CASE STUDY: TRUE TRIAXIAL APPARATUS OF ROCK

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The Key Laboratory Ministry of Education on Safe Mining of Deep Metal Mines at Northeastern University was launched in 2011.

The laboratory focuses on process evaluation, disaster control, safe and high efficiency mining technology in the field of stability and catastrophic evolution of complex engineering rock mass in deep metal mines.

The laboratory is equipped with advanced facilities and some self-developed research equipment and has completed over 100 projects, resulting in over 30 granted national invention patents, and more than 300 papers published. In November 2016, the 111 project of the education and the state administration of foreign experts was approved. The laboratory has established many working relationships with research institutions in the USA, Canada, UK, and Australia.

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THE PROBLEM

Engineering activities such as underground mining and large excavation of unconventional resource, are all potentially liable to induce engineering disasters such as earthquake, rockburst and large-scale collapse. The rock mass in the earth's crust are usually subjected in the true triaxial stress state (Feng et al, 2016), but the majority of existing rock testing apparatus can only simulate the conventional triaxial stress state, which is not in accord with the actual stress state of rock mass (shown in Fig 1).

In addition when using a single actuator designed for active loading in the vertical loading direction only, the centre of the rock specimen will deform and so the parameters obtained are also not appropriate. Based on the considerations above, it was necessary to modify a true triaxial apparatus to understand the deformation and strength behaviour of rock mass under complex stress paths.

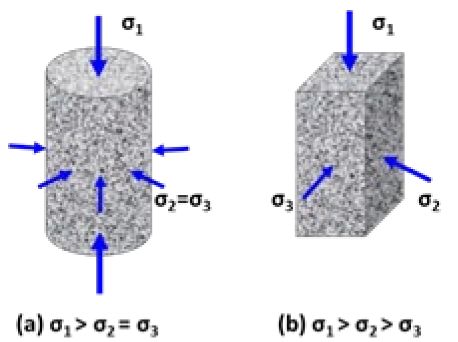

Fig 1. Illustration of stress state under (a) conventional triaxial compression, CTC and (b) True Triaxial Apparatus (GDSTTA).

THE SOLUTION

To simulate the complex multi-axial stress conditions of rock, a customized GDS True Triaxial Apparatus (GDSTTA) for rock (as shown in Fig 2) was manufactured for Northeastern University, combining the design requirements of the customer and Earth Products China (EPC).

Fig 2. GDS True Triaxial Apparatus of Rock (GDSTTA)

The GDSTTA consists of two vertical and two horizontal servo-motor actuators for applying σ_1 and σ_2, and two high-performance pressure controllers to apply confining pressure and pore pressure respectively. The axial stress (σ_1), horizontal stress (σ_2), confining pressure (σ_3) and pore pressure can be controlled independently.

For the GDSTTA, the stiffness of the loading frame is evaluated as 1GN/m, and the actuators are designed to produce a force up to 32kN. The confining pressure and pore pressure are both 2MPa. The dimension of the rock specimen is 20mm×5mm×40mm (Fig 3). Four LVDT's are used to monitor the displacement of the actuator and specimen deformation. Four internal encoders are configured to provide maximum accuracy and resolution, which can also be used to verify the sample LVDT's for additional test confidence. In the advanced software module, the synchronous off-centre loading function is able to accomplish the various stress path tests under load/displacement/stress/strain control modes, including uniaxial and biaxial, conventional triaxial and true triaxial compression. The triaxial cell has a large transparent plexiglass visual window, which is used in conjunction with the existing microscope, so as to facilitate real-time observation of the rock fracture process under uniaxial and biaxial compression conditions.

