Japanese Geotechnical Society Standard (JGS 0524-2020) Method for consolidated-drained triaxial compression test on soils

1 Scope

This standard specifies a test method to determine the strength and the deformation characteristics of a soil specimen when it is subjected to drained axial compression after isotropic consolidation. The test shall be carried out on three or more specimens prepared from a same sample, under different consolidation stresses within required consolidation stress range. In this test, the relationship between the volume change (and axial displacement, if possible) during the consolidation process and time shall also be obtained. This standard applies mainly to saturated cohesive soils.

Note 1: In this standard, it is assumed that the axial displacement is measured, but if the axial displacement is not measured, provisions relating to axial displacement may be ignored.

Note 2: This standard is also applicable to unsaturated coarse-grained soil whose maximum particle size exceeds 20 mm.

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).

JGS 0520 Preparation of soil specimens for triaxial tests
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 CD triaxial test.

3.1 CD

Shearing soil under the drained condition after consolidating it (Consolidated and Drained: CD).

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 specimen and the back pressure during the consolidation process.

3.9 Drained compressive strength of soil

The maximum principal stress difference that can be applied to the specimen when subjected to the effective lateral stress maintained after consolidation is completed.

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, a compression device, and measurement devices for load, displacement, and volume change. The apparatus shall satisfy the following conditions. Figure 1 shows an example of the configuration of triaxial compression test apparatus. The back pressure burette, the back pressure gauge, and the double tube burette indicated in Figure 1(a) in broken lines shall be required only when back pressure is used. The conditions that this apparatus must satisfy shall be given in 4b), d). Figure 2 shows the schematic structure of the triaxial pressure cell: (a) is an example in which the 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 having 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. Note that, for testing unsaturated soil, the volume change measurement device shown in Figure 1(b) shall be necessary, and the apparatus shall satisfy the requirements in 4g).

a) The apparatus shall have sufficiently 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 the cell pressure and the back pressure with an allowable tolerance of 0.1% 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. 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 using a burette or other devices with equivalent or higher measurement accuracy. When testing unsaturated soil, and if a volume change measuring device is used to measure the volume change of the specimen, the relationship between the cell pressure and the expansion of the triaxial pressure cell shall be determined in advance, and the volume change of the specimen shall be corrected accordingly.

5 Test method

5.1 Preparation and set-up of test specimen

Preparation and set up of the test specimen shall be in accordance with JGS 0520 Preparation of soil specimens for triaxial tests or JGS 0530 Preparation of specimens of coarse granular materials for triaxial tests. Additionally, the specimen shall have a height not less than twice its diameter.

5.2 Consolidation process

The test shall be carried out in accordance with the following requirements for consolidation.

a) Install the displacement transducer, and make zero adjustments. Also, take the initial reading of the burette.

Note: When testing unsaturated soils, check and adjust the zero point of the volume change measuring device.

b) Close the drainage valve connected to the burette. Increase only the isotropic stress so that the difference between the isotropic stress and the back pressure is equal to the desired value of consolidation stress. If the loading piston is not rigidly connected to the cap, set the load cell, the piston, and the cap in contact with each other before this process. If back pressure is used, apply it in accordance with Section 5.2b) of JGS 0520 Preparation of soil specimens for triaxial tests or JGS 0530 Preparation of specimens of coarse granular materials for triaxial tests.

c) Open the drainage valve to start consolidation.

d) Record readings of the volume change ΔV_t (mm^3) and if possible also the axial displacement ΔH_t (mm) of the specimen at appropriate time t intervals, and plot them. Consolidation shall be continued at least until the end of primary consolidation. Measure the volume change ΔV_c (mm^3) and the axial displacement ΔH_c (mm) of the specimen due to consolidation. The termination of consolidation shall comply with Section 5.2(d) of JGS 0522 Method for consolidated-undrained (CU) triaxial compression test on soils. If the axial displacement cannot be measured during consolidation because the loading 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. If unsaturated soil is tested, the value of the reading for volume change due to consolidation shall be corrected for expansion of the triaxial pressure cell and the movement of the loading piston, and this value shall be taken to be the volume change due to consolidation ΔV_c (mm^3).

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 deformation transducer.

b) Compress the specimen continuously with a constant strain rate keeping the cell pressure constant. If the axial strain ε_{af} (%) at the peak principal stress difference can be estimated, the axial strain rate $\dot{\varepsilon}_a$ (%/min) shall not exceed the value calculated from the following equation. However, the axial strain rate shall not exceed 0.5 % per minute regardless of the value calculated from the above equation.

$$\dot{\varepsilon}_a = \frac{\varepsilon_{af}}{15 t_c}$$

where

t_c: Consolidation time (min)

c) Record the axial compression force P (N), the axial displacement ΔH (mm), and the volume change ΔV (mm^3) during compression. When testing unsaturated soil, the volume change shall be corrected for the amount of the loading piston intrusion into the triaxial cell.

