Japanese Geotechnical Society Standard (JGS 0522-2020)
Method for consolidated-undrained triaxial compression test on soils

1 Scope

This standard specifies a test method to determine the strength and deformation characteristics of soils when they are subjected to undrained compression after consolidation in an isotropic stress state. The test shall be carried out on three or more specimens prepared from a same sample under different consolidation stresses within the required consolidation stress range. The relationship between the volume change (and the axial displacement if possible) and consolidation time should also be obtained. This standard applies mainly to saturated cohesive soils.

Note 1: In this standard, testing is in principle carried out with back pressure. However, the standard does not preclude testing with no back pressure. If testing is carried out without back pressure, all provisions that specify devices and methods relating to back pressure are to be ignored and values for back pressure are to be read as zero.

Note 2: The measurement of axial displacement during consolidation process is assumed, but if axial displacement is not measured, provisions relating to axial displacement may be ignored.

Note 3: This standard is applicable also to saturated coarse-grained soil.

2 Normative references

The following standards shall constitute a part of this standard by virtue of being referenced in this standard. The latest versions of these standards shall apply (including supplements).

The specimens to be used in this test shall be prepared and installed in accordance with the following standard.

JGS 0520 Preparation of soil specimens for triaxial tests

For coarse-grained soil with a maximum grain size exceeding about 20 mm, the specimens to be used in this test shall be prepared and installed in accordance with the following standard.

JGS 0530 Preparation of specimens of coarse granular materials for triaxial tests

3 Terms and definitions

The terms and definitions used in this standard are as follows:

Note: The test covered by this standard can be referred to in abbreviated form as CU triaxial test.

3.1 CU

Shearing soil in the undrained condition after consolidating it (Consolidated and Undrained: CU).

3.2 Axial stress

The stress acting on the specimen in the cylinder axis direction.

3.3 Lateral stress

The stress acting in the radial direction of the specimen.

3.4 Principal stress difference

The difference between the axial stress and the lateral stress. The value of stress shall be defined at the mid-height of the specimen.

3.5 Isotropic stress state

The stress state when the axial stress is equal to the lateral stress.

3.6 Cell pressure

The pressure applied to the triaxial pressure cell. The lateral stress is equal to the cell pressure.

3.7 Back pressure

The pressure applied to the pore water within the test specimen (JIS A 1227).

Note: In this standard, the back pressure means the pore water pressure applied to the specimen to achieve a higher degree of saturation of the specimen while maintaining a constant effective stress.

3.8 Consolidation stress

The stress of soil element that induces consolidation.

Note: In this standard, the consolidation stress means the difference between the externally applied stress on the test specimen and the back pressure during the consolidation process.

3.9 Undrained compressive strength of soil

The maximum principal stress difference that can be applied to the consolidated specimen when no pore water is allowed to flow in or out of the specimen.

4 Equipment

4.1 Triaxial compression test apparatus

The triaxial compression test apparatus shall consist of a triaxial pressure cell, a system for applying cell pressure and back pressure, a compression device, and measuring instruments for load, displacement, and volume changes. The apparatus shall satisfy the following conditions. Figure 1 shows an example of the configuration of triaxial compression test apparatus. For testing without back pressure, the components indicated by the broken lines in the figure are not needed. Figure 2 shows the schematic structure of triaxial pressure cell: (a) is an example in which the loading piston and cap are rigidly connected while (b) is an example in which the two are not rigidly connected. Both forms must allow for mounting of a specimen with the same diameter as the cap and pedestal between the cap and pedestal, covered with a rubber sleeve, and sealed with an O-ring, etc.

a) The apparatus shall have high load-bearing strength and load capacity to handle the maximum cell pressure, back pressure and maximum axial compression force to be applied to the specimen.

b) The apparatus shall be capable of maintaining the cell pressure and back pressure within ±4 kN/m^2 of a target value for pressures up to 200 kN/m^2, and within ±2 % of the target value for pressures of 200 kN/m^2 or greater, for the duration of a single test.

c) The apparatus shall be capable of applying and sustaining axial displacement up to 15 % or more of the specimen height.

