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Crack Formation and Growth in Reinforced Concrete Members: The Cause for the Collapse of Buildings

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Introduction

Building collapse is frequently caused by crack development and propagation in reinforced concrete elements. Such catastrophic failures affect structural behaviour and may cause property and person harm. A thorough analysis of the fracture propagation is required. To study crack formation in a concrete part and detect fracture failure at an early stage, numerical approaches are being developed.

Description

However, in the investigation of shear fractures in reinforced concrete components, more research and action is necessary. The propagation of bending shear cracks in a concrete beam without transverse reinforcement is studied using numerical simulations and continuum mechanical models in this research. The extended finite element method (XFEM) is used as a numerical approach to map discrete fractures. The crack propagation is compared to the smeared crack propagation [1,2].

Using a concrete damage plasticity material model, the crack propagation is compared to the smeared crack technique. The fracture patterns of real beam testing are compared to the findings of several finite element models for validation. The numerical study will help to better understand fracture formation and interior force redistribution in concrete members. The XFEM allows for the prediction of concrete member fracture behaviour.

The numerical simulation of fracture propagation and the study of crack development in reinforced concrete members are still unresolved problems that are a major focus of current research. Traditionally, the finite element technique (FEM) is utilised. Because the FEM is based on a continuum approach, discontinuities like as fractures cannot be represented. Regions with high strain rates are used to map cracks (smeared crack method). The split of the crack opening into an equivalent element length of a finite element causes the smeared crack formation phenomenon. However, because the position of the distortion and the discontinuity in the displacement field are not mapped, this technique does not accurately depict the genuine crack pattern.

Alternatively, discontinuities are added at the element edges in the discrete crack technique. Due of the continual re-meshing in each iteration step, this approach is coupled with a large numerical effort. Several numerical algorithms have been developed in recent decades to overcome this problem. Numerical mechanics allows the approaches to be embedded as extensions into the FE or to construct specific approach functions such that they are no longer restricted to finite elements. Even if there are potential advantages in approaches of the last option in terms of simulation accuracy and flexibility, the computing effort is quite large, therefore extensions of the traditional FE are frequently utilised for practical purposes. One of these potential analytical tools is the extended finite element method (XFEM). XFEM, in comparison to other methods, has the advantages of a substantially faster computation time, ease of initial crack delineation and production of the needed FE mesh, and a simplified application. Discontinuities can be expressed mesh-independently using the Partition of Unity Method (PUM) and extra degrees of freedom. Cracks can be modelled as strong discontinuities inside the finite elements using the numerical approach. However, in the case of reinforced concrete members, the analytical approach provided still limits the prediction of crack propagation.

The numerical crack simulation using XFEM is briefly discussed in this study, and the approach is confirmed using the fracture pattern of beam testing from Nghiep's test series, which was undertaken as part of his research at Hamburg University of Technology (TUHH). The elastic-plastic material model "Concrete Damage Plasticity (CDP)" for concrete is used to analyse the fracture and failure behaviour of reinforced concrete elements without shear reinforcement, in particular. The test results are compared to the outcomes of this technique and the XFEM simulations. Based on a mix of plasticity and damage theory (Lee and Fenves), the CDP model assumes isotropic damage (1998). Discontinuities are mapped in traditional FEM by refining the element mesh or raising the polynomial degree of the form function utilised [3-5].

Conclusion

This refining method, however, is linked with a significant numerical effort. Belytschko created the XFEM to prevent this effort and to avoid permanent re-meshing during simulation. It is feasible to combine discontinuous geometries into the conventional FE form function and perform a mesh independent crack propagation analysis using the Partition-of-Unity Method (PUM) proposed. The notion of XFEM in combination with the PUM and the Level-Set-Method (LSM) specified for crack location.

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Conflict of Interest

None

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