METHOD A6

THE DETERMINATION OF THE GRAIN SIZE DISTRIBUTION IN SOILS BY MEANS OF A HYDROMETER

SCOPE

This method covers the quantitative determination of the distribution of particle sizes in soils. The distribution of particles sizes larger than 0,075 mm is determined by sieving, while the distribution of particle sizes smaller than 0,075mm is determined by a sedimentation process, based on Stokes' law defined here under, using a specially calibrated hydrometer. This method does not give absolute results, but gives data which are comparable and consistent if the method is followed in detail (see 5.1).

Stokes' law:

Stokes' law states that : Maximum grain diameter can be determined by :

$$d = \sqrt{\frac{300nL}{980(G - G_1)T}}$$

where

n = viscosity of the suspending medium in Pascal-seconds. The viscosity of distilled water at 20 EC is 0,001005 Pa.s.
L = the distance in centimetre through which the grains settle in a period of time, T.
T = time in minutes, period of sedimentation
G = relative density of soil particles
G_1 = relative density of suspending medium (which is 0,99823 tor water at 20 EC)

2 APPARATUS

2.1 A balance to weigh up to 200gram, accurate to 0,1 gram.

2.2 A canning lar, wide mouth, about 1000 ml capacity.

2.3 A Bouyoucos cylinder, graduated at 1130 and 1205 ml.

2.4 A Bouyoucos hydrometer (ASTM 152 H).

2.5 A dispersing apparatus with paddle as shown in Figure A6/l. The paddle is anached to a 120 to 150 mm shaft which is rotated (by an electric motor) at a rate of 1450 revolutions per minute. If such a disperser is not available an egg whisk with 4 vanes may be used.

2.6 A tablespoon.

2.7 A stop-watch.

2.8 A water-bath suitably lined or fitted with a thermostat unit to maintain a constant temperature of 20 + 1 EC.

2.9 A wash-bottle.

2.10 A dish or small bssin + 150 mm diameter.

2.11 A thermometer measuring 0-50EC graduated in 0 2 EC.

2.12 A pipette 10 ml capacity.

2.13 Sodium silicate solution to be prepared as follows:

Dissolve sodium silicate (preferably the waterglass solution) in distilled water until the solution gives a reading of 36 at 20 EC on the standard soil hydromebr. Filter the solution.

2.14 Sodium oxalate solution - this consists of a filtered saturated solution of sodium oxalate.

3 METHOD

3.1 Preparation of sample

100 gram accurate to 01gram (50 gram for samples containing a reasonably high percentage of the silt and clay fractions) of the soil fines as prepared in accordance with Method A1 is weighed out. The weighed sample is transferred to a canning jar and about 400 ml of distilled water (see 5.2) and 5 ml each of the sodium oxalate and sodium silicate solutions (see 5.3) are added. The soil water mixture is stirred well with a glass rod and left to stand tor at least two hours but preferably overnight. After the mixture has been allowed to stand, it is dispersed tor 15 minutes with the standard dispersing paddle or five minutes with the egg whisk. The paddle is washed clean with distilled water allowing the wash water to run into the container with suspension.

3.2 Filling the cylinder and correcting the temperature.

The suspension is poured into the Bouyoucos cylinder and the canning jar is rinsed with distilled water from the wash-bottle. All the suspension is transferred quantitatively to the cylinder. The cylinder is then filied with distilled water to the 1205 ml mark (1 130 for a 50 gram sample) with the hydrometer inside.
The hydrometer is removed, the cylinder inverted a few times, using the palm of the one hand as a stopper over the mouth of the cylinder to ensure that the temperature is uniform throughout. It is then placed in the thermostat bath which is kept as near to 20 EC as possible. When the contents of the cylinder are approximately at 20 EC (see 5.4), the cylinder is again shaken end over end until a homogenous suspension is obtained. The cylinder is returned to the water-bath and the time recorded. The water

in the bath should come to almost the top of the contents of the cylinder but should not be too high as it will then not be possible to read the hydrometer.