d) The apparatus shall be capable of measuring cell pressure and back pressure with an allowable tolerance of 2 kN/m^2 for pressures up to 200 kN/m^2 and of 1 % for pressures of 200 kN/m^2 or greater.

e) The apparatus shall be capable of measuring the axial compression force up to the specimen's maximum axial compressive strength within an allowable tolerance of 1 %. If the test apparatus is set up such that the load cell is located outside the triaxial pressure cell, the frictional force at the point of sliding between the piston and the triaxial pressure cell shall be measured. This friction value shall be used to correct the measured value of axial compression force. If the load cell is located inside the triaxial pressure cell, the effect of cell pressure shall be determined and the measured value of axial compression force shall be corrected.

f) The apparatus shall be capable of measuring the axial displacement up to 15 % of the specimen height within an allowable tolerance of 0.1 %.

g) The apparatus shall be capable of measuring the volume change of the specimen up to its maximum value within an allowable tolerance of 0.1 % of the specimen's initial volume. In a standard setup, when testing saturated soil, the volume change of the specimen shall be determined as the amount of water expelled from the specimen during the test measured by using a burette or other devices with equivalent or higher measurement accuracy. In the sections below, a burette is used as a representative device for measuring the volume change.

5 Test method

5.1 Preparation and set-up of test specimen

Preparation and mounting of the specimen shall be in accordance with JGS 0520 Preparation of soil specimens for triaxial tests. Additionally, the specimen shall have a height not less than twice its diameter. For coarse-grained soils with a maximum particle diameter greater than about 20mm, the specimen shall be prepared in accordance with JGS 0530 Preparation of specimens of coarse granular materials for triaxial tests.

5.2 Consolidation process

The consolidation procedure of the test shall be in accordance with the following requirements.

a) Make zero adjustments to the displacement transducer, and ensure application of the prescribed back pressure u_b. At the same time, take the initial reading of the burette. If the piston and cap are not rigidly connected, bring the load cell, piston, and cap into contact before the above operation.

b) Close the drainage valve connected to the burette. Increase only the isotropic stress so that the difference between isotropic stress and back pressure is equal to the desired value of consolidation stress.

c) Open the drainage valve to start consolidation.

d) Record readings of the volume change ΔV_t (mm^3) and the axial displacement ΔH_t (mm) of the specimen at appropriate time t intervals during consolidation, and plot them. Consolidation shall be continued at least until the end of primary consolidation. Measure the volume change ΔV_c (mm^3) (which, for saturated soil, is equal to the amount of water expelled from the specimen) and the axial displacement ΔH_c (mm) due to consolidation. The termination of consolidation is to be determined by the following method in principle: Plot the measured values (ΔV_t, log$t$) on logarithmic-normal paper and draw the ΔV_t-log$t$ curve. Locate the steepest part of the curve. Draw a straight line parallel to the steepest part of the curve and at the 3t point in time (termed the "3t line"). The point at which the ΔV_t-log$t$ curve touches the 3t line is defined as the point at which consolidation terminates. If determining the end of primary consolidation is not possible, such as when the specimen is in an excessively consolidated state, terminate consolidation at an appropriate point after 100 minutes of consolidation for specimens with a diameter of 35 mm and 150 minutes for specimens with a diameter of 50 mm or above. If the axial displacement cannot be measured during consolidation because the piston is not rigidly connected to the cap, carefully bring the piston into contact with the cap, while observing the load cell reading such that no additional force is applied to the specimen. Then take the reading of the displacement transducer. This measured value is to be taken as the axial displacement

ΔH_c (mm) due to consolidation.

Note: In selecting a measurement time interval, use as a guide JIS A 1217 Test method for one-dimensional consolidation properties of soils using incremental loading.

5.3 Axial compression process

The axial compression shall be carried out in accordance with the following procedure.

a) Check and adjust the zero reading of the load cell and the displacement transducers.

b) Close the drainage valve.

c) Start compressing the specimen at a steady rate under a constant cell pressure. The standard rate of compression shall be 1 % axial strain per minute.

d) Record the axial compression force P (N) and axial displacement ΔH (mm) during compression.

