AMENDED The effect of type, concentration and volume of dispersing agent on the magnitude of the clay content determined by the hydrometer analysis

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ABSTRACT: Knowledge of the physical properties of soils, including the clay content, is of utmost importance in the field of Geotechnical Engineering. The hydrometer analysis is the most widely used technique for the analysis of the particle size distribution of the fine grained fraction of a soil, calculated using sedimentation principles. The hydrometer analysis utilizes a dispersing agent. Calgon 33:7 (comprising 33 grams of sodium hexametaphosphate and 7 grams of sodium carbonate when mixed in 1 litre of water) is universally considered as the most effective dispersing agent.

In this investigation, hydrometer analyses were conducted (according to the TMH1 1986 method) on two soils (alluvium and black clay), using five dispersing agents. The results show that the clay size fraction can vary significantly (from 1 % to 32 %) for the two soils, depending upon the dispersing agent used. From these initial results, the two most effective dispersing agents (Calgon and sodium pyrophosphate decahydrate – NaPP) were investigated further to establish the optimum concentration and volume.

Calgon proved to be the most effective in the alluvial soil increasing the clay content by 38%. The NaPP was most effective in the relatively active black soil increasing the clay content by 25%.

KEYWORDS: Grain-size analysis, Hydrometer tests, Dispersing agents, Concentration, Volume.

INTRODUCTION

The determination of the particle size distribution of a soil, including the clay content, is one of the most problematic areas in geotechnical engineering testing. The particle size analysis is a method of separating soils into different fractions based on the sizes of particles present in the soil. The particle size analysis is divided into two categories (coarse and fine) with associated laboratory test methods. A sieve analysis is used to separate the coarse grained fraction of soil, i.e. the fraction of soil with particle sizes greater than 425 microns. On the other hand, sedimentation analysis, which is based on the principles of dispersion and sedimentation, is used for the analysis of the fine grained fraction of the soil, such as silt and clay whose particle size is less than 75 microns. Analysis of these fine grained soils is done either by the pipette method or by the hydrometer method (Arora, 2003).

Since the clay content of a soil is used to determine its activity, which in turn is used for design purposes, it is very important to accurately determine the clay content of soils. Inaccurate clay content determinations have resulted in inappropriate design solutions which have even led to unacceptable damage to the structures. In South Africa, there is a problem with the accurate determination of the clay content of soils. This problem, which was formally expressed by Jacobsz and Day (2008), reinforces the need for research into all of the variables of the hydrometer test with a view to improving its accuracy and perhaps to standardize the test nationally and possibly, in future, internationally.

In the hydrometer analysis, dispersing agents are used to disperse the fine grained particles of the soil in the suspension medium (water). 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).

A variety of dispersing agents is used in different parts of the world for the sedimentation analysis. These include sodium silicate and sodium oxalate (TMH1, 1986), Calgon (BS 1377: 1990, IS 2720: 1985 and ISRIC: 2002), sodium pyrophosphate decahydrate (Schuurman and Goedewaagen, 1971), sodium tetra pyrophosphate (Yoo and Boyd, 1994), sodium hexametaphosphate (ASTM D422-63, Lambe 1951, SANS 3001) and Di-sodium Di-hydrogen pyrophosphate (formerly used by the Soils Testing Laboratory of Department of Water Affairs of South Africa). The justification for the use of this latter dispersing agent (Di-sodium Di-hydrogen pyrophosphate) could not be established.

Calgon, which is a combination of sodium hexametaphosphate and sodium carbonate, is one of the popular dispersing agents adopted by various countries for the sedimentation test analysis. The BS 1377 Part 2 -1990 and IS 2720 - Part IV methods recommend 33 grams of sodium hexametaphosphate with 7 grams of sodium carbonate, while the (South African) Council for Scientific and Industrial Research (CSIR) recommends 35 grams of sodium hexametaphosphate with 7 grams of sodium carbonate and the International Soil Reference and Information Centre (ISRIC) recommends 40 grams of sodium hexametaphosphate with 10 grams of sodium carbonate. All the methods mentioned above use 125 ml of solution of the prescribed concentrations, except for ISRIC which uses only 20 ml of solution of the prescribed concentration.

Sridharan et al (1991) described a study on the effect of different types and quantities of dispersing agents on the grain size distribution, particularly the percentage of clay sized material. They concluded that the clay size fraction can vary from 4% - 45% for marine clays, depending upon the dispersing agent used, strictly following the IS (1985) method. It was further seen that 100 – 125 ml of Calgon (33 grams of sodium hexametaphosphate and 7 grams of sodium carbonate in 1 litre of distilled water) was found to be the most effective dispersing agent.

Bindu and Ramabhadran (2010) conducted a study to evaluate the effect of the concentration of the dispersing agent on the hydrometer analysis and attempted to optimize the concentration of the dispersing agent to be added to obtain maximum dispersion. It was observed that the addition of sodium carbonate improved the dispersing capacity of sodium hexametaphosphate. The optimum volume and concentration was found to be 100 ml of 6% mixture of sodium hexametaphosphate and sodium carbonate and there was a significant decrease in dispersion with a further increase in the concentration as well as volume of the dispersing agent added.

