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Quality Evaluation of a Commonly Used Drilling Fluid (Bentonite) and Development of the Properties of Dhaka Clay for Using as an Alternative Drilling Fluid

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Abstract- This paper deals with the properties and use of drilling fluids which are used for aiding the drilling of borehole into the earth along with the process of development of properties of a local soil called 'Dhaka clay' in order to use as a drilling fluid. Here the most commonly used drilling fluid named as 'bentonite' slurry is addressed with its properties and functions involving standard laboratory investigation. Then a distinguish between the determined properties of collected Bentonite sample from local market and properties determined by previous scholars has been demonstrated which leads to a decision that local bentonite clay doesn't meet desired qualities of drilling fluids physically and economically. However, properties of local soil known as Dhaka Clay were also investigated in the laboratory to compare with normal bentonite sample. The results provide some supports to introduce the use of local soil as drilling fluids. After that, a special test was conducted to develop the local soil as a drilling fluid by means of separating finer portion of the particles from Dhaka Clay which eventually justifies the suitability of this finer potion of Dhaka clay for using as a drilling fluid.

Keywords- *Bentonite, Slurry, Dhakaclay, Montmorillonite, Kaolinite, Liquid Limit, Plastic Limit, Marsh Funnel Viscosity*

I. INTRODUCTION

Drilling fluid has set a benchmark in drilled shaft foundation as it is responsible for the increment of strength of the piles driven in soil. Advancement of technology in the field of production and use of drilling fluids are significant in recent years. In Bangladesh there are several options regarding drilling fluids or slurries of which bentonite slurry can be considered as the most preferable considering its availability, price and effectiveness in comparison with other types of slurries. Slurries produced from local clays can be another good option as it's the most available one. In this paper, a comparative analysis of quality between slurry made from bentonite sample (bought from market) and a slurry of locally available clay (Madhupur clay) has been performed on the basis of marsh funnel viscosity test, Atterberg test for liquid and plastic limit .later a finer portion of the Dhaka clay has been taken and all the tests discussed above have been performed.

II. STATEMENT OF THE PROBLEM:

In Bangladesh, Bentonite is one of the most commonly used drilling fluids which basically contains a mineral named montmorillonite. This montmorillonite has a higher plastic limit and liquid limit than a usual clay soil. Besides due to presence of montmorillonite, bentonite has a high viscosity that makes it suitable for using as a drilling fluid. Therefore, for being used as a drilling fluid a slurry must have a liquid and plastic limit close to montmorillonite along with high viscosity. Based on this property we have analyzed the quality of a bentonite sample and eventually Dhaka clay as a drilling fluid.

III. SAMPLE COLLECTION AND TEST METHODS

A. *Sample collection*

We ran our experiment over two soil samples, one was Bentonite clay and other was the local soil named as Dhaka Clay. Bentonite clay is not so available in Bangladesh. And contractors mainly import these chemicals from abroad. Even in local market there is some sample which is also used in drilled shaft construction in Bangladesh. We have bought bentonite clay as powder manufactured in industry from Sabbir Enterprise, 250 Nawabpur road, Dhaka.

One of the most promising parts of our project was introducing local soil sample called 'Dhaka clay' as slurry in drilled shaft construction. Therefore, we had run some tests on local soil. Our local soil sample is also known as Madhupur Clay. We had collected this sample from 15 feet depth of a hole excavated due to the government work purpose for utility at Palashi Bazar, Dhaka.

B. *Sampling of soil samples*

Freshly mixed slurry is sampled from the slurry tanks immediately prior to its introduction into the drilled hole. For this purpose, satisfactory samples may be taken from almost anywhere in the storage tank. The important point is to obtain a sample that is representative of the mixture. During drilling, it is highly recommended (and should be required by appropriate specifications) that slurry has to be sampled from the borehole and tested at least every two hours after its introduction. Typically, samples are taken from mid-height and near the bottom of the borehole. Several types of sampling tools are available to obtain a representative sample from the desired location in the slurry column. When the sampler is brought to the surface, its contents are usually poured into a plastic slurry cup for subsequent test.

C. Laboratory test of slurries:

1) Specific gravity

The specific gravity of a soil is defined as the ratio of the weight in air of a given volume of soil particles to the weight in air of an equal volume of distilled water at a temperature of 4°C. It is used for determination of void ratio and particle size. The specific gravity of the bentonite, GB can be obtained from

$GB=W_s*G_T/W_s- W_1+ W_2$

Where,
GB=Specific gravity of bentonite sample

G_T=Specific gravity of distilled water at temperature T

W_S= Dry weight of bentonite

W_1= Weight of pycnometer, bentonite and water

W_2= Weight of pycnometer and water

The specific gravity was determined in the laboratory by pycnometer method. Then it was compared with the standard values. Standard values of specific gravity are presented here:

