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JTG E40-2007

Test Methods of Soils for Highway Engineering

公路土工试验规程

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1 General Provisions

1.0.1 This standard is formulated with a view to testing the basic engineering properties of soil, unifying the test methods, and providing reliable calculation index and parameter for the highway engineering and construction.

1.0.2 This standard is applicable to basic engineering properties tests of foundation soil, subgrade soil and other road using soil in highway engineering.

1.0.3 For engineering of all kinds, the reasonable testing program is prepared, the representative samples are selected, the accurate data are gotten, and the correct analysis and arrangement of data is conducted. The soil indexes to reflect the actual situation are provided for engineering and construction.

1.0.4 The analysis and arrangement for soil test material are conducted according to Annex A, and the overall (soil mass unit) characteristics and change regularity are estimated by the research on the samples (data gotten in the test).

1.0.5 For soils of different type and gradation, the soil test reports shall state basic particle gradation, liquid limit and plastic limit indexes of soils; for special soil, it shall also provide test indexes in indicate the essential characteristic of special soil.

1.0.6 The highway soil tests shall meet the requirements of relevant current national and professional standards, besides this standard.

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2 Terms and Symbols

2.1 Terms

2.1.1 Water content

Ratio of soil water mass to particle mass, expressed in a percentage

2.1.2 Density

Mass per unit volume of soil

2.1.3 Porosity

Ratio of soil void volume to total volume, expressed in a percentage

2.1.4 Void ratio

Ratio of soil void volume and solid particulate volume

2.1.5 Specific gravity of soil particle

Ratio of soil particle to the mass of 4℃ distilled water

2.1.6 Gradation

Relative content of particle group divided of soil particles with similar particle size. it is a concept to evaluate the state of particle size distribution curve of soil particles through the nonuniformity coefficient (Cu) and the coefficient of curvature (Cc).

2.1.7 Consistency limit

Limit water content where cohesive soil changes from a state to other state with the change of water content

2.1.8 Consolidation

Procedure of soil volume reduction and density increase due to gradual moisture discharge from saturated soil mass venting under external loads

2.1.9 Coefficient of compressibility

Ratio of void ratio decrease and effective pressure increase of soil sample in K0 consolidation test, i. e. gradient of the secant of a pressure section in e-p compression curve, expressed in absolute value

2.1.10 Compression index

Gradient of straight segment in the relation curve of the void ratio (gotten in compression test) to the effective pressure Logarithm, i.e. gradient of the straight segment in e-lgp curve after pre-consolidation pressure

2.1.11 Constrained modulus

Ratio of vertical effective pressure to vertical strain of soil mass compressed under lateral confinement condition

2.1.12 Modulus of resilience

Ratio of vertical pressure to rebound strain (during the unloading process) of the soil mass under partial lateral confinement condition

2.1.13 Coefficient of permeability

Proportionality coefficient of the relation of flow speed proportional to action hydraulic gradient where soil water seepage is under laminar condition

2.1.14 Shear strength

Ultimate shearing stress withstood by soil mass on a shear surface

2.1.15 Unconfined compression strength

Ultimate strength of soil mass (without lateral confinement condition) to resist the axial

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4 Soil Sample Acquisition and Preparation

T 0101-2007 acquisition, transportation and storage of soil sample

1 Requirements in soil sample

1.1 Undisturbed soil or disturbed soil may be selected and sampled according to the engineering object. the undisturbed soil shall be sampled for natural subsoil and excavation side slope of bridge, culvert, tunnel, retaining wall and building construction; disturbed soil shall be sampled for landfill subgrade, dyke, borrow pit (yard) or for only soil classification test. Where the undisturbed soil of frozen soil is sampled, the temperature, structure and water content of the original soil shall be kept constant.

1.2 The soil samples may be gotten from test pit, flat-hole, shaft, natural ground and drilling hole. If the undisturbed soil sample is needed, the original structure and natural water content of the soil sample must be kept constant, and the soil sample shall be free from disturbance. If a drilling machine is used to borrow soil, the diameter of the soil sample must not be less than 10cm, and special thin wall soil sample barrel shall be used; where the undisturbed soil is borrowed from test pit or natural ground, a soil sample barrel (with iron wall) with upper and lower covers may be used. The operation method is to press the soil sample barrel till the barrel being filled with soil, to excavate the bottom soil layer (or swing left or right to break), to take the barrel out and to shave the soil sample off after turning. Fill the surrounding space with original soil, cover the lower cover; seal the soil sample barrel. For sampling disturbed soil, clear the surface soil, and sample with the sample quartering method by layers. for sampling salty soil, sample by layer at vertical depth 0 ~ 0.05, 0.05 ~ 0.25, 0.25 ~ 0.50, 0.50 ~ 0.75 m and 0.75 ~1.0 m. in addition, record the season, time, and air temperature of sampling.

1.3 Quantity of soil sample: sample according to the quantity specified by corresponding test item.

1.4 Soil borrowing records and numbering: no matter what method is adopted, the "sample log" is used for recording, and half page is teared out as label which is pasted on the soil sample barrel (undisturbed soil) or placed into the soil sample bag. The "sample log" should be made of tough paper and filled in with a pencil. The recorded content of the sample log shall include project name, route kilometrage (or location), start date of record, and end data of record, sampling unit, characteristics of soil sample, test pit number, sampling depth, soil sample number, soil sample number, soil sample name, function, test item or sampling explanation, sampling staff, date of sample, etc. the sample method, disturbed or original state, sampling direction and phenomenon in sampling procedure shall be recorded in the sampling explanation column.

2 Soil sample package and transportation

2.1 Undisturbed soil or disturbed soil whose natural water content needs be kept constant, after sampling, shall be immediately sealed in the soil sample barrel, i.e. the air-gap on the soil sample barrel shall be closed with adhesive tape, and red oil is covered on both ends for marking the text "upper, lower" (soil sample layer location). The label teared down from the "sample log" are stuck on the barrel wall; the barrels enveloped with gauze fabric and poured with molten wax to avoid moisture loss. For undisturbed soil sample, the soil

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sample structure shall be kept constant; for frozen soil, the undisturbed soil sample hereof shall be kept constant.

2.2 The undisturbed soil after sealing shall be placed at cool and dark place before being cased, and the frozen soil sample shall be kept constant temperature; for disturbed soil whose natural water content needs not be kept constant, the soil should be placed into bags after being air dry and crushed.

2.3 The soil samples shall be checked with the "sample log" in casing, and they are encased in upon without fault. The case number shall be recorded in the record book stub. the barrel for the undisturbed soil shall be placed vertically in the wooden case and the upper and lower positions are identified. The open space in the barrel shall be filled tight with straw (wheat straw) or soft material to prevent being vibrated and frost during the transportation process. The text "handle with care", "keep upright", "upward" and "downward" shall be marked clear and the wooden case shall be numbered. The bag for disturbed soil sample may be packed into the jute bag upon being checked with the list. The gunny is marked with the number and arranged with the label (like baggage label) after the opening is tightened. The label shall be marked with gunny number, the quantity of soil bags in it and the number of the soil bags.

2.4 The disturbed soil sample of salty soil should be packed with plastic bags, and a small plastic bag in the large bad is used to pack the sample log label to prevent the label being rotted due to wetness; or the folded label is placed in the plastic bag opening and the bag opening is folded for closing in, and a rubber ring is used to bundled the bag opening below the label. The bag opening with the label is folded under and tied down the rest rubber ring. The 5plastic bag of soil sampled from each salty soil section may be packed together in a larger cloth bag and they shall be checked with the record book stub before being packed into the cloth bag. The cloth bag number is recoded in the primary record book.

3 Receiving and management of soil samples

3.1 The soil sample attached with "Test Commission Form" shall be submitted to the test organization, and the columns of the "Test Commission Form" shall be filled in clearly according to the stub of the "sample log"; the other test requirement, if needed, may be indicated in the Test Commission Form. the Commission Form for soil sample test shall include the following information: laboratory name, commission date, soil sample number, laboratory number, soil sample number (field identification), sampling site or mileage stake number, hole (it) number, test purposes, test item, and responsible person (director, engineer in charge, entrusting organization and contact, etc.).

3.2 Where receiving the soil samples, the test organization shall check the soil samples according to the Test Commission Form and check whether the delivered soil sample meet the requirements of the test items. Simultaneously, where a soil sample is checked, it shall be numbered in the laboratory numbered column in the Commission Form, and the new number is recorded in the original label to avoid confusing with other soil sample numbering.

3.3 After the soil samples are checked and received, they shall be registered in the "Soil Sample Receiving and Dispatching Register Book" and handed over to the test responsible person for storage and testing item by item as required. After completing the tests, rest soil sample shall be packed in the original bag. Where the test results are given off and the entrusting organization receives the report a month later, the soil sample may be disposed id

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no person or organization enquiries. For any problems, the rest soil may be used for re-test.

T 0102-2007 Soil sample and sample preparation

1 Preparation procedure of disturbed soil sample of fine particle soil

1.1 The disturbed soil sample shall be described like color, soil type, smell and enclosure; if necessary, the disturbed soil samples are mixed, and the representative soil sample is sampled for water content determination.

1.2 The blocky disturbed soil is placed in a sheet rubber and rolled disperse with a wood roller or crasher, but the particle shall not be crushed; if the disturbed soil cannot be rolled disperse due to high water content, it may be dried in air and then rolled disperse.

1.3 The rolled soil sample is sieved according to the required amount of soil sample in the test. the soil sample shall be sieved with 0.5mm sieve for the physical tests like liquid limit, plastic limit and shrinkage limit; the soil sample for general water test and mechanical test shall be sieved with 2mm sieve; the maximum particle diameter of the soil sample for compaction test must satisfy the requirement in the maximum particle diameter of the soil sample in the test with different compaction mold. After the soil sample is sieved by the standard sieve as required, enough amount of typical sample is selected and placed in a container and marked with the label in which the information including project name, soil sample number, sieve diameter, function, preparation date and personnel are indicated. if loose soil sample contains a large amount of coarse sand and a small amount of fine particle soil (sand or clay), it shall be selected typical sample by fourfold division method after wetting and loosening; typical sample; if the soil sample is clean sand, the typical sample may be selected with a soil balance.

1.4 For making the sample with certain water content, 1~ 5kg is sieved with a 2mm sieve and the water addition is calculated by the procedure 2.2 in this method; the selected soil sample is spread in a non-absorbent tray and the water of required amount is sprayed with a spraying equipment; after being mixed fully, the sample is put into a container and covered close, and the sample is wetted for 24h for use (the wetting time of sandy soil may be reduced properly).

1.5 Where the water content of humid soil on different position (at least two), the difference of the water content shall satisfy the permissible parallel difference in the water content determination.

1.6 Where soil samples from different soil layers are selected for preparing mixed sample, the corresponding mass proportioning shall be calculated in proportion according to the thickness of soil layers, and the preparation of disturbed soil is conducted by procedure 1.1 ~ 1.4 in this method.

2 Calculation for disturbed soil sample preparation

2.1 The arid soil mass is calculated according to the following formula:

$$m_s = \frac{m}{1 + 0.01 w_h} \qquad \text{(T 0102-1)}$$

Where,

m_s——Arid soil mass (g);

m——Air dried soil mass (or natural soil mass) (g);

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small height; and sample pressing method for ones with large height.

4.1 Compacting method

4.1.1 Corresponding ramming (compacting) energy is adopted to compact as required by the engineering.

4.1.2 Wet soil samples are prepared by item 1 and 3 in this method according to the required dry mass and water content, and the mass hereof are weighed to the accuracy of 0.1g.

4.1.3 The in-wall of the soil-cutting ring for test is coated with a thin layer of vaseline, and placed on the specimen, the cutting edge facing downward; the specimen is cut by the soil-cutting ring to a soil column whose diameter is lightly larger than the one of the cutting ring; the cutting ring is pressed downwards vertically, cutting while pressing, till the soil sample outstretches the upper part of the cutting ring; the both ends of the cutting ring is shaves off, the cutting ring outer wall is wiped up and the total mass of the soil and the soil-cutting ring is weighed to the accuracy of 0.1g, and the water content of the soil sample shaved off from the both ends of the cutting ring.