The objective of the current study was to investigate the effect of different dispersing agents on two different soil samples with varying mineralogy. An effort was made to compare the results of the hydrometer test analyses by varying the concentration and volume of the best two dispersing agents on the two soil samples, following the THM1 (1986) test method.

EXPERIMENTAL DETAILS

Materials

Two soil samples were collected from various parts of South Africa. The first sample comprised an alluvial soil from the Sebokeng Township in the Gauteng Province and the other was a black soil from the town of Brits in the North-west Province. The Atterberg Limits and Activity of these soils were determined, at the laboratories of the Department of Civil Engineering Technology of the University of Johannesburg, as shown in Table 1. TMH1 (1986) method was used for the determination of the Liquid Limit and Plastic Limit. The clay content was determined by means of the hydrometer analysis (Method A6 of TMH1 – 1986) with a deviation in the prescribed dispersing agent type, quantity and adjustment in the readings by subtracting the hydrometer readings obtained on the "blank" companion specimens to account for the effect of the dispersing agent. TMH1 (1986) Method A6 prescribes 5 ml of sodium silicate and 5 ml of sodium oxalate as the dispersing agent. The activities of the soils used for current study were computed by using the clay content obtained by the hydrometer analysis when 125 ml of Calgon 33:7 (a solution comprising 33 grams of sodium hexametaphosphate (NaHMP) and 7 grams of sodium carbonate (Na_2CO_3) in 1 litre of distilled water) was used.

Table 1 Atterberg Limits, Linear Shrinkage and Activity of the soils sampled

Properties	**Alluvial Soil**	**Black Soil**
Liquid Limit (LL)	32	56
Plastic Limit (PL)	16	22
Plasticity Index (PI)	16	34
Clay Content (%)	21.4	32
Activity (A)	0.75	1.07

Hydrometer Tests

Hydrometer analyses were conducted on both samples, according to the TMH1 (1986) method, to determine their clay content.

These analyses were carried out in three stages. Stage I comprised two tests, one on each soil type, which excluded dispersing agents. These served as the control test results.

Stage II testing entailed a total of ten hydrometer tests, five on each of the two soil types, using the dispersing agents shown in Table 2.

Table 2 Details of various dispersing agents used

Dispersing Agent	Preparation of Stock Solutions
5 ml of Sodium silicate and 5 ml of Sodium oxalate	Sodium Silicate: Dissolve sodium silicate, preferably the water glass solution (Na_2SiO_3) in distilled water until the solution yields a reading of 36 at a temperature of 20°C on the standard soil hydrometer. Sodium Oxalate: This consists of a filtered saturated solution of sodium oxalate ($Na_2C_2O_4$).
125 ml of Calgon solution	Calgon: Mix 35 grams of Sodium hexametaphosphate ($NaPO_3$) with 7 grams of sodium carbonate (Na_2CO_3) and add a sufficient quantity of distilled water to bring the volume of the solution to one litre.
20 ml of sodium pyrophosphate	Sodium pyrophosphate decahydrate: Mix 36 grams of sodium pyrophosphate decahydrate ($Na_4P_2O_7.10H_2O$) with a sufficient quantity of distilled water to bring the volume to the solution to one litre.
20 ml of Sodium tetra pyrophosphate	Sodium tetra pyrophosphate: Mix 36 grams of sodium tetra pyrophosphate with a sufficient quantity of distilled water to bring the volume of the solution to one litre.
40 ml of sodium silicate and 40 ml of di-sodium di-hydrogen pyrophosphate	Di-sodium di-hydrogen pyrophosphate: Mix 36 grams of di-sodium di-hydrogen pyrophosphate ($Na_2H_2P_2O_7$) with a sufficient quantity of distilled water to bring the volume of the solution to one litre. Sodium Silicate: Add sodium silicate syrup (Na_2SiO_2) to distilled water until the solution yields a reading of 36 at the temperature of 19.5°C on the standard soil hydrometer.

Stage III comprised further testing, on each of the two soil types, which entailed varying the concentration and volume of two of the dispersing agents (Calgon and sodium pyrophosphate decahydrate). These two dispersing agents were selected for further investigation as the results of the Stage II testing indicated these to be the most effective of the five dispersing agents. The objective of this Stage III testing was to compute the optimum concentration and volume of the dispersing agent.

Internationally, there are at least four methods (BS 1377 Part 2 – 1990, IS 2720 Part IV – 1985, South African CSIR, International Soil Reference and Information Centre (ISRIC – 2002) which recommend the use of Calgon as a dispersing agent. However, all four of them use Calgon in different concentrations. BS 1377 Part 2 – 1990 and IS 2720 Part IV – 1985 both recommend 125 ml of Calgon 33:7 (33 grams of sodium hexametaphosphate and 7 grams of sodium carbonate mixed with 1 litre of distilled water), CSIR recommends 125 ml of Calgon 35:7 while ISRIC recommends 20 ml of Calgon 40:10.

