Journal of Constructional Steel Research 71 (2012) 83–91

Contents lists available at SciVerse ScienceDirect

Journal of Constructional Steel Research

Simplified nonlinear simulation of steel–concrete composite beams

Huiling Zhao [a], Yong Yuan [b,*], Zhiming Ye [a]

[a] Shanghai University, China
[b] Key Laboratory of Geotechnical and Underground Engineering of Ministry of Education, Tongji University, China

ARTICLE INFO

Article history:
Received 25 May 2011
Accepted 31 August 2011
Available online 20 October 2011

Keywords:
Composite beams
Macro-modeling
Shear–slip
Nonlinear analysis

ABSTRACT

A computationally efficient macro-model approach is proposed for investigating the nonlinear response of steel–concrete composite beams. The methodology accounts for material nonlinearity and interface slip between the concrete slab and the steel beam. The validity of the technique is evaluated through comparison of the macro-model-based simulations with results obtained from experimental testing of composite beams. Four full scale composite beams are tested under monotonic positive and negative bending. The results show that the proposed macro-element-model can capture the essential characteristics of the nonlinear load–deformation response of composite beams. Such an approach is a compromise between simplicity and accuracy and a viable alternative to detailed finite elements analysis. Additionally, a parametric study, including the compressive strength of slab concrete, the yield strength of the steel flanges and web, and the shear connection degree, of the steel–concrete composite beams subjected to positive moment is conducted utilizing the numerical macro-model proposed. The slips and their influences on the behaviors of composite beams during loading process have been analyzed.

1. Introduction

Steel–concrete composite beams mobilize composite action between the concrete slab and the steel beam through mechanical connectors such as shear studs. Compared to traditional steel and concrete construction, composite structures possess increased strength and stiffness and also economize cost through less construction material and more slender floor depth.

Current engineering designs of structures require inelastic deformation in the beams to achieve the ductility required in seismic design. In the case of composite beams, the interactions of different components bring associated complexities and challenges for nonlinear structural analysis. There is an increasing need for reliable nonlinear analysis tools to enable accurate predictions of inelastic limit states for composite beams. As suggested by Spacone [1], most of the nonlinear analysis models for composite structures that have appeared in the literature can be broadly categorized into micro-models applied with continuum finite elements (Nethercot and Ahmed [2], Baskar et al. [3], El-Lobody and Lam [4], Nie et al. [5]), and macro-models compiled by macro-elements such as line (frame) elements and spring connections (El-Tawil and Deierlein [6], Ayoub and Filippou [7], Sebastian and McConnel [8], Salari and Spacone [9], Ranzi et al. [10]). Continuum-based micro-models predict the behavior of composite members accurately, but such models are computationally inefficient for nonlinear analysis of complete structural systems. Simple yet reliable macro-models therefore provide an alternative approach for evaluating nonlinear frame responses. Several researchers have developed discrete line elements for composite members, incorporating concentrated or distributed plasticity. Beam-with-hinges elements are a typical application of concentrated plasticity and have been formulated by Hilmy and Abel [11], Hajjar and Gourley [12], and Kim and Engelhardt [13]. Distributed plasticity models are usually based on discrete fibers of the cross section and can be found in works of Hajjar et al. [14], El-Tawil and Deierlein [15] and Lee and Pan [16].

However, most of these formulations are complex and not amenable to generic and routine application in engineering analyses and designs.

This paper presents a simple approach for the nonlinear analysis of the composite beam considering partial interaction between the concrete slab and the steel beam. The proposed methodology can be used readily with many existing nonlinear structural analysis programs. The reliability of the proposed macro-model is validated by comparisons with experiment results obtained through full-scale tests of four composite beams subjected to both positive and negative bending. The responses by means of the macro-model are also compared to results generated from high fidelity finite element simulations. Lastly, the parameter analysis of the composite beam is conducted based on the macro-model.

2. Composite beam modeling

2.1. Proposed model

The model is proposed to represent critical characteristics of the inelastic response of steel–concrete composite beams, while with

* Corresponding author.
E-mail address: yuany@tongji.edu.cn (Y. Yuan).

0143-974X/$ – see front matter
doi:10.1016/j.jcsr.2011.08.015