3.3 Hydrometer readings

Sixty minutes after the cylinder has been placed in the bath, the hydrometer is inserted and a reading is taken to the nearest 0,5. The temperature of the contents is also determined. The hydrometer is removed and the cylinder is shaken again as previously described. It is placed on a table and the stop-watch started. At about 20 seconds the hydrometer is inserted and a reading taken at 40 seconds.
An 18-second reading, if required, can also be taken in the same way as the 40-second reading, except that the hydrometer is inserted at about 10 seconds (see 5.5).
The temperature measured for the one hour reading is also taken as the temperature for the 40 and 18-second readings, provided the readings are taken immediately one after the other.
The hydrometer readings, taken to the nearest 0,5, and the temperature should be recorded on any suitable data sheet.

4 CALCULATIONS

4.1 The following table gives the maximum diameter of the particles which are accounted tor by the hydrometer after different time intervals (see 5.6).

Hydrometer Readings at	**Maximum diameter of particles in mm's**	**Common term**
18 seconds	0.075	Material passing the 0.075 sieve
40 seconds	0.05	Silt & Clay
1 hour	0.005	Clay

4.2 The following corrections should be applied to the hydrometer readings:

4.2.1 If the temperature of the suspension at the time of the hydrometer reading is not 20 EC, a correction should be made to the reading in accordance with the following table:

Temperature in Degrees Celsius	Correction
18.2 - 18.4	-0.6
18.5 - 18.7	-0.5
18.8 - 19.0	-0.4
19.1 - 19.3	-0.3
19.4 - 19.5	-0.2

19.6 - 19.8	-0.1
19.9 - 20.1	0.0
20.2 - 20.4	+0.1
20.5 - 20.6	_0.2
20.7 - 20.9	+0.3
21.0 - 21.2	+0.4
21.3 - 21.5	+0.5
21.6 - 21.8	+0.6

4.2.2 If a 50 gram sample is used, the readings must be doubled after the correction for temperature has been made. The rest of the calculations are then the same as set out below.

4.3 The material smaller than 0,075mm (18-second reading) is always expressed as a percentage of the total sample. The material smaller than 0,05 mm is expressed as a percentage of the total sample and also as a percentage of the soil mortar (i.e. the traction passing the 2,0mm sieve). The material smaller than 0,005 mm is only expressed as a percentage of the soil mortar.

4.4 The soil mortar is divided into four fractions viz.:

Coarse sand: passing 2,0 and retained on 0,425 mm sieve
Fine sand: passing 0,425 mm and retained on 0,05 mm sieve
Silt: passing 0,05 and retained on 0,005 mm sieve
Clay: passing 0,005 mm sieve

These fractions are expressed as percentages of the soil mortar and are calculated as follows:

4.4.1 Coarse sand

$$P_1 = \frac{(Sm - Sf)}{Sm} x100$$

where

P_1 = percentage coarse sand in the soil mortar
Sm = percentage soil mortar in total sample (determined in Method A1)
Sf = percentage soil fines in total sample (determined in Method A1)

4.4.2 Fine sand

The percentage fine sand in the soil fines is obtained by subtracting the reading obtained with the hydrometer at 40seconds from 100 (the mass of soil fines used for hydrometer analysis). The percentage of tine sand in the soil mortar can thus be

calculated as follows:

$$P_2 = \frac{Sf(100 - F)}{Sm}$$

where
P_2 = percentage of fine sand in soil mortar
F = 40-second hydrometer reading

