THREE-DIMENSIONAL DISCONTINUOUS DEFORMATION ANALYSIS (3-D DDA) COUPLED WITH FINITE ELEMENT METHOD

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Discontinuous Deformation Analysis (DDA) originally proposed by Shi [1] is a two-dimensional numerical model for the statics and dynamics of discontinuous block system. DDA method is regarded as an alternative to the distinct element method (DEM) for the analysis of jointed rock masses. As one of the members of discrete numerical method families, DDA method is similar to DEM in the aspects of model-establishment for pre-processing and description of discrete blocks' contact. However, DDA method more closely parallels with FEM in solution techniques: (1) DDA method employs the displacement model similar to that of FEM, using one order polynomial or higher polynomial approximations; (2) it establishes the global equilibrium equation by minimizing the total potential energy; and (3) it uses the penalty functional method to force block elements to meet the restraint conditions of no-penetration and no-tension at the block contact interfaces.

With many pepople contributing to its developement and applications, the original 2-D DDA has been well developed in terms of both theory and computer coding, e.g. [2]. In recent years, DDA has been also extended to three-dimensional. However, only some preliminary work on this subject has been published. Using complete one order polynomial approximations, Shi [3] presented some basic formular of 3-D DDA. Jiang and Yeung [4] developed a model of point-to-face contact as a part of the contact theory for 3-D DDA. Because one order polynomial displacement functions are assumed, so the stresses and strains within a block element in the model are constant. The approximations preclude the application of this algorithm to the problems with significant stress variations within the block.

In this paper, a numerical model that coupled 3-D DDA with finite element method is developed. The displacement field and the stress field are solved by proper internal discretization of deformable blocks using finite element meshes. The contacts between the deformable blocks are modelling by DDA algorithm. By minimizing the total potential energy, the global equilibrium equations of the coupling method are established. The stiffness matrix, the initial stress matrix, the loading matrix, the inertia matrix, displacement resistance matrix, the contact matrix and friction force matrix are derived and added to the global equations. The coupling model can not only describe the deformability of generally shaped polyhedral blocks but also solve such movement forms as sliding and opening along block boundaries, having the advantages of both DEM and FEM.

This coupling model has also been implemented into a DDA-FEM computer program. The program can divided the distinct blocks into tetrahedral elements automatically and the users can also adjust the mesh density to satisfy demand. The problem of interaction of the concrete foundation and the elastic base is analyzed to illustrate the application of the proposed method. As shown in Figure 1, the calculational model is consist of two blocks. The material constants for the concrete foundation are: Young's modulus E=300MPa, Poisson's ratio v=0.17 and density ρ =2800kg/m^3. The material constants for the elastic base are: Young's modulus E=2MPa, Poisson's ratio v=0.25 and density ρ =2000kg/m^3.The properties for contact interface between the concrete foundation and the base are: friction angle $\varphi = 30^0$, cohesion C=1KPa, tensile strength T=5KPa. The bottom boundary and four side boundaries of the base are fixed in their respective normal directions. Besides the self-weight loading, a uniformly distributed loading q=100KPa is acted on the top boundary of the concrete foundation. Figure 2 shows the settlement deformation of the elastic base (the displacements are magnified to 10 times), and Figure 3 shows the normal contact forces distribution on the interface between the concrete foundation and the base. Obviously, the normal contact forces ar concentrated at the corner of the interface.

In conclusion, the coupling method which incorporates a finite element mesh into the distinct blocks is a significant development in DDA. It not only overcomes the difficulties of using a simple constant strain concept to represent deformations of geometrically complex blocks, but also provides a platform for developing algorithms for progressive failure of rockmass structures.

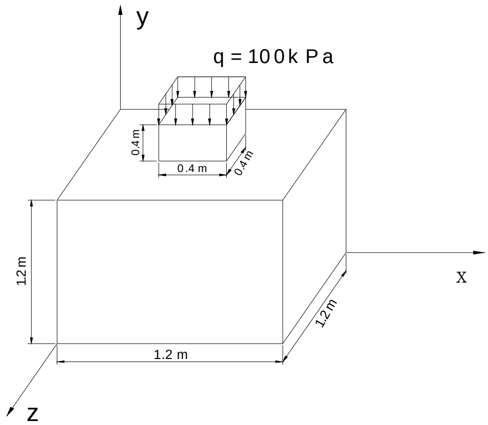

Fig.1. Interaction of the concrete foundation and the elastic base

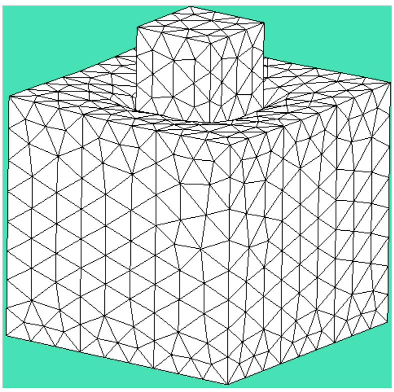

Fig.2. Settlement deformation of the base

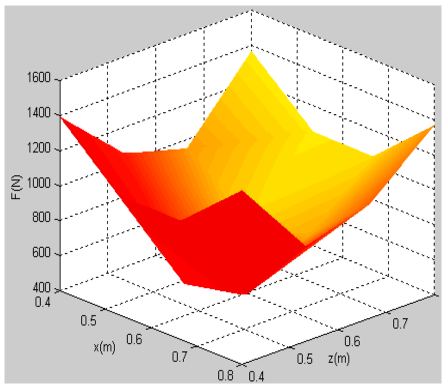

Fig.3. Normal contact forces distribution

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