A numerical study on the behaviour of steel beam-concrete slab composite structure

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1. INTRODUCTION

Reinforced concrete slab supported over structural steel beam section or steel girder connected through shear connectors form a composite flexural section that are now widely used in civil engineering construction especially in buildings and bridges. However, the strength and stiffness of a composite section depend on the degree of composite action between the concrete and steel components. The degree of composite action is related to the geometrical and mechanical properties of the shear connectors. Both experimental and numerical ([1],[2],[3],[4],[5],[6]) approach are followed by the previous researchers around the globe to assess the functionality, behaviour under different loading conditions and failure mechanism of this composite flexural section. In the present research work it is aimed to develop a three dimensional finite element model of this composite beam section considering the nonlinear material behaviour such as cracking of concrete in tension, yielding and crushing of concrete in compression, yielding of the reinforcement bar, yielding of the structural steel and non-linear material behavior of shear connector and realistic interaction between reinforced concrete slab and structural steel section and analyzing it under the action of gradually increasing external mechanical load. The entire modeling and analysis of the composite sections has been done using finite element package ANSYS.

2. FINITE ELEMENT MODEL OF COMPOSITE SECTION

The geometrical data of a typical steel beam-concrete slab composite section and its corresponding finite element model developed in ANSYS is shown in Figure 1. While modeling with ANSYS, SOLID65 element is chosen to model three dimensional concrete elements, Link180 is adopted for flexural reinforcement bars, SOLID185 element has been taken to model the steel beam, COMBIN39 along with LINK180 elements are taken to model the shear connectors and the TARGET170 and CONTA174 elements are used to represent the contact at slab-beam interface.

3. NUMERICAL RESULTS AND DISCUSSION

The load-displacement response, the distribution of stress, and the cracking pattern obtained from the analysis of the present basic model of a simply supported composite flexural member subjected to concentrated force at the mid-span are compared with that of previous published literature [2] and it is found that there is a slight variation between the load-displacement response but other two are quite realistic. The analysis considering the contact element CONTA174 and TARGET170 have shown more nearer result to the previous one with respect to that of the solution without considering contact element.

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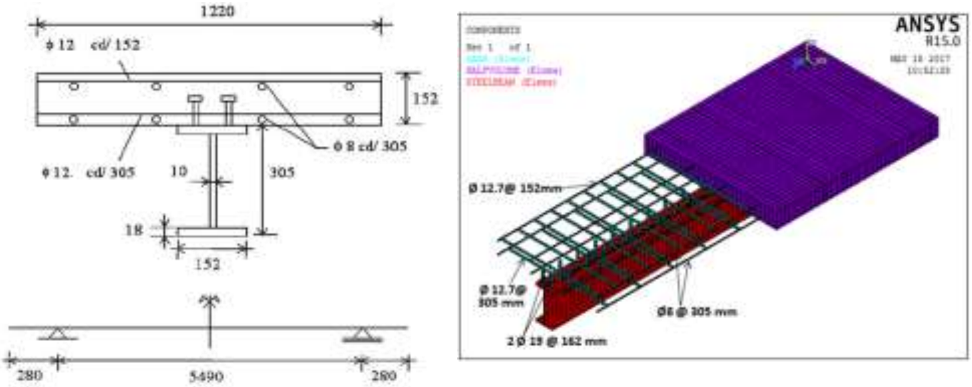

Figure 1. Cross-section of a typical composite section and its finite element model

In the first set of parametric study, the cross-sectional area of concrete slab portion and the steel beam part and their relative proportion are changed. Comparing the variation of load-displacement response coming from nine different models, following conclusions are made: a) the higher stiffness of the curve is observed for the model having higher thickness of the concrete section irrespective of the depth of steel section. But the difference is prominent for the model having lesser depth of steel section. And also it is to be mentioned that higher the depth of steel section lower the nature of the curvilinear part of the response; b) higher depth of steel section is giving higher stiffness of the model which is quite obvious. But the non-linearity in the load-displacement response is not prominent for the cases having higher depth of the steel sections compared to that of concrete section; c) the stiffness increases to a large extent with the depth of the steel section but the change in stiffness and ultimate load is due to mainly the increase in the depth of the steel section, instead of concrete section.

In the second set of parametric study, diameter, height and spacing of shear connectors are changed. The change in diameter keeping the height same as well as the simultaneous change in the diameter and the height of the shear connectors keeping the ratio between the height and diameter same does not contribute any significant variation in the load deflection curve. But it is observed that the stress in the shear connector gradually decrease due to increase in the diameter. The change in the spacing of shear connectors does not affect the overall stiffness significantly but lesser spacing of the connectors contributes to considerably high ultimate load.

Finally, it is concluded that the non-linear finite element analysis of concrete slab-steel girder composite section can be advantageously done using ANSYS but the results coming from the analysis depend on different parameters like the material behaviour, the proportion of concrete section and steel section, the reinforcement details, the mechanical properties of shear connection as well as the geometrical properties of the shear connection system.

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