Amounts of 4%, 4.2%, 5%, 7%, 8% and 9% solution of Calgon and 3%, 3.6%, 5%, 6% and 7% solution of sodium pyrophosphate decahydrate were prepared, by mixing the required quantity in 1 litre of distilled water. The quantities (in grams) of chemicals added for the preparation of these stock solutions are given in Table 3.

Table 3 Quantity of chemicals added for preparation of Calgon and Sodium pyrophosphate decahydrate solutions

Concentration of Solution (%)	**Calgon**		**Sodium Pyrophosphate decahydrate**
	Quantity of NaHMP Added (g)	**Quantity of Na_2CO_3 Added (g)**	**Quantity of NaPP Added (g)**
3	-	-	30
3.6	-	-	36
4	33	7	-
4.2	35	7	-
5	40	10	50
6	-	-	60
7	60	10	70
8	70	10	-
9	80	10	-

In these tests the minimum volumes of Calgon and sodium pyrophosphate decahydrate used were 100 ml and 20 ml, respectively. These volumes were incrementally increased until the optimum volume for each concentration was established.

Testing Procedure and Calculations

The testing was in accordance with the procedure described in TMH1 (1986). For all the tests performed, 50 grams of soil sample passing through a 425 micron sieve was mixed with the desired quantity of dispersing agent and about 400 ml of distilled water in a canning jar. The soil water mixture was allowed to stand overnight. After the mixture had been allowed to stand, it was dispersed for 15 minutes with a standard paddle. The paddle was washed clean with distilled water allowing the wash water to run into a container with the suspension.

The suspension was then poured into the Bouyoucos cylinder and the canning jar was rinsed with distilled water from the wash bottle. The cylinder was then filled with distilled water to 1130 ml mark with the Bouyoucos hydrometer (152H) inside. Then, the hydrometer was removed and the cylinder was inverted a few times, using the palm of one hand as a stopper over the mouth of the cylinder to ensure that the temperature was uniform throughout. After bringing the cylinder to a vertical position, a stop watch was started. The hydrometer was inserted and readings were taken at 18 and 40 seconds without removing the hydrometer from the cylinder. The hydrometer was then taken out and rinsed with water and it was again inserted into suspension when the elapsed time was 2 minutes. This reading was noted and the hydrometer was removed and placed in distilled water. This procedure was repeated for the 5 minutes, 15 minutes, 30 minutes, 1 hour, 4 hour and 24 hour readings. After taking each hydrometer reading, the temperature of the liquid was recorded. Temperature corrections were applied to the readings.

Also a blank solution comprising distilled water and dispersing agent was prepared, in a second Bouyoucos cylinder in the same proportions as solutions prepared with the soil. The dispersing agent and water mixture was also soaked overnight and identical hydrometer tests were performed for the blank solutions.

The hydrometer reading taken on the samples which contained soil were appropriately adjusted by subtracting the hydrometer readings obtained on the “blank” companion specimens, at the relevant times. This accounted for the effect of the dispersing agent on the readings. It should be noted that TMH1 does not make any provisions for this correction.

The percentages finer than 0.075 mm, 0.05 mm, 0.04 mm, 0.026 mm, 0.015 mm, 0.01mm, 0.0074 mm, 0.0036 mm and 0.0015 mm were respectively calculated by the readings taken at 18 sec, 40 sec, 2 min, 5 min, 15 min, 30 min, 1 hour, 4 hour and 24 hours, by means by Equation 1.

$$P = \frac{C \times Sf}{Sm} \tag{1}$$

Where, P = Percentage finer than relevant size,

S_m = Mass of soil fines used in analysis (50 grams),

S_f = Percentage soil fines in total sample (<0.425 mm),

C = Corrected hydrometer reading

The percentage clay content present in each sample (fraction finer than 0.002 mm) was obtained from the relevant particle size distribution curve. The tests which gave the best dispersing agent, optimum concentration and volume were repeated to check the consistency of the results.

RESULTS AND DISCUSSION

Stage I Results

In this stage, two tests were performed, one on each soil. These were the control tests that excluded dispersing agents. Figure 1 shows the soil suspension after 24 hours of both the black soil and the alluvial soil. In both the cases, it can be seen that the supernatant water is almost clear of soil grains including colloids.

[Insert Figure 1]

The particle size distribution curves for these two control tests are shown in Figure 2.

Stage II Results

The particle size distribution curves obtained for the two soil types, with the use of each of the five dispersing agents used (detailed in Table 2), are shown in Figure 2.

[Insert Figure 2]

From Figure 2, it is evident that the control samples of both the alluvial and black soils yielded near zero clay contents.

