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Technical Note

Comparison of experimental results in a testing device for swelling rocks

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1. Introduction

The swelling behavior of rocks depends on, among other factors, the boundary conditions imposed on the rock mass under consideration. For this reason, it is important that the conditions under which the testing of swelling rocks is performed are realistic and well known.

Most of the tests on swelling rocks are performed in a typical oedometric apparatus which allows only the control of vertical stress over the rock specimen. For the determination of the axial swelling stress as a function of the axial swelling strain suggested by Huder and Amberg [1] and by the ISRM [2], the rock specimen is tested under stress control.

An alternative apparatus for measuring the swelling rock behavior was developed at the Institute of Soil Mechanics and Rock Mechanics at the University of Karlsruhe [3–5]. This testing device allows control over the deformation or the load on the specimen in order to perform stress or strain controlled swelling tests. For the interpretation of the measured quantities, the stiffness of the testing system may become crucial if the deformation of the rock specimen is inferred from the deformation of the testing device under constant strain conditions. Some specific modifications have been made to this apparatus [6] in order to avoid the influence of the device stiffness in measuring the deformation of the specimen. Nevertheless, the original unmodified device continued being used in subsequent publications [4,5] and the importance of this issue was neither recognized nor discussed. Some interesting results are presented in this paper, comparing the performance of swelling tests in the previous unmodified device with the new version of this testing device.

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2. Testing apparatus

The apparatus mentioned above (Fig. 1) consists of a rigid frame formed by two plates and four columns (1). The rock specimen, inserted into a ring (2), is installed in the watering cell (3) between two porous metal plates (4). The load and deformation on the specimen are applied from the top and controlled manually with a spindle (5). The load acting on the specimen is measured by a load cell mounted on the bottom plate of the apparatus (6). The deformation of the specimen is measured by a mechanical or digital dial gauge placed on top of the spindle (7).

2.1. Advantages

This testing device offers a substantial advantage over the device proposed by the ISRM [2] because the vertical deformation or load on the specimen can be finely and easily controlled. This apparatus allows to perform stress or strain controlled tests and facilitates the realization of multistage tests [4]. The measurement of the maximum axial swelling stress and the determination of the axial swelling stress as a function of the axial swelling strain can be performed within the same test. Multistage tests can be carried out by first allowing the specimen to swell without axial deformation, and then, after the stress reaches its maximum, unloading the specimen stepwise. In each step either the stress or the strain is kept constant until a new equilibrium is reached at the end of the step. Following this procedure, the swelling curve of the specimen can be obtained [7].

2.2. Disadvantages

A major disadvantage of the testing device shown in Fig. 1 lies in the fact that the axial deformation is measured outside the frame, and therefore the deformation produced by the swelling

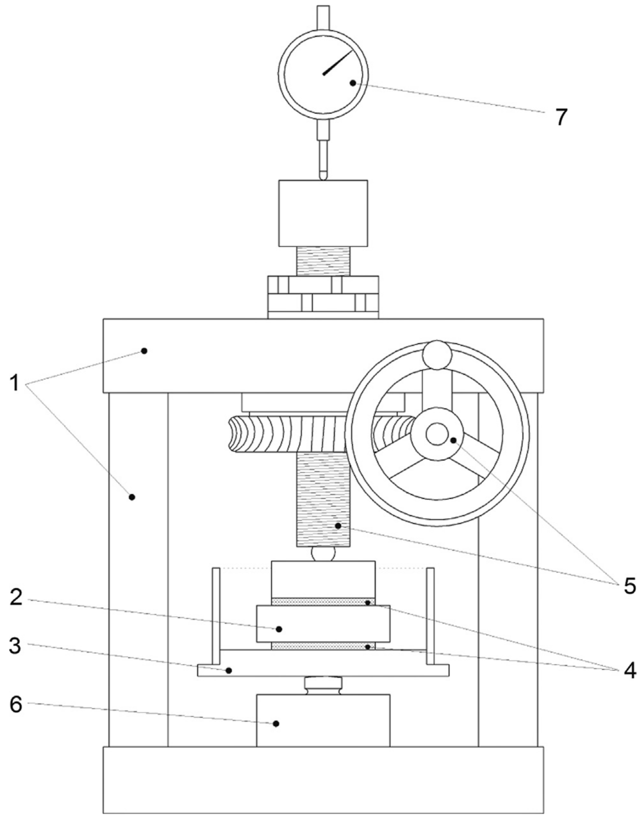

Fig. 1. Apparatus for performing rock swelling test [4]: (1) rigid frame, (2) ring with rock specimen, (3) watering cell, (4) porous metal plates, (5) spindle, (6) load cell and (7) dial gauge.