TABLE I. SPECIFIC GRAVITY OF DIFFERENT SOIL TYPE

Soil Type	Specific Gravity
Gravel	2.65
Sand	2.65-2.68
Silty Sands	2.66-2.70
Inorganic Clays	2.68-2.80
Organic Clays	Below 2.00

2) Grain Size Distribution- Hydrometer Test:

Grain sizes in soil samples are found by means of two tests. The sieve analysis is used for coarser materials and hydrometer test is used for finer soils. If significant quantities of both coarse and fine grained soils are in the sample, the results of both the test will have to combine to get the grain sizes in the sample. In this research we have performed some tests on Bentonite and Dhaka clay samples. Both samples were finer material. Even bentonite was totally manufactured on industry and passed through #200 sieves. So we conducted only Hydrometer test on these samples.

3) Atterberg limits Test:

The behavior of fine grained cohesive soil depends on its mineral composition, water content, degree of saturation and structure. Water content has always been considered as an important and reliable indication of the behavior of cohesive soils since the beginning of soil mechanics (Lancellotta, 1995). Swedish scientist Atterberg, in the early 1990's first identified that a gradual decrease in water content of clay soil slurry causes the soil to pass through four states; liquid, plastic, semi-solid and solid.

Liquid Limit: The liquid limit (WL or LL), is the water content at which soil transfers from liquid state to plastic state .Generally two methods are used to determine liquid limit;

1) Cassagrande's Method
2) Cone Penetration Method.

Cassagrande's method is popularly used and so did we. Cassagrande's (1932) developed a standard device for the determination of liquid limit suggesting that at the water content of liquid limit a clay soil has a shearing strength of approximately 2.5 kPa. Dried and broken soil, passed through no. 40 sieve is taken for limit test. The soil, mixed with water, forms a paste which is leveled off in the device to form a depth of 8mm. A grooving tool is used to form a groove at mid-section of the cup. Then using the handle blow is started and no of blow is counted until the soil come in contact. From the cup sample is taken and water content is determined from it. The liquid limit according to this method is defined as the moisture content at which 25 blows are required.

Plastic limit: Plastic Limit (PL) is the minimum moisture content at which the soil can be deformed plastically. As standardized, it can be taken as the smallest water content at which the soil begins to crumble when rolled out into thin threads, approximately 3 mm in diameter. That is at plastic limit the soil must gain some minimum stiffness or strength. According to Skempton and Northey (1953), the shear strength at plastic limit is about 100 times that at liquid limit.

Plasticity Index: PI is the range of water contents over which the soil remains plastic. As such, plasticity index is the numerical difference between liquid and plastic limits.

$PI = LL – PL$

The plasticity of soil gives a good direction of the types of soil grains present in the soil sample. Low values of limits are indicative of silty soils, with higher values in clay soils. Very high limits are found in extremely fine grained clays such as bentonite and montmorillonite.

TABLE II. TYPICAL VALUES OF LIQUID LIMIT AND PLASTIC LIMIT (AFTER ATKINS, 1977)

Soil	Liquid Limit	Plastic Limit
Silt clay mixture	25-40	20-30
Kaolinite clay	40-70	20-40
Montmorillonite clay/bentonite	300-600	100-200

4) Marsh funnel viscosity test

The viscosity of a fluid is its ability to resist flow under shear stress. Viscosity that is verified with a viscometer is the ratio of shear stress to strain rate. When determining the viscosity in the field a Marsh funnel is used (Figure). This determines the time required for one quart of material to pass through a standard funnel (qt/sec). The material tested is passed first through a No. 12 sieve when introduced to the funnel. The Marsh funnel is based on the principles of the falling head flow; therein, fluid flows faster with higher pressure (when the 13 funnel is full) and progressively slows as the pressure decreases (funnel empties) As a result, longer emptying times indicate higher viscosity, but the Marsh funnel test is not a true viscosity test (shear stress/strain rate). The test is simply an indicator of gel strength and/or the presence of clay mineral content. However, the flow times can be affected by the presence of suspended solids.

5) pH Test

The pH of the slurry is an indicator of the degree of acidity or alkalinity of the slurry. Maintenance of a proper range of pH is important to the proper functioning of the slurry and is an indicator of the effectiveness of anti-hardness additives. For example, neutral-to-acid pH (7.0 or lower) can reflect conditions in a borehole that is being drilled through an acidic fill and that a bentonite-based slurry may be in danger of flocculating, or it could indicate that a polymer slurry is mixing with acidic groundwater and is in danger of agglomerating. The pH can be determined readily by the use of pH paper or by a pocket pH meter. The pocket pH meter, which is the size of a large pencil, is more accurate and is easy to use, but it must be calibrated often against a standard buffer solution.

