Japanese Geotechnical Society Standard (JGS 0520-2020) Preparation of soil specimens for triaxial tests

1 Scope

This standard covers the preparation and mounting of specimens for testing according to any of the triaxial soil test series. The standard diameter of a specimen shall be from 35 to 100 mm, which is prepared by using soils with a maximum particle size up to about 20 mm.

Note: Specimens containing particles with a maximum particle size exceeding about 20 mm shall be prepared and set up in accordance with the method stipulated in JGS 0530 Preparation of Specimens of Coarse Granular Materials for Triaxial Tests.

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).

JIS A 1202 Test method for density of soil particles
JIS A 1203 Test method for water content of soils
JIS A 1205 Test method for liquid limit and plastic limit of soils
JIS A 1224 Test method for minimum and maximum densities of sands
JIS A 1210 Test method for soil compaction using a rammer
JGS 0051 Method of classification of geomaterials for engineering purposes
JGS 0102 Practice for handling undisturbed samples for laboratory testing to determine mechanical properties of cohesive soils
JGS 0122 Test method for water content of soils by the microwave oven
JGS 0142 Test method for liquid limit of soils by the fall cone

The triaxial test series mentioned above refers to the following standards.

JGS 0521 Method for unconsolidated-undrained (UU) triaxial compression test on soils
JGS 0522 Method for consolidated-undrained (CU) triaxial compression test on soils
JGS 0523 Method for consolidated-undrained ($\overline{CU}$) triaxial compression test on soils with pore water pressure measurements
JGS 0524 Method for consolidated-drained (CD) triaxial compression test on soils
JGS 0525 Method for K_0 consolidated-undrained triaxial compression ($K_0\overline{CU}C$) test on soils with pore water pressure measurements
JGS 0526 Method for K_0 consolidated-undrained triaxial extension ($K_0\overline{CU}E$) test on soils with pore water pressure measurements
JGS 0527 Method for triaxial compression test on unsaturated soils
JGS 0541 Method for cyclic undrained triaxial test on soils
JGS 0542 Method for cyclic triaxial test to determine deformation properties of geomaterials

3 Equipment

3.1 Equipment for preparing specimens

In the case of the trimming method, a) to c) shall be used, and in the case of the negative pressure method, d) and e) shall be used for preparing a specimen. Fig. 1 gives an example of the equipment used.

Note: Frozen and other samples may be shaped using a core cutter, disc cutter, or other tools as needed.

a) Trimmer

b) Miter box

In general, the miter box should be in two parts and have an inner diameter about same as the diameter of the specimen. The two end faces shall be parallel to each other and also perpendicular to the axis of the inserted specimen.

c) Wire saw and straight knife

The diameter of the steel wire used for the wire saw shall be about 0.2-0.3 mm. The straight edge shall be made of steel and single-edged.

d) Mold

In general, the mold should be separated into multiple parts and have the same height as the specimen when assembled on the pedestal. The inner diameter shall be greater than the diameter of the specimen by twice the thickness of the rubber sleeve. The mold shall have suction pores on its inner surface to ensure that the rubber sleeve comes into close contact with the inner surface of the mold.

e) Equipment for supplying samples and equipment for compacting samples

Note: The equipment below shall be prepared according to the specimen preparation methods, as needed.

1) Air- and water-pluviation methods: Funnel, nozzle, nested sieves, etc.

2) Compaction methods: Ramming rod, disk plate for compaction, plastic or wooden hammer, vibrator, etc.

3.2 Other equipment

The equipment used for preparation, mounting, etc., of specimens shall conform to the following requirements.

a) Negative pressure generator

The negative pressure generator shall be capable of applying negative pressure to bring the rubber sleeve into close contact with the inner surface of the mold. When preparing specimens using the negative pressure method, it is also used to support the specimen to keep its shape.

b) Rubber sleeve

The rubber sleeve must be longer than the rubber sleeve expander. Its inner diameter in its natural state should be about 95% of the diameter of the specimen. The rubber thickness should be about 0.15-0.3 mm.

c) Rubber sleeve expander

The rubber sleeve expander should be cylindrical with height and inner diameter about 5-10 % greater than the height and diameter of the specimen. The design of the expander should ensure that the rubber sleeve fits tightly to the inner surface of the expander under an applied negative pressure. Where the cap and piston are rigidly connected, it is recommended that a two-part expander be used. In this case, there must be an airtight joint between the two parts.

d) Filter

The permeability of the filter must be greater, by a suitable margin, than that of the specimen.