The analyses using the five dispersing agent types indicated that, the clay content of the alluvial soil ranged from 7 % to 21 % and that of the black soil ranged from 0.1 % to 32 %. Further, it can be seen that in the case of both soil types, Calgon (combination of sodium hexametaphosphate plus sodium carbonate), which has been recommended by many methods and researchers internationally (BS 1377 Part 2 - 1990, IS 2720 Part IV - 1985, ISRIC - 2002, Bindu and Ramabhadran (2010) and Sridharan et al (1991)), yielded the maximum clay content. This was most effective in the case of the black soil.

The second best dispersing agent, after Calgon, was found to be sodium pyrophosphate decahydrate (NaPP). Calgon yielded 21 % and 32.1 % clay content while sodium pyrophosphate decahydrate yielded 20 % and 20.5 % clay content in alluvial and black soil, respectively.

In addition, sodium silicate and sodium oxalate, which is prescribed in TMH1 (1986) was the least effective dispersing agent in the case of the black soil yielding a clay content of 0%. The least effective dispersing agent in the case of the alluvial soil was sodium silicate and di-sodium di-hydrogen pyrophosphate which yielded a clay content of 6.2 %.

Stage III Results

Calgon

The effect of different concentrations and volumes of Calgon, for the alluvial and black soils is shown in Figures 3 and 4, respectively. The clay contents determined by the different concentration and volume combinations are shown in Table 4. The best and worst results for each concentration are shown in green and red, respectively.

[Insert Figure 3]

[Insert Figure 4]

It is evident that at the volume of 125 ml (the volume recommended by BS 1377 Part 2 - 1990 and IS 2720 Part IV - 1985), 5% Calgon yielded the maximum clay content of 25.5% for the alluvial soil (Figure 3 and Table 4), while for black soil, the 4.2%, 5% and 7% Calgon all yielded the maximum clay content of 32 % (Figure 4 and Table 4).

Table 4 Variation of clay content depending on the concentration and volume of Calgon added to alluvial soil and black soil

Volume (ml)	Alluvial Soil						Black Soil					
	4%	4.2%	5%	7%	8%	9%	4%	4.2%	5%	7%	8%	9%
100	19.7	22.8	22.7	21.5	22.2	25	28.5	32.5	28.2	30.5	30	26.6
125	20.1	21.4	25.5	23.2	21.1	24.3	29.1	32	32	32	29	26.4
150	20.2	23	23.5	21.8	24.7	22.1	28.2	32.6	33.7	28.4	29.5	27.5
175	19.9	21.5	25	21.7	23.3	21.7	28	33	34	28.5	26	25.3
200	18	24	22.5	20.6	23.6	19.5	26.5	**35**	31.5	26	26.2	22.5
225		**29.5**	19.7	26.4	23.4	18.2	25.5	34.6	32	27.9	23.5	22
250		20.1	19.5	25	20.7	15.6		32.8	31.6	24.6	22.7	22.2
275				24.4	23.2			32	30.5	21.8	22	20.5
300				24.9	20.7			26	25	22	16.8	18.6
325				20.5					24	19.3	13	16
350				17								11.9
375				15.5								

The bold numerals indicate the optimum concentration and volume for each soil type.

Figures 3 and 4 and Table 4 indicate the following.

- The 4.2 % Calgon proved to be the best dispersing agent yielding maximum clay contents of 29.5 % and 35 % for the alluvial and black soils, respectively. This is in close agreement with the concentration prescribed by the South African CSIR CA 17 method, but in disagreement with Bindu and Ramabhadran (2010) and Sridharan et al (1991). According to Bindu and Ramabhadran (2010), the optimum concentration of Calgon was found to be 53:7 while Sridharan et al (1991) found Calgon 33:7 to be the optimum concentration.

- The optimum volumes of Calgon for the alluvial and black soil were 225 ml and 200 ml, respectively. This is in disagreement with Bindu and Ramabhadran (2010) and Sridharan et al (1991). An optimum volume of 100 ml (53:7) was obtained by Bindu and Ramabhadran (2010) while Sridharan et al (1991) indicated that 100 - 125 ml of Calgon 33:7 yielded the optimum clay content. The results obtained by Sridharan et al (1991) were in close agreement with the concentrations and volumes prescribed by the British and Indian standards.
- Low (4 %) and high (9 %) concentrations of Calgon proved to be less effective in the case of both soils.
- In the case of the alluvial soil, 5 % and 8 % Calgon concentrations were more effective than 4.2% Calgon for volumes up to 175 ml.
- In the case of the black soil, the 5 % Calgon was more effective that 4.2% Calgon for volumes ranging from 125 to 175 ml.
- In the case of the black soil, for all the concentrations of dispersing agent, any further increase in volume of chemical after attaining optimum volume, generally resulted in a decrease in clay content. Similar results were obtained by Bindu and Ramabhadran (2010) and Sridharan et al (1991).

