Effect of Concentration of Dispersing Agent on the Grain Size Distribution of Fine Grained Soil

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ABSTRACT

The particle size of fine grained soil has been shown to have significant effect on the permeability, shear strength and consolidation behavior of soil. Thus the measurement of particle size distribution is of importance in geotechnical engineering. Hydrometer analysis is the most widely used technique for the analysis of fine grained soil. Dispersing agents are added in the analysis to increase the interparticle repulsion and thereby decrease the tendency of particle flocculation during sedimentation. Study has been conducted to evaluate the effect of concentration of dispersing agent on hydrometer analysis. It has been observed that the result varied significantly with change in concentration of the dispersing agent. An attempt has been made to optimize the concentration of the dispersing agent to be added in the analysis to obtain maximum dispersion. The result obtained is not in accordance with the Indian Standard Specifications.

1. INTRODUCTION

The particle size analysis is a method of separation of soils into different fractions based on the sizes of particles present in soil. The different fraction of soil is shown graphically on a particle size distribution curve. The particle size analysis maybe sieve analysis or sedimentation analysis. Sieve analysis is used to separate the coarse grained fraction of soil, i.e. the fraction of soil whose particle size is greater than 75 micron. Sedimentation analysis, which is based on the principles of dispersion and sedimentation, is used for the analysis of fine grained soil (silt and clay) whose particle size is less than 75 micron. Sedimentation analysis is performed either by pipette method or by hydrometer analysis (Arora, 2003)

Stoke’s law forms the basis of sedimentation analysis, according to which the velocity of free fall of grains is directly proportional to the square of particle’s diameter. The expression used to determine the particle diameter in sedimentation analysis is based on this settling velocity. Hence the individual soil particles must be dispersed to enable the determination of particle size distribution accurately. However, the finer grains of soil carry charges on their surface and hence have a tendency to form flocs. Thus if the floc formation is not prevented the grain diameter obtained would be the diameter of flocs and not of the individual grain (Ranjan, 1991). Hence in sedimentation analysis, deflocculating agents are to be added.

Dispersing agents can either act as a protective colloid on the solid particle or alter the electrical charge on the particle to prevent the formation of flocs (Sridharan et al., 1991). Sodium hexametaphosphate, sodium oxalate, sodium silicate etc are some of the most commonly used dispersing agents. The British Standard recommends 35g of sodium hexametaphosphate with 7g of sodium carbonate along with distilled water to make 1 litre of standard solution. The Indian Standard Code of Practice (IS 2720-Part IV) recommends 33g of sodium hexametaphosphate with 7g of sodium carbonate in distilled water to make 1 litre of standard solution. Both codes recommend 100ml of this standard solution for each experiment. ASTM Standard Method of Particle Size Analysis (D422-ASTM 1965) suggests that 125 ml of solution of sodium hexametaphosphate shall be used in distilled water at the rate of 40g of sodium hexametaphosphate per litre of solution. In the study conducted by Sridharan et al (1991), it was seen that the clay fraction obtained as a result of hydrometer analysis varied from 4% to 45% depending upon the type of dispersing agent added. Also they had found out that mixture of sodium hexametaphosphate and sodium carbonate gave the maximum percent clay size. In another study (Sachan et
al., 2008), it was seen that greater clay fraction was obtained on increasing concentration of the dispersing agent added i.e. sodium hexametaphosphate alone. This indicated the breaking of the group of particles and separating the clay platelets from each other due to the effect of dispersing agent. In the study conducted by Nettleship et al. (1997) hydrometer analysis was conducted by using two dispersing agents i.e. sodium hexametaphosphate and mixture of sodium triphosphate and sodium carbonate. Here better dispersion was obtained when sodium triphosphate and sodium carbonate mixture was the dispersing agent. The objective of the present study is to determine the effect of concentration of dispersing agent on the dispersing of clay particles. Also a comparison is made between the dispersing agents sodium hexametaphosphate and mixture of sodium hexametaphosphate and sodium carbonate. An attempt has been made to reach the optimum concentration of dispersing agent.

2. MATERIALS AND METHOD

Clay samples used were Kaolinite, Kuttanad clay and Calcium Bentonite. The dispersing agents used were Sodium Hexametaphosphate (NaHMP) and mixture of Sodium Hexametaphosphate and Sodium Carbonate (NaHMP + Na$_2$CO$_3$). 2%, 4%, 6%, 8% solution of the above chemicals was prepared by mixing the required quantity in 1000ml of distilled water. The quantities of chemicals added for preparation of the solution are given in Table 1 and 2.

<table>
<thead>
<tr>
<th>Solution Concentration (%)</th>
<th>Quantity of NaHMP Added (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>20</td>
</tr>
<tr>
<td>4</td>
<td>40</td>
</tr>
<tr>
<td>6</td>
<td>60</td>
</tr>
<tr>
<td>8</td>
<td>80</td>
</tr>
</tbody>
</table>

Table 2. Quantity of Chemicals Added to 1000ml Distilled Water for Preparation of NaHMP + Na$_2$CO$_3$ Solution

<table>
<thead>
<tr>
<th>Solution Concentration (%)</th>
<th>Quantity of NaHMP Added (g)</th>
<th>Quantity of Na$_2$CO$_3$ added (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>13</td>
<td>7</td>
</tr>
<tr>
<td>4</td>
<td>33</td>
<td>7</td>
</tr>
<tr>
<td>6</td>
<td>53</td>
<td>7</td>
</tr>
<tr>
<td>8</td>
<td>73</td>
<td>7</td>
</tr>
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</table>

