

## Soil Investigation Report



**November, 2014**



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## OBSERVING THE CONDITIONS AND COLLECTING REPRESENTATIVE SOIL SAMPLES AT LOCATIONS OF SEVERAL CLUSTERS (FIELD STUDY)

### 1.1 TERMINOLOGY:

#### 1.1.1 Representative Soil Sample:

A soil sample that represents the constituents of the soil as in the field defined as a representative soil sample. A representative soil sample is essential in order to conduct laboratory tests.

#### 1.1.2 Disturbed Soil Sample:

Disturbed soil sample is broken-up soil but representative soil, disturbed during the process of collection. Geotechnical engineers do not consider them to be representative of underground soils unless they're for tests that don't depend on the soil structure. Usually, scientists test the disturbed samples of soil for texture, soil type, moisture content, as well as the nutrient and contaminant analysis. Most of the soil samples that engineers and geologists collect are disturbed samples since they're a lot easier to collect and the need for obtaining an undisturbed sample isn't required for many soil tests.

*For the purpose of collecting disturbed soil sample in this study a hand auger was used.*

#### 1.1.3 Undisturbed Soil Sample:

Undisturbed soil samples keep the structural integrity of the in-situ soil and they have a higher recovery rate in the sampler. It's actually tough to gather a perfectly undisturbed sample and the samplers may contain a small portion of disturbed soil at the top as well as the bottom of the sample length. Undisturbed samples allow the engineer to identify the properties of strength, permeability, compressibility, as well as the fracture patterns among others.



For the purpose of collecting undisturbed soil sample in this study, Two (2) feet long ‘Shelby Tubes’ were used.

#### 1.1.4 Hand Auger:

The hand auger is suitable for unconsolidated soil formations: sand, silt and soft clay. The hand auger consists of extendable steel rods, rotated by a handle (Figure 1.1). A number of different steel augers (drill bits) can be attached at the bottom end of the drill rods. The augers are rotated into the ground until they are filled, and then lifted out of the borehole to be emptied (Figure 1.2).

Figure 1.1: A typical hand auger.

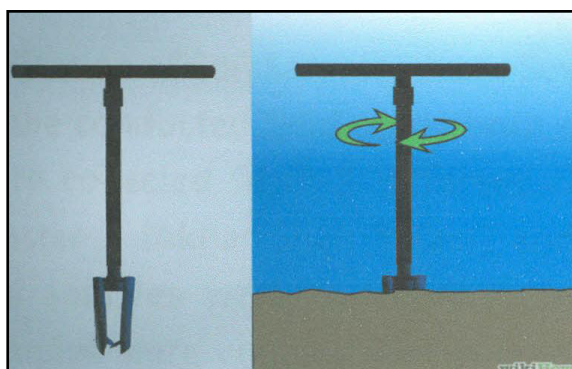


Figure 1.2: Extracting soil from bore-hole.

Source: *Field Survey, September, 2014*



#### 1.1.5 Shelby Tube:

Shelby tube samplers are thin-walled, hollow steel tubes, which are driven into the ground to extract a relatively undisturbed soil sample for use in laboratory tests used to determine density, permeability, compressibility and strength. Each tube has one end that is chamfered to form a cutting edge and the upper end includes holes for securing the tube to a drive head (Figure 1.3). Shelby tubes are useful for collecting soils that are particularly sensitive to sampling disturbance, including fine cohesive soils and clays. The tubes can also be used to transport samples back to the lab as well.

Figure 1.3: Shelby Tube used for Collecting Undisturbed Soil Sample.



## 1.2 PROCEDURE OF COLLECTING SOIL SAMPLES

### 1.2.1 Classification of the Chittagong Metropolitan Area (CMA) into Different Clusters

In Inventory Report, the Chittagong Metropolitan Area (CMA) was divided into 10 clusters initially taking into consideration the landslide hazard locations, tentative similarity of the surroundings and landslide mechanisms (Chapter-2, Inventory Report). After the preparation of landslide inventory, it was necessary to collect representative soil samples from different clusters.

### 1.2.2 Collection of Soil Samples from Several Clusters

In the conducted field study both disturbed and undisturbed soil samples were collected from 3 different clusters namely Cluster-1 (Moti Jharna), Cluster-5 (Akbar Shah Mazar) and Cluster-9 (Panchlaish) (Figure 1.4, Figure 1.5 and Figure 1.9). For Cluster-1 soil samples were collected from ‘Tankir Pahar’, for Cluster-5 soil samples were collected from Two (2) hills namely ‘Golpahar and Lal Pahar/ Kata Pahar’ and for Cluster-9 soil samples were collected from ‘Medical Hill (Goachibagan)’.

Figure 1.4: Cluster- 1 (Moti Jharna Area).

Source: Google earth and field survey August, 2014



Figure 1.5: Cluster-5 (Akbar Shah Mazar Area)

Source: Google earth and field survey August, 2014





Figure 1.6: View from top of Golpahar (Cluster- 5), the densely packed human settlement can be seen who are living constantly under the risk of an imminent landslide.

Source: *Field Survey, August, 2014*



Figure 1.7: Closely packed temporary houses, narrow muddy pathways and settlements built on dangerous slopes.