Note 1: When fitting filters to the cap and the pedestal in order to drain water both upward and downward, a low-compressibility material with the smallest possible coefficient of friction should be chosen.

Note 2: When a filter is fitted around a specimen in order to reduce consolidation time, it should be of such a shape that its influence on the specimen shear deformation is minimized, such as by providing a slit in the filter.

e) O-ring or rubber band

O-rings must be set tightly to prevent leakage. The inner diameter of the O-rings should be about 80% of the diameter of the specimen.

f) Instrument for measuring specimen size

The instrument used to measure the specimen size shall be capable of determining the diameter and height of a specimen to a precision of 0.05 mm or better. The specimen diameter is measured using a caliper or a steel measuring tape with a vernier.

g) Weighing scale

The weighing scale shall have a precision of 0.01 g or better.

4 Methods of preparing and installing specimens

4.1 Specimen preparation methods and their selection

Two methods of preparing specimens are available, as follows:

a) Trimming method

The trimming method shall be used for samples that are stable and in large pieces, either at room temperature or frozen, including those collected by block sampling or certain types of samplers, those prepared by pre-consolidation or compaction, and those that are frozen.

b) Negative pressure method

The negative pressure method shall be used for samples obtained in a loosened state that cannot be formed into large pieces by compaction and consolidation.

4.2 Shape and dimensions of test specimens

The shape and dimensions of the test specimens shall be as follows:

a) The specimen shall have a cylindrical shape.

b) The standard diameter of the specimen shall be from 35 to 100 mm, and it shall be at least 20 times the maximum particle size of the sample.

Note: The diameter of the specimen may be 5 times or greater the maximum particle size of a sample for soils having a wide range of particle sizes.

c) The standard height of the specimen shall be 1.5 to 2.5 times the diameter.

4.3 Preparation and measurement of specimens by trimming method

Following the procedures listed in a) through g), specimens must be prepared with care so as to avoid changes in sample water content. Particular care must be exercised to avoid disturbing the sample. Before molding frozen samples, cool the specimen preparation equipment. During molding and when measuring the dimensions of the specimen, the work must be performed quickly so as to avoid melting of the sample.

a) Any soil material that is deemed to have been disturbed in the sampling process, etc., must be removed from the sample before preparing specimens. In principle, the sample is to be greater than the specimen in diameter and height by a sufficient margin.

b) The side face of the specimen shall be shaped using a trimmer, wire saw, straight edge, or similar to give it a cylindrical shape with the specified diameter. When shaping is performed using a trimmer, care shall be paid not to apply torque and/or compression force to the specimen. Specimen preparation is usually conducted by scraping the sample with a wire saw, while a straight edge may be used when the specimen is stiff.

Note: If the sample might be overly disturbed by shaping the sides, it is permissible to omit the shaping of the sides of a sample extracted from a sample tube.

c) The specimen is shaped using a miter box, wire saw, straight edge, or similar, so that the two end faces of the specimen become parallel to each other and perpendicular to the specimen axis.

d) Measure the diameter of the specimen in two orthogonal directions with a precision of 0.1% or better, at upper, middle and lower positions of the specimen. Take the mean value of the three measurements as the initial diameter D_i (mm) of the specimen. When the above precision is smaller than that of the measuring device to be used, the precision shall be set at 0.05 mm.

e) Measure the height of the specimen with a precision of 0.1% or better at three or more points that are assigned by dividing evenly the circumference of the specimen. Take the mean value of the three measurements as the initial height H_i (mm) of the specimen.

f) Measure the mass m_i (g) of the specimen with a precision of 0.1% or better.

