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Finite Element Analysis of Composite Beam with Shear Connectors

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Abstract

Composite structures consisting of concrete slab and rolled up steel sections are widely used structural members in bridges and high rise buildings. The composite action is established by connecting the concrete slab and the steel section by using shear connectors. In this paper, four different types of shear connectors have been analyzed and the best connector for a particular composite beam has been evaluated based on its performance under static load keeping the loading and the amount of steel in the connector as a common aspect.

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Keywords: Composite structures ; Shear Connector

1. Introduction

A composite beam constructed by placing a concrete slab on a steel or concrete girder equipped with shear connectors is a commonly used structural member for structures such as bridges and high-rise buildings. Slab and beam type constructions are commonly used in bridges and buildings. Slab beam interaction is possible through the use of shear connector welded at the top of the flanges of the steel beam. By the use of an appropriate connection provided between the beam and the concrete slab, the slip between them can be eliminated. Thus the steel beam and the slab act as a "composite beam" similar to the action of a monolithic T- beam. Concrete is stronger in

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compression than in tension whereas steel is susceptible to buckling in compression. Hence by the composite action between the two, we can utilize their respective advantages to the fullest extent.

1.1. General

A composite beam usually shows partial composite behavior as a result of the slip deformation along the interface of the beam. In the case of pre-stressed composite structures, external axial loads are applied by a pre-stressing effect and this induced axial effect also influences the interfacial slip behavior of the composite beam. A typical composite beam consisting of a concrete slab, steel I-section and stud type shear connectors is shown in fig 1.

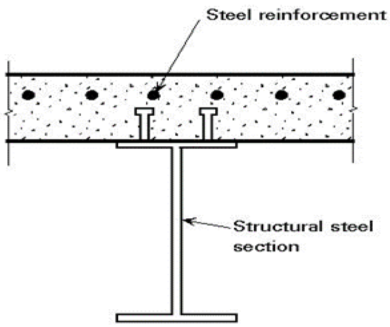


Fig 1. Composite structure with stud type shear connectors

Sandatmanesh et al. [1989] analysed the behaviour of steel beams pre- stressed with high strength steel tendon and compositely connected to a concrete deck. Bradford and Gilbert [1992] presented the derivation of a theoretical model for the time dependent response of simply supported steel-concrete composite beams. Ayoub and Filippou [2000] presented an inelastic beam element for the analysis of steel- concrete girders with partial composite action under monotonic and cyclic loading.

Dall'Asta and Zona [2002] conducted non- linear analysis on composite beams by FE method by comparing solutions deriving from finite elements with 8, 10 and 16 DOF. Liang et al. [2005] investigated the ultimate flexural and shear strengths of simply supported composite beams under combined bending and shear using the finite element method. Gattesco et al. [1997] conducted experiments on stud shear connectors to analyze the different values of slip amplitude and for a given slip history of the connectors.

Badie et al. [2002] experimented on large shear studs for composite action in steel bridge girders to propose the effect of increase in capacity and reduce the possibility of damage in connectors. Xue et al. [2008] investigated on the effect of stud type shear connectors on the composite behaviour of composite beam by conducting thirty push-out tests.

This paper evaluates the performance of various types of shear connectors commonly used in composite beam construction by conducting a nonlinear static analysis and comparing the displacements using the commercially used finite element package Ansys.

2. Description of the sample composite beam and shear connectors

A composite beam with a uniform cross section along the beam axis was analysed using ANSYS software. A uniform distribution of shear connectors designed to obtain full shear connection was adopted. i.e., the connector was designed in such way as to avoid collapse before the reinforced concrete slab or the steel beam reach their ultimate state. Fig 2 shows the details of the composite beam. The properties of the beam are given below.

- I- section: welded I steel beam of size 454x 100x 254mm
- Concrete slab of 100mm thick

Table 1 shows the material properties of the beam specimen considered.

