Analysis On The Structural Behaviour And Effect Of Shear Connectors In Composite Flexural Members

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Abstract - **Concrete is a versatile construction material which has several advantages due to its compressive strength and mouldable shape. But it is weak in tension and has poor ductility. Ductility is an important characteristic of a structure to resist earthquake, impact and blast loading. Steel has excellent ductile property. Hence a judicious combination of structural steel and concrete utilizing the strength possessed by them and suppressing their weakness resulted in the composite construction. A structural member composed of two or more dissimilar materials joined together to act as a unit is referred as composite structure. Joining two dissimilar materials to form a composite member does not only combine the collective strengths of the two materials, forming a union between relevant materials actually enhances their physical characteristics and makes the composite stronger than the sum of their strengths. In order to design the structural member with maximum efficiency and minimum cost, steel-concrete composite construction is adopted. It is a powerful construction concept in which compressive strength of concrete and the tensile strength of steel are almost effectively used. Steel and the concrete have almost the same thermal expansion apart from an ideal combination of strength. Hence, these essential different materials are completely compatible and complementary to each other. Steel-concrete composite structures, particularly, are structures consisting of two materials, a steel section located mainly in the tension region and a concrete section located in the compression cross sectional area. Composite action between the steel and the concrete is achieved by means of mechanical connectors. These connectors are generally dubbed as 'shear connectors'. They are typically connected by welding to the top flange of a steel beam and cast within the concrete slab. It is only through this connection that composite action is achieved. Without these connectors, the concrete and the slab act independently. The main functions of these connectors are to restrict longitudinal slipping and uplifting at the elements interface and to take shear forces. The project work deals with the analysis of composite beams. Analysis was done using ANSYS finite element software. The model provided by ANSYS is used to simulate the behaviour of shear connectors in composite beam. The parametric studies are conducted to study the behaviour of shear connectors.**

keywords - **Composite Structures, Shear Connectors, Stud Connector, Finite Element Method, Parametric Study, Von-mises Stress, Crack Pattern**

INTRODUCTION

MODERN civilization relies upon the continuing performance of civil engineering infrastructure ranging from industrial building to power station and bridges. For the satisfactory performance of the existing structural system, the need for strengthening is inevitable. Commonly encountered engineering challenges such as increase in service loads, changes in use of the structure, design and/or construction errors, degradation problems, changes in design code regulation and seismic retrofits are some of the causes that lead to the need for new techniques to upgrade the performance of the structures.

Though concrete a versatile construction material has several advantages due to its compressive strength and mouldable shape, it has its own tensional limitation and poor ductility. Ductility is an important characteristic of a structure to resist earthquake, impact and blast loading. Steel has excellent ductile property. Hence a judicious combination of structural steel and concrete utilizing the strength possessed by them and suppressing their weakness resulted in the composite construction. The present day demands in construction on parameters such as strength, safety, serviceability, satisfactory and reliable performance expected of a structure apart from economical solutions has also made it imperative to use steel concrete composite construction techniques. A structural member as a unit is referred as composite structure. Joining two dissimilar materials to form a composite member does not only combine the collective strengths of the two materials, forming a union between relevant materials actually enhances their physical characteristics and makes the composite stronger than the sum of their strengths. An example is the steel-concrete composite beam in which a steel wide-flange shape (I or W shape) is attached to a concrete floor slab. Steel-concrete composite structures, particularly, are structures consisting of two materials, a steel section located mainly in the tension region and a concrete section, located in the compression cross sectional area , both connected by metal devices known as shear connectors. The main functions of these connectors are to allow for the joint behaviour, to restrict longitudinal slipping and uplifting at the elements interface and to take shear forces. In these composite sections, the greatest shear stress occurs at the neutral axis which is always near the top flange of the joist. Objective of this study is to find the behavior of shear connectors in composite beams under incremental loading.

