WORK INSTRUCTIONS FOR ENGINEERS

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OP-3-42. CHECKLIST FOR ISOTROPIC CONSOLIDATED UNDRAINED SHEAR STRENGTH IN TRIAXIAL COMPRESSION (CIU) LABORATORY TEST

42.0 CHECKLIST FOR ISOTROPIC CONSOLIDATED UNDRAINED SHEAR STRENGTH IN TRIAXIAL COMPRESSION (CIU) LABORATORY TEST

No.	42.1- CHECKLIST FOR SAMPLE PREPARATION	G&P Check	Remarks
1.0	**REFERENCES : BS 1377 : PART 8 : 1990**		
2.0	**PRELIMINARY PREPARATION**		
2.1	SAMPLE • Diameter range from 38mm to 100mm [A set of three (3) Untrimmed Specimen of ϕ75mm is preferable] • Size of test specimens [check for sufficiency of samples, e.g. ϕ75mm specimen, at least 500mm long of ϕ75mm sample is required] • Number of specimen to be tested as a set (generally, for a set of 3 specimens, effective consolidation pressures are of ½, 1 and 2 times the vertical effective stress on the soil in-situ, σ_v'.) • Type of drainage (one end or both ends) • Cell confining pressures • Method of saturation (use back pressure, or state the method adopted)		
2.2	TEST EQUIPMENT • Triaxial compression load frame • Triaxial cell with connections to cell chamber, base pedestal and top loading cap • Calibrated Electronic pore pressure transducer, range 0 – 1000kPa • Calibrated Electronic pressure transducers connected to cell pressure and back pressure lines. • Calibrated Electronic displacement transducer • Calibrated Electronic load cell • Volume-change transducers for digital read-out of movement of water in cell or back pressure lines		
2.3	ANCILLARY ITEMS • Sample Extruder – to extrude sample from the tube or sampler • Support for Sample Extruder – to hold extruder & avoid sample disturbance • Split-tube or cutter - for test specimen cutting and preparation • Lubricating oil or silicone grease – to apply on the inner surface of split cutter or sample holder as a lubricant. • Timer accurate to 1s – time measurement • Thermometer – to measure the room temperature during the test • Balance readable to 0.1g – to measure weight of sample • Wiping Cloth – to wipe the triaxial cell and equipment • Flat glass plate – not to use plate that may absorb moisture of sample • Small metal tray – for sample transporting, if necessary • Wire Saw, cutter or knife – to cut and trim soil sample • Wax – to rewax the unused sample.		

2.4	PRE-TEST CHECKS • Pore pressure measuring device : Ensure entire system filled with de-aerated water and check for air free and leak free. • Back Pressure System : Flush freely de-aired water through the back pressure connecting line from volume-change indicator and check the back pressure system for leak-free. • Cell Pressure System : Ensure maximum test pressure required can be maintained constant to within ± 0.5% of the reading indicated.		
	• Constant Pressure Sources, e.g. (i) Compressed Air System (ii) Mercury Pot System (If any) (iii) Oil-water System (iv) Pressure Gauges • Ancillary Items (i) De-aired Water (ii) 2 Porous discs (boiled for 30 minutes in distilled water to remove air, kept under de-aerated water until required) (iii) Electronic Measuring Devices should be already calibrated. (iv) Triaxial Cell – Piston to be dry and free movement in its bushing (v) Rubber Membranes – New membrane leak-free shall be soaked in de-aired water overnight before used. (vi) Split-tube stretcher for O-rings (vii) Rubber O-rings – Clean, dry and stretchable. (viii) Suction membrane stretcher with rubber tube and pinch clip (ix) Test Recording Forms		
2.5	OTHERS • Data logging and automatic data processing system • Plentiful supply of de-aired water (not de-ionised) in overhead reservoir		
3.0	**TEST SPECIMEN PREPARATION**		
3.1	SPECIMEN : • Normally orientated in lab test in the same direction relative to the stratum as in-situ. • Extrude an undisturbed specimen from the tube/sampler. Avoid applying two times of extrusion. (Sample holding tray or split-tube is preferable) • Cut off the extruded portion (specimen) and place on a flat glass plate for trimming (if smaller size specimen to be used). • Take adjacent (top and bottom) soil for moisture content test to compare • Sample should never be left exposed to the atmosphere for too long during the specimen preparation. (Not more than 15 minutes) • Quickly measure the specimen height to 0.05mm • Place the specimen on watch glass (or metal tray), weigh to 0.1g • Take a similar soil sample for Particle Density, Atterberg Limits tests and Initial Moisture Content determination.		

