DEVICE FOR MEASURING SUBSIEVE SIZES IN THE FIELD

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A device for measuring percentage finer by weight of subsieve sizes in the field is described. The device measures the specific gravity of a soil-water dispersion with a small hydrometer (called a urinometer) inside a plexiglass tube. To determine the percentage finer than a certain size, the dispersion is sampled at a predetermined depth and time after mixing, and the specific gravity of the sample is measured. Results using the new device agreed with results using the standard ASTM hydrometer technique. Graphs for four nonplastic soils are presented showing typical comparisons of particle size distributions measured by both techniques. Application of the device to decrease the time required for wet sieving is discussed. Possible modification of procedures when using the device for plastic soils is noted.

•MONITORING particle size distribution of soils used for construction often requires information on the amount of particles finer than a subsieve size. For example, in a region subject to frost, information on the percentage finer by weight than 0.02 mm may be desired as an indicator of the susceptibility of a soil to frost heave. The standard method of making subsieve measurements requires equipment not well suited for use in the field.

In the technique described here, a small hydrometer is used in a device that can be easily handled in the field. This technique was designed to make measurements of the percentage finer than one or two subsieve sizes in the field. The technique can also be used in the laboratory to decrease the time required for wet sieving.

DESCRIPTION OF THE FIELD HYDROMETER DEVICE

The basic apparatus used in the test has two main components: a field hydrometer device and a 1-gallon widemouthed, polyethylene bottle. The field hydrometer device (FHD), shown in Figure 1, consists of a small hydrometer, sold commercially as a urinometer, inside a plexiglass tube. Attached to the bottom of the plexiglass tube is a glass stem having horizontal openings for withdrawing a sample of dispersion. The stem is made from 6-mm tubing. At the upper end of the plexiglass tube is attached a rubber bulb that allows the correct amount of suspension to be withdrawn and held within the chamber while the hydrometer is read. A plastic screen is placed in the tube above the stem to allow the flow of dispersion into and out of the chamber without any hindrance from the urinometer. The openings in the screen are about 5 mm wide.

To make the dispersion, approximately 450 g of soil are weighed and then mixed in the polyethylene bottle with 3,000 cc of water containing a suitable dispersant. At the appropriate time after mixing, the stem of the FHD is inserted into the soil-water dispersion to a predetermined depth and a sample of the dispersion extracted. The specific gravity of the extracted sample is read on the hydrometer, and the percentage of the sample finer by weight is computed in the usual way (6). The particle size of interest fixes the time and depth at which measurement is made and can be computed by Stoke's Law (p. 329, 5). The plexiglass tube has an inside diameter just slightly

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larger than that of the urinometer. This allows a measurement to be made with a minimum amount of suspension being withdrawn. The scale on the urinometer used in the tests described here measures specific gravities from 1.000 to 1.020. Commercial urinometers are also available to measure specific gravities from 1.020 to 1.040 and from 1.000 to 1.060.

DESIGN CONSIDERATIONS

Several features of this technique have been adopted from recommended procedures and methods previously published (1, 2, 6; 7, p. 386). The basic techniques are from the Andreason pipette method (2) and the standard ASTM method for soils passing the No. 200 sieve (3, 4). Hydrometers have been used for many years to determine the subsieve size gradation in soils. The standard method requires a large hydrometer, which is difficult to use when making a measurement in the field. When using the Andreason pipette method of particle size analysis, a portion of the dispersion is extracted from a measured depth and the amount of solids determined, usually by drying (2). Because of the great amount of water in the sample, this method is time-consuming. The method using the FHD combines the feature of extracting a portion of dispersion by utilizing a pipette, with a more rapid determination of solid content by the hydrometer.

Other investigators have reported that a horizontal withdrawal of the sample may give different results than a vertical withdrawal (2). Both of these stem types were tried, and their results were compared. No discernible differences in results were noted.

The specific gravity of the dispersion changes rapidly near the top surface. If the sample is withdrawn too close to the surface of the dispersion, the measurement will be in error. Each measurement required 40 cc of dispersion. The extreme possible shapes of a sampled volume are shown in Figure 2. The configuration shown in Figure 2b is a thin disk-shaped volume proposed by Heywood (2) and indicates a thickness of 0.6 cm for the sampled volume. The other extreme of sampled volumes is the spheres shown in Figure 2a. The spheres have a diameter of 1.79 cm. The shapes of actual sampled volumes probably fall between these two extremes. To ensure good resolution of particle size, the thickness of the sampling zone must not exceed one-sixth of the mean depth (2). The case of spherical sampled volumes was assumed, and the depth of sample withdrawal was set at 11.7 cm for the tests reported here. The total depth of dispersion in the polyethylene jug is about 17 cm. At a depth of 11.7 cm, the sampled volumes are not influenced by sediment on the bottom.