SHEAR CONNECTORS

Composite construction consists of providing monolithic action between prefabricated units like steel beams or pre-cast reinforced concrete or pre-stressed concrete beams and cast-in-situ concrete, so that the two will act as one unit. Although there is bound to be a certain amount of natural bond between concrete and steel at least at the initial stages, this bond cannot be relied upon as the same is likely to be deteriorate due to use and over load. Mechanical shear connectors are therefore provided to help the steel and concrete element to act in a composite manner ignoring the contribution made by the inherent natural bond towards this effect.

Primarily shear connectors are intended to resist the horizontal movement between the concrete slab and the steel beam and to transmit the horizontal shear between the two. Shear Connectors are also called upon to prevent vertical separation of the slab from the steel girder at the contact surface to transmit the longitudinal shear along the contact surface without slip. There are different types of shear connectors namely, rigid, flexible and bond type connectors.

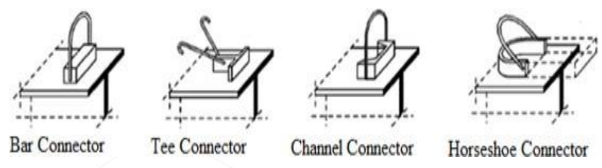


Fig. 1. Rigid type shear connectors

Fig. 2. Flexible type shear connectors

OBJECTIVE

The objective is to verify the influence of the amount and diameter of shear connectors in composite beams. These verifications were made by means of the study of vertical displacement, von-mises stress and crack pattern of the composite beams.

FINITE ELEMENT MODEL

Numerical Modelling

The geometry and parameters of the composite beam used in this paper is shown in Fig. 3[2]. The composite beam is a simply supported beam and the interaction between the concrete and steel I-section is provided by stud connectors. The beam is subjected to a point load in the mid span. The model implementation started with the definition of the geometry of the composite beam. Secondly, finite elements were chosen to represent the composite materials. Thirdly, the properties and constitutive relations of the materials involved were introduced. Finally, the meshing was done considering the beam support conditions and the applied load. Then, to analyze the connectors influence on the structural behavior of the composite beam, several alternatives for connectors were analyzed, with different diameters and number. The material properties are given in table 1.

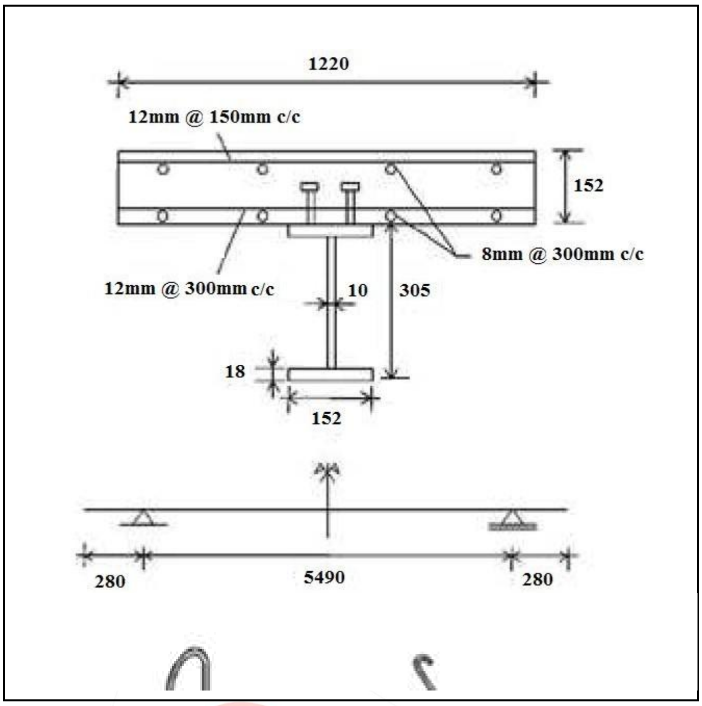


TABLE 1 MATERIAL PROPERTIES

CONCRETE	
Modulus of Elasticity	2.1×10^7 N/m^2
Poisson's Ratio	0.15
Density	25 kN/m^3
STEEL	
Modulus of Elasticity	2.1×10^{11} N/m^2
Yield stress	250 MPa
Poisson's Ratio	0.3
Density	7850 kg/m^3

Software and Element Types

Advances in computational features and software have brought the finite element method within reach of both academic research and engineers in practice by means of general-purpose nonlinear finite element analysis packages, with one of the most used nowadays being ANSYS. In this paper, the structural system modelling is based on the use of this commercial software.

