METHOD A7

THE DETERMINATION OF THE MAXIMUM DRY DENSITY AND OPTIMUM MOISTURE CONTENT OF GRAVEL, SOIL AND SAND

SCOPE

The maximum dry density and optimum moisture content, as defined below, is determined by establishing the moisture-density relationship of the material when prepared and compacted at the Modified AASHTO compaction effort at different moisture contents.

Definition

Maximum density: The maximum density of a material for a specific compactive effort is the highest density obtainable when the compaction is carried out on the material at varied moisture contents.
Optimum moisture content: The optimum moisture content for a specific compactive effort is the moisture content at which the maximum density is obtained.

2 APPARATUS

2.1 A 152,4 ± 0,5mm diameter mould, 152,4 ± 1 mm high, with detachable collar, base plate and a 25,4 ±1 mm thick spacer plate with the proviso that with the spacer plate inside the mould the effective depth of the mould shall be 127 ± 1 mm. The spacer plate should be firmly attached to the base plate (Figure A7/l). The compaction base plate should be bolted onto a concrete block ot at least 150mm thick and weighing at least 200 kg.

2.2 A 4,536 kg ± 20 gram tamper with a 50,8 ±1,0 mm diameter face and with a sheath to give a 457,2 ± 2 mm drop.

2.3 A steel straight-edge, about 300 mm in length and having one bevelled edge.

2.4 A riffler.

2.5 A balance to weigh up to 15 kg, accurate to 5 gram.

2.6 A balance to weigh up to 2 kg, accurate to 0,1 gram.

2.7 A steel tamper or a small laboratory crusher.

2.8 Sieves: 19.0 mm and 4,75 mm complying with SABS 197.

2.9 An iron mortar and pestle and a rubber-tipped Pestle.

2.10 Basins, approximately 350 mm in diameter.

2.11 A mixing basin, approximately 500 mm in diameter.

2.12 A garden trowel.

2.13 A spatula.

2.14 Suitable containers to hold about 1 000gram of material for the determination of moisture contents.

2.15 A drying oven, thermostatically controlled and capable of maintaining a temperature of 105 to 110 EC.

2.16 Measuring cylinders, 1000 ml and 500 ml capacity.

2.17 A water spray or sprinkler.

2.18 Filter paper, 150 mm rounds.

2.19 A sample extruder, i.e. a jack, lever, frame or other device adapted for the purpose of extruding compacted specimens from the mould (optional).

For calibrating the mould:

2.20 A 180 mm x 180 mm glass plate approximately 7 mm thick.

2.21 Lubricating grease.

2.22 A 5 ml pipette.

2.23 A thermometer measuring 0 to 50 EC.

3 METHOD

3.1 Preparation

An adequate quantity of the air-dried sample is sieved through a 1gram,0 mm sieve. The aggregate retained on the 1gram,0 mm sieve is crushed lightly by means of a steel tamper (or laboratory crusher) to pass the 19,0 mm sieve and added to the portion passing the sieve. Care should be taken that the aggregate is not crushed unnecessarily small. If the material contains soil aggregations, these should be disintegrated as finely as possible with a mortar and pestle with-out reducing the natural size of the individual particles (see 5.1).
Mix the material thoroughly and quarter out a specimen of approximately 35 kg, which in turn is. again quartered so as to obtain five basins of exactly similar material. This is best done by dividing the sample into 16 equal portions by means of the riffler and using three portions, i.e. 3/16 of the sample, for the debrmination of one point on the moisture-density relationship curve. The one portion which is surplus may be discarded. The mass of the material in each of the five basins should be between 6 and 7 kg - the higher mass to be used for material with a high relative density. For convenience the mass in the five basins may be made the same.