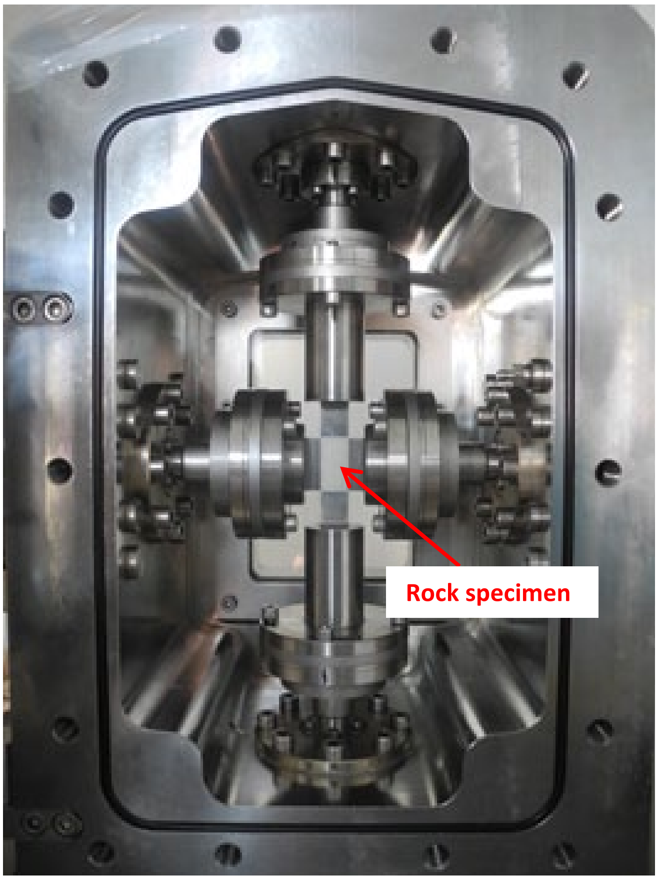

Fig 3. Installation of rock specimen on the GDSTTA equipment

The apparatus uses two paired actuators to synchronize loading in the same direction at the same time, which can effectively avoid the off-centre problem during testing. The loading method requires extremely high servo control precision. Figure 4 shows a comparison between single actuator loading and synchronous loading under biaxial compression.

CONCLUSION & TESTIMONIAL

The GDSTTA, with the features of stable control, servo-loading and high measurement precision, can carry out a series of rock strength and deformation tests under various stress paths, and solves the off-center problem during

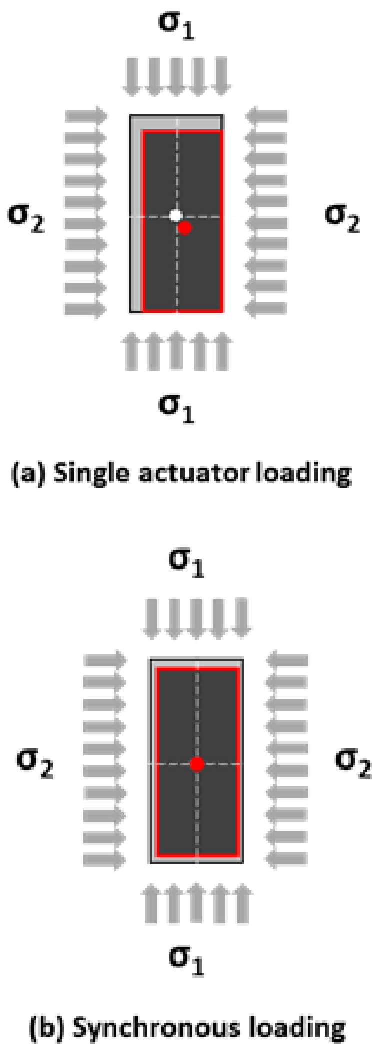

Fig 4. Comparison between single actuator loading and synchronous loading under biaxial compression

multi-axis loading. The experiments and data analysis is currently underway in the research group, results are expected to be published in subsequent papers. During the whole process from design, delivery, installation and training, engineers from EPC and GDS Instruments provided vital support and assistance, that enabled the GDSTTA to be put into use quickly. We look forward to cooperating with both EPC and GDS on future projects.

REFERENCES

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