Specific gravity

Nielsen, Benjaminn Nordahl; Nielsen, Søren Dam

DEPARTMENT OF CIVIL ENGINEERING
AALBORG UNIVERSITY

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Benjaminn Nordahl Nielsen
Søren Dam Nielsen

ISSN 1901-7286
DCE Lecture Notes No. 67

Aalborg University
Department of Civil Engineering
Section for building and infrastructure

DCE Lecture Notes No. 67

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by

Benjaminn Nordahl Nielsen
Søren Dam Nielsen

2019

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Published 2019 by
Aalborg University
Department of Civil Engineering
Thomas Manns Vej 23
DK-9220 Aalborg E, Denmark

Printed in Aalborg at Aalborg University

ISSN 1901-7286
DCE Lecture Notes No. 67

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Preface

This guide deals with the determination of specific gravity – pycnometer method.

The guide is part of a series, which explain the execution of geotechnical classification experiments as carried out at the Geotechnical Engineering Laboratory.

The guide is constructed as follows:

- *Appertaining standards*
- *Definitions*
- *Apparatus*
- *Equipment calibration*
- *Preparing the test sample*
- *Procedure for experiment*
- *Calculation*
- *Reporting*
- *Remarks*
- *Schema for experiment execution*
- *Appendix, if any*

It is recommended that the user of this guide reads the entire guide before the experiment is started.

Numbering of figures in the text is indicated by { }.

Units are indicated by [ ], e.g. [%].

Appertaining standard

The experiment is based on and further described on the standard DS/CEN ISO/TS 17892-3.

Definition

Specific gravity is the ratio between the weight of the soil solids to the weight of water of equal volume:

$$G_s = \frac{weight\ of\ a\ given\ volume\ soil\ solids}{weight\ of\ the\ same\ volume\ de-ionised\ water\ at\ 4^o C}$$

The weight of the soil solids is not corrected for buoyancy.

With the above-mentioned definition, makes:

$$G_s = \frac{\rho_s}{\rho_w{}^{4^o}} = \frac{W_s}{V_s \cdot \rho_w^{4^o}}$$

V_s Volume of dry grain material [cm^3]

W_s Weight of dry grain material [g]

ρ_s Density of grain material [g/cm^3]

$\rho_w^{4^o}$ Density of de-ionised water at 4^{o}C, $\rho_w{}^{4C}$= 1g/cm^3

For soil without organic content, G_s is expected to vary from 2.65 for clean quartz sand to 2.85 for certain clay minerals.

For soil containing especially heavy or light minerals, G_S can adopt values outside of this interval.

Content of organic matter can reduce G_s down to 1.0.

The volume of the soil solids is defined as the volume of the solid mass, the closed pores and the part of the open pores unavailable when following this guide.

Apparatus

The apparatus used in the experiment. Numbers refer to figure 1.

- Pycnometer {1}
- Beaker {2}
- Thermometer, accuracy 0.1 ^{o}C {2}
- Scale, weighing accuracy of 0.001 g
- Drying oven, temperature at 105^{o}C
- Vacuum desiccator

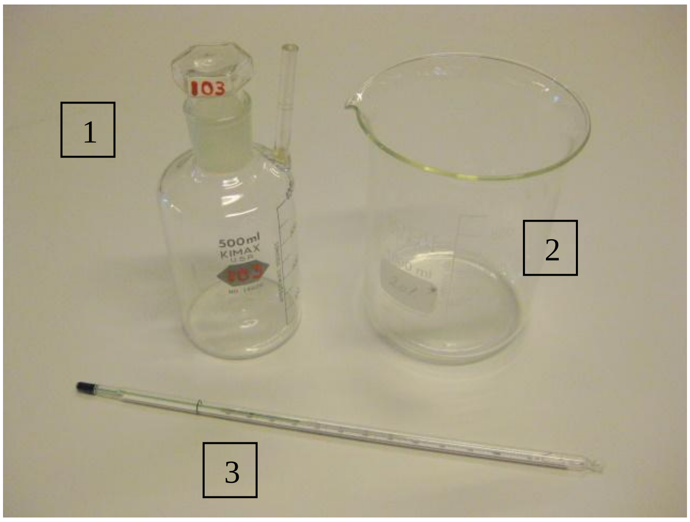

Figure 1: Apparatus for specific gravity mass experiment. The numbers refer to the apparatus list above.

Equipment calibration

The pycnometer must be calibrated annually. No equipment needs to be calibrated prior to the experiment.

For determining the volume of the soil grains, a pycnometer (glass bottle) is used.