3.2 Mixing

Weigh the sample in each basin accurate to the nearest 5 gram and transfer it to the mixing basin.
A measured volume of water is placed in the spray-can or sprinkler and added slowly to the material in the basin. While adding the water, the material should be mixed continuously with a trowel. Water is added until, in the opinion of the operator, the optimum moisture content is reached (see 5.2). The mixing of the moist material is continued for another few minutes. The water remaining in the spray-can or sprinkler is measured in order to obtain the quantity actually added, which is then expressed as a percentage of the air-dried material. The moist material should now be covered with a damp sack to prevent evaporation and allowed to stand for half an hour so that the moisture may become evenly distributed throughout. (In the meantime another basin of material may be treated by mixing at a moisture content of one per cent lower or hi~her than the first moisture content.) If the material has been moistened beforehand and allowed to soak overnight, as described in Method A8, it is not necessary to wait for halt an hour and compaction may there to recommence immediately after the water has been mixed in.

3.3 Preparation of the mould

The volume of the mould is determined as set out in 5.3.
The clean, dry mould is weighed accurate to the nearest 5 gram and assembled on the base plate with the spacer plate. Two 150mm rounds of filter paper are placed on the spacer plate to prevent the material trom sticking to the plate. The collar is then fitted to the mould.

3.4 Compaction

The moist material is now mixed again and about 1,000gram of material is weighed out and transferred to the mould. The surface of the soil is levelled by hand by pressing down and light tamping, and tamped 55 times with a 4,536 kg tamper which is dropped exactiy 457,2 mm. The blows must be dhtrlbuted over the whole layer in five cycles ot 11 blows each. In each cycle eight blows are applied to the outside circumference and three blows round the centre (see 5.4). When the tamper is raised, the operator should ensure that the guide sheath is resting on the soll and that the tamper is right at the top of the sheath betore the tamper is dropped. The fall of the tamper should be pertectly free. The operator should also be aware that the tamping face of the tamper is kept clean and that no cake of material is formed on the face.
After tamping the first layer, the depth of the surface of the tamped material below the top of the mould, without the collar, is measured and should be between grams and 96 grams and 99 mm. If the depth is not correct, the mass of moist material weighed out for the next layer should be increased or decreased slightly. Four more layers of material should be tamped in in exactly the same manner and each layer should be slightly more than 25 mm but not more than 30mm thick. The depths from the top of the mould to the surfaces of the compacted layers should preferably be between the following limits:

1st layer	:	96 to 99mm
2nd layer	:	68 to 71 mm
3rd layer	:	43 to 46 mm
4th layer	:	15 to 20 mm

After the compaction of the 5th layer, the surface of the material should be between 5 and 15 mm above the top of the mould without the collar.

3.5 Determination of moisture content

After the second layer has been compacted, a representative sample is taken from the material in the basin and placed in a suitable container to determine the moisture content.
The sample should be between 500 and 1000 gram. The more coarsely graded the material, the larger the sample. The moist sample is weighed immediately, accurate to the nearest 0.1gram and dried to constant mass in an oven at 105 to 110 EC. The moisture content is determined to the nearest 0,1 per cent. The results are recorded on Form A7/1 or similar.

3.6 Removal of excess material

The material which adheres to the collar of the mould is gently eased trom the collar with a spatula. The collar is turned round gently and removed without disturbing the projecting layer of material. The projecting material is cut off carefully with a steel straight-edge (a little at a time) until the material is level with the top of the mould. Loose pebbles should be pressed in with the flat of the straight-edge. The excess material which was cut ott, and, if required, also the remaining material in the mixing basin, is sieved rapidly through a 4,75 mm sieve. The material passing the sieve is spread over the surface of the material in the mould and tapped lightly with the flat of the straight-edge and cut off. If necessary, this process is repeated so as to obtain an even and compact surface. Where pebbles project slightly above the top of the mould, these should be pressed in below the level of the mould.
The surface of the moulded material is inspected. If it is hard and unyielding to pressure from the thumb it is probable that the optimum moisture content (o.m.c.) has not been exceeded. If, however, the material tends to be slightly spongy or yields when pressed down by the thumb, then the o.m.c. has been exceeded .

3.7 Mass of mould

Remove the mould with compacted material from the base plate and weigh it accurately to the nearest 5 gram.
The compacted material can now be removed from the mould with an extruder or other suitable means.