With regards to the concentrations of Calgon, no general trend was evident regarding the relative effect of the quantities (ratio of) sodium carbonate and sodium hexametaphosphate on the results obtained for both soils. However, in the black soils, with the exception of the 4% Calgon results, an increase in sodium hexametaphosphate resulted in a decrease in clay contents. This decrease is due to saturation absorption of the dispersants on to the clay particles after which aggregation of particles might occur (Bindu and Ramabhadran (2010)).

Sodium Pyrophosphate Decahydrate (NaPP)

The effect of different concentrations and volumes of NaPP, for the alluvial and black soils are shown in Figures 5 and 6, respectively. The clay contents determined by the different concentration and volume combinations are shown in Table 5. The best and worst results for each concentration are shown in green and red, respectively.

[Insert Figure 5]

[Insert Figure 6]

Table 5 Variation of clay content depending on the concentration and volume of NaPP added to alluvial soil and black soil

Volume (ml)	Alluvial Soil					Black Soil				
	3%	3.6%	5%	6%	7%	3%	3.6%	5%	6%	7%
20	18.4	20	24	24	24.4	10	20.4	20.5	22.3	25.4
40	17.7	25.5	**26**	25.2	24.7	20	27	26.1	33.5	33.4
60	20.5	24	23.3	25	24.3	22.2	32	32.1	32.5	28
80	19.3	25.4	24.2	24	23.5	21.9	**35.2**	28.3	34.2	34
100	20.3	24.9	24.9	23.5	23.1	26	32.5	34	33.5	33.4
120	18.7	25.2	25.3	24.7	21.2	26	34	34	33.9	22.7
140		25.1	24.7	21.2		27	32.1	34.8	32	26
160		21.9	24.7			25	33	32.3	34	22.5
180		21.2	25			25	27.8	31.8	26.9	21.3
200		21.1	23.2						20.8	20
220										21
240										17.9

The bold numerals indicate the optimum concentration and volume for each soil type.

From Figures 5 and 6 and Table 5, the following is evident.

- In the case of the alluvial soil, 40 ml of NaPP 5% gave the maximum clay content of 26% while 40 ml of NaPP 3.6% yielded a clay content of 25.5% (which is a little less than the former). Hence, NaPP 3.6% may be considered as the optimum concentration for the alluvial soil.

- When the test was conducted on the black clay, the clay fraction obtained was at a maximum (35.2 %) when using 80 ml with a 3.6% concentration. Hence, 80 ml of NaPP 3.6% is considered as the optimum concentration and volume for the black soil.
- In general, the 3.6 % NaPP appears to be the most effective concentration in the case of both soils.
- Low (3 %) and high (7 %) concentrations of NaPP generally proved to be less effective in the case of both soils.
- NaPP concentrations of 5 % and 6 % yielded similar results in the case of both soils.
- The volume of dispersing agent generally appeared to have an insignificant effect in the volume range of 40 ml to 120 ml in the alluvial soil and for the volumes in excess of 40 ml in the case of the black soil.

On the basis of the above, the optimum NaPP volume for the alluvial and black soil appears to be 40 ml and 80 ml, respectively.

Summary of Results

Table 6 shows the optimum concentrations and volumes of Calgon and NaPP for the alluvial and black soil and the clay contents yielded by these dispersing agents.

Table 6 Summary of results

Property	Alluvial Soil		Black Soil	
	Calgon	NaPP	Calgon	NaPP
Optimum Concentration (%)	4.2	3.6	4.2	3.6
Optimum Volume (ml)	225	40	200	80
Clay Content (%)	29.5	25.5	35	35.2
Δ% in Clay Content (Relative to Table 1)	38	19	9.4	10
Activity	0.54	0.63	0.97	0.97
Δ% in Activity (Relative to Table 1)	-28	-16	-9.4	-9.4

With reference to Table 6, it is evident that the Calgon and NaPP yielded the highest clay contents for the alluvial and black soils, respectively.

Furthermore, Figures 3 to 6 and Tables 4 and 5 indicate that increase in volume beyond the optimum volume resulted in a decrease in the percentage clay content in most cases. However, a contradictory trend was noticed where, with an increase in volume there was an increase in percentage of clay content. The reason for this is that with an increase in the volume of dispersing agent in the companion "blank" solutions, the hydrometer readings increased but the increase was not constant.

It was also found that, in the case of both soils and both dispersing agents, there was no correlation between the mass of dispersing agent granules in solution and the clay contents yielded.

Furthermore, when comparing the maximum clay contents of the two soils determined as part of this investigation (Table 6) with those in Table 1, the maximum clay content for the alluvial soil increased by 38 % (from 21.4 % to 29.5 %). The maximum clay content for the black soil increased by 10 % (from 32 % to 35.2 %). These increases in clay content resulted in decreases in the Activity of the alluvial and black soils of 28 % (from 0.75 to 0.54) and 10 % (from 1.07 to 0.97), respectively.

