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On discrete element method for rebar-concrete interaction

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HIGHLIGHTS

- Simple and comprehensive study on the interfacial characteristics in DEM.
- An optimization study to determine the characteristics of rebar-concrete interaction.
- General and accurate for considering bond-slip effects in numerical modeling.
- The ratio of surrounding pressure to compressive strength of concrete obtained.
- The range of variation for friction coefficient obtained.

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ABSTRACT

This work discusses the input parameters of discrete element method (DEM) for defining contact element between concrete and rebar. A comprehensive study is performed from a numerical database built in this study. A targeted method of discrete element model considering key parameters of bond strength between concrete and steel bar is developed for reinforced concrete structures so that DEM is customized for defining bond-slip effect between rebar and surrounding concrete. Accuracy of hypothesis is validated by an experimental program. Results show that the targeted method of discrete element model is more applicable and precise than embedded element method in which the perfect bond with no slip is dominant between the materials.

1. Introduction

The interaction between the reinforcing bar and the surrounding concrete has impressive effect on the bearing capacity and also ductility of a reinforced concrete member. In order to properly evaluate the concrete-bar interaction, it is essential to simulate the interaction effects in numerical models accurately. Discrete and embedded elements are the two common types of method used in the modeling of the reinforced concrete members.

Embedded element is a simple method for modeling reinforcing bar in concrete bulk in which the reinforcing bar is considered as an additional axial component like stiffening fiber embedded in concrete element and its nodal displacements are consistent with those of the concrete elements [1,2]. Perfect bond between reinforcing bar and surrounding concrete without slip is the basic assumption of this method. Although this method is widely applicable for modeling composite members, there is significant deviation between the experimental results and model with embedded element method [2,3]. Until now, new modified embedded models considering interactional effect between concrete and steel bar have been developed for reinforced concrete structures. Dehestani and Mousavi [3] have presented a modified steel bar model in embedded elements to consider the bond-slip phenomenon. As expressed in their study, elastic modulus of the steel reinforcing bars should be reduced in embedded elements to consider the bond-slip effects. In addition, Mousavi and Dehestani [4] have used this modified embedded element to determine the effect of rebar-concrete slippage under static and cyclic loading. They also have used proposed method in the multi-story reinforced concrete buildings. They have deduced that due to simplicity of the proposed modified embedded method, it can be used in complex composite structures.

Discrete element is an accurate method in which the concrete and steel parts are modeled separately. Although the discrete element method (DEM) leads to restrictions on mesh generation and

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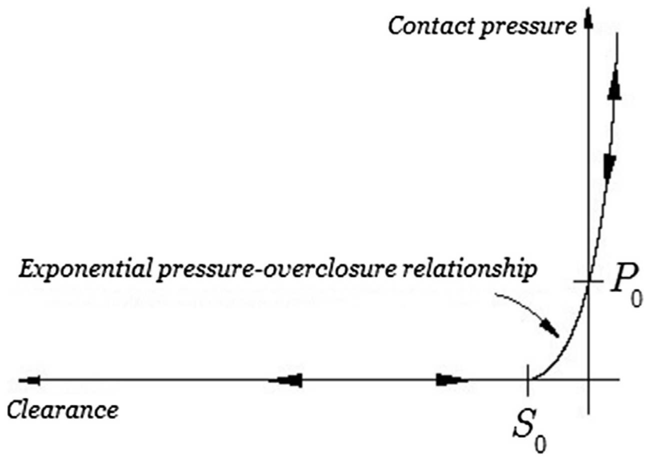

Fig. 1. Exponential "softened" pressure-overclosure relationship for contact modeling.