4.1.4 The specimen preparation shall be completed as quick as possible, to avoid water evaporation.

4.1.5 The quantity of specimen prepared is determined as required by the test; generally, more 1~2 groups of standby specimens shall be prepared. The difference of density, water content and preparation standard of the specimens in parallel or in same group shall respectively within $\pm 0.1 g/cm^3$ or 2%.

4.2 Sample pressing method

4.2.1 As required by 4.1.2 in this method, the wet soil is placed in the pressure die and pressed with static pressure to a certain height after leveling the soil sample; the bulldozing device is used to pull the soil out.

4.2.2 Operate according to the requirements of 4.1.3 ~4.1.5.

5 Preparation procedure of undisturbed soil specimen

The undisturbed soil package is unpacked carefully according to the upper and lower layer of the soil sample, and the soil sample is taken out and placed straight; the both ends are leveled. the in-wall of the soil-cutting ring for test is coated with a thin layer of vaseline, and placed on the specimen, the cutting edge facing downward; without special requirement, the direction of soil-cutting shall be perpendicular to the natural soil layer surface.

The specimen us cut by the operation procedure specified in 4.1.3 in this method, and the specimen and the cutting ring shall be close; otherwise, the specimen shall be re-selected.

During the cutting process, the specimen shall be carefully observed, and the information like specimen stratum, smell, color, impurity, uniform condition, and crack shall be recorded.

If several specimens are cut continuously, and the water content of them shall be kept constant.

As required by the specimen itself and the engineering, whether or not the specimen shall be saturated; if the test or saturation is not conducted immediately, the specimens shall be stored in the moist chamber.

After cutting the specimens, the rest undisturbed soil sample shall be packed with wax paper and placed in the moist chamber for complementation test; the residual soil in cutting may be used for physical property test; the density difference of specimens in parallel test or in same group shall not be larger than $\pm 0.1 g/cm^3$, and the water content difference shall not be

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knob;9-elevation and subsidence handwheel;10-coring head;11-upright column cover;12-speeder;13-battery jar;14-transport wheel;15-alignment pin

2.1.1 Pedestal: consists of pedestal platform, alignment pin (15), transport wheel (14) The platform represents the base of the entire instrument; The alignment pin shall be used for locating the instrument where it is on operation; The transport wheel shall be used for the short distance movement of the instrument where it changes position for coring, four wheels shall be pulled from the ground surface where locating the position.

2.1.2 Upright column: consists of upright column (1) and upright column cover (11) on the pedestal platform as the support of elevation mechanism, coring organization, power and transmission mechanism.

2.1.3 Elevation mechanism: consists of elevation and subsidence handwheel (9), locking knob (8) which shall be used for adjusting high-low of the coring structure. Loosen locking knob, twirl the elevation and subsidence flywheel and coring structure for elevation and subsidence, and tighten up the handle positioning where the location required.

2.1.4 Coring structure: consist of coring head (10), lifting shaft (2). The coring head shall be the metal circular cylinder, and its lower port shall be symmetry welded two alloy steel cutter heads, and the flat-cover shall be welded on the upper end surface with welding the nut connected to the lifting shaft by spiral. The coring head has three kinds of specifications, i. e. φ50mm×50mm, φ70mm×70mm, φ100mm×100mm, the coring head shall be removable. With other accessories such as relevant coring sleeve, spanner and aluminum box, etc.

2.1.5 The power mechanism and the transmission mechanism: consists of the direct current dynamo (4), speeder (12) and gear case, with other accessories such as accumulator and charger. Where the power-driven machine is on the work, the gear through gear case should transmit the power to the coring organization to rotate the lifting shaft and the coring head shall enter into the working state of rotary cutting.

2.1.6 The main technical details of the power-driven soil sample barrel: Operating voltage DC 24 V (36 A·h); 50 ~ 70 R / min rotational speed; stepless speed regulation; complete machine weight is about 35 kg.

2.2 Balance:1 000 g weighing, 1.0 g sensibility (used for weighing the coring head sample with 10 cm diameter);1 000 g weighing, 0.1 g sensibility (used for weighing the coring head sample with less than 7 cm diameter).

2.3 Others: soil-trimming knife, wire saw and the equipment for water ratio determination, etc.

3 Test procedures

3.1 Fit on the coring head with the specification required. At the construction field site, select a piece of flat ground and lift up four transport wheels with four positioning pins by manual pressurizing to impress into the soil layer of the roadbed before the work of coring. Loosen the locking knob, swirl the elevation and subsidence handwheel to make the coring head and the soil layer well contacted and tighten up the handle.

3.2 Put through the accumulator and the speed regulator, the output terminal of the speed regulator shall be accessed to the power jack of the coring machine. The power indicator light is lit, which means the power is connected; Start the switch, the operation of the motor shall drive the rotation of the coring organization. In accordance with the soil layer water ration to adjust rotational speed, and operate the elevation and subsidence handle to lift upward the

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4.6 Precision and admissible error

Carry out parallel determinations twice at each grade of temperature, and the difference in these two measured values shall not be larger than 0.002g, and take the average value of two measured values.

5 Reports

5.1 specimen source, and appearance description

5.2 The maximum particle diameter of the sample (mm)

5.3 Test pit dimension (cm).

5.4 The sample dry density ρ_d (g/cm^3).

T 0110-1993 sand replacement method

1. Purpose and application scope

This test shall be applicable to the on-site measurement of the soil density including fine textured soil, sandy soil and gravel. Generally, the sample maximum particle diameter shall not exceed 15 mm, and the thickness of the density shall be determined at 50~200mm

Note: (1) Where determinate the fine textured soil density, the small-scale sands inserting barrel with φ100mm shall be adopted.

(2) Provided the maximum particle diameter exceeds 15 mm, the dimensions of the sands inserting barrel and the prover tank shall be enlarged accordingly, namely, the coarse particle soil with 40~60 mm particle diameter, and the diameter of the sands inserting barrel and the on-site test hole shall be at 150 ~ 200

2 Instruments and equipment

2.1 Sands inserting barrel: the metal circular cylinder (tin plate available) shall be with 100 mm internal diameter and 360 mm total height. The sands inserting barrel mainly consists of two parts: the upper part is sand barrel with 270 mm tube depth (volume is about 120cm^3), and there is a round hole with 10 mm diameter in the tube bottom center. And an inverted conoid funnel whose upper end opening with 10mm diameter shall be installed, then it shall be welded on an iron plate with 100 mm diameter, and the round hole with 10 mm diameter at the iron plate center shall be connected to the funnel upper end opening. The switch shall be installed between the bottom of the sand barrel and the iron plate on the funnel top end. The switch shall be sheet iron plate and its one end shall be hinged to the tube bottom and the funnel iron plate, and another end shall stretch out the tube, and there also shall be a round hole with 10 mm on the iron plate of the switch. Where the switch should be moved to left, the round hole on the switch iron plate shall be overlapped to the round hole of the tube bottom and the funnel opening, namely, three round hole shall be overlapped together in the plane, then sands can freely drop through the round hole. Where the switch moves to right, the switch should block the round hole of the tube bottom, then the sand should stop dropping.

The form and main dimension of the sands inserting tube such as Figure T 0111-1 shows

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V——The volume of the prover tank (cm^3);

m_a——The sand mass (g).

4 Test procedures

4.1 In the experiment field, select a flat ground surface with 40 cm× 40 cm and clean it; then the baseplate should be laid on the flat ground surface; Provided the surface with high roughness, then put the sand displacement tube with m5 sand on the round hole of the central baseplate; open the switch of the sand displacement tube to let the sand flow into the mesopore of the baseplate, then shut the switch till the sand in the sand tube do not run off; And take down the sand displacement tube to weigh its sand mass in the tube m6 to the accuracy of 1g.

4.2 Take away the baseplate and reclaim the sand left in the experiment field to clean the surface again; and put the baseplate on the cleaned surface along the baseplate mesopore hole with 100 mm diameter. In the process of digging the hole, the sample cut out shall not be lost and take out the material loosened by chiseling at any time to put them into the plastic bags with known mass and to seal them. The test hole depth shall be approached to or fit to the tank prover height. After hole is made, weigh the entire sample mass in the plastic bags to the accuracy of 1 g. Then subduct the known mass of the plastic bags, namely, the total mass of the sample m_t

4.3 Take the representative sample from the entire samples excavated and place it in the aluminum box to determinate its water ratio w. Sample size: the fine textured soil shall be not less than 100 g; and the coarse particle soil shall be not less than 500g.

4.4 The baseplate should be laid on the test hole, and the sand displacement tube should be placed between the baseplate (the sand filling in the sand barrel till to be constant quantity m1), to make the lower port of the sand displacement tube overlap to the mesopore of the baseplate and the test hole. Open the switch tube to let the sand flow into the test hole. And shut the switch. Take away the sand displacement tube carefully, and weigh its surplus sand mass m4 to the accuracy of 1g.

4.5 Provide the surface that is clean, flat and without roughness, which means it do not require for placing the baseplate, and the sand displacement tube should be lay directly on the test hole dug. Open the switch tube to let the sand flow into the test hole. The sand displacement tube shall not be touched in the meantime. Till the sand in the sand barrel tube no longer run off, then shut the switch. Take away the sand displacement tube carefully, and weigh its surplus sand mass m4 to the accuracy of 1g.

4.6 Take out the sand in the test hole to prepare it for the next test. Provided the sand humidity has been changed or impurities exist in the sand, then the sand shall be dried and sieved again and place it for a long time, and utilize it till it reaches the balance of the air humidity.

4.7 Provided there is pore in the test hole, one layer of soft gauze inside shall be put loosely in line with the test hole outline to prevent the sand may enter into the hole. Then pour sand into it

5 Results disposal

5.1 The sand mass required for filling the test hole shall be calculated according to the following formula:

The situation on pouring sand into test hole with placing baseplate.

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7 Specific Gravity Test of Soil

T 0112-1993 Pyknometer Method

1 Purpose and application scope

This test method is applicable to the soil with grain size less than 5mm.

2 Instruments and equipment

2.1 Pyknometer: volume: 100 (or 50) mL.

2.2 Balance: Weighing range: 1000g; sensibility 0.01g.

2.3 Constant temperature water tank: sensitivity: ± 1℃.

2.4 Sand bath.

2.5 Vacuum pumping equipment.

2.6 Temperature meter: Scale: 0~50℃; scale interval: 0.5℃.

2.7 Others: Such as baking oven, distilled water, neutral liquid (like kerosene), sieves (hole diameter of 2mm and 5mm), hopper, drip tube, etc.

2.8 Calibration of pyknometer.

2.8.1 Clean and dry the pyknometer, weigh its mass to the accuracy of 0.001g.

2.8.2 Inject the boiled cold pure water into the pyknometer. Inject the pure water up to the scale for the long-neck pyknometer or fully fill the short-neck pyknometer with the pure water, plug up the bottle stopper, and the excess moisture will overflow from the capillary tube of bottle stopper. Adjust the constant temperature water tank to 5℃ or 10℃, where after, put the pyknometer into this constant temperature water tank till the water temperature in the pyknometer is constant. Take out the pyknometer and wipe it to dry, weigh the total mass of the pyknometer and wall to the accuracy of 0.001g.

2.8.3 Adjust the water temperature of the constant temperature water tank with a gradation of 5℃, and measure the total mass of pyknometer and water at different temperatures till the local highest natural atmospheric temperature step by step. Carry out parallel determinations twice at each grade of temperature, and the difference in these two measured values shall not be larger than 0.002g, and take the average value of two measured values. Draw the relation curve of temperature with the total mass of pyknometer and water.

3 Test procedures

3.1 Dry a 100mL pyknometer and put 15g oven-dry soil into it (Where adopting 50mL pyknometer, put about 12g oven-dry soil into it), and then weight the pyknometer.

3.2 In order to eliminate the subsurface air in the soil, inject distilled water into that pyknometer that has been loaded with dry soil till to its half scale, shake the pyknometer and soak the soil sample for over 20h, and then boil the pyknometer in a sand bath, the boiling time is counted as soon as the suspension is boiled, which shall not be less than 30min for sand and clay with low liquid limit and shall not be less than 1h for the clay of high liquid limit, so as to disperse the soil particles. Pay attention to adjusting the temperature of sand bath after the suspension is boiled so that the soil solution will not overflow.

