

Used Marble Slurry as Stabilization for Land Filling by Clay as Additive Product

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1. INTRODUCTION

1.1 GENERAL

SOIL STABILIZATION is the process of changing the properties of soil to satisfy a specific engineering requirement. A soil's properties can be changed in a variety of ways, including chemical, thermal, mechanical, and other methods. It must be understood, however, that because to the wide variety of soils, no single approach is even effective in more than a small percentage of them.

Stabilization is utilized in a number of engineering projects, such as the building of low-cost road and air field pavements, where the main goal is to increase the strength or stability by utilizing locally accessible materials to the greatest extent possible. There are several methods of stabilization may be grouped under two main types:

1. Modification or improvement of properties of existing soil i& performed without addition of any admixture, and
2. Improvement of properties with the help of adding admixtures

Drainage and compaction are the examples of first type, which Improve inherent shear strength of soil.

Whereas mechanical Stabilization, lime stabilization with cement, bitumen and by various chemical are the examples of the second type. Hence when a less stable Soil is treated by any means to improve its strength and resistance against deformation, it is said to be stabilized.

Marble as raw material for building construction was not extensively used in ancient time. People belonging to higher strain of the society used marble as decorative slabs in houses, monumental buildings etc. Lesser use of marble generated less wastage but commercial production of marble and rapid urbanization has placed its use as first choice even of middle class; thereby increase in waste material is manifold.

As per Indian mineral year book 1993, there are total of 1004.3 million tones reserves of marble in our country. Out of the total reserves more than 90% are in Rajasthan. The year wise production of marble in Rajasthan is as under.

Table A. Year wise production of marble in Rajasthan

Year	Production in Tones
2017-18	13199265
2018-19	8252000
2019-20	10621000

The figures given above shows that the production has raised from 82.5 lac tones to 106.2 tons in 1 year i.e. an average is more than 20% per year.

To put the marble rock in its final shape as per necessity, the marble industry was dumping 15% solids here and there waste including blasting muck, marble pieces (waste of cutting machine) etc. with technological changes wastage has gone down. Smaller pieces of marble are crushed or finally grounded and used as abrasive in soaps and other products.

Crushed marble is also used in paving roads and in manufacturing roofing materials and soil treatment products. But wastes produced by machine like Diamond gang saw, Diamond wire saw is in very fine powdered form, passing 75 micron is still of no commercial use and therefore, being thrown away here and there. Heaps of this powder can be seen on roadsides of Makrana-Kishangarh bypass, Ranger etc. the powder blows away with wind causing air pollution. The gravity of the problem can be visualized by the fact that a plot of more than 50 bigha land arranged by the municipality of Makrana town was completely filled by this waste within a few years.

Mathur, K.K, (2000) admix the marble slurry with clay for making bricks. He concluded that only 5% marble slurry is useful to increase the strength of bricks. No more literature is available on reuse of marble slurry.

CHAPTER -2 LITERATURE REVIEW

2.1 GENERAL

Soil stabilization is the process of enhancing the soil's engineering qualities and thereby increasing its stability. When the soil available for construction is unsuitable for the intended purpose, it is necessary. Compaction, reconsolidation, and other forms of stability are all included in this comprehensive definition. Short-term stabilization, on the other hand, is usually limited to procedures that alter the soil material itself in order to improve its qualities. For the objective of stability, a cementing substance or a chemical is added to natural soil.

Soil stabilization is a technique for reducing the permeability and compressibility of a soil mass while increasing its shear strength in an earth structure. To raise the carrying capacity of foundation soil, soil stabilization is essential. The main application of stabilization is to improve natural soils for the construction of motorways and airports. Soil stabilization principles are used to manage the grading of soils and aggregates in the construction of roadway and airfield bases and sub bases.

For military and other emergency needs, soil stabilization is also utilized to make a region trafficable in a short amount of time.

Various strength improving techniques available today are mechanical stabilization with special stabilizer, Complex stabilization, Thermal stabilization, Bitumen stabilization, Lime and Cement stabilization, Electrical stabilization and Chemical stabilization.

2.2 STRENGTH IMPROVING TECHNIQUES

The methods generally used for strength improvement of deposits are:

2.2.1 Mechanical Stabilization

Mechanical stabilization is the technique of modifying the gradation of a soil to improve its qualities. Two or more types of natural soils are combined to create a composite material that outperforms its constituents. To accomplish the desired grading, coarse-particle soils are occasionally supplied, or fine-particle soil is removed.

2.2.2 Complex Stabilization

When the soil is stabilization with two or more than two stabilizers then it is called complex stabilization. The complex stabilization is used for organic soils, highly fat clays etc.

