METHOD OF TEST FOR DETERMINATION OF SPECIFIC GRAVITY OF SOILS

1. SCOPE

1.1 This method covers the determination of the specific gravity of soils that pass 4.75 mm sieve.

1.2 When the soil is composed of particles larger than 4.75 mm, procedures outlined in LS-604 shall be used for the material retained on 4.75 mm sieve, and this test method shall be used for material passing the 4.75 mm sieve. The weighted average of the two values shall be the specific gravity value for the soil.

1.3 Procedures for performing test on oven-dried as well as moist specimens are provided. The test procedure to be used shall be specified by the authority requesting the test.

1.4 The specific gravity test shall be made on the material passing 2.0 mm sieve, when the specific gravity value is to be used for the hydrometer portion of LS-702 and for the calculation of volume of solids in ASTM D2435.

2. RELEVANT DOCUMENTS

2.1	MTO LS-604	Method of Test for Relative Density and Absorption of Coarse Aggregate
	MTO LS-702	Method of Test for Determination of Particle Size Analysis of Soils
2.2	AASHTO T 100	Standard Method of Test for Specific Gravity of Soils
2.3	ASTM D854-98	Standard Test Method for Specific Gravity of Soils
	ASTM D2435	Standard Test Method for One-Dimensional Consolidation Properties of Soils Using Incremental Loading
	ASTM D4753	Standard Guide for Evaluating, Selecting, and Specifying Balances and Standard Masses for Use in Soil, Rock, and Construction Materials Testing

3. DEFINITION

The specific gravity of a soil is the ratio of the mass of a given volume of the material at a stated temperature to the mass of an equal volume of de-aired or gas-free distilled water at a stated temperature.

4. SIGNIFICANCE AND USE

4.1 The specific gravity of a soil is used in relating a weight of soil to its volume and in calculation of phase relationship, i.e. the relative volume of solids to water and air in a given volume soil.

4.2 The specific gravity is used in the computations of most of the laboratory tests, and is needed in nearly all pressure, settlement, and stability problems in soil engineering.

5. APPARATUS

5.1 PYCNOMETER: with a volume of at least twice the volume of the soil to be tested, and shall consist of one of the following depending on the maximum size of the largest particle:

5.1.1 STOPPERED BOTTLE: having a capacity of at least 50 ml: The stopper shall be of the same material as the bottle, and shall have a small hole through its centre to permit the emission of air and surplus water when the stopper is put in place.

5.1.2 VOLUMETRIC FLASK: having a capacity of at least 100 ml.

5.2 Desiccator: A desiccator cabinet or large desiccator jar of suitable size containing silica gel or anhydrous calcium sulphate.

5.3 BALANCE: meeting the requirements of ASTM D4753, Class GP1, and readable, without estimation to at least 0.1% of the specimen mass.

5.4 THERMOMETER: readable to 0.5^{o}C, and shall be calibrated to a thermometer accurate to 0.1^{o}C.

5.5 OVEN: A thermostatically controlled, forced-draft type oven, capable of maintaining a uniform temperature throughout the drying chamber.

5.6 VACUUM SYSTEM: A vacuum pump capable of producing a partial vacuum of 100 mm Hg absolute pressure.

5.7 LABORATORY CONTROL SAMPLE: A supply of clay from Dresden, Chatham is available from the Soils and Aggregates Section, Ministry of Transportation, 1201 Wilson Avenue, Downsview, Ontario M3M 1J8, Phone (416) 235-3735, Fax (416) 235-4101.

6. CALIBRATION OF PYCNOMETER

6.1 Determine and record the mass of a clean and dry pycnometer. Fill the pycnometer with distilled water to the calibration mark. After a visual inspection of the pycnometer and its content to ensure that there are no air bubbles, weigh and record the mass of pycnometer and water, m_a. Insert a thermometer in the water and record the temperature of the water, T, to the nearest 0.5^{o}C.