The finite element types considered in the model are as follows: shell (SHELL43) and solid (SOLID65) elements are used for the steel section and the concrete slab respectively. The three dimensional element SOLID65 were adopted to discretize the concrete, which are also able to simulate cracking behavior of concrete in tension and crushing in compression, to evaluate the material non-linearity and also to enable the inclusion of reinforcement. The nonlinear springs (COMBIN39) to represent the shear connectors. Link180 is used for the reinforcing bars and CONTA174 and TARGE170 is provided for the contact between concrete and steel section.

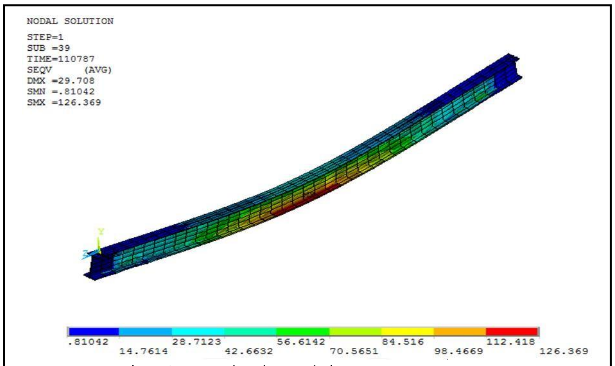
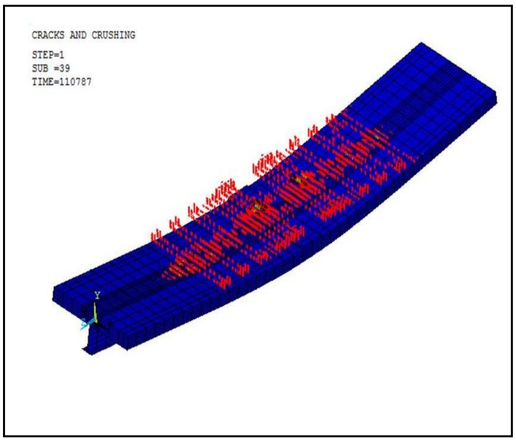
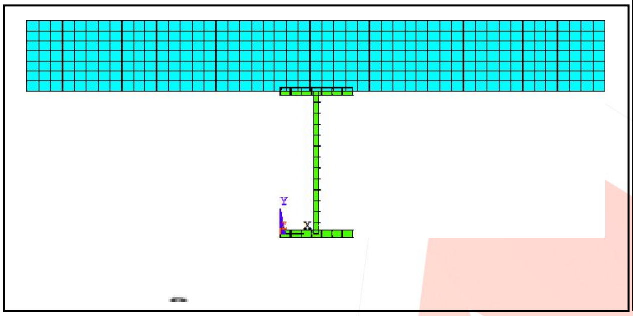


Fig. 4. Meshed model





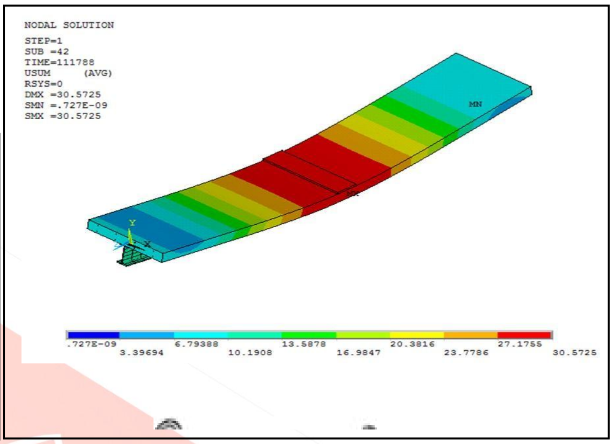
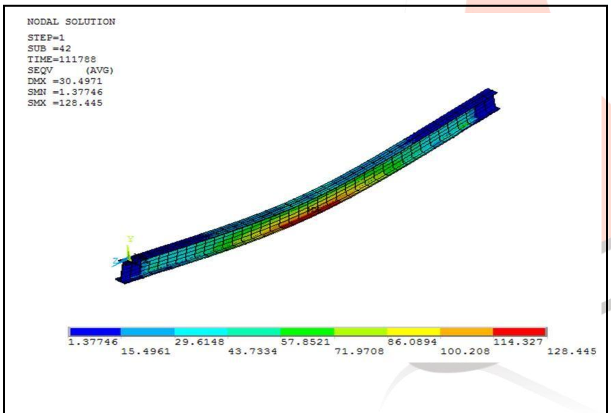