The weight of a pycnometer filled with de-aired de-ionised water (W_2) at a given temperature must be known in advance. This calibration of pycnometer can be done experimentally by weighing the pycnometer filled with air free de-ionised water at different temperatures. The calibration can also be done theoretically when you know the room expansion coefficient for the pycnometer (duran and pyrex glass $\beta = 10^{-5}\,\text{pr.}\ ^{o}\text{C}$).

The weight of the pycnometer filled with de-aired de-ionised water (W_2) as a function of temperature, can be read on the calibration scheme made for the individual pycnometer. The most recent calibration schemes for used pycnometers can be found in the Geotechnical Engineering Laboratory at Aalborg University.

Preparing testing sample

Normally, a 500 ml pycnometer is used. If there is only a small soil sample available (minimum 10 g dry matter), a 50 ml pycnometer can be used.

The further procedure depends on whether G_s is being determined for cohesive soil or friction soil.

The stated sample sizes in the following have been calculated for a 500 ml pycnometer.

The stated sample amounts are indicated for dry soil, but in situ soil is used, which is why the water content must be considered.

Cohesive soil. Wet method

- The sample is grated or divided into small pieces, and a representative subsample equalling approx. 50 g dry soil is taken.
- The sample is stirred together with at least 200 ml deionised water into homogenous slurry. This can be done on a vibrating table where the slurry has to stand for approx. 4 hours at a frequency of 170 vibrations á minute.
- The slurry is poured into the pycnometer.
- If necessary, remnants in the bowl are rinsed over in the pycnometer with air free de-ionised water. Air free de-ionised water is poured into the pycnometer until it is half-full.

Friction soil. Dry method

- A subsample equalling approx. 150 g dry matter is taken.
- The sample is placed in the pycnometer. Use a funnel if necessary.
- De-aired de-ionised water is poured in the pycnometer by letting it run down the inside of the pycnometer until approx. half full, figure 2.
- Make sure that the whole sample is saturated and that no hidden air bubbles are in the sample. This can be done by titling the pycnometer sideways and slowly turning it so the trapped air bubbles are released. Turn until no more air is released by turning an additional, full turn.

Figure 2: Pycnometer with friction soil and deionised water.

Procedure for experiment

The following experiment description is applicable for both friction and cohesive soil.

- The pycnometer <u>without</u> a plug is put in the vacuum desiccator where the soil is boiled for about 60 min. until air free, figure 3.
- The pycnometer is taken out of the desiccator and filled with air free de-ionised water by pouring the water down on the inside of the pycnometer, figure 4. Put enough water in to make excess for when the plug is put in.
- The pycnometer without a plug is put aside until the temperature in the pycnometer equals the room temperature.

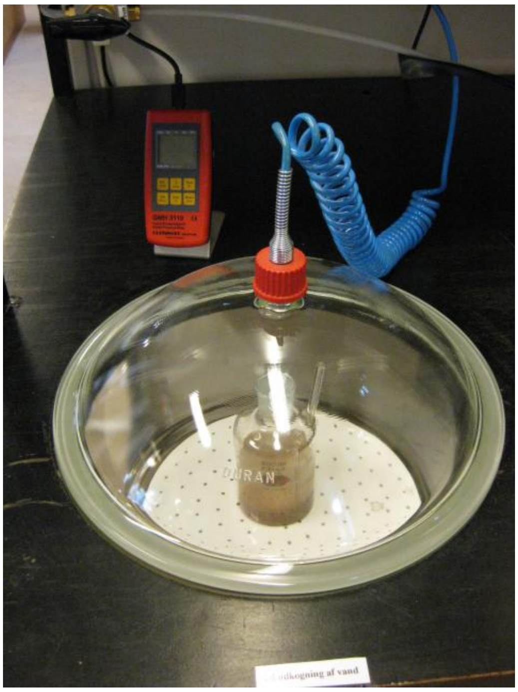

Figure 3: The pycnometer in the vacuum desiccator.