3.8 Establishing additional points for the molsture-density relationship curve

The above represents the determination of one point on the moisture-density relationship curve and additional points have still to be obtained. The whole procedure is, therefore, carried out on each of the other four basins of prepared material at various moisture contents. After the second compaction the approximate dry density for the two compaction's is calculated, using an assumed moisture content which is the percentage of water added plus the estimated moisture content of the air-dried sample. The approximate dry densities are plotted against the assumed moisture contents and the relative position of the two points will indicate the amount of water to be added for the third point. After plotting the third point, the shape of the curve will indicate the best moisture contents for the remaining points. If possible, at least two points differing by about one per cent in moisture content should be obtained on either side of the peak of the moisture-density curve and the last point should be taken as near to the peak as possible unless one has already been obtained earlier near that point.

4 CALCULATIONS

4.1 Calculate the moisture content of the material for each point to the nearest 0,1% as follows:

$$d = \frac{a-b}{b-c} x100$$

where

d = moisture content expressed as a percentage of the dry soil
a = mass of container and wet material
b = mass of container and dry material
c = mass of container only.

4.2 Calculate the dry density for each point to the nearest 1 kg/m3 as follows:

$$D = \frac{W}{d+100} x \frac{100}{V} x1000$$

where

D = dry density in kg/m3.
W = mass of wet material in gram.
V = volume of mould in ml

As the volume (V) of the mould is a constant, the above formula can be simplified as follows:

$$D = \frac{W}{d+100} xF$$

where

F (the factor of the mould)(see 5.3) = (100/V) x 1000

Calculate moisture content to the nearest first decimal figure and density to the nearest whole number.

4.3 Moisture-density relationship

After the calculations have been completed the moisture contents are plotted graphically against the respective dry densities (see appended Figure A7/ll). The peak of the curve indicates the optimum moisture content and the maximum density of the material when compacted under this particular effort.

4.4 Reporting of results

The maximum density shall be reported to the nearest whole number on forms such as A10(a)/1 if the results are required for field densities, or on the A8/1 (or similar) Form if required for CBR determinations (Method A8).
The optimum moisture content shall be reported to the nearest first decimal figure.

5 NOTES

5.1 In cases where the material contains soft and friable aggregate which will break up during compaction, e.g. certain types of ferricrete, calcrete, soft sandstone, etc., such aggregate should be disintegrated. The operator should use his discretion in borderline cases and also as regards the extent to which particles should be disintegrated.

5.2 The material is at or near its optimum moisture content when it can be readily pressed together by hand to form a lump that will not crumble. A spongy feeling is an indcation that the moisture content exceeds optimum.

5.3 To determine the volume of the mould, both ends of the mould and the circumference of the spacer plate are greased and the mould, spacer and base plate assembled. Any excess grease which may be squeezed out between the mould and spacer plate is removed. The assembled mould plus the 180 mm square glass plate is weighed. Water is now poured into the mould and, when full, the glass plate is slid gently over the top of the mould. Before the glass plate quite covers the mould, the final drops of water are added by means of a pipette. When the container is covered fully by the glass plate, no air bubbles should be entrapped under the plate. The mould with water and glass plate are weighed and the mass of water in the mould is calculated. This determination should be carried out at least in duplicate. The temperature of the water is measured and the volume (V) as well as the factor (F) of the mould are obtained as follows:

$$V \text{ in ml} = \frac{\text{Mass of water in gram}}{\text{RD of water at test temperature}}$$

and

$$F = \frac{100}{V} \ x \ 1000$$

Temp. °C	RD of Water	Temp. °C	Rd of Water
15	0.99913	23	0.99756
16	0.99897	24	0.99732
17	0.99880	25	0.99707
18	0.99862	26	0.99681
19	0.99843	27	0.99654
20	0.99823	28	0.99626
21	0.99802	29	0.99597
22	0.99780	30	0.99567

5.4 The material can also be compacted with a mechanical tamping machine of satisfactory design. At least ten comparative tests should be carried out on different material and for 90 per cent of the results, the densities should not differ by more than 16 kg/m^3 from those obtained with the hand tamper.

