Numerical simulation of failure process of rock mass with a joint

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Abstract. In this paper failure process of rock mass with a natural joint is presented by numerical simulation based on RFPA^{2D}. numerical simulation shown that failure of rock mass with a natural joint begin first in joint for rock mass, with the increase of the vertical load, joint is closed, along the joint plane within the rock mass near the damage area, rock mass became damaged gradually near joint, the damage area expands unceasingly, then cave is formed. That provided location and avenue for movement and accumulation of underground water .That is of significance and valuable to research strength for jointed rock mass and to research mechanism of propagation and coalescence and evolvement of joints in rock mass and to research mechanism of mine water and gas outburst in underground mining and to research catastrophe and bifurcation of non Darcy flow system in post failure of rock mass. Numerical simulation shown that when angle between the joint plane and horizontal plane is 30^0 , and when the lateral pressure is 1 Mpa, compressive strength of rock mass with a natural joint is compressive strength of 25.9% without joint.

Introduction

In the study of rock mass mechanics, crack propagation and the polymerization is an important content in the research of rock fracture mechanics. It is difficult to research the failure process for rock mass with natural joint under the load condition by analytical method. With the development of numerical simulation technology, Using numerical simulation method to study contains natural joint rock fracture process under outside load has become possible. RFPA, rock failure process analysis system provides the economy method to research rupture process containing natural joint rock. To research failure process containing natural joint rock under the influence of outer load, for revealing aggregation and transfixion and evolution mechanism under the influence of outer load extension, to research groundwater migration and enrichment regularity, the mine water inrush hazard mechanism, has the research significance and application value.

Numerical Model

In order to simulate the natural joint rock failure process, the mesh elements used for this modeling is 100×100 in elements with a geometry of 100mm×100mm×100mm in size, as shown in Fig.1 and the simulated rock sample for sandstone is with a geometry of 100mm×100mm×100mm in size, all the elements have the same size, the mechanical parameters， such as strength and elastic modulus of element, according to the statistical strength theory obeys weibull distribution

$$\Phi(x) = \frac{m}{x_0}(\frac{x}{x_0})^{m-1} e^{-(\frac{x}{x_0})^m} \qquad (1)$$

Numerical simulation model and mechanical parameters

Numerical simulation model is divided into 100 x 100 units, to simulate the large size 100mm×100mm×100mm cube contains natural joint sandstone samples. joint plane and horizontal

plane angle is 30 degrees. As shown in figure 1. Numerical simulation model of the sandstone rock mechanics parameters are shown in Table 1, the numerical model of the joint mechanical parameters are shown in Table 2.

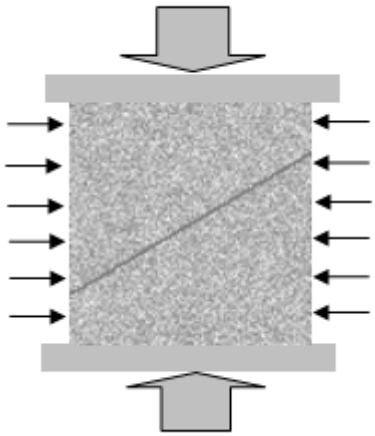

Fig.1 Numerical simulation model containing natural joints for large size sandstone

Table 1.Parameters of numerical simulation for sandstone

Homogeneneity index, m	3
Mean elastic modulus, $E_{\circ}$, Gpa	20
Average compressive strength of elements for rock σ_o, Mpa	80
Internal friction angle, ϕ°	30
Poisson's ratio, μ	0.25
Ratio of compressive to tensile strength, C/T	10
Confining pressure, Mpa	1

Table 2. Parameters of numerical simulation for natural joint

Homogeneneity index, m	3
Mean elastic modulus, $E_{\circ}$, Mpa	1
Average compressive strength of elements for rock σ_o, Mpa	0.1
Internal friction angle, ϕ°	30
Poisson's ratio, μ	0.25
Ratio of compressive to tensile strength, C/T	10

Boundary conditions and loading method for Numerical simulation

Numerical simulation model for lateral pressure is 1 Mpa , axial pressure load by displacement control, the initial value of axial load displacement is 0.001 mm, axial load displacement increment is 0.1 mm/each step, the total number of numerical simulation is 700 steps.