3.2	SETTING UP : • Cover the cleaned base pedestal with a film of de-aired water • Take a de-aired saturated porous disc from under water and slide it on to the pedestal without trapping any air. • Place the prepared specimen on the porous disc without delay • Place a second saturated porous disc, with excess surface water removed, on the top end of the sample. • Fit two rubber O-rings and a rubber membrane over the stretcher. • Place the membrane over the sample while applying suction to the rubber tube, then release the suction so that the membrane clings to the sample at the correct height. • Roll the lower end of the membrane over the base pedestal and seal it in place with both O-rings. • Unroll the upper end of the membrane and remove the stretcher. • Slip two O-rings over and past the top loading cap so that they encircle the drainage lead to the cell base. • Open the drainage valve for an instant to allow a little water to moisten the top cap, before fitting it on to the porous disc covering the sample, but avoid excess free water. • Seal membrane on to the top cap with 2 O-rings, without disturb sample. • Check the sample axis is vertical and the sample and top cap are properly seated. • Carefully lower the cell body into position over the sample with cell piston raised to its maximum extent, and adjust the piston contact with the ball or dome on the top cap. • Fill the cell with water (de-aired water for a saturated soil) from the supply system or reservoir with air-bleed valve open. Close the valve when the water begins to emerge.		

	42.2- CHECKLIST FOR CIU TEST PROCEDURE		
4.0	**TEST PROCEDURE**		
4.1	**STAGE 1: SATURATION STAGE** **- BY APPLICATION OF BACK-PRESSURE (UNDRAINED)**		
4.1.1	• Raise the pore pressure to a level high enough for water to absorb into solution all the air originally in the void spaces. Simultaneously, raise the confining pressure to maintain a small positive effective stress in the sample. • Do not excessively prestress or over consolidate the specimen. • Continue the above step and maintain a constant difference between them. The difference between cell pressure and back pressure shall not be greater than the desired effective test pressure, or 20kPa, whichever is less and shall not be less than 5kPa. (A differential pressure of 10kPa is suitable for many soils which swelling is not significant at this effective stress) • Apply a "back-pressure" to the pore fluid incrementally, alternating with increments of confining pressure. The back pressure is always a little less than the confining pressure by checking the pore pressure coefficient B each time the confining pressure is raised. (B greater than 0.95 represents an acceptable degree of saturation) • Monitoring of pore pressure enables each stage to be held for as long as necessary (but within practical period) to reach equilibrium.		
4.1.2	procedure:- (1) Ensure the back pressure valve and the flushing system valve are closed. Apply first increment of cell pressure after setting up. (2) Record the pore pressure when reaches an equilibrium value, u_1. Ensure that the pore pressure does not reach zero. (3) Increase cell pressure by 50kPa and repeat step (2) until a steady value of pore pressure is reached. Calculate the change on pore pressure (δu, in kPa) resulting in this increment. Calculate the pore pressure coefficient ($B=\delta u/\delta\sigma_3$). If B is equal or ≥ 0.95, the specimen is considered as saturated. (4) Otherwise, close the back pressure valve and the flushing system valve, increase the pressure in the back pressure line to a value equal to the (cell pressure – selected differential pressure). Record the back pressure line volume-change indicator (V_1) when it reaches a steady value. (5) Open back-pressure valve to admit the back pressure into the specimen. Observe the pore pressure and volume-change indicator readings. (6) When the pore pressure becomes equal to the back pressure and the volume-change indicator shows that movement of water into the specimen has ceased, record the pore pressure, u_2 and volume change, V_2. (7) Increase the cell pressure by 50kPa to give 100kPa. When the change in pore pressure is steady, calculate the value of the pore pressure coefficient B.		

