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DISCRETE CRACK ANALYSIS OF RC STRUCTURE USING HYBRID-TYPE PENALTY METHOD WITH DELAUNAY TRIANGULATION

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Recent large earthquakes have caused significant damages to concrete structures. Therefore, understanding the failure mechanism of concrete structures is important. A dominant crack is initiated in a concrete structure because of tensile stress. The crack subsequently grows, propagates, and branches until the structure finally collapses. To predict the progressive failure of a concrete structure, accurate computation of a discrete crack is essential.

In the hybrid-type penalty method (HPM) developed by Takeuchi *et al.*[4], the rigid body spring model[3] is modified for calculating the elastic deformations of elements using the finite element method. The method is suitable for representing failure phenomena that occur during the transition from continua to discontinua in materials such as concrete. The HPM models a discrete crack by eliminating the penalty for the separation of elements at the intersection boundary. This procedure is easy because no change is required in the degrees of freedom of the discrete crack. In addition, it is important to correctly evaluate the deformation of the continua before crack initiation. To achieve this, we implemented a constitutive model of reinforced concrete for the HPM.

Constitutive model of the discrete crack was evaluated at the intersection boundary between the HPM subdomains. It was easy to simulate the tensile stress behavior and crack displacement using the empirical expressions introduced by Hordijk *et al.*[1] (Fig.1).

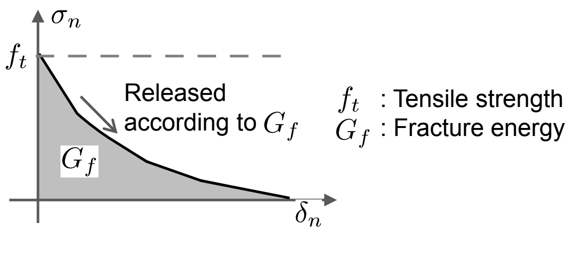

Figure 1. Tension-softening curve for concrete.

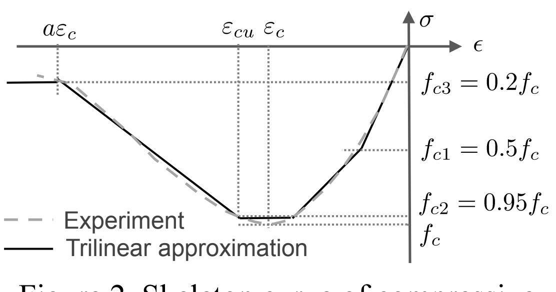

Figure 2. Skeleton curve of compressive stress.

Constitutive model of the compressive behavior was considered in the compressive stress–strain components of the HPM subdomains using the trilinear approximation function of an empirical stress–strain relationship (Fig.2). The reinforcing bar was implemented using a layered element as an anisotropic material (Fig.3).

The crack model was implemented in the HPM to solve the progressive failure problem. To confirm the validity of the new HPM, we simulated a deep beam test. A schematic of the test model is shown in Fig.4. The details of the experiment are reported by the Japan Concrete Institute (JCI)[2]. Comparison of the numerical results with the experimental observations revealed good agreement between the respective relationships between the shear force and the vertical displacement (Fig.5).

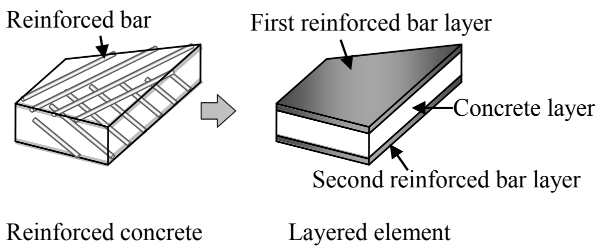

Figure 3. Modeling of reinforced concrete.

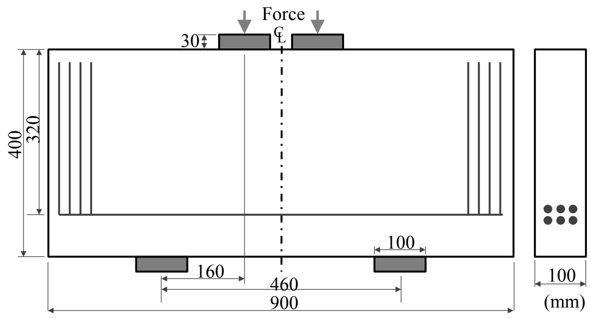

Figure 4. Schematic of test model.

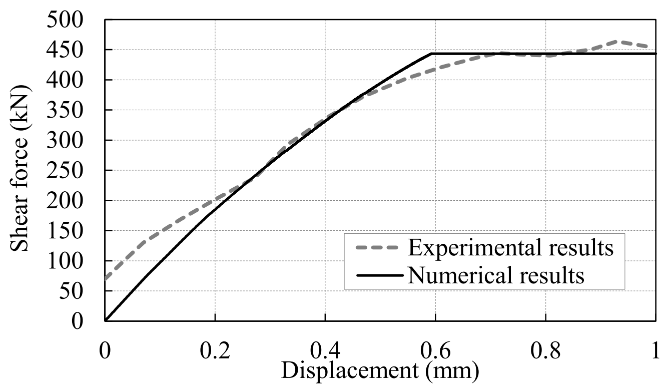

Figure 5. Relationship between shear force and vertical displacement.

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