Japanese Geotechnical Society Standard (JGS 0550-2020)
Practice for preparing hollow cylindrical specimens of soils for torsional shear test

1 Scope

This standard specifies a method of preparation of specimens for tests carried out in accordance with the series of torsional shear tests on soils. The standard applies to cohesive soils and sandy soils.

Note: This standard can also be applied to other geomaterials.

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 0207 Technical terms for geotechnical engineering
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
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
JGS 0520 Preparation of soil specimens for triaxial tests

The series of torsional shear test methods refers to the following standards.

JGS 0543 Method for cyclic torsional shear test on hollow cylindrical specimens to determine deformation properties of soils
JGS 0551 Method for torsional shear test on hollow cylindrical specimens of soils

3 Equipment

3.1 Test specimen preparation equipment

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.

Note: Frozen and other samples may be shaped using a core cutter, disc cutter, drill 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 external diameter of the specimen. The two end faces shall be parallel to each other, and also perpendicular to the axis of the inserted specimen. The miter box shall have at its both ends extension collars having a hole with a diameter equal to the internal diameter of the 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) External and internal molds

In general, the external mold should be separated into multiple parts. The hollow part height when assembled on the pedestal shall be equal to the height of the specimen, and the internal diameter shall be greater than the external diameter of the specimen by twice the thickness of the rubber sleeve. The external 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.

In general, the internal mold should be separated into multiple parts and have a height greater than the combined height of the specimen and cap. Its external diameter shall be smaller than the internal diameter of the specimen by twice the thickness of the rubber sleeve.

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-pluviation method or water-pluviation method: Funnel, nozzle, nested sieves, etc.

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

3.2 Other equipment

The equipment used for preparing and installing the specimens shall conform to the following requirements.

Note: When necessary an O-ring expander, rubber sleeve expander, and filter are used.

a) Negative pressure generator

The negative pressure generator shall be capable of applying negative pressure to ensure close contact between the external rubber sleeve and the internal surface of the external mold, and, when preparing specimens using the negative pressure method, it is also used to make support the specimen to keep its shape.

b) Rubber sleeve

The thickness of the rubber sleeve in its natural state shall be between 0.15 and 0.3 mm, and the internal diameter of the rubber sleeve shall be about 95% of the external diameter or the internal diameter of the specimen.

c) O-ring or rubber band

The O-ring internal diameter shall be about 80% of the diameter of the part that is tightened, and the tightening force shall be sufficient to prevent leakage.

d) Instrument for measuring specimen size

The instrument used to measure the specimen size shall be capable of determining the external diameter, internal diameter, and height of the specimen to a precision of 0.05 mm or better. A caliper or a steel measuring tape with a vernier scale (Pi Tape) shall be used for measurement of the external diameter of the specimen. Also, a caliper or similar shall be used for measuring the internal diameter.

e) Weighing scale

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

4 Test specimen preparation and installation method

4.1 Types and selection of the test specimen preparation method

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 specimens shall be as follows.

a) The specimen shall have a hollow cylindrical shape.

b) The standard external diameter of the specimen shall be 70 mm or more for sandy soils, 50 mm or more for cohesive soils. The standard internal diameter shall be 30 mm or more for sandy soils, and 20 mm or more for cohesive soils.

c) The standard height of the specimen shall be between 1 and 2 times the external diameter as standard.

d) The standard thickness of the specimen shall be at least 10 times the maximum particle size in the test sample.

Note: The thickness of the specimen may be up to 5 times the maximum particle size of a sample for soils having a wide range of particle sizes.

4.3 Preparation and measurement of specimens by the trimming method

Following the procedures listed in a) through h), 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 surface 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) The hollow part of the specimen shall be formed to a hollow cylinder of the prescribed internal diameter using a miter box, wire saw, straight edge, etc. The hollow part of the specimen is formed by installing extension collars having a central hole of the same size as the specified internal diameter of the specimen onto the miter box.

e) Measure the external diameter and the internal 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 external diameter D_{oi} (mm) and the initial internal diameter D_{ii} (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 0.05mm. The allowable difference between the measured values shall be within ±1% of D_{oi} and D_{ii}.

f) 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 (cm) of the specimen. The allowable difference between the measured values shall be within ±0.5% of H_i.

g) The mass of the specimen m_i (g) shall be measured with a precision of 0.1% or better.

