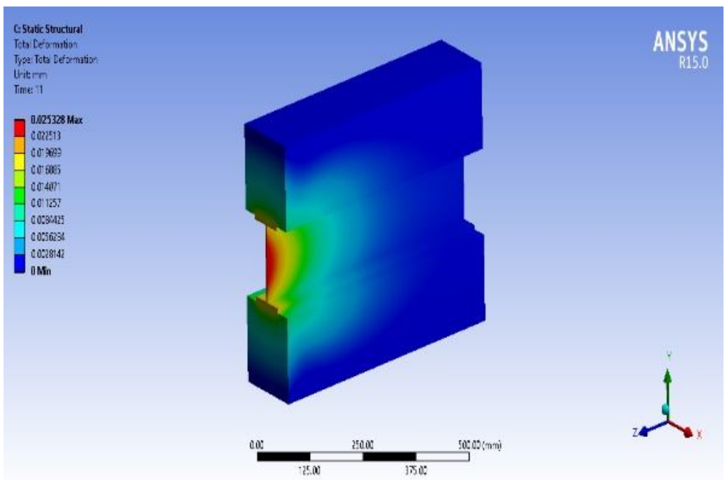

Figure 17 Channel connector – deformation

iv. Stress

Figure 18 shows the channel connector – stress.

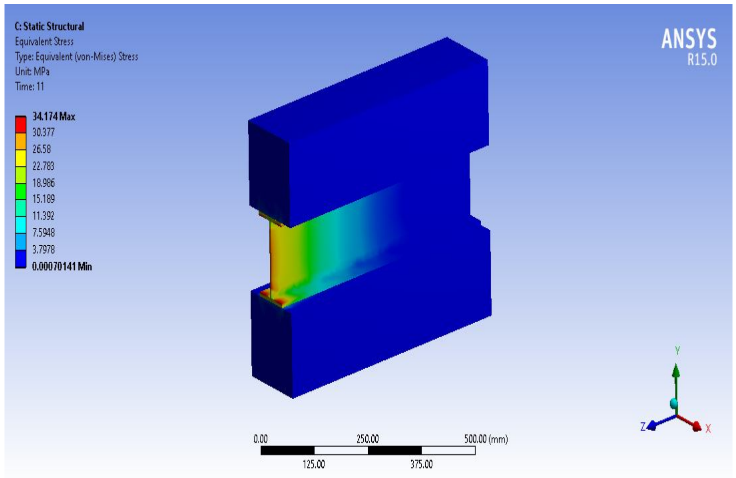

Figure 18 Channel connector – stress

v. Strain

Figure 19 shows the channel connector – strain.

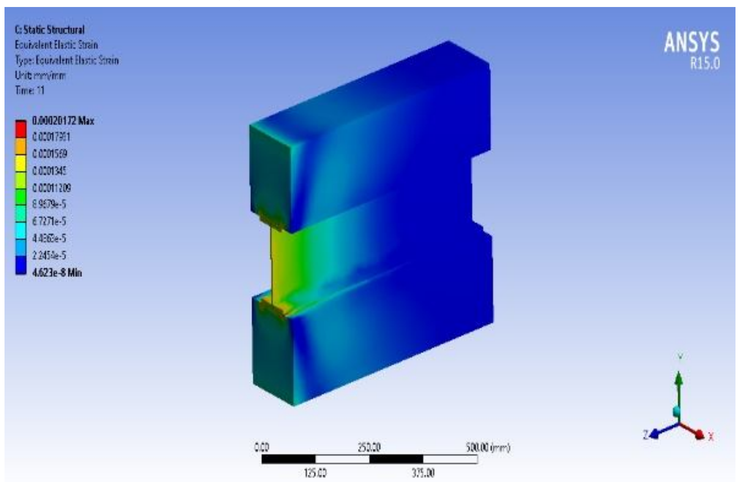

Figure 19 Channel connector – strain

vi. Safety Factor

Figure 20 shows the channel connector – safety factor.

