NEW ZEALAND STANDARD

METHODS OF TESTING SOILS FOR CIVIL ENGINEERING PURPOSES

Part 4

Soil compaction tests

4.1
DETERMINATION OF THE DRY DENSITY/WATER CONTENT RELATIONSHIP

TEST 4.1.1
New Zealand standard compaction test

4.1.1.1
Scope
This method covers the determination of the dry density when the soil passing a 19.0 mm test sieve (see Note (1)) is compacted in a specified manner, over a range of water contents, including that which gives the maximum dry density.

4.1.1.2
Related documents
The provisions of Part 1 of this Standard are applicable to, and shall be read in conjunction with, this method of test. Reference is made to Tests 2.1 and 6.1.1 of this Standard.

4.1.1.3
Apparatus
(a) A rigid cylindrical metal mould having an internal diameter of 105 ±0.5 mm and internal effective height of 115.5 ±0.5 mm and a nominal volume of 1 litre. The volume of the mould shall be known to 1 part in 1000. The mould shall be fitted with a detachable baseplate and a removable extension collar approximately 50 mm high. A suitable design is shown in fig. 4.1.1.
(b) A standard compaction rammer having a 50 ±0.5 mm diameter flat face and 2.5 kg ±25 g mass. The rammer shall be controlled by a suitable arrangement to ensure that the free vertical fall of the rammer is 300 ±1 mm. One suitable apparatus is shown in fig 4.1.2.

NOTE – Alternatively, mechanical apparatus may be used. A mechanical device must provide the correct mass and free vertical fall of the rammer with provision for rotation of the mould. The machine must be firmly attached to a concrete plinth of sufficient mass to prevent deflection of its base.

(c) A balance readable and accurate to 5 g.
(d) A palette knife with blade about 150 mm long and 25 mm wide.
(e) A straight-edge or T-bar scraper, for example, a steel strip 300 mm long, 25 mm wide and 3 mm thick, with one bevelled edge.
(f) A 19.0 mm test sieve and receiver.
(g) A wash bottle, or a dispenser with pressure spray nozzle.
(h) A large tray (a convenient size is about 900 mm x 600 mm x 80 mm).
(j) At least 6 small trays (a convenient size is about 300 mm x 300 mm x 80 mm).
(k) At least 6 heavy grade plastics bags or other suitable airtight, non-corrodible containers.
(m) Apparatus for extruding specimens from the mould (optional).
(n) Apparatus for water content determination as specified in Test 2.1

4.1.1.4
Procedure
(a) Take the sample obtained as specified in 1.6.9 of Part 1 (see Note (1)), thoroughly mix it in the large tray, and divide it into 2.5 kg samples by riffling or quartering (see Notes (2) and (3)).
(b) Assess the range of water content required for the test (see Note (4)).
(c) Within this range adjust the water content of the individual samples by removing or adding water to provide a series of samples at different water contents which span the optimum water content (see Note (5)). Make at least two samples wetter than optimum water content and at least three samples dryer than optimum water content.
(d) Place each sample in an airtight container or in a heavy grade plastics bag, and seal so as to minimize the air space between the container and the soil, and cure in a cool place (see Note (6)).

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(e) Weigh the mould with baseplate attached, to 5 g and record (M_1). Place it with the extension collar attached, on a smooth solid base, for example a concrete floor or plinth. Take one of the samples, thoroughly remix and compact into the mould in three layers of approximately equal mass. Give each layer 27 blows with the rammer dropped vertically from a height of 300 mm above the soil, distributing the blows uniformly over the surface. (If a mechanical rammer is used, the machine must be capable of achieving this uniform distribution.) Keep the guide and rammer clean and free from soil so that the rammer falls freely over the entire length of the stroke. Use just sufficient soil so that the mould is slightly overfilled after compaction is completed, leaving not more than 6 mm to be struck off when the extension collar is removed (see Note (7)). Remove the extension collar and carefully trim the compacted soil level with the top of the mould, using the straight-edge or T-bar scraper. Patch with smaller size material any holes in the surface caused by the removal of coarse material. Weigh the mould complete with base plate to 5 g and record (M_2).