CONCLUSIONS

The following conclusions were drawn from the study conducted:

Tests with different dispersing agents clearly indicated that the percentage of clay sized material can vary significantly depending upon the type of dispersing agent. In this investigation, which included ten dispersing agent types, Calgon and Sodium pyrophosphate decahydrate (NaPP) were the most effective dispersing agent types.

In the case of both soils, the optimum concentrations of Calgon and NaPP were found to be 4.2 % and 3.6 %, respectively. Furthermore, 225 ml of Calgon yielded the highest clay content in the case of the alluvial soil whereas 80 ml of NaPP yielded the highest clay content in the case of the black soil.

Relatively high and low concentrations of Calgon and NaPP yielded low clay contents in the case of both soil types.

No correlation exists between the mass of the dispersing agent granules in solution and the clay contents yielded.

The results of this investigation confirm the findings of Means and Parcher (1963) that different dispersing agent types are more effective with certain clay types.

Finally, the effect of the dispersing agent on the hydrometer readings, particularly in the case of relatively high volumes, was considerable and hence should be accounted for by accordingly correcting (reducing) the hydrometer readings. The current South African method (SANS 3001) which utilizes Sodium hexametaphosphate as a dispersing agent, makes provision for such a correction to the hydrometer readings.

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Figures

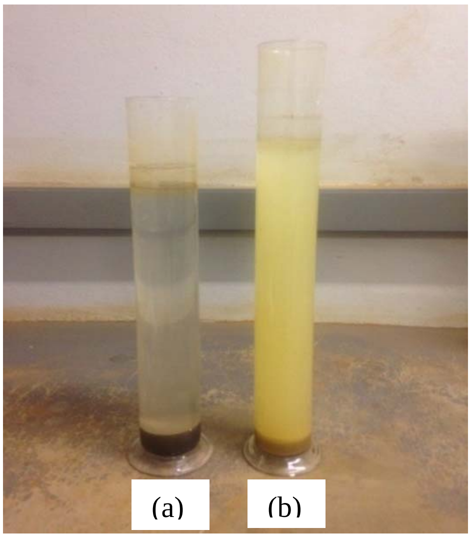

Figure 1. a) Black soil without dispersing agent; b) Alluvial soil without dispersing agent.

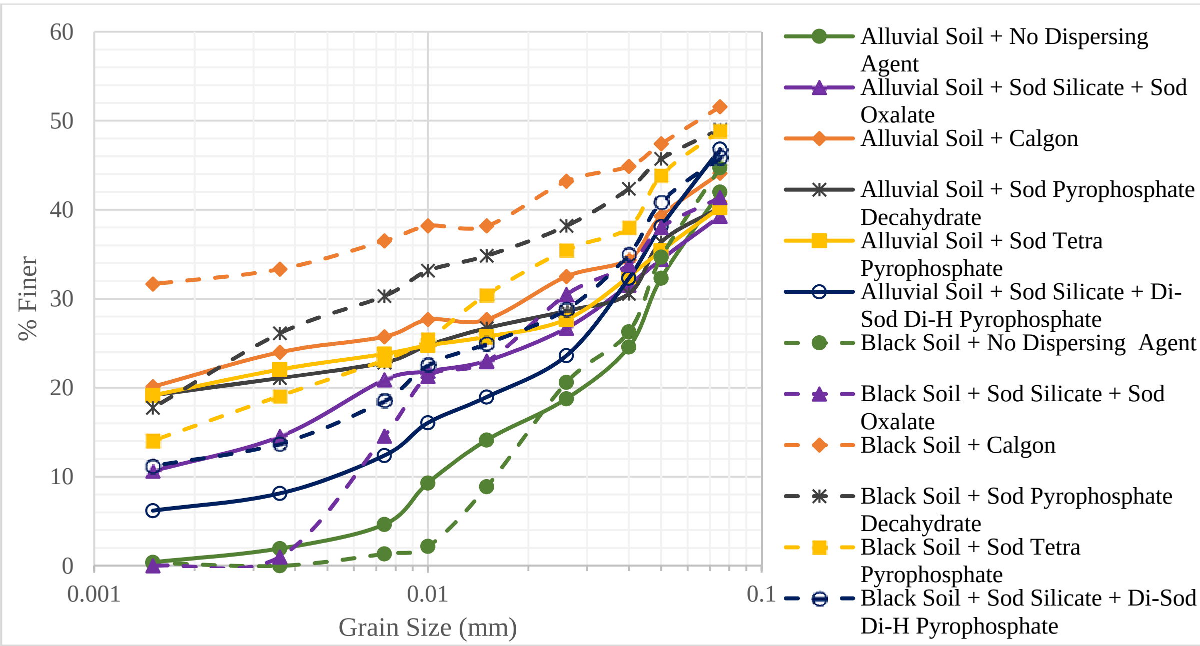

Figure 2. Effect of different dispersing agents in grain-size analysis.

