NEW ZEALAND STANDARD

METHODS OF TESTING SOILS FOR CIVIL ENGINEERING PURPOSES

Part 4
Soil compaction tests

4.2
DETERMINATION OF THE MINIMUM AND MAXIMUM DRY DENSITIES AND RELATIVE DENSITY OF A COHESIONLESS SOIL

TEST 4.2.2
Maximum dry density

4.2.2.1
Scope
This method provides a standard technique for the laboratory determination of the maximum dry density of a cohesionless soil (see Notes (1) and (2)) by vibratory compaction of a fully saturated sample (see Note (3)). The laboratory density may be used for comparison with field determinations but should not be considered as an absolute value.

4.2.2.2
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 test 4.2.1 of this Standard.

4.2.2.3
Apparatus

(a) A vibrating table consisting of a steel table of adequate size to accommodate the required size of mould (see (b) below), and actuated by a unidirectional vibrator, with a nominal frequency of 50 Hz, a vertical double amplitude (peak to peak) setting of 0.5 ±0.05 mm when the table is complete with mould and material (see Note (4)). Refer fig. 4.2.1.

NOTE – The double amplitude of vertical vibration has been found to have a significant effect on the density obtained. For a more precise measurement, select the optimum double amplitude of vibration as determined by the procedure set out in Note (5).

(b) A cylindrical metal mould with base, of appropriate size requirements as given in table 4.2.3 (see Note (6)). The mould shall be of sufficient rigidity to retain its form under rough usage.

(c) A guide sleeve of the same diameter as the mould to fully accommodate a surcharge. The sleeve shall have a clamp assembly to enable it to be rigidly attached to the top of the mould (see fig. 4.2.1).

(d) A surcharge of total mass, including the lifting handle if fitted, sufficient to give a surcharge pressure of 14 ±0.2 kPa. The surcharges suitable for standard test moulds are listed in table 4.2.3. The surcharge shall consist of a metal cylinder with either rigidly attached metal flanges top and bottom or a removable aligned bottom flange. The cylinder shall have a diameter not greater than 5 mm less than the inside diameter of the mould and the flanges shall have a diameter between 1 mm and 2 mm less than the inside diameter of the mould (see fig. 4.2.1).

(e) A metal scoop with a flat base and width not more than half the diameter of the mould.

(f) A balance of suitable capacity readable and accurate to 0.1 % of the mass of soil required to fill the mould.

(g) A drying oven complying with the requirements of 1.4.2 of Part 1 and of sufficient capacity to accommodate all of the test sample.

(h) A metal dish or tray of suitable size to hold the sample during the drying, soaking and filling process.

(j) A steel straightedge of length at least 1.5 times the diameter of the mould used.

Part 4
Soil compaction tests

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4.2.2.4
Sample preparation

(a) By adequate mixing and subdividing, obtain a sub-sample from material that has been prepared in accordance with the procedure described in 1.6.3 of Part 1. The size of the sub-sample shall be dependent on the size of mould selected which shall be consistent with the maximum particle size shown in table 4.2.3.

NOTE – If the maximum particle size of the material tested is smaller than the minimum particle size of the material supplied to the laboratory, the mass of the oversize material discarded shall be measured and recorded for calculation of the percentage of the mass discarded (see 4.2.2.7.1 (b)).

(b) Alternatively, if both the minimum and the maximum dry densities are being determined, recombine all of the sub-sample material obtained for the minimum dry density test (see Test 4.2.1).

(c) Place the sub-sample in the dish or tray and add sufficient water to cover the material and leave to soak for at least 30 min (see Note (3)).

4.2.2.5
Procedure

(a) Select the mould and scoop suitable to the maximum size of particle in the sample as indicated in table 4.2.3. Determine the volume of the mould to 1 part in 1000, either from direct measurement, or from weighing the water required to fill the mould. If the latter method is used, take the density of water corresponding to its temperature (see table 4.2.2).

(b) Fit and clamp the guide sleeve to the mould, and the assembly to the vibrating table (see fig. 4.2.1).

(c) Mix the saturated material in the dish or tray to obtain an even distribution of the particle sizes, and transfer it by means of the scoop to the mould. Vibrate the mould during the filling and fill to above the top of the mould. If necessary, add sufficient water to allow a small amount of free water to accumulate on the surface of the material during filling. To avoid boiling and fluffing of the mix, which may occur with some materials, reduce the amplitude of vibration as much as is necessary. After filling continue the vibration for at least 5 min, removing any water appearing above the surface of the test material.