Note: Use the following equations to obtain the wet density ρ_{ti} (Mg/m^3), dry density ρ_{di} (Mg/m^3), void ratio e_i, degree of saturation S_{ri} (%), and relative density D_{ri} (%) of the specimen in the initial state, as needed.

$$\rho_{ti} = \frac{m_i}{V_i} \times 1000$$

$$\rho_{di} = \frac{m_s}{V_i} \times 1000$$

$$e_i = \frac{V_i \rho_s / 1000}{m_s} - 1$$

$$S_{ri} = \frac{m_i - m_s}{V_i \rho_s / 1000 - m_s} \times \frac{\rho_s}{\rho_w} \times 100$$

$$D_{ri} = \frac{e_{max} - e_i}{e_{max} - e_{min}} \times 100$$

where

V_i: Initial volume of specimen (mm^3) ($V_i = \pi D_i^2 H_i / 4$)
ρ_s: Density of soil particle (Mg/m^3)
ρ_w: Density of water (Mg/m^3)
m_s: Oven-dried mass of specimen (g)
e_{max}: Void ratio of specimen by minimum density test
e_{min}: Void ratio of specimen by maximum density test

g) A representative sample of the specimen shall be taken from the soil removed when forming the specimen, for which the water content shall be measured to obtain the initial water content of the specimen w_i (%).

4.4 Preparation and measurement of specimens by negative pressure method

When using the negative pressure method, specimens shall be prepared and measured as follows.

Figure 2 shows a specimen in the process of preparation by the negative pressure method.

a) Assemble the pedestal, rubber sleeve, and mold by the prescribed method. Apply negative pressure to bring the rubber sleeve into close contact with the inner surface of the mold.

b) Fill the mold with the sample material using one of the methods given below. When the prescribed height is reached in the mold, smooth the upper surface of the specimen. The following methods may be used to fill the mold with sample material.

Note: Control the water content of the sample as needed. If a saturated sample is being tested, permeate a sufficient amount of deaerated water into the sample to remove the air in advance.

1) Air-pluviation method

Drop the dry sample into the mold through a nozzle or nested sieves. If using a nozzle, adjust the density of the specimen by varying the drop height between the nozzle and the top surface of the specimen in the mold, and by the nozzle opening area. If using nested sieves, adjust the density of the specimen by varying the diameter of the opening at the bottom of the funnel and the drop height.

2) Water-pluviation method

Pour a dry sample or a sample that has been stored in a sample tank with a large quantity of water into the mold filled with deaerated water in advance, using a nozzle or spoon. Adjust the density of the specimen by controlling the amount of sample poured each time or by varying the drop height between the nozzle and the top surface of the sample in the mold.

3) Wet tamping method

Place the sample inside the mold in several batches using a spoon or nozzle, and compact it each time using a ramming rod or similar. Compaction may also be done by tapping the lower part of the mold with a hammer or agitating the mold using vibrator or by other methods.

c) Place a cap on the top of the specimen, draw the rubber sleeve around the cap, and use an O-ring, etc., to seal the rubber sleeve against the cap.

d) Apply appropriate negative pressure (typically 5-10 kN/m^2) to inside the specimen, and remove the mold. When applying the negative pressure to the specimen, vertical displacement of the cap must not be constrained so as to ensure that the isotropic stress state of the specimen is maintained.

Note: Measures must be taken to offset the loading applied by the cap and the loading piston as needed.

e) After increasing the negative pressure to about 20 kN/m^2, measure the diameter of the specimen including the rubber sleeve in two orthogonal directions with a precision of 0.1% or better using a caliper or similar, at upper, middle and lower positions of the specimen. Taking the mean of the measured values, correct for the thickness of the rubber sleeve as measured in advance and determine the initial diameter D_i (mm) of the specimen. The negative pressure must remain lower than the prescribed effective stress in the lateral direction at the termination of consolidation. When the above precision is smaller than that of the measuring device to be used, the precision shall be set at 0.05 mm.

f) Measure the height of the specimen with a precision of 0.1% of the height or better at three or more points that are assigned by dividing evenly the circumference of the specimen, and obtain the mean value to determine the initial height H_i (mm) of the specimen.

g) Determine the mass of the specimen with a precision of 0.1% of the mass or better, as the difference between the mass of the whole original sample before forming the specimen and that of the residual amount after preparing the specimen. Alternatively, the whole sample can be collected and weighed after testing with a precision of 0.1% of the mass or better.