Source: *Field Survey, August, 2014*



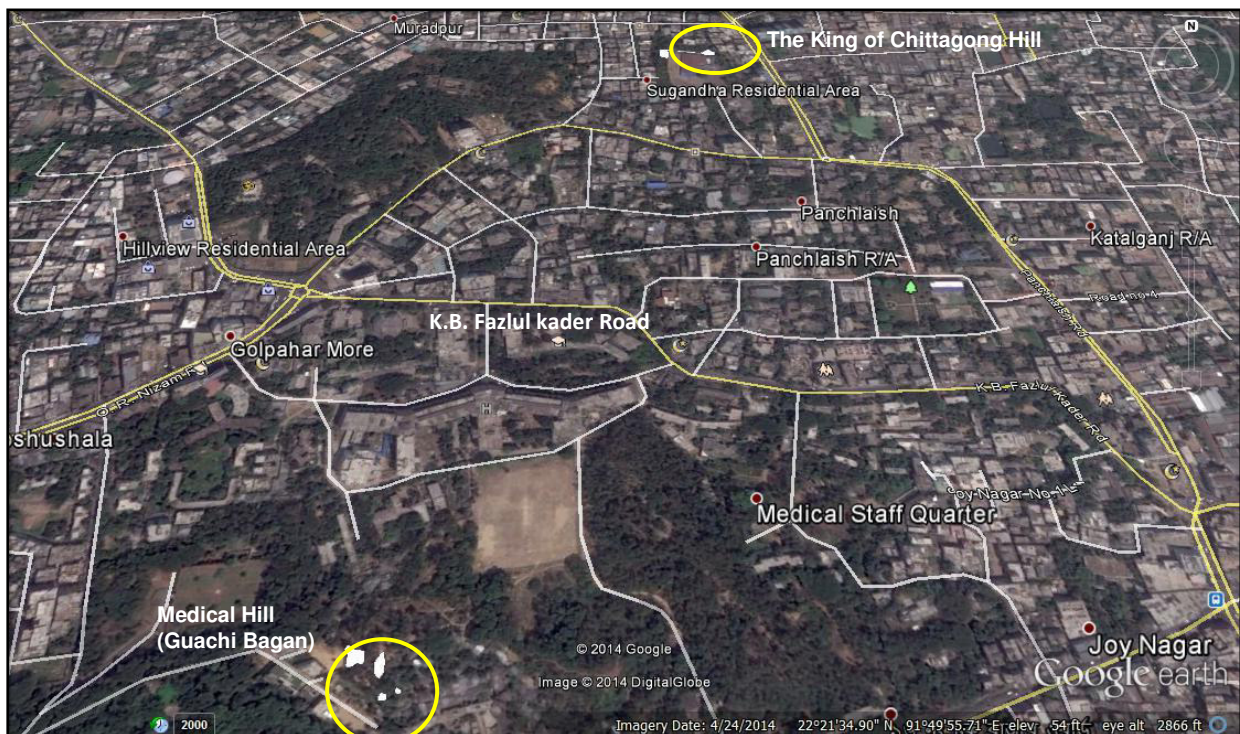
Figure 1.8: Lal Pahar/ Kata Pahar (Cluster- 5); Clear signs of illegal hill cutting can easily be seen leading to the risk of a probable landslide any time - local authorities remain unaware of such problems.

Source: *Field Survey, August, 2014*



Figure 1.9: Cluster - 9 (Panchlaish Area).

Source: *Google earth and field survey, August, 2014*



### 1.2.3 Procedure for Collecting Disturbed Soil Sample

1) Digging and removing the top cover of the soil surface with a Shovel initially. Even while taking disturbed soil sample at the surface level, soil sample cannot be taken from the very top. After removing almost 6 inches of soil (eye estimation) from the top considering for weeds and withering, soil sample for top surface was collected (Figure 1.10-a and Figure 1.10-b).

2) After collecting disturbed soil sample at the surface level, the hand auger was used to go down the soil surface, bore a hole in the process and dig into the soil gradually (Figure 1.10-c). A 3-feet long iron tube was attached with the auger and with that iron tube a rotating device was also incorporated. By means of the rotating arrangement, the auger gradually dug deep into the soil. After going certain depths into the ground, the excavated depth was measured with the measuring tape, the auger was taken out of the bore-hole and soil sample was extracted from the auger and kept inside a polythene bag (Figure 1.11). For most of the cases, e.g., the four hills that were studied, at a particular slope, 3 samples were collected at 3 different depths i.e. at the surface level, below 1.5 feet of surface, below 3 feet of surface.

