Verification of reinforced concrete D-regions designed with strut-and-tie models by nonlinear FE-Methods

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Abstract

The design of structural discontinuities (D-Regions) of reinforced concrete (RC) structures, such as openings and dapped ends, put practical engineers in a challenging situation. Few skilled enough, develop Strut-and-Tie Models (STM) for the design. In this paper, the ultimate load capacities of a deep beam designed with STM are checked and examined with the help of nonlinear FEM simulations. These were performed with two different material models: The Concrete-Damaged-Plasticity (CDPM) in Abaqus and the Coupled-Damage-Plasticity-Microplane (MPM) in Ansys. This paper provides an overview of all the relevant aspects regarding modelling the material nonlinearities and provides an example on how to use both material models. The conclusions of this work shall pave the way for further studies, especially for D-Regions with non-metallic reinforcement such as Glass Fibre Reinforced Polymer (GFRP) rebars.

Keywords: Deep beam; D-regions; strut-and-tie models; reinforced concrete simulation; finite-element-method; nonlinear FEM; microplane; concrete material models; design; fracture energy.

1 Introduction

Structural discontinuities (D-regions), such as openings and dapped ends, are still a demanding task for the practical design. These D-regions are practically designed with Strut-and-Tie Models (STM). Alternatively, software based on the Finite Element Method (FEM) can be used. The proper use of these, however, requires deep understanding of the theoretical background. Especially when trying to simulate nonlinear material behaviour.

This paper provides an overview of all the relevant aspects, regarding the consideration of material nonlinearities. A well-known example from literature, which was designed with the use of the STM-method, has been simulated by FEM-Software. The FEM simulations were performed with the material models called the Concrete-Damaged-Plasticity (CDPM) in Abaqus and the Coupled-Damage-Plasticity-Microplane (MPM) in Ansys. A comparison of the FEM simulation results, obtained with the two different material models is given. The comparison is focused on the ultimate load capabilities. This study shows, that the STM is a good tool for ultimate load design. The conclusions of this work shall pave the way for further studies, especially for D-Regions with non-metallic reinforcement such as Glass Fibre Reinforced Polymer (GFRP) rebars.

2 Strut-and-Tie modelling

The currently method known and practically applied as the STM is due to the work of several researchers including Prof. Dr.-Ing. Jörg Schlaich and Prof. Dr.-Ing. Kurt Schäfer [1, 2] and has proven to be an effective method for the design of D-regions. Based on the lower bound theorem of plasticity it is a safe model as long as two conditions are satisfied: Equilibrium and a certain ductility of

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