DRY DENSITY: SAND REPLACEMENT METHOD

1 SCOPE

This method describes the procedure for the in situ determination of the dry density of undisturbed or compacted soils and granular materials by sand replacement.

2 SAFETY

This method does not attempt to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this method to establish appropriate occupational health and safety practices that meet statutory regulations.

3 REFERENCED METHODS

Australian Standard

AS 1152 Test Sieve Specification

Main Roads Western Australia

WA 100.1 Sampling Procedures for Soil and Manufactured Granular Pavement Materials

WA 110.1 Soil and Granular Pavement Material Moisture Content: Convection Oven Method

WA 110.2 Soil and Granular Pavement Material Moisture Content: Microwave Oven Method

4 APPARATUS

(a) Sand cone pouring apparatus. A suitable design is shown in Figure 1.

NOTE: The choice of hole diameter depends on the soil type. It is recommended that a 200 mm diameter cone be used for coarse grained soils and a 150 mm diameter cone be used for fine and medium grained soils.

(b) Metal tray approximately 300 mm square with 200 mm or 150 mm diameter hole in centre. A suitable design is shown in Figure 1.

NOTE: Refer to Note 4(a)

(c) Quantity of well mixed clean, dry, one-sized sand (e.g. 100 percent passing 0.600 mm Test Sieve and 100 percent retained 0.300 mm Test Sieve) free from organic matter.

NOTE: Other one sized sands or grits may be used. The size of the particles to use in a dry density test depends on the size of the largest particles and voids in the compacted soils. The sand should be shielded at all times from any moistening, e.g. rain, as bulking may invalidate volume calculations.

(d) Excavation tools e.g. scoop, spoon, trowel, chisel, mallet, brush.

(e) Metal calibrating cylinder similar to the size of the hole to be excavated. A suitable design is shown in Figure 1.

(f) Balance, of suitable capacity, readable to 1 g with a Limit of Performance (F) of not more than 5 g.

(g) Straightedge approximately 400 mm long.

(h) Flat plate approximately 300 mm square.

(i) Air-tight container.

(j) 19.0 mm sieve complying with AS 1152.

(k) Suitable measuring cylinder or siphon can.

(l) Sand container to suit cone.

5 CALIBRATION

(a) Calibration tests for each different batch of sand and for each cone and metal tray shall be carried out. If the sand is not stored under controlled conditions, carry out a calibration test either before each group of dry density tests or daily, as appropriate.

5.1 Mass of Sand in the Cone of the Pouring Apparatus and Metal Tray.

(a) From the initially filled sand container remove a volume of sand approximately equal to that of the metal calibrating cylinder.

NOTE: On all occasions it is necessary to start with the same nominal mass of sand in the container, otherwise the pouring bulk density of the sand may vary.

(b) Replace the lid on the sand container and determine the mass \(m_1\) to at least the nearest gram.

(c) Remove the lid of the sand container and attach the cone with the tap closed.

(d) Place the metal tray on the flat plate and position the cone and sand container centrally over the hole in the metal tray.
(e) Open the tap on the cone and allow the sand to flow, taking care that the apparatus is not vibrated or knocked whilst the tap is open. When no further movement of the sand takes place in the container, close the tap and carefully remove the cone and sand container.

(f) Allow the sand in the tap to fall back into the container by upending the cone and sand container and opening and closing the tap.

(g) Remove the cone and replace the lid on the sand container. Determine the mass \( m_3 \) to at least the nearest gram, of the sand and container.

(h) Calculate the mass of sand in the cone and metal tray using the formula:
\[
 m_3 = m_1 - m_2
\]
Where:
\[
 m_1 = \text{initial mass of sand and container in grams}
\]
\[
 m_2 = \text{final mass of sand and container in grams}
\]
\[
 m_3 = \text{mass of sand in the cone and metal tray in grams}
\]

(i) Repeat Procedures 5.1 (a) to 5.1 (h) a further two times. Where the range of the three values is greater than 10 g the calibration shall be repeated. From the three values calculate the average mass \( \bar{m}_3 \) of sand in the cone and metal tray.