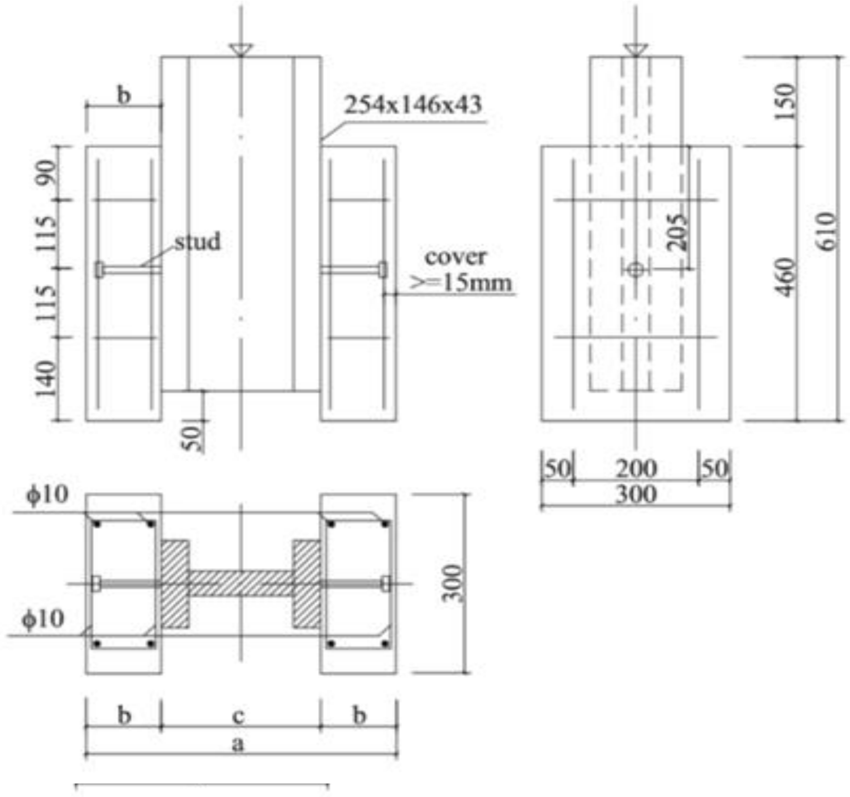


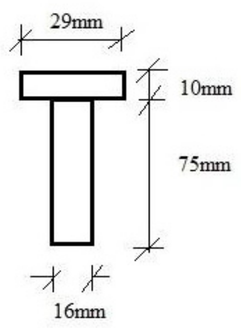
Fig 2. Composite beam used in the analysis

Table 1. Material Properties

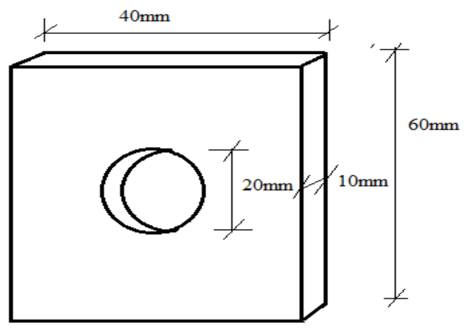
Material	Young's modulus of elasticity (GPa)	Poisson's ratio
Concrete Slab	29	0.17
I section	200	0.3

Shear connectors	200	0.3

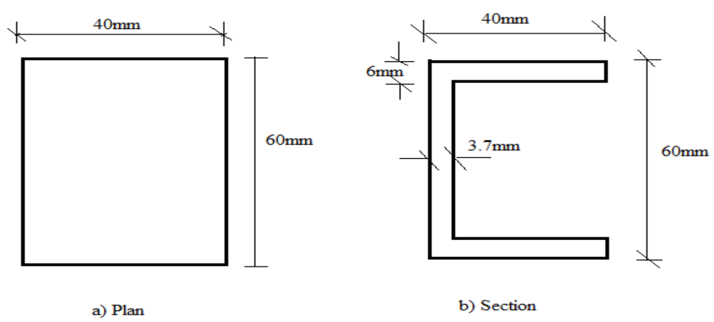
The different types of connectors used for the analysis are stud, channel, tee, and perfobond connectors which are commonly used in the construction of composite beams. The section details of the connectors are shown in fig 3.



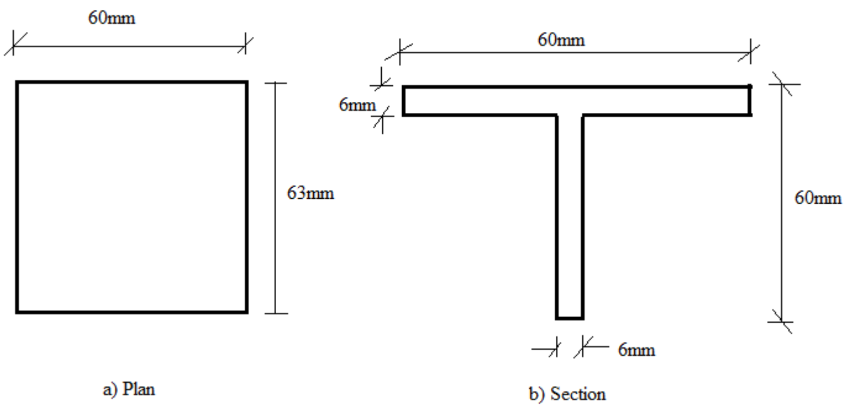
(a)