Numerical results

Based on RFPA ^{2D} ,Numerical simulation of failure process containing natural joint sandstone joint rock is shown in figure 2. numerical simulation of failure process of no joint sandstone cube sample under lateral pressure 1 Mpa is shown in figure 3. Numerical results shown that contains a single natural joint sandstone cube sample when the lateral pressure is 1 Mpa, peak load Nmax = 6555 N. Therefore contains a single natural joint sandstone cube sample when the lateral pressure is 1 Mpa, Compressive strength of rock mass is 6.555 Mpa, However, without joint sandstone cube sample when the lateral pressure is 1 Mpa, Compressive strength of rock mass is 25.276 Mpa

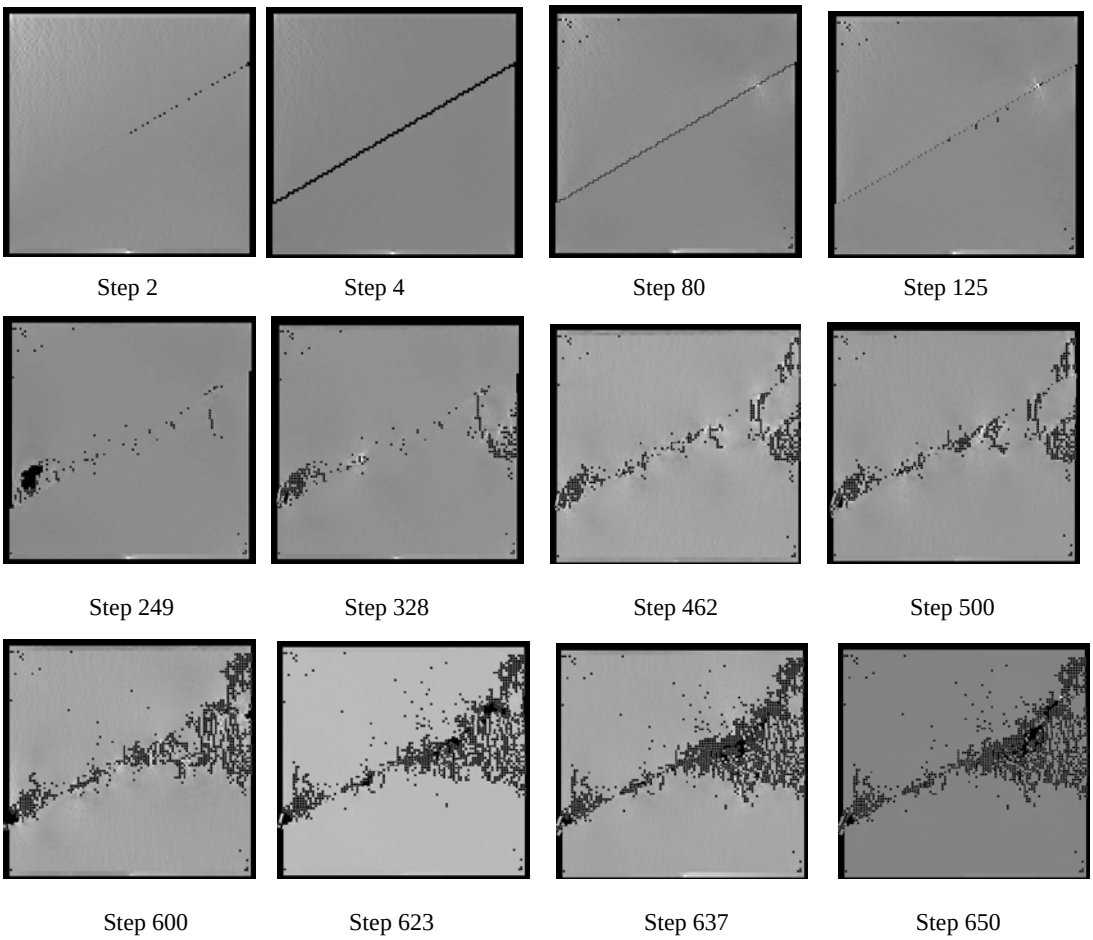

Fig 2. Failure process of compressive experiment of rock mass with a natural joint by numerical simulation.