Figure 1.10: (a) Removing the top layer of soil cover,

(b) Using rotating device to dig the auger deep into the ground,

(c) Extraction of soil from the bore hole

Source: *Field Survey, September, 2014*

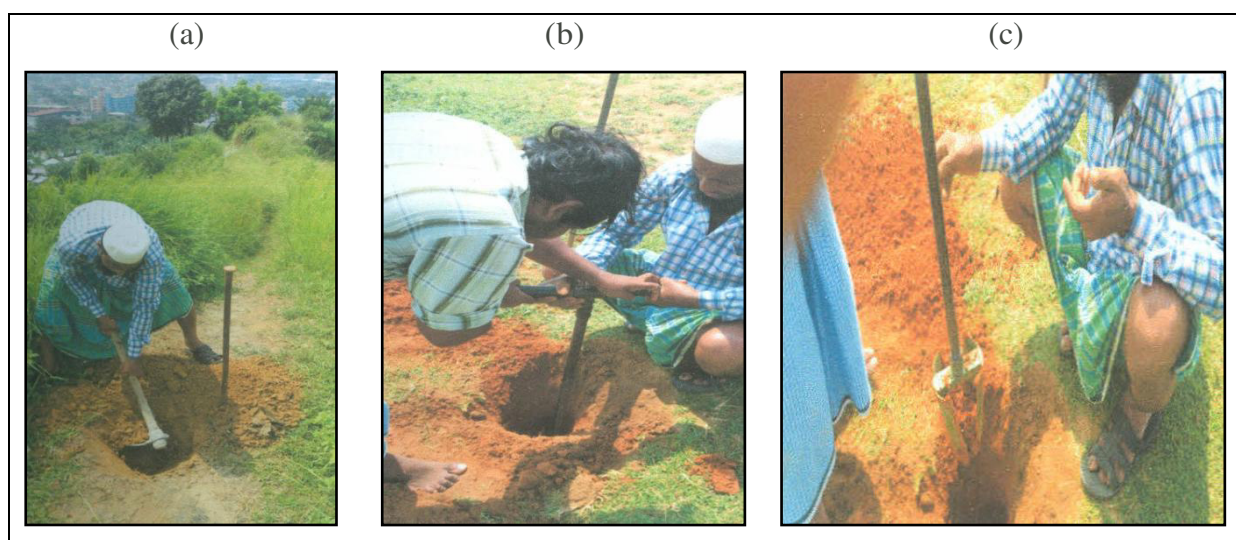


Figure 1.11: Collection of disturbed soil samples into separate polythene bags.

Source: *Field Survey, September, 2014*



#### 1.2.4 Procedure for Collecting Undisturbed Soil Sample:

A Two (2) feet long Shelby Tube was used to collect undisturbed soil sample. First, it was placed on the ground vertically and above it a square wooden plate was placed so that the blows from modified proctor hammer get distributed properly and also do not damage the steel Shelby tube (Figure 1.12).

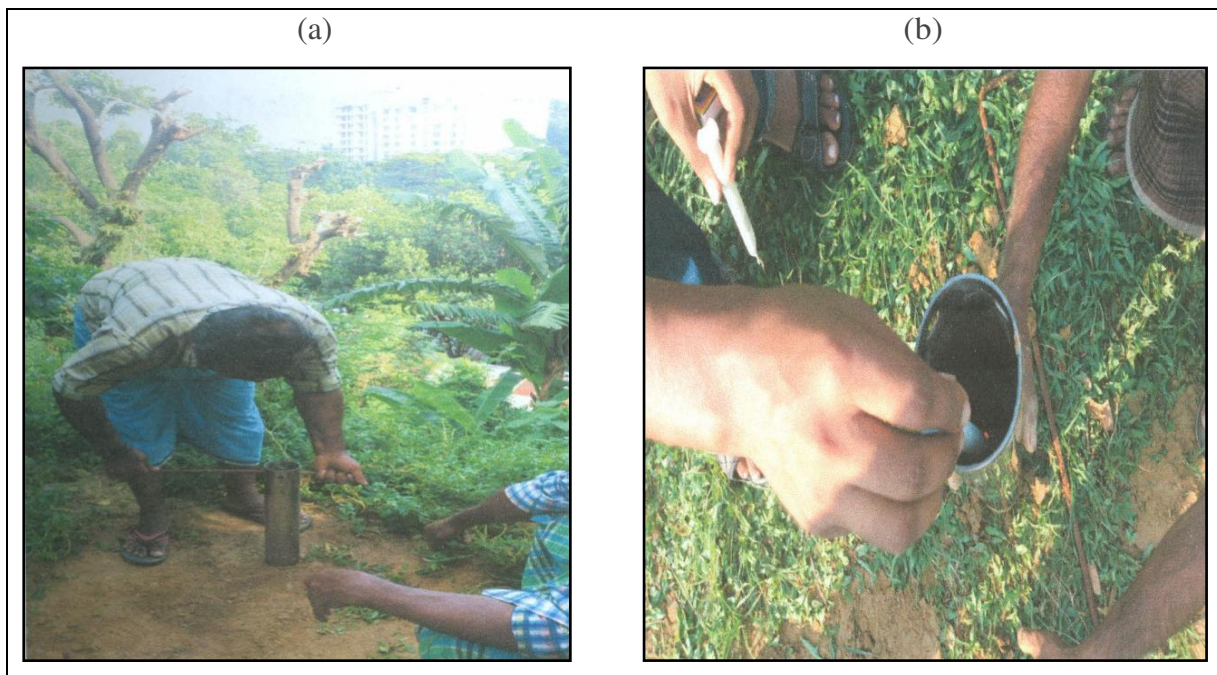
Figure 1.12: Inserting the Shelby tube deep into the ground by means of a 10 lb modified proctor hammer, blows were at a constant rate.

Source: *Field Survey, September, 2014*



Figure 1.13: (a) Extracting the Shelby tube from the ground with the help of a twisted steel rod (b) Waxing both the ends of the Shelby tube after soil sample collection.