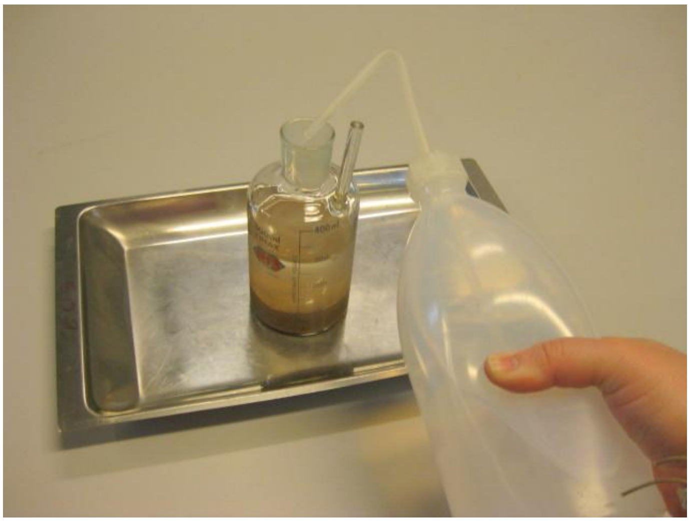

Figure 4: The pycnometer is filled carefully with deionised water. The water runs down on the inside of the pycnometer.

- When the temperature equals room temperature, the plug is carefully put in the pycnometer so that the excess water runs over, figure 5. The overflow pipe must be filled with water. Air must not be present in this either.
- Make sure the water is completely free of air bubbles; around the plug as well.
- The pycnometer is carefully dried off; pay attention to any water around the plug.
- The filled pycnometer with plug is weighed, *(W_1).*
- The temperature in the middle of the pycnometer is measured, figure 6.
- The weight of the pycnometer filled with air free de-ionised water at the measured temperature (W_2) is read in the calibration scheme. Linear interpolation is used to find the weight of the pycnometer at temperatures different from those stated in the calibration scheme.

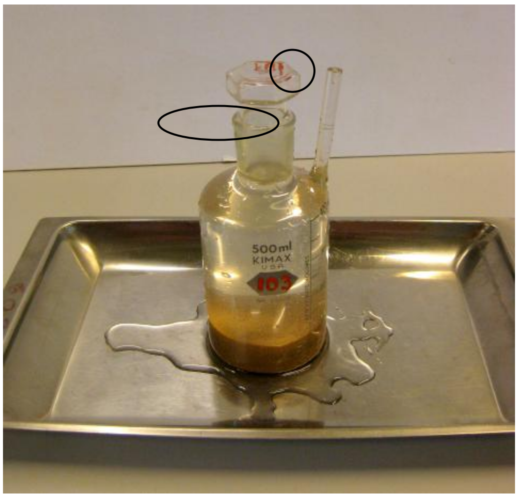

Figure 5: Pycnometer with plug (marked with O) where the excess water has run over. The pycnometer is carefully dried off before being weighed.

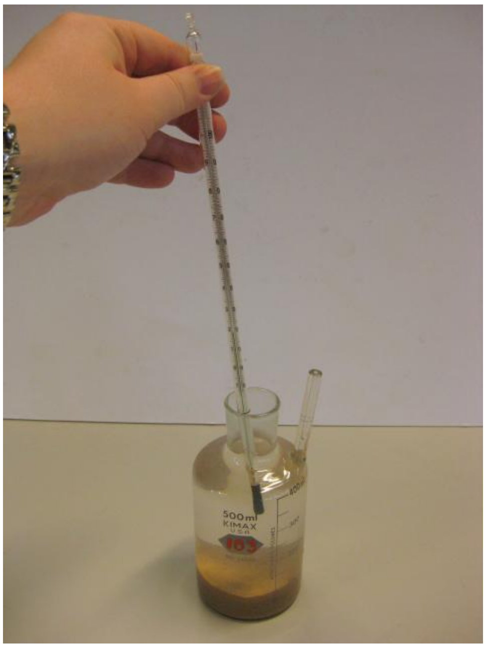

Figure 6: The temperature is measured in the middle of the pycnometer.

- A beaker is weighed (W_{beaker}), and the content of the pycnometer is poured into this, figure 7.
- Remnants in the pycnometer are rinsed into the beaker with de-ionised water.
- The slurry is dried in a drying oven at 105^{o} C.

This is a slow process and can take up to several days depending of the amount of water.

- The slurry is controlled daily. When there is no visible water left, the sample must stand an additional 24 hours to ensure complete dryness.
- The slurry is placed in desiccator until the sample has the same temperature as the room temperature, and the beaker with the slurry is weighed ($W_{beaker} + W_S$).