IV. Test Report and Analysis

A. Laboratory Testing Result of Bentonite sample

TABLE III. LABORATORY TESTING RESULT OF BENTONITE CLAY

Name	Value
Specific Gravity	2.456
Liquid Limit	43
Plastic Limit	22
Plasticity Index	21
pH	6.00

1) Result of hydrometer analysis

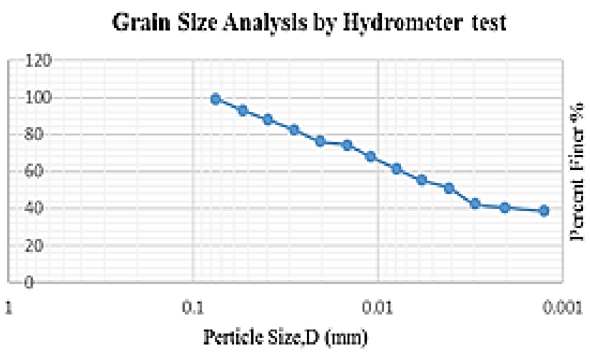

Figure 1. Grain size analysis of bentonite sample by Hydrometer test

TABLE IV. PERCENTAGE OF PARTICLES FROM GRAIN SIZE ANALYSIS

Particles	Percentage
Silt	47.5
Clay	52.5

TABLE V. LABORATORY TESTING RESULT OF DHAKA CLAY

Name	Value
Specific Gravity	2.52
Liquid Limit	49
Plastic Limit	25
Plasticity Index	24
Flow Index	11.3
pH	7.00

B. Laboratory Testing Result of Dhaka clay

1) Result of Hydrometer Analysis

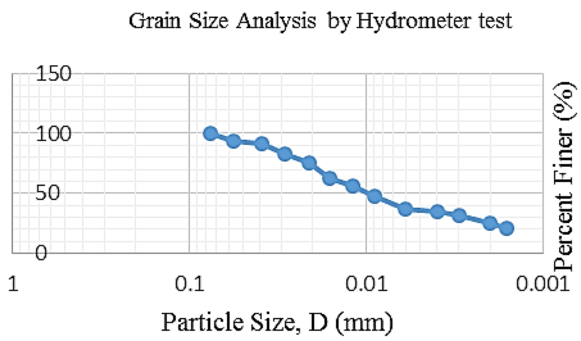

Figure 2. Grain size analysis of Dhaka clay sample by Hydrometer test

TABLE VI. PERCENTAGE OF PARTICLES FROM GRAIN SIZE ANALYSIS

Particles	Percentage
Silt	53.5
Clay	46.5

C. Analysis of the quality of the bentonite sample

Earlier we have mentioned that bentonite majorly contains a mineral named monmorillonite which is basically a clay. In table 1 we can see the specific gravity of montmorillonite and in table 2 we can see the liquid limit and plastic limit of the mineral.A bentonite sample of a good quality should have a value of sp.gravity,liquid limit and plastic limit close to that of montmorillonite.however table 3 shows us the sp. gravity, liquid limit and plastic limit of our sample and comparing these values with the value of montmorillonite. Therefore, it's obvious that our sample of bentonite is of very poor quality.

D. Comparative Analysis Between Bentonite and Dhaka Clay Slurry

- From the analysis report, it is found that our soil samples were almost identical in behavior. Both are CL soil and contain Kaolinite minerals. Liquid limit was also between same ranges.
- Bentonite sample was comparatively acidic than Dhaka clay sample.
- Desired viscosity was obtained in Dhaka clay slurry earlier than bentonite slurry. It results in less densified slurry compared to bentonite slurry provides satisfied results.
- As weight/volume ratio is reduced, soil sample required to make slurry is less required than bentonite slurry which results in economical solution.
- Improved Dhaka clay (separation of finer particles) provides better results than normal Dhaka clay and bentonite sample.

E. Improvement of Dhaka clay as a drilling fluid

This method basically involves separation of finer particles from a clay water mixture. Two such mixtures of Dhaka clay were taken and then settled soils were separated from one sample after 10 minutes and from another sample after 60 minutes. After that Atterberg limit test was performed and the result was the following table:

TABLE VII. VALUE OF LIQUID LIMIT AND PLASTIC LIMIT FOR TWO CLAY MIXTURES OF DHAKA CLAY SAMPLE SETTLED FOR TWO DIFFERENT TIMES

Property	Mixture of 10 min settlement	Mixture for 60 min settlement
Liquid limit	57	125
Plastic limit	31	47

From the table we can see that, the finer portion of sample gives better value of liquid limit and plastic limit. Therefore the finer portion of the sample we can take the better quality of drilling fluid from the Dhaka clay sample we can get.

V. CONCLUSION

To conclude it can be said that, Bentonite slurry from local market was not as much as satisfactory and local soil- Dhaka clay can be used as an alternative of bentonite slurry in bored pile construction with some improvement by means of separation of finer particles from collected sample.

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