LS-DYNA

The numerical model reproduces the realistic geometry of experimental sample, i.e., cylindrical sample with a diameter of 50mm and a height of 100mm, Brazilian disc with a thickness of 25mm and a diameter of 50mm, and cubic sample with a dimension of 100mm×50mm×100mm (length × width × height) and a hole diameter of 20mm. The numerical setups and boundary conditions for various loading scenarios are illustrated in Fig. 1, where both specimen and platens are discretised by solid elements. The element size of specimen is between 0.5mm~1.0mm, and a total of 246,502, 873,400, 1,384,402 elements are used in Fig. 1(a), Fig. 1(b) and Fig. 1(c) respectively after a mesh sensitivity study. A velocity loading boundary with a constant value of 0.01mm/s to mimic the quasi-static condition is applied on the upper platen while the supporting end of the bottom platen is fixed. "Automatic_surface_to_surface" is adopted to characterise the contact between the platen and the specimen, and a static friction coefficient of 0.50 is selected as suggested in [1-2]. Mohr-column criterion in LS-DYNA is used to reproduce the mechanical behaviour of rock materials, while rigid model is selected for the platens due to their negligible deformation during the loading process in experiment. The input parameters for platen and three type of rock materials are listed in Table 1.

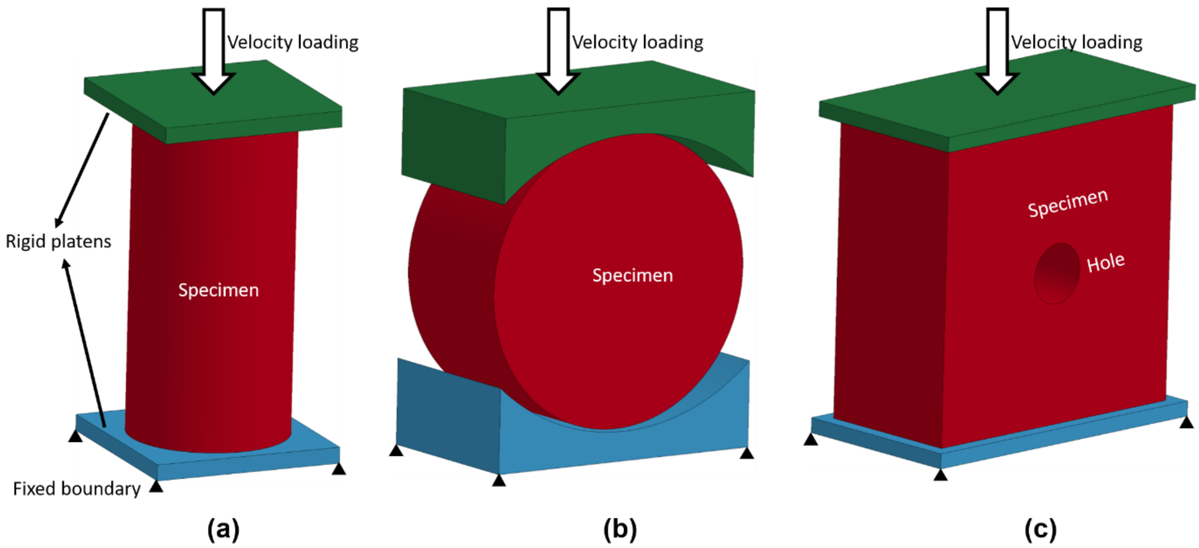


Fig. 1 Numerical setup for (a) uniaxial compression on cylinder (b) Brazilian test on disc and (c) uniaxial compression on cuboid with a hole

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

Parameters	Granite	Marble	Red sandstone	Platen
Density (g/cm^3)	2.63	2.85	2.43	8530

Poisson's ratio	0.265	0.274	0.225	0.30
Young's modulus (GPa)	42.25	59.70	21.09	210
Friction angle (°)	50.18	51.11	53.74	-
Cohesion (MPa)	29.00	21.50	19.10	-

The simulated results of granite, marble and sandstone in UCS (uniaxial compression strength) and BTS (Brazilian tensile strength) tests including failure mode, UCS and BTS are given in Fig. 2, Fig. 3 and Table 2. It can be seen from Fig. 2 that when subjected to uniaxial compression condition, X type failure mode is observed in granite and marble, while Y type failure mode is more dominate in red sandstone. As for the failure mode under Brazilian test, a curved failure band in the middle of the disc is observed in all rock materials as shown in Fig. 3. In addition, the simulated UCS matches very well with the experimental values, while the predicted BTS is a bit higher than the experimental results, see Table 2. The reason may be due to the unsatisfied performance of Mohr-column criterion in describing the tensile performance of rock materials.