(f) Remove the compacted soil from the mould and place it on the small tray. Immediately take a representative portion over the full height of the specimen, determine the water content as specified in Test 2.1 (see Note (8)) and record (w).

(g) Treat each of the remaining samples as specified in 4.1.4 (e) and (f).

4.1.1.5
Calculations
(see Form 4.1.1, 4.1.2, (2 sheets)):

(a) Calculate the bulk density (ϱ) of each compacted specimen from the formula:

$$\varrho = \frac{M_2 - M_1}{V} \quad \text{.......................................} (t/m^3)$$

where M_1 = mass of mould and baseplate (g)
M_2 = mass of mould, baseplate and soil (g)
V = volume of mould (ml)

(b) Calculate the dry density (ϱ_d) from the formula:

$$\varrho_d = \frac{100\,\varrho}{100 + w} \quad \text{.....................................} (t/m^3)$$

where w = water content of soil (%)

(c) Plot the dry densities (ϱ_d) obtained in the series of determinations against the corresponding water contents (w) as in fig. 1.1 of Part 1. Draw a smooth curve fitting the resulting points and determine the position of the maximum on this curve (see Note (9)).

4.1.1.6
Reporting of results

4.1.1.6.1
Report the following values:

(a) Maximum dry density (the dry density corresponding to the maximum point on the water content/dry density curve) (t/m³) to the nearest 0.01 (see Note (10)).

(b) Optimum water content (the water content corresponding to the maximum dry density on the water content/dry density curve) (%) to the nearest 0.2 for values below 5 %, to the nearest 0.5 for values from 5 % to 10 % and to the nearest whole number for values exceeding 10 % (see Note (11)).

NOTE – If the values of maximum dry density and optimum water content cannot be clearly determined from the curve, this fact shall be reported.

(c) If the air voids lines are to be plotted (see Note (9)), the solid density of soil particles (t/m³) used in the calculations and whether this value was measured or assumed.

4.1.1.6.2
State whether the material used in the test was whole soil or fraction passing a 19.0 mm test sieve.

4.1.1.6.3
State the history of the sample, for example, natural state, air-dried, oven-dried, or unknown.

4.1.1.6.4
State that the result was obtained in accordance with this Standard Test Method.

NOTES ON TEST 4.1.1

NOTE (1). The removal of small amounts of stone (up to 5 %) retained on a 19.0 mm test sieve will affect the density obtainable only by amounts comparable with the experimental error involved in measuring the maximum dry density. The exclusion of a large proportion of stone coarser than 19 mm (such as is present for example in a gravel of 75 mm maximum size) may have a major effect on the density obtained compared with that obtainable with the soil as a whole, and on the optimum water content. There is at present no generally accepted method of testing or of calculation for dealing with this difficulty in comparing laboratory compaction test results with densities obtained in the field. The following notes may be of assistance in providing a basis for action which will avoid major error. They are not considered comprehensive, however, and are not to be read as part of the standard method of test. (The term "gravel" should be taken to include rock fragments).

(a) For soils containing up to about 20 % or 25 % of coarse gravel, a correction may be calculated for the maximum dry density based on the displacement of a proportion of soil of given density by stone of known solid density. A check of the validity of this calculation may be obtained by replacing the coarse gravel in the soil by an equal quantity of 19 to 9.5 mm gravel of similar characteristics and carrying out a compaction test on this material. For soils containing little fine or medium gravel the proportion of coarse gravel permissible may be extended to 40 % or 50 %.

(b) For soils containing larger proportions of coarse gravel, various methods have been advocated, but it is not considered that any can be satisfactory which does not involve the use of a mould which is large compared with the maximum size of gravel involved. California Bearing Ratio (CBR) moulds are sometimes used for this purpose but because of the difference in volume, the number of blows per layer should be increased (see Test 6.1.1).