Fig. 5(c). Resultant Displacement (19mm Φ)



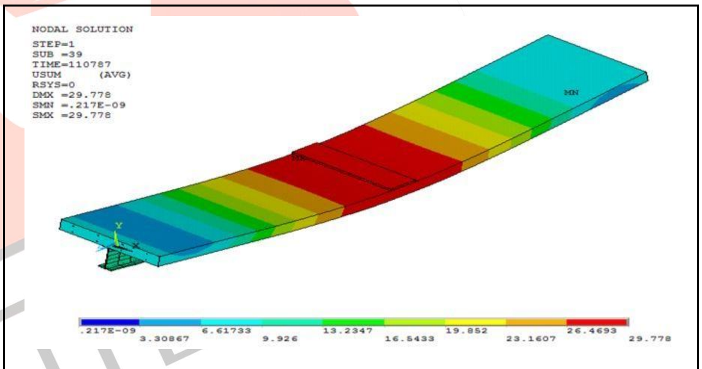


Fig. 5(a). Resultant Displacement (16mm Φ)

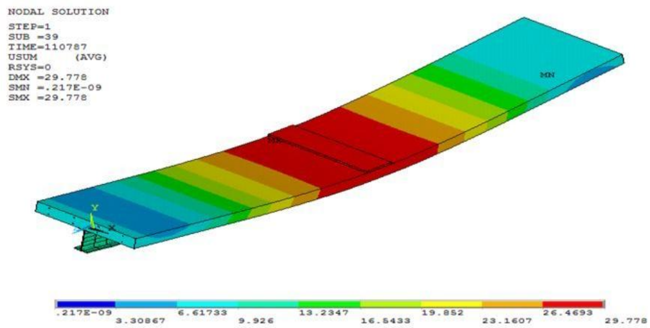
5.2 Parametric Study

To analyze the connectors influence on the structural behavior of the composite beam, several alternatives for connectors were analyzed, with diameters ranging from 16mm, 19mm and 22mm and numbers of connectors ranging from 72, 100 and 126. The height of the connectr is kept as 102mm. The composite beam is subjected to a point load on mid span.

RESULTS AND DISCUSSIONS

The structure was analyzed and the deflection, von-mises stress and crack pattern were studied for different diameters and number of connectors.

Influence of Connectors – Variation in Diameter



The study was conducted by changing the diameter from 16mm, 19mm and 22mm. The number of connectors was kept as 76mm and height as 102mm.