This depth of sampling proved to be a convenient one. A dispersion sample from the depth of 11.7 cm, taken 5 min after mixing shows the percentage finer than 0.02 mm, when the temperature is 20 C, and the specific gravity of the soil solids is 2.7. By sampling at this depth, the distributions of subsieve sizes were determined in shorter times than by standard methods.

Rapid sampling is also not recommended because preferential sampling may result. Small particles outside the sampling zone may be drawn in because of their lower inertia. Allen (2) mentions Johnson's experiments; however, Allen varied the sampling times between 12 and 140 sec. Johnson recommends a sampling time of about 20 sec. The "quick" test sampling time is about 10 sec, which is felt to be sufficient considering the small amount of dispersion withdrawn. The final verification of the technique is the comparison of the results using the FHD method with those using the ASTM method (3).

VERIFICATION OF FHD RESULTS

The object of the laboratory tests was to show that the FHD gives results comparable to the standard ASTM hydrometer technique. Comparison of results from the two techniques required identical soil samples. For purposes of verification, it was decided, therefore, to use only the soil passing the No. 10 sieve as recommended by the ASTM procedures (3). The particle size distributions of 13 soils were measured by both the FHD device and the standard ASTM hydrometer technique. The soils were limited to

types that might be used in highway construction in Connecticut and showed little or no plasticity.

Sodium pyrophosphate was selected as the dispersant to be used in the tests. Trials using various concentrations of dispersant indicated that a 0.5 percent solution was adequate to disperse the particles.

The recommended ASTM procedures are designed to be adequate for a broad spectrum of soils. Part of the experimental verification of the FHD was to determine which parts of the standard procedures could be shortened to save time in the field. The steps that required checking when the FHD is used with plastic soils are covered in the following discussion.

Experimental Procedure

Sample Preparation—Each soil was air-dried and then split with a No. 10 sieve. Of the soil passing the No. 10 sieve, two representative samples were removed. One sample was tested in accordance with the ASTM Tentative Method for Grain-Size Analysis of soils (3). The other was tested with the FHD. Hydroscopic moisture was determined by drying a sample in an oven at 105 C for 12 hours. Specific gravity of solids was determined for each soil by using the ASTM procedure (3).

Testing the FHD—Approximately 450 g of air-dried soil weighed to 0.1 g were added to 3 liters of dispersing solution in the polyethylene bottle. A series of measurements was run, with the soaking time for the soil varied from 10 min to 24 hours. The soil was dispersed in the solution by end-over-end mixing for 1 min. No differences in measurements could be ascertained for the tested soils between the shorter and longer soaking times with the FHD, and the results agreed with standard hydrometer method. The minimum soaking time for the FHD was taken as 20 min on the basis of these results. During the soaking time the dispersion was mixed end over end twice. The specific gravity of the dispersing solution was checked with the FHD before each measurement. The hydrometer was always read at the top of the miniscus. Time was measured from the end of mixing. The stem of the FHD was marked with a piece of tape 11.7 cm above the center of the horizontal openings, and all measurements were made at this depth.

With a dispersion of 450 g of soil and 3,000 cc of deflocculant, the polyethylene bottle is about three-quarters full. This allows the dispersion to be easily mixed. The dispersion and bottle weigh less than 8 lb and can be easily handled.

A series of tests was run to determine the percentage finer curve for each soil for sizes ranging from the No. 200 sieve to clay. The FHD disrupts the dispersion with each measurement. As a result the sample withdrawn was replaced after each measurement, and the entire dispersion was remixed for 1 min and the timing begun for the next measurement. Time from mixing to measure at a depth of 11.7 cm was computed for each desired particle size.

RESULTS AND DISCUSSION

Typical results for the particle size distributions measured by each of the two methods are compared in Figures 3 through 6. The graphs shown are for the tested samples having the greatest and least amounts passing the No. 200 sieve. Two intermediate samples are also shown. The results shown in these figures, which are typical of all soils tested, indicate that the two techniques produce essentially the same curve for each soil. The results are reported as percentages finer by weight based on a wet-sieve analysis of the total sample.