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

d) 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 been fallen to about 2/3 of its peak value, or when an axial strain of 15 % has been reached.

e) 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.

f) 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, or if the water content of the specimen is determined from a representative sample of the sample taken from the specimen after completion of compression.

6 Processing test results

6.1 Initial state of the specimen before consolidation

Refer to Section 6.1 of JGS 0522 Method for consolidated-undrained (CU) triaxial compression test on soils for the initial state of the specimen before consolidation.

6.2 Consolidation process

Refer to Section 6.2 of JGS 0522 Method for consolidated-undrained (CU) triaxial compression test on soils for the method of calculation for the consolidation process. If the amount of penetration of the rubber sleeve associated with loading of the cell pressure is measured or estimated, the volume change of the specimen due to consolidation, ΔV_c (mm^3) shall be corrected accordingly.

6.3 Axial compression process

The method of calculation for the axial compression process shall be as follows.

Note: If necessary, the void ratio of the specimen at the maximum principal stress difference shall be calculated from the following equation, which shall be rounded to the two digits after the decimal point.

$$e_f = \frac{V_f / 1000 \times \rho_s}{m_s} - 1$$

where

V_f: Volume of the specimen at the maximum principal stress difference (mm^3)

a) The axial strain of the specimen ε_a (%) shall be calculated from the following equation, where compression is defined to be positive.

$$\varepsilon_a = \frac{\Delta H}{H_c} \times 100$$

where

ΔH: Axial displacement of the specimen in the axial compression process (mm), where compression is defined to be positive

b) The volumetric strain ε_v (%) (compression positive) when the axial strain is ε_a (%) shall be calculated from the following equation, where compression is defined to be positive.

$$\varepsilon_v = \frac{\Delta V}{V_0} \times 100$$

where

ΔV: volume change of the specimen in the axial compression process (mm^3), where compression is defined to be positive

c) The principal stress difference ($\sigma_a - \sigma_r$) (kN/m^2) at axial strain of ε_a (%) shall be calculated from the following equation.

$$\sigma_a - \sigma_r = \frac{P}{A_c} \times \frac{1 - \varepsilon_a/100}{1 - \varepsilon_v/100} \times 1000$$

where

P: Axial compression force (N) applied to the specimen at the axial strain of ε_a (%), where P=0 in the isotropic stress state
σ_a: Axial stress (kN/m^2) acting on the specimen
σ_r: Lateral stress (kN/m^2) acting on the specimen

d) Draw graphs of the principal stress difference – axial strain curve and the volumetric strain – axial strain curve.

e) Obtain the maximum value of the principal stress difference $(\sigma_a - \sigma_r)_{max}$ in the range $0 < \varepsilon_a \leq 15$ % from the graph, and the corresponding value of axial strain shall be taken as the strain at failure (%), which shall be rounded to one digit after the decimal point. The value of this maximum principal stress difference shall be taken as the compressive strength, which shall be rounded to three significant digits.

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 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 and at the maximum principal stress difference, if necessary.

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

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

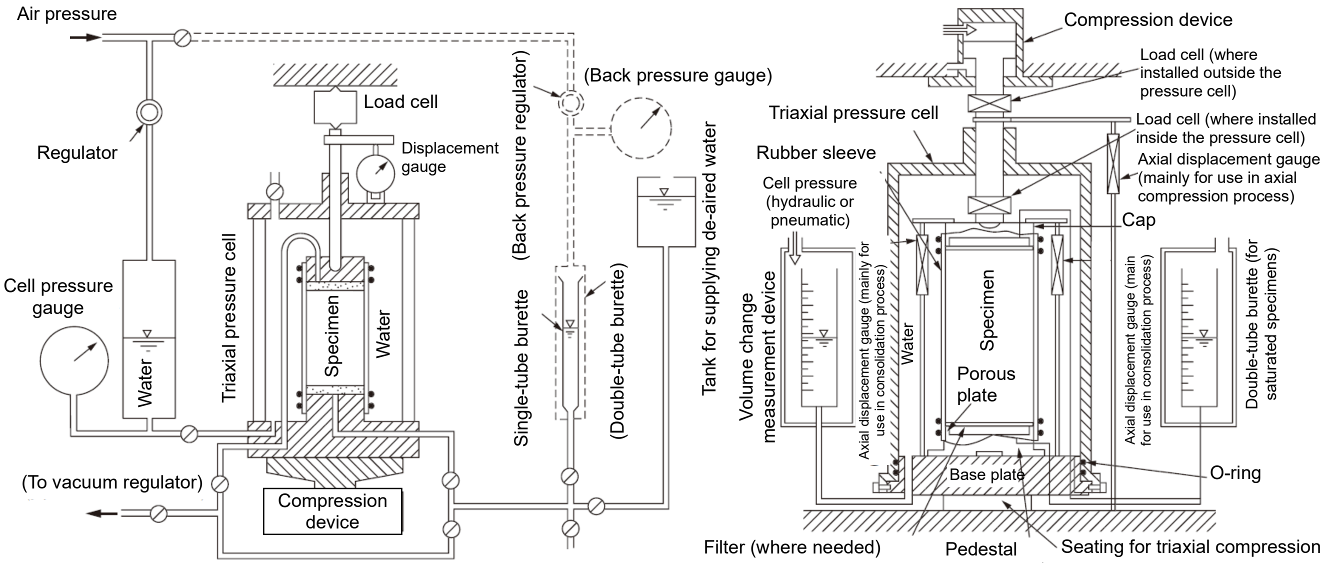
h) Principal stress difference versus axial strain curve and volumetric strain versus axial strain curve