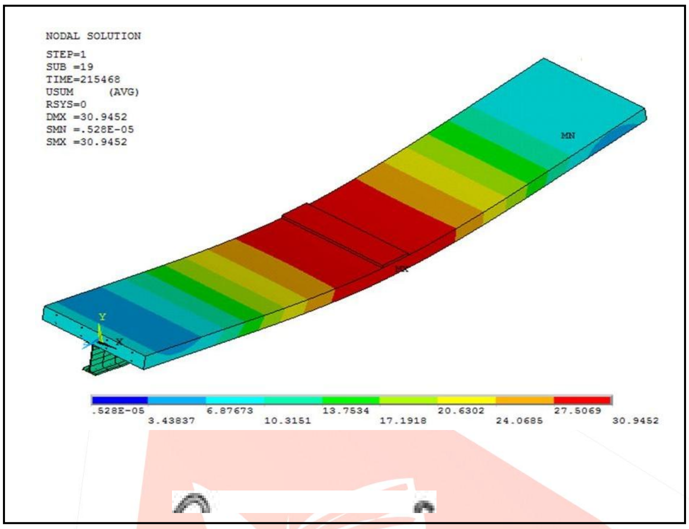


TABLE 2 SUMMARY OF RESULTS CONSIDERING THE INFLUENCE OF CHANGES IN DIAMETER

Parameter	Height (mm)	Load at 1st crack (kN)	Deflection (mm)
Φ = 16mm	102	110.787	29.778
Φ = 19mm	102	111.788	30.5725
Φ = 22mm	102	215.468	30.9452

Fig 5 and table 2 displays the result of the influence of the diameter of the connector in the load and the vertical displacement at mid span. It shows that increasing the diameter of the connector increases the load capacity and the vertical displacement, whose highest value corresponds to the connector with diameter 22mm.

Permissible Stress

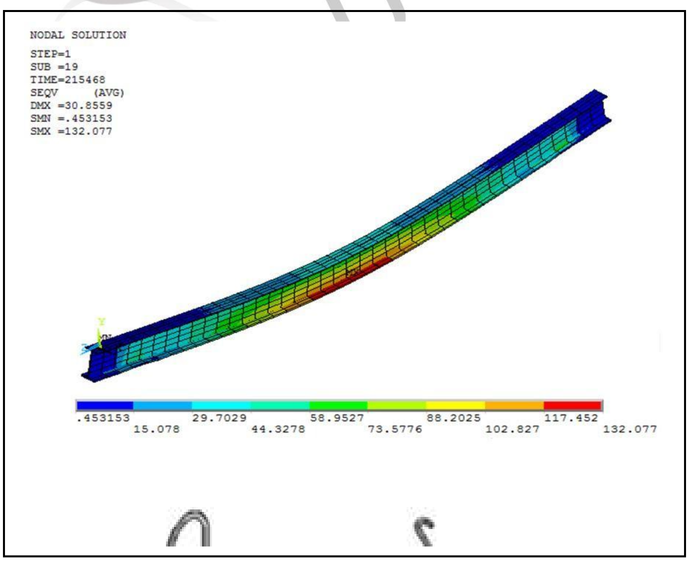


Fig. 5(f). Resultant Displacement (22mm Φ)

The yield strength or yield point of a material is defined in engineering and materials science as the stress at which a material begins to deform plastically. Prior to the yield point the material will deform elastically and will return to its original shape when the applied stress is removed. Once the yield point is passed, some fraction of the deformation will be permanent and non-reversible. Knowledge of the yield point is vital when designing a component since it generally represents an upper limit to the load that can be applied. Maximum stress of the analyzed models and allowable stresses are tabulated.

TABLE 3 CHECK FOR PERMISSIBLE STRESS

Diameter (mm)	Load at 1st crack (kN)	Maximum stress (MPa)	Yield stress (MPa)
16	110.787	126.369	250
19	111.788	128.445	250
22	215.468	132.077	250

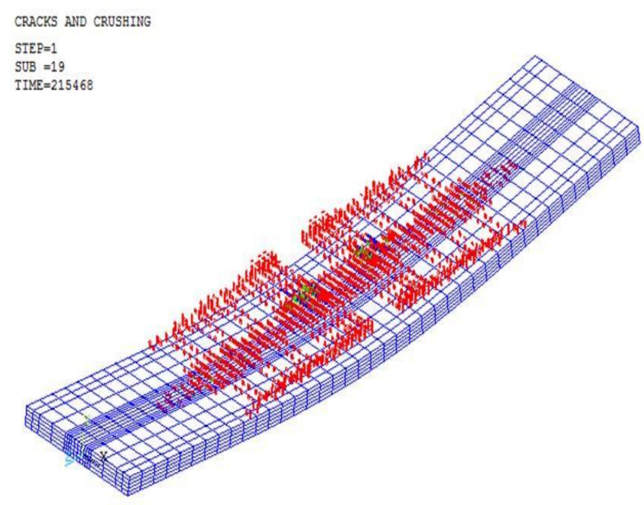


Fig. 5(h). Crack Pattern (22mm Φ)

The maximum stresses in all the three models were below the yield stress indicating a safer section.