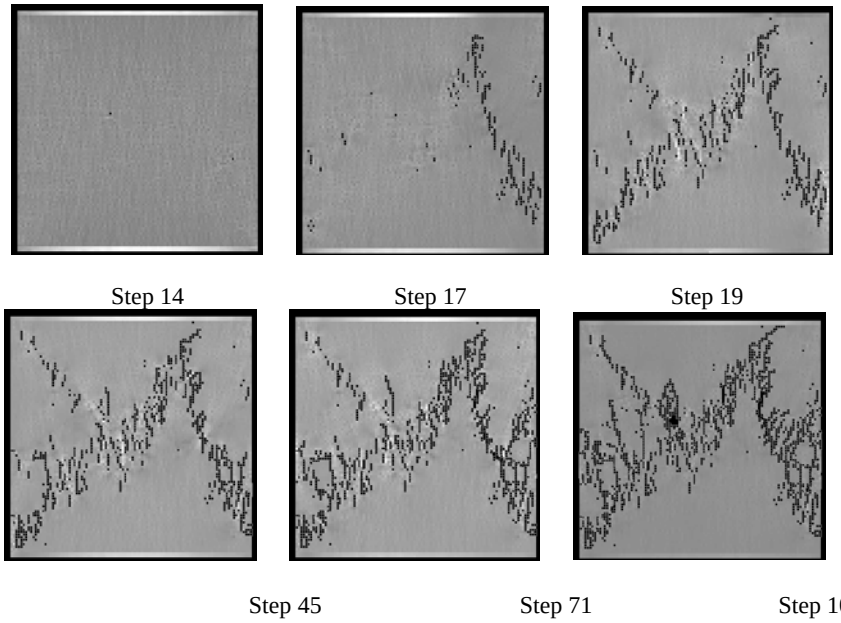

Fig 3.The Failure process for sandstone without joint for numerical simulation

Conclusions

In this paper failure process of rock containing a natural joint by numerical simulation, the following preliminary conclusions can be obtained:

1. With a single natural joint, joint plane and horizontal plane Angle of 30 degrees, containing a single joint rock compressive strength is no joint rock compressive strength of 25.9%.

2. Contains natural joint rock failure process from the results of numerical simulation can be seen that the joint rock burst, starting from the joint rock mass, cracking along the joint part, first, the rock mass along the joint plane all through. Along with the increase of the vertical load of the rock mass, joint was closed. Along the joint plane, the rock mass within the rock mass near the damage area. With the increase of the vertical load, the damage area expands unceasingly, along the joint plane of rock mass near formation connected channels and hollow. For the occurrence of groundwater, gather and provide the places and ways, also affected by mining, for research on joint rock peak after the non-Dacy seepage mutation and bifurcation, provides the basis of a visual image which is significance to understand the performance of the rock in deep underground.

Acknowledgements

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References

[1] C.A.Tang, Numerical simulation of progressive rock falure and associated seismicity. Int J Rock Mech Min Sci[J] 1997.34(2):249-261

[2] C.A.Tang, S.Q.Kou, Crack propagation and coalescence in brittle material under compression, Engineering Fracture Mechanics [J]. 1998.61:311-324

[3] E.Hoek, E.T.Brown, Underground excavation in rock[M], London, 1980.

[4] C.A.Tang, Numerical test on micro-macro relationship of rock failure under uniaxial compresion ,part I: effect of heterogeneneity, Int J Rock Mech Min Sci[J],2000, 37: 555-569

[5] C.A.Tang,.B.Zhang,Z.Z.Liang,T.Xu,L.G.Tham,P_A.Lindqvist,S.Q.Kou,H.Y.Liu,Fracture spacing in layered materials and polygonal fracture, Physical Review E [J], 2006, 73(3): 70-83