DETERMINATION OF TRIAXIAL SHEAR PARAMETERS USING SIMPLE TRIAXIAL TEST

1 SCOPE

This method describes the determination of triaxial shear parameters (cohesion and internal angle of friction) of Bitumen Stabilised Materials by measuring the resistance to failure (monotonic) of a cylindrical 150 mm diameter and 300 ± 2 mm height specimen prepared according to Vibratory Hammer Compaction Procedure (Appendix L of the Technical Memorandum on Updating Bituminous Stabilised Materials Guidelines – Mix Design Report Phase II).

2 APPARATUS

2.1 Triaxial Cell

Comprising:

- Galvanised steel casing 5 mm thick comprising a ring handle and simple mechanical clamps top and bottom
- A base with bottom platen for sitting specimen
- Top disk; and
- Latex tube at least 320 mm height.

2.2 Testing System

Material Testing System (MTS) or its equivalent system must at least comprise of an actuator, reaction frame, control panel and data acquisition system. The system must be capable of providing ramp loads with minimum loading capacity of 100 kN and a minimum stroke of 40 mm.

It is preferable that the actuator be operated by a servo-controlled hydraulic pressure system with a closed loop feedback system that is capable of both displacement and load
controlled testing if required.

2.3 Measuring Devices

Measuring devices should include but not limited to:

- Load cell (100 kN Capacity) for measuring load
- Actuator displacement transducer (> 40 mm stroke) for measuring displacement (deformation)
- Pressure regulator, gauges, and valves for lateral pressure

2.4 Others

- Air compressor
- Loading ram
- Silicon oil or grease

3 SPECIMEN PREPARATION

Specimen must be prepared according to Vibratory Hammer Compaction Procedure (Appendix L) and cured according to curing protocol suggested in Appendix G and H of the Technical Memorandum on Updating Bituminous Stabilised Materials Guidelines – Mix Design Report Phase II Report.

4 PROCEDURE

4.1 Assembly of specimen in a triaxial cell

The triaxial testing of the specimens must be planned to take place within 48 – 72 hours after completion of the curing procedure. This delay must be kept as constant as possible.

The following steps describe the procedure taken to assemble specimen in the simple triaxial cell and the cell in the loading frame:

(i) Place the specimens, casing with tube, top disk and base plate in a climate chamber and condition them overnight at 25ºC.

(ii) Lightly grease the sides of the top disk and base plate to reduce friction as much as possible.

(iii) Place the specimen in the middle of the base plate.

(iv) Carefully introduce the casing, comprising the tube, around the specimen. Take care not to damage the edges of the specimen during this procedure.

(v) Clamp the casing in position on to the base plate using simple mechanical clamps on the casing.

(vi) Put the top disk on top of the specimen.

(vii) Place the cell in the hydraulic loading frame; adjust actuator position until visual contact is made with the loading ram.

(viii) Connect the air supply to the cell; open the regulator and valve on the cell pressure port until the cell pressure is stable at the desired level.

(ix) Set monotonic test parameters on the MTS controller including displacement rate of strain (2.1%), full-scale for the loading (10.0V = 98.1 kN) and half-scale for the displacement (10.0V = 40mm)

(x) Run the test.

4.2 Monotonic Triaxial Test

Select four specimens of comparable density, moisture content and conditioned at 25°C. Assemble the specimen in the triaxial cell according to 4.1. Ensure the tube is air tight by observing step (iv) in 4.1 above.

Operate the testing system in displacement control mode. Ensure that there is sufficient space between the actuator and the reaction frame to accommodate the triaxial cell. Place the triaxial cell in the hydraulic loading frame as shown in step (vii) in 4.1 above.

Adjust the actuator position until visual contact is made with the loading ram. Monitor the load cell reading to prevent loading of the specimen during this process.

Connect the air supply to the cell pressure port. Open the valve on the cell pressure port and open the regulator until the cell pressure is stable at the desired level. The cell pressures for a series of monotonic tests are 0 kPa, 50kPa, 100 kPa and 200 kPa.

Test the first specimen without confinement pressure (0 kPa). Begin the test by compressing the specimen at a constant rate of displacement of 2.1%. Record the load versus displacement during the test with a minimum sampling rate of 10 Hz, as well as the cell pressure, temperature and specimen identifier.

Stop the test and the recording when the total displacement exceeds 18 mm (6% strain) or when the specimen bulges excessively before the end displacement is reached.

Repeat this procedure for other three specimens until all specimens have been tested at the four levels of confinement pressures.

Remove the specimen according to 4.3.

4.3 Removal of specimen after completion of test

After completion of a test, hold the actuator to its current position, close the valve on the cell pressure port and release the cell pressure by disconnecting the pressure supply tube to the cell (if possible speed up the pressure release by applying suction).

Return the actuator to a position whereby the cell can easily be removed from the loading frame.

Remove the top disk. Clean the top disk and wipe it of any grease.

Unclamp the casing and lift the casing with tube from the cell base. Clean the tube from possible remains of the deformed specimen (it is not necessary to remove the tube from the casing).

Remove the tested specimen from the base plate. Place it in the plastic bag and seal. Clean the base plate and wipe it of any grease.

Once all the specimens have been tested, remove the tested specimens one by one from the plastic bags. Break the tested specimens up and sample between 500 and 1000 gr. of material from the middle of the specimen.

Use this sample to determine the moisture content during testing according to the procedure given in TMH1 Method A7.