Influence of connectors – variation in number

The study was conducted by changing the number from 72, 100 and 126. The diameter of connectors was kept as 19mm and height as 102mm.

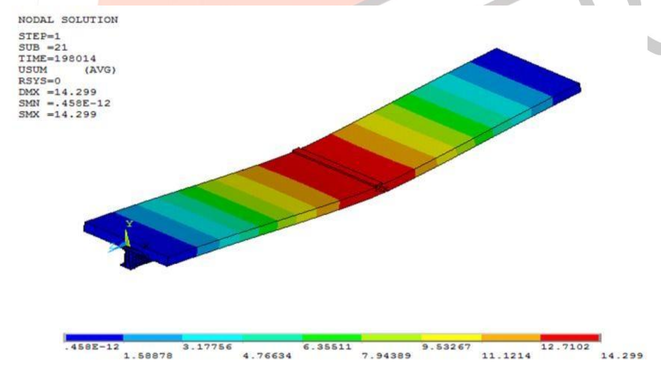


Fig. 6(a). Resultant Displacement (100 nos)

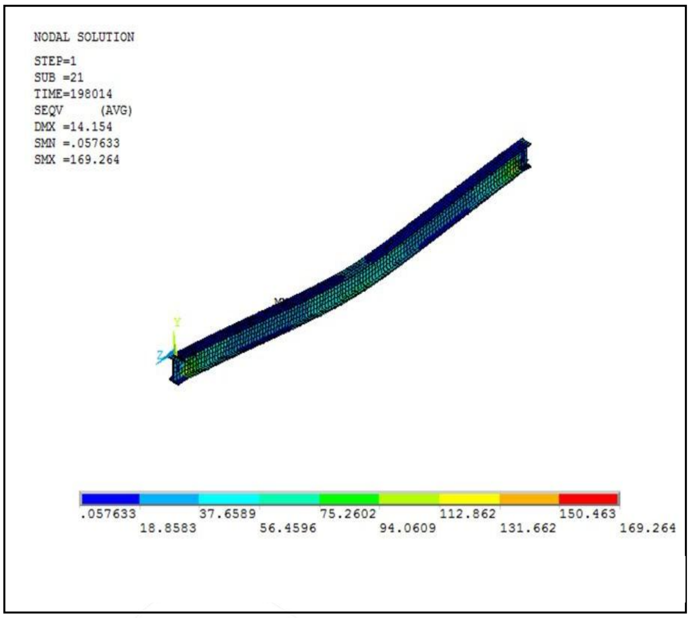


Fig. 6(b). Vonmises Stress in I-section (100 nos)

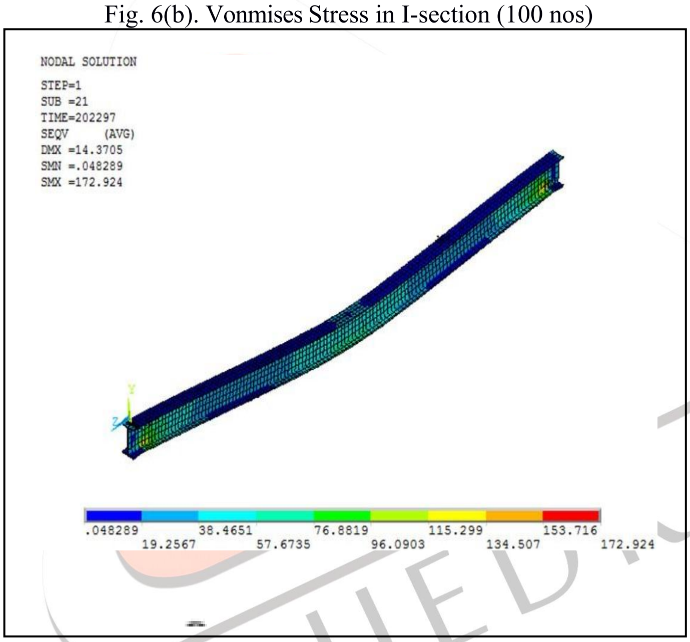


Fig. 6(e). Vonmises Stress in I-section (126 nos)

