I－B 344

Fracture analysis of continuos media using *Distinct Element Algorithm*

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1. Summery

Sudden discharge of a large amount of energy, nonlinearity in geometry and physical properties of material are the main reason for fracture and failure of structural media under dynamic loads, specially earthquakes. 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 media using the Distinct Element Algorithm. Here, the crack pattern and fracture mechanism of a 15x30 cm plain concrete specimen is studied and the stress-strain relation is presented and compared with typical ones from experiments.

2. Introduction

The DEM simulation was developed by Cundall et al [1] for analysis of blocks of rock and granular media. Most of the DEM codes written after him followed the same bases which are as follows:
1- The Voigt-Kelvin model for viscoelastic behavior of material.
2- Using the Molecular Dynamic algorithm (Newton double integration scheme) for movement of elements.
3- Using an approximation (linear, nonlinear, hysteretic) of Hertz-Mindlin contact law for contact forces (contact springs for compression and shear).
4- Local damping which is related to the relative velocity between two contacted elements and global damping which is related to the relative velocity between an element and the global coordinates system.
5- The media are noncohesive granular material.

For using the original DEM for analysis of cohesive media (such as cohesive soils) or heterogeneous continuos material (such as concrete) , it is assumed that the normal contact spring can resist against tension. Also, in Culomb criteria for shear failure, the cohesive term is added to the friction.

In a modified version of DEM by Hukuno et al [2], the cohesion is modeled by another set of springs proposed by Iwashita [3].

3. Fracture analysis of continuos media

A computer program is developed for analyzing the continuos (solids) media based on the followings:
1- The circular elements represent the lumped masses which their centers are the fixed ends of viscoelastic beams which transfer the forces (compression. tension, shear and bending), due to the relative displacement and velocity of the masses.
2- For viscoelastic behaviour of the beams, a mixed model of Voigt-kelvin and Maxwell models is employed, assuming that the stiffness of elements and pore medium are almost equal.
3 - Calculating the model parameters through the macrostructure physical elastic properties.
4- The Newton double integration scheme for tracing the movement of masses (elements).
5- Using the Culomb failure criteria through the friction and cohesion of macrostructure of material.

The advantages of this method comparing to the original DEM and the modified DEM are as follows:
1- Ability of analysis of solids.
2- Faster computation because of less time for contact detection (only pore springs).
3- Applying more realistic model parameters and failure criteria.

4. Compression failure of plain concrete specimen

The results for fracture analysis of a 15x30 cm concrete specimen under the dynamic loading are presented and compared with the experimental results of reference 4. Because of the high speed of loading, the results of analysis is higher than the experimental results with a low level of loading speed.

5. Conclusion

1- The developed method is able to analyze the fracture of continuos media.
2- The mixed model of Voigt and Maxwell models are more realistic than each of them, separately.
3- The approximation of concrete response is almost same as the typical response of concrete.

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Table 1 Input data for analysis

Input Data	Unit	Concrete type	
		f'_c =200	f'_c =400
Specific gravity	kg/m3	2500	2500
Elastic Modulus	kg/cm2	210000	320000
Poison's ratio	-	0.13	0.17
Internal friction coef.	-	0.5	0.5
Cohesive strength	kg/cm2	20	40
Tensile strength	kg/cm2	20	40
Tensile fracture strain	-	0.0003	0.0003
Voigt damping ratio	-	0.03	0.03
Maxwell damping ratio	-	0.02	0.02
loading speed	cm/sec	30.0	30.0
Time step	μ sec	0.3	0.25

f'c=Ultimate compressive strength of concrete

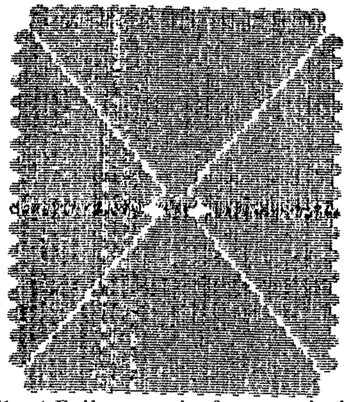

Fig. 1 Failure mode from analysis

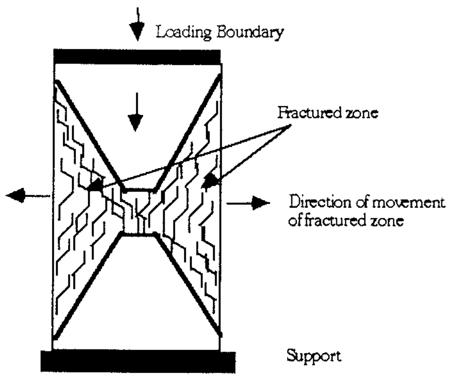

Fig. 2 Typical mode of failure

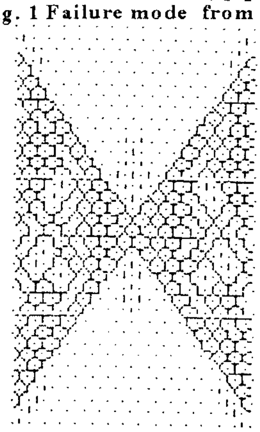

Fig. 3 Crack pattern from analysis

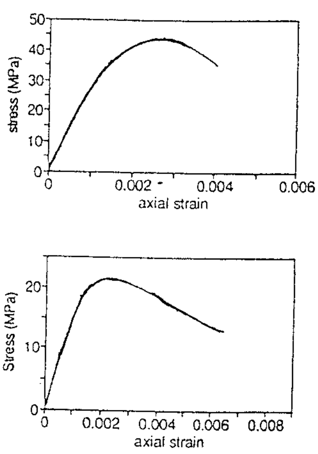

Fig. 4 Experimental Stress-Strain Curves [4]

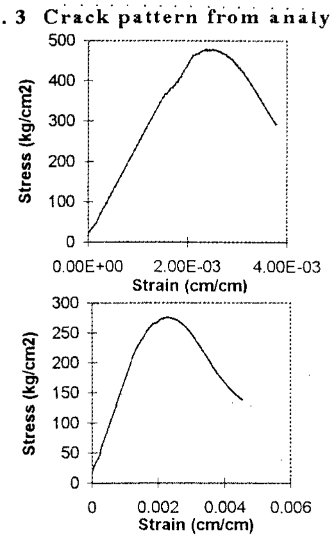

Fig. 5 Stress-Strain Curves from analysis

References

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