5 CALCULATIONS

(i) Determine the applied failure load $P_{a,f}$ for each specimen tested. The applied failure load is defined as the maximum applied load during the test. Calculate the applied failure stress $\sigma_{a,f}$:

$$\sigma_{a,f} = \frac{P_{a,f}}{A} \cdot 10^{-3}$$

Where

$\sigma_{a,f}$ = applied failure stress [kPa]

$P_{a,f}$ = applied failure load [N]

A = end area of a cylindrical specimen at beginning of test [m^2]

(ii) Calculate the major principle stress at failure $\sigma_{1,f}$ for each tested specimen:

$$\sigma_{1,f} = \sigma_{a,f} + \sigma_{dw}$$

Where
$\sigma_{1,f}$ = major principle stress at failure [kPa]

$\sigma_{a,f}$ = applied failure stress [kPa]

$\sigma_{d,w}$ = pressure resulting from dead weight of top disk and loading ram [kPa]

(iii) According to Jenkins et al (2007), the relationship between $\sigma_{1,f}$ and confinement stress (σ_3)is described by:

$$\sigma_{1,f} = A \cdot \sigma_3 + B$$

Where

$$A = \frac{1+\sin\varphi}{1-\sin\varphi} \quad \text{And} \quad B = \frac{2 \cdot C \cdot \cos\varphi}{1-\sin\varphi}$$

Values of A and B can be determined by performing a linear regression analysis on the four combinations of $\sigma_{1,f}$ and σ_3 per mix.

(iv) Values of φ [^{o}] and C [kPa] can be calculated as follows:

$$\varphi = \sin^{-1}\left(\frac{A-1}{A+1}\right)$$

$$C = \frac{B(1-\sin\varphi)}{2 \cdot \cos\varphi}$$

6 REPORT

Report the following in the table format as illustrated in Table 1 below:

- Specimen number or identifier;
- Confinement pressure (σ_3);
- Applied stress at failure ($\sigma_{a,f}$);
- Major principal stress at failure ($\sigma_{1,f}$);
- Cohesion, C [kPa];
- Angle of internal friction, φ [°]; and
- Coefficient of variance, R^2

Plot the Mohr Circles and the Mohr-Coulomb failure envelope as shown in Figure 1. Note from Figure 1 that:

- The centre of Mohr circle must be on the abscissa and is given by $(\sigma_{1,f} + \sigma_3)/2$;
- The radius of such circle is $(\sigma_{1,f} - \sigma_3)/2$;
- Angle of internal friction is the angle of the Mohr-Coulomb failure envelope (failure line); and
- The failure line intersects with ordinate at the cohesion value

Table 1: Table Format Report for Simple Triaxial Test

<table>
<tr><th>Specimen No.</th><th>Confining Pressure, σ_3 [kPa]</th><th>Applied Stress at Failure $\sigma_{a,f}$ [kPa]</th><th>Principle stress at Failure $\sigma_{1,f}$ [kPa]</th><th>Cohesion [kPa]</th><th>Internal Friction Angle [°]</th><th>Correlation Coefficient [R^2]</th></tr>
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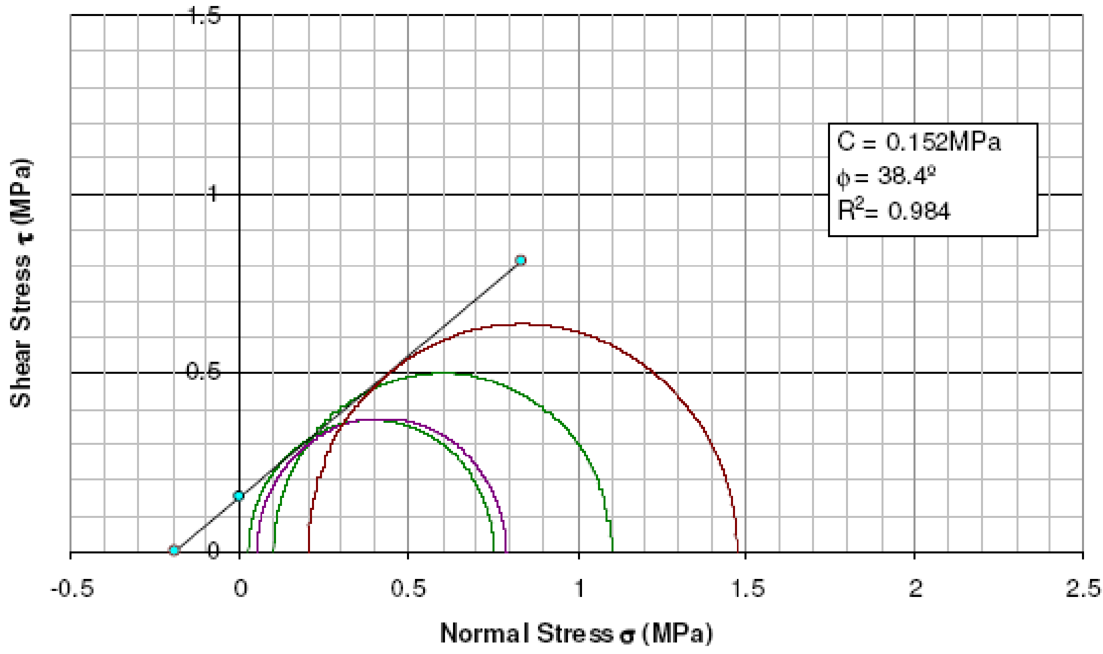

Figure 1 – Example of Mohr Circle Plot

7 REFERENCE PROTOCOLS AND STANDARDS

(i) Jenkins, K. J. and Ebels, L. J., 2007. **Determination of Shear Parameters, Resilient Modulus and Permanent Deformation Behaviour of Unbound and Bound Granular Materials Using Triaxial Testing on 150 mm ø by 300 mm high Specimens,** Technical Memorandum First Draft May 2007**.** Stellenbosch, South Africa, 2007.

(ii) Texas Department of Transport, 2002. **Triaxial Compression for disturbed soils and base materials,** TxDOT Designation: Tex-117-E, August 2002.