Japanese Geotechnical Society Standard (JGS 0530-2020)
Preparation of specimens of coarse granular materials for triaxial tests

1 Scope

This standard covers the preparation and mounting of specimens of coarse granular materials for triaxial testing. The standard diameter of a specimen shall be from 300 mm, which is prepared by using soils with a maximum particle size exceeding about 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).

JIS A 1202 Test method for density of soil particles
JIS A 1203 Test method for water content of soils
JIS A 1204 Test method for particle size distribution of soils
JIS A 1210 Test method for soil compaction using a rammer
JGS 0051 Method of classification of geomaterials for engineering purposes
JGS 0520 Preparation of soil specimens for triaxial tests
JGS 0525 Method for K_0 consolidated-undrained triaxial compression ($K_0\overline{\mathrm{CU}}\mathrm{C}$) test on soils with pore water pressure measurements
JGS 0526 Method for K_0 consolidated-undrained triaxial extension ($K_0\overline{\mathrm{CU}}\mathrm{E}$) 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

The following equipment shall be used for preparing a specimen.

a) Straight knife

b) Material for leveling end faces of specimen

When using the trimming method of preparing specimens, leveling material for the end faces is primarily gypsum. When using the negative pressure method, the material should be fine fractions separately prepared from same sample.

c) Mold

The mold should be separated into multiple parts and have the same height as 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 should be of airtight structure with suction pores to ensure that the rubber sleeve comes into close contact with the inner surface of the mold when negative pressure is applied.

d) Equipment for compacting samples

When using the compaction method to prepare specimen, the following equipment shall be prepared as needed. Collar (for use in compacting the uppermost layer), rammer, tool for disturbing the compacted surface, ramming rod, vibrator (top-driven or bottom-driven type), disk plate for compaction, and plastic or wooden hammer.

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 should be slightly less than the diameter of the specimen. The rubber thickness in its natural state should be about 0.5-2 mm; however, if the particle shape or other characteristics of the sample mean there is a danger of puncturing the rubber sleeve during testing, a thicker rubber sleeve is required.

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. The filter must be fine enough to ensure that fine fractions do not escape.

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 the 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) Rubber cord and tool for fastening rubber sleeve

Fastening force must be sufficient to prevent leakage.

f) Instrument for measuring specimen size

The dimensions of the specimen are measured with a caliper, a linear steel ruler, or a steel measuring tape. The measurement by these instruments must be at least 0.1 % of the dimension being measured. The diameter of a specimen is preferably measured with a steel measuring tape.

g) Weighing scale

The weighing scale shall have a precision of 0.1 g or better.

h) Sieve

As stipulated in JIS Z 8801-1 Test sieves – Part 1: Test sieves of metal wire cloth.

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 that are cut on site into the required dimensions. In principle, the side surface of a specimen is not shaped in the laboratory.

b) Negative pressure method

The negative pressure method shall be used for samples obtained in a loosened state and that cannot be formed into large pieces by compaction and consolidation. It shall be also used for those that may deform under its own weight when the mold is removed, even if compaction gives the sample reasonable stability.

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 300 mm, and it shall be at least 10 times the maximum particle size of the sample.

Note: The diameter of the specimen may be about 5 times 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 2.0 to 2.5 times the diameter.

4.3 Preparation and measurement of specimens by trimming method

Following the procedures listed in a) through e), specimens must be prepared with care so as to avoid changes in sample water content. In principle, the sample should be of the same diameter as the specimen and it should be a little higher. 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) With a straight knife, etc., shape the end faces of the specimen. If it is difficult to shape the end faces of undisturbed samples collected from the site, use a leveling material to form a cap on the upper and lower end faces of the specimen. This ensures that the upper and lower end faces of the specimen are flat and perpendicular to the axial direction.

b) 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.

c) 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 as the initial height H_i (mm) of the specimen.

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

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

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

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

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

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

where

V_i: Initial volume of the specimen (mm^3) ($V_i = \pi D_i^2 H_i/4$)
ρ_s: Density of the 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 the sample by minimum density test
e_{min}: Void ratio of the sample by maximum density test

e) 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 1 shows a specimen in the process of preparation by the negative pressure method.

a) Regulate the particle size of the sample by sieving, as needed.

