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A SIMPLE SOLUTION FOR TRIAXIAL APPARATUSES WITH RODS OUTSIDE THE CELL

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ABSTRACT

Triaxial testing is widely used both in research and commercial laboratories, but the quality of the tests may be restricted by the triaxial apparatus construction. If the rods are built outside the cell, one of the constraints encountered when testing soft soil is the impossibility to close the membrane and fasten the cap without disturbing the specimen. Although the purchase or construction of a new triaxial apparatus is always advisable, some of triaxial apparatuses could be improved using the solution described in this paper: a structure is constructed inside the cell to keep the cap immovable during the specimen installation. This structure was built and used for a triaxial cell with an accessible bottom, but a similar idea could be applied to other types of cells, allowing safe installation of the soft specimens and, after the cell is closed, lowering the loading piston onto the cap and fastening to it without disturbances.

Keywords: laboratory testing, triaxial apparatus, soft soils, improvement

INTRODUCTION

Triaxial testing is rather widely used and developments in computers as well as testing techniques allow more sophisticated and meaningful tests (Rendulic, 1937; Bishop & Henkel, 1962; Bishop & Wesley, 1975; Jardine et al., 1984; Menzies, 1988; Burland, 1989; Tatsuoka, 1988; Jamiolkowski et al., 1999; Tatsuoka, 2000; Tatsuoka et al., 2001, Di Benedetto, 2003; Kiyota & Tatsuoka, 2006). Certainly, quality of testing is restricted by the construction of the apparatus. Such a constraint is encountered in apparatuses with rods built outside the cell where it is impossible to close the membrane and fasten the cap without disturbing a soft specimen (Tatsuoka, 1988).

The solution proposed here was developed on such an apparatus built with rods outside the cell, and with no space left to rebuild them. After placing the specimen on the pedestal, the cap should have been put on the specimen and the membrane pulled over and tightened while supported by the specimen only, which was invariably ending with at least a slight tilting of the cap. Just after the cell was put in place, the loading piston should have been lowered until touching the cap, and, with activating the vacuum system, fastened to the cap. It was not possible to improve the position of the cap once the cell was closed, and, thus, the stress heterogeneity was only worsened during the loading process thus reducing the quality of testing.

However, an additional structure – named “bridge” – was constructed inside the cell to keep the cap in place during the specimen installation. This device was built and used for a triaxial cell with an accessible bottom, but a similar idea could be applied to other types of cells.

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For computer control of the tests three digital pressure-volume controllers were used, which measured both pressure and volume change and controlled pressure or volume change for (a) pore water, (b) cell water and (c) chamber on which the pedestal was floating – so that axial pressure or movement of the pedestal was controlled (Atkinson et al., 1985; Atkinson and Sallfors, 1991; Baldi et al., 1988; Menzies, 1988; Sheahan, 1993; Lo Presti et al., 1995; Scholey et al., 1995). The local strains were measured using Hall Effect transducers (Clayton et al., 1989).

CONSTRUCTION OF THE BRIDGE

Figure 1 shows the cross-section of the triaxial apparatus with the structure to be described, just after the loading piston is fastened to the cap. Numbers shown in Figure 1 are used in the following text.