6.2 From the mass m_a determined at the observed temperature T_i, prepare a table of values of masses m_a for a series of temperatures that are likely to be encountered during performance of the test. The values of m_a can be determined experimentally or calculated as follows:

$$m_a \text{ (at } T_x,) = \frac{\text{density of water at } T_x}{\text{density of water at } T_i} \quad x \quad [\, m_a(\text{at } T_i) - m_f \,] + m_f$$

Where: m_a = mass of pycnometer and water, g

m_f = mass of pycnometer, g

T_i = observed temperature of water, °C

T_x, = any other desired temperature, °C

7. TEST SPECIMEN

7.1 The test specimen shall be representative of the total sample, and shall be oven-dried or moist for specimens of organic soils and high plastic clays. The minimum mass of specimen in its oven-dried state shall as follows:

Maximum Particle Size (100% Passing)	Sieve Size	Minimum Mass, g
2.00 mm	No. 10	20
4.75 mm	No. 4	100

7.2 Oven-dried specimens shall be prepared by drying to a constant mass in an oven maintained at 110 $\pm$ 5^{o}C and cooled it in a desiccator.

7.3 Moist specimens of high plastic clays shall be dispersed in distilled water by using the equipment specified in section 3.3 of LS-702, before the soil is placed in the pycnometer. A pycnometer with capacity not less than 500 ml shall be used when the test is performed on moist specimens.

8. TEST PROCEDURE

8.1 PROCEDURE FOR OVEN-DRIED SPECIMEN:

8.1.1 Prepare the specimen in accordance with section 6.2, and keep it in a desiccator until ready for placing in the pycnometer.

8.1.2 Select three clean, dry, and calibrated pycnometers with capacity to accommodate twice the volume of the test specimens to be tested. Weigh and record the mass of the pycnometers selected. Place the soil specimen in the pycnometer. Weigh and record the mass of the specimen and pycnometer.

8.1.3 Fill the pycnometers with distilled water to a level slightly above the mark of soil (20-30 ml) to cover the test specimen completely. The test specimens shall be soaked for at least 12 hours.

Note 1: Kerosene may be used in place of distilled water, when soils that contain significant fraction of organic matter or that expands when water is added to oven-dried samples. If kerosene is used, a vacuum system must be used to remove the entrapped air.

8.1.4 Entrapped air from the test specimen shall be removed by one of the following methods:

8.1.4.1 Place all three pycnometers with their contents in a desiccator connected to a vacuum pressure not exceeding 100 mm Hg, and subject the contents to the vacuum for at least 30 minutes. Alternatively, the pycnometer shall be connected to the vacuum pump directly. Gently agitate the pycnometer periodically to assist in the removal of air while the vacuum pressure is being applied.

During this operation, care shall be taken to avoid violent boiling of soil specimen by reducing the air pressure at a slower rate. Upon removal of the entrapped air completely, gently release the vacuum and remove the pycnometers from the desiccator.

Note 2: Oven-dried specimens may require 2-4 hours to remove the entrapped air. However, low to high plastic clay specimens tested at its natural moisture content may require 4-8 hours to remove entrapped air. A larger pycnometer may be required if violent boiling cannot be stopped by reducing the vacuum pressure.

8.1.4.2 Alternatively, the entrapped air shall be removed by boiling the specimen gently for 10 minutes. The pycnometer shall be gently agitated periodically to assist in the removal of air. Upon removal of the entrapped air, cool the heated pycnometer to the room temperature.

8.1.5 Carefully fill the pycnometer with distilled water at room temperature to slightly below the calibration mark. Add distilled water slowly and carefully to avoid entrapment of air bubbles in the specimen. Allow the pycnometer to reach a uniform water temperature.

8.1.6 Fill the pycnometer with distilled water at the same temperature to its calibration mark. Carefully remove the excess water from the outside of the pycnometers using an absorbent cloth or paper towel. Weigh and record the pycnometer filled with soil and water.

8.1.7 Insert the thermometer into the water, and record its temperature to the nearest $0.5^{o}C$.

8.2 PROCEDURE FOR MOIST SPECIMENS:

8.2.1 Place the test specimens prepared in accordance with Section 6.3 in 3 calibrated pycnometers, and proceed as described in Sections 7.1.4 to 7.1.7.

8.2.2 Carefully remove the specimens from the pycnometers and dry the specimens to a constant mass in suitable containers in an oven maintained at $110 \pm 5^{o}C$. Cool the specimens in a desiccator to the room temperature.

8.2.3 Weigh and record the mass of oven-dried specimen.

9. CALCULATIONS

9.1 Calculate the specific gravity of the soil, based on water at a temperature T_x, as follows:

$$\text{Specific Gravity, G at } T_x = \frac{m_o}{[m_o + (m_a - m_b)]}$$

Where: m_o = mass of oven-dried specimen, g

m_a = mass of pycnometer filled with water at temperature T_x, g, this value can be obtained from the table prepared under Section 5.2

m_b = mass of pycnometer filled with water and soil at temperature T_x,g

T_x = temperature of the contents of the pycnometer when the mass m_b was determined, °C

9.2 Unless stated otherwise, relative density values shall be reported based on water at 20°C. This value shall be calculated from the value obtained at temperature T_x, as follows:

Specific Gravity G at 20°C = K (G at T_x)

Where K is a number found by dividing the density of water at temperature T_x, by the density of water at 20°C. Values for a range of temperatures are given in Table 1.