Note: If the axial compression force and axial displacement are not recorded continuously, the measurement time interval shall be sufficiently small to enable a smooth curve for the principal stress difference versus axial strain to be drawn. It is recommended, for example, to measure axial displacement at a maximum interval of 0.2 mm up to the maximum value of the axial compression force, and thereafter at a maximum interval of 0.5 mm.

e) Terminate the compression either when an axial strain of more than 3 % has been reached since the maximum axial load reading, when the load reading has fallen to about 2/3 of its peak value, or when an axial strain of 15 % has been reached.

f) Remove the specimen from the triaxial pressure cell, and observe and record its deformed shape, failure mode, and other features. The observation shall be made in the direction that captures the features of failure most clearly. If a slip surface is found, observe it from the direction in which the steepest gradient is determined and record it so that the gradient angle can be approximately read. Any heterogeneity of the specimen and the presence of any foreign materials shall be observed and recorded.

g) Measure the oven-dried mass of the specimen m_s (g).

Note: This step in the process may be omitted if the water content of the specimen is determined from the trimmed waste of the sample.

6 Processing test results

6.1 Initial state of specimen before consolidation

The volume V_0 (mm^3) and height H_0 (mm) of the specimen before consolidation shall be calculated using the following equations.

$$V_0 = V_i - \Delta V_i$$

$$H_0 = H_i - \Delta H_i$$

where

V_i : Initial volume of the specimen (mm^3)

H_i : Initial height of the specimen (mm)

ΔV_i : Volume change of the specimen between the initial state and prior to the start of consolidation (mm^3), where compression is defined to be positive

ΔH_i : Axial displacement of the specimen between the initial state and prior to the start of consolidation (mm), where compression is defined to be positive

6.2 Consolidation process

The test results from the consolidation process shall be processed as follows:

a) The volume of the specimen after consolidation V_c (mm^3) shall be calculated using the following equation.

$$V_c = V_0 - \Delta V_c$$

where

ΔV_c: Volume change of the specimen due to consolidation (mm^3), where compression is defined to be positive

Note: The void ratio of the specimen after consolidation (before axial compression) e_c should be calculated using the following equation, if necessary.

$$e_c = \frac{V_c/1000 \times \rho_s}{m_s} - 1$$

where

ρ_s: Density of soil particles (Mg/m^3)

b) The height of the specimen after consolidation H_c (mm) shall be calculated using the following equation.

$$H_c = H_0 - \Delta H_c$$

where

ΔH_c: Axial displacement due to consolidation (mm), where compression is defined to be positive

Note: If the piston is not rigidly connected to the cap and the measurement of the axial displacement due to consolidation ΔH_c (mm) is uncertain, the following equation should be used to calculate the specimen height after consolidation H_c (mm), assuming isotropic strain in the specimen. If the value of H_c is obtained using this equation, this fact must be clearly indicated in the report.

$$H_c = \left(1 - \frac{\Delta V_c}{3V_0}\right) \times H_0$$

c) The specimen's cross-sectional area after consolidation A_c (mm^2) shall be calculated using the following equation.

$$A_c = \frac{V_c}{H_c}$$

d) The dry density of the specimen after consolidation ρ_{dc} (Mg/m^3) shall be calculated using the following equation, which shall be rounded to two digits after the decimal point.

$$\rho_{d0} = \frac{m_s}{V_0} \times 1000$$

where

m_s: Oven-dried mass of the specimen (g)

6.3 Axial compression process

Refer to Section 6.2 of JGS 0521 Method for unconsolidated-undrained (UU) triaxial compression test on soils for the method of calculation for the consolidation process.

7 Reporting

The following test results and other items shall be reported.

a) Method of specimen preparation

b) Dimensions of the specimen before the consolidation

c) Magnitude of the cell pressure (kN/m^2) and the back pressure (kN/m^2)

d) Relationship between the volume change (mm^3) and time (min) in the consolidation process

Note: Report the relationship between the axial displacement and time in the consolidation process, if necessary.

e) Oven-dried mass (g) of the specimen and the dry density (Mg/m^3) after consolidation

Note: Report the void ratio of the specimen after consolidation, if necessary.

f) Strain rate (%/min) in the axial compression process

g) Compressive strength (kN/m^2) and strain at failure (%)

h) Principal stress difference versus axial strain curve

i) Failure condition of the specimen

j) Relationship between compressive strength and consolidation stress

k) If the method used deviates in any way from this standard, give details of the method used.