Note: Follow the procedure given in Note of 4.3 f) to obtain the wet density ρ_{ti} (Mg/m^3), dry density ρ_{di} (Mg/m^3), void ratio e_i, degree of saturation S_{ri} (%), and relative density D_{ri} (%) of the specimen in the initial state as needed.

h) Split a representative quantity from the original sample and measure the water content to determine the initial water content w_i (%) of the specimen as needed.

4.5 Mounting of specimen

The specimen shall be mounted by one of the following two methods, depending on the method of preparation used. The axial stress acting at the upper end of the specimen must be 10 kN/m^2 or less from the time the cap is placed on the upper end of the specimen until the negative pressure or cell pressure are applied to the specimen. If the cap and piston are rigidly connected in the equipment being used, apply axial compression force through the piston in addition to the cell pressure in order to attain the prescribed isotropic stress state. The relationship between applied axial compression force and cell pressure, which varies with piston diameter and weight, should be obtained in advance. The procedure used to mount the specimen on the pedestal depends on the rubber sleeve expander to be used.

a) Specimen prepared by the trimming method

1) Mount the specimen on the pedestal, place a cap on it, draw the rubber sleeve over the specimen, and use O-rings, etc., to seal the two ends of the rubber sleeve onto the pedestal and the cap.

Note 1: Place filters for drainage onto the upper and lower surfaces and around the side of the specimen as needed.

Note 2: Use a cap and pedestal with no drainage holes, or place a flat, rigid water-impermeable plate of the same diameter as the specimen on the cap and pedestal, as needed.

Note 3: In the case of frozen specimens, the cap and the pedestal shall be cooled in advance as needed.

1.1) Procedure when using a split (two-part) rubber sleeve expander

1.1.1) Place the specimen on the pedestal.

1.1.2) Insert the rubber sleeve into the split rubber sleeve expander and fit the O-rings, etc., over the ends of the expander. Apply negative pressure to bring the rubber sleeve into close contact with the inner surface of the expander. While maintaining this state, lower the expander over the specimen and on to the pedestal.

1.1.3) After lowering the top cap into contact with the specimen, fix the piston to the top plate of the triaxial pressure cell. If the cap and piston are not rigidly connected in the equipment being used, simply place the cap on the specimen.

1.1.4) Release the upper and lower ends of the rubber sleeve from the expander and use the O-rings, etc., to seal the sleeve onto the cap and pedestal.

1.1.5) Disassemble and remove the rubber sleeve expander.

1.1.6) Ensure that the central axis of the specimen, the top cap and the pedestal are aligned.

1.2) Procedure when using a cylindrical rubber sleeve expander

1.2.1) Place the specimen on a suitable table.

1.2.2) Fit an O-ring, etc., on the pedestal and on the cap.

1.2.3) Insert the rubber sleeve into the rubber sleeve expander and use negative pressure to bring the rubber sleeve into close contact with the inner surface of the expander. While maintaining this state, lower the expander over the specimen.

1.2.4) Release the upper and lower ends of the rubber sleeve and cover the ends of the specimen with it. Fold back the extra part of the rubber sleeve at the two ends of the specimen.

1.2.5) Place the specimen on the pedestal, lower the top cap into contact with the specimen, and roll the folded part of the rubber sleeve over the pedestal and cap.

1.2.6) Use the pre-fitted O-rings or rubber cord to fasten the rubber sleeve onto the pedestal and cap.

1.2.7) Ensure that the central axis of the specimen, the top cap and the pedestal are aligned.