Source: *Field Survey, September, 2014*



After that a 10 lb. modified proctor hammer was used to drive the Shelby tube vertically into the ground. Blows from modified proctor hammer were at a constant rate and also the ball was allowed to drop freely. The modified proctor hammer was placed just above the Shelby tube.

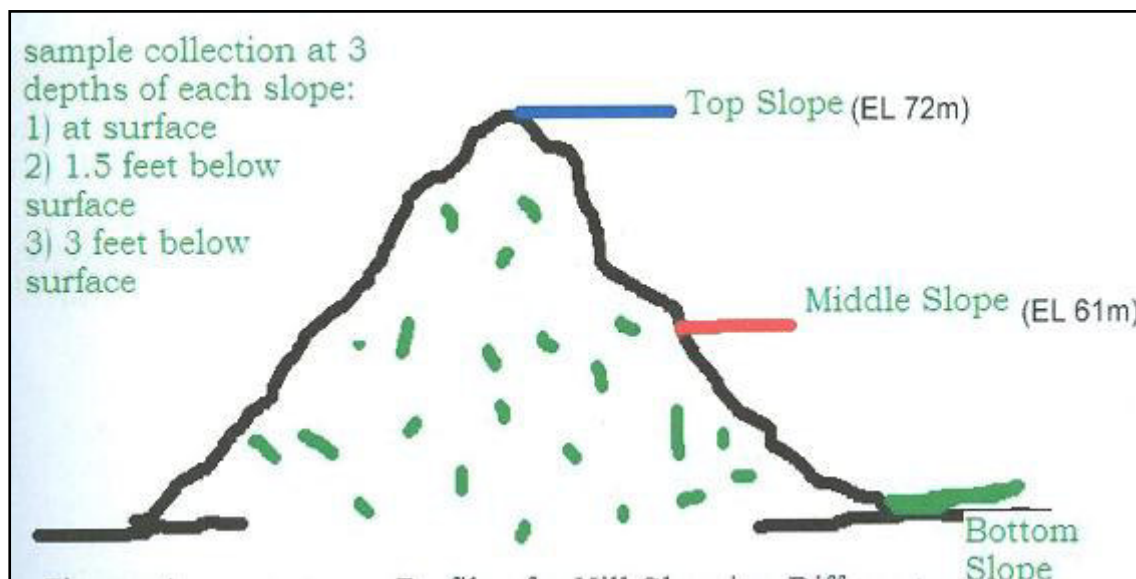
In between the hammer and the tube a 1 inch thick wooden plate was placed.

After going into the ground as much as possible, the Shelby tube was extracted from the ground. At the top of the Shelby tube, there are two holes. A twisted steel rod was entered through both the holes and then by twisting the rod with pressure applied by the hand, the Shelby tube was easily extracted from the ground (Figure 1.13).

After extracting the Shelby tube, with the soil sample still inside, both the ends of it were waxed to retain the original moisture condition of the field.

Figure 1.14: A vertical profile of a hill (Goachibagan Medical Hill, Panchlaish, Cluster-9) showing different slopes of it (Top, Middle and Bottom).

Source: *Field Survey, September, 2014*



## 1.3 TESTS PERFORMED ON DISTURBED SOIL SAMPLES

### 1.3.1 Determination of Atterberg Limits

#### Purpose:

This laboratory test is performed to determine the plastic and liquid limits of a fine-grained soil. The liquid limit (LL) is arbitrarily defined as the water content, in percent, at which a part of soil in a standard cup and cut by a groove of standard dimensions will flow together at the base of the groove for a distance of 13 mm (1/2 in.) when subjected to 25 blows from the cup being dropped 10 mm in a standard liquid limit apparatus operated at a rate of two shocks per second. The plastic limit (PL) is the water content, in percent, at which a soil can no longer be deformed by rolling into 3.2 mm (1/8 in.) diameter threads without crumbling.

#### Standard Reference:

ASTM D 4318 - Standard Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils.

**Significance:**

The Swedish soil scientist Albert Atterberg originally defined seven “limits of consistency” to classify fine-grained soils, but in current engineering practice only two of the limits, the liquid and plastic limits, are commonly used. (A third limit, called the shrinkage limit, is used occasionally.) The Atterberg limits are based on the moisture content of the soil. The plastic limit is the moisture content that defines where the soil changes from a semi-solid to a plastic (flexible) state. The liquid limit is the moisture content that defines where the soil changes from a plastic to a viscous fluid state. The shrinkage limit is the moisture content that defines where the soil volume will not reduce further if the moisture content is reduced. A wide variety of soil engineering properties have been correlated to the liquid and plastic limits, like “Atterberg Indices” namely Plasticity Index, Flow Index, Toughness Index.

**Plastic Limit:**

The plastic limit is the threshold point at which soil begins to behave as a plastic material. At plastic limit the soil must gain some minimum strength. According to Skempton and Northey (1953) the shear strength at plastic limit is about 100 times that at liquid limit.

**Plasticity Index:**

Plasticity Index is an indication of plasticity of soils. Plasticity Index greater than 20 indicates high plastic soil, 10-20 indicates medium plastic and less than 10 indicates non-plastic soils. It is known that high percentage of clay exhibit high plastic properties. Plasticity Index also a measure of the range of water content for which it remains plastic. The table below shows the quality of soil based on the vulnerability to landslides.