9.3 Calculate the weighted average specific gravity, G_{WS}, for soil samples that contain both materials passing and retained on 4.75 mm (No. 4) sieve using the equation given below:

$$G_{WS} = 1/[(R/100G_R) + (P/100G_S)]$$

Where: P = Percent of soil particles passing the 4.75 mm sieve

R = Percent of material retained on the 4.75 mm sieve

G_R = Specific gravity of particles retained on 4.75 mm sieve as determined by LS-604

G_S = Specific gravity of soil particles passing 4.75 mm sieve as determined by this test procedure

Table 1: Density of Water and Conversion Factor K for Various Temperatures

Temperature, °C	Density of Water (g/cc)	Correction Factor K	Temperature, °C	Density of Water (g/cc)	Correction Factor K
16.0	0.99887	1.0007	23.5	0.99745	0.9992
16.5	0.99889	1.0007	24.0	0.99732	0.9991
17.0	0.99880	1.0006	24.5	0.99720	0.9990
17.5	0.99871	1.0005	25.0	0.99707	0.9988
18.0	0.99862	1.0004	25.5	0.99694	0.9987
18.5	0.99853	1.0003	26.0	0.99681	0.9986
19.0	0.99843	1.0002	26.5	0.99668	0.9984
19.5	0.99833	1.0001	27.0	0.99654	0.9983
20.0	0.99823	1.0000	27.5	0.99640	0.9982
20.5	0.99812	0.9999	28.0	0.99626	0.9980
21.0	0.99802	0.9998	28.5	0.99612	0.9979
21.5	0.99791	0.9997	29.0	0.99597	0.9977
22.0	0.99780	0.9996	29.5	0.99582	0.9976
22.5	0.99768	0.9995	30.0	0.99567	0.9974
23.0	0.99757	0.9993			

9.4 The calculated test results from 3 samples should be within 0.02 of each other, or the test must be repeated.

10. REPORTING OF RESULTS

10.1 The data card shown in Figure 1 may be used for recording the data and reporting the results. The mean value of the relative density shall be reported to 3 decimal places.

10.2 The report shall include the following:

10.2.1 Identification of the sample such as bore hole number, sample number;

10.2.2 Specific Gravity value of the soil at $20^{o}C$ to the nearest three decimal;

10.2.3 Maximum particle size of the test specimen;

10.2.4 Type of fluid used, if distilled water not used; and

10.2.5 The portion on which the test was performed, if any portion of the original sample was eliminated.

11. USE OF LABORATORY CONTROL SAMPLE

11.1 Every 10 samples, or once in 6 months, a sample of the reference soil shall be tested. The material shall be taken from a stock supply maintained by the Soils and Aggregates Section. The mean of the reference soil sample should be 2.721. Individual test data should not normally be greater than 2.765 or less than 2.677.

11.2 Control Chart Use: The specific gravity of the last 20 samples of reference material shall be plotted on a control chart in order to demonstrate the performance of the laboratory.

Ontario

SPECIFIC GRAVITY

Sample No: _____ Date: _____

Project: _____

Specimen No.	**G1**	**G2**	**G3**
Pycnometer Reference No.			
Mass of Pycnometer (m_f)			
Mass of Dry Specimen + Pycnometer (m_s)			
Mass of Dry Soil ($m_s - m_f = m_o$)			
Mass of Pycnometer + Water (m_a)			
Mass of Pycnometer + Specimen + Water (m_b)			
Mass of Water Displaced = $[(m_a + m_o) – m_b]$			
Temperature, T_x, of the Content			
Specific Gravity, $G = \frac{m_o}{[m_o + (m_a - m_b)]}$			
Mean Specific Gravity at Temperature T_x, $G_{avg} = (G_1 + G_2 + G_3)/3$			
Specific Gravity at 20°C, $G_S = K (G_{avg})$			

Removal of entrapped air by a) Vacuum ☐
b) Boiling ☐

Name of Operator: _____

Remarks: _____

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Figure 1 Specific Gravity Data Card