l) Other reportable matters

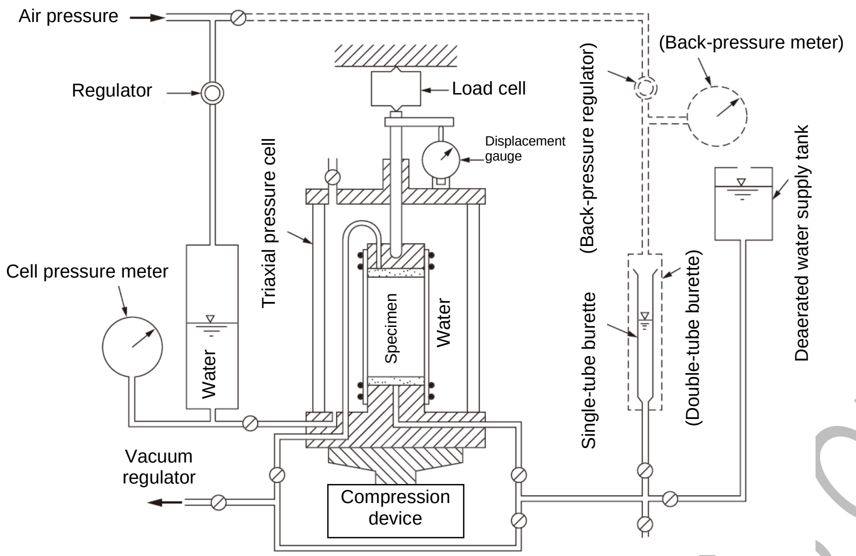

Figure 1 Example of configuration of CU triaxial test apparatus (back pressure apparatus shown in broken lines)

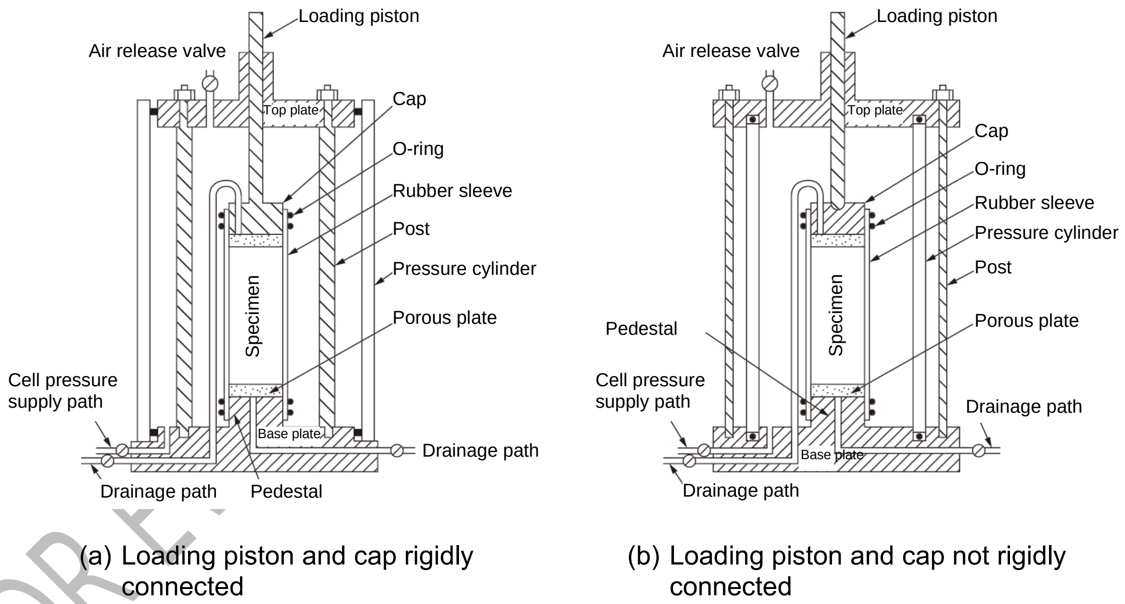

Figure 2 Schematic structure of triaxial pressure cells