**Test Procedure:****Liquid Limit:**

- (1) Soil was pulverized, passed through a No. 40 sieve, air-dried. The soil was thoroughly mixed with a small amount of distilled water until it appears as a smooth uniform paste.
- (2) The liquid limit apparatus was adjusted by checking the height of drop of the cup. The point on the cup that comes in contact with the base should rise to a height of 10 mm. The block on the end of the grooving tool is 10 mm high and should be used as a gage.



It was practiced to rotate the cup and the correct rate to rotate the crank was determined so that the cup drops approximately two times per second.

- (3) A portion of the previously mixed soil was placed into the cup of the liquid limit apparatus at the point where the cup rests on the base. The soil was squeezed down to eliminate air pockets and it was spread into the cup to a depth of about 10 mm (half inch) at its deepest point. The soil pat should form an approximately horizontal surface (Figure 1.15).

Figure 1.15: Liquid limit device.

Source: *Field Survey, September, 2014*

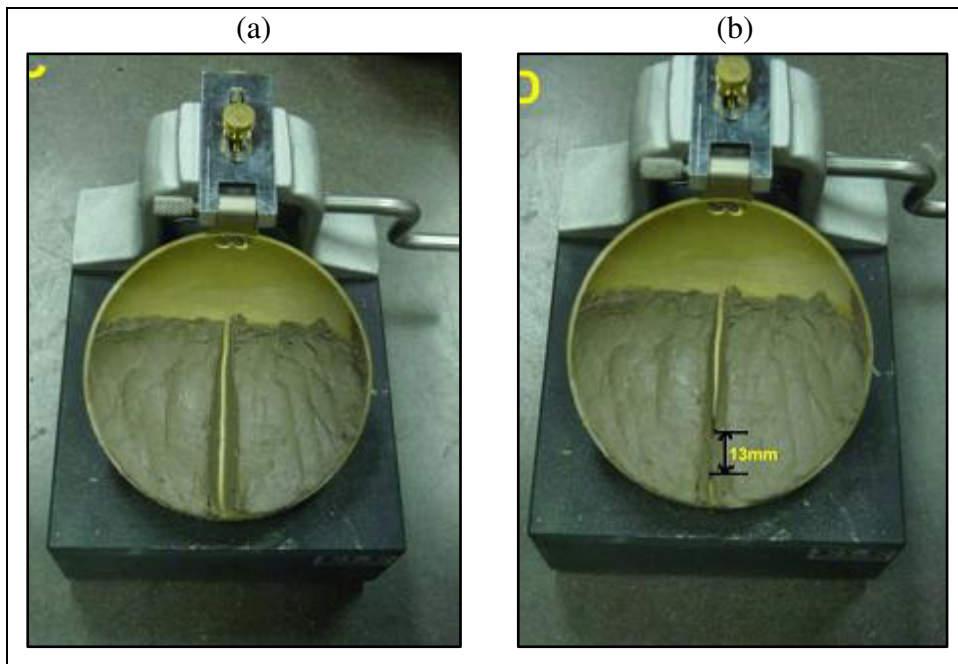


- (4) The grooving tool was used carefully to cut a clean straight groove down the center of the cup. The tool should remain perpendicular to the surface of the cup as groove is being made. Extreme care was taken to prevent sliding the soil relative to the surface of the cup (Figure 1.16-a).



Figure 1.16: Determination of liquid limit.

Source: *Field Survey, September, 2014*



- (5) It was made sure that the base of the apparatus below the cup and the underside of the cup was clean of soil. The crank of the apparatus was turned at a rate of approximately two drops per second and count the number of drops,  $N$ , it takes to make the two halves of the soil pat come into contact at the bottom of the groove along a distance of 13 mm (1/2 in.) (Figure 1.16-b).

If the number of drops exceeds 50 or is less than 10, then the number of drops was not recorded, otherwise, the number of drops was recorder on the data sheet.

- (6) Using the spatula, sample was taken from both sides of where the groove came into contact. The soil was placed into a moisture can, weighed and placed into the oven. The moisture can was left in the oven for 24 hours to obtain oven dry weight.
- (7) The entire soil specimen was remixed in the porcelain dish. A small amount of water was added into the specimen to increase the water content so that the number of drops required to close the groove decrease.
- (8) Steps six, seven, and eight were repeated for at least two additional trials producing successively lower numbers of drops to close the groove. One of the trials shall be for a

closure requiring 25 to 35 drops, one for closure between 20 and 30 drops, and one trial for a closure requiring 15 to 25 drops. The water content from was determined for each trial. The same balance was used for all weighing.

