HBRC Journal (2015) xxx, xxx–xxx

Housing and Building National Research Center

HBRC Journal

http://ees.elsevier.com/hbrcj

Structural analysis of a composite continuous girder with a single rectangular web opening

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Received 7 June 2015; accepted 21 June 2015

KEYWORDS

Composite steel–concrete;
Finite element analysis (FEA);
Web steel opening;
Shear connection

Abstract In the design of most bridge girders with composite girders composed of steel–concrete composite plate girders, an opening in the steel girder is often used to provide passage for utility ducts and pipes. This results in significant savings in material and construction costs. So it is necessary to study the effect of an opening in the web steel on the behavior of the composite girders if the designer wishes to provide adequate opening in the structural elements without reducing its load carrying capacity.

In this paper, a non-linear finite element analysis has been done to analyze the deflection in the steel section and internal stresses in the concrete slab for continuous composite girders with a single rectangular opening in the steel web. ANSYS computer program (version 15) has been used to analyze the three-dimensional model. The reliability of the model was demonstrated by comparison with experimental results of continuous composite beams without an opening in the steel web carried out by another author. The parametric analysis was executed to investigate the width, height, and position of the opening in one span on the behavior of a composite girder under vertical load. The results indicated that when the width of opening is less than 0.05 of length of a single span and the height is less than 0.15 of the steel web, the deflection and internal stresses increased less than 10% comparing to continuous composite girders without an opening.

Introduction

The use of composite steel beams with regular web-openings is becoming increasingly popular in multi-story building construction [1–3]. Openings are provided in the beam webs so that services can pass through the webs. In highway bridges and ship structures web openings in girders are provided in order to lighten the structure and to enable space for services, inspection and maintenance [4–7]. This form of construction results in reduced floor height, systematic installation of pipes or ducts and cost effectiveness but at the same time, causes

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Peer review under responsibility of Housing and Building National Research Center.

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http://dx.doi.org/10.1016/j.hbrcj.2015.06.004

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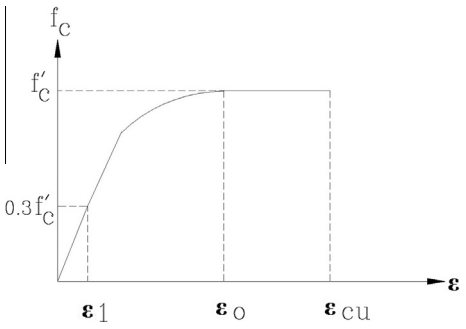

Fig. 1 Compressive stress–strain curve for concrete used in ANSYS model.

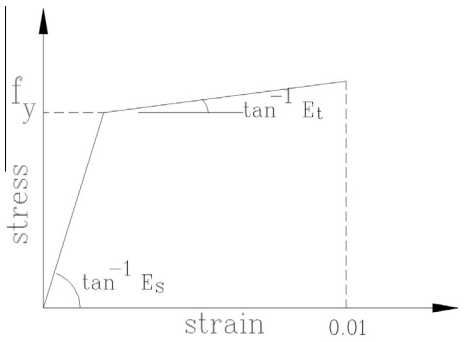

Fig. 2 Stress–strain curve for steel girder used in ANSYS model.

penalty on the shear strength of the girders depending on the parameters of the openings [2,8]. The behavior of the composite girders (concrete slab-steel girder) has been the subject of several researches all over the world [9].

It is widely known that laboratory tests require a great amount of time and, in some cases, can even be impractical [10]. The finite element method (FEM) can be used as a very useful tool in predicting the failure load of composite concrete-steel beams and can allow very detailed information for the distribution of stresses and strains in composite beams [10–12]. Ibrahim et al. [13] used a finite element model to study the behavior of simple prestressed composite beams by means of a developed computer program (ANSYS 12) and compared the numerical results to the experimental results. The numerical results showed that the behavior in the concrete slab and steel beam responded well with the experimental results. Patil and Shaikh [14] presented 3D numerical models of steel–concrete composite beams to simulate their structural behavior with emphasis on the beam-slab interface. Simulations were made using version 14.0 of the ANSYS code, based on the FEM. The results were compared with those either provided by standards, experimental work, or found in the literature, and such comparisons demonstrated that the numerical approach followed is a valid tool in analyzing steel–concrete composite beams.

A detailed literature review showed that the studies mostly focused on the behavior of simple composite girders with an opening in the steel web. Also the review showed that little information was available on the structural analysis of composite continuous girders with rectangular openings in the steel web. Therefore, the present study is concerned with the behavior of this type of structure using FEM.

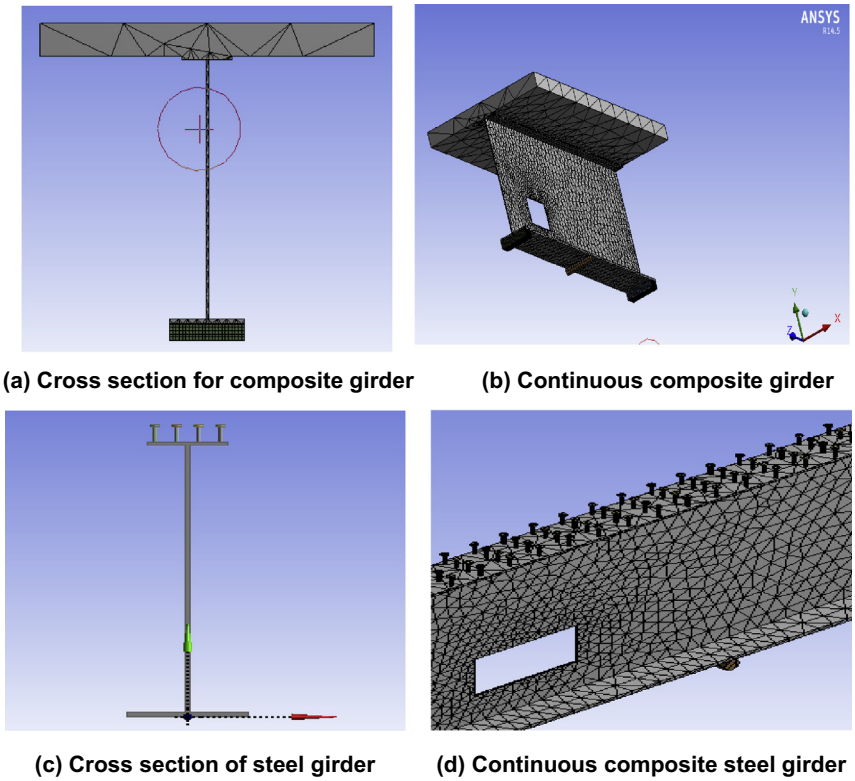

Fig. 3 (a–d): Finite element model.

Please cite this article in press as: M.A. ElShaer, Structural analysis of a composite continuous girder with a single rectangular web opening, HBRC Journal (2015), http://dx.doi.org/10.1016/j.hbrcj.2015.06.004