5.5 In following this method, the operator should ensure that the optimum obtained is the true optimum as some materials, particularly sandy and silty materials, often have a false optimum at a lower moisture content than the true optimum. The plastic limit can be used as a gauge for the optimum moisture content, as in many cases the optimum moisture content is approximately two per cent lower than the plastic limit. In estimating the optimum moisture content from the plastic limit, it should be remembered that the percentage of material passing the 0,425 mm sieve must be considered because the higher the percentage of this fraction, the more closely the plastic limit and the optimum moisture content agree.

5.6 The maximum density and optimum moisture content can also be determined using other compaction. efforts. The test procedure remains the same.
The following efforts are commonly used:

Mass of Tamper (Kg)	Drop in mm's	Blows per Layer	Layers	Description of effort
4.536	457.2	55	5	Mod. AASHTO
4.536	457.2	25	5	NRB
2.495	304.8	55	3	Standard Proctor
2.495	304.8	20	3	-

5.7 Once material has been compacted it should not be used for another compaction, i.e.

fresh material should be used for every compaction. However, if for some reason the field sample was too small for the usual five test points, or if additional test points are required to obtain a satisfactory curve with a well-defined peak, the same material may be used for another compaction.

5.8 Throughout the test the utmost care must be exercised to keep all the following variables as constant as possible:

(a) Grading of material
(b) Uniform mixing-in of water
(c) Time of standing before compaction
(d) Evaporation of water during test
(e) Height of fall of tamper
(f) Free fall of tamper
(g) Distribution of tamper blows
(h) Thickness of successive layers
(i) Final layer to project between 5 and 15 mm above the top of the mould
(j) Finishing off of the top surface.

5.9 Although it is not necessary to determine the volume and the mass of the mould for each test, these should, nevertheless, be checked regularly.

REFERENCES

AASHTO Designation T180-61
ASTM Designation D1557-70.