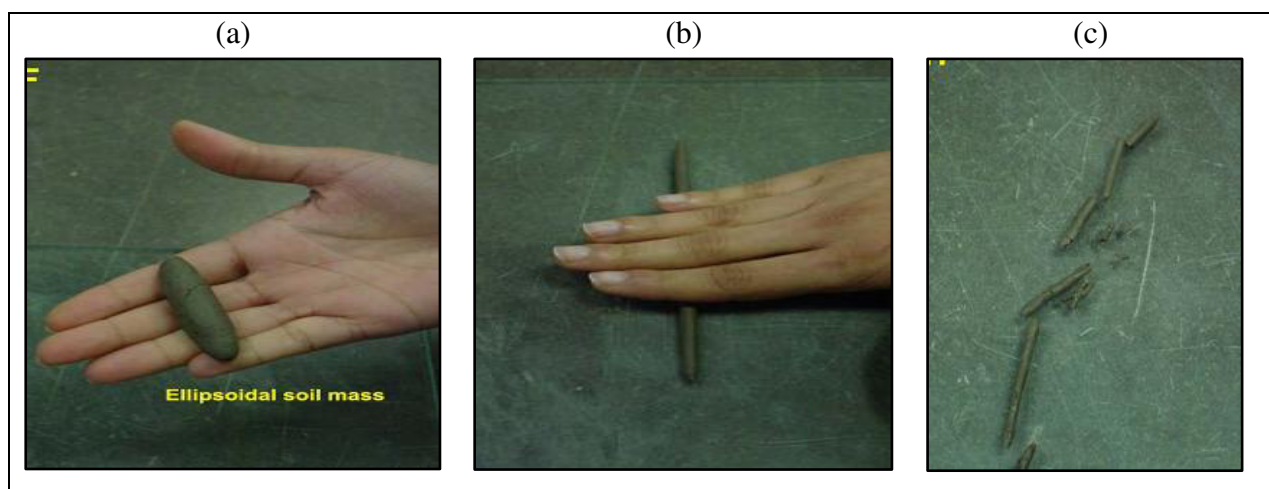
- (9) From plot of number of blows versus water content, the flow curve is obtained. Number of blows corresponding to 25 blows is the liquid limit.

### Plastic Limit:

- (1) Empty moisture cans were weighed.
- (2) The soil sample was taken and water was added until the soil is at a consistency where it can be rolled into a thread without sticking to the hands.
- (3) The soil was formed into an ellipsoidal mass (Figure 1.17-a). The mass was rolled between the palm or the fingers and the glass plate (Figure 1.17-b). Sufficient pressure was used to roll the mass into a thread of uniform diameter by using about 90 strokes per minute. (A stroke is one complete motion of the hand forward and back to the starting position). The thread shall be deformed so that its diameter reaches 3.2 mm (1/8 in.), taking no more than two minutes.

Figure 1.17: Determination of plastic limit.

Source: *Field Survey, September, 2014*



(4) The pieces were kneaded and reformed into ellipsoidal masses and rolled and re-rolled into threads. This alternate rolling, gathering together, kneading and re-rolling were continued until the thread crumble just begins to reaching a 3.2 mm diameter size (Figure 1.17-c).

(5) The portions of the crumbled thread were gathered together and the soil were placed into a moisture can, and then covered. If the can does not contain at least 6 grams of soil, soil was added to the can from the next trial (Step 6). Finally, the moisture can was left in the oven for 24 hours.

(6) Steps three, four, and five were repeated at least one more time.

### **Analysis:**

#### ***Liquid Limit:***

(1) The water content of each of the liquid limit moisture cans was calculated after they have been in the oven for 24 hours.

(2) The number of drops, N, (on the log scale) versus the water content (w) was plotted. Draw the best-fit straight line through the plotted points and the liquid limit (LL) as the water content at 25 drops was determined.

#### ***Plastic Limit:***

(1) The water content of each of the plastic limit moisture cans was calculated after they have been in the oven for at 24 hours.

(2) The average of the water contents was calculated to determine the plastic limit, PL. If the difference between the water contents is greater than the acceptable range of two results (2.6 %) was checked.

(3) The plasticity index,  $PI=LL-PL$  was calculated. The liquid limit, plastic limit, and plasticity index were calculated to the nearest whole number, omitting the percent designation.

Table 1.1: Data of Lal Pahar (Akbar Shah Mazar Cluster)

Source: *Field Survey, September, 2014*

Liqud Limit and Plastic Limit Determination								
Liqud Limi Determnation								
blow number	Can Number	Can wt	Can+wt soil	Can+dry soil	Water	Dry soil	w%	Liquid Limit (graph)
10	809	6.4	16.5	13.1	3.4	6.7	50.75	
25	2233	10.5	21.6	18.3	3.3	7.8	42.31	42.31
28	2007	10.4	18.9	16.3	2.6	5.9	44.07	
32	2232	10.4	25.1	21	4.1	10.6	38.68	
Plastic Limit Determnation								
	Can number	Can weight	Can+ wet soil	Can+Dry soil	Water	Dry soil	w%	Plastic Limit
	203	6.4	9.6	9	0.6	2.6	23.08	22.93
	832	11.3	21	19.2	1.8	7.9	22.78	

**Result:**

Liquid Limit: 42%

Plastic Limit: 23%

Plasticity Index:  $42 - 23 = 19\%$

Figure 1.18: Flow curve- percentage of water content and number of blow Akbar Shah Mazar Cluster).