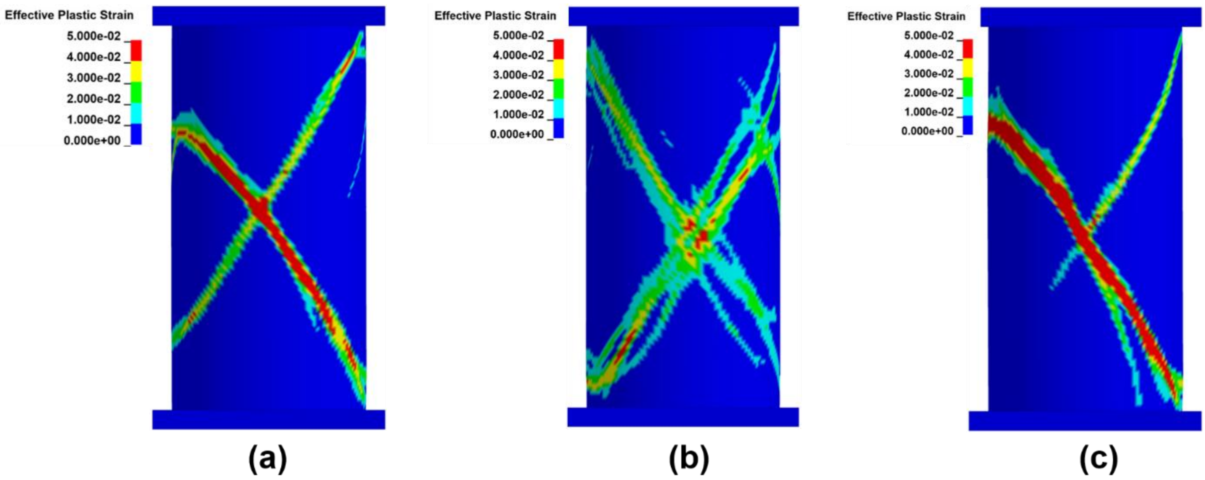


Fig. 2 Simulated failure mode of (a) granite, (b) marble and (c) sandstone under uniaxial compression

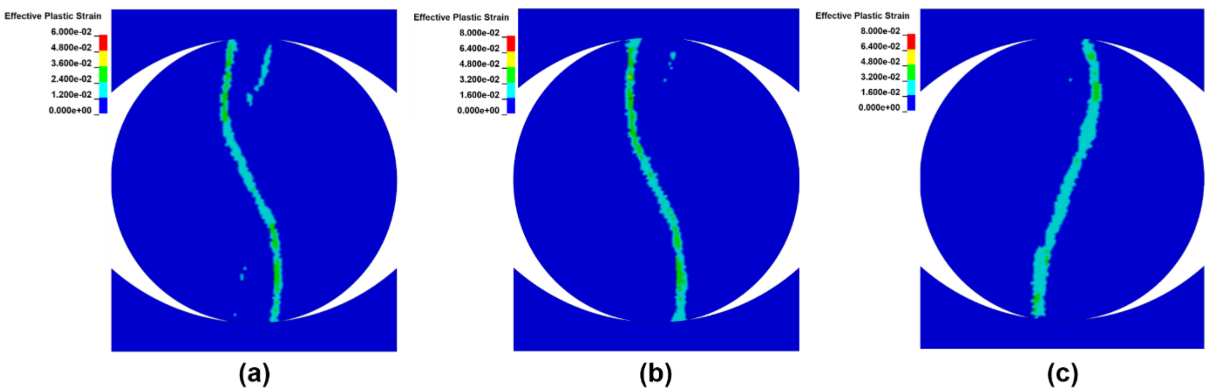
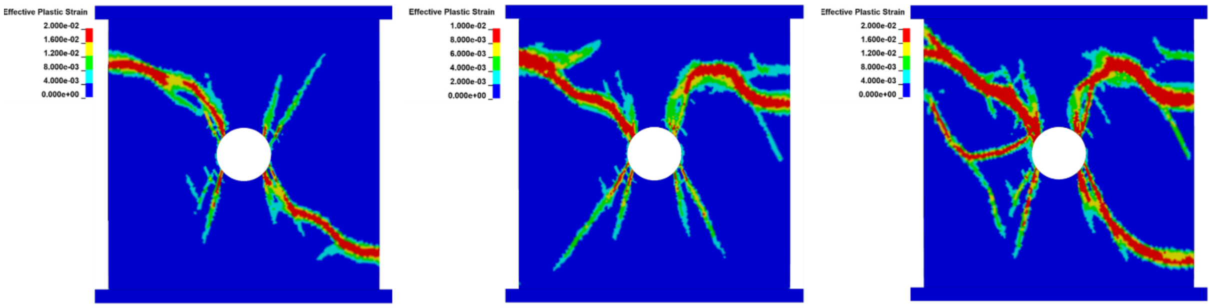


Fig. 3 Simulated failure mode of (a) granite, (b) marble and (c) sandstone under Brazilian test

Table 2 Comparison between experiment and simulation on Granite

Rock type	UCS (MPa)		BTS (MPa)	
	Experiment	Simulation	Experiment	Simulation
Granite	159.30	154.9	7.19	14.17
Marble	121.38	117.19	6.06	9.98
Red sandstone	116.44	112.61	5.78	8.97

The predicted failure pattern and peak compressive load for cuboid rock specimen with a hole are given in Fig.4 and Table 3 respectively. As illustrated in Fig.4, the crack mainly propagates along the diagonal direction of the specimen and the model mainly presents shear failure mode, regardless of the rock type. However, the sandstone presents a more tortuous and complicated damage pattern compared with granite and marble. In addition, the predicted compressive load for granite, marble and sandstone is 62.2kN, 47.7kN and 45.5kN, respectively.



(a) (b) (c)

Fig. 4 Predicted failure mode of cuboid (a) granite, (b) marble and (c) sandstone specimens with a hole under uniaxial compression

Table 3 Predicted peak load of three types of rocks

Rock material	Peak compressive load (kN)
Granite	62.2
Marble	47.7
Red sandstone	45.5

Reference

[1] Kucewicz M, Baranowski P, Małachowski J. Determination and validation of Karagozian-Case Concrete constitutive model parameters for numerical modeling of dolomite rock. International Journal of Rock Mechanics and Mining Sciences. 2020 ;129:104302.

[2] Weeks JD, Tullis TE. Frictional sliding of dolomite: A variation in constitutive behavior. Journal of Geophysical Research: Solid Earth. 1985;90(B9):7821-6.