(b)



(c)



(d)

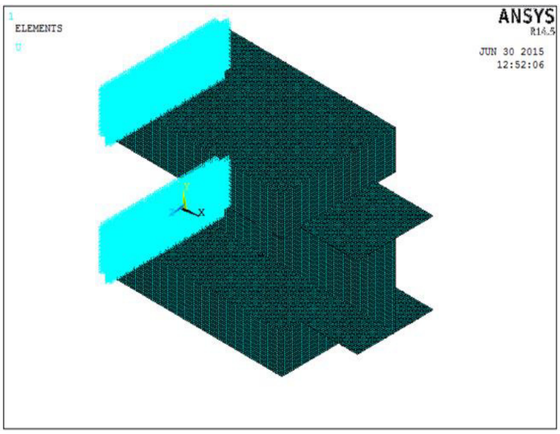
Fig. 3. (a) stud; (b) perfobond; (c) channel; (d) tee

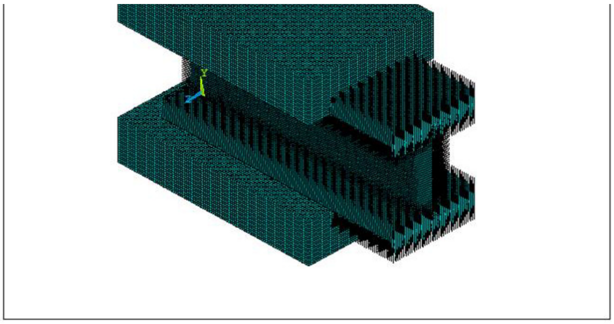
3. Finite elements used for analysis

For modelling the concrete slab, SOLID 65 is used which is defined by eight nodes with three degrees of freedom at each node. BEAM 189 is used to model the stud connectors and this element is a 3 nodded element with six degrees of freedom at each node. For the steel section and the other connectors, a 4 nodded element SHELL 63 is used which has six degrees of freedom per node. For the composite beam with channel connector, the model consists of 35969 nodes and 31696 elements. For the beam with stud connector, the number of nodes is 35829 and that of elements is 31106. For the composite structure with perfobond connector, the number of nodes and elements are 35872 and 31149 respectively and for beam with T-connector the number of nodes and elements are 36487 and 31696 respectively.

4. Results and discussion

The composite beam is modeled with the different types of connectors and analyzed in ANSYS 14.5. The boundary conditions given is as shown in the fig 4 (b). The displacement with uniformly distributed load increments of 50.7kN is evaluated for each connector till 254kN load. The load is applied at the end face of the I-section as shear force. The maximum displacements of composite beams for the load increments is shown in table 2 and fig 5.





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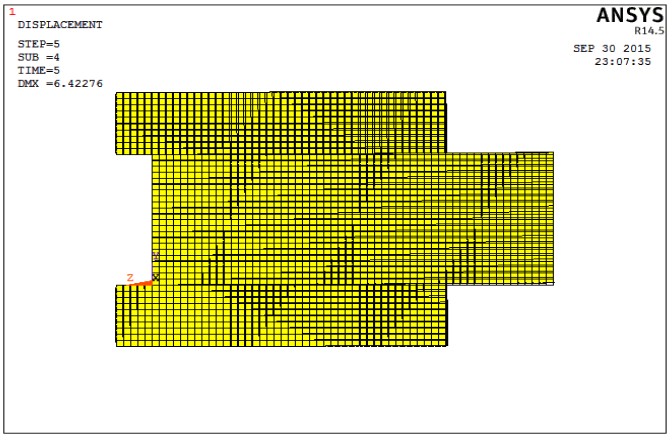
(a) (b)