3.3 If use long-neck pyknometer, adjust the liquid surface rightly to the scale of pyknometer with drip tube (being subject to the bottom edge of the meniscus surface), wipe

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8 Grain Size Analysis Test

T 0115-1993 Sieve Method

1 Purpose and application scope

This test method is applicable to analyzing the composition of such soil particles with grain size larger than 0.075mm. This test method is not applicable to the soil sample with grain size larger than 60mm.

2 Instruments and equipment

2.1 Standard sieves: coarse sieve (round hole) with hole diameter of 60mm, 40mm, 20mm, 10mm, 5mm and 2mm; fine sieve with hole diameter of 2.0mm, 1.0mm, 0.5mm, 0.25mm and 0.075mm.

2.2 Balance: Weighing range: 5000g, sensibility: 5g; weighing range: 1000g, sensibility: 1g; weighing range: 200g, sensibility: 0.2g.

2.3 Sieve shaker.

2.4 Others: Baking oven, sieve brush, beaker, wood roller, mortar and pestle, etc.

3 Sample

Typical samples shall be taken out of the air-dried loose soil sample with quarter dividing method according to the following requirements:

3.1 Soil (grain size is less than 2mm): 100~300g.

3.2 Soil (maximum particle diameter is less than 10mm): 300~900g.

3.3 Soil (maximum particle diameter is less than 20mm): 1000~2000g.

3.4 Soil (maximum particle diameter is less than 4mm): 2000~4000g.

3.5 Soil (maximum particle diameter is larger than 40mm): above 4000g.

4 Test procedures

4.1 For cohesionless soil

4.1.1 Sample shall be taken and weighed according to the requirements, and also shall be screened with 2mm sieve in batches.

4.1.2 Sample (>2mm) shall be screened with different levels of coarse sieves (>2mm) according to a sequence from large to small. Soils left on the sieve shall be separately weighed.

4.1.3 If a large amount of soil is screened off through 2mm sieve, the sample may be divided into 100~800g with quarter dividing method. Sample shall be screened with different levels of fine sieves (<2mm) according to a sequence from large to small. The sieves may be shaken with sieve shakers. Generally, the shaking time is 10~15min.

4.1.4 The sieves shall be taken down in order starting from the sieve with maximum hole diameter, they shall be knocked and shaken gently by hands above plain paper till the screened quantity per minute is no larger than the 1% of the excess mass of this level of sieve. The soil particles screened off shall be wholly put into the sieve of the next level, and the soil sample left one the sieve shall be brushed off with soft fur brush, and the soil shall be separately weighed.

4.1.5 The difference between the total mass of the soils on the under the sieve of each level and the sample mass before sieving shall not be larger than 1%.

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poor or no dispersing effect, add 14mL of 0.125mol/L sodium pyrophosphate for per 30g of soil sample. The solution preparation method: weigh 55.8g of $Na_4P_2O_7 \cdot 10H_2O$ (chemically pure), add distilled water and scale the volume to 1 000mL after being dissolved, shake well. $Na_4P_2O_7 \cdot 10H_2O$

For soil that cannot be dispersed by strong dispersion agent like sodium pyrophosphate, add 100g of cation exchange resin (particle size >2mm) into the soil sample and soak together; shake up for 2h, sieve with a 2mm sieve and separate the cation exchange resin away; add 15mL of 0.083mol/L metaphosphoric acid.

As for the soil sample with possible water soluble salt that cannot be dispersed by above methods, the water soluble salt inspection shall be conducted: take 3g of the sample to a beaker, inject 4~6 mL of distilled water; pestle disperse with a glass rod (with eraser cap); add 25mL distilled water and boil for 5~10min; and inject the solution into a 30mL test tube by a hopper; block the tube opening, keep it still in the test tube rack for 24h. The coagulation (loosening flocculus on the upper part of the sediments) of the suspension in the test tube means there is water soluble salt that can make the soil particle descend, so leaching shall be conducted.

7 Leaching (filtration method)

7.1 Place the sample for dispersing in a soil balancing basin, inject a small amount of distilled water and mix uniform; cleave the slightly wetted filter paper to a hopper, and pour the soil paste in the soil balancing basin into the a hopper, and inject hot distilled water to rinse and filter. Wash the soil particle on the basin wall to the hopper; in case the filtrate cloudiness, it shall be re-filtered.

7.2 The liquid level in the hopper shall be kept 5mm higher than the soil surface, and it shall be covered with a watch glass after adding water each time.

7.3 To test whether the water soluble salt is washed out, take 3~ 5mL of the filtrate with two test tube, add drops of 10 % hydrochloric acid and 5% barium chloride in a tube; and add drops of 10% nitric acid and 5% nitrate in the other test tube. In case white deposit in any test tube, it means the water-soluble salt is not removed completely, and it shall be washed again, till no white deposit appears. The soil sample in the hopper is washed carefully, and dried by air drying.

8 Test procedures

8.1 The air-drying sample pre-weighed should be poured into the Erlenmeyer flask with adding 200mL distilled water for soaking one night. And add dispersing agent in accordance with the above specification.

8.2 The Erlenmeyer flask should be shaken slightly, after that, lay it on the electric heater for boiling 40 min (provided it shall be dispersed by ammonia water, the condenser pipe equipment should be used; provided the cation exchange resin shall be used, then it shall not require for boiling.

8.3 The suspension cooled after boiling should be poured into the beaker for resting 1 min. The suspension on the upper part should be through sieve with 0.075 mm, and inject it into the 1000ml measuring cylinder. The settled soil in the cup shall be ground carefully by the glass stick with eraser head. And add water into the cup, rest it for 1 min after stirring, and then pour the upper part suspension into the measuring cylinder through 0.075 mm sieve. Repeat it till it rest for 1 min, after that the upper part suspension shall be clear. And finally,

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9 Limit Water Content Test

T 0118-2007 Liquid limit and plastic limit combined method

1 Purpose and application scope

1.1 The purpose of this combined test is to determinate the liquid limit and the plastic limit, which is used for dividing soil groups and calculating the natural consistency and the plasticity index. This can be used for highway engineering and construction.

1.2 This test shall be applicable to the soil with less than 0.5 mm particle diameter, and its organic content shall be no greater than 5% of the sample total mass.

2 Instruments and equipment

2.1 Cone penetrator: the cone mass shall be 100 g or 76 g, and the cone angle shall be 30°, while the photoelectric type, digital type, Vernier type and dial-gauge type should be adopted for displaying the reading.

2.2 Soil cup: 50 mm diameter, 40~50mm depth

2.3 Balance: 200g weighing, 0.01g sensibility

2.4 Others: sieve (0.5 mm aperture), the knife for mixing soil, the vessel for mixing soil, weighing box, mortar (attach a pestle with eraser head or rubber plate, wood board), dryer, suction tube and vaseline, etc.

3 Test procedures

3.1 Adopt representative sample with the natural water ratio or the air-drying representative sample. Provided the soil contains soil particles or sundries with larger than 0.5 mm, the air-drying soil sample shall be crushed by the pestle with eraser head or the wood stick on the rubber sheet to get through the sieve with 0.5mm.

Adopt 200g representative soil sample from the 0.5 mm sieve to place them in three soil vessels respectively, then add the distilled water with different mass, and the water ratio of the soil sample shall be controlled at the liquid limit (point a), a little larger than the plastic limit (point c) and the intermediate state of both points (point b) respectively. Use the knife for mixing soil to stir even and cover damping cloth to place it for 18 h or above. Determinate the cone depth at the point a, and the cone with 100g shall be 20mm ± 0.2 mm, and the cone with 76g shall be 17 mm. Determinate the cone depth at the point c, and the cone with 100g shall be controlled below 5 mm, and the cone with 76g shall be controlled below 2 mm. As for the sandy soil, the cone depth at the point c determined by the cone with 100g shall be larger than 5 mm, and the cone depth at the point c determined by the cone with 76 g shall be larger than 2 mm.

3.2 The soil sample prepared should be completely mixed, and pack into the soil cup by layering, then pressure it tightly to let the air out. As for the dry soil sample, it shall be kneading enough firstly, then use the knife for mixing soil to compact it again and again. After filling the test cup, scrape it to make it be flush with the cup edge.

3.3 Where use the Vernier type or the dial-gauge type liquid-plastic limit combing test, level the instrument and lift the spike (here the reading of the Vernier or the dial-gauge shall be zero), and clad a little vaseline on the conehead.

3.4 The test cup filled with soil sample should be laid on the pedestal of the combing test apparatus, and rotate the knob of the elevation and subsidence, then stop the elevation and subsidence where the conical tip contact with the soil sample surface, and unscrew the falling

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knob and start the stopwatch at the same time, after 5 s, the knob shall be loosened, and the cone shall be stopped, here the Vernier reading shall be the cone depth h1.

3.5 Change the contact position of the conical tip and soil (the distance of two cone locations of the conical tip shall not be less than 1 cm), and repeat the procedures of the test 3.3 and 3.4 to obtain the cone depth h2. The parallel error permitted of h1 and h2 shall be 0.5 mm, otherwise, the test shall be made again. Adopt the average value of h1, h2 as the cone depth h at this point.

3.6 Scrape the vaseline on the conical tip where can be used for putting the soil, and adopt two soil samples with above 10g, and pack them into the weighing box respectively to weigh the mass (to the accuracy of 0.01g), and determinate their water ratio w1, w2 (calculate to 0.1%) And calculate the average value of the water ratio w.

3.7 Repeat procedures of the test 3.2 ~ 3.6, and carry out test to another two soil samples with water ratio to determinate its cone depth and water ratio.

3.8 Where use photoelectric type or digital type liquid-plastic limit combing test apparatus to determinate, get through the power, level the apparatus body, open the switch and lift the cone. (Here degree scale or the numeral display shall be zero) The test cup filled with the soil sample should be laid on the pedestal, and rotate the knob of the elevation and subsidence, then the test cup shall be gone up slowly, where the soil sample surface and the conical tip contact exactly, the indicator light is on lit, stop the knob, the cone sinks by itself immediately, and it shall be stop dropping automatically at 5 s, then the entering depth shall be displayed on the counter window or the digital tube. After the test, press the reset button, the cone shall be replaced, and the reading shall be zero.

4 Results disposal

4.1 On the log-log coordinate, the water ratio w shall be as the lateral coordinate, and the cone depth h shall be as longitudinal coordinate, draw the h-w graph of the water ratio at three points a, b, c (Figure T 0118-1) Those three points shall be connected to be a straight line. Provided those three points do not at the same straight-line, two straight-line shall be connected through point a and point b and point c, then get h_P on the h_P - w_L Figure in accordance with the liquid limit, and determine relevant two water ratios on the ab and ac lines of h-w by focusing on h_P. Where the difference of two water ratios is less than 2%, the average value of two water ratios shall be connected into a straight line with point. Where the difference of two water ratios is not less than 2%, the test shall be made again.

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standard ones shall be within ± 0.1g/cm^3 or 2% respectively.

3.2 Procedures to prepare undisturbed soil specimens

Undisturbed soil package is carefully opened according to upside-down stratum of soil sample; then soil sample is taken out and placed flatly; in addition, both ends of the sample shall be leveled. Internal wall of the soil-cutting ring (for test) is coated with a thin layer of vaseline; then the cutting ring is placed on soil sample with its cutting edge downward; unless otherwise specified, soil-cutting direction shall be perpendicular to natural soil stratum.

Specimen is cut according to the processes specified in Article 3.1.3 of this test during which specimen and cutting ring shall tightly be closed to each other. Otherwise, specimen shall be cut again.

During cutting, the stratum, smell, color, impurity, soil quality uniformity and crack etc. of specimen shall be observed and recorded cautiously.

If several specimens are cut continuously, the water content shall be ensured to be the same.

Whether the specimens shall be saturated shall be determined according to the requirements of specimens themselves and the project; if test is not carried out or specimens are not saturated immediately, the specimens shall be kept in moist chamber temporally.

After cutting specimens, the residual undisturbed soil sample shall be wrapped with stencil and put into a moist chamber for the preparation of retest. Cut residual soil is used for physical test. Density difference in parallel test or of the same group specimens shall not be greater than ± 0.1g/cm^3 and the water content difference shall not be greater than 2%.

During the preparation of undisturbed soil sample with frozen soil, the temperature, structure and water content of the original soil sample shall be kept unchanged.

