

# Finite element analysis of diagonal tension failure in RC beams

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**ABSTRACT:** Finite element analysis of diagonal tension failure in a reinforced concrete beam is performed by using different meshes and different concrete crack models. It is found that inserting specific finite element bands in the mesh to model diagonal cracking improves crack localization and propagation. Multi-directional fixed crack and rotating crack models exhibit convergence problems, and lead to flexural or shear compression failure rather than diagonal tension failure. It is shown that the Multi Equivalent Series Phase Model clearly describes the complex mixed mode fracture that is typical of diagonal tension failure.

## 1 INTRODUCTION

Numerical analysis is important and effective for studying complicated mechanisms of diagonal tension failure of reinforced concrete beams without shear reinforcement, since numerical analysis can take factors influencing the failure and the causes of failure into account individually and systematically, whereas experiments cannot easily do so. In the previous study (Hasegawa 2004b) finite element analysis of diagonal tension failure in a reinforced concrete beam was performed using the Multi Equivalent Series Phase Model (MESP model; Hasegawa 1998), and the failure mechanisms were discussed by analyzing the numerical results. The first series of analysis showed that in order for diagonal tension failure of the beam to be complete, the longitudinal splitting crack should propagate unstably, leading to widening and propagation of the diagonal crack. In addition the second series of analysis with the branch-switching method was performed to simulate diagonal tension failure, assuming that the failure results from a bifurcation starting at a singular point (bifurcation or limit point) on the equilibrium path. Both series of analysis were able to simulate localization and initial propagation of diagonal cracks, but not unstable propagation of the cracks, and the formation of final shear collapse mechanism of beam could not be simulated.

In the present study (Hasegawa 2004a, 2005, 2006), based on the results of the previous analysis, another series of finite element failure analysis of a reinforced concrete beam is performed using different finite element meshes and alternative concrete crack models as factors to influence the diagonal tension failure.

## 2 ANALYSIS MODEL

### 2.1 Analysis cases D

As in the previous analysis, the diagonal tension failure of a reinforced concrete slender beam specimen, BN50, having an effective depth of 450 mm, tested at the University of Toronto (Podgorniak-Stanik 1998) is simulated in this study. The experimental cracking pattern after failure is shown in Figure 1. Figures 2 and 3 are cracking pattern results for the previous analysis cases A1 and A5. In each analysis a regular cross-diagonal (CD) mesh (finite element mesh type e-1: Fig. 4) or a random Delaunay triangulation mesh (finite element mesh type e-2: Fig. 5) was utilized. The plotted line in the figures indicates the maximum principal strain  $\epsilon_1 \geq 5\epsilon_{t0}$  with the thickness proportional to its value. This represents crack strain and crack direction

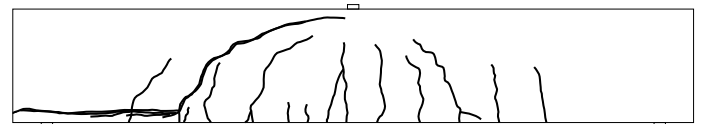


Figure 1. Experimental cracking pattern after failure.

Table 1. Analysis case.

Analysis case	Finite element mesh type	Reinforcement	Concrete crack model
A1	e-1	embedded	MESP model
A5	e-2	beam	MESP model
D1	e-1A	embedded	MESP model
D2	e-1B	embedded	MESP model
D3	e-1B	beam	MESP model
D4	e-2A	beam	MESP model
E1	e-2	beam	MDFC model
F1	e-2	beam	RC model