2) Assemble the pressure cell and inject water into the cell. Apply an appropriate magnitude of isotropic pressure to the specimen in the drained state as needed. The isotropic pressure shall be about 20 kN/m^2, and shall be lower than the prescribed effective stress in the lateral direction at the termination of consolidation. At this state, measure the axial displacement ΔH_i (mm) and volume change ΔV_i (mm^3) with an allowable tolerance of 0.1% of the specimen height and volume, respectively. If the specimen is frozen, thaw it by any of the following methods. If it is not possible to directly measure the volume change ΔV_i, measure the axial displacement ΔH_i (mm) of the specimen with an allowable tolerance of 0.1% of the specimen height, and calculate the volumetric change in the specimen ΔV_i (mm^3) from the following equation, which assumes that an isotopic strain is produced in the specimen.

$$\Delta V_i = \frac{3\Delta H_i}{H_i} V_i$$

2.1) Method of thawing under negative pressure

Allow the specimen to thaw while keeping it under appropriate negative pressure. The magnitude of this negative pressure shall be about 20 kN/m^2, and shall be lower than the prescribed effective stress in the lateral direction at the termination of consolidation. After thawing, measure the height and diameter of the specimen with a precision of 0.1% or better to determine the resulting axial displacement ΔH_i (mm) and volume change ΔV_i (mm^3) due to thawing. Assemble the pressure cell and inject water into the cell. By controlling the cell pressure, negative pressure, and axial load so that the effective isotropic stress in the specimen does not change, replace the negative pressure with the cell pressure.

2.2) Method of thawing under cell pressure

Assemble the pressure cell and inject water into the cell. Apply cell pressure and allow the specimen to thaw under appropriate isotropic pressure. The magnitude of this isotropic pressure shall be about 20 kN/m^2, and shall be lower than the prescribed effective stress in the lateral direction at the termination of consolidation. Measure the resulting axial displacement ΔH_i (mm) and volume change ΔV_i (mm^3) with an allowable tolerance of 0.1% of the specimen height and volume, respectively.

b) Specimen prepared by the negative pressure method

1) Assemble the pressure cell and inject water into the cell.

2) By controlling the cell pressure, negative pressure, and axial load so that the effective isotropic stress in the specimen does not change, replace the negative pressure with the cell pressure.

4.6 Saturation of specimen

Refer to the following for the methods available to saturate the specimen. Volume changes that occur as a result of the saturation process shall be measured as required.

a) When there is a need to increase the degree of saturation of a specimen, an appropriate combination of the following four methods should be used according to the soil type and the state of the specimen.

1) Passing deaerated water through the specimen under cell pressure

2) Applying sufficient back pressure

3) Apply methods 1) and 2) after replacing void air inside the specimen with carbon dioxide gas under a cell pressure

4) Extraction of air from within the specimen by applying a negative pressure of about 90 kN/m^2 to the specimen and to the pressure cell without changing the effective isotropic stress. Supply deaerated water while applying the negative pressure as needed.

b) When using back pressure, apply the back pressure u_b (kN/m^2) to the specimen and the isotropic pressure concurrently without changing the effective isotropic stress inside the specimen. If a back pressure is applied, it shall be about 50-200 kN/m^2, and the back pressure should be increased gradually in order to avoid large fluctuations in effective stress inside the specimen. The following procedure is appropriate: Close the drainage valve connected to the burette and apply an appropriate increment of isotropic stress to the specimen. Then, apply an equivalent magnitude of back pressure and open the valve. In this way, the difference in the isotopic stress and the back pressure acting on the specimen is always maintained at the initially set pressure difference. Repeat this operation until the back pressure reaches the prescribed value. The increments of the isotropic pressure and the back pressure for each step shall be set by paying attention to keep the effective stress to be lower than the prescribed effective stress in the lateral direction at the termination of consolidation, even when the degree of saturation of the specimen is low, exhibiting a small B value. In K0 consolidation testing (JGS 0525 and JGS 0526), the B-value measurement process is additionally carried out at the state when applying the back pressure.