Source: *Field Survey, September, 2014*

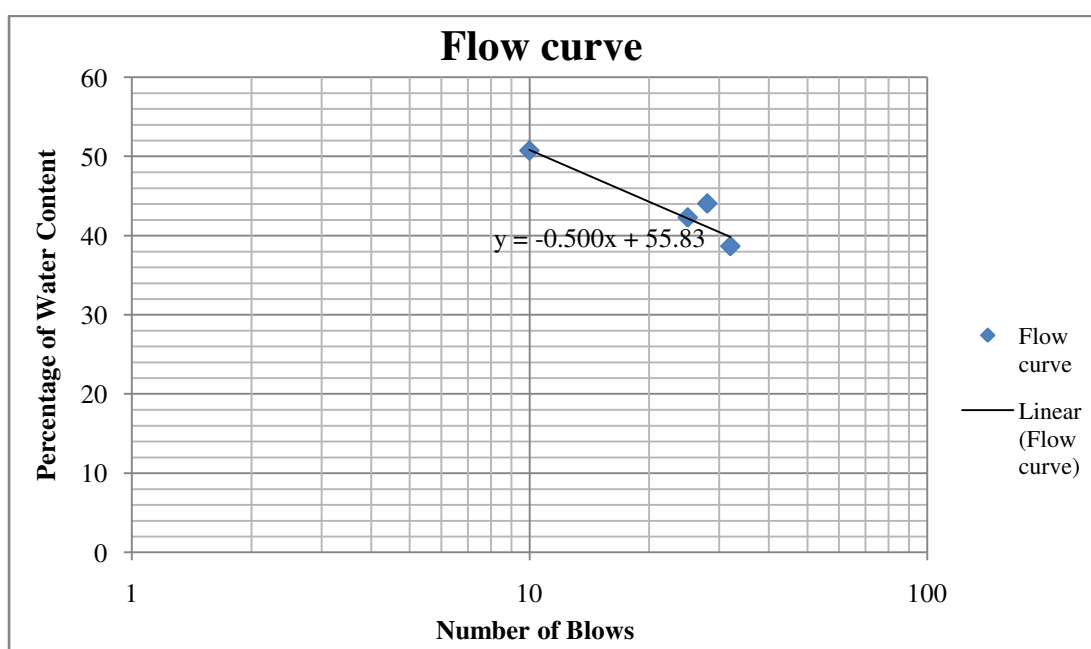


Table 1.2: Data for Tankir Pahar (Moti Jharna Cluster)

Source: *Field Survey, September, 2014*

Liquid Limit and Plastic Limit Determination								
(soil sample from Tankipahar)								
Liquid Limit determination								
No. of blow	can number	can wt	can+ wet soil	can+dry soil	water	dry soil	moisture content w%	Liquid Limit
17	2120	9.7	24.6	20	4.6	10.3	44.66	
27	2047	9.1	23.9	20.3	3.6	11.2	32.14	36.57
31	2186	9.3	25.6	21.8	3.8	12.5	30.40	
40	2199*	9	21.6	18.8	2.8	9.8	28.57	
Plastic Limit Determination								
	Can number	Can Wt.	can+ wet soil	can+ dry soil	water	dry soil	moisture content w%	plastic limit
	2244	8.7	27.7	24.1	3.6	15.4	23.38	23.10
	2080	10.8	22.1	20	2.1	9.2	22.83	

**Result:**

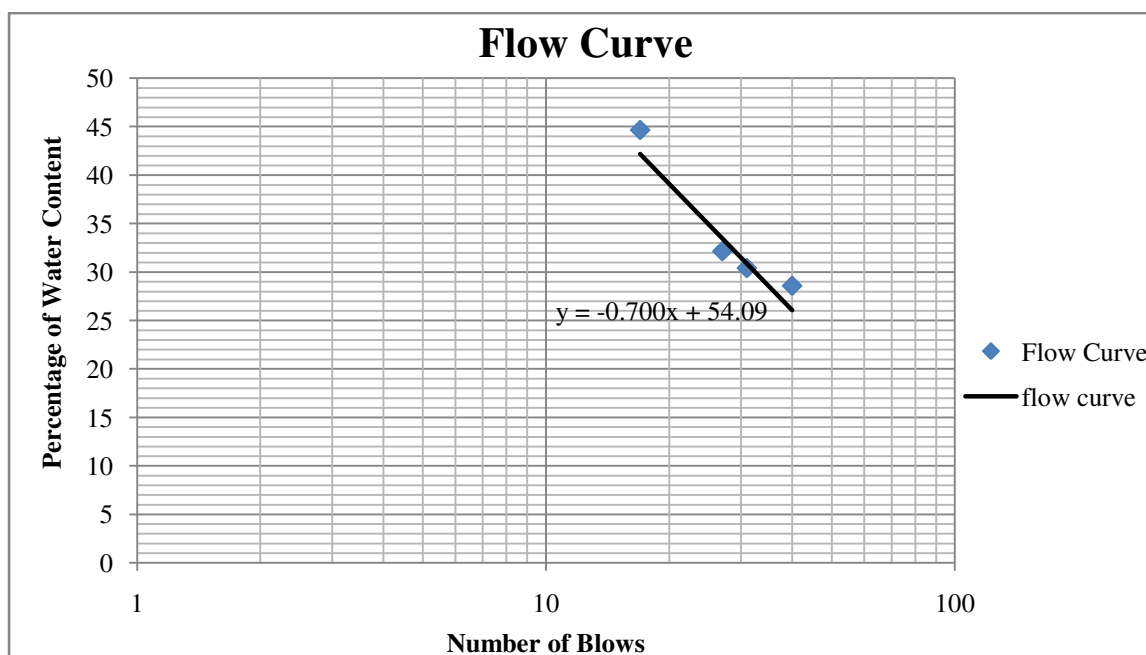
Liquid Limit = 37%

Plastic Limit = 23%

Plasticity Index = 37-23 = 14%

Figure 1.19: Flow curve- percentage of water content and number of blow (Moti Jharna Cluster).