2.2.3 Freezing and Heating

Artificial soil refrigeration (freezing the pore water) has been used to facilitate construction of open and underground excavation; Heating is adopted for clay soils. A cohesive soil may be burnt in kilns to produce artificial aggregate. Heating is also adopted in situ for road bases by the use of traveling road burners at temperatures 400° to 600°.

2.2.4 Electrical Stabilization

When a direct current potential is applied to a most fine grained soil, the pore water is induced to flow from the positive electrode (anode) to the negative electrode (cathode) and at the same time electrolysis occurs with the anions and of the dissolved salts moving towards the anode and cathodes respectively. The process is known as Electro-osmosis. This Electro chemical treatment can be applied for in situ strengthening of soil under existing structures without any disturbance Electro-osmosis is commonly applied to improve the stability of cuts and trenches- It has been used to increase the bearing capacity of friction piles.

2.2.5 Stabilization by Grouting

A grout is a stabilizing material of fluid consistency, which is pumped into soil pores (and fissures) with the purposes of reducing permeability, increasing shear strength and preventing excessive settlement. Grouting is the process in which the grouts are injected into the soil for its stabilization.

2.2.6 Stabilization by Geo-textiles

Geo-textiles are permeable synthetic fabrics, which can be used to improve soil properties. They are even used in a vast

array of construction works like as pavements, embankments, retaining structures, reservoirs, canals, dams, bank protection, and coastal engineering.

2.2.7 Stabilization by Bituminous Material

Bituminous materials (asphalts and tars) are used to improve the engineering properties of soils in a variety of forms. In cohesive soils, which traditionally have adequate bearing capacity at low moisture contents, bitumen mainly serves the purpose of waterproofing the soil and reducing water absorption. In the case of sandy soils lacking cohesion, bitumen serves as a bonding or cementing agent. Bitumen requirements commonly range from 4 to 7% of the dry weight of the cohesive soils.

2.2.8 Chemical Stabilization

Chemical weathering involves the insertion of various compounds to preserve soils. The main advantage of chemical stabilization is that it allows you to control the setting and curing times. Chemical stabilization, on the other hand, is typically more expensive than other types of stabilization. Sodium chloride, calcium chloride, Sodium silicate, polymers, formaldehyde etc. are few chemicals, which have successfully been used in chemical stabilization.

2.2.9 Stabilization by Cement

The ordinary Portland cement and soil mixed at the proper moisture content produce "soil cement" a structural material, which is Hard and durable. Soil cement has been used mainly as bases under concrete pavement for highways and airfields. At the beginning of 1935, the Portland cement Association launched a program of investigations, tests and development for involving predicable and dependable principles of control resulting on test procedures, which were development into standards by the A.S.T.M.

Z.C, Meh et. al. (1967) carried out a series of experimented investigations on the responses of six selected lateristic soils to the stabilization by Portland cement and derived some valuable conclusion.

wide range of soils can be treated and improved by mixing with cement the notable exception of highly organic soils, Weil graded granular soils with 10-35 percent fines ($W_L < 40 < I_p < 20$) give best results and require lesser amounts of cement. Soils with high clay content are difficult to be pulverized. The cement requirement increases with the amount and water affinity of clay,

Kulkarni (1970) tested three desert sands of Rajasthan stabilized with cement. He observed that there was an

increase in the compressive strength, tensile strength and tensile strength in flexural for all the three soils with the increase in the cement content and curing days.

2.2.10 Stabilization by Lime

Lime is one of the several products that can be successfully used in the improvement of the engineering characteristics of soils. When lime is added to a lime reactive soil there is a reduction in plasticity and a gradual increase in strength with time after compaction, which may be attributed to the following reactions (Thompson 1964, Herein and Mitchell 1961).

- A) Cation exchange
- B) Flocculation, agglomeration
- C) Pozzolanic reactions

ARBA (1948) advocated the formation of calcium alumina silicate complexes from the lime and silica provided by the breakdown of the clay mineral as the result of high pH. Laguros et. al. (1956) advocated flocculation as a result of decreased potential. Clare and cruchley (1957)

Advocated flocculation caused by proton transfer and subsequent binding by Ca^{++} Miller and McNichol (1958) suggested a formation of crystalline $\text{Ca}(\text{OH})_2$.

A soil deposit can also be stabilized by treatment with lime piles or lime columns. Physics of quick lime pits has been worked out by Holliman et. al. (1983) When quick lime of a pile and moist soil are brought into contact, several processes can take place that will affect the properties of the soil.