Note: Appropriate values of the increments of the isotropic pressure and the back pressure are typically 10-50 kN/m^2.

c) Measure the axial displacement ΔH_i (mm) and volume change ΔV_i (mm^3) of the specimen from the initial state until prior to consolidation (before testing) with an allowable tolerance of 0.1% of the specimen height and volume, respectively. These include ΔH_i (cm) and ΔV_i (cm^3) measured in 4.5 a).

Note: If the volumetric change ΔV_i cannot be directly measured, then ΔV_i may be calculated from the following equation, which assumes that an isotropic strain is produced in the specimen. If ΔV_i is obtained using this equation, it shall be clearly stated in the reporting items.

$$\Delta V_i = \frac{3\Delta H_i}{H_i} V_i$$

5 Reporting

The following items of the specimens shall be reported.

a) Type of soil

Note: Report the density of soil particles (Mg/m^3), liquid limit (%), plastic limit (%), minimum dry density (Mg/m^3) and maximum dry density (Mg/m^3) as needed.

b) Specimen preparation method

c) Initial height (mm), diameter (mm), and volume (mm^3) of specimen

Note: Report the wet density (Mg/m^3), dry density (Mg/m^3), void ratio, degree of saturation (%) and relative density (%) of the specimen in the initial state as needed.

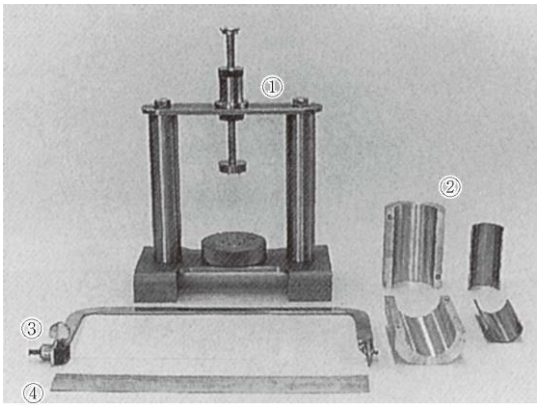
d) The initial mass (g) and water content (%) of the specimen if measured

e) The axial displacement (mm) and volume change (mm^3) of the specimen that occur from the initial state until prior to consolidation (before testing), and the measurement methods used

f) Details of any difference between the methods specified in this standard and the methods actually used. If the specimen is separated from a large lump sample or if part of a tube sample is used, provide sketches of the sections taken. If a sample is prepared by compaction or preconsolidation, report the method used along with the test results.

Note: If necessary, report the ambient temperature at the time of preparation.

g) Other reportable matters



① Trimmer ③ Wire saw
② Miter box ④ Straight knife

Figure 1 Example of equipment for preparing specimen

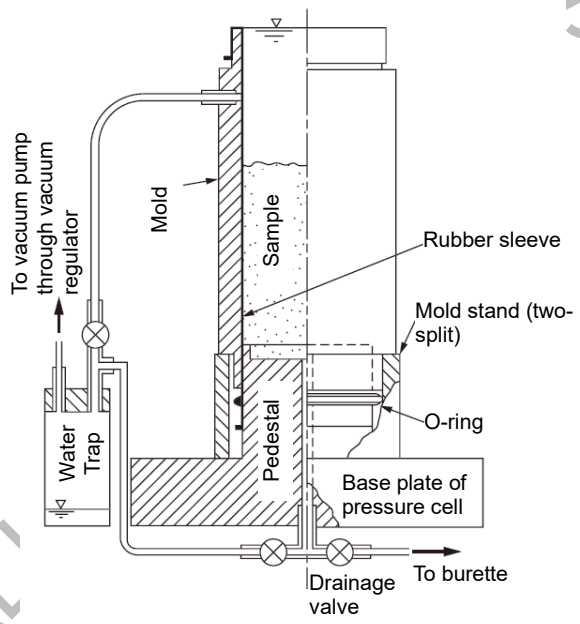


Figure 2 Example of saturated specimen preparation by the negative pressure method