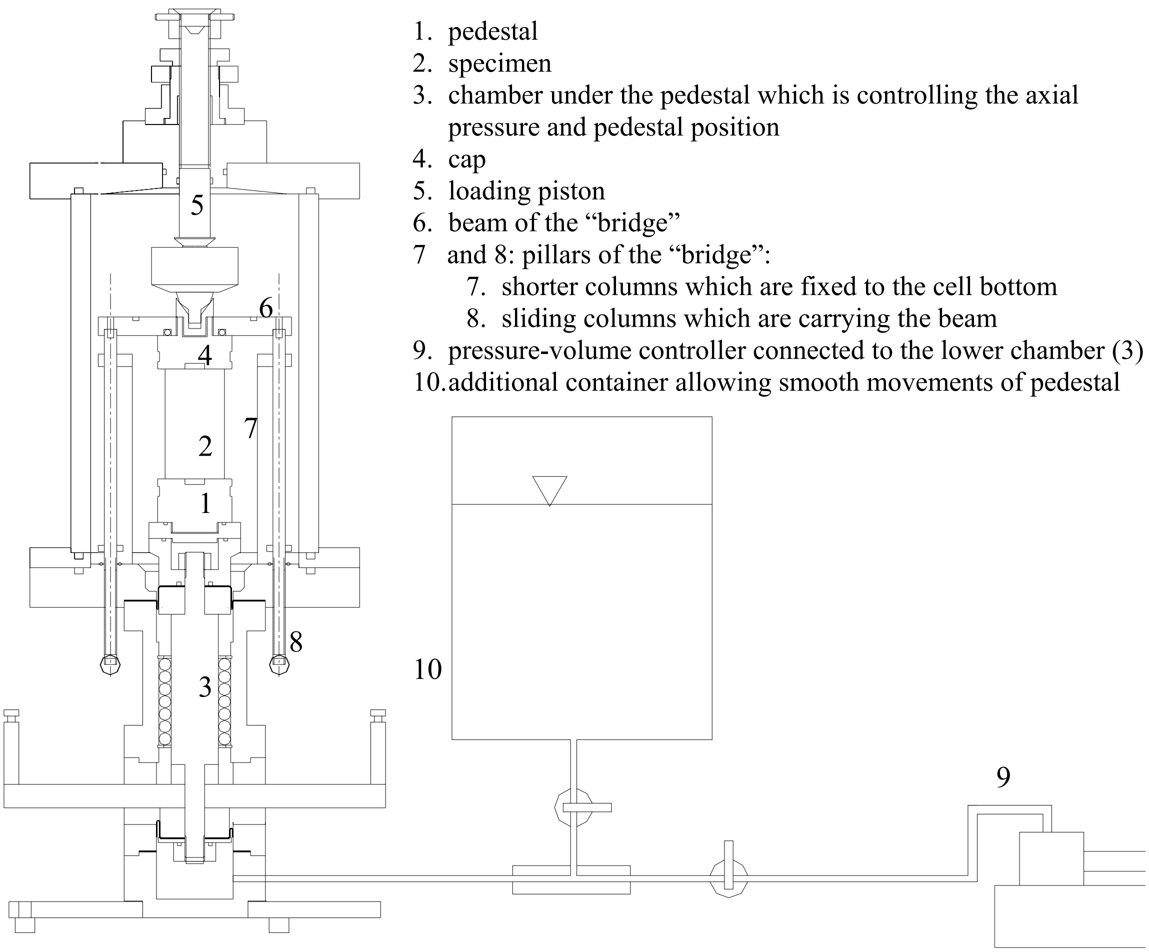

Figure 1. Setup of the triaxial apparatus with the improvements

The purpose of the proposed structure is to bear the weight of the cap (4) before any pressure (vacuum) is applied to the freestanding specimen and to prevent possible disturbances caused by pulling up the membrane and tightening it, also to avoid transferring any load to the specimen while lowering the loading piston (5) and attaching the piston to the cap (4). However, this structure must allow for specimen deformation once vacuum is applied to the specimen. Also, once the cap (4) is attached to the piston (5) – and while the cell is already mounted – the structure must be disassembled without causing any disturbance to the specimen. Obviously, any leaks in the cell could not be permitted.

In this construction, the cap (4) is widened with a beam (6) to rest on two stable but movable pillars (7, 8). In the first stages of the specimen installation, the cap with the beam (4, 6) is fixed firmly to the pillars (7, 8) until the membrane is tightened, then unfastened, as is shown later on, but left on the pillars in a stable position. After the loading piston (5) is fastened to the beam (6), the beam is detached from the pillars (8), which are then pulled down not to hinder the process of testing.

Each of the pillars consists of two immovable shorter columns (7) and a sliding taller column (8) which attaches to the beam (6) at first and slides down afterwards. The shorter columns (7) are wide enough to assure stability; they are fixed at the bottom of the cell and interconnected with the little beam at their top. The tight cylindrical opening in this little beam gives horizontal stability to the column (8) sliding through it, which is turning through the screwhole at the cell bottom and into the screwhole in the beam connected to the specimen cap.

In earlier versions, the cap was fastened to the loading piston using vacuum. For this purpose the loading piston was provided with a concave widening at its bottom, and an O-ring (still shown in Figure 1) was installed at the top of the beam on the cap, to form a small chamber in which vacuum was applied. To avoid often problems with leakage, softness and loading limits, another solution was developed which is presented here. In the second version, the loading piston (5) is fastened to the beam (6) using screw thread (explained in detail by Matesic 2002).

INSTALLATION OF A SPECIMEN

Figure 2 shows a cross-section of the triaxial apparatus with the described structure through the specimen installation process, step by step.