(d) Lower the surcharge onto the surface of the material in the mould. Ensure that the surcharge is fully within the guide sleeve. Set the vibrator control to obtain either the optimum double amplitude of vertical vibration, or 0.5 mm vertical double amplitude, and vibrate the loaded specimen for 10-11 min.

(e) Remove the surcharge and guide sleeve assembly. If the surface of the compacted test material at the completion of vibration is below the top of the mould repeat the test. Screed off the surplus material with the straightedge, or in the case of coarse material, carefully remove any pieces projecting so that the surface voids, and the amount of material projecting above the mould, are judged to be reasonably equal in volume. An alternative method for determining the volume of compacted soil is given in Note (7).

(f) Empty the entire contents of the mould into suitable dishes or trays and dry to constant mass in an oven at 105 °C to 110 °C. Weigh the dried material to the nearest 0.1 % and record (M).

(g) Repeat steps (b) to (f). If the two values of M differ by less than 1 %, use the mean value. Otherwise repeat steps (b) to (f) again. If from these three values, two are obtained within 1 % use the mean value of those two. Otherwise repeat the whole test.

4.2.2.6
Calculations

Calculate the maximum dry density ($\varrho_{d\,max}$) of the material from the formula:

$$\varrho_{d\,max} = \frac{M}{V} \text{ .... t/m}^3$$

where M = mass of dry material in the mould (g)
V = volume of the mould (ml)

4.2.2.7
Reporting of results

4.2.2.7.1
Report the following:

(a) The date of test

(b) The maximum size of particle used in the test (mm)

(c) Percentage of oversize material discarded

(d) The maximum dry density (t/m^3) to the nearest 0.02

(e) Whether the optimum double amplitude of vibration was measured or assumed

(f) Whether the screeding or depth indicator method was used to establish the densified material volume

(g) The nominal volume of the mould used (ml)

(h) The condition of the soil e.g. saturated, as received or dry.

4.2.2.7.2
State that the result was obtained in accordance with this Standard Test Method.

NOTES ON TEST 4.2.2

(1) Soils for which this method is applicable may contain up to 5 % by mass of soil particles passing a 75 µm sieve, except that silty sands with non-plastic fines may contain up to 12 % passing a 75 µm sieve.

(2) The test method may be used for soils with maximum size particles of 75 mm to 200 mm and will require a mould size dependent on the grading of the material. The diameter and depth of the mould shall not be less than 3 times the maximum particle size for well graded soils but may need to be up to 5 times the size for gap graded or uniformly graded soils.

(3) Since the maximum dry density of free draining coarse material is likely to be unaffected by water content, such material may be tested dry or as received.

(4) A simple measurement of double amplitude of vertical vibration can be obtained by attaching a copy of the gauge shown in fig. 4.2.2 to the mould and identifying the vertex of the dark lines that form when the table is vibrated.

It may be necessary to surcharge the vibrating table to keep the amplitude to within the specified requirements.

(5) To obtain a more precise measurement of maximum density for a material, the relationship between the density and the double amplitude of vertical vibration should be found. A number of tests should be carried out as described in this Standard Test Method except that for each test the vertical double amplitude should be varied until the optimum double amplitude corresponding to the maximum density is obtained.

To comply with the Standard the optimum double amplitude shall be in the range 0.3 mm to 0.9 mm, which corresponds to a simple harmonic motion peak acceleration range of 15 m/s^2 to 45 m/s^2. Calibrations should be carried out for each mould that is used with the material under test.

(6) The mould dimensions listed in table 4.2.3 are those considered appropriate for a given maximum size of particle. The larger mould sizes may be used for finer soils if desired.

(7) The following alternative method may be used to determine the volume of compacted soil by measuring the mean height of the densified material prior to removal of the surcharge.

A depth indicator and holder, together with guide brackets on opposite sides of the guide sleeve, are required to measure the height of the top of the surcharge. The measuring system is to be calibrated to allow determination of the mean height (h) of the densified material to 0.02 %.

Using this method, the densified material shall occupy 90 % to 100 % of the mould height. The guide sleeve shall be removed before the surcharge, and care shall be taken to prevent any fines that have collected on the lower flange from entering the mould.

