DICE2D

1. Calibration experiment

1.1 Model setup

The two-dimensional numerical specimen of three types of rocks for UCS test was 100 mm in height and 50 mm in width. Each specimen contained 37,242 particles, with radius distributed within 0.15 to 0.25 mm. The rock specimen for BTS test was a circle specimen with a diameter of 50 mm. It contained 14,738 particles. The two tests adopt the same loading conditions. The vertical speed applied to the up and low walls were set to -0.05m/s and 0.05m/s simultaneous. The time step was set to 2.5×10^{-8} seconds to ensure numerical stability. The corroding displacement increment of cutters is only 2.5×10^{-9} m/ step. A local damping coefficient was set to 0.7 to make sure simulation remains in quasi-static conditions.

1.2 Calibration procedure

(1) Adjust the ratio of the normal to shear stiffness to match the Poisson's ratio.

(2) Adjust the normal shear stiffness to match the Elastic module.

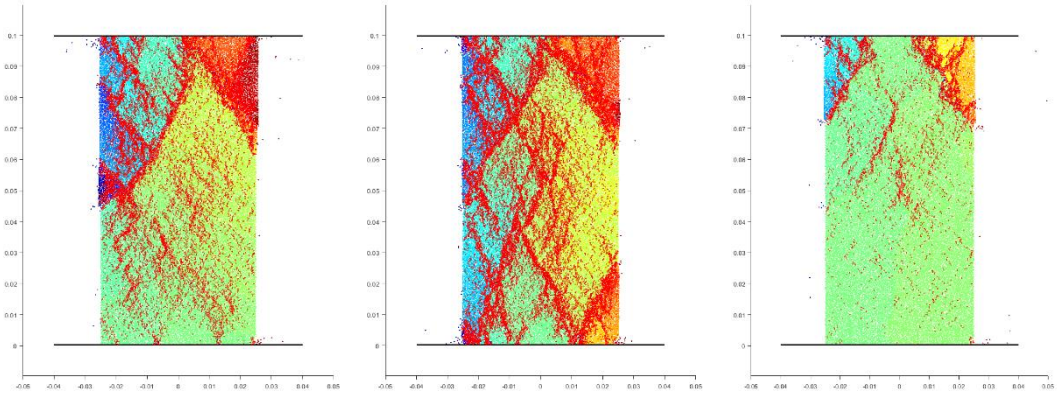
(3) Adjust the *Ft* and the ratio of *Fc* to *Ft* to match the UCS and BTS.

1.3 Calibration result

Table 1. Calibrated parameters of three types of rocks for the numerical simulation

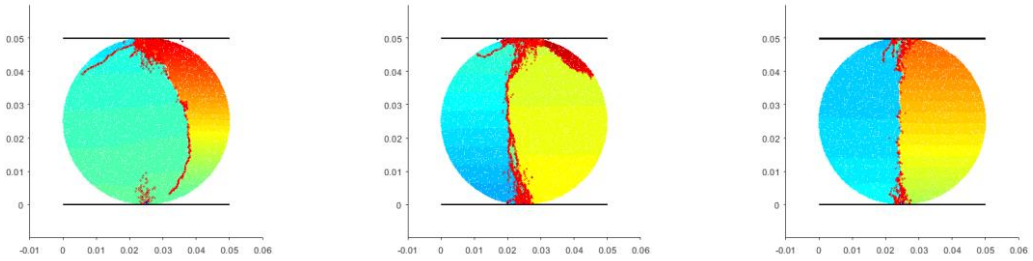
	Parameters	Rock types		
		Granite	Marble	Red-sandstone
physical experiment	Compressive strength (MPa)	159.30	121.38	116.44
	Tensile strength, (MPa)	7.19	6.06	5.78
	Young’s modulus (Gpa)	42.25	59.70	21.09
	Poisson’s ratio	0.265	0.274	0.225
numerical simulation	Compressive strength (MPa)	163.1	125.9	113.1
	T ensile strength, (MPa)	14.5	11.2	9.5
	Young’s modulus (Gpa)	41.95	59.5	21.2
	Poisson’s ratio	0.259	0. 271	0.227

1.4 Failure pattern



(a) Granite (b) Marble (c) Red sandstone

Fig 1 Failure pattern of UCS test.



(a) Granite (b) Marble (c) Red sandstone

Fig 2 Failure pattern of BTS test.

2. Prediction experiment

2.1 Model setup

The two-dimensional numerical specimen of three types of rocks for prediction test was 100 mm in height and 100 mm in width. The diameter of the hole in the center of the sample was 20 mm. The specimen contained 72,147 particles. The three types of rocks were built according to the above microscopic material parameters, respectively. The loading conditions were used for the previous tests. Five test were performed for each rock. Each test sample was randomly assigned the strength parameters of contacts as a normal distribution N (f_t, $(0.1f_t)^2$). The final result was taken as the average of the five experiments.