4.2	**STAGE 2 : CONSOLIDATION STAGE (ISOTROPIC)**		
4.2.1	• The objective is to bring the specimen to the state of effective stress required for carrying out the compression test. • The effective stress is increased to the desired value by raising the cell pressure and dissipating the resulting excess pore pressure to an appropriate back pressure. • The back pressure should not be reduced below the pore pressure in the final step of the saturation stage, or 300kPa, whichever is greater.		
4.2.2	Procedure:- (1) Increase the cell pressure (σ_3) and adjust the back pressure if necessary, to give a difference to the required effective stress. Record pore pressure and volume gauge readings when they are steady. (2) Start the consolidation by open the back-pressure valve to admit the pressure into the cell and open the pore pressure valve to observe the pore pressure changes. Record the pore pressure and volume gauge readings when they are steady. Calculate the new B value. (3) Record readings of pore water pressure and back pressure volume change gauge at suitable time intervals, e.g. 0, ¼, ½, 1, 21/4, 4, 9, 121/4, 16, 25, 36, 64 mins, and 2, 4, 8, 16, 24 hours. Plot graphs of sample volume change against square-root time and pore pressure dissipation (%) against log time. (4) Continue the consolidation until no further significant volume change and until at least 95% dissipation is reached. (5) When consolidation is complete, record the reading of the volume change indicator and calculate the total volume change (ΔVc) during the consolidation stage. Record the pore pressure, u_c. Calculate the value of the coefficient of consolidation, C_v and coefficient of volume compressibility, m_v. (6) Calculate the significant testing time tf (in min) in the compression test (Without side drains : $t_f = 0.51 \times t_{100}$ minutes). However, the actual time to undrained failure should not be less than 2 hours. (7) Estimate the significant strain interval for the test specimen, ε_f to determine the rate of displacement. This gives the maximum normal displacement speed for the compression.		
4.3	**STAGE 3 : SHEARING STAGE**		
4.3.1	During the compression stage, the cell pressure is maintained constant while the specimen is sheared at a constant rate of axial deformation (strain controlled compression) until failure occurs. No drainage is permitted. Changes in pore pressure to be measured.		
4.3.2	Procedure :- 1) Close the back pressure valve and let the cell pressure valve and valve to pore pressure measuring device open. 2) Set the gearbox or speed controller on the compression machine to give the required rate off displacement. [Not exceeding the rate calculated in 4.2.2 (7)] 3) Adjust the machine platen until the cell loading piston makes contact with the top cap. Check that the piston is properly seated and in correct alignment with only a small seating load (indicated on the load dial gauge). 4) Secure the strain dial gauge vertically in position and adjust the bracket on which the stem rests to set the dial to zero, or to a convenient initial reading. Ensure the dial gauge has enough travel and the clearances are large enough, to permit a strain movement of at least 25% of the sample length.		

	5) Record the initial readings for • date and clock time • displacement dial gauge reading • Dial gauges Readings • Pore water pressure • Cell pressure 6) Apply compression to the specimen, simultaneously start the timer 7) Things to be checked during the test. • Cell pressure should be checked periodically during the course of the test to ensure it remains constant. • Elapsed time reading shall be recorded periodically to provide a check on the applied rate of strain. • Calculated values of deviator stress (σ_1-σ_3) and effective principal stress ratio (σ_1'/σ_3'), and plot against the axial strain(%), while test is still in progress. • Continue the test until one of the following the test failure criteria achieved: (a) Maximum deviator stress; (b) Maximum effective principal stress ratio; (c) Constant shear stress and constant pore pressure. If none of the required failure conditions is achieved, terminate the test at an axial strain of 20%.		
4.3.3	**End of Test** 1) When the displacement reaches the intended limit, and the final readings have been taken, switch off the motor, close the back pressure valve and valve to pore pressure measuring device, unload the sample and remove the specimen from the triaxial cell pedestal as quickly as possible. 2) Sketch the specimen as viewed from two directions at right angles to illustrate the mode of failure. Record any features observed. 3) Final Measurement:- • Weigh the whole specimen. • A small sample to be taken and dried overnight in an oven as to determine the moisture content of the specimen.		

5.0	**RECORDS**		
	• Statement of method used • Initial specimen dimension • Undisturbed or remoulded specimens and the method of specimen preparation • Initial moisture content, bulk density and dry density • Depth and orientation of test specimen within original sample • Thickness and type of membrane used • Pore Water Pressure Coefficient (B Ratio) • Degree of saturation reached • Cell Pressure and Back Pressure Applied • Duration for consolidation and coefficient of isotropic consolidation (C_V) and coefficient of volume compressibility (m_V). • Rate of strain (Loading Rate) and stress ratio applied • Tabulated data at failure and the specimen Failure mode		
6.0	**PLOTTINGS**		
	1) Pore Pressure (B Ratio) vs Cell Pressure 2) Volume Change vs Square-root Time 3) Pore Water Pressure vs Root Time 4) q'-p' Plot 5) Deviator Stress vs Axial Strain 6) Pore Water Pressure vs Axial Strain 7) Shear Stress vs Normal Stress (Undrained and Drained)		
Signature: **Note: Once a copy is signed, this procedure has been witnessed by the engineer and with acknowledgement from contractor involved.**		**SIGNED BY**	