The data of each curve seem to diverge a little above the 0.05-mm size or a Reynolds number of 0.10. A possible reason for the divergence of test data may be counterflow. This phenomenon is most pronounced at short times after mixing when a large quantity of particles are settling out of suspension. While they are moving downward, the volume of water that they displace is rushing upward. The resulting particle velocity is somewhat less than that calculated by Stokes' equation. Retardation due to counterflow occurs for a longer period in the hydrometer jar than in the polyethylene bottle for the field test.

Figure 1. Field hydrometer device.

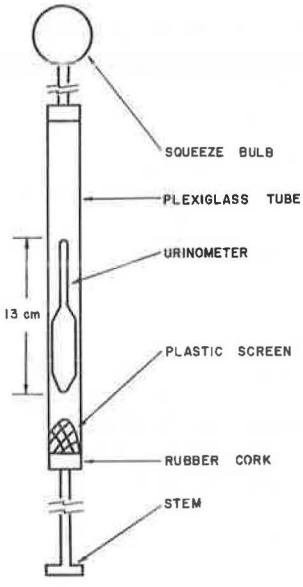


Figure 2. Extreme possibilities of sampled volume shapes.

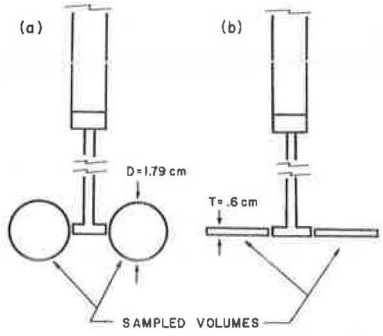


Figure 3. Distribution of particles smaller than the No. 200 sieve from silty sand No. 1 (USCS SM).

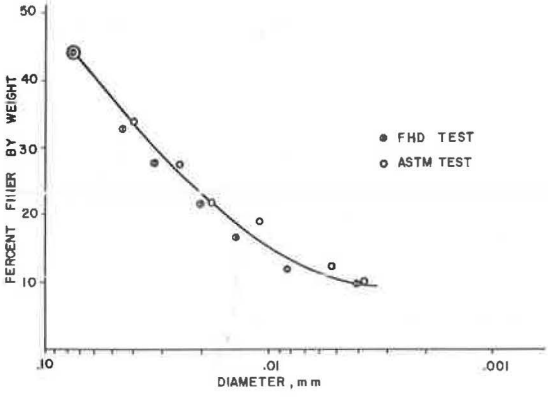


Figure 4. Distribution of particles smaller than the No. 200 sieve from a silt (USCS ML).

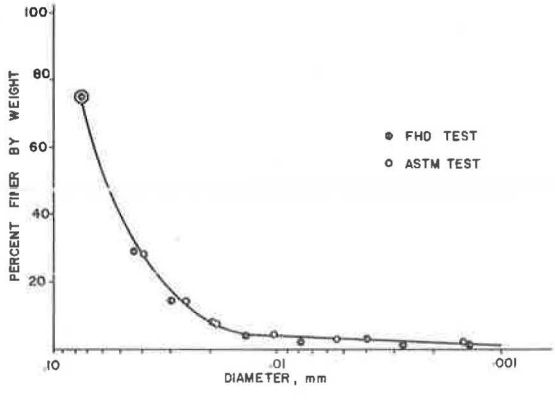


Figure 5. Distribution of particles smaller than the No. 200 sieve from silty sand No. 2 (USCS SM).

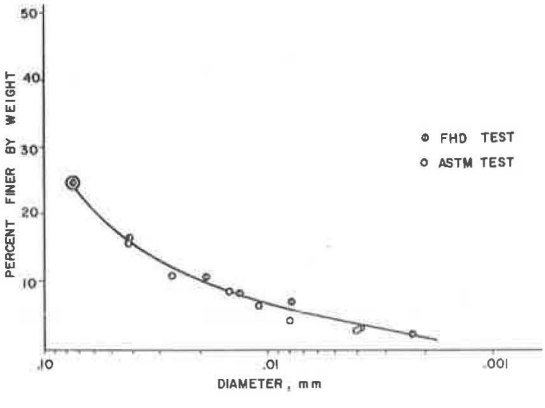
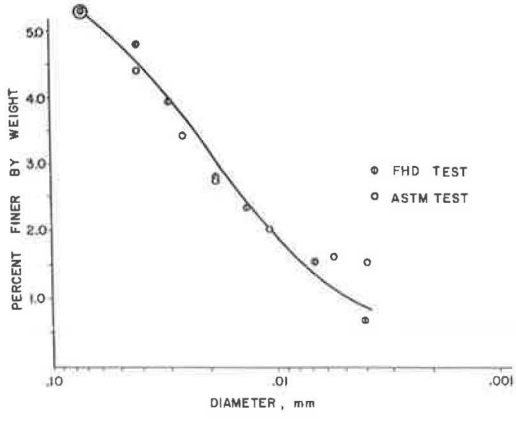


