Engineering Structures 33 (2011) 1277–1290

Contents lists available at ScienceDirect

Engineering Structures

journal homepage: www.elsevier.com/locate/engstruct

Mechanical properties of constitutive parameters in steel–concrete interface

Yong-Hak Lee [a], Young Tae Joo [b], Ta Lee [c], Dong-Ho Ha [a,*]

[a] Department of Civil Engineering, Konkuk University, Gwangjin-Gu, Seoul 143-701, South Korea
[b] MidasIT Co., Boondang-Gu, Seongnam 463-400, South Korea
[c] Ssangyong Eng. & Const. Co., Songpa-Gu, Seoul 138-240, South Korea

ARTICLE INFO

Article history:
Received 4 November 2008
Received in revised form
27 December 2010
Accepted 6 January 2011
Available online 5 February 2011

Keywords:
Steel–concrete interface
Bond and slip
Fracture energy
Elasto-plasticity

ABSTRACT

Mechanical properties of steel–concrete interfaces are evaluated on the basis of three existing experimental evidences. The properties include bond strength, unbonded and bonded friction parameters, residual level of the friction parameter, normal fracture energy release rate, bonded and unbonded slip fracture energy release rates under different levels of normal stress, and shape parameters defining the geometrical shape of the failure envelope. For this purpose, a typical type of constitutive model for describing steel–concrete interface behavior is presented based on a hyperbolic three-parameter failure criterion. The constitutive model depicts the strong dependency of interface behavior on bonding condition of the interface, bonded or unbonded. Mechanical roles of the interface parameters are discussed with reference to those of the presented interface constitutive model. Values of the interface parameters are determined through interpretation of existing experimental results, geometry of the failure envelope and sensitivity analyses. These values are applied to push-out tests of concrete-infilled rectangular steel columns with three different cases of interface lengths. The failure process of concrete-infilled rectangular steel columns is discussed through comparison of experimental measurements with numerical results.

1. Introduction

Numerical prediction of interface behavior using nonlinear finite element framework requires a constitutive model to describe the progressive failure localized in the interface region. Numerous research works have been made to model the localized failure process on the steel–concrete interface in the lumped manner ([1–12] among others). Most of the models except for the early work of [1] that used a Lagrange multiplier method have adopted the fracture energy release concept to depict the localized deformation process. However, even if those models are well-established based on a robust continuum theory of plasticity, the values of parameters defining the constitutive equation have to be properly determined from the experimental results for a practical purpose. The parameters may be bond strength, bonded and unbonded frictions, residual level of friction, normal (or mode I) fracture energy release rate, bonded and unbonded slip (or mode II) fracture energy release rates under different level of normal stress, and shape parameters defining the geometrical shape of the failure envelope. Little effort has been expended to extract the fundamental properties from post-peak measurements as only a limited literature is currently available [13–15]. Consequently, the lack of quantitative definition of parameters has hampered the numerical implementation to predict the behavior of steel–concrete composite structures and the further development of constitutive formulation of steel–concrete interfaces. The aim of this paper is laid on defining the mechanical properties of constitutive parameters in steel–concrete interfaces.

Steel–concrete interface behavior is defined in the normal and tangential directions to the interface plane. Once reaching their critical states, tensile and shear behaviors in the normal and tangential directions, respectively, follow mode I type of normal fracture (or debonding) and mode II type of slip fracture failure mechanisms. The slip on the interface strongly depends not only on the magnitude of the normal stress to the interface but also on the bonding condition of interface, bonded and unbonded, as [13,15] observed in their experiments performed on sandwich-typed steel–concrete interface specimen tests. To identify the constitutive parameters, a comprehensive constitutive model that accounts for the strong dependency of interface slip on the bonding condition of interface is presented by modifying the hyperbolic failure criterion of [5,7]. The modification is attained by expressing the bonded friction parameter in terms of the unbonded friction parameter and friction adjusting parameter. Values of parameters defining the model are determined through existing experimental results, geometry of failure envelope and sensitivity analyses. Only

* Corresponding author. Tel.: +82 2 450 3514; fax: +82 2 2201 0783.
E-mail addresses: leeyo@konkuk.ac.kr (Y.-H. Lee), ytj@midasit.com (Y.T. Joo), leeta@ssyenc.co.kr (T. Lee), hadongho@konkuk.ac.kr (D.-H. Ha).

0141-0296/$ – see front matter
doi:10.1016/j.engstruct.2011.01.005