1. Absorption of water from soil to hydrate the quick lime and fill its voids.
2. Heating caused by hydration of the lime
3. Expansion of lime upon hydration, which result in compression of the soil in horizontal direction.
4. Hardening of annual zone around the pile into which there has been diffusion of lime.

a) Compaction

The success of lime soil stabilization technique depends to a great extent on adequate compaction of the mixture. Compaction is considered to be necessary for bringing the clay minerals into close and intimate contact with the lime particles so that the inter growth of crystalline reaction products is facilitated. With soil-lime mixture, the greater the comp active effort, the more is strength attained. Taking typical from Remus and Davidson, a calicite lime (6

percent) used with glacial till soil yielded an unconfined compressive strength (7 days cure and 24 hours immersion) of 16 kg/cm^2 at standard AASHTO compaction. For the same conditions, but with modified AASHTO compaction, the strength increased to 32 kg/cm^2 .

b) Shear Strength

Lime has beneficial influence in increasing the shear strength properties of soil. Both the cohesion and angle of shearing resistance (ϕ) are seen to increase. In one case, cohesion values of lime-soil mixtures for 1 day curing periods were 1.5 to 5 times larger than those of untreated soils, and the (ϕ) values increased from 7 to 18 degree to 25 to 35 degrees. Some investigations report that the strength is mainly due to increase in cohesion increased from 1.96 kg/cm^2 after one day.

c) Percentage of Additive Lime

The amount of lime used determines the strength of the lime-soil mixture to a significant extent. Small amounts of lime, such as 1 to 2 percent, aid in the immediate amelioration of Base Exchange and flocculation effects.. As the time content of the mixture is raised, the tangible influence of lime stabilization of soil in raising the strength of the mixture begins to be felt, and this is due to pozzolanic reactions resulting in the creation of cementitious compounds. This strength rise is also seen to be time-dependent, with variances in strength gain due to varying lime concentrations being more evident with longer curing intervals.

2.3 MARBLE DEPOSITION IN RAJASTHAN

The term marble is derived from the Latin work "marmor" which is having its root in Greek "marmaros", meaning there by shining stone In ancient times stone capable of taking polish without any regard to this chemical composition was designated as Marble. With the advances in earth science a more sophisticated and accurate classification of rock on the basis of their birth history and chemical composition has come into vogue.

The term "marble" generally indicates carbonic acid subject to a polishing process and to use as ornamental material. They include all those litho logic types in which the two most common carbonated calcite and dolomite, form at least 50% of the total of the rock. In the natural state there is a whole series of transition terms, as from rocks entirely made of CaCO_3 , limestone to dolomite rocks whose main component is dolomite $\text{CaMg}(\text{CO}_3)_2$. Petro CHART ically marble intends those calcareous rocks, which undergoing metamorphic processes are being subjected to re-crystallization taking to sacchariod structure. Calcite,

Onyx, Dolomite, Serpentine and Travertine are the qualities of marble depending upon the presence of magnesium and other minerals.

Marble has a broad range of Chemical and physical properties. The chemical composition determines many physical properties of marble, particularly its suitability with reference to weathering. Marbles are more susceptible to acid conditions, in the form of rain, smoke etc. The chemical composition of some of the world famous commercial marble is given below.

Table 2.01: Chemical Composition of Marble of Rajasthan

Chemical	Locality			
Analysis	Piloti	Ghoratan kari	Perwa	Serngw
Insoluble	3.97	16.16	8.52	7.80
$\text{Fe}_2\text{O}_3, \text{Al}_2\text{O}_3$	0.67	0.74	0.54	0.02
CaO	49.55	47.89	51.49	52.98
MgO	3.47	0.70	0.90	0.11
Loss on Ignition	42.34	34.82	39.36	39.72

A minor quantity of organic material in the form of impurities often produces decorative pattern and colors in the marble. The acceptable physical qualities of marble may differ depending on our intended usage. The most essential physical features of marble are strength, durability, and attractiveness, while a variety of additional properties can influence its usability and worth. Hardness is a measure of how resistant a substance's surface is to abrasion.. The presence of flint or silicate mineral increases the hardness of the marble. The index of abrasive hardness (Ha) ranges from 8 to 48 for marble (Anon, 1993). The specific gravity of marble depends on its chemical composition, Dolomite marbles are-heavier than pure calcite marbles. The specific gravity of calcite marble is around 27. The average specific gravities of some of the marbles are-given here

Specific Gravity of Different Marbles

Locality	Specific Gravity
Piloti	2.74
Gharatankari	2.86
Perwa	2.72
Sarangwa	2.74
Makrana	2.702 to 2.747