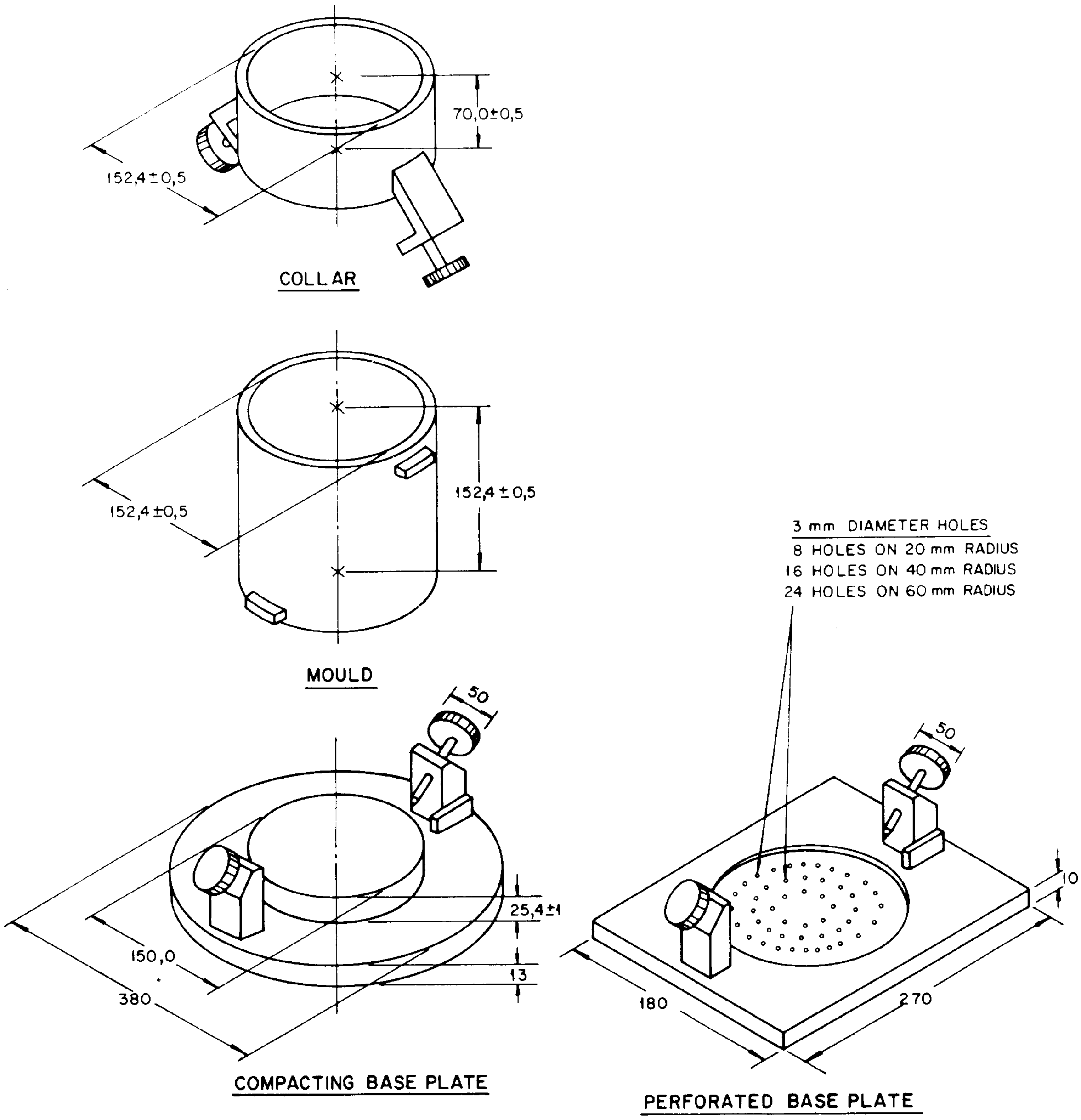
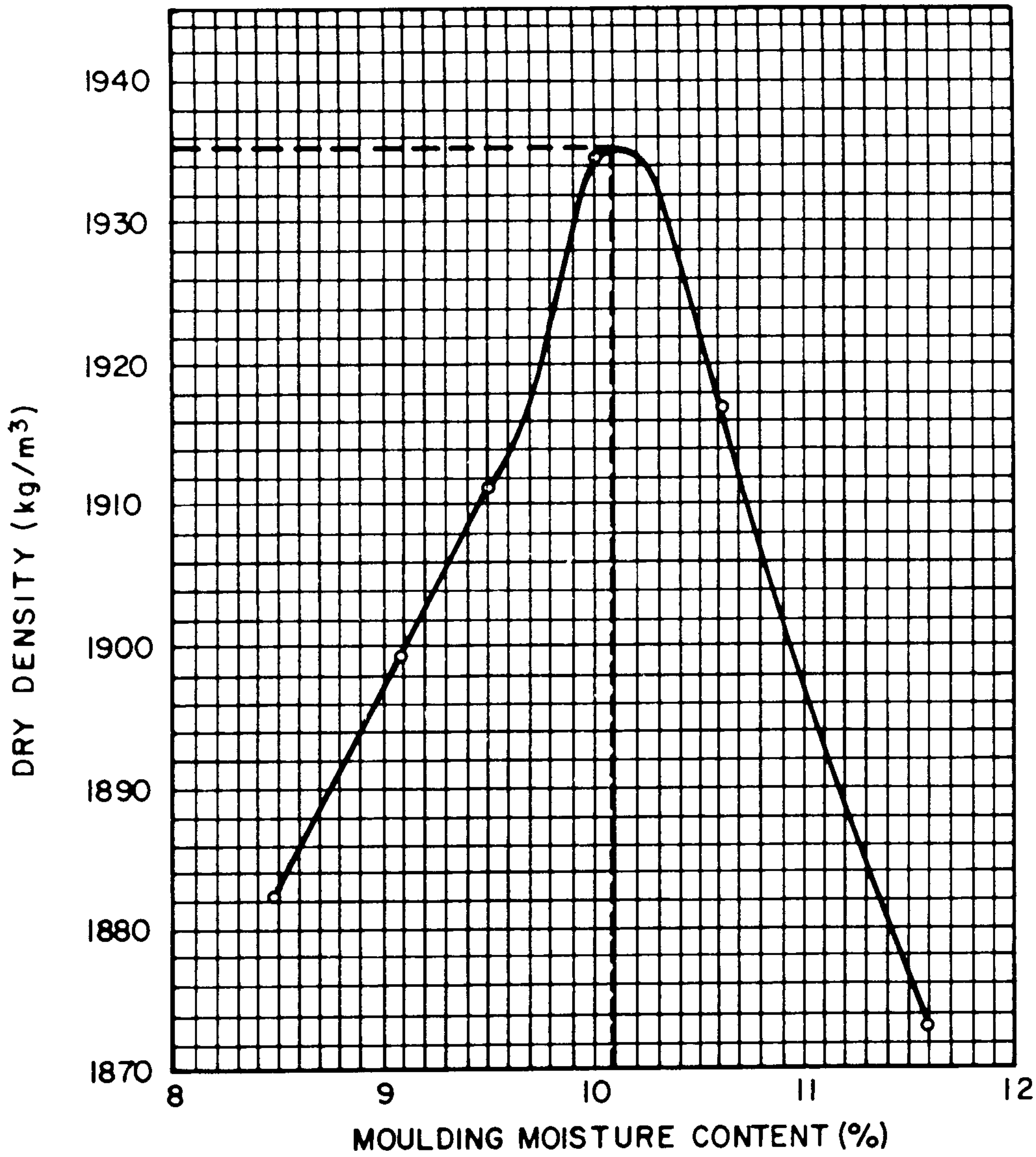


