**Objective:**

To obtain an approximate particle size distribution of soil passing sieve #200 by using the hydrometer method.

**General discussion:**

The hydrometer method is used to approximate the particle size distribution for particles that passes sieve #200. The need of this test arises when more than 12% of the soil specimen is finer than sieve #200, as under this case the soil can’t be classified under any classification, so the hydrometer test is held as an extension to the sieve analysis to make us able to classify the soil.

The hydrometer device is used originally to measure the specific gravity of solution; it is calibrated starting from zero at the upper part so that the higher the density is for a solution the higher the hydrometer will flow and the higher the reading it will provide. One more important thing that should be known about hydrometer is that it reads the density of the solution at the center of its bulb.

In the test of particle size analysis a correction to the obtained reading “Rh’ ” must be applied due to the meniscus of the water surface, the reading shall be obtained from the bottom of the meniscus but that is not possible because of the uncleanness of the suspension. So by placing the hydrometer in a clean water in the control jar, the error value can be obtained “Mc” and then the corrected value of the reading is:

*But this device was related to stocks law to be used in particles size analysis of a soil sample.*
Stocks law relates velocity of falling spheres in a fluid to their diameters.

This relation depends on several constants related to the solid and the fluid, and it takes the formula:

All the constants can be dealt with as one constant “B”:

The range of diameters this relation can be applied to is:

\[ 0.002 < D < 0.2 \text{ mm} \]

and this is the reason why the hydrometer test is only held on particles finer than sieve #200.

The existence of larger particles will cause:

- Excessive fluid turbulence.
- Brownian movement (attraction and repulsion) to the finer particles.

The main problem is to relate stocks law to hydrometer measurements. From Stocks law it is obvious that the constant B can be measured in the laboratory, but the velocity is measure by using the hydrometer and utilizing the formula:

Obviously the main problem is to find “L” in the previous equation, and as the hydrometer gives specific gravity reading “Rh”, “L” which is denoted as “HR” must be related to “Rh”. This is done by drawing the Calibration graph which has the X-axis as Rh and the Y-axis as HR.
Drawing the calibration graph:

These is done by taking any arbitrary 2 points on the hydrometer, and draw a straight line between them on the graph as the relationship between “Rh” and “HR” is linear.
But after measuring the distance “HR” on the hydrometer, an error distance shall be subtracted from it; this error is due to the rise in the level of water due to the volume of the hydrometer.
This distance of rise is calculated as follows:
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This distance shall be subtracted as soil particle never travels this distance and including it in calculations will be a source of error.
The corresponding “HR” to the arbitrary “Rh” is calculated as follows;
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Note that the calibration graph depends only on the geometry of the hydrometer.

From the calibration graph, “HR” values at different times are obtained and then can be used in the Nomographic chart of Stocks law to determine the values of “D”.
These diameters are dealt with as sieves and take the X-axis on the distribution chart.
The percent passing “K%” is obtained by using the formula:
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The obtained particle distribution curve is combined with the distribution curve obtained from the sieve analysis by multiplying “K%” with the percent passing from #200 sieve.
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**Dispersing soil sample:**

As clays are very cohesive they tend to gather in flocks, this will cause the particle size analysis to indicate coarser particle distributions. For that reason; a process of particle dispersion shall be held on soil samples. (Neutralizing particles charges) The choice of the dispersion agent depends on:

1- Soil type.
2- Trial tests.

In our experiment we used two dispersion agents, Sodium hexametaphosphate (NaPo3) which is acidic solution that is useful for dispersing alkali soil, and Sodium carbonate (Na2Co3) alkali solution that is useful for dispersing acidic soil. In general clay soils are alkaline but it may move toward acidic solution due to the presence of certain salts or other impurities, and that’s why we used a combination of the 2 agents.

**Sample identification:**

Dark brown clay specimen.

**Equipments:**

- Sedimentation cylinder of 1000mL capacity (Hydrometer jar).
- Control jar; a cylinder of 1000mL capacity.
- Magnetic stirrer; as a dispersion device.
• Dispersion agents; Sodium hexametaphosphate (NaPo$_3$) and Sodium carbonate (Na$_2$Co$_3$).

• Thermometer.

• Hydrometer.

**Procedures:**

1. Making the dispersing solution by adding 33g of NaPo$_3$ and 7g of Na$_2$Co$_3$ to 1 liter of water so that we obtain a solution of condensation $= 0.004$.

2. Weigh 25g of the oven dry soil previously washed through sieve #200.

3. Mix the sample with the dispersing solution and place them on the magnetic stirrer for about 1 hour.

4. The clay is moved to the sedimentation cylinder which contains water slightly less than 1000mL to allow for excess water used in washing the dispersing cup and the sides of the sedimentation cylinder.

5. Cap the cylinder and agitate for about one minute, agitation is defined as turning the cylinder upside down and back movement in 2 turns.

6. The sedimentation cylinder is then placed on the table, un capped and the hydrometer is placed in it. Reading shall be taken on times written on the sheet of calculation. After obtaining the four minutes reading, the hydrometer shall be cleaned in the control jar as the clay particle stuck to it will increase its weight.

7. The temperature of the suspension is measured by the thermometer.
Discussion and results:

The obtained results from the Nomographic chart are reasonable as the diameter decreases with time; this indicates that with time the larger particles (Heavier) sink first to the center of the bulb. But the first obtained diameter which was 0.1mm, was not satisfactory as we worked on a sample which was assumed to pass sieve #200 (0.075mm), this indicates that we have used 2 different soils in our analysis. This result cased a problem in the combination of the sieve analysis curve to the hydrometer analysis curve.

The soil analyzed can be classified by USC system as SC (Sand with clay): as 93% passed sieve #4 the soil is classified as sand, and as the fines are larger than 12% then is considered as Clay sand SC. From the values of $C_u$ and $C_c$ that the soils is poorly graded as $C_c < 1$

Sources of error:

1. Errors resulted from using stocks law.
   - Soil particles are not spheres
   - The fluid is not of infinite extent
   - The specific gravity of individual particles may vary
   - Turbulence caused by larger particles falling
   - Brownian movement of smaller particles
   - Disturbance due to insertion and removal of hydrometer
2. Errors of mistakes.  
The watch has stopped while making the experiment, and we had to assume new timing as we haven’t recorded the starting time.