3.3 Specimen saturation

The process during which soil pinhole is gradually filled with water is called saturation. The soil whose pinhole is completely filled with water is called saturated soil.

Saturation method is determined according to soil properties:

Sandy soil: it may be directly saturated in an instrument by soaking.

Easily permeable clay soil: i.e. Where the coefficient of clay soil permeability is greater than 10^{-4}cm/s, it is convenient by adopting capillary-tube saturation method; or soaking saturation method may also be adopted.

Non-permeable clay soil: i.e. Where the coefficient of permeability is less than 10^{-4}cm/s, vacuum saturation method is adopted. If the structure of soil is weak, during air-pumping, the soil may be disturbed, so vacuum saturation method should not be adopted.

Sample is removed from cutting ring (Where sample is loose, it may be removed from cutting ring with air drying method) and place on a perforated plate; then the mass of sample and perforated plate is weighed to the accuracy of 0.1g.

4 Test procedures

4.1 Dial gauge is installed, and the initial reading is recorded.

4.2 Shrinkage test is carried out at the ambient temperature of not greater than 30℃. Dial gauge readings shall be recorded every other 1~4h according to sample temperature and shrinkage speed; the mass of complete set of equipment and sample shall be weighed, to the accuracy of 0.1. After two days, dial gauge readings shall be recorded every other 6~24h and sample mass shall be weighed till adjacent two readings do not change any more. In Phase I

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Figure T 0123-1 Long neck funnel
1- Conical plug; 2-Long neck funnel; 3- leveling instrument

Figure T 0123-2 vibration meter (mm)

Figure 0123-3 Driving hammer (mm)
1- Driving hammer; 2- hammer holder

2.9 Platform balance: sensibility, 1g

3 Test procedures

3.1 Measurement of Maximum void ratio

3.1.1 About 1.5kg typical sample is sufficiently dried; then it is kneaded by hand or scattered on sheet rubber with round timber rod; later, it is mixed evenly.

3.1.2 Conical plug rod is penetrated from the lower opening of funnel and lifted upward so as to block up the funnel pipe orifice with the cone; next, all of them are placed in a 1000mL measuring cylinder and the lower end of funnel is connected with measuring cylinder.

3.1.3 700g sample is weighed, to the accuracy of 1g, and poured into a funnel evenly; both funnel and plug rod are lifted simultaneously; then the plug rod is moved to make cone a little apart from pipe orifice which shall often be kept 1~2cm above sand surface so that the sample will be ensured to place into measuring cylinder slowly and evenly.

3.1.4 After all sample is poured into measuring cylinder, the funnel and conical plug are removed; then sand surface is flattened with leveling instrument during which the measuring cylinder must not be vibrated; next, the sand sample volume is measured and recorded, estimating to 5mL.

3.1.5 After measuring cylinder opening is blocked up by hand or with rubber stopper, the measuring cylinder is reversed; next, the sample in the cylinder is rotated slowly and returned to the originally position; repeating this process several times and recording the maximum volume, estimating to 5mL.

3.1.6 The greater value measured by the aforementioned two methods is used to calculate maximum void ratio.

3.2 Measurement of minimum void ratio

3.2.1 About 4kg typical sample is taken and treated according to the processes specified in Article 3.1.1 of this test.

3.2.2 Such sample is poured into a container by three times and compacted: first, 600~800g the such sample (the amount of the sample shall ensure that the post-compacted sample volume is slightly greater than 1/3 container volume) is taken and poured into a 1000cm^3 container after which, both sides of container is beaten with a vibration meter at a speed of 150~200 times/min and meanwhile, the sample surface is hammered with driving hammer at a speed of 30~60 times/min till sand sample volume does not change any more (5~10 min in general). Beating shall be forceful enough to ensure sample to be in vibration; during vibrating and compacting, coarse sand may be compacted for more times and fine sand, less times.

3.2.3 If electric minimum-void-ratio test instrument is used, after sample is filled in a container according to the above processes, motor is powered on to conduct vibrating and compacting test.

3.2.4 After vibrating and hammering of two added sample is carried out according to the processes specified in Article 3.2.2 of this test. Before adding the third portion of sample,

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14 Test on Rising Height of Capillary Water in Soil

T 0128-1993 Test on Rising Height of Capillary Water

1 Purpose and application scope

1.1 Rising height of soil capillary water is the rising peak height of water in soil void due to capillary action.

1.2 This test is aimed at measuring the rising height and speed of soil capillary water both of which is used to estimate the subgrade soaking possibility and subgrade soaking degree where groundwater level increases.

1.3 Basing on the characteristics of highway projects, direct observation method is adopted in this method. This test is applicable to determine the rising height of intense capillary water which endangers road, namely, the lower height on the relation curve of water content and rising height where water content is equal to plastic limit is the rising height of intense capillary water.

2 Instruments and equipment

2.1 Capillary test instrument: including test frame, organic-glass test tube, organic-glass water-holing cylinder, particular hang spring and hang rope etc.

Organic-glass tube is 4.0~4.5cm in inside diameter and about 3mm in wall thickness; pinhole with 10mm in diameter is opened every 10cm; the hole opening is equipped with organic glass small cap which can be screwed down; the lower end is connected with organic glass pedestal with screw thread; and a row of small pores are opened in the position which is 1cm from zero point. Tube top is equipped with draughty aluminium cap. Pedestal is equipped with rubber washer and copper wire gauze. If two tubes are connected, there are also coupling joints and bolts. Particular spring is used to remain constant water level where the holding water declines, shown in Figure T 0128-1.

2.2 Others: balance (sensibility, 0.01g), baking box, funnel and tamper etc.

3 Test procedures

3.1 Capillary test instrument is installed; pedestal washer and copper wire gauze are padded; then organic-glass tube is screwed down and simultaneously all vent holes and pinholes on tube are screwed on and capped. For the soil with greater rising height of capillary water, if two or more than two tubes are needed, the joints and bolts shall be prepared in advance so as to split and joint at any time.

3.2 About 5kg representative air-dried soil sample is taken (each tube shall be filled with 2.0~2.5kg soil) and then filled in organic-glass tube by several times with funnel; in addition, the soil shall be vibrated with tamper continuously so as to achieve even compactness. If tube shall be jointed after one tube is filled, two tubes are packed up with rubberized fabric and jointed with connector on the outside; then fixed bolt is screwed down and soil sample is filled continuously; meanwhile, the soil is vibrated with tamper till the tube is fully filled. Finally, the top is covered with aluminium cover.

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up to cutting ring full of soil sample. Flattening the both ends with scraper; scraper shall not repetitively scrape soil surface Where scraping the test sample. In the process of scraping, observing the test sample carefully and record the hierarchy, color and impurity of soil sample.

3.3 Cleaning out the ectotheca of cutting ring; and weighting the total mass of cutting ring and soil; taking the soil sample which cut by the both sides of cutting ring to measure water content. In the case of required saturated test sample, air exhaust saturation shall be carried out,

4 Testing sequence

4.1 Coating a shallow layer of vaseline on the ectotheca of cutting ring after cut the soil sample, and then put the cutting ring into protective ring with knife-edge downward.

4.2 Place the soleplate into vessel and put perforated stone, filter paper, put soil sample cutting ring and protective ring into vessel by lifting dog screw; the soil sample covered by filter paper and perforated stone, and then put down pressurizing guide ring and pressure transmission piston, in order to make intimate contact of each part and keeping steady.

4.3 Placed the constriction vessel into the pressurizing frame, pressurizing pressure transmission piston and transom, prepressing 1.0kPa pressure to make each part of consolidometer close contacted; mounting dial-gauge and regulating its reading to zero point.

4.4 Unloading prepressing load and bring pressure to bear on by the first level load. Where adding the weight, shock and swag shall be avoided, and running the stopwatch immediately at the same time. Load levels generally are intended to be 50kPa, 100kPa, 200kPa, 300kPa and 400kPa. According to the rigidity of soil, the first load level also takes 25kPa.

4.5 For the saturated specimen, filling the vessel with water immediately after the first load level is applied. For the non-saturated specimen, pervious surface shall be enclosed with wet cotton yarn to avoid evaporation of water.

4.6 Where required to determine the pre-consolidation pressure of undisturbed soil, load rate should be less than 1, 0.5 or 0.25 times also can be adopted, and the final load level shall greater than 1000kPa, in order to make tangential path present at the lower extreme of e-1gp curves.

4.7 Where required to measure the indices as sedimentation rate, coefficient of consolidation, generally in pursuance of 0s, 15s, 1min, 2min, 4min, 6min, 9min, 12min, 16min, 20min, 25min, 35min, 45min, 60min, 90min, 2h, 4h, 10h, 23h, 24h, until come to tranquilization. Standard of stabilization by consolidation is the amount of deformation in the final 1h not exceeding 0.01 mm.

Where not required to measure sedimentation velocity, measure and write down the altitude variation of test sample 24h after applied each load level and take this result as the stabilization standard. Where permeability coefficient of test sample greater than 10-5Cm/s, take primary consolidation completion as relative stabilization standard also allowable. Increasing pressure level by level according to this procedure, until test completion.

Note: sedimentation rate measurement is applied to saturated soil only.

4.8 Dismantle the instruments after test, take out integrated soil sample carefully and weigh the weight of soil sample; measure the final water content (If not required to measure saturation of soil sample after test, final water content measurement is not required), and wash clean the instruments.

5 Result collation

5.1 Void ratio in the beginning of test can be calculated according to the following formula:

$$e_0 = \frac{p_s(1+0.01w_0)}{p_0} - 1 \qquad \text{(T 0137-1)}$$

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stone shall be the same.

2.4 Deformation measuring equipment: dial-gauge or zeroth level position transmitter with the measuring range of 10 mm and minimal scale mark of 0.01mm.

2.5 Other: balance, stopwatch, baking oven, fret saw, scraper, aluminum box, etc.

3 Testing sequence

3.1 Coating a shallow layer of vaseline on the ectotheca of cutting ring after cut the soil sample, and then put the cutting ring into protective ring with knife-edge downward.

3.2 Place the soleplate into vessel and put perforated stone, filter paper, put soil sample cutting ring and protective ring into vessel by lifting dog screw; the soil sample covered by filter paper and perforated stone, and then put down pressurizing guide ring and pressure transmission piston, in order to make intimate contact of each part and keeping steady.

3.3 Placed the constriction vessel into the pressurizing frame, pressurizing pressure transmission piston and transom, prepressing 1.0kPa pressure to make each part of consolidometer close contacted; mounting dial-gauge and regulating its reading to zero point.

3.4 Unloading prepressing load and bring pressure to bear on by the first level load. Where adding the weight, shock and swag shall be avoided, and running the stopwatch immediately at the same time. Load levels generally are intended to be 50kPa, 100kPa, 200kPa, 300kPa and 400kPa. According to the rigidity of soil, the first load level also takes 25kPa.

3.5 For the saturated specimen, filling the vessel with water immediately after the first load level is applied. For the non-saturated specimen, pervious surface shall be enclosed with wet cotton yarn to avoid evaporation of water.

3.6 Where required to determine the pre-consolidation pressure of undisturbed soil, load rate should be less than 1, 0.5 or 0.25 times also can be adopted, and the final load level shall greater than 1000kPa, in order to make tangential path present at the lower extreme of e-1gp curve.

3.7 Where required to measure the indices as sedimentation rate, coefficient of consolidation, generally in pursuance of 0s, 15s, 1min, 2min, 4min, 6min, 9min, 12min, 16min, 20min, 25min, 35min, 45min, 60min, 90min, 2h, 4h, 10h, 23h, 24h, until come to tranquilization. Constriction time of each load level was intended to be 1h, add the final load level to the reading come up to the reading of stabilization sedimentation. Standard of stabilization by consolidation is the amount of deformation in the final 1h not exceeding 0.01 mm.

Where not required to measure sedimentation velocity, measure and write down the altitude variation of test sample 24h after applied each load level and take this result as the stabilization standard. Where permeability coefficient of test sample greater than 10-5Cm/s, take primary consolidation completion as relative stabilization standard also allowable. Increasing pressure level by level according to this procedure, until test completion.

Note: sedimentation rate measurement is applied to saturated soil only.

3.8 Dismantle the instruments after test, take out integrated soil sample carefully and weigh the weight of soil sample; measure the final water content (If not required to measure saturation of soil sample after test, final water content measurement is not required), and wash clean the instruments.