FIGURE A7/1

The compacting base plate, the perforated base plate, the mould and the collar



MAXIMUM DRY DENSITY : 1 935 kg/m^3
OPTIMUM MOISTURE CONTENT : 10,1 %

FIGURE A7/II

Example of a moisture-density relationship curve

SAMPLE NO/ MONSTER NR :____________

DATE/DATUM:_______________ MASS TAKEN/MASSA GENEEM :__________

OPERATOR/TOETSER:________________

DESCRIPTION/BESKRYWING:____

____

1. APPROXIMATE VALUES / BENADERDE WAARDES

a) WATER ADDED/WATER BYGEVOEG

MILLILITRE / MILLILITER					
PERCENTAGE / PERSENTASIE					
ASSUMED M.C. / VERONDERSTELDE VG. % (DI) % ADDED + HYGROSCOPIC MOISTURE CONTENT / % BYGEVOEG + HIGROSKOPIESEVOG-INHOUD					

b) DRY DENSITY / DROË DIGTHEID

MOULD NO / VORM NR.					
MOULD FACTOR / VORM FAKTOR (F)					
MASS OF MOULD + WET SOIL MASSA VAN VORM + NAT GROND					
MASS OF MOULD / MASSA VAN VORM					
MASS OF WET SOIL/MASSA VAN NAT GROND (W)					
APPROXIMATE DRY DENSITY / BENADERDE DROË DIGTHEID $\left(\frac{W \times F}{100 + DI}\right)$					

2. ACTUAL VALUES / WERKLIKE WAARDES

a) MOISTURE / VOG

CONTAINER NO. / HOUER NR.					
MASS OF CONTAINER + WET SOIL MASSA VAN HOUER + NAT GROND					
MASS OF CONTAINER + DRY SOIL MASSA VAN HOUER + DROË GROND					
MASS OF CONTAINER / MASSA VAN HOUER					
MASS OF WATER / MASSA VAN WATER					
MASS OF DRY SOIL / MASSA VAN DROË GROND					
MOISTURE CONTENT(%) / VOGINHOUD(%) (D)					

b) DRY DENSITY / DROË DIGTHEID

$\left(\frac{W \times F}{100 + D}\right)$					

MAX DRY DENSITY / OPTIMUM MOISTURE CONTENT

MAKS. DROË DIGTHEID / OPTIMUM VOGINHOUD

FORM A7/1

Recording sheet for the determination of the maximum dry density and the optimum moisture content