A. Specimen (2) is placed onto pedestal (1). Sliding columns (8) are fastened in their upper position so that the beam (6) with the cap (4) is not going to touch the specimen.

B. The beam (6) with the cap (4) is placed carefully onto the columns.

C. Screw threads through the bottom of the cell allow gentle driving and lowering of the columns until the cap touches the specimen. Axial load to the specimen is controlled through the added container (10) from this step to the end of the installation.

D. Using bolts with wide heads, the beam with cap is fastened manually to the columns (in small steps) and tightening of the membrane can be done without movements of the cap. After the membrane is closed, in case of sandy specimens, a small negative pore pressure is applied, usually chosen to be around 20 to 30 kPa, to protect the specimen from disturbances during the following steps of installation. Otherwise, the thread connection between the columns with the base of the cell could allow the desired movements of the cap. A similar procedure may be needed if collapse of the specimen in the process of saturation becomes significant. Subsequently, the transducers for local strain measurement were glued to the membrane and the local deformation of the specimen could be measured.

E. To allow the installation of the cell and further free movements of the cap, the bolts fastening the cap to the columns of the bridge must be gently loosened and removed. However, the weight of the cap is still supported by the columns (8) and does not disturb the specimen.

F. The cell could be put into place carefully and rods tightened causing only very small deformation of the specimen.

G. Then the loading piston could be lowered until it touches the cap and is fastened.

H. Once the cap is fixed to the loading piston, the bridge must be disassembled. As the cap (4) is fixed, these are the sliding columns (8) that must be lowered sufficiently to permit the free deformation of the specimen. The wide accessible bottom of the cell that was used allows easy access to the columns from the outside. To prevent leakage through the opening in the cell bottom around the sliding column, a widening with an O-ring was provided on the column (8). Simple manual tightening was sufficient and it was made easier with a small mobile ring on the very bottom.