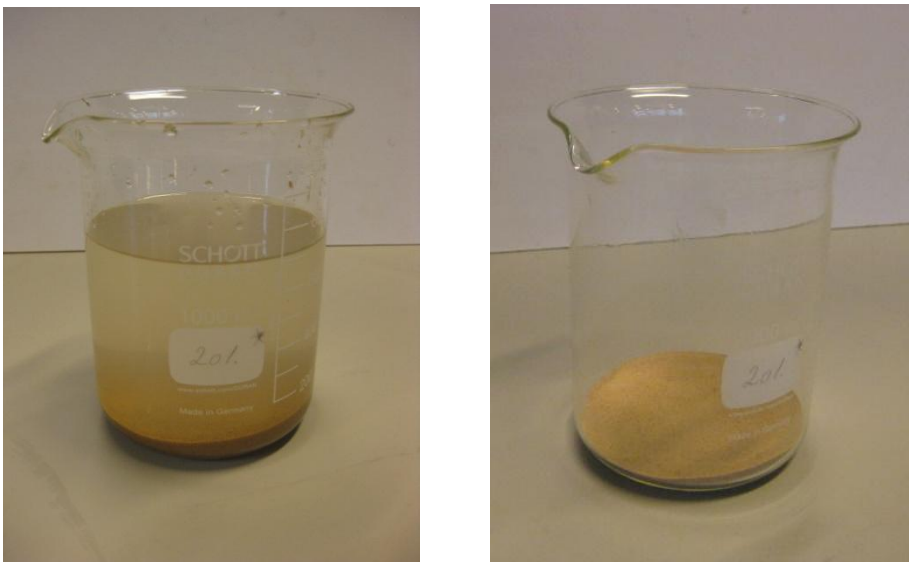

Figure 7: Beaker with the sample – before and after it has been dried at 105^{o}C. The drying period can last up to several days.

Calculations

Volume of dry matter $= \dfrac{W_s + W_2 - W_1}{\rho_w^t}$

$$G_s = \frac{W_s}{\dfrac{W_s + W_2 - W_1}{\rho_w^t} \cdot \rho_w^{4^o}}$$

$$G_s = \frac{W_s \cdot \rho_w^t}{W_s + W_2 - W_1}$$

W_1 Weight of pycnometer filled with sample and de-ionised water [g].

W_2 Weight of pycnometer filled with de-ionised water [g].

ρ_w^t Density of de-ionised water at temperature t, [g/cm^3].

V_s Volume of dry grain material [cm^3]

$\rho_w^{4^o}$ Density of de-ionised water at 4^{o}C, $\rho_w{}^{4C}$= 1g/cm^3

Reporting

The specific density is given by 2 decimals.

Remarks

The air pressure in the desiccator must be reduced slowly so the boiling does not cause water and soil to be taken out of the neck of the pycnometer.

Great meticulousness with the weighing and temperature measurements is necessary as G_s is calculated on the basis of a difference in weight, which is small compared to the scales themselves.

Use the same scale to calibrate the pycnometer and the individual weight determinations.

Two common sources for errors are:

- Dissimilar temperature in the pycnometer
- Incomplete removal of encapsulated air in the soil

Dissimilar temperature difficulties are avoided if the temperature in the pycnometer is equal to the room temperature before the plug is put in the pycnometer.

The boiling procedure described is usually enough to remove the encapsulated air in the soil. The soil must not be boiled in the pycnometer at normal air pressure as the pycnometer shape can be altered.

If the specific density is determined on the sift-out part of the soil sample, this is indicated on the experiment form.

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Specific gravity

Case			Case no.
Examined	to	Lab. no.	Boring no.
Controlled d.	Approved d.	Level	Appendix no.

SAMPLE SIZE

Sample	No					
Bowl (Beaker)	no					
Bowl + W	g					
Bowl	g					
	g					

RELATIVE DENSITY

Sample	No					
Pycnometer	no					
Pyc in/out desiccator	time					
W_1 $(W_{pyc} + W_s + W_{water})$	g					
Temperature t	^oC					
W_2 $(W_{pyc+water})$	g					
Beaker	No					
Beaker in drying oven	dd. h.					
Beaker out drying oven	dd. h.					
$W_{beaker} + W_s$	g					
W_{beaker}	g					
Dry matter W_s	g					
Water density ρ_w^t	g/ml					
Specific gravity $G_s = \dfrac{W_{s\cdot} \cdot \rho_w^t}{W_s + W_2 - W_1}$						

DE-IONISED WATER DENSITY ρ_w^t

^{o}C	10	11	12	13	14
g/ml	0,99973	0,99963	0,99953	0,99941	0,99927
^{o}C	15	16	17	18	19
g/ml	0,99913	0,99897	0,99880	0,99862	0,99843
^{o}C	20	21	22	23	24
g/ml	0,99823	0,99802	0,99780	0,99757	0,99733
^{o}C	25	26	27	28	29
g/ml	0,99708	0,99681	0,99654	0,99626	0,99598

ISSN 1901-7286
DCE Lecture Notes No. 67