Fig 4. (a) model in ANSYS; (b) model with support conditions

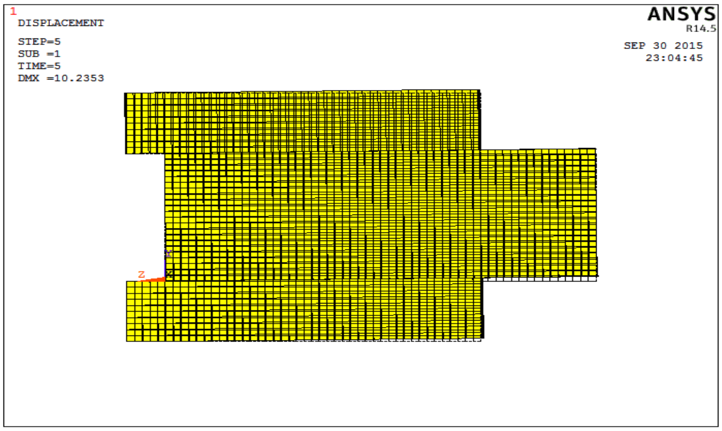
Table 2. Nodal displacements

Type of connectors	Nodal displacements (mm)				
	Load 1 (50.7kN)	Load 2 (101.4)	Load 3 (152.1kN)	Load 4 (202.8kN)	Load 5 (254kN)
Stud	1.281	2.562	3.844	5.127	6.423
Perfobond	2.04	4.057	6.129	8.1721	10.235
Channel	0.104	0.209	0.314	0.420	0.527
Tee	0.765	1.530	2.296	3.061	3.839

From table 2, it can be seen that the perfobond shear connector attains maximum displacement and the channel section attains the minimum displacement at the maximum load level (254kN).



(a)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TIME=5
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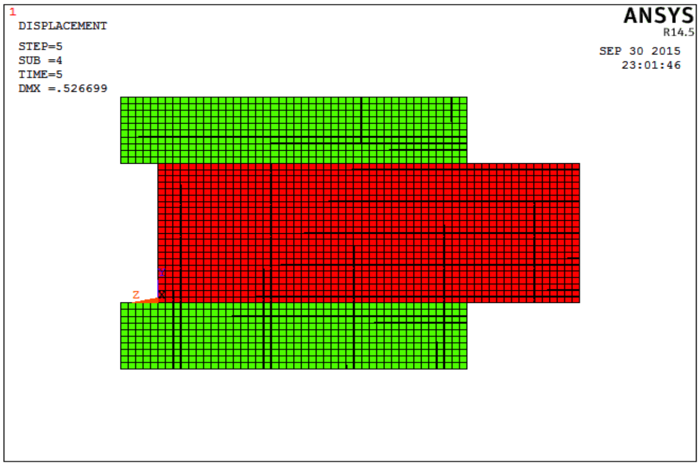
ANSYS
R14.5
SEP 30 2015
23:04:45

(b)


1
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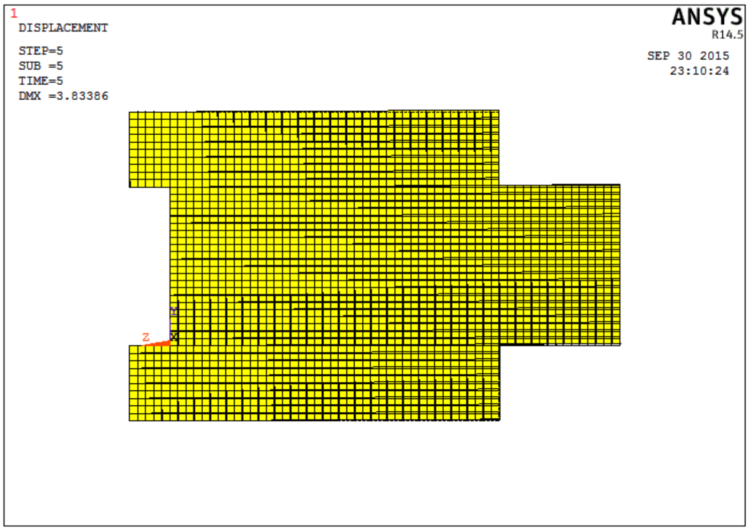
ANSYS
R14.5
SEP 30 2015
23:01:46

(c)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SUB =5
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ANSYS
R14.5
SEP 30 2015
23:10:24

(d)

Fig 5. Nodal displacements of (a) stud; (b) perfobond; (c) channel; (d) tee connectors

5. Conclusion

Finite element analysis of the different types of steel shear connectors in a composite beam has been carried out. The nodal displacements at a load of 155kN is applied in increments and the corresponding displacements has been compared. Considering the results obtained from the finite element analysis, it can be concluded that the channel type shear connector has less displacement compared to the other types and the perfobond type connector shows maximum displacement for the given load.

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