2.2 Predicted strength

Rock type	Peak compressive strength (MPa)						Average (MPa)	Predicted peak force (KN)
	1	2	3		4	5		
Granite	107.9	108.6	104.4	103.0	105.3	105.8	105.8	529.2
Marble	82.3	85.6	81.9	85.1	79.4	82.8	82.8	414.2
Red-sandstone	76.8	74.3	76.1	73.8	72.5	74.7	74.7	373.3

2.3 Failure pattern

(1) Granite

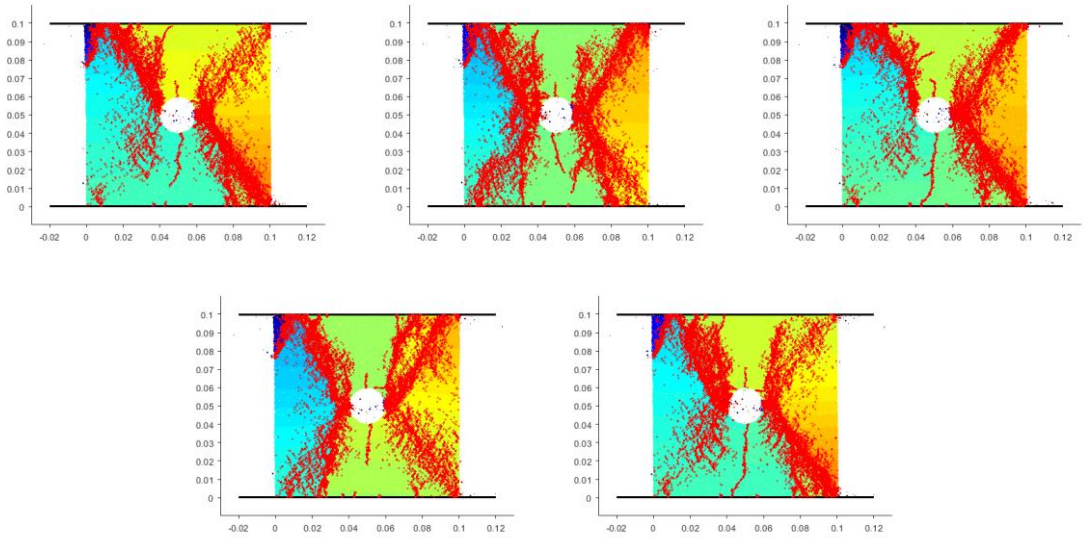
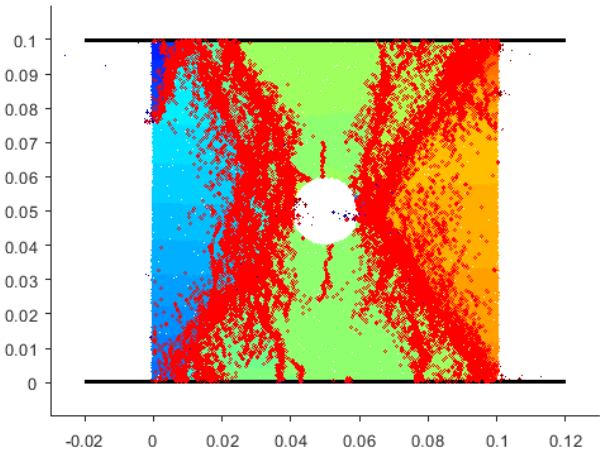


Fig 3 Failure patterns of the UCS test for granite with a hole.