5.2 Bulk Density of Sand

(a) Calculate the interval volume, in cm\(^3\), of the calibrating cylinder, either by calculation based on internal dimensions measured to the nearest 0.2 mm or from the mass of water necessary to fill the cylinder.

(b) Determine the mass \( m_4 \) to at least the nearest gram, of the sand container filled with sand and with the lid on.

NOTE: Refer to Note 5.1 (a)

(c) Remove the lid of the sand container and attach the cone with the tap closed.

(d) Place the metal tray on the calibrating cylinder, aligning the holes, and position the cone and sand container centrally over the hole in the metal tray.

(e) Open the tap on the cone and allow the sand to flow, taking care that the apparatus is not vibrated or knocked whilst the tap is open. When no further movement of the sand takes place in the container, close the tap and carefully remove the cone and sand container.

(f) Allow the sand in the tap to fall back into the container by upending the cone and sand container and opening and closing the tap.

(g) Remove the cone and replace the lid on the sand container. Determine the mass \( m_5 \) to at least the nearest gram, of the sand and container.

(h) Calculate the mass of the sand in the calibrating cylinder using the formula:
\[
 m_6 = m_4 - m_5 - \bar{m}_3
\]
Where:
\[
 \bar{m}_3 = \text{mean mass of sand in the cone and metal tray in grams}
\]
\[
 m_4 = \text{initial mass of sand and container in grams}
\]
\[
 m_5 = \text{final mass of sand and container in grams}
\]
\[
 m_6 = \text{mass of sand in the calibrating cylinder in grams}
\]

(i) Calculate the bulk density of the sand using the formula:
\[
 \rho_s = \frac{\bar{m}_6}{\nu}
\]
Where:
\[
 \rho_s = \text{bulk density of sand in t/m}^3
\]
\[
 \bar{m}_6 = \text{average mass of sand in the calibrating cylinder in grams}
\]
\[
 \nu = \text{volume of calibrating cylinder in cm}^3
\]

6 PROCEDURE

(a) Select a sample site in accordance with Test Method WA 100.1.

(b) Expose a flat area approximately 450 mm square of the material layer to be tested and trim to an approximately level surface.

NOTE: Where the surface of the ground is very irregular or where the hole will be so shallow that a slight irregularity in the surface would produce a large error in the density determination, determine the mass \( m_1 \) of the sand required to fill the pouring cone and tray when the tray and cone rests on the surface where the hole is to be excavated. If the surface is so irregular that the sand is likely to escape under the tray, fill the irregularities under the tray with clay or plasticine. After this calibration is made, carefully brush the sand off the surface before commencing excavation.

(c) Place the metal tray on the prepared surface of the material layer with the hole over the portion of soil to be tested. If necessary, peg to avoid movement.
(d) Excavate an approximately cylindrical hole in the soil using the hole in the tray as a pattern. The hole should be excavated with care to minimise disturbance of surrounding soil and to ensure a shape that the sand will fill. The depth of the hole will be restricted by the thickness of the material layer at the test site. The hole shall be as large as practicable but preferably should not exceed the diameter of the hole in the metal tray nor be less than 50 mm depth. Where a hole of less than 50 mm depth must be used the test method may be inappropriate and the test result should be viewed cautiously and an alternative test method considered.

**NOTE:** Refer to Note 4 (a)

(e) Carefully deposit the excavated soil in the air-tight container, removing all loose soil from the sides and bottom of the hole with a brush as necessary. Keep the air-tight container sealed as much as possible opening only for minimum periods to deposit the excavated soil in the container. The hole and container must be protected from rain and strong wind.

(f) Remove the lid of a sand container, filled with sand and of known mass \(m_{\text{s,2}}\) and attached the cone.

**NOTE:** Refer to Note 5.1 (a)

(g) Place the cone and sand container centrally over the hole in the metal tray.

(h) Open the tap on the cone and allow the sand to flow, taking care that the apparatus is not vibrated or knocked whilst the tap is open. When no further movement of the sand takes place in the container, close the tap and carefully remove the sand cone pouring apparatus and sand container.

(i) Allow the sand in the tap to fall back into the container by upending the cone and sand container and opening and closing the tap.