4.4.3 Silt

The percentage of silt in the soil fines is obtained by subtracting the one-hour hydrometer reading trom the 40-second reading and the percentage of silt in the soil mortar can then be calculated as follows:

$$P_3 = \frac{Sf(F - C)}{Sm}$$

where

P_3 = percentage silt in the soil mortar
C = one-hour hydrometer reading

4.4.4 Clay
The percentage of clay in the soil mortar can be calculated trom:

$$P_4 = \frac{CxSf}{Sm}$$

where

P_4 = percentage of clay in the soil mortar

4.5 *Percentage of silt plus clay in the total sample*

This can be calculated from:

$$P_5 = Fx\frac{Sf}{100}$$

where

P_5 = percentage silt plus clay in total sample

4.6 *Percentage passing the 0,075mm sieve in the total sample*

This can be calculated from:

$$P_6 = Ex \frac{Sf}{100}$$

where

P_6 = percentage smaller than 0,075 mm
E = 18-second hydrometer reading

The calculations should be done to the nearest 0,1 and the percentage passing the 0,075 mm sieve and the soil mortar analysis reported on the A6/1 (or similar) Form.

5 NOTES

5.1 If absolute results are required the method given in ASTM Designation D442 should be used.

5.2 Demineralised water or clean rain-water and sometimes even tap water may be used instead of distilled water. If any water other than distilled or demineralised water is used it is necessary to carry out comparative tests with distilled water.

5.3 If the dispersing agents are being used up regularly and rapidly equal volumes of each may be premixed and 10ml of the mixture added instead of 5 ml of each agent.

5.4 A skilled operator will be able to make up the suspension in the cylinder so that the temperature is very near to the required 20 EC by using warm water and/or cold water when filling up the cylinder. It will then not be necessary to leave the cylinder with suspension in the water bath to acquire the right temperature. This procedure is in fact commonly followed.
In this respect, it must be emphasized, however, that if the temperature in the cylinder is slightly high, it is unsound practice to make the water bath slightly colder (or vice versa) in order to obtain more or less the correct temperature in the cylinder when the one-hour reading is taken. This means that the temperature in the cylinder is never constant during the settlement period. Furthermore, if the correct temperature cannot be obtained, it is better theoretically to have a slightly high temperature than a slightly low temperature.

5.5 The percentage passing the 0,075mm sieve which is obtained from the 18-second reading, can also be determined by wet sieving. The procedure is fully described in Method A5, which is considered to be a more accurate method. In case of dispute, Method A5 shall be regarded as the referee method.

5.6 The maximum particle sizes after 40 seconds and one hour are those given by Bouyoucos in his paper. The maximum particle size after 18 seconds has been obtained from Stokes' equations, assuming average test conditions as far as L and G are concerned.

5.7 The hydrometer method for determining particle size distribution as detailed above does not give absolute results, but does give data which are comparable and, provided the method is followed in detail, these data are consistent. The method is rapid and the calculations have been reduced to a minimum.

5.8 The hydrometer should be kept in a soap solutions (of about 10%) when not in use, as this removes all traces of grease which may be present through handling and which will result in wrong readings.

5.9 Calcareous materials and some materials containing soluble salts cannot always be tested, as the suspension becomes flocculated. If excessive flocculation occurs, the one-hour readings are not taken. Only the 40-second readings are taken.

REFERENCES

AASHTO Designation T88-51
ASTM Designation D422~3
Bouyoucos, G.J. *Directions for making mechanical analysis of soils by the hydrometer method*. Soil Science Vol. 42. 3 September 1936.

