CS-25

# FAILURE BEHAVIOR OF HIGH STRENGTH CONCRETE UNDER COMPRESSION

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## 1. INTRODUCTION

Methods for fracture analysis are divisible into two main categories. The first category including ordinary finite element and boundary element methods can be applied to problems in which the medium is regarded as continuous even after fracture, but difficulties arise if the elements become separated after fracture. The second category including distinct element and interface element methods can be used both before and after fracture continuously. The Distinct Element Method (DEM) was introduced by Cundall to analyze the granular assembly numerically. The first model[1)] used two dimensional polygonal elements and the second model[2)] used circular elements to reduce the complexity of the model and computational time. In this research the modified DEM [3)] is used to simulate the internal failure behavior of high strength concrete under compression taking into account the statistical variation of material properties between the elements. The numerical results are compared with an experiment which is conducted to a model concrete specimen.

## 2. NUMERICAL MODEL USING DISC ELEMENTS

Fig. 1 shows two general disc elements in contact with each other. In the figure, X,Y are the global axes, n,t are the local axes defined at the contact point.

The reactions of the elements can be obtained by the following equation.

$$\boldsymbol{R} \equiv \boldsymbol{KU} \quad \cdots\cdots (1)$$

where $R$ is the global reaction vector for all the elements in sequence, $K$ is the global stiffness matrix for the structure, and $U$ is the global displacement vector for the elements in sequence.

## 3. NUMERICAL SIMULATION AND EXPERIMENTAL OBSERVATION

Fig. 2 shows the simulation and experiment results for a high strength model concrete specimen under compression. In the simulation analysis the elements in the top and bottom rows are not constrained horizontally. It can be noticed from Fig. 2(d) that the stress-strain curve obtained using numerical simulation with the coefficient of variation for the material properties between the elements ($w$ = 40%) has a good agreement with that obtained from the experiment and can continue with the softening behavior up to the global failure. Also, the volume change process could be simulated numerically and compared with the experiment result as shown in Fig. 2(e). It can be noticed that the simulation result coincides with the experiment one describing the volume decreasing due to the compression occurred in the model

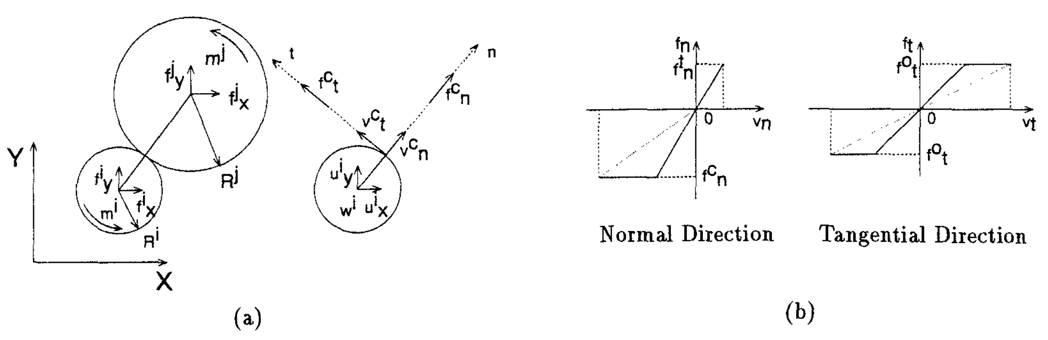


**Figure 1** Two-Disc Elements with the Material Modeling
(a) Two-Disc Elements ; (b) Material Modeling Between the Elements

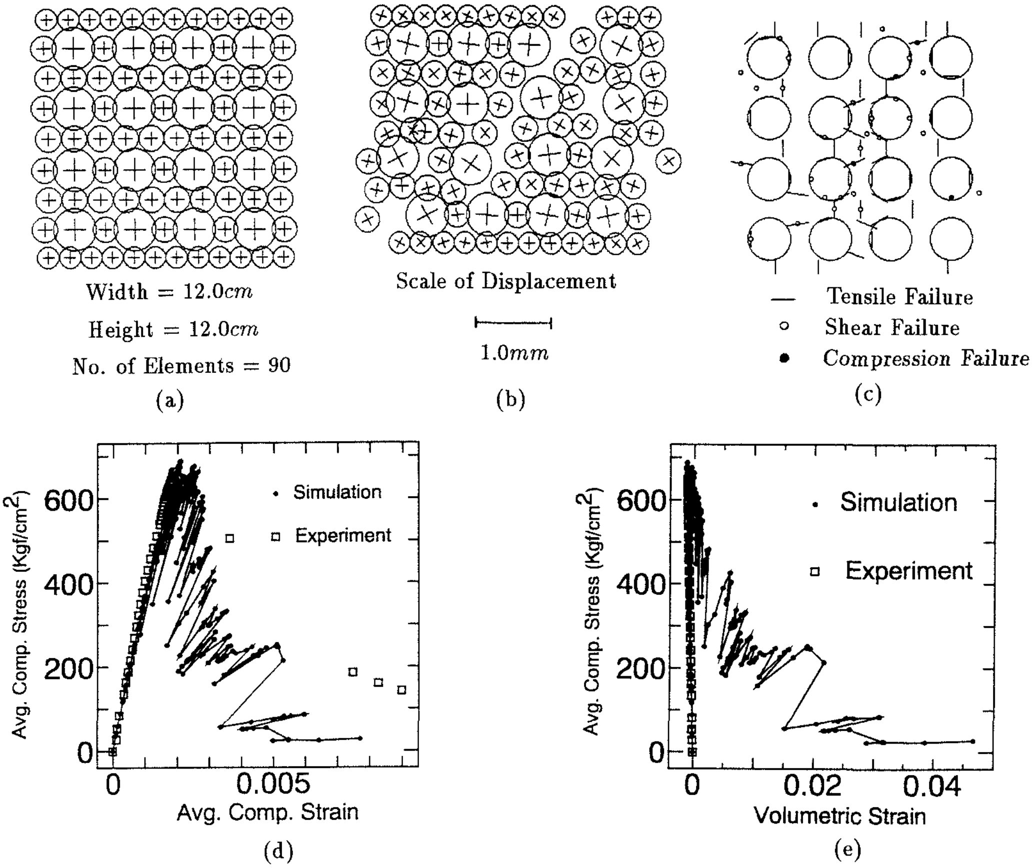


**Figure 2** Simulation of Model Specimen Under Compression

(a) Mesh Pattern ; (b) Final Deformation Pattern ; (c) Final Crack Pattern ;
(d) Stress-Strain Relationship ; (e) Volume Change Process

specimen. Also, the numerical model can continue to describe the volume expansion of the model specimen due to the excessive cracks occurred inside the specimen. The deformation pattern in Fig. 2(b) indicates that the elements near the vertical sides separate first and after that near the global failure, a nearly diagonal separation between the elements inside the model occurred due to the excessive tensile and shear cracks as shown in the crack pattern in Fig. 2(c) and that is verified experimentally.

## 4. CONCLUSION

Through numerical simulations and experimental observations, it is confirmed that the disc element model is able to simulate the stress-strain relationship and the volume change process of high strength concrete under compression up to the global failure. Also, the internal crack propagation can be obtained through the numerical model.

## REFERENCES

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