4 Result collation

4.1 Void ratio in the beginning of test can be calculated according to the following formula:

$$e_0 = \frac{\rho_s(1+0.01w_0)}{\rho_0} - 1 \qquad \text{(T 0138-1)}$$

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20 Test on Water Content of Standard Absorption for Soil

T 0172-2007 Test on Water Content of Standard Absorption

1 Purpose and application scope

This method is applicable to measure the water content of soil-sample standard absorption under the following standard conditions: temperature, 20℃±2℃; relative humidity, 60%±5%. In addition, it is also applicable to determine the properties such as specific surface of these fine materials, for instance, soil sample or cement.

2 Instruments and equipment

2.1 Oven: it may be electric oven or other ovens which can maintain the temperature to be 105~110℃; besides, infrared oven may also be used.

2.2 Balance: sensibility, 0.001g

2.3 Weighing box: aluminium box is adopted. Water evaporation speed of soil sample is positively correlated to aluminium box diameter and negatively correlated to aluminium box height. The diameter and height of weighing box should not be greater than 6cm or 1.5cm, respectively.

2.4 Test device: dry cylinder with calcium chloride or other desiccants; or temperature humidity chamber etc.

3 Reagent

1000mL saturated saline solution of sodium bromide is prepared with distilled water. There may be a little crystal in saturated saline solution of sodium bromide so as to thoroughly ensure the saline solution is saturated.

4 Test procedures

4.1 Dry cylinder method

4.1:1 Clean aluminium box is baked at 105~110℃ constant temperature for 3~ 4 hours; then it is removed and cooled in dry cylinder till room temperature Where it is weighed immediately. This procedure is repeated till constant mass (the mass difference of two weighing is not greater than 0.001g), Where aluminium box mass is recorded.

4.1.2 About 4g typical natural soil sample is taken, cut into sheets with penknife and then put into a small aluminium box (given mass, m_0). The soil sample is horizontally laid at box bottom and the box is covered tightly. Finally, the total mass (m_1) of box and wet soil is weighed.

4.1.3 Box is uncovered and the small aluminium box with soil sample is put on the perforated plate on saturated saline solution directly.

4.1.4 Soil sample is taken out every day for measuring and recording the total mass of box and wet soil until constant sample mass, Where the total mass (m_2) of box and constant wet soil after absorbing water is weighed, to the accuracy of 0.001g.

4.1.5 Soil sample with constant mass is put into an oven and baked for 8 hours at constant temperature, 105~110℃.

4.1.6 Aluminium box is taken out and covered properly; then it is placed in a dryer with $CaCl_2$ to be cooled to room temperature (0.5~1h in general), Where it is weighed immediately.

4.1.7 Aluminium box is placed into an oven again and baked for 3~4h at constant

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pressurized to different pre-determined pressures, respectively. Test is carried out as specified below till stabile soaking deformation of samples.

(1) Preload is removed; immediately, 50 kPa first-grade of load is applied. Where weight is added, stopwatch shall be started. Then dial gauge is read according to the following interval: 10min, 20min, 30min; later dial gauge is read once every 1h till stable settlement achieves. Next, second grade load is applied. If the amount of deformation in each hour is not greater than 0.01mm, settlement stabilization achieves.

(2) Second grade load is 100Kpa; the later loads are 150Kpa, 200Kpa and 400kPa, respectively. In addition, the pressurizing interval is 50KpaAfter loads are added, dial gauge readings are recorded according to the time specified in 4.1.4 (1) of this test till stable settlement achieves.

(3) 5 samples achieve stable settlement under the last grade pressure respectively and the stable settlement achieves Where the deformation in each hour is not greater than 0.01mm. Then water is added for the sample from its top. Dial gauge readings are recorded according to the time interval specified in 4.1.4(1) of this test till stable settlement achieves again. Stable settlement standard is that the deformation in every 3d is not greater than 0.01mm.

4.1.5 Dial gauge reading Where the last grade load realizes the assumed settlement is read and recorded. Then instrument is dismounted, and sample is taken out to measure the water content and dry density of this sample.

4.1.6 If the relationship between macro-void ratio and pressure must be measured, two additional soil samples with the same property shall be cut from the same piece of soil. Then the density and water content of these two samples shall be measured. Instrument installation and test shall be carried out according to the above procedures. As the first sample shall maintain its natural water content during the whole process, wet cotton shall be used to cover the surrounding of pressure transmission piston. Wet cotton shall be used to cover the surrounding of pressure transmission piston. The second sample achieves stable settlement under 50Kpa pressure, and the stable settlement achieves Where the deformation in each hour is not greater than 0.01mm. Then water is added from sample top surfaces till samples watering-deformation becomes stable under each grade pressure. Stable settlement standard is that the deformation in every 3d is not greater than 0.01mm.

4.1.7 In order to determine the macro-void ratio and relative settlement coefficient under actual pressure, test may be carried out according to the procedures specified in Article 4.1.4 (2) and (3) of this test for determining the actually maximum ones.

4.1.8 After test, standing water in container is removed; instrument is dismounted, and soil sample is taken out. Then soil is taken from sample center to measure its water content.

4.2 Double lines method

4.2.1 2 cutting ring samples are taken and a thin layer of vaseline is coated on the cutting-ring outer surface of the cut undisturbed soil samples, respectively. Then these samples are put into a guard ring with the cutting edge downward.

4.2.2 Base plate with porous stone and filter paper is put into a container; then guard ring is also put into the container with the help of lifting ring screw; soil sample is covered with filter paper and porous stone; next, pressurizing guide ring and pressure transmission piston are let down to enable all parts to contact tightly and keep balance.

4.2.3 Pressurizing container is placed at the middle of pressurizing frame; the pressure

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Whether the specimens shall be saturated shall be determined according to the requirements of specimens themselves and the project. If test is not carried out or specimens are not saturated immediately, the specimens shall be kept in moist chamber temporally.

After cutting specimens, the residual undisturbed soil sample shall be wrapped with stencil and put into a moist chamber for the preparation of retest. Cut residual soil is used for physical test. Density difference in parallel test or of the same group specimens shall not be greater than ± 0.1g/cm^3 and the water content difference shall not be greater than 2%.

3.2 Single line method

3.2.1 5 cutting ring samples are taken and a thin layer of vaseline is coated on the cutting-ring outer surface of the cut undisturbed soil samples, respectively. Then these samples are put into a guard ring with the cutting edge downward.

3.2.2 Base plate with porous stone and filter paper is put into a container; then guard ring is also put into the container with the help of lifting ring screw; soil sample is covered with filter paper and porous stone; next, pressurizing guide ring and pressure transmission piston are let down to enable all parts to contact tightly and keep balance.

3.2.3 Pressurizing container is placed at the middle of pressurizing frame; the pressure transmission piston and cross beam are fitted tightly; 1.0kPa pressure is pre-applied to make all parts of consolidometer contact tightly; next dial gauge is set up and zeroed.

3.2.4 Saturated deadweight pressure of soil is approximately divided into 5 uniform grades and then applied to the 5 samples, respectively. Where the applied pressure is less than or equal to 50Kpa, the pressure may be applied once. If the pressure is greater than 50kPa, it shall be applied in grades; the pressure in each grade shall not be greater than 50kPa and the time to apply each grade pressure shall not be less than 15min; this procedure is repeated till set pressure. After pressurizing, deformation reading is recorded once every other 1h till the amount of deformation in each hour is not greater than 0.01mm.

3.2.5 Pure water is injected in the container till the water surface is higher than sample top surface; then deformation reading is recorded every other 1h and the dial gauge reading after the sample-watering-deformation readings of 5 samples stabilize shall be recorded respectively till sample watering deformation becomes stable. Stable standard is that the deformation in every 3d is not greater than 0.01mm.

3.2.6 Instrument is dismounted, and sample is taken out to measure the water content and dry density of sample.

3.3 Double lines method

3.3.1 2 cutting ring samples are taken and a thin layer of vaseline is coated on the cutting-ring outer surface of the cut undisturbed soil samples, respectively. Then these samples are put into a guard ring with the cutting edge downward.

3.3.2 Base plate with porous stone and filter paper is put into a container; then guard ring is also put into the container with the help of lifting ring screw; soil sample is covered with filter paper and porous stone; next, pressurizing guide ring and pressure transmission piston are let down to enable all parts to contact tightly and keep balance.

3.3.3 Pressurizing container is placed at the middle of pressurizing frame; the pressure transmission piston and cross beam are fitted tightly; 1.0kPa pressure is pre-applied to make all parts of consolidometer contact tightly; next dial gauge is set up and zeroed.

3.3.4 Saturated deadweight pressure of soil if applied to on sample. Where the

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If several specimens are cut continuously, the water content shall be ensured to be the same.

Whether the specimens shall be saturated shall be determined according to the requirements of specimens themselves and the project. If test is not carried out or specimens are not saturated immediately, the specimens shall be kept in moist chamber temporally.

After cutting specimens, the residual undisturbed soil sample shall be wrapped with stencil and put into a moist chamber for the preparation of retest. Cut residual soil is used for physical test. Density difference in parallel test or of the same group specimens shall not be greater than ± 0.1g/cm^3 and the water content difference shall not be greater than 2%.

3.2 Single line method

3.2.1 5 cutting ring samples are taken and a thin layer of vaseline is coated on the cutting-ring outer surface of the cut undisturbed soil samples, respectively. Then these samples are put into a guard ring with the cutting edge downward.

3.2.2 Base plate with porous stone and filter paper is put into a container; then guard ring is also put into the container with the help of lifting ring screw; soil sample is covered with filter paper and porous stone; next, pressurizing guide ring and pressure transmission piston are let down to enable all parts to contact tightly and keep balance.

3.2.3 Pressurizing container is placed at the middle of pressurizing frame; the pressure transmission piston and cross beam are fitted tightly; 1.0kPa pressure is pre-applied to make all parts of consolidometer contact tightly; next dial gauge is set up and zeroed.

3.2.4 All these 5 samples are graded and pressurized at natural moisture; they are pressurized to different pre-determined pressures, respectively. Test is carried out as specified below till stabile soaking deformation of samples.

(1) Preload is removed; immediately, 50 kPa THE first-grade load is applied. Where weight is added, stopwatch shall be started. Then dial gauge is read according to the following interval: 10min, 20min, 30min; later dial gauge is read once every 1h till stable settlement achieves. Next, second grade load is applied. If the amount of deformation in each hour is not greater than 0.01mm, settlement stabilization achieves.

(2) Second grade load is 100Kpa; the later loads are 150Kpa, 200Kpa and 400kPa, respectively. In addition, the pressurizing interval is 50Kpa. After loads are added, dial gauge reads are recorded according to the time specified in 3.2.4(1) of this test till stable settlement achieves.

(3) After 5 samples achieve stable settlement under the last grade pressure respectively, they are watered from their top surfaces, Where the dial gauge readings are recorded according to those specified in Article 3.2.4(1) of this test till stable settlement realizes again.

3.2.5 Samples are penetrated with water continuously during which deformation readings are recorded every 2h. After 24h, deformation readings are recorded 1~3 times every day till the deformation in every 3d (72 h) is not greater than 0.01mm.

3.2.6 Dial gauge reading Where lixiviation deformation becomes stable shall be recorded. Instrument is dismounted and sample is taken out to measure the water content and dry density of sample.

3.3 Double lines method

3.3.1 2 cutting ring samples are taken and a thin layer of vaseline is coated on the

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If several specimens are cut continuously, the water content shall be ensured to be the same.

Whether specimens shall be saturated shall be determined according to the requirements of specimens themselves and the project. If test is not carried out or specimens are not saturated immediately, the specimens shall be kept in moist chamber temporally.

After cutting specimens, the residual undisturbed soil sample shall be wrapped with stencil and put into a moist chamber for the preparation of retest. Cut residual soil is used for physical test. Density difference in parallel test or of the same group specimens shall not be greater than ± 0.1g/cm^3 and the water content difference shall not be greater than 2%.

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(3) After 5 samples achieve stable settlement under the last grade pressure respectively, they are watered from their top surfaces, where the dial gauge readings are recorded according to those specified in Article 3.2.4(1) of this test till stable deformation realizes again. Stable deformation standard is that the deformation in every 3d is not greater than 0.01mm.