NOTE (2). Many soils, especially those of volcanic origin, are susceptible to major change during compaction. For this reason a separate sample is used for each individual compaction.

NOTE (3). It is recommended that at least 8 samples be prepared at this stage to allow for repeat testing if required. Samples of mass greater than 2.5 kg may be required for particularly well graded soils or those having a high solid density of soil particles.

NOTE (4). The working range of water content required in this test will vary with the type of soil under test. In general, with sandy and gravelly soils, the working range of water content may lie between 20 % and 5 %. With cohesive soils the percentage water content range may lie between PL + 15 and PL – 15. The ease of assessment of the working range for the test is dependent on experience.

NOTE (5). The material when received may be above or below the optimum water content:

(a) Soils with a water content greater than the optimum value shall be carefully dried to the desired water content. If each sample is of known mass, control of water loss can be achieved by comparative weighing during drying. Drying may be accomplished with a current of warm air, but whatever method is used, regular stirring is essential to prevent over-drying of any part of the surface of the soil. A sample, any part of which has been accidentally over-dried must not be used unless it can be shown that such drying has no effect on its compaction characteristics.

(b) Soils with a water content less than the optimum will require water to be added. Add water as a fine spray to each sample and thoroughly mix. If each sample is of known mass, control of the amount of water to be added can be achieved by comparative weighing during wetting.

NOTE (6). When soil is stored in sealed containers water may condense on the container walls. Soil shall be packed tightly into the container to minimize air space and reduce the problem of condensation. A curing period of 16 h is recommended for most soils. Some heavy clays may require longer than 16 h to establish equilibrium and may require remixing at intervals to hasten the process. Some soils of low clay content, especially if of low activity, may not require such long periods of curing and the test may be made almost immediately after mixing.

NOTE (7). It is necessary to control the total volume of soil compacted, since it has been found that if the amount of soil struck off after removing the extension collar is too great, the test results will be inaccurate.

NOTE (8). The entire compacted sample shall be used for the water content determination of coarse soils.

NOTE (9). The zero air voids line is a valuable aid to the correct drawing of the compaction curve. At water contents above optimum water content, the compaction curve should asymptotically approach the zero air voids line but should never cross it. Should any of the plotted dry density/water content values be to the right of the zero air voids line, an error has occurred either in the value of the solid density used or in the compaction test. The 5 % and 10 % air voids lines can enable estimation of the air voids present in the compacted soil.

If the solid density of the soil particles has not been determined, assume a reasonable value based on previous knowledge of similar materials and report this value. Calculate the values for plotting the air voids lines using the formula given in 1.3.1 of Part 1.

NOTE (10). Some soils containing allophane or related minerals show such marked irreversible changes in physical properties when dried below natural water content that each point on the compaction curve relates effectively to a different soil. Commonly, there is no real maximum dry density or optimum water content, but a region of essentially constant dry density over a wide range of water content. In extreme cases the dry density continues to increase with a decrease in water content even to quite low values of water content.

NOTE (11). For some highly permeable soils such as clean sands and gravels, the results of the compaction test may provide only a poor guide for specifications on field compaction. The labora tory test often indicates a higher value of optimum water content than would be desirable for field compaction, and a maximum dry density often much lower than can readily be obtained in the field.