The maximum dry density ($\varrho_{d\,max}$) of the material can be calculated from the formula:

$$\varrho_{d\,max} = \frac{1000\,M}{A \times h} \text{ .... t/m}^3$$

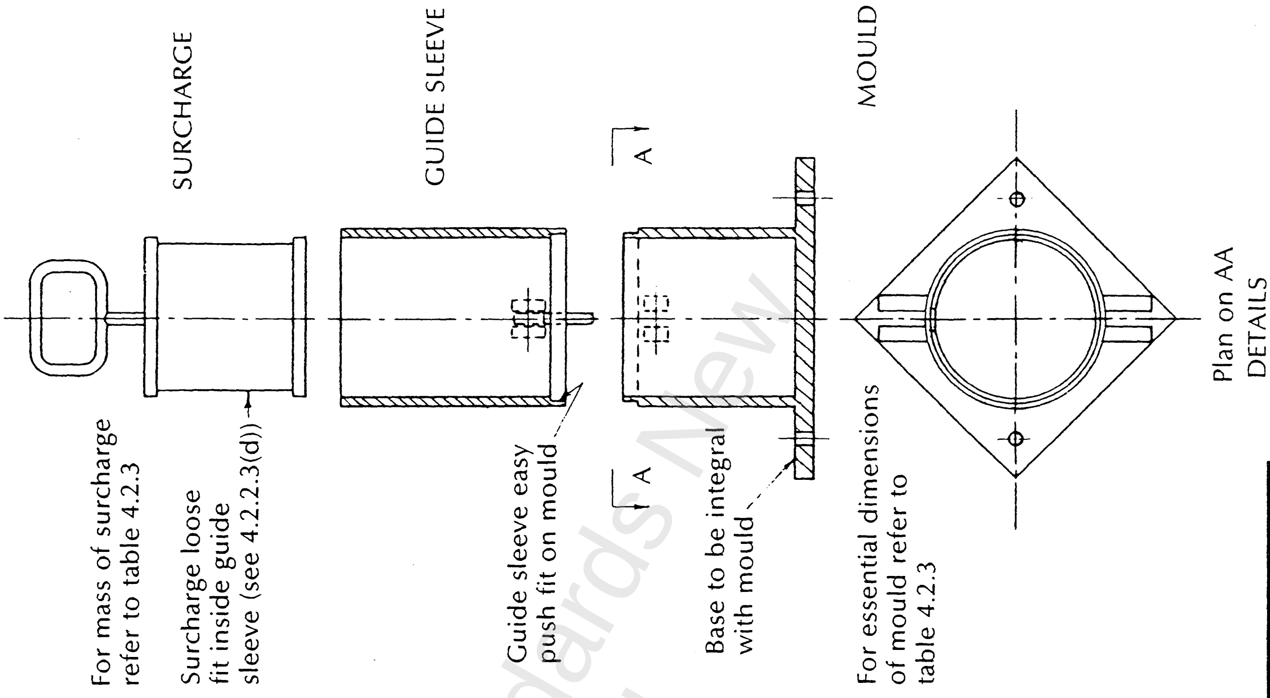
where M = mass of dry material in the mould (g)
A = mean cross sectional area of the mould (mm^2)
h = mean height of the densified material (mm)