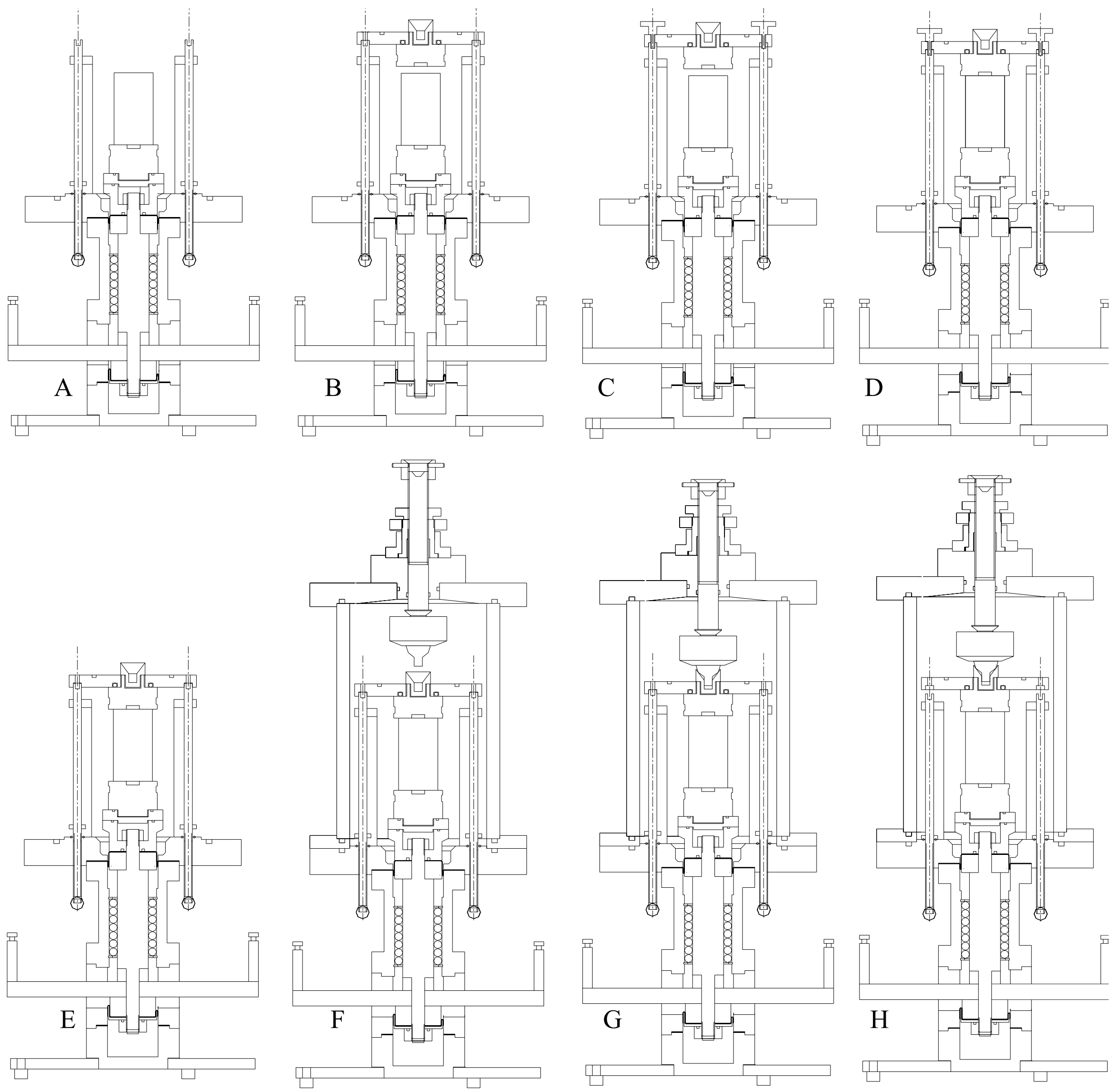

Figure 2. Sequence of specimen installation

TESTS ON KOSINJ CLAY

To prove the performance of this structure, one test on Kosinj clay is shown. This clay (w_P = 23%, w_L= 44%, w_0 = 22 %) was tested during investigations for a dam at the retention Kosinj, Croatia. The diameter of the specimen was 52.8 mm and the height 96.6 mm.

Figure 3 shows the deformation measured by Hall effect transducers during installation, and figures 4, 5 and 6 show the results of a strain controlled cycling test.

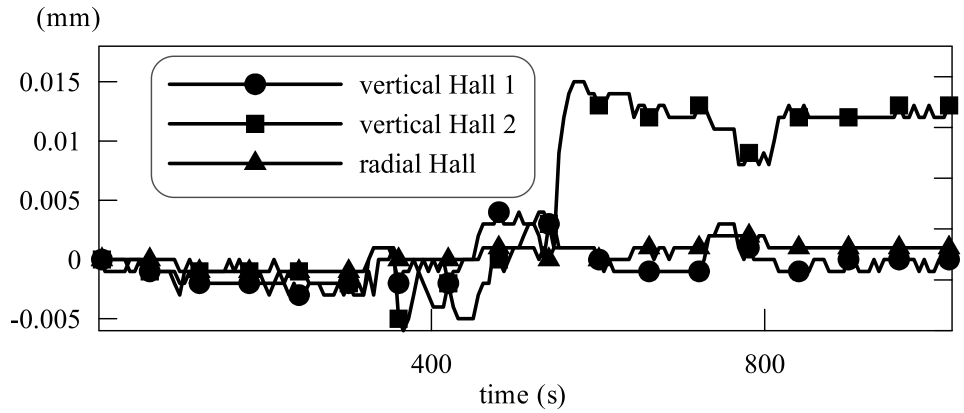

Figure 3. Kosinj clay. Deformation of the specimen during installation.