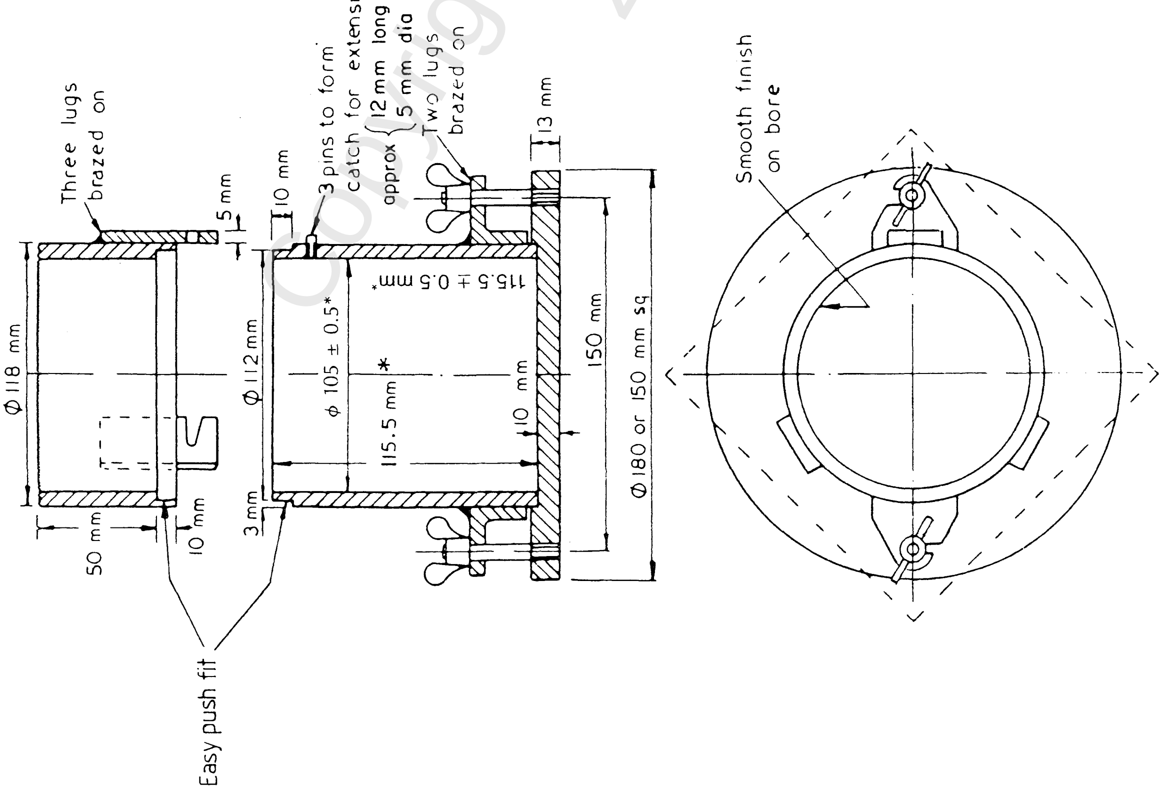

Fig. 4.1.1
MOULD FOR COMPACTION TEST

This design has been found satisfactory, but alternative designs may be employed provided that the essential requirements are fulfilled. (Essential dimensions are indicated by an asterisk.)

