Determination of Percentage Refusal Density Test

Lab Test Reference :
British Standard Reference : BS598 : Part 104 : 1989

1. Summary of Method

The bulk density of the sample shall be measured by weighing it in air and water, the sample being coated in paraffin wax to prevent the ingress of water. After removal of the wax coating, the sample shall be then heated and compacted with a vibrating hammer to refusal. The final density of the sample shall be then measured by weighing it in air and water, no wax coating being required.

2. Definition of Percentage Refusal Density

The Percentage Refusal Density (PRD) is defined as the ratio of the bulk density of the sample to the final density, refusal density, expressed as a percentage.

3. Apparatus and Materials

The apparatus shall consist of:-

(i) A drying oven capable of being maintained at 40^{o} (+3)^{o}C.

(ii) A balance capable of weighing up to 10kg with an accuracy of +1g.

(iii) A bath containing paraffin wax.

(iv) A water bath maintained at a temperature of 20(+5)^{o}C, for immersing the sample in water while suspended from the balance.

(v) A split core mould and base plate, as described in TRRL Contractor Report 1 "Precision experiment: Percentage Refusal Density Test" and Fig 1 of BS598 : Part 104 plus spare base plate.

(vi) A heating oven of adequate capacity and power to raise the temperature of the cores and moulds from ambient to the temperature specified in Table 9/4 for compaction of the sample to refusal.

(vii) An electric vibrating hammer with a small and a large tamping foot, as specified in sub-Clause 10 of this Clause.

(viii) A 50-75mm wide paint stripping knife and a pallet knife, 300mm steel rule and external callipers.

(ix) Stop Watch

(x) 35^{o}-160^{o} Thermometer

(xi) Paraffin wax with a known density (D) at the test temperature of 20°C for sealing the surface of the core.

(xii) Filter papers which shall be used to prevent the ends of the core from sticking to the base plate or the tamping foot, and which shall be peeled off when they have served this purpose.

(xiii) Silicon grease that is immiscible with bitumen used as a releasing agent. Talcum Powder and inert filling material.

4. Preparation of Test Sample

4.1 Cut a core 150mm to 153mm in accordance with BS598 Part 100.

4.2 Measure the diameter of the core to the nearest 1mm in two directions.

4.3 If the core is more than 150mm deep it shall be sawn in two equal halves and the test carried out on each half. The PRD value for the core shall be the average of the value obtained from each half.

4.4 The core or sawn portions of the core shall be placed upright in the drying oven at a temperature of 40°C until its mass is stable.

[Note : It will normally take 16 hours for the core mass to become stable].

4.5 If the core sample consists of more than one layer of material the layers shall be separated immediately after removing it from the drying oven by placing the core on a flat surface and working the paint stripping knife around the circumference of the core at the interface between the layers. If the bond is too strong then cool the core, saw cut the interface and return to the oven for drying as described in 4.4.

4.6 Any loose material shall be removed from the core and this recorded.

5. Procedure

5.1 The specimen shall be allowed to cool to room temperature and weighed in air (mass A) to the nearest 1g.

5.2 The surface of the core shall be sealed by immersing it in the molten paraffin wax.

[Note 1. To facilitate the later removal of the wax coating, the core may be lightly dusted with powdered talc prior to coating.]

[Note 2. Application of the wax may be accomplished by chilling the core in a refrigerator to a temperature of about 5°C for half an hour and then dipping the core in the molten wax. It may be necessary to brush the surface of the wax with hot wax in order to fill any pinholes.]

5.3 The wax shall be allowed to harden and the waxed core weighed, to the nearest 1g first in air (mass B), and then suspended in the water bath at 20+5oC (mass C).

5.4 As much wax as possible shall be scraped off the core with the pallet knife. The mass must be reduced to less than 1.005A.

5.5 The split mould and base plate shall be coated with a thin film of silicone grease and a filter paper placed on the base plate.

5.6 The core shall be inserted into the mould with the flatter of the two ends uppermost, the mould tightened and clamped to the base plate.