Note: Control the water content of the sample as needed. Moreover, if a saturated sample is being tested, permeate a sufficient amount of deaerated water into the sample to remove the air in advance. If the particle size distribution and dry density of the specimen to be prepared are specified, adjust the samples by the non-drying method or the air-drying method and then sort them by sieving according to any of the following methods to obtain a suitable sample. Determine the water content w_n (%) for each sorted sample group.

1) Method of sorting into several specified particle sizes

Select appropriate sieves from the whole set of test sieves and combine them for sorting. Pass the sample through the series of sieves. For each sieve, the soil material that remains in the next finer sieve shall be taken as the sample for that particle size classification.

2) Method of sorting into a single particle size using one specified sieve

Soil material that has passed or that remains on a single sieve shall be used as the sample.

Note 1: When preparing a specimen from a sorted sample by the compaction method, calculate the mass m_n* of each particle size group of the sample required to form the specimen to a precision of 1 g, based on the specified dry density, the specimen's dimensions, the mass percentage f_n (%) and the water content w_n (%) of each particle size group, to satisfy the specified particle size distribution. The resulting value shall be divided by the number of layers k to determine the target required mass per layer (m_n*/k). Here, the symbols marked * are calculated values and those without * are measured values or specified values.

Note 2: Use the weighing scale to weigh out the required mass of each particle size group for each layer (m_n*/k) and for all layers. Aggregate the weighed values for each particle size group. The aggregated value should be taken as the sample mass m_n for each particle size group in the specimen.

b) 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. Place a filter on the pedestal as needed.

c) 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.

1) Water-pluviation method

Use a scoop, bowl, etc., to pour a dry sample or a sample at its natural water content into the mold filled with deaerated water in advance. The amount added each time should be adjusted by monitoring the drop height from the pouring point to the top surface of the specimen inside the mold. To adjust the specimen to the prescribed density, tap the mold with a hammer or agitate it with a vibrator as needed.

2) Compaction method

Fill the mold with the sample up to the target height in five to six separate layers using the scoop, bowl, etc. and compact it to the prescribed density by agitation with a vibrator or hammer. Place the sample material into the mold to ensure that large particle sizes are evenly distributed in the layers. Additionally, lightly disturb the top surface of the sample material before adding the next layer. Finish the top face of the uppermost layer.

d) Place a cap on top of the specimen, draw the rubber sleeve around the cap and use a rubber cord, etc., to seal the rubber sleeve against the cap. Insert a filter on the top surface of the specimen as needed.

e) Apply appropriate negative pressure (typically 20-30 kN/m^2) to the specimen and remove the mold. The negative pressure must remain lower than the prescribed effective stress in the lateral direction at the termination of consolidation. 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 1: Measures shall be taken to offset the loading applied by the cap and the loading piston as needed.

Note 2: When preparing specimens by the compaction method with a rammer or by tamping, note that the amount of particle breakage varies greatly with the type of sample material.

f) While applying the negative pressure, measure the diameter of the specimen to the outer surface of the rubber sleeve in two orthogonal directions with a precision of 0.1 % of the diameter 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 diameter D_i (mm) of the specimen.

g) 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.

h) Determine the mass m_i (g) of the specimen with a precision of 0.1% of the mass or better, as the difference between the mass of the whole sample prepared in advance 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 4.3 d) 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. If a specimen is prepared from sorted samples by the compaction method, the oven-dried mass m_s of the specimen should be obtained using the following equation.

$$m_s = \sum_{n=1}^{j} m_{sn} = \sum_{n=1}^{j} \frac{m_n}{1+\frac{w_n}{100}}$$

where

j: Number of particle size group
m_n: Mass of sample for each particle size group (g)
m_{sn}: Oven-dried mass of sample for each particle size group (g)
w_n: Water content of sample for each particle size group (%)

i) 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.

Note: If a specimen is prepared from sorted samples by the compaction method, the water content w_i (%) of the specimen should be obtained using the following equation.

1) Where prepared from several particle size groups

$$w_i = \sum_{n=1}^{j} \frac{f_n w_n}{100}$$

2) Where prepared from a single particle size group

The measured water content shall be set as w_i (%).