3.2.5 Dial gauge reading Where the sample realizes the assumed settlement under the last grade load is recorded. Instrument is dismounted and sample is taken out to measure its water content and dry density.

3.3 Double lines method

3.3.1 2 cutting ring samples are taken and a thin layer of vaseline is coated on the cutting-ring outer surface of the cut undisturbed soil samples, respectively. Then these samples are put into a guard ring with the cutting edge downward.

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Direct shear test of soil

During cutting, the stratum, smell, color, impurity, soil quality uniformity and crack etc. of specimen shall be observed and recorded cautiously.

If several specimens are cut continuously, the water content shall be ensured to be the same.

Whether the specimens shall be saturated shall be determined according to the requirements of specimens themselves and the project. If test is not carried out or specimens are not saturated immediately, the specimens shall be kept in moist chamber temporally.

After cutting specimens, the residual undisturbed soil sample shall be wrapped with stencil and put into a moist chamber for the preparation of retest. Cut residual soil is used for physical test. Density difference in parallel test or of the same group specimens shall not be greater than ± 0.1g/cm^3 and the water content difference shall not be greater than 2%.

3.2 Procedures for preparing disturbed sample of fine particle soil

3.2.1 Disturbed soil sample shall be described in details, such as color, soil type, odor and impurity. Disturbed soil sample shall, if necessary, be mixed evenly and then representative soil sample shall be taken to measure its water content.

3.2.2 Lumpy disturbed soil is placed on sheet rubber and scattered with wooden grind or crasher, but the particles shall be ensured not to be crushed. If the lumpy soil cannot be scattered with wooden grind or crasher due to its great water content, it shall be dried till it can be scattered.

3.2.3 Scattered soil sample shall be sieved according to the amount of soil samples needed in the test. For physical test such as liquid limit, plastic limit and shrinkage limit tests, soil sample shall be sieved with 0.5mm sieve; for routine water-property test and mechanical test, soil sample shall be sieved with 2mm sieve; and for compaction test, the maximum particle diameter of soil sample must meet the requirements of the maximum particle diameter of soil sample Where compaction test is carried out by adopting different compaction cylinders. After sample is sieved as required, adequate amount of typical samples shall be taken out and put into containers respectively and then labeled. These labels shall expressly read project name, soil sample number, sieving diameter, purpose, preparing date and staff so as to prepare for various tests. If the soil is loose soil with much coarse sand and little fine particle soil (silt or clay), the soil shall be wetted and loosened with water; then typical sample shall be taken out with quartering method. If the soil is clean sand, typical samples may be taken with soil uniformizing machine.

3.2.4 In order to prepare samples with certain water content, adequate air-dried soil for test, 1~5g, after being sieved by 2mm sieve shall be taken. Additional water for preparing soil sample shall be calculated according to the following formula:

$$m_w = \frac{m}{1+0.01w_h} \times 0.01(w - w_h): \qquad \text{(T 0140-1)}$$

Where, m_w—Additional water needed by soil sample (g);

M—Mass of soil sample Where its water content is dried (g);

w_h—Dried water content (%);

w—Water content required by soil sample (%)

Taken soil sample is laid in a nonabsorbent tray; it is sprayed with pre-determined

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additional water with spraying equipment and then properly mixed; next the sample is put into a container and covered to be wetted for one day and night for standby usage (the wetting duration of sandy soil may be shortened according to specific condition).

3.2.5 Where the water contents at different positions (at least more than two) of wetted soil sample are measured, the difference of these water contents shall meet the permissible and parallel difference for measuring water content.

3.2.6 Where mixed samples are prepared with the soil from different soil layers, the corresponding mass proportion shall be calculated according to the thickness of each soil sample; then disturbed soil is prepared according to those processes stated in Article 3.2.1~3.2.4 of this method.

3.3 Specimen saturation

The process during which soil pinhole is gradually filled with water is called saturation. The soil whose pinhole is completely filled with water is called saturated soil.

Saturation method is determined According to soil properties:

Sandy soil: it may be directly saturated in an instrument by soaking.

Easily permeable clay soil: i.e. Where the coefficient of clay soil permeability is greater than 10^{-4}cm/s, it is convenient by adopting capillary-tube saturation method; or soaking saturation method may also be adopted.

Non-permeable clay soil: i.e. Where the coefficient of permeability is less than 10^{-4}cm/s, vacuum saturation method is adopted. If the structure of soil is weak, during air-pumping, the soil may be disturbed, so vacuum saturation method should not be adopted.

4 Test procedures

4.1 Fixed pin is inserted by aligning with both the upper and lower boxes of shearing container; porous stone and filter paper are placed in the lower box and the blade of cutting ring with sample is put upward to align with shearing box; filter paper and porous stone are put on the sample and then the sample is carefully pushed into the shear box.

4.2 Gearing is moved to enable that the steel ball in front of the upper box exactly contact with dynamometer; then pressure transmission plate and pressurizing frame are added consequently; next, vertical-displacement measuring unit is installed to measure and record the initial reading.

4.3 Vertical pressure in various grades are applied according to project reality and the soil rigidity; then the box is injected with water. Where the sample is non-saturated one, pressurizing plate shall be wrapped with wet cotton around.

4.4 Vertical pressure is applied, and vertical deformation is recorded every 1h. The vertical deformation Where sample consolidation is stable is the one Where the vertical deformation of clay soil is not greater than 0.005mm every hour.

4.5 Fixed pin is removed, and shearing is carried out at a speed of less than 0.02mm/min; in addition, the dial gauge reading shall be measured and recorded at regular intervals till shearing failures.

4.6 Shearing failure time of sample may be estimated according to the following formula:

$$t_f = 50t_{50} \qquad \text{(T 0140-2)}$$

Where, t_f—Duration to achieve shearing failure (min);

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samples simultaneously till soil sample outstretches cutting ring top; next, both ends of cutting ring are smoothed and outer wall of the cutting ring is cleaned. The total mass of ring and soil is weighed, to the accuracy of 0.1g; in addition, the water content of the soil sample cut by both ends of cutting ring shall be measured. Specimen shall be tightly closed to cutting ring. Otherwise, specimen shall be cut again.

During cutting, the stratum, smell, color, impurity, soil quality uniformity and crack etc. of specimen shall be observed and recorded cautiously.

If several specimens are cut continuously, the water content shall be ensured to be the same.

Whether the specimens shall be saturated shall be determined according to the requirements of specimens themselves and the project. If test is not carried out or specimens are not saturated immediately, the specimens shall be kept in moist chamber temporally.

After cutting specimens, the residual undisturbed soil sample shall be wrapped with stencil and put into a moist chamber for the preparation of retest. Cut residual soil is used for physical test. Density difference in parallel test or of the same group specimens shall not be greater than ± 0.1g/cm^3 and the water content difference shall not be greater than 2%.

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3.2.3 Scattered soil sample shall be sieved according to the amount of soil samples needed in the test. For physical test such as liquid limit, plastic limit and shrinkage limit tests, soil sample shall be sieved with 0.5mm sieve; for routine water-property test and mechanical test, soil sample shall be sieved with 2mm sieve; and for compaction test, the maximum particle diameter of soil sample must meet the requirements of the maximum particle diameter of soil sample Where compaction test is carried out by adopting different compaction cylinders. After sample is sieved as required, adequate amount of typical samples shall be taken out and put into containers respectively and then labeled. These labels shall expressly read project name, soil sample number, sieving diameter, purpose, preparing date and staff so as to prepare for various tests. If the soil is loose soil with much coarse sand and little fine particle soil (silt or clay), the soil shall be wetted and loosened with water; then typical sample shall be taken out with quartering method. If the soil is clean sand, typical samples may be taken with soil uniformizing machine.

3.2.4 In order to prepare samples with certain water content, adequate air-dried soil for test, 1~5g, after being sieved by 2mm sieve shall be taken. Additional water for preparing soil sample shall be Calculated according to the following formula:

$$m_w = \frac{m}{1 + 0.01 w_h} \times 0.01 (w - w_h) \qquad \text{(T 0141-1)}$$

Where, m_w—Additional water needed by soil sample (g);

m—Mass of soil sample Where its water content is dried (g);

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w_h—Dried water content (%);

w—Water content required by soil sample (%)

Taken soil sample is laid in a nonabsorbent tray; it is sprayed with pre-determined additional water with spraying equipment and then properly mixed; next the sample is put into a container and covered to be wetted for one day and night for standby usage (the wetting duration of sand soil may be shortened according to specific condition).

3.2.5 Where the water contents at different positions (at least more than two) of wetted soil sample are measured, the difference of these water contents shall meet the permissible and parallel difference for measuring water content.

3.2.6 Where mixed samples are prepared with the soil from different soil layers, the corresponding mass proportion shall be calculated according to the thickness of each soil sample; then disturbed soil is prepared according to those processes stated in Article 3.2.1~3.2.4 of this method.

3.3 Specimen saturation

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Non-permeable clay soil: i.e. Where the coefficient of permeability is less than 10-4cm/s, vacuum saturation method is adopted. If the structure of soil is weak, during air-pumping, the soil may be disturbed, so vacuum saturation method should not be adopted.

4 Test procedures

4.1 Fixed pin is inserted by aligning with both the upper and lower boxes of shearing container; porous stone and filter paper are placed in the lower box and the blade of cutting ring with sample is put upward to align with shearing box; filter paper and porous stone are put on the sample and then the sample is carefully pushed into the shear box.

4.2 Gearing is moved to enable that the steel ball in front of the upper box exactly contact with dynamometer; then pressure transmission plate and pressurizing frame are added consequently; next, vertical-displacement measuring unit is installed to measure and record the initial reading.

4.3 Vertical pressure in various grades are applied according to project reality and the soil rigidity; then the box is injected with water. Where the sample is non-saturated one, pressurizing plate shall be wrapped with wet cotton around.

4.4 Vertical pressure is applied, and vertical deformation is recorded every 1h. The vertical deformation Where sample consolidation is stable is the one Where the vertical deformation of clay soil is not greater than 0.005mm every hour.

4.5 Fixed pin is removed and shearing during consolidated quick shear test is carried out at a speed of 0.8mm/min; the shearing shall fail within 3~5 min. In addition, the dial gauge reading shall be measured and recorded at regular intervals till shearing failure.

4.6 Shearing failure time of sample may be estimated according to the following formula:

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After cutting specimens, the residual undisturbed soil sample shall be wrapped with stencil and put into a moist chamber for the preparation of retest. Cut residual soil is used for physical test. Density difference in parallel test or of the same group specimens shall not be greater than ± 0.1g/cm^3 and the water content difference shall not be greater than 2%.

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3.2.4 In order to prepare samples with certain water content, adequate air-dried soil for test, 1~5g, after being sieved by 2mm sieve shall be taken. Additional water for preparing soil sample shall be calculated according to the following formula:

$$m_w = \frac{m}{1+0.01w_h} \times 0.01(w - w_h) \qquad \text{(T 0142-1)}$$

Where, m_w—Additional water needed by soil sample (g);

m—Mass of soil sample Where its water content is dried (g);

w_h—Dried water content (%);

w—Water content required by soil sample (%)

Taken soil sample is laid in a nonabsorbent tray; it is sprayed with pre-determined additional water with spraying equipment and then properly mixed; next the sample is put into a container and covered to be wetted for one day and night for standby usage (the wetting duration of sand soil may be shortened according to specific condition).

3.2.5 Where the water contents at different positions (at least more than two) of wetted soil sample are measured, the difference of these water contents shall meet the permissible and parallel difference for measuring water content.

3.2.6 Where mixed samples are prepared with the soil from different soil layers, the corresponding mass proportion shall be calculated according to the thickness of each soil

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Non-permeable clay soil: i.e. Where the coefficient of permeability is less than 10-4cm/s, vacuum saturation method is adopted. If the structure of soil is weak, during air-pumping, the soil may be disturbed, so vacuum saturation method should not be adopted.

4 Test procedures

4.1 Fixed pin is inserted by aligning with both the upper and lower boxes of shearing container; porous stone and filter paper are placed in the lower box and the blade of cutting ring with sample is put upward to align with shearing box; filter paper and porous stone are put on the sample and then the sample is carefully pushed into the shear box.