5.7 The temperature of the mould and core shall be raised to that specified in Table 9/4 + 5°C for the grade of binder in use, by placing the mould, base plate and core in a preheated oven maintained at not more than 5°C above the specified temperature.
The core shall be kept in the oven for at least 4 hours.

TABLE 9/4: Temperature of Cores and Moulds for Compaction to Refusal

PRIVATE Binder Type Test	Binder Grade	Temperature
Bitumen	50 pen	150°C
	100 pen	140°C
	200 pen	130°C
Tar	C50	90°C
	C54	95°C
	C58	100°C

5.8 While the core is in the oven heat up the 2 tamping feet of the Kango in an oven set at 80°C.

5.9 The core and mould shall be removed from the oven and placed on a level rigid floor for immediate compaction . The mould shall be tightened until the split is closed and there is no gap remaining. A filter paper shall be placed on the surface of the core.

[Note : The hammer may need to be warmed up, particularly in cold weather, before being used on specimens, by running it for at least 2 mins.]

5.10 The core shall be compacted with the vibrating hammer, using the 102mm small foot which has been coated with a thin layer of silicone grease.

The hammer shall be held firmly with the shaft vertical and the tamping foot moved from one position to another around the mould as described in sub-Clause 5.11 of the Clause giving 2-10 seconds compaction at each position. The period of compaction at each position will depend on the material; the tamping foot must be moved from one position to the next before material bulges above the edge of the tamping foot.

5.11 The sequence for the positioning of the tamping foot, which must remain in contact with the side of the mould, shall be in terms of the points of the compass, N, S, W, E, NW, SE, SW, NE. This sequence shall be repeated until the total compaction period amounts to 2 minutes. If the mould tends to wander, use may be made of a suitable plywood board and on which the operator stands to keep it steady.

5.12 When the compaction process is complete, any irregularities on the surface of the core shall be removed by using the vibrating hammer fitted with the large tamping foot, which has been coated with a thin layer of silicone grease.

5.13 Clamp the square base plate and the mould and remove from the original base plate ensuring that a filter paper adheres to each end of the core. The core shall be driven into contact with the base plate with the vibrating hammer fitted with the large tamping foot which has been coated with silicone grease.

5.14 The compaction procedure given in 5.10, Clauses 5.11 and 5.12 of this Clause shall be repeated.

5.15 The core shall be allowed to cool in air for at least 2 hours and then removed from the mould, by loosening the screws and tapping the mould to destroy the adhesion, and then the filter papers shall be removed.

5.16 The sample shall be weighed, in air (mass E), and suspended in water at 20°C (mass F). If the core has been cut in two the procedure is repeated for each sub-specimen or layer.

6. Calculation and Report

Table 9/5: Calculation of PRD and Report

PRIVATE Core No		
Mass of dry core in air	g	A
Mass of waxed core in air	g	B
Calculations		
PRIVATE Mass of waxed core in water	g	C
Density of wax	Mg/m³	D
Mass of compacted core in air	g	E
Mass of compacted core in water	g	F
Bulk Density G = A/ [B – C (B – A) /D]	Mg/m³	G
Refusal Density H = 1/[1 – F/E]	Mg/m³	H
Percentage Refusal Density (PRD) = 100G/H	%	PRD

Report the Percentage Refusal Density to the nearest 0.1

Electric Vibrating Hammer and Tamping Feet

10.The small tamping foot shall have a diameter of 102mm + 2mm and the large one a diameter of 146mm + 2mm.

The electric vibrating hammer used for the PRD test shall have a power consumption of 750 Watts and operate at a rate in the range 2000-4000 blows per minute.

The hammer shall be tested for suitability for use in the PRD test by carrying out the test described in sub-Clause 11 of this Clause.

Test Method for the Vibrating Hammer

11. The test method for the vibrating hammer shall be as follows:-

(i) Scope

This method determines the suitability of a vibrating hammer for use in the PRD test.

