HYDRAULICS RESEARCH DIVISION
Technical Note

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TITLE: Determination of Specific Gravity in Sediments

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REASON FOR REPORT:

Partial fulfillment of objectives of Project H 78 040.

CORRESPONDENCE FILE NO:

2242-1

1.0 INTRODUCTION

The specific gravity of sediment is defined as the ratio of the weight of a given volume of sediment to the weight of an equal volume of distilled water at a given temperature (Lambe, 1967). The method used to determine specific gravity in the sedimentology/geotechnical laboratory generally follows that developed by Lambe (1967). It consists of:

1) placing a measured amount of sediment in a calibrated pycnometer half full of deaired, distilled water
2) removing the air entrapped in the sediment by boiling
3) filling the pycnometer with deaerated water
4) weighing the pycnometer, water and sediment
5) computing the specific gravity according to:

$$G_s = \frac{W_s G_T}{W_s - W_1 + W_2}$$

where W_s = dry weight of sediment

G_T = specific gravity of deaired, distilled water at temperature T

W_1 = weight of pycnometer, when filled with water-sediment mixture

W_2 = weight of pycnometer, when filled with water

This report describes in detail the equipment and method used for specific gravity determinations and discusses some possible sources of error in the method.

2.0 EQUIPMENT

The equipment required for the analysis is listed as follows and shown in Figure 1:

1) pycnometer - although it is possible to use a volumetric flask as a pycnometer, the 50 ml flask shown in Figure 1 (Fisher Scientific; Cat. #3-230C) with a thermometer insert and an overflow vent is the most suitable.
2) Hot plate and magnetic stirrer
3) Vacuum system
4) Balance - sensitivity of 0.0001 g
5) Drying oven
6) Freeze-drier
7) Desiccator
8) Deaired, distilled water - this can be obtained by placing a flask of distilled water under vacuum and constant agitation for five hours
9) Acetone

3.0 PROCEDURE

3.1 Calibration of the Weight of Pycnometer when Filled with Water

1. Fill a clean pycnometer with deaired, distilled water and insert a thermometer in the neck of the flask. The displaced water will escape via the overflow vent.
2. Dry the outside of the flask carefully and place the cap on the overflow vent.
3. Weigh the flask + distilled water to 0.0001 g and record the weight.
4. Mix the contents of the flask and record the temperature to 0.1°C.
5. Heat the flask + distilled water briefly and reweigh at the new temperature (steps 2-4 above). Repeat at least five times for each pycnometer.
6. A least square regression is used to determine the weight of the pycnometer when filled with water, W_2, as a function of temperature T.

$$W_2 = a + bT$$

where

$$a = \frac{(\Sigma W_2)(\Sigma T^2) - (\Sigma T)(\Sigma TW_2)}{n(\Sigma T^2) - (\Sigma T)^2}$$

$$b = \frac{n(\Sigma TW_2) - (\Sigma T)(\Sigma W_2)}{n(\Sigma T^2) - (\Sigma T)^2}$$

T = temperature
W_2 = wt. of pycnometer + water
n = number of data points

An example of the calculation is given in Appendix 1.

3.2 Analysis

1. Label the Specific Gravity Determination work sheet (Figure 2) with Sample Number, the person requesting the analysis, the Study Number, the Date and the Analyst.
2. Freeze-dry the sample.
3. Split to approximately 10 g and store in a desiccator.
4. Weigh a clean pycnometer and record the weight and Flask Number on the work sheet.

5. Add the sample to the pycnometer and weigh to 0.0001 g and record the weight (W_s) on the work sheet.
6. Carefully add deaired, distilled water until flask is half full. Gently agitate the flask until all particles are wetted.
7. Install a glass chimney in the neck of the flask (Figure 1).
8. Remove the entrapped air from the sediment by boiling for ten minutes while mixing occasionally.