Ambaji	2.7
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Source: Marble in India Bureau of Mines, Nagpur,

Marble has been known as building stone since ages. In India a good quality of marble are found in Andhra Pradesh, Gujarat, Madhya Pradesh and Rajasthan. However, best quality marble comes from Marana in Rajasthan. Marbles of various

textures and colours like white, pink, black, green yellow, brown and multi colour combinations, exists in India. Of the total production, Rajasthan shares 90% production of marble. During the year 1990-91, 17,04 lac tonnes of marble valued to Rs. 69.63 crores was produced. On the basis of colour, us shade and pattern marble has been classified into 10 groups b\ BIS AH the 10 groups are found to occur in Rajasihan As per Mineral Yearbook - 1993, there is total 1004.3 million tonnes of marble in our country. In Rajasthan marble deposits suitable for commercial exploitation have been identified in many districts of the state.

The main marble belts are located at Makrana, Tripura-Sundri and Rajnagar, respectively. In the year 1996-97 Rajsamand, Nagaur, Udaipur, Alwar and Banaswara were the districts produced more than 80% of the total marble produced in Rajasthan.

The compositions of rocks directly affect the sawing characteristics. Composition of Rajasthan Marbles shows variable nature. The Makrana marble and Sirohi marble is of calcite nature. Rajnagar, Banaswara, Alwar and Jaipur marble is of dolomitic in nature.

As given in annexure variety of marbles are available in Rajasthan. Accordingly the marble slurry has its composition as siliceous, dolomitic and calcite. The slurry formed has very fine powder (particles passing 75 micron = 100%).

According to unauthenticated reports, marble slurry powder has been used as ingredient for plastering, making floor tiles etc. but being finer; the percentage of quantity of cement required in these works was very high. This makes

the products un-viable, being costlier as compared to traditional products of similar strength.

3 METHODOLOGY

3.1 GENERAL

The laboratory investigation on marble slurry stabilization with Clay were conducted. The marble slurry was brought from marble cutting factory and Clay used here to be investigating with Marble slurry was taken from a site nearby Jaipur. It is moderately stiff in nature

3.2 MATERIALS

3.2.1. Marble Cutting Powder

The marble powder used to admix for stabilization was obtained from local marble cutting machine of Jodhpur as marble slurry, after sun dried it was used as marble powder. The physical properties of the marble powder were tested, and the same are reported as under.

Physical properties of Marble Cutting Powder

S.No.	Physical properties of marbles cutting powder	
1.	Max. Dry density	1.714gm/c.c
2.	(ρ_{dmax})	18.1%
3.	Optimum moisture Content	2.70
4.	Specific gravity	100%
	Particle smaller than 75 micron	

Chemical Composition of Marble of Rajasthan

Chemical Analysis	Locality			
	Piloti	Ghorat ankari	Perwa	Serngw a
Insoluble	3.97	16.16	8.32	7.80
Fe ₂ O ₃	0.67	0.74	0.54	0.02
Al ₂ O ₃				
CaO	49.55	47.89	51.49	52.58
MgO	3.47	0.70	0.90	0.11

Loss on Ignition	42.34	34.82	39.36	39.72
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The particle size analysis of marble powder is determined by I hydrometer and is shown in Fig. 3.01, A typical pattern of the moisture content, dry density CHART is shown in Fig. 3.02. Optimum moisture content was determined by conducting light compaction test. The direct shear test was carried out under stress control condition determined angle of internal friction and cohesion as shown in Fig 3.U3

3.2.3. CLAY

- Clay consist of microscopic and sub-microscopic particles derived from the chemical decomposition of rocks
- Contains large quantity of clay minerals.
- It exhibits considerable strength when dry.
- It is a cohesive soil.
- It can be made plastic by adjusting the water content.

Physical & Chemical properties of Clay:

Clay contains minerals; out of them 3 main types of mineral govern the chemical as well as physical properties of clay soil. These three minerals are Montmorillonite. Kaolinite & Illite.

Clay minerals are composed of two basic structural units:
(1) Tetrahedral unit, (2) Octahedral unit.

- Clay has high plasticity and swelling property due to clay mineral Montmorillonite.
- Their particles are colloidal in shape. Due to such shape they assembled either in flocculated or in depressed state.
- Clay has high specific surface. Due colloidal particle it remains in suspension for longer time.
- When it assembled in loose state it possess high voids ratio. However it has very low permeability or low seepage. This paradox shown by clay can be explained by its particles shape.
- Its particles have very thin sheet type structure on saturation a water film form surround the each particle and this water which called adsorbed water

obstruct the flow of water through clay by surface tension force.