Source: *Field Survey, September, 2014*



### 1.3.2 Determination of specific gravity

**Purpose:**

This laboratory test is performed to determine the specific gravity of soil by using a pycnometer. Specific gravity is the ratio of the mass of unit volume of soil at a stated temperature to the mass of the same volume of gas-free distilled water at a stated temperature.

**Standard Reference:**

ASTM D 854-00 – Standard Test for Specific Gravity of Soil Solids by water Pycnometer.

**Significance:**

The specific gravity of a soil is used in the phase relationship of air, water, and solids in a given volume of the soil.

**Equipment:**

Pycnometer, Balance, Vacuum pump, Funnel, Spoon.

**Test Procedure:**

- (1) 50g of soil sample (passed through the sieve No. 10) was placed in the pycnometer. Distilled water was added to fill about three-fourth of the pycnometer. The sample was soaked for 10 minutes.
- (2) A partial vacuum was applied to the contents for 10 minutes, to remove the entrapped air.
- (3) The vacuum was stopped and the vacuum line was carefully removed from pycnometer.
- (4) The pycnometer was filled with distilled (water to the mark), the exterior surface of the pycnometer was cleaned with a clean, dry cloth. The weight of the pycnometer and contents ( $W_1$ ) was determined.
- (5) 4 separate bowls were cleaned and their weights were determined.
- (6) The pycnometer was left like this for about 24 hours. Then it was emptied and cleaned.



The soaked soil was placed in bowls and then put into oven for 24 hours to be oven dried. Then the pycnometer was filled with distilled water only (to the mark). The exterior surface of the pycnometer was cleaned with a clean, dry cloth. The weight of the pycnometer and distilled water ( $W_2$ ) was determined.

(7) The Oven dry sample was taken out after 24 hours and the weights was determined ( $W_s$ ).

### Data Analysis Procedure:

Specific gravity of the soil solids were calculated using the following formula:

$$G_s = G_T W_s / (W_s - W_1 + W_2)$$

Where,

$W_1$  = Wt. of pycnometer + water + soil

$W_2$  = Wt. of pycnometer + water

$W_s$  = Wt. of soil

$G_T$  = Specific gravity of water at room temperature ( $T^\circ\text{C}$ )

Table 1.3: Data for determining the specific gravity.

Source: *Field Survey, September, 2014*

Sample Name	Bottle+water+soil ( $W_1$ )	Bottle+water ( $W_2$ )	wt. of dish	Dish+dry soil	Dry soil ( $W_s$ )	Specific Gravity
Lalpahar	377.1	346.2	82.1	131.2	49.1	2.69
GuachiBagan	373.2	341.8	71	120.7	49.7	2.71
Golpahar	376.3	345.5	75.2	124.9	49.7	2.62
Tankiapahar	372.2	341.2	79.8	128.8	49	2.71

The room temperature was  $27^\circ\text{C}$  and specific gravity of water at that temperature was 0.9965.

### Result:

The specific gravities for the four hills are given below.

LalPahar: 2.69

GuachiBagan: 2.71

GolPahar: 2.62

Tankir Pahar: 2.71

### 1.3.3 Sample calculation for grain size analysis

#### Selection of “Wash Sieve” over normal Sieve Analysis

Soil samples of four different hills (Lal Pahar, Golpahar, Tankir Pahar, Goachibagan) were collected and tested for grain size analysis which will facilitate the classification of those soils. From observation it was understood that two of the hills had predominantly sandy soil (Golpahar, Goachibagan) whereas the rest of the two had a mixture of sand, silt and clayey soil. Because of the presence of cohesive material “Wash Sieve” was performed.

#### Wash Sieve Procedure:

- 1) For each of the hills, 100g of soil sample was taken at first. All of them were crushed and ground into very fine powder like substances. All the lumps were powdered too.
- 2) Then it was sieved only with #200 sieve (opening 0.075mm). Then the sieve was shaken manually with hands and the soil that passed the #200 sieve and retained on the pan was weighed.
- 3) The sample that was retained over the #200 sieve was subjected to “Wash Sieving”, whereby clay lumps can be broken.

The grain size from field survey is given in table 1.3

Table 1.4: Data for determining the grain size.

Source: *Field Survey, September, 2014*

Site	Sand (%)	Silt & clay (%)
Lalpahar	34.1	65.9
Tankir Pahar	18.2	81.8
Golpahar	58.4	41.6
Goachibagan	64.5	35.5



The following table summarizes the index properties of the soil samples from four hill top sites.

Table 1.5: Index proportion of soil sample collected from hill top sites.

Source: *Field Survey, September, 2014*

Site	Specific Gravity	Liquid Limit	Plastic Limit	Plasticity Index	Sand (%)	Silt & clay (%)
Lalpahar	2.69	42	23	19	34.1	65.9
Tankir Pahar	2.71	37	23	14	18.2	81.8
Golpahar	2.69	Non plastic			58.4	41.6
Goachibagan	2.71	Non plastic			64.5	35.5