Note: Use the following equations to obtain the wet density ρ_{ti} (Mg/m³), dry density ρ_{di} (Mg/m³), 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 the specimen (mm³) $\left(V_i = \pi\left(D_{oi}^2 - D_{ii}^2\right)H_i/4\right)$
ρ_s: Density of the soil particle (Mg/m³)
ρ_w: Density of water (Mg/m³)
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

h) 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 Producing and measuring the test specimens by the negative pressure method

When using the negative pressure method, specimens shall be prepared and measured as follows. Figure 1 shows a specimen in the process of preparation by the negative pressure method.

a) Assemble the pedestal, the rubber sleeves, and the internal and external molds by the prescribed method. The rubber sleeves shall be fitted in close contact to the internal surface of the external mold, and, the external surface of the internal mold. Check that the molds have been correctly installed. When there is a rigid connection between the cap and the loading piston, check that the central axes of the cap and molds coincide. In case of other connection types, check that the bottom plate and the top surface of the mold are horizontal, using a level or similar. Apply a vacuum pressure at the sleeve-mold interface to ensure that the external rubber sleeve is always in close contact with the internal surface of the external mold.

b) Fill the space between the external mold and the internal mold with the sample material using one of the methods given below. When the prescribed height is reached, 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 annulus between the molds 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 between the molds, 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 annulus between the molds filled with deaerated water in advance, using a nozzle or spoon. Adjust the density of the specimen by controlling the amount of the sample poured each time or by varying the drop height between the nozzle and the top surface of the specimen between the molds.

3) Wet tamping method

Place the sample in the annulus between the molds in several batches using a spoon or nozzle, and compact it each time using a ramming rod. 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 the cap on the top of the specimen, and bring the external and internal rubber sleeves and the cap into close contact using an O-ring or similar.

d) Apply appropriate negative pressure (typically 5-10 kN/m^2) to inside the specimen, and remove the external and internal molds. 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 external diameter and the internal diameter of the specimen including the rubber sleeve in two orthogonal directions with a precision of 0.1% or better 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 external diameter D_{oi} (mm) and the initial internal diameter D_{ii} (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 0.05mm. The allowable difference between the measured values shall be within ±1% of D_{oi} and D_{ii}. The negative pressure must remain lower than the prescribed effective stress in the lateral direction at the termination of consolidation.

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. The allowable difference between measured values shall be within ±0.5% of H_i.

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 the testing with a precision of 0.1% of the mass or better.

Note: Follow the procedure given in Note of 4.3 g) 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.

5 Specimen installation processes

The external pressure and the internal pressure applied to the specimen shall always be equal.

5.1 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 upper end of the specimen until the negative pressure or the external pressure and internal pressure are applied to the specimen. Sufficient care shall be taken not to disturb the specimen when installing the specimen. In particular, when installing specimens prepared by the trimming method, sufficient care shall be taken not to excessively disturb the top and bottom ends of the specimen with the ribs installed on the cap and the pedestal.

a) Specimen prepared by the trimming method

1) Mount the specimen on the pedestal to which the internal rubber sleeve has been fitted, apply the external rubber sleeve, and tighten the rubber sleeves to the pedestal and the cap using the O-ring or similar. Take care that there is no misalignment between the central axes of the specimen and the pedestal.

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

Note 2: In the case of frozen specimens, the cap and the pedestal shall be cooled in advance as needed.

2) Assemble the pressure cell and inject water into the cell and the hollow part of the specimen. If necessary, 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 the volumetric 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.

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, external diameter, and internal diameter of the specimen with a precision of 0.1% or better to determine the resulting axial displacement ΔH_i (mm) and volumetric change ΔV_i (mm^3) due to thawing. Assemble the pressure cell, and inject water into the cell and the hollow part of the specimen. By controlling the external pressure, internal pressure, negative pressure, and axial load so that the effective isotropic stress in the specimen does not change, replace the negative pressure with external pressure and internal pressure.

