Evaluation of the current concrete design code on shear and end anchorage of deep beams by a limit analysis based on concrete plasticity

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Summary

The current ACI code provision on the shear strength of a simply supported deep beam and its end anchorage details suggests that deep beams should be designed using the strut-and-tie model provided in its appendix. Although this is a useful methodology to design members in disturbed regions, the quality of the design is highly dependent on the truss model that designers create. In this paper, we investigate the validity of the current ACI design code on these issues by comparing the estimates by the code with those of the shear equations proposed by Hong et al. (2002). The comparison shows that deep beam members designed by the ACI strut-and-tie model approach retain the shear strengths close to the values predicted by the shear strength equations, but its requirements on end anchorage details may be rather conservative.

Keywords: strut-and-tie model; concrete deep beams; end anchorage; shear strength.

1. Introduction

The structural behavior of reinforced concrete deep beams is mainly governed by the flow of shear force in the member and their ultimate strengths are generally well predicted by the limit analysis based on concrete plasticity such as strut-and-tie models [1-5]. However, their bond and anchorage characteristics are difficult to be identified with this approach since they are highly complicated phenomena dealing with force transfer and deformation at the bar-concrete interface. Nonetheless, Hong et al. [6] derived the shear strength equations of reinforced concrete deep beams based on the upper bound theorem in the theory of plasticity by considering several realistic failure mechanisms involving their end anchorage failures. The validity of these equations was investigated through experimental work, and it showed the proposed equations are able to accurately predict the shear strength of a RC deep beam and its associated failure mechanism.

The current ACI code provision [7] on the shear strength of a simply supported deep beam and its end anchorage details suggests that deep beams should be designed using the strut-and-tie model provided in its appendix. The strut-and-tie model is a design methodology based on the lower bound theorem of concrete limit analysis and allows designers to create proper strut-and-tie models for members with geometric or static discontinuities and to provide steel reinforcement in accordance with its detailing requirements. Although this is a useful methodology to design members in disturbed regions, the quality of the design is highly dependent on the truss model that designers create. Therefore, we investigate the validity of the current ACI design code on these issues by comparing the estimates by the code with those of the strength equations by Hong et al. A representative example is chosen for this comparison, and the effectiveness of the ACI strut-and-tie model (STM) is discussed. The comparison shows that deep beam members designed by the ACI STM retain the shear strengths close to the values predicted by the shear strength equations, but its requirements on end anchorage details may be rather conservative.

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