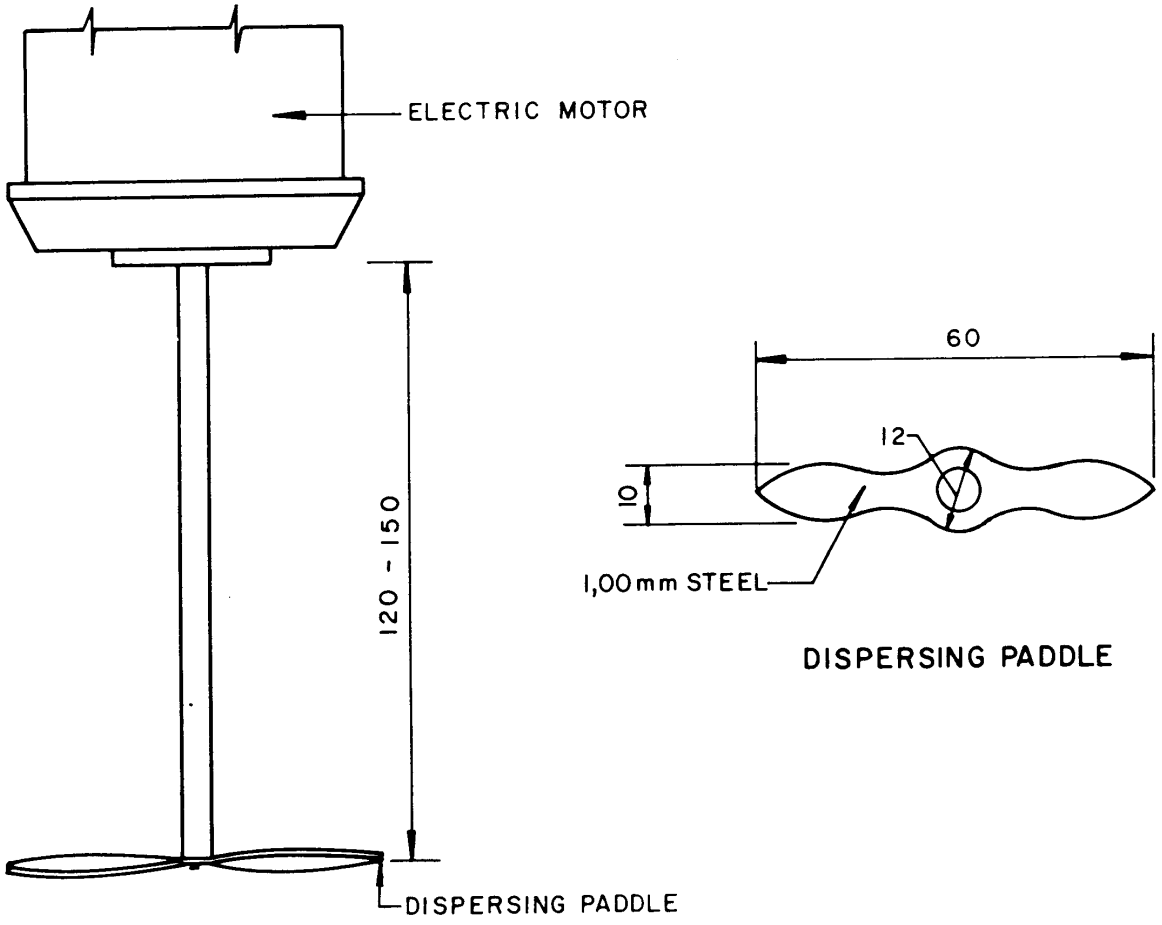

FIGURE A6/1

Dispersing apparatus

			SIEVE ANALYSIS / SIFONTLEDING											SOIL MORTAR ANALYSIS GRONDBINDSTOFONTLEDING				ATTERBERG CONSTANTS / -KONSTANTES		
SAMPLE NO. MONSTER NR.	DISTANCE AFSTAND (km) PEG NO. PEN NR.	DEPTH (mm) DIEPTE (mm)	PERCENTAGE PASSING SIEVES (mm) PERSENTASIE DEUR SIWWE (mm)											SAND		SILT SLIK	CLAY KLEI	LIQUID LIMIT VLOEIGRENS	PLASTICITY INDEX PLASTISITEITSINDEKS	LINEAR SHRINKAGE LINEÊRE KRIMPING
			63,0 mm	53,0 mm	37,5 mm	26,5 mm	19,0 mm	13,2 mm	4,75 mm	2,0 mm	0,425 mm	0,075 mm	0,05 mm	COARSE GROF <2,0 >0,425 mm	FINE FYN <0,425 >0,05 mm	<0,05 >0,005 mm	<0,005 mm			

FORM A6/1

Data sheet for sieve analysis (hydrometer) and Atterberg constants