(ii) Apparatus

The following apparatus is required in addition to that required for the PRD test:

(a) A cylindrical metal mould having an internal diameter of 152mm and an internal effective height of 127mm, with a detachable baseplate and a collar 50mm deep as described in Test 16 of BS 1377. A thin coating of oil shall be applied to the internal faces of the mould and collar before each test.

(b) BS test sieves sizes: 600um, 425um and 300um.

©A straightedge, e.g. a steel strip 300mm long, 25mm wide and 3mm thick.

(d) A device which will enable the sample depth to be measured to an accuracy of 0.5mm, e.g. a depth gauge or steel rule.

(e) A large metal tray (a convenient size is one about 600mm x 500mm and with sides 80mm deep).

(f) A stop watch or stop clock.

(g) Apparatus for the determination of moisture content in accordance with Tests 1(A), 1(B), or 1© of BS 1377.

(iii) Materials

(a) A 10kg sample of dry unused clean silica sand shall be taken 100% of which passes the 600um BS test sieve and is retained on the 425um BS test sieve 0 to 25% passing the 425um BS test sieve and is retained on the 300um BS test sieve. Water shall then be mixed with the sand sufficient to raise its moisture content to 2.5+ 0.5%.

(iv) Procedure

(a) The hammer may need to be warmed up for a time, particularly in cold weather, before being used on specimens.

(b) The mould, together with its 50mm collar and baseplate fixed firmly, shall be weighed (m_1), and then stood on a solid base, e.g. a concrete floor or plinth. A quantity of the moist sand, sufficient to give a specimen 127mm to 133mm deep after compaction in the mould, shall be compacted in the mould in three layers of approximately equal mass, using the vibrating hammer fitted with the circular steel tamper. Each layer shall be compacted for a period of 60 seconds and throughout this period a firm downward pressure shall be applied to the vibrating hammer so that the total downward force, including that resulting from the mass of the hammer and tamper, shall be 300 N to 400 N. The application of pressure combined with vibration is essential to ensure the required degree of compaction.

[Note 1: The downward force required of 300 N to 400 N, including that resulting from the mass of the hammer and tamper, is greater than that required to prevent the hammer bouncing on the specimen. It is recommended that when an operator lacks experience in this test, the vibrating hammer should be applied initially, without vibration, to a platform scale where a mass of 30kg to 40kg should be registered when the required force is applied.]

© When the final layer has been compacted, any loose material around the sides of the mould shall be removed from the surface of the specimen. The straightedge shall be laid across the top of the collar of the mould and the depth of the specimen below the top collar measured to an accuracy of 0.5mm. Readings shall be taken at four points spread evenly over the surface of the specimen, all at least 15mm from the side of the mould, and the mean height, h, of the specimen calculated. If the specimen is more than 133mm or less than 127mm in height, it shall be rejected and a further test carried out.

(d) The mould, together with the collar, baseplate and sand shall be weighed to the nearest 5g (m_2).

(e) The compacted sand specimen shall be removed from the mould and placed on the large metal tray. A representative sample of the specimen shall be taken and its moisture content, w, shall be determined as in Test 1(A), 1(B) or 1(C) of BS 1377.

(v) Calculations

(a) The bulk density, d in Mg/m^3, of each compacted specimen shall be calculated as follows:

$$d = \frac{(m_2 - m_1) \times 10^3}{0.25\, n k^2 h}$$

where

n = 3.142
m_1 is the mass of the mould + base + collar (g);
m_2 is the mass of the mould + base + collar + compacted specimen (g);
k is the diameter of the mould (mm);
h is the height of the specimen (mm).

(b) The dry density, d_d in Mg/m_3, shall be calculated from the equation:

$$d = \frac{100d}{100 + w}$$

where

w is the moisture content of the sand (%)

(vi) Reporting

(a) A total of three tests, shall be carried out, all on the same sample of sand, and the mean dry density determined. The dry density values shall be determined to the nearest 0.002 Mg/m^3, and if the range of values in the three tests exceeds 0.03 Mg/m^3 the procedure shall be repeated. The vibrating hammer shall be considered suitable for use in the vibrating compaction test if the mean dry density of the sand exceeds 1.74 Mg/m^3.