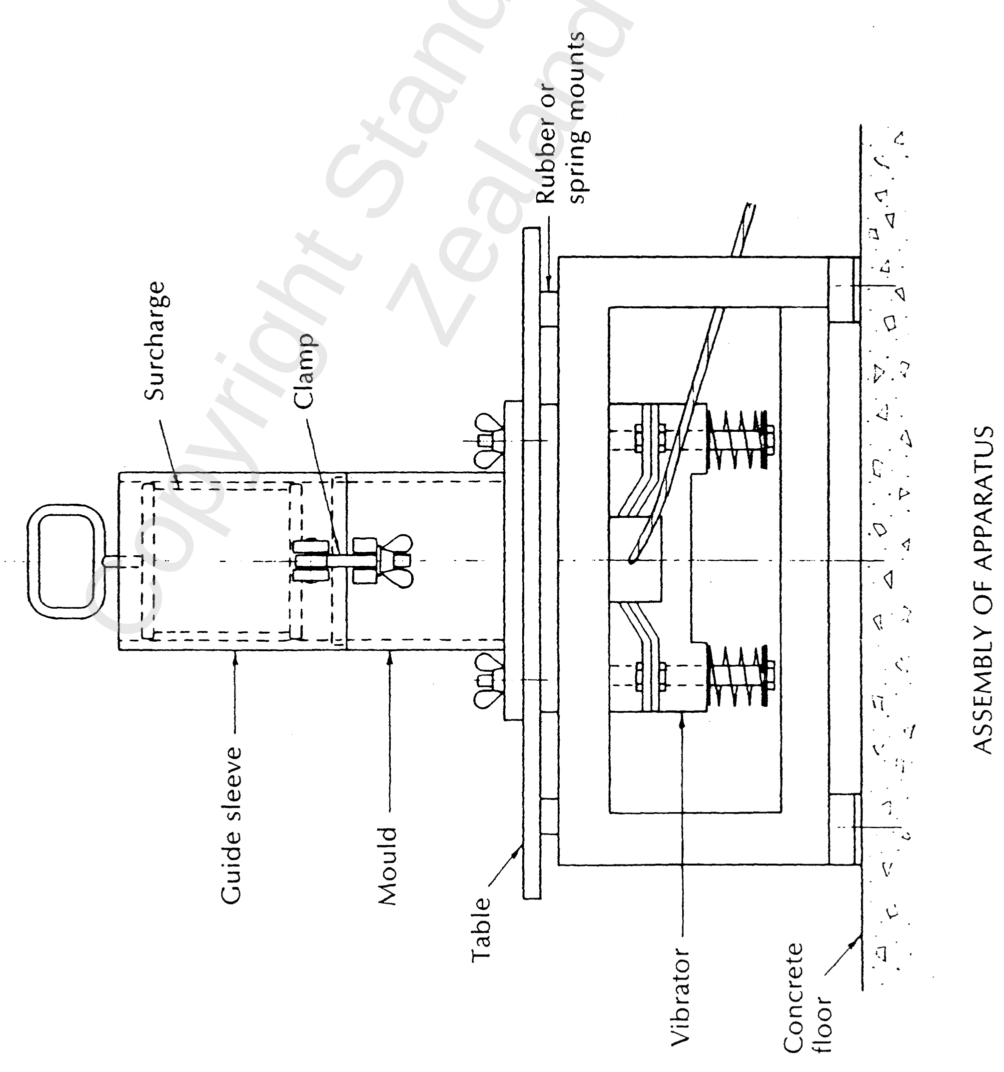
Table 4.2.2
ABSOLUTE DENSITY OF WATER (t/m^3) OVER TEMPERATURE RANGE 5 ° – 30 ° C

Degrees C	*Density*	*Degrees C*	*Density*
5	1.0000	18	0.9986
6	0.9999	19	0.9984
7	0.9999	20	0.9982
8	0.9998	21	0.9980
9	0.9998	22	0.9978
10	0.9997	23	0.9975
11	0.9996	24	0.9973
12	0.9995	25	0.9970
13	0.9994	26	0.9968
14	0.9992	27	0.9965
15	0.9991	28	0.9962
16	0.9989	29	0.9959
17	0.9988	30	0.9956
Column 1	2	3	4

Table 4.2.3
MAXIMUM SIZE OF PARTICLE AND DIMENSIONS OF APPARATUS FOR STANDARD MOULDS

Nominal volume of mould	*Maximum size of particle*	*Nominal internal diameter of mould*	*Nominal mass of sample*	*Corresponding surcharge mass*
L	mm	mm	kg	
1	4.75	105	5	12.4
3	19.0	150	12	25.3
15	37.5	250	40	70.5
30	75.0 to 200 (See Note (2))	350	80	138.5
Column 1	2	3	4	5





This design has been found to be satisfactory, but alternative designs may be employed provided that the mould and the guide sleeve can be rigidly clamped together and the assembly rigidly attached to the table.

Fig. 4.2.1
MAXIMUM DRY DENSITY APPARATUS

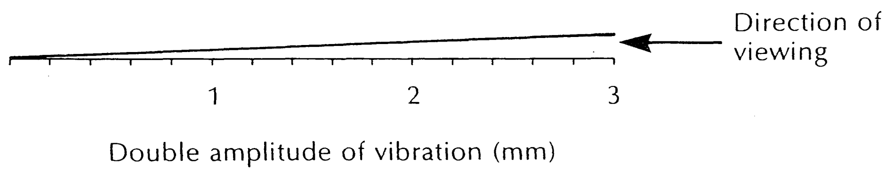


Fig. 4.2.2
AMPLITUDE OF VIBRATION GAUGE