i) Failure condition of the specimen

j) Compressive strength – consolidation stress relationship, which shall be shown by drawing a graph with the compressive strength on the vertical axis and the consolidation stress on the horizontal axis, or by drawing a Mohr's stress circle of ($\sigma_a - u_b$) and ($\sigma_r - u_b$) at $(\sigma_a - \sigma_r)_{max}$, where u_b is the back pressure. If necessary, report the Mohr's stress circle envelope, and the angle of shear resistance, $ø_d$ (°), and the intercept on the vertical axis, c_d (kN/m^2), obtained from the envelope.

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

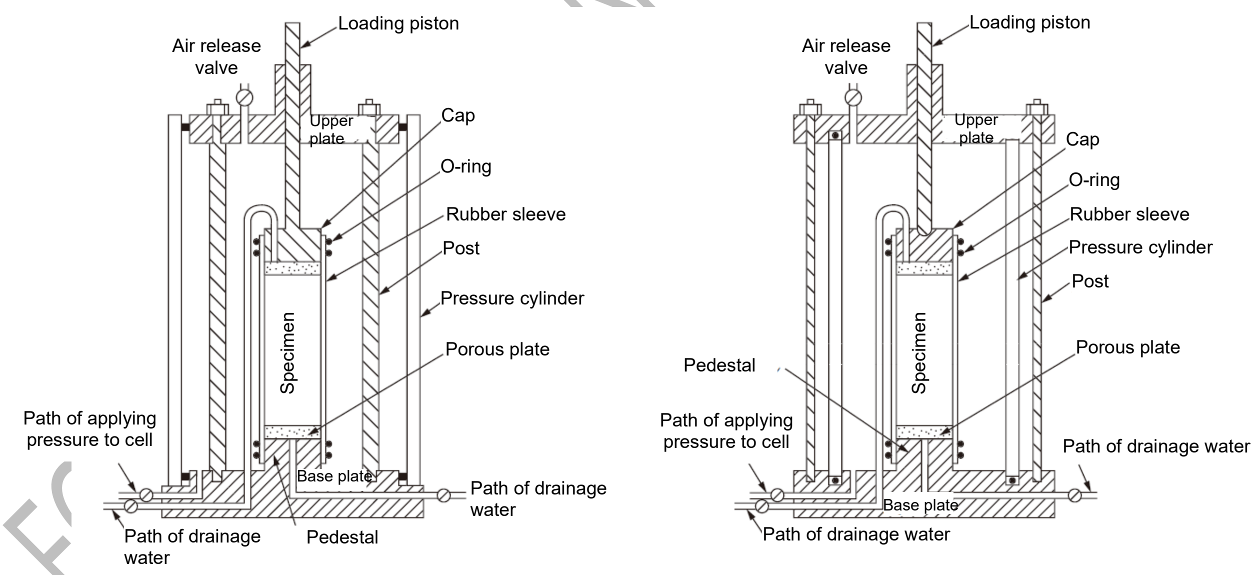
l) Other reportable matters



(a) Small-scale apparatus (broken lines: back pressure supply device)

(b) Large-scale apparatus for coarse-grained soil whose maximum grain size exceeds 20 mm

Figure 1 Example of the configuration of CD triaxial test apparatus



(a) Case in which loading piston and cap are rigidly connected

(b) Case in which loading piston and cap are not rigidly connected

Figure 2 Schematic structure of the triaxial pressure cell