   Caution: Some sediments are prone to boiling over. If sediment gets on the walls of the chimney from overboiling, simply wash it back into the flask with deaired, distilled water.
9. Remove chimney from the flask and check for entrapped air in sediment by applying and releasing a vacuum to the flask. If there is a movement on the suspension surface, repeat step 7.
10. Remove the flask from the heat and allow the flask to cool.
11. Fill the flask with deaired, distilled water and insert the thermometer. The excess water will escape through the overflow port.
12. Carefully dry the outside of the flask and install the cap on the overflow port.
13. Carefully mix the contents of the flask to ensure the suspension is at a uniform temperature.
14. Weigh the flask and its contents to 0.0001 g and record the weight as Wt. Flask + Water + Sediment (W_1) on the work sheet.
15. Simultaneously record the suspension temperature to 0.1°C as Temperature (T) on the work sheet.
16. Calculate the weight of flask + water (W_2) with the appropriate calibration formulae given in Appendix 1.
17. Enter the appropriate value for specific gravity of water and T (GT) from Table 1.
18. Calculate the specific gravity by substitution in the following equation:

$$G_s = \frac{W_s G_t}{W_s - W_1 + W_2}$$

19. Repeat steps 3-18 for each sample and average the results.

4.0 DISCUSSION

Although the method is relatively straight forward, the analyst must be very careful in conducting the tests. The most common sources of error are:

1. Imprecise weighing - since the computation of specific gravity is based on a difference in weights which is small in comparison with the weights themselves, a small error can have a significant effect on the results. As a result, it is advisable to use the same balance for all weighing.
2. Temperatures not representative - it is important to mix the contents of the flask at the time of weighing to ensure a uniform temperature within the flask.
3. Entrapped air in sediment - all of the air must be removed from the sediment during boiling.
4. Improper cleaning of pycnometer - to clean the pycnometer, wash it thoroughly with distilled water and drain; then rinse with acetone and place in an oven to dry.
5. Use of contaminated water - use only deaired, distilled water.
6. Absorption of water by sediment - sediment must be stored in a desiccator before weighing.

APPENDIX 1

Calibration Calculation

Pycnometer #1

T	W_2	T^2	TW_2
19.4	96.6889	376.36	1875.7647
23.2	96.6640	538.24	2242.6048
26.2	96.6316	686.44	2531.7479
29.8	96.6251	888.04	2879.4280
98.6	386.6096	2489.55	9529.5454

$$a = \frac{(\Sigma W_2)(\Sigma T^2) - (\Sigma T)(\Sigma TW_2)}{n(\Sigma T^2) - (\Sigma T)^2}$$

$$b = \frac{n(\Sigma TW_2) - (\Sigma T)(\Sigma W_2)}{n(\Sigma T^2) - (\Sigma T)^2}$$

substituting

$$a = \frac{(386.6096)(2489.55) - (98.6)(9529.5454)}{4(2489.55) - (2489.55)^2} = 96.8128$$

$$b = \frac{4(9529.5454) - (98.6)(386.61)}{4(2489.55) - (2489.55)^2} = -0.0065$$

Since the equation of the least squares line is $W_2 = a+bT$
then for pynometer #1 $W_2 = 96.8128 - 0.065T$

PYCNOMETER CALIBRATION CHART

PYCNOMETER	CALIBRATION
1	$W_2 = 96.8128-0.0065T$
2	$W_2 = 130.3244-0.0251T$
3	$W_2 = 129.1254-0.0236T$

Where T = temperature of distilled water ^{o}C

W_2 = weight of pycnometer + water g

TABLE 1

SPECIFIC GRAVITY OF WATER AT TEMPERATURE T° AND CORRECTION FACTOR FOR 20° C

TEMPERATURE °C	SPECIFIC GRAVITY OF WATER	CORRECTION FACTOR
18.0	0.99862	1.0004
18.5	0.99852	1.0003
19.0	0.99843	1.0002
19.5	0.99833	1.0001
20.0	0.99823	1.0000
20.5	0.99813	0.9999
21.0	0.99802	0.9998
21.5	0.99791	0.9997
22.0	0.99780	0.9996
22.5	0.99768	0.9995
23.0	0.99756	0.9993
23.5	0.99744	0.9992
24.0	0.99732	0.9991
24.5	0.99720	0.9990
25.0	0.99707	0.9988
25.5	0.99694	0.9987
26.0	0.99681	0.9986
26.5	0.99668	0.9984
27.0	0.99654	0.9983
27.5	0.99640	0.9982
28.0	0.99626	0.9980
28.5	0.99611	0.9979
29.0	0.99597	0.9977
29.5	0.99582	0.9976
30.0	0.99567	0.9974