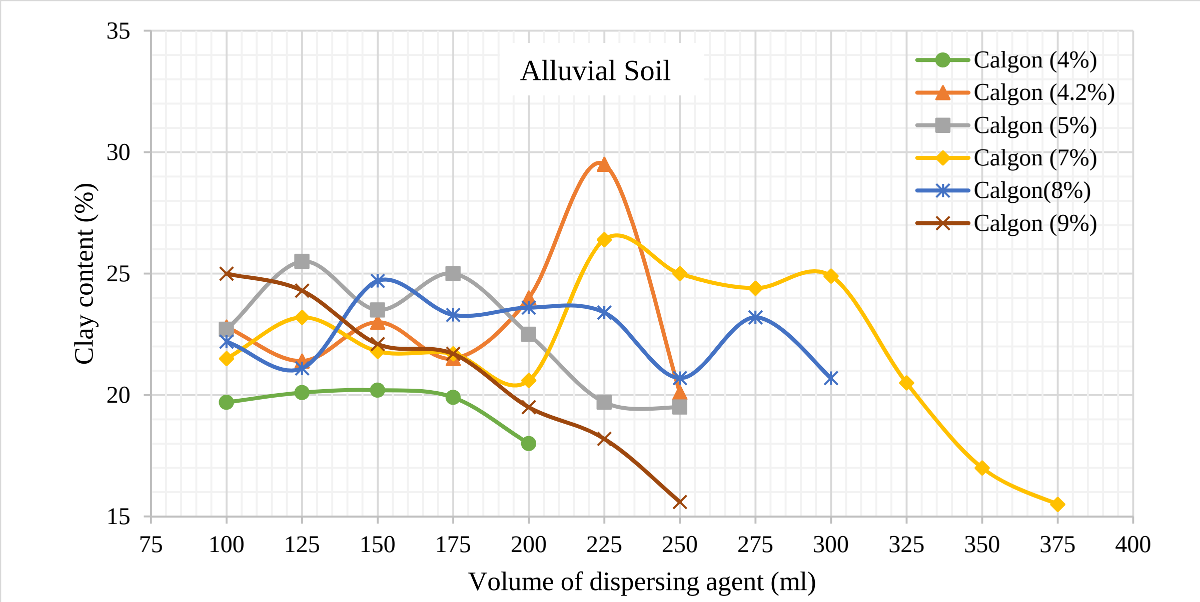

Figure 3. Effect of volume and concentration of Calgon as a dispersing agent in determining the clay content of Alluvial Soil.

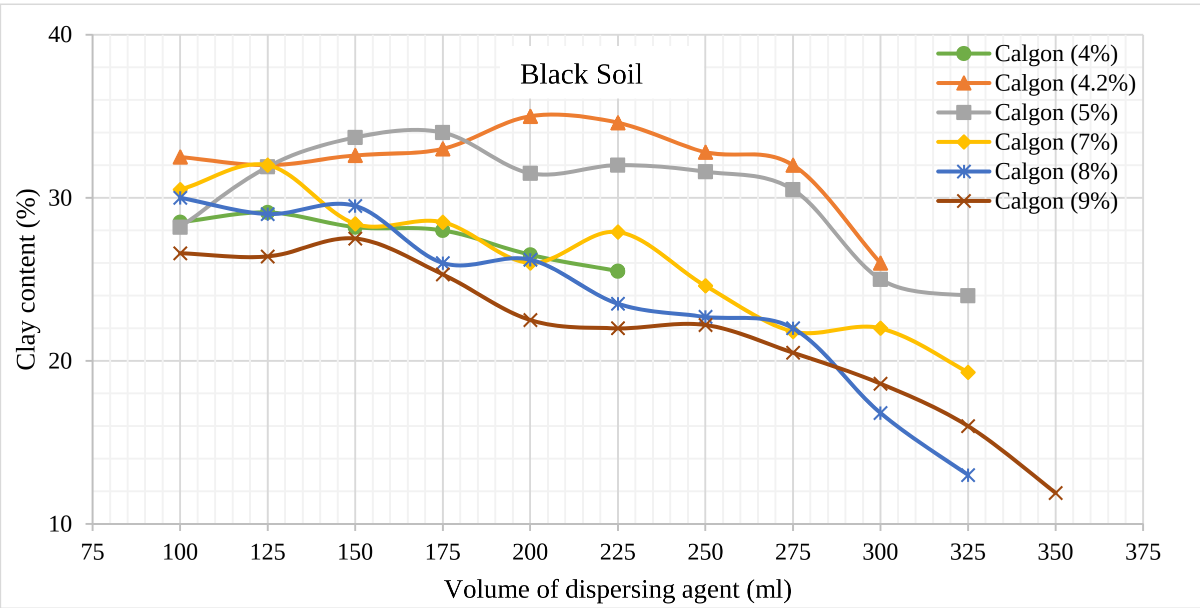

Figure 4. Effect of volume and concentration of Calgon as a dispersing agent in determining the clay content of Black Soil.