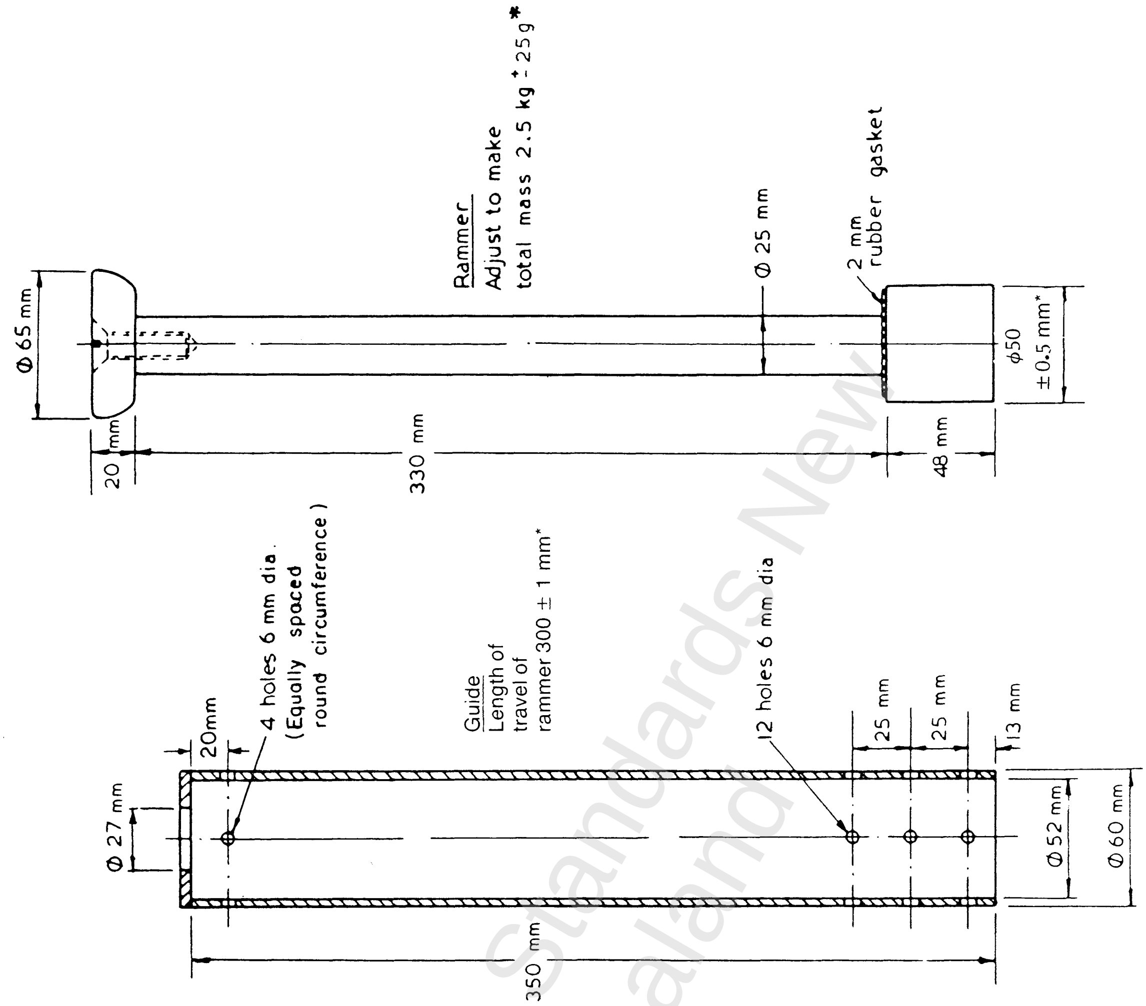

Fig. 4.1.2
2.5 kg RAMMER FOR THE STANDARD COMPACTION TEST

This design has been found satisfactory, but alternative designs may be employed provided that the essential requirements are fulfilled. (Essential dimensions are indicated by an asterisk.)

Form 4.1.1, 4.1.2
(Sheet 1)
DETERMINATION OF THE DRY DENSITY/WATER CONTENT RELATIONSHIP – N.Z. STANDARD COMPACTION OR N.Z. HEAVY COMPACTION
(Tests 4.1.1, 4.1.2)

Job:
Location:
Depth:
Test details:*

Compaction used: New Zealand standard/heavy compaction. Test performed on whole sample/fraction passing 19 mm test sieve

Total mass of sample: .... g

Mass retained on 19 mm test sieve: .... g

History: Natural/air-dried/oven-dried/unknown

Solid density of soil particles (ϱ_s): .... t/m³ , measured/assumed

Sample no.:
Tested by:
Date:
Checked by:
Date:

Determination of bulk density							
Test no.							
Volume of mould V ml							
Mass of mould + base + compacted soil M_2 g							
Mass of mould + base M_1 g							
Mass of compacted soil $M_2 - M_1$ g							
Bulk density $\varrho = \frac{M_2 - M_1}{V}$ t/m³							
Determination of water content							
Container no.							
Mass of container and wet soil M g							
Mass of container and dried soil M_S g							
Mass of container M_C g							
Mass of water $M - M_S$ g							
Mass of dried soil $M_S - M_C$ g							
Water content $w = \frac{M - M_S}{M_S - M_C} \times 100$ %							
Dry density $\varrho_d = \frac{100\,\varrho}{100 + w}$ t/m³							

* Delete the inappropriate words.

Form 4.1.1, 4.1.2
(Sheet 2)