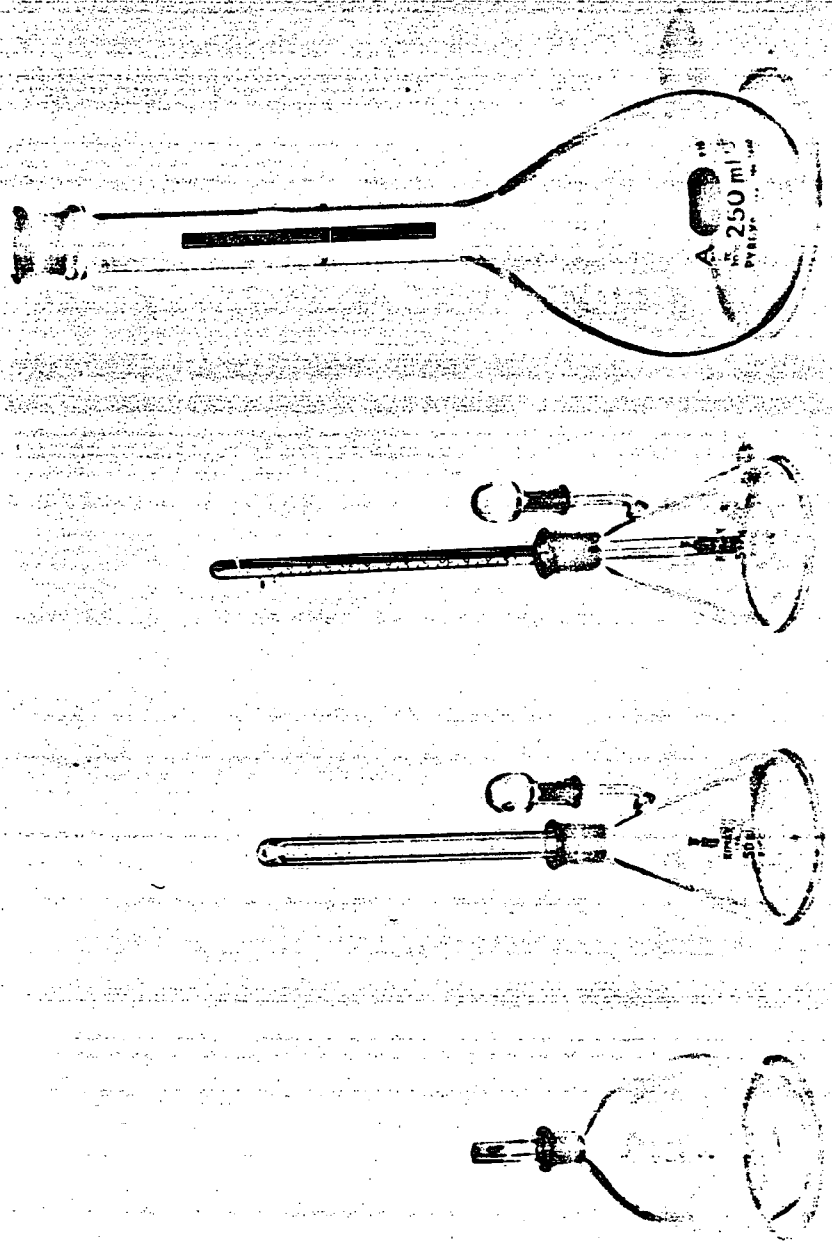

Figure 1 PYCNOMETER FLASKS

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FIGURE 2

SPECIFIC GRAVITY DETERMINATION
SEDIMENTOLOGY LABORATORY

SAMPLE NO. _____ DATE _____
SUBMITTED BY _____ TESTED BY _____
STUDY NO _____

DETERMINATION NO.	1	2	3
Flask No.			
Wt. Flask + Dry Sediment			
Wt. Flask			
Wt. Sediment (W_s)			
Wt. Flask + Water + Sediment (W_1)			
Temperature (T)			
Wt. Flask + Water (W_2)			
Specific Gravity of Water at T (G_T)			
Specific Gravity of Sediment (G_s)			

$$G_s = \frac{G_T W_s}{W_s - W_1 + W_2}$$

G_s = _____