(j) Remove the cone and replace the lid on the sand container. Determine the mass \(m_{\text{s,3}}\) to at least the nearest gram, of the sand and container.

(k) Determine the west mass \(m_{\text{w}}\) to at least the nearest gram, of the excavated soil.

**NOTE:** It is often convenient to use an air-tight container of known mass to avoid material loss during mass determinations. It is recognised that when material is removed from the air-tight container for the dry mass determination an insignificant amount may remain in the container.

(l) Using the total mass of excavated soil; determine the moisture content \(w\) in accordance with Test Method WA 110.1 or WA 110.2. Record the total mass \(m_{\text{w}}\) to the nearest gram, of dry soil.

**NOTE:** When it is impracticable to use the total mass of excavated soil, a test increment for the moisture content determination may be taken and should be as large as practicable. The dry mass \(m_{\text{d}}\) of soil excavated from the hole shall be calculated using the formula:

\[
m_{\text{d}} = \frac{m_{\text{w}} \times 100}{w + 100}
\]

Where:

- \(m_{\text{d}}\) = mass of dry soil excavated from the hole in grams
- \(m_{\text{w}}\) = mass of wet soil excavated from the hole in grams
- \(w\) = moisture content of soil excavated from the hole

(m) If in the dried excavated material there are particles greater than a 19.0 mm Test Sieve determine their total mass \(m_{\text{y}}\) to the nearest gram.

(n) Determine the volume \(V_{\text{c}}\) to at least the nearest 1 cm³, of material greater than the 19.0 mm Test Sieve by measuring directly the displacement of water in a measuring cylinder or siphon can.

**NOTE:** Where the porosity of the retained 19.0 mm fraction significantly effects its volume determination, it will be necessary to saturate the fraction prior to measurement by displacement.

7 **CALCULATIONS**

(a) Calculate the mass of sand required to fill the excavated hole using the formula:

\[
m_{\text{h}} = m_{\text{h}} - m_{\text{s}} - m_{\text{y}}
\]

Where:
- \(m_{\text{h}}\) = mass of sand to fill the hole in grams
- \(m_{\text{s}}\) = average mass of sand container in grams
- \(m_{\text{y}}\) = initial mass of sand container in grams
- \(m_{\text{h}}\) = final mass of sand container in grams

(b) Calculate the gross volume of the excavated hole using the formula:

\[
V_{\text{c}} = \frac{m_{\text{h}}}{\rho_{\text{s}}}
\]

Where:
- \(V_{\text{c}}\) = gross volume of hole in cm³
- \(m_{\text{h}}\) = mass of sand to fill the hole in grams
- \(\rho_{\text{s}}\) = bulk density of sand in t/m³
(c) Calculate the net volume, excluding material greater than a 19.0mm Test Sieve, of the excavated hole using the formula:

\[ Net \text{ Volume} = V_G - V_S \]

Where:

\[ V_G = \text{gross volume of hole in cm}^3 \]
\[ V_S = \text{volume of material greater than 19.0 mm in cm}^3 \]

(d) Calculate the net mass, excluding material greater than 19.0 mm Test Sieve, excavated from the hole using the formula:

\[ Net \text{ Mass} = m_d - m_s \]

Where:

\[ m_d = \text{mass of dry soil excavated from hole in grams} \]
\[ m_s = \text{mass of material greater than 19.0 mm in grams} \]

(e) Calculate the dry density using the formula:

\[ \rho_d = \frac{m_d - m_s}{V_G - V_S} \]

Where:

\[ \rho_d = \text{dry density in t/m}^3 \]
\[ m_d - m_s = \text{net mass excavated from hole in grams} \]
\[ V_G - V_S = \text{net volume of excavated hole in cm}^3 \]

8 REPORTING

For each test site the following shall be reported.

(a) Report the dry density of the soil to the nearest 0.001 t/m\(^3\)

(b) Report the moisture content to the nearest 0.1\%.
9 FIGURES AND DRAWINGS

![Figure 1](image-url)
10 ISSUING AUTHORITY

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11 REVISION STATUS RECORD

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