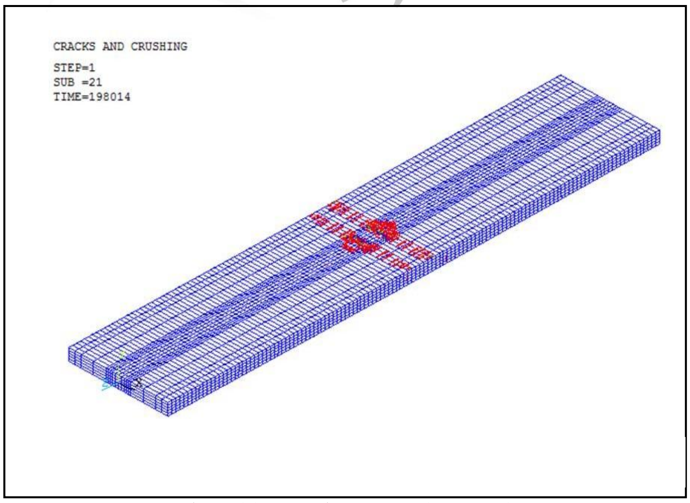


Fig. 6(c). Crack Pattern (100 nos)

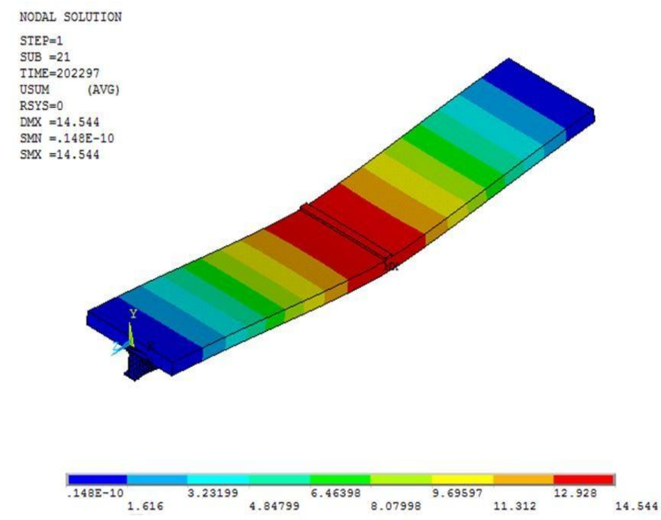


Fig. 6(d). Resultant Displacement (126 nos)

TABLE 4 SUMMARY OF RESULTS CONSIDERING THE INFLUENCE OF CHANGES IN NUMBER OF CONNECTORS

Number of Connectors	Height (mm)	Load at 1st crack (kN)	Deflection (mm)
72	102	111.788	29.778
100	102	198.014	14.299
126	102	202.297	14.544

Fig 6 and table 4 displays the result of the influence of the number of connector in the load and the vertical displacement at mid span. It shows that increasing the number of the connector increases the load capacity. The vertical displacement decreases considerably when the number of connectors increases from 72 to 100. Beyond that, the increase in the number does not influence very much on the load capacity and deflection.

TABLE 5 CHECK FOR PERMISSIBLE STRESS

Number of Connectors	Load at 1st crack (kN)	Maximum stress (MPa)	Yield stress (MPa)
72	111.788	126.369	250
100	198.014	169.264	250
126	202.297	172.924	250

The maximum stresses in all the three models were below the yield stress indicating a safer section.

CONCLUSION

In this study, three-dimensional finite element models have been developed to investigate the effect of shear connectors in composite beams. The study was conducted by using stud shear connectors. A parametric study was also done by changing the diameter and number of connectors. It shows that increasing the diameter of the connector increases the load capacity and the vertical displacement. The maximum stresses were obtained within the permissible limit. It shows that increasing the number of the connector increases the load capacity. The vertical displacement decreases considerably when the number of connectors increases from 72 to 100.

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