4.2 Gearing is moved to enable that the steel ball in front of the upper box exactly contact with dynamometer; then pressure transmission plate and pressurizing frame are added consequently; next, vertical-displacement measuring unit is installed to measure and record the initial reading.

4.3 Vertical pressure in various grades are applied according to project reality and the soil rigidity; then the box is injected with water. Where the sample is non-saturated one, pressurizing plate shall be wrapped with wet cotton around.

4.4 Vertical pressure is applied, and fixed pin is removed; immediately stopwatch is started to record the shearing carried out at a speed of 0.8mm/min.

4.5 Where the reading of dynamometer dial gauge does not change or fall back, shearing is continued till the shear displacement is 4mm Where the failure value is recorded. Where there is no peak of dynamometer dial gauge during shearing, shearing is carried out till the shear displacement is 6mm.

4.6 After shearing, standing water in the box is absorbed; shearing force and vertical pressure are withdrawn; pressure frame is moved and then sample is taken out to measure its water content.

5 Results disposal

5.1 Shear displacement is calculated according to the following formula:

$$\triangle l=20n-R \qquad \text{(T 0142-2)}$$

Where, $\triangle l$—Shear displacement (0.01mm), to the accuracy of 0.1;

n—Revolution number of hand-wheel;

R—Dial gauge reading

5.2 Shear stress is calculated according to the following formula:

$$\tau=CR \qquad \text{(T 0142-3)}$$

Where, τ—Shear stress (kPa), to the accuracy of 0.1;

C—Correction coefficient of dynamometer (kPa / 0.01 mm)

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methods on preparing undisturbed sample (T 0102-2007) which are then put into shear box. Sample is pre-sheared under the vertical pressure being less than 50kPa and at a relatively quick speed so as to bring into a fracture surface. If the sample is hard, it may be cut with a shearing surface with knife or saw etc.; then vertical load is applied. After consolidation gets stable, shearing may be carried out.

3.1.3 As for soft interlayer and land sliding layer with thick muddy zone, 1~2mm soil next to sliding surface is taken; as for sliding surface with soft and thin muddy zone, muddy soil is taken; for fissure-plane without muddy zone, soil closed to both sides of fissure-plane is taken. Such taken soil is soaked with pure water for 24h after which it is mixed evenly to prepare it into soil paste at liquid limit; then the soil paste is filled into cutting ring. During filling, the periphery of cutting ring is filled at first and then the middle. Air in sample shall be exhausted.

3.1.4 For undisturbed sample, the soil on fracture surface shall be taken to measure its water content; for disturbed sample, the cut residual soil may be taken to measure the water content.

3.1.5 Sample shall be in saturation. It is generally saturated with air-pumping method.

3.1.6 4 samples shall be prepared for each group of test; in addition, the density difference of the samples in the same group shall not be greater than 0.03g/cm^3.

3.2 Sample shearing

3.2.1 At first, instruments are inspected. Then upper and lower shear boxes are aligned, and fixed pin is inserted; next saturation porous plate and filter paper are put into consequently and sample is pushed into shear box. Filter paper, porous plate, pressurizing cover plate, steel ball and pressurizing frame etc. are put into; in addition, vertical dial gauge (displacement gauge) is installed. Piston is wrapped with wet cotton around so as to prevent evaporation of water. Finally, the initial readings of dynamometer and vertical displacement gauge are measured and recorded.

3.2.2 4 samples shall be taken for each group of test to carry out shear test under 4 different vertical pressures. Thereinto, one vertical pressure is equivalent to the expected maximum pressure on site; one is greater than and others are less than the expected maximum pressure on site. The difference between vertical pressures in grades shall be approximately equal. In addition, the vertical pressures may be 100kPa, 200kPa, 300kPa and 400kPa respectively which is slightly applied at once; while if the soil is soft, the pressures may be applied in grades so as to prevent sample extrusion.

After specified vertical pressure is applied on the samples, vertical deformation readings are measured and recorded. If the vertical deformation readings do not change by greater than 0.005mm in each hour, it is deemed that the sample has achieved stable consolidation. Sample may also be consolidated on other instruments and then removed into shear box to continue the consolidation till the consolidation becomes stable after which sample is sheared.

3.2.3 Except the shearing of samples whose water content is equivalent to liquid limit, during the shearing of general undisturbed soil and hard clay soil test, the shear box shall be slotted with a width of 0.3~1.0mm.

3.2.4 Hand wheel is rotated so make the steel ball in front of shear box exactly contact with dynamometer; then dynamometer reading is zeroed again.

3.2.5 Fixed pin is pulled out and transmission case is adjusted. For general silty soil,

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saturation of sample shall be improved, carbon dioxide shall be injected into the sample from its bottom to replace the air in the void; then water head saturation is carried out again.

5.3 Counter-pressure saturation

Where sample shall be saturated completely, sample shall be applied with counter-pressure. Counter-pressure system is the same with ambient pressure system but in counter-pressure system, bilayer volume super-control tube shall replace water discharge tube. After sample is properly filled, void water pressure is adjusted to be 101.325kPa (atmospheric pressure); later, void water pressure valve, counter-pressure valve and volume super-control tube valve are closed to measure and record the reading of volume super-control tube. Ambient pressure valve is opened to apply 10~20kPa ambient pressure to the sample; then void pressure valve is opened; after the void pressure becomes stable, the reading is measured and recorded. Void pressure valve is closed; next, volume super-control tube valve and counter-pressure valve are opened, simultaneously ambient pressure and counter-pressure is applied with an increment of 30kPa in each grade. Void pressure valve is opened slowly to check the increment of void water pressure. After the void water pressure becomes stable, the readings of void water pressure and volume super-control tube are read and recorded after which the next grade of ambient pressure and counter-pressure are applied. Void water pressure shall be measured once after each application of one grade pressure. Where the ratio of void water pressure increment to ambient pressure one is $\triangle u/\triangle\sigma_3>0.98$, sample is saturated.

6 Test procedures

6.1 Waterproof plate, sample and sample cap are placed on the pedestal of pressure chamber in turn after which rubber membrane is covered outside the sample; in addition, both ends of rubber membrane shall be tightened with pedestal and sample cap, respectively.

6.2 Pressure chamber cover is set, and pure water is filled into the pressure chamber; then air evacuation valve is closed. Besides, the pressure chamber shall be free from any residual air bubble. More importantly, piston shall be aligned with dynamometer and sample top.

6.3 At the closing of drain valve, ambient pressure valve is opened to apply ambient pressure which shall be match with actual project load. The maximal grade ambient pressure shall be approximately equal to the maximal actual load.

6.4 Hand-wheel is rotated to enable sample cap contact with piston and dynamometer. Deformation dial gauge is mounted and then the readings of dynamometer and deformation dial gauge are zeroed.

7 Sample shearing

7.1 Shear strain rate should be 0.5%~1% per minute.

7.2 After motor is started, clutch is switched on to begin shearing. Readings of dynamometer and axial strain shall be read or measured once at every 0.3%~ 0.4% axial strain of sample. Where the axial strain is greater than 3%, reading shall be read and recorded every other 0.7% ~ 0.8% strain.

7.3 Where the reading of dynamometer is the peak one, shearing shall be continued till the reading is greater than 5% axial strain. Where there is no peak of dynamometer reading, shearing shall be continued till the axial strain is 15% ~20%.

7.4 At the end of test, ambient pressure valve and motor are closed in return after

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pressure shall be measured once after each application of one grade pressure. Where the ratio of void water pressure increment to ambient pressure one is $\Delta u/\Delta\sigma_3>0.98$, sample is saturated.

6 Test procedures

6.1 Sample assembling

6.1.1 Void water pressure valve and drain valve are opened. After void water pressure system and pressure chamber pedestal are filled with water and exhausted, the void water pressure valve and drain valve are closed. Porous plate, filter paper, sample and sample cap are put on the pedestal of Pressure chamber in turn. Sample is pasted with soaked filter paper strips around; then the sample is covered with rubber membrane whose lower end is tightened with pedestal. Sample is filled with water from its bottom to exhaust the air bubbles between sample and rubber membrane; in addition, the upper part of rubber membrane shall be tightened with sample cap. Drain-pipe is lowered to ensure the water surface in the pipe being by 20~40cm below sample center; then the surplus water is exhausted and drain valve is closed. Where the stress strain shall be measured, two layers of circular rubber membranes with silicone grease in the middle shall be placed between sample and porous plate; in addition, circular hole with 1cm in diameter shall be reserved between membranes for drainage.

6.1.2 Pressure chamber cover is set, and pure water is filled into the pressure chamber; then air evacuation valve is closed. Besides, the pressure chamber shall be free from any residual air bubble. More importantly, piston shall be aligned with dynamometer and sample top. Drain-pipe is lifted to enable the water surface in pipe to align with sample height center after which the reading of drainage surface is read and recorded.

6.1.3 Void water pressure valve is opened to ensure the void water pressure is equal to atmospheric pressure; then the valve is closed.

6.1.4 Waterproof plate, sample and sample cap are placed on the pedestal of pressure chamber in turn after which rubber membrane is covered outside the sample; in addition, both ends of rubber membrane shall be tightened with pedestal and sample cap, respectively.

6.1.5 Pressure chamber cover is set, and pure water is filled into the pressure chamber; then air evacuation valve is closed. Besides, the pressure chamber shall be free from any residual air bubble. More importantly, piston shall be aligned with dynamometer and sample top.

6.1.6 At the closing of drain valve, ambient pressure valve is opened to apply ambient pressure which shall be match with actual project load. The maximal grade ambient pressure shall be approximately equal to the maximal actual load.

6.1.7 Hand-wheel is rotated to enable sample cap contact with piston and dynamometer. Deformation dial gauge is mounted and then the readings of dynamometer and deformation dial gauge are zeroed.

6.1.8 Axial pressure being adjusted to zero axial strain and void water pressure; besides, the reading of volume change burette shall be recorded. If counter-pressure shall be applied, it is applied according to those specified in Article 5.3 of this test.

6.2 Drainage consolidation of sample

6.2.1 Void water pressure valve is opened to measure void water pressure; drain valve is opened as well. Where drainage process shall be measured, drain-pipe water surfaces and

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6.1.1 Void water pressure valve and drain valve are opened. After void water pressure system and pressure chamber pedestal are filled with water and exhausted, the void water pressure valve and drain valve are closed. Porous plate, filter paper, sample and sample cap are put on the pedestal of pressure chamber in turn. Sample is pasted with soaked filter paper strips around; then the sample is covered with rubber membrane whose lower end is tightened with pedestal. Sample is filled with water from its bottom to exhaust the air bubbles between sample and rubber membrane; in addition, the upper part of rubber membrane shall be tightened with sample cap. Drain-pipe is lowered to ensure the water surface in the pipe being by 20~40cm below sample center; then the surplus water is exhausted and drain valve is closed. Where the stress strain shall be measured, two layers of circular rubber membranes with silicone grease in the middle shall be placed between sample and porous plate; in addition, circular hole with 1cm in diameter shall be reserved between membranes for drainage.

6.1.2 Pressure chamber cover is set, and pure water is filled into the pressure chamber; then air evacuation valve is closed. Besides, the pressure chamber shall be free from any residual air bubble. More importantly, piston shall be aligned with dynamometer and sample top. Drain-pipe is lifted to enable the water surface in pipe to align with sample height center after which the reading of drainage surface is read and recorded.

6.1.3 Void water pressure valve is opened to ensure the void water pressure is equal to atmospheric pressure; then the valve is closed.

6.1.4 At the closing of drain valve, ambient pressure valve is opened to apply ambient pressure which shall be match with actual project load. The maximal grade ambient pressure shall be approximately equal to the maximal actual load.

6.1.5 Hand-wheel is rotated to enable sample cap contact with piston and dynamometer. Deformation dial gauge is mounted and then the readings of dynamometer and deformation dial gauge are zeroed.

6.1.6 Axial pressure, axial strain and void water pressure are adjusted to zero and the reading of volume change burette shall be recorded. If counter-pressure shall be applied, it is applied according to those specified in Article 5.3 of this test.

6.2 Drainage consolidation of sample

6.2.1 Void water pressure valve is opened to measure void water pressure. Next, drain valve is opened. Where drainage process shall be measured, the drain-pipe water surface and void water pressures are measured till greater than 95% void water pressure dissipates. After consolidation, drain valve is closed and then the readings of draining-pipe and void water pressure are read and recorded.

