Modelling rebar-concrete interaction with an equivalent transition layer

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Abstract

For the finite element (FE) simulation of reinforced concrete (RC) structures, concrete-steel interaction is crucial, especially under seismic loading scenarios. Typically, a desired bond stress-slip law may be defined directly into interaction elements; however, a more direct way of using perfect bond but with a transition layer method has not been discussed systematically. This paper presents an equivalent transitional layer approach to represent the interaction (bond) behaviour from a macroscopic point of view for FE analysis. The experimental "bond"- slip phenomenon is realised through the stress and shear strain in a solid layer of transitional elements with mesh-objective equivalent material properties. This equivalent "bond" scheme is then verified by FE simulation in ABAQUS in pullout test and general FE analysis of RC structures. The model can also be employed to investigate bond-sensitive behaviours in the connection regions of precast RC columns/walls.

Keywords: rebar-concrete interaction; FE simulation; bond behaviour; RC structures; FE Analysis

1 Introduction: problem statement

The concrete-steel rebar interaction is crucial for modelling and investigating reinforced concrete structures, especially under a seismic loading scenario. Apart from the "rib scale" bond model [1], which is often applied in the detailed analysis of critical areas in an RC structure, the FE numerical modelling for bond behaviour is more generally based on the phenomenological "rebar scale" model. In such a modelling scheme, the bond behaviour is equivalently represented by spring connectors[2], interaction elements[3], or a transition layer of solid elements assuming a perfect bond at the geometric interface. A desired bond stress-slip law, which has been established in existing literature[4], can be defined directly into spring connector or interaction elements; however, a transitional layer with a perfect bond method has not been discussed systematically in the literature.

In a physical rebar-concrete bond interaction zone, especially with deformed rebar, what exactly happens at the interface is very complex, and the so-called "slip" is typically measured at a certain distance away from the true interface, and therefore is always a combination of any interface slip and shear-kind deformation within the inner layer of concrete. From this point of view, it is not unreasonable to adopt a perfect bond plus a softening equivalent concrete layer model to represent the concrete-rebar interaction zone behaviour. Similar to the "slip", the so-called "bond" strength in the physical concrete-rebar interaction zone is also a comprehensive result of interface bond and the complex damage within the concrete surrounding the rebar. The "bond" strength is neither an independent strength parameter nor a simple derivative of the concrete strength property. For this reason, for modelling the concrete-rebar interaction zone, it is rational both numerically and physically to use a solid inner layer concrete model with equivalent properties to represent the rebar-concrete stress transformation and capture the macroscopic "slip" for the interaction without explicit interface elements. This treatment will also potentially reduce a