Analysis of compression failure of reinforced concrete by the Modified Distinct Element Method

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1. Introduction

To get a more clear understanding of damage and failure mechanism of civil structures during the earthquakes, a new computer program is developed for 2-D fracture and failure analysis of continuos structures using the Distinct Element Algorithm. As a step for more investigation about the failure of a large number of reinforced concrete structures during the Hanshin Great Earthquake in Kobe City, this program is used for simulation of the fracture and failure of the failed reinforced concrete structural elements. In this paper, the crack pattern and fracture mechanism of a 15x30 cm concrete specimen is studied in three cases of plain concrete, longitudinally reinforced and both longitudinally and transversely reinforced concrete, by simulating the axial compression failure .

2. 2D DEM program for granular and continuum media

Most of the DEM codes are written for granular media, using contact springs and dash pots between circular or polyhedral elements. The springs almost are linear and calculated from the Hertz's theory approximately. For considering a cohesive pore media between the elements, two assumptions have been used:
1- Element springs can resist against tension.
2- The pore media also can be modeled by spring and dash pot.
A computer program is developed for analyzing both the granular and continuum media using both element and pore springs and dash pots mostly based on the Cundall and Hakuno's formulation and assumptions with some differences in algorithm, model parameters and failure criteria. To have more realistic nonlinearity, a fiber breakage crack propagation mechanism in pore medium, is developed in this program as a new model in DEM. This program is used to analyze structural elements and systems.

3. Reinforced concrete fracture analysis by DEM

This is one of the interesting topics to know how the structures are cracked, fractured and failed during the different types of loading. specially dynamic loads (e.g. impact, earthquake,..). This research is going to simulate such a phenomenon in continuos media by Distinct Element Method.
In simulating the reinforced concrete as a continuos composite material the following models are used:

1) **Plain concrete model:** Concrete has been modeled as a dense packing of circular elements (aggregates) which are connected by springs and dash pots and the cement is modeled as pore spring and dash pot.

2) **Longitudinal reinforcement (main bars):** The main bars are simulated as circular elements with the element and pore springs and dash pots, which the pore medium has the same properties of bar material.

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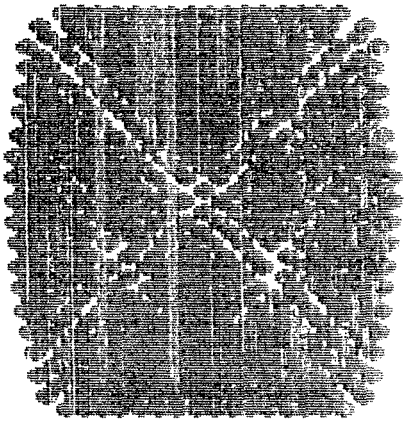
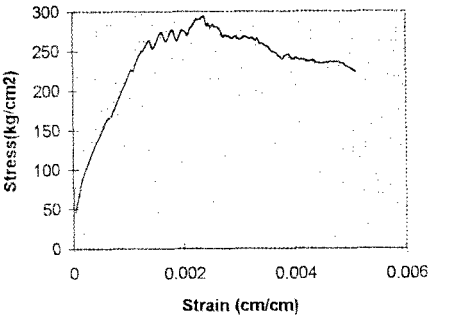
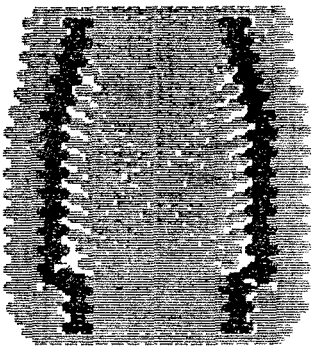
3) Transverse reinforcement (stirrups): In 3D analysis transverse bars will be modeled as main bars, but in 2D case, the confinement effect of stirrups is modeled by considering the suitable properties for concrete in the confined sections.
Some qualitative and quantitative results of stress-strain and fracture analyses of 15x30 cm concrete specimen are presented in Fig. 1.



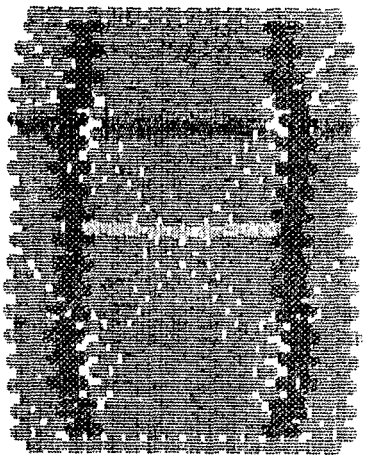
(a)Fracture of plain concrete



(b)Stress-strain curve



(c)Without stirrup



(d)one stirrup in the middle

Fig. 1 Reinforced concrete failure in compression

4. Concluding remarks

1- The method can be used for fracture analysis of continuos structure, not only for qualitative analysis of crack propagation and failure mechanism, but also for quantitative analysis using more accurate model and parameters.
2- The numerical results using the new model for crack propagation and failure of pore medium, is in a well agreement with the experimental and typical strain hardening and softening in stress-strain curve of plain concrete.