stress of the specimen is not considered, but instead, the entire deformation of the system is measured. The swelling of the rock specimen under restricted axial and radial strain produces a vertical force and consequently a vertical deformation of the spindle and of the load cell, allowing at the same time the deformation of the specimen along the same axis. This deformation of the specimen may occur without being measured by the dial gauge installed over the spindle. Furthermore, if the frame of the apparatus is not rigid enough, an additional vertical deformation of the specimen will take place. A typical load cell allows a certain vertical displacement in order to measure the force acting on it. This deformation is measured by strain gauges as electrical signals. In the case of the spindle, its deformation will depend on its stiffness. The vertical deformation of the complete system depending on the vertical force acting between the load cell and the spindle is shown in Fig. 2. It is observed that after a certain deformation has occurred the curve shows a linear behavior. The stiffness obtained from the linear part of the curve is approximately 105 kN/mm.

Uncontrolled axial deformation of the specimen results in a loss of swelling stress which depends on the rock specimen's properties. Even if a small amount of vertical deformation is transferred to the specimen it will have a noticeable effect on the measured swelling stress.

3. Modified apparatus

A modification of this apparatus is shown in Fig. 3. The improvement consists of two dial gauges, attached at opposite diameter ends of the loading plate, which measure the distance between the loading plate and the bottom of the container where the specimen is installed. This allows keeping the axial deformation of the specimen in the desired amount, thereby avoiding the influence of the vertical deformation of the load cell, the spindle and the frame. If the test is performed under constant strain, the vertical deformation of the specimen has to be corrected manually with the spindle during the course of the test. A modification of the testing device discussed here, which also included internal measuring of the specimen's deformation, was used to evaluate the stress – strain behavior and permeability of bentonite [6].

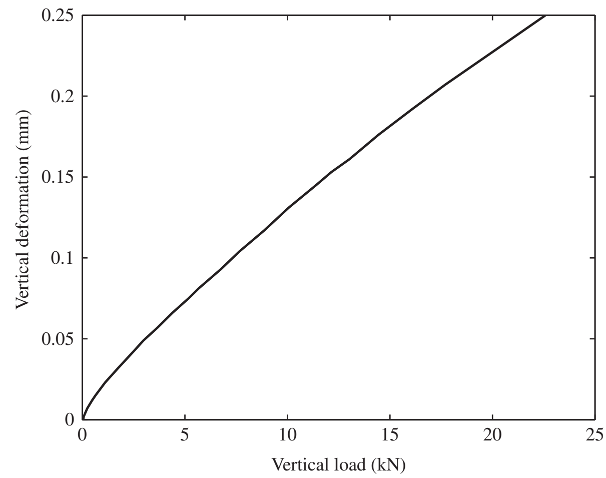

Fig. 2. Vertical deformation as a function of the vertical load in the testing device.

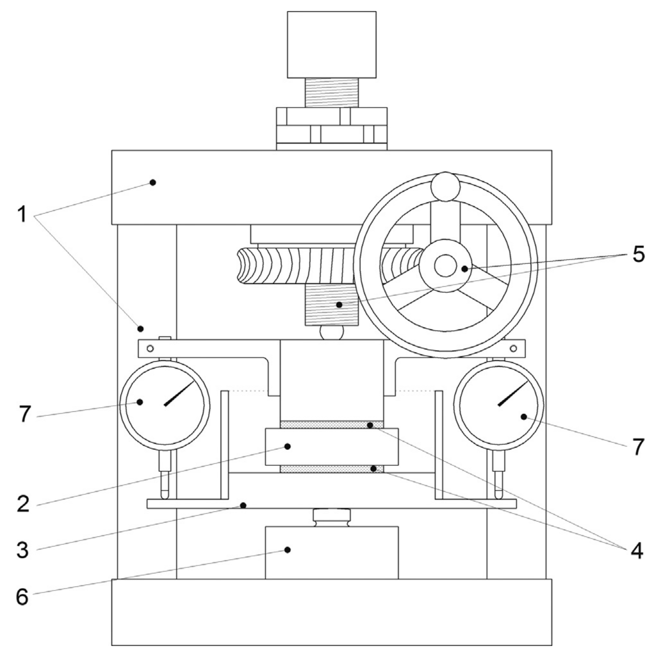

Fig. 3. Modified apparatus for performing rock swelling test: (1) rigid frame, (2) ring with rock specimen, (3) watering cell, (4) porous metal plates, (5) spindle, (6) load cell and (7) dial gauges.

4. Comparison of results and discussion

Swelling tests were performed with the original as well as the modified version of the device presented here. The load cell used is an HBM C2 with a nominal force of 50 kN, an accuracy class of 0.1 and a nominal displacement of less than 0.06 mm. All tests were carried out preventing axial deformation of the specimen which was measured with the dial gauges installed in each apparatus. The tests were carried out until the maximum swelling stress of