5 Specimen installation process

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 on the upper end face of the specimen must be 10 kN/m^2 or less between placement of the cap on the top of the specimen and the application of negative pressure or cell pressure. 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.

a) Specimen prepared by trimming method

1) Mount the specimen on the pedestal, place a cap on it, draw the rubber sleeve over the specimen, and use rubber cords, etc., to fasten the two ends of the rubber sleeve onto the pedestal and the cap. The following procedures may be used to mount a specimen on the pedestal, depending on the rubber sleeve expander to be used.

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 without drainage holes, or place 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 a frozen specimen, pre-cool the cap and pedestal as needed.

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

1.1.1) Place the specimen on the pedestal such that the axes of the specimen and pedestal are aligned.

1.1.2) Insert the rubber sleeve into the split rubber sleeve 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, place the cap on the specimen.

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

1.1.5) Disassemble and remove the rubber sleeve expander.

1.2) Procedure when using a cylindrical rubber sleeve expander

1.2.1) Place the specimen on the pedestal such that the axes of the specimen and pedestal are aligned.

1.2.2) 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.

1.2.3) Release the upper and lower ends of the rubber sleeve. Pull the lower end of the sleeve down to cover the pedestal. Fold back the excess at the upper end of the rubber sleeve over the expander.

1.2.4) After lowering the 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, place the cap on the specimen.

1.2.5) Unfold the upper end of the sleeve over cap.

1.2.6) Use rubber cords, etc., to fasten the rubber sleeve onto the pedestal and the cap.

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 30 kN/m^2, which must 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 of the specimen does not change, replace the negative pressure with the cell 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 the 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. In this process, in order not to apply over-consolidation history, an appropriate magnitude of negative cell pressure shall be simultaneously applied so that the difference between the negative pressure in the specimen and the cell pressure must be smaller than the effective stress in the lateral direction at the termination of consolidation, and then the methods in 1) and 2) shall be applied. 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. A back pressure of about 50-200 kN/m^2 shall be used. 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 attentions 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.

c) Measure the axial displacement ΔH_i (mm) and volume change ΔV_i (mm^3) of the specimen that occurred 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 (mm) and ΔV_i (mm^3) measured in 5.1 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.

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

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), liquid limit (%), plastic limit (%), maximum dry density (Mg/m^3), and minimum dry density (Mg/m^3) as needed.

b) Specimen preparation method

Note 1: If the specimen is prepared from sorted samples, report the sample control method (non-drying method or air-drying method), sorting method (whether several particle size groups or a single particle size group), and the particle size groups and their percentage contributions.

Note 2: If the specimen is prepared by the compaction method, report the compaction procedure and the specifications of the compaction equipment.

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 specimens in the initial state as needed.

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

Note: If the specimen is prepared from sorted samples, report the particle size classifications and their water content (%), and the specified dry density (Mg/m^3).

e) The axial displacement (mm) and volume change (mm^3) of the specimen that occur from the initial state until prior to consolidation, 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 the sample is prepared by compaction, report the method used along with the test results.

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

g) Other reportable matters

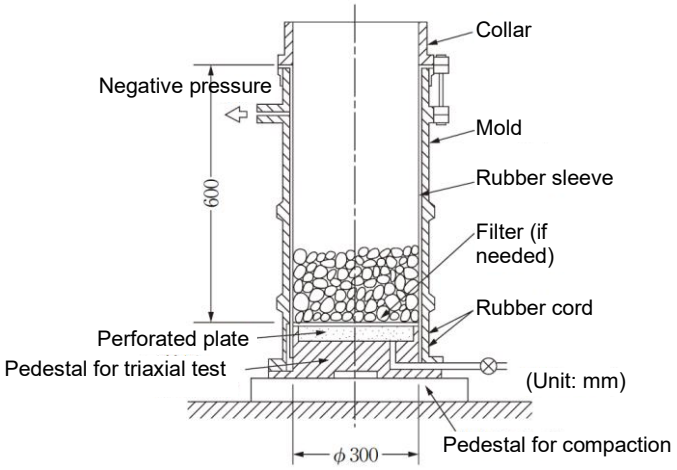

Figure 1 Example of specimen preparation by negative pressure method