Figure 6. Distribution of particles smaller than the No. 200 sieve from a well-graded sand (USCS SW).



Another source of error is the small amount of dispersion from near the surface that is trapped in the stem of the FHD when it is submerged. This error tends to lower slightly the "percentage finer than" as measured by the FHD.

The scale of the urinometer inside the FHD is smaller and, therefore, less precise than the larger ASTM hydrometer. This difficulty may also account for some of the divergence shown in the curves.

When making each measurement, the specific gravity of the sodium pyrophosphate solution must be determined. An error of 0.001 in the reading of the specific gravity of the deflocculant solution will affect the percentage finer determination of the soil suspension. This error would be largest for soils with small amounts passing the No. 200 sieve. All readings with the FHD must be made carefully. The experimental results show that the FHD used properly produces the same particle size distribution curve as the larger hydrometer.

When using the FHD with plastic soils, the most important items to check are the soaking and mixing times. For the tests reported here, short soaking times and little mixing were required. Both of these may have to be increased for plastic soils. Use of a mortar and pestle to break up aggregations of particles might be helpful for plastic soils.

USE OF THE FHD IN THE FIELD AND FOR WET SIEVING

Splitting a field sample on the No. 10 sieve may be difficult. Perhaps a better sieve for field use would be a No. 4. The sample passing the No. 4 sieve could be mixed with deflocculant solution in the polyethylene bottle. The Bureau of Reclamation (7) has used hydrometer tests to measure soil passing a sieve of about the same size.

Use of the FHD in the field requires equipment in addition to the polyethylene bottle. A balance to weigh the sample and some means of drying the soil are needed. Other accessories, such as bowls and thermometers, are also required. Perhaps the best way to include all the necessary equipment in a kit for the field is to run one test outdoors near the laboratory and bring out equipment as needed until the test can be made. Then a list of all the items can be made. In the process of checking the FHD, one test was run outdoors with a minimum of equipment.

A complete wet-sieve analysis can be made by treating the soil in three ranges: the portion retained on the No. 4 sieve, the portion passing the No. 4 but retained on the No. 200 sieve, and the portion passing the No. 200 sieve.

The analysis of the particles finer than the No. 200 sieve is made using the portion passing the No. 4 sieve in the polyethylene bottle and the FHD, as previously described. In many instances information on one subsieve particle size will be sufficient. After determining this information by using the FHD, the next step is to wash all the soil contained in the polyethylene bottle on a No. 200 sieve so that the finer particles will pass through. To facilitate the washing, the sample in the jar is again mixed and immediately poured over the sieve. The mixing action suspends the fine particles that, once the dispersion is poured, will reach the sieve first and proceed through with little resistance. The last particles of soil in the jar will tend to cling to the sides. These particles can be washed out and onto the sieve with a standard laboratory wash bottle. After all the particles are on the sieve, tap water should run over the soil, and the sieve should be agitated lightly by hand until the water coming through the sieve is clean. The soil particles remaining on the sieve are those passing the No. 4 sieve but retained on the No. 200 sieve. The No. 200 sieve and the soil contained on it should be dried and weighed to determine the amount of the total sample in each of the two size ranges. The portion passing the No. 4 but retained on the No. 200 sieve may now be sieved to determine the distribution of sizes in this range. The portion of the soil retained on the No. 4 sieve can also be analyzed after drying, by using a nest of sieves having openings larger than the No. 4 size, to determine the distribution of sizes in this range.

CONCLUSIONS

The report data substantiate the following conclusions:

1. The FHD gives particle size distribution curves comparable to those from the standard ASTM hydrometer procedure, and
2. The technique can be used in the field to monitor subsieve sizes of soil or in the laboratory to decrease the amount of time required for a wet-sieve analysis.

ACKNOWLEDGMENT

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