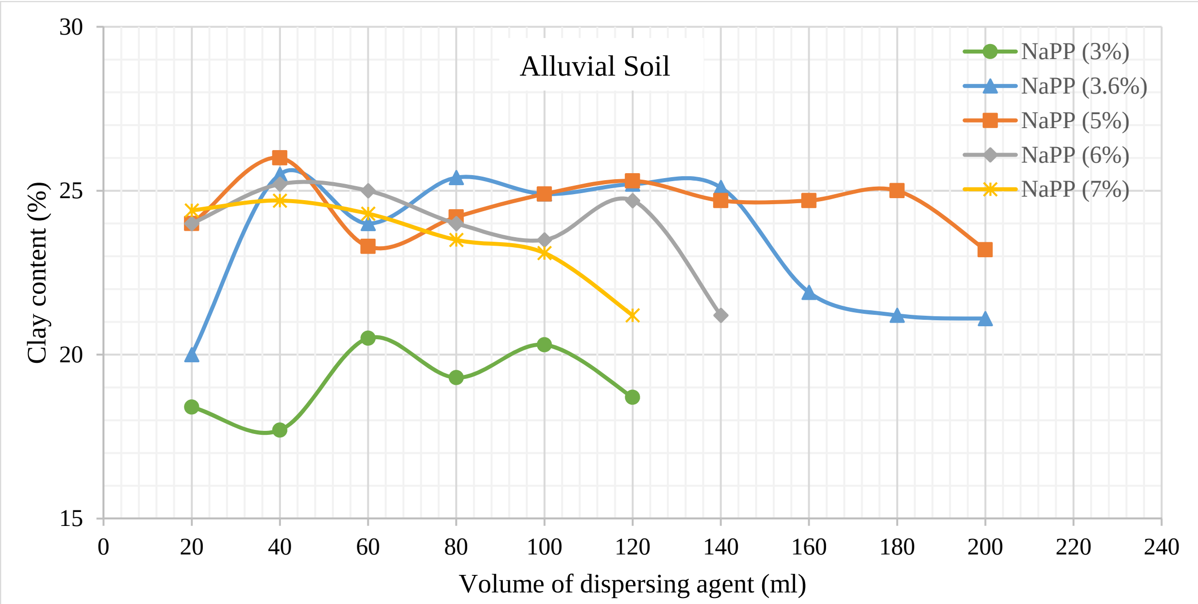

Figure 5. Effect of volume and concentration of NaPP as a dispersing agent in determining the clay content of Alluvial Soil.

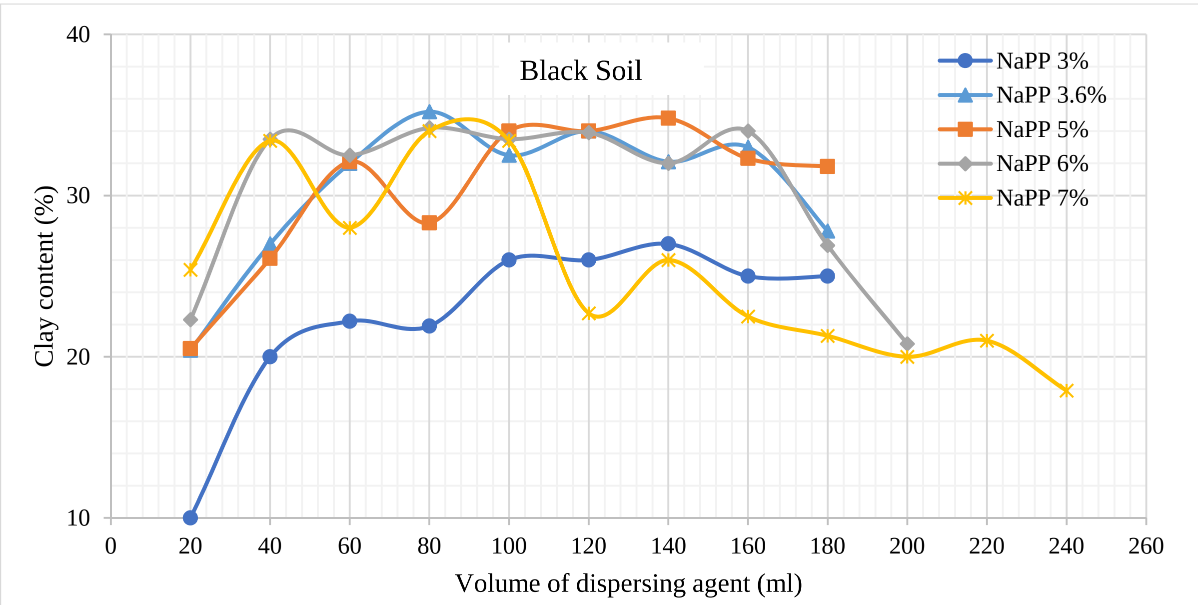

Figure 6. Effect of volume and concentration of NaPP as a dispersing agent in determining the clay content of Black Soil.