Two test set ups were adopted. In the first set up hydrometer analysis was conducted in clay sample by adding 100ml of each concentration mentioned above of the dispersing agents. In the first set up hydrometer analysis was conducted in clay sample by adding 100ml of each concentration mentioned above of the dispersing agents. About 50g of the clay sample passing through 75 micron sieve was mixed with 100ml of dispersing agent. The mixture was then transferred to the cup of mechanical stirrer. Distilled water was added to make the cup about three fourth full. The suspension was stirred about 15 minutes. After mixing, the suspension was washed into a 1000ml jar and enough water added to make 1000ml suspension. The rubber bung was placed on the open end of the cylinder containing the soil suspension. The cylinder was shaken vigorously to end over end to mix the suspension thoroughly. The bung was removed after the shaking was completed. Immediately after bringing the cylinder to vertical position, the stop watch was started. Hydrometer was inserted and readings were taken after 0.5,1,2,4 minutes without removing hydrometer from the cylinder. The hydrometer was then taken out and rinsed with distilled water. The hydrometer was then allowed to float in another cylinder containing distilled water. The hydrometer was then inserted into the suspension when the total elapsed time is 8 minutes. Reading was noted and hydrometer was removed and placed in distilled water. This was repeated for taking readings when elapsed time is 15 minutes, 30 minutes, 1 hour, 2 hours, 4 hours and 24 hours. Meniscus correction and dispersing agent corrections were applied to the readings.

The calibration curve is plotted. Mean diameter and percentage finer are obtained using the equation 1 and 2 respectively.

\[
D = \sqrt{(0.3H_e/g(G-1)p_w t)}
\]

\[
N = (GxR/(G-1)xMs)) \times 100
\]

Where, N = percentage finer,

D = mean diameter in cm,

\(\eta\) = viscosity in poise (0.01 poise),

\(H_e\) = effective length in cm,

g = acceleration due to gravity = 981 cm/s$^2$,

G = specific gravity of the sample,

\(\rho_w\) = unit weight of water = 1 gm/cc,

t = time in minutes,

R = corrected hydrometer reading,

Ms = weight of sample taken in gm,

The percentage clay content present in each sample was obtained from the particle size distribution curve obtained.

In the second set up hydrometer analysis was conducted by varying the volume of dispersing agent added. In this test setup the dispersing agents added were 4% NaHMP+Na$_2$CO$_3$ and 6% NaHMP+Na$_2$CO$_3$. 50ml, 75ml, 100ml, 125ml, 150ml and 200ml of the dispersing agents were added for each hydrometer test conducted and the percentage clay fraction obtained was compared. The tests which gave optimum concentration were repeated to check if consistent results are obtained. The test setup is as shown in figure 1.
The percentage clay content present in each sample was obtained from the particle size distribution curve obtained. In the second set up hydrometer analysis was conducted by varying the volume of dispersing agent added. In this test setup the dispersing agents added were 4% NaHMP+Na$_2$CO$_3$ and 6% NaHMP+Na$_2$CO$_3$. 50ml, 75ml, 100ml, 125ml, 150ml and 200ml of the dispersing agents were added for each hydrometer test conducted and the percentage clay fraction obtained was compared. The tests which gave optimum concentration were repeated to check if consistent results are obtained.

3. RESULTS AND DISCUSSION

Test Set Up 1
In this set up the volume of dispersing agent added was kept constant, i.e. 100ml. In the test conducted in kaolinite clay using varying concentration of NaHMP maximum clay content was obtained when 6% dispersing agent was added. When 6% NaHMP+Na$_2$CO$_3$ mixture was used better dispersion was obtained. This is indicated by the clay fraction of 78% which was obtained in the corresponding test. When the test was conducted in Kuttanad clay the clay fraction obtained was maximum when using 6% NaHMP+Na$_2$CO$_3$ mixture. A clay content of 38% was obtained for the test. As the first two clay samples gave maximum dispersion when using 6% NaHMP + Na$_2$CO$_3$ mixture the test in calcium bentonite used only NaHMP + Na$_2$CO$_3$ mixture as dispersing agent. Maximum clay content of 78% was obtained when the concentration of dispersion agent used was 6%. In all these cases a decrease in clay content was observed when the concentration was increased beyond 6%. This decrease might be due to saturation adsorption of the dispersants on to the clay particles after which aggregation of particles might occur. The test results are represented in Figure 2.

Test Set Up 2
Hydrometer analysis was conducted in kaolinite clay by using varying volumes of mixture of NaHMP and Na$_2$CO$_3$. The concentration of dispersing agent added in this test were 4% and 6%. Figure 3 represent the result obtained. Maximum dispersion was observed when the dispersing agent used was 100ml of 6% solution. The clay content obtained in the test was 72%.

4. CONCLUSIONS

The following conclusions were drawn from the study conducted:

It has been observed that addition of Na$_2$CO$_3$ has improved the dispersing capacity of NaHMP.

The optimum concentration of dispersing agent was found to be 100 ml of 6% mixture of NaHMP and Na$_2$CO$_3$, i.e. the mixture prepared by dissolving 53g of NaHMP and 7g of Na$_2$CO$_3$ in 1000ml of distilled water. This is not in accordance with the IS specification.

There is significant decrease in dispersion on further increasing the concentration as well as volume of dispersing agent.
agent added. This indicates that after a particular concentration there would be saturation adsorption of the dispersants on to the clay particles after which aggregation of particles might occur.

REFERENCES