is very time-consuming, this type of modeling is more precise than the embedded model. So far, many researches have been accomplished on the discrete modeling of steel rebar and concrete. Ngo and Scordelis [5] have introduced bond-link model to consider bond-slip effect in finite element analysis. In their study, a node of concrete is connected to a node of steel rebar and the link element has no physical dimension. In this field, Groot et al. [6] have defined an area between surrounding concrete and rebar, denoted as bond-zone. Different kinds of movement such as translation and rotation have been defined in their method. Kwak and Filippou [7] have proposed a modified model to develop bond-link element. In their model, the stiffness of the reinforcing steel element has been reduced due to the bond-slip effect. Despite of the simplicity of the method, some of the effective parameters cannot be considered in their method. Kwak and Kim [8] have introduced a modified steel bar model in analysis of RC frame under cyclic load. In this model, the strength and elastic modulus of steel reinforcing bar are modified to consider the effect of bond-slip. Although, the procedure of this method is accurate, the method needs much computational

Table 1
Properties of specimens used in experimental tests and numerical modeling.

Type	D(mm)	C(mm)	f_c (MPa)	B(mm)	H(mm)	L(mm)	f_y (MPa)	f_u (MPa)	ε_u	Max Load (Experimental) (N)
B-1	12	30	30	100	150	900	400	600	0.09	27,351.5 26,277.3
B-2	16	30	30	100	150	900	400	600	0.09	35,113.7 28,561.8
B-3	14	20	30	100	150	900	400	600	0.09	30,526.3 34,057.9
B-4	14	40	30	100	150	900	400	600	0.09	27,421.4 28,812.0
B-5	14	30	60	100	150	900	400	600	0.09	33,837.1 28,823.0

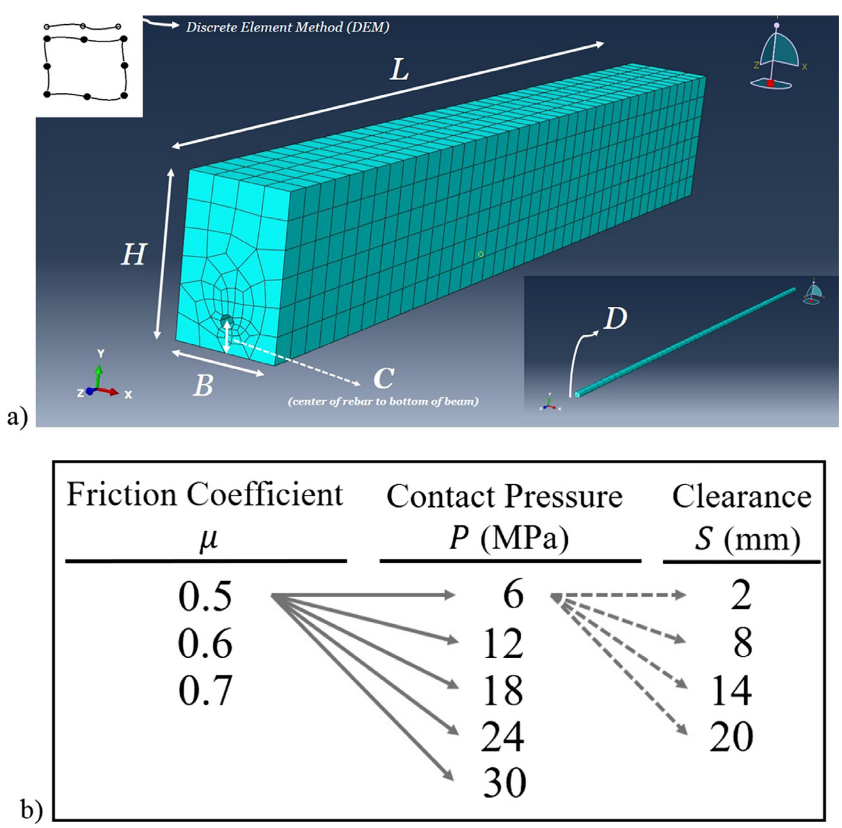

Fig. 2. Illustration of: (a) details of the beam specimens; (b) value of the key parameters used in DEM.