2.2) Method of thawing under cell pressure

Assemble the pressure cell and inject water into the cell and the hollow part of the specimen. Apply external pressure and internal pressure, and allow the specimen to thaw under appropriate isotropic pressure. 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. Measure the resulting axial displacement ΔH_i (mm) and volumetric change ΔV_i (mm^3) with an allowable tolerance of 0.1% of the specimen height and volume, respectively. 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.

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

b) Specimen prepared by the negative pressure method

Assemble the pressure cell and inject water into the cell and the hollow part of the specimen. By controlling the external pressure, internal pressure, negative pressure, and axial load so that the effective isotopic stress in the specimen does not change, replace the negative pressure with the external pressure and internal pressure.

5.2 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 and the hollow part of the specimen without changing the effective isotropic stress. Supply deaerated water while applying the negative pressure as needed.

b) Back pressure u_b (kN/m^2) within the specimen and isotropic pressure shall be applied simultaneously to the specimen, without changing the effective isotropic stress within the specimen. The value of the back pressure shall be about 50 to 200 kN/m^2, and in order to avoid fluctuations in the effective stress in the specimen during pressurization, it is desirable that it be applied gradually as follows. 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 with. 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.

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 the volumetric change ΔV_i (mm^3) of the specimen from the initial state until prior to consolidation with an allowable tolerance of 0.1% of the specimen height and volume, respectively. These include ΔH_i (mm) and ΔV_i (mm^3) measured in 5.1a).

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.

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

6 Reporting

The following items of the specimens shall be reported.

a) Type of soil

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

b) Specimen preparation method

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

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

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

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

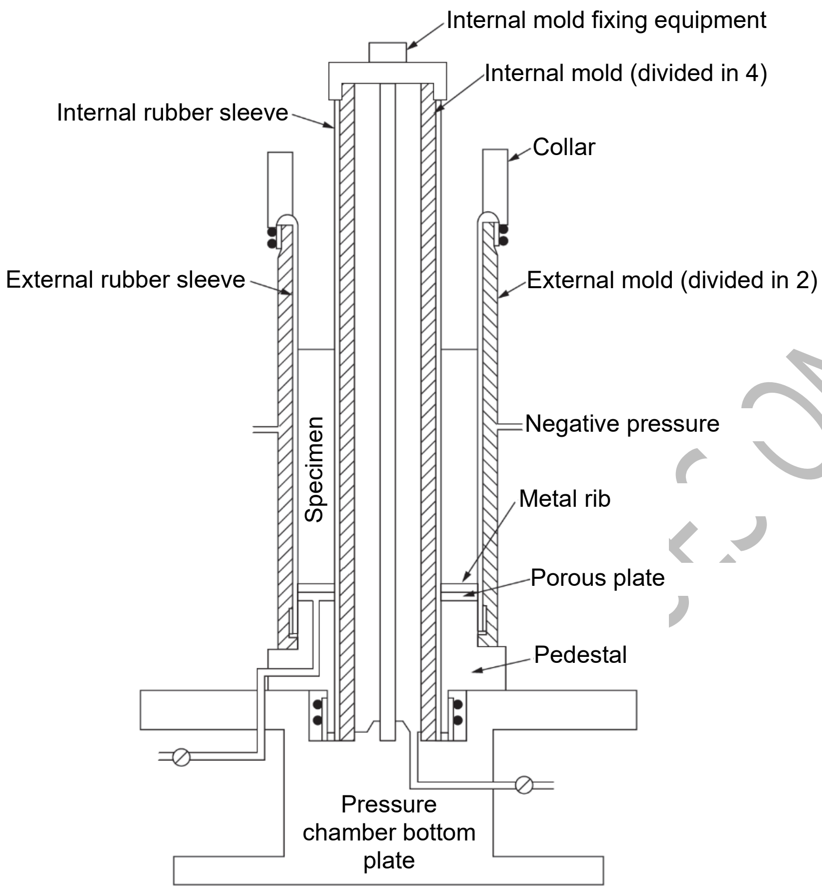

Figure 1 Example of a hollow cylindrical test specimen being produced by the negative pressure method