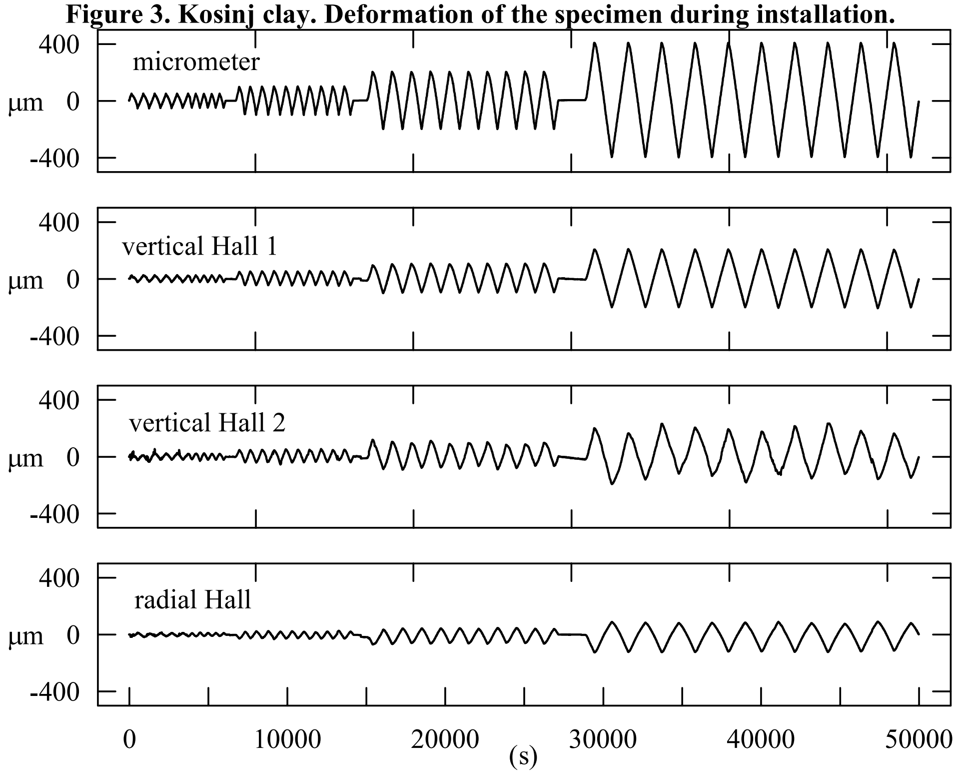

Figure 4. Deformations during strain-controlled cycling.
a. The deformation applied controlled by the micrometer.
b, c, d The deformation measured by Hall effect transducers: b, c axial, d radial deformation

During installation, one vertical Hall Effect transducer measured shortening of around 15 μm, the other vertical one and the radial one deformation of few μm. During further testing the two vertical transducers showed almost equal deformations which means that the developed structure protected the specimen from significant tilting and bending.

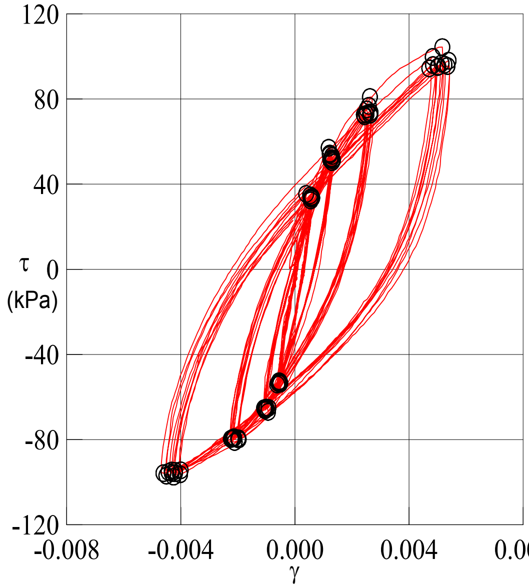

Figure 5. Resulting stress strain diagram: shear strain versus shear stress

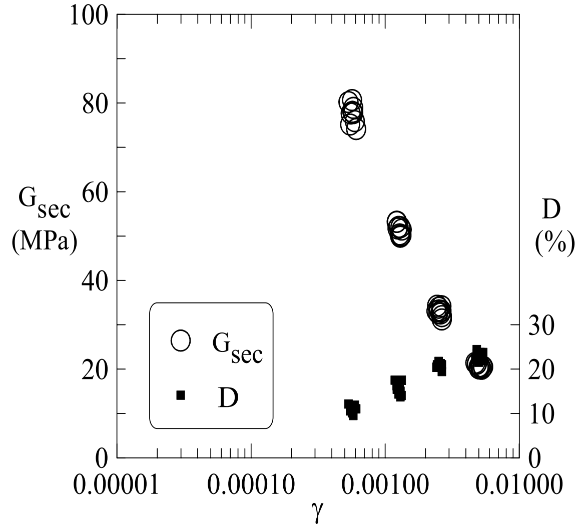

Figure 6. Shear modulus (G_{sec}) and damping (D) from the cyclic triaxial tests versus shear deformation

CONCLUSIONS

For many triaxial apparatuses in use, a serious problem with specimen disturbances is caused by the impossibility to keep the cap immovable during specimen installation. A solution is offered in form of a small structure, so called bridge, to be built inside the cell, consisting of a widened cap and a pair of pillars to support it during installation, but dismantled after cap is fastened to the loading piston. The efficacy of this solution was shown in a series of tests, one of which is presented.

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