(2) Marble



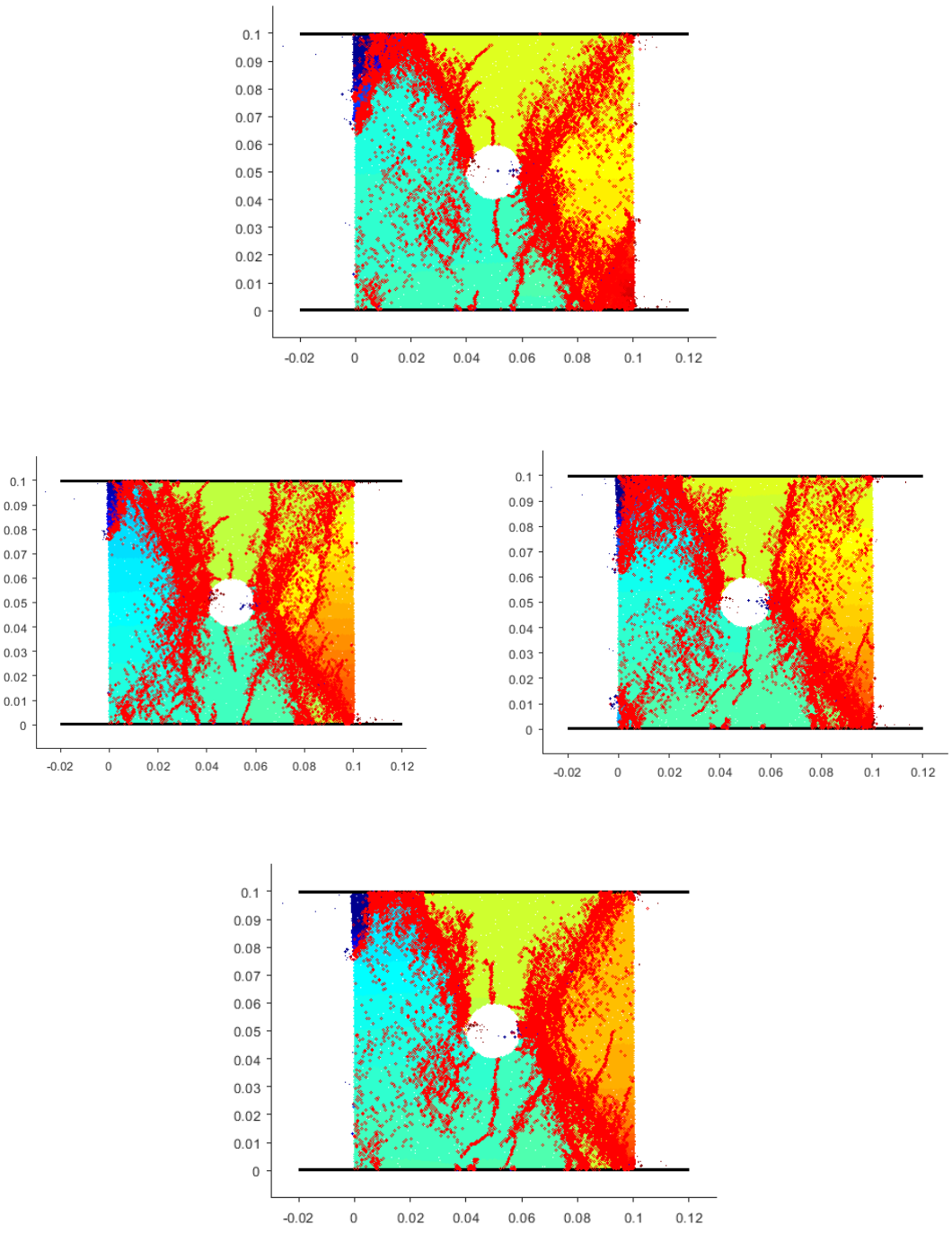


Fig 4 Failure patterns of the UCS test for granite with a hole.

(3) Red-sandstone

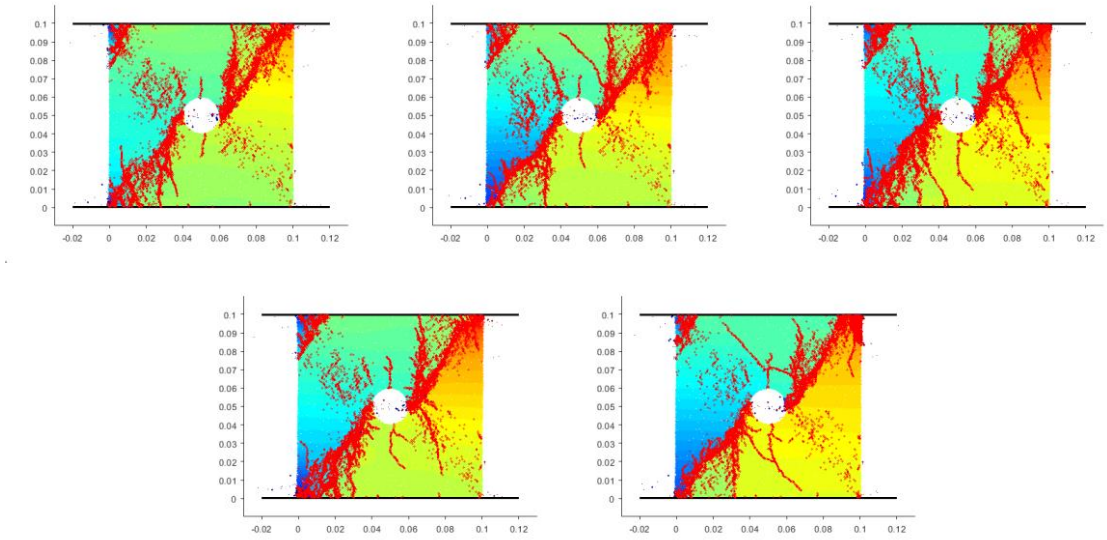


Fig 5 Failure patterns of the UCS test for Red-sandstone with a hole..