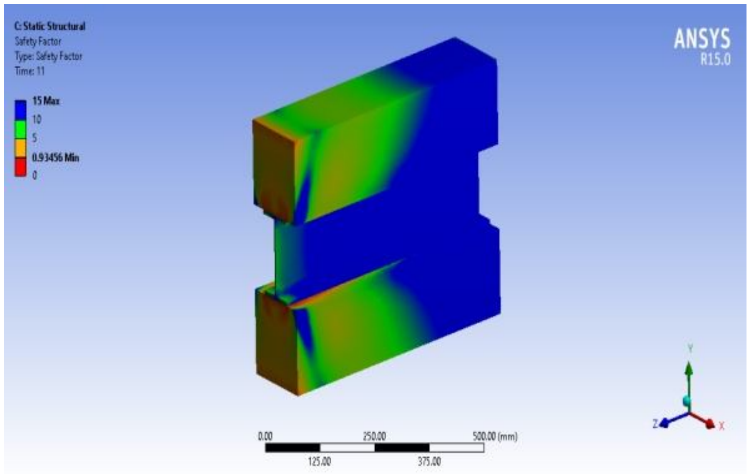

Figure 20 Channel connector – safety factor

7. RESULT & DISCUSSION

Table 4 shows the comparison of all the connector.

Table 4: Comparison of all the connector

Load	Stud			Channel			Tee		
	Deformation	Stress	Safety	Deformation	Stress	Safety	Deformation	Stress	Safety
5	0.002352	3.1551	9.1693	0.002298	2.9962	11.402	0.002302	3.1067	10.280
10	0.004703	6.3102	4.5846	0.004596	5.9924	5.7012	0.004605	6.2135	5.1401
15	0.007055	9.4653	3.0564	0.006895	8.9886	3.8008	0.006907	9.3202	3.4267
20	0.009407	12.620	2.2923	0.009193	11.985	2.8506	0.009210	12.427	2.5700
25	0.011760	15.775	1.8339	0.011492	14.981	2.2805	0.011513	15.534	2.0560
30	0.014112	18.931	1.5282	0.013790	17.977	1.9004	0.013815	18.640	1.7134
35	0.016464	22.086	1.3099	0.016088	20.973	1.6289	0.016118	21.747	1.4686
40	0.018816	25.241	1.1462	0.018387	23.970	1.4253	0.018420	24.854	1.2850
45	0.021168	28.396	1.0188	0.020685	26.966	1.2669	0.020723	27.961	1.1422
50	0.023520	31.551	0.9169	0.022983	29.962	1.1402	0.023025	31.067	1.0280
55				0.025282	32.958	1.0366	0.025328	34.174	0.9345
60				0.027580	35.955	0.9501			

Figure 21 shows the comparison of over all deformation.

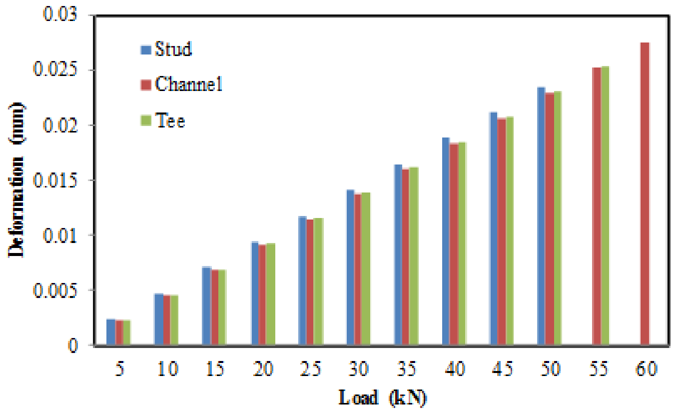

Figure 21 Comparison of overall Deformation

Figure 22 shows the comparison of stress.

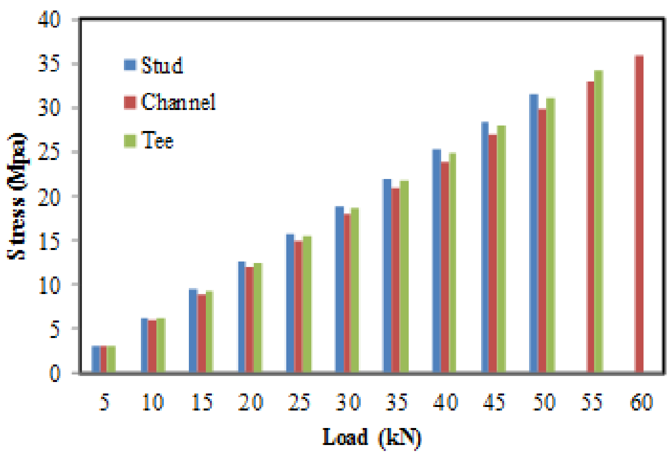

Figure 22 Comparison of Stress

8. CONCLUSION

Finite element analysis of the different types of steel shear connectors based on structural analysis in Ansys software was executed, to predict the deformation, stress, strain & safety factor on all the connectors and comparison of better shear connector is showed through pictorial representation. It is observed that the channel connector has better properties and the reason is low deformation and stress. It's also has better safety factor compared to other shear connectors.

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