6.2.2 Lifting table of compression machine is finely adjusted to make piston contact with sample Where the change of axial-deformation dial gauge shall be the variation of the height of sample during its consolidation.

6.3 Sample shearing

6.3.1 All the readings of axial dynamometer, axial-deformation dial gauge and void water pressure are zeroed, after which drain valve is opened.

6.3.2 Shear strain rate is selected for shearing. Shear rate shall be that per minute strain is 0.003%~0.012%.

6.3.3 Axial pressure and axial deformation are measured and recorded as below:

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its bottom to replace the air in the void; then water head saturation is carried out again.

4.3 Counter-pressure saturation

Where sample shall be saturated completely, sample shall be applied with counter-pressure. Counter-pressure system is the same with ambient pressure system but in counter-pressure system, bilayer volume super-control tube shall replace water discharge tube. After sample is properly filled, void water pressure is adjusted to be 101.325kPa (atmospheric pressure); later, void water pressure valve, counter-pressure valve and super-control tube valve are closed to measure and record the reading of volume super-control tube. Ambient pressure valve is opened to apply 10~20kPa ambient pressure to the sample; then void pressure valve is opened; after the void pressure becomes stable, the reading is measured and recorded. Void pressure valve is closed; next, volume super-control tube valve and counter-pressure valve are opened, simultaneously ambient pressure and counter-pressure is applied with an increment of 30kPa in each grade. Void pressure valve is opened slowly to check the increment of void water pressure. After the void water pressure becomes stable, the readings of void water pressure and super-control tube are read and recorded after which the next grade of ambient pressure and counter-pressure are applied. Void water pressure shall be measured once after each application of one grade pressure. Where the ratio of void water pressure increment to ambient pressure one is $\triangle u/\triangle\sigma_3>0.98$, sample is saturated.

5 Test procedures

5.1 Sample assembling

5.1.1 Un-consolidated and undrained shear test (UU test)

(1) Waterproof plate, sample and sample cap are placed on the pedestal of pressure chamber in turn after which rubber membrane is covered outside the sample; in addition, both ends of rubber membrane shall be tightened with pedestal and sample cap, respectively.

(2) Pressure chamber cover is set, and pure water is filled into the pressure chamber; then air evacuation valve is closed. Besides, the pressure chamber shall be free from any residual air bubble. More importantly, piston shall be aligned with dynamometer and sample top.

(3) At the closing of drain valve, ambient pressure valve is opened to apply ambient pressure which shall be match with actual project load. The maximal grade ambient pressure shall be approximately equal to the maximal actual load.

(4) Hand-wheel is rotated to enable sample cap contact with piston and dynamometer. Deformation dial gauge is mounted and then the readings axial-pressure dynamometer, axial-strain-deformation dial gauge as well as void water pressure are zeroed.

5.1.2 Consolidated and undrained test (CU test)

(1) Void water pressure valve and drain valve are opened. After void water pressure system and pressure chamber pedestal are filled with water and exhausted, the void water pressure valve and drain valve are closed. Porous plate, filter paper, sample and sample cap are put on the pedestal of pressure chamber in turn. Sample is pasted with soaked filter paper strips around; then the sample is covered with rubber membrane whose lower end is tightened with pedestal. Sample is filled with water from its bottom to exhaust the air bubbles between sample and rubber membrane; in addition, the upper part of rubber membrane shall be tightened with sample cap. Drain-pipe is lowered to ensure the water surface in the pipe being by 20~40cm below sample center; then the surplus water is exhausted and drain valve is closed. Where the stress strain shall be measured, two layers of circular rubber membranes

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with silicone grease in the middle shall be placed between sample and porous plate; in addition, circular hole with 1cm in diameter shall be reserved between membranes for drainage.

(2) Pressure chamber cover is set, and pure water is filled into the chamber. Draining pipe is lifted to enable the water surface in pipe to align with sample height center after which the reading of drainage surface is read and recorded.

(3) Void water pressure valve is opened to ensure the void water pressure is equal to atmospheric pressure; then the valve is closed.

(4) Application of ambient pressure: waterproof plate, sample and sample cap are placed on the pedestal of pressure chamber in turn after which rubber membrane is covered outside the sample; in addition, both ends of rubber membrane shall be tightened with pedestal and sample cap respectively. Pressure chamber cover is set, and pure water is filled into the pressure chamber; then air evacuation valve is closed. Besides, the pressure chamber shall be free from any residual air bubble. More importantly, piston shall be aligned with dynamometer and sample top. At the closing of drain valve, ambient pressure valve is opened to apply ambient pressure which shall be match with actual project load. The maximal grade ambient pressure shall be approximately equal to the maximal actual load. Hand-wheel is rotated to enable sample cap contact with piston and dynamometer. Deformation dial gauge is mounted and then the readings axial-pressure dynamometer, axial-strain-deformation dial gauge as well as void water pressure is zeroed. Furthermore, the reading of volume change burette shall be recorded.

Where sample shall be saturated completely by applying counter-pressure, it shall be done as required. Counter-pressure system is the same with ambient pressure system but in counter-pressure system, bilayer volume super-control tube shall replace water discharge tube. After sample is properly filled, void water pressure is adjusted to be 101.325kPa (atmospheric pressure); later, void water pressure valve, counter-pressure valve and super-control tube valve are closed to measure and record the reading of volume super-control tube. Ambient pressure valve is opened to apply 10~20kPa ambient pressure to the sample; then void pressure valve is opened; after the void pressure becomes stable, the reading is measured and recorded. Void pressure valve is closed; next, super-control tube valve and counter-pressure valve are opened, simultaneously ambient pressure and counter-pressure is applied with an increment of 30kPa in each grade. Void pressure valve is opened slowly to check the increment of void water pressure. After the void water pressure becomes stable, the readings of void water pressure and volume super-control tube are read and recorded after which the next grade of ambient pressure and counter-pressure are applied. Void water pressure shall be measured once after each application of one grade pressure. Where the ratio of void water pressure increment to ambient pressure one is $\triangle u/\triangle\sigma_3>0.98$, sample is saturated.

(5) Before sample shearing, void pressure valve and burette valve are closed.

5.2 Sample shearing

5.2.1 Un-consolidated and undrained shear test (UU test)

(1) After sample is assembled according to those specified in Article 5.1.1 of this test, the first grade of ambient pressure (being applied in 2~3 grades) is applied on the sample.

(2) Shear strain rate shall be 0.5%~1.0% per minute. Shearing is started and at the initial stage of which the readings of dynamometer and axial displacement are read and recorded at

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every other 0.3%~0.4% sample strain; Where the strain is equal to or greater than 3%, these readings are read and recorded at every other 0.7%~0.8%.

(3) Where the reading of dynamometer becomes stable or is near stable, the readings of axial displacement gauge and dynamometer are read and recorded after which motor is powered off to stop shearing; then axial pressure is zeroed.

(4) Secondary ambient pressure is applied during which dynamometer reading increases along ambient pressure application; but the dynamometer reading shall be adjusted to its former one; then hand-wheel is rotated. Slight fluctuation of dynamometer reading indicates that sample cap contacts with dynamometer again after which the sample is sheared at the speed of the former one till dynamometer reading becomes stable or gets approach to stable.

(5) Test in other grades of ambient pressures are carried out according to those specified in 5.2.1 (4). The shearing accumulation under the action of the last grade of ambient pressure shall not be greater than 20%.

(6) After test, ambient pressure valve is closed, and pressure chamber cover is removed as soon as possible; then sample is taken out to be weighed and its water content after shearing is measured.

5.2.2 Consolidated and undrained test (CU test)

(1) After sample is assembled according to those specified in Article 5.1.2 of this test, the first grade of ambient pressure is applied on the sample. In addition, the sample is consolidated as below.

① Void water pressure valve and drain valve are opened. After void water pressure system and pressure chamber pedestal are filled with water and exhausted, the void water pressure valve and drain valve are closed. Porous plate, filter paper, sample and sample cap are put on the pedestal of pressure chamber in turn. Sample is pasted with soaked filter paper strips around; then the sample is covered with rubber membrane whose lower end is tightened with pedestal. Sample is filled with water from its bottom to exhaust the air bubbles between sample and rubber membrane; in addition, the upper part of rubber membrane shall be tightened with sample cap. Drain-pipe is lowered to ensure the water surface in the pipe being by 20~40cm below sample center; then the surplus water is exhausted and drain valve is closed. Where the stress strain shall be measured, two layers of circular rubber membranes with silicone grease in the middle shall be placed between sample and porous plate; in addition, circular hole with 1cm in diameter shall be reserved between membranes for drainage.

② Pressure chamber cover is set, and pure water is filled into the chamber. Draining pipe is lifted to enable the water surface in pipe to align with sample height center after which the reading of drainage surface is read and recorded.

③ Void water pressure valve is opened to ensure the void water pressure is equal to 101.325kPa (atmospheric pressure); then the valve is closed.

Application of ambient pressure: waterproof plate, sample and sample cap are placed on the pedestal of pressure chamber in turn after which rubber membrane is covered outside the sample; in addition, both ends of rubber membrane shall be tightened with pedestal and sample cap respectively. Pressure chamber cover is set, and pure water is filled into the pressure chamber; then air evacuation valve is closed. Besides, the pressure chamber shall be free from any residual air bubble. More importantly, piston shall be aligned with dynamometer and sample top. At the closing of drain valve, ambient pressure valve is opened

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to apply ambient pressure which shall be match with actual project load. The maximal grade ambient pressure shall be approximately equal to the maximal actual load. Hand-wheel is rotated to enable sample cap contact with piston and dynamometer. Deformation dial gauge is mounted and then the readings of dynamometer and deformation dial gauge are zeroed.

Axial pressure, axial strain and void water pressure are adjusted to zero and the reading of volume change burette shall be recorded.

Where sample shall be saturated completely by applying counter-pressure, it shall be done as required. Counter-pressure system is the same with ambient pressure system but in counter-pressure system, bilayer volume super-control tube shall replace water discharge tube. After sample is properly filled, void water pressure is adjusted to be 101.325kPa (atmospheric pressure); later, void water pressure valve, counter-pressure valve and super-control tube valve are closed to measure and record the reading of volume super-control tube. Ambient pressure valve is opened to apply 10~20kPa ambient pressure to the sample; then void pressure valve is opened; after the void pressure becomes stable, the reading is measured and recorded. Void pressure valve is closed; next, super-control tube valve and counter-pressure valve are opened, simultaneously ambient pressure and counter-pressure is applied with an increment of 30kPa in each grade. Void pressure valve is opened slowly to check the increment of void water pressure. After the void water pressure becomes stable, the readings of void water pressure and volume super-control tube are read and recorded after which the next grade of ambient pressure and counter-pressure are applied. Void water pressure shall be measured once after each application of one grade pressure. Where the ratio of void water pressure increment to ambient pressure one is $\triangle u/\triangle\sigma_3>0.98$, sample is saturated.

④ After stabilization by consolidation, volume super-control tube valve or drain valve are closed.

(2) The first grade of sample shearing is carried out according to the provisions specified in Article 5.2.1 (2) and (3).

(3) After the first-grade shearing, axial pressure is adjusted to zero. At the stabilization of void pressure, the second grade of ambient pressure is applied; in addition, drainage consolidation is carried out according to those specified in Article 5.2.2 of this test method.

(4) After sample consolidation becomes stable, volume super-control tube valve or drain valve is closed and hand-wheel is positively rotated till piston contact with sample cap, Where the reading of axial displacement gauge $\triangle h_2$ (at this moment sample height, $h_2=h_0-\triangle h_2$) is recorded.

(5) Sample shearing is carried out according to the provisions specified in Article 5.2.1 (2) and (3).

(6) Test under the next grade of ambient pressure is carried out according to the provisions specified in Article 5.2.2 (3) and the accumulation strain of shear under the last grade of ambient pressure shall not be greater than 20%.

(7) Sample is removed according to those specified in Article 5.2.1 (6) of this test; then its mass and post-test water content are weighed and measured, respectively.

6 Result re-arrangement

6.1 The axial strain and area of sample during the shearing under the first grade of ambient pressure in unconsolidated and undrained test are calculated according to the following two formulae:

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