- A high value of toughness index indicates a high percentage of colloidal clay containing mineral montmorillonite.
- Clay used here to be investigating with Marble slurry was taken from a site nearby Jaipur. It is moderately stiff in nature

3.3. TEST PROGRAM

TEST FOR INDEX PROPERTIES,

Determination of Liquid limit,

Determination of Plastic limit,

Determination of Shrinkage limit,

Determination of Plasticity Index,

Determination of Flow index,

Determination of Toughness index

TEST FOR ENGINEERING PROPERTIES,

Standard Proctor Test

Determination of Optimum moisture Continent.

Determination of Maximum dry strength.

Direct Shear Test

(A-Strain Controlled Test / B-Stress Controlled Test)

Determination of Shear angle

Determination of Cohesion value

SAMPLE TAKEN FOR VARIOUS TESTS

(100% Mp & 0% Clay)

(90% Mp & 10% Clay), (80% Mp & 20% Clay)

(70% Mp & 30% Clay), (60% Mp & 40% Clay)

(55% Mp & 45% Clay), (50% Mp & 50% Clay)

45% Mp & 55% Clay), (40% Mp & 60% Clay)

(35% Mp & 65% Clay), (30% Mp & 70% Clay)

(20% Mp & 80% Clay), (10% Mp & 90% Clay)

(0% MP & 100% Clay)

4 ANALYSIS OF TEST RESULTS AND DISCUSSIONS GENERAL

The Following test has been conducted to find the Liquid limit, Plastic limit, Shrinkage limit, Plasticity Index, Flow index and Toughness index

1 LIQUID LIMIT

- 1.1 Liquid limit test for (100% Mp & 0% Clay)
- 1.2 Liquid limit test for (90% Mp & 10% Clay)
- 1.3 Liquid limit test for (80% Mp & 20% Clay)
- 1.4 Liquid limit test for (70% Mp & 30% Clay)
- 1.5 Liquid limit test for (60% Mp & 40% Clay)
- 1.6 Liquid limit test for (55% Mp & 45% Clay)
- 1.7 Liquid limit test for (50% Mp & 50% Clay)
- 1.8 Liquid limit test for (45% Mp & 55% Clay)
- 1.9 Liquid limit test for (40% Mp & 60% Clay)
- 1.10 Liquid limit test for (35% Mp & 65% Clay)
- 1.11 Liquid limit test for (30% Mp & 70% Clay)
- 1.12 Liquid limit test for (20% Mp & 80% Clay)
- 1.13 Liquid limit test for (10% Mp & 90% Clay)
- 1.14 Liquid limit test for (00% MP & 100% Clay)

Liquid Limit for 100% MP& 0% Clay

Test No.	Wt. Of Empty Crucible (W ₁) gm	Wt of Empty crucible + Wet Sample (W ₂) gm	Wt of Empty Crucible + Dry Sample (W ₃) gm	Water Content (w%)	No. of Blows
1	23.25	35.36	31.21	52.13	14
2	24.96	40.39	35.14	51.56	17
3	31.52	45.14	40.69	48.53	23
4	29.7	44.03	39.44	47.13	35
5	35.68	51.46	46.47	46.23	41

LIQUID LIMIT----48.13%

No. of Blows	Water Content (w %)
11	65.98
19	63.24
24	61.97

29	60.49
39	58.17

Test no	Wt. Of Empty Crucible (W ₁) gm	Wt of Empty crucible + Wet Sample (W ₂) gm	Wt of Empty Crucible + Dry Sample (W ₃) gm	Water Content (w%)	No. of Blows
1	31.53	43.89	39.71	51.09	19
2	29.7	45.37	40.12	50.36	22
3	31.05	44.48	40.08	48.73	29
4	35.68	49.87	45.26	48.13	32
5	22.11	37.45	32.52	47.36	39

LIQUID LIMIT----49.73%

o. of Blows	Water Content (w%)
16	63.27
21	62.14
30	58.63
39	55.86
35	56.23

Liquid Limit for 90% MP & 10 %Clay

T e s t N o .	Wt. Of Empty Crucible (W ₁) gm	Wt of Empty crucible + Wet Sample (W ₂) gm	Wt of Empty Crucible + Dry Sample (W ₃) gm	Water Content (w%)	No. of Blows
1	31.53	43.89	39.71	51.09	19
2	29.7	45.37	40.12	50.36	22
3	31.05	44.48	40.08	48.73	29
4	35.68	49.87	45.26	48.13	32
5	22.11	37.45	32.52	47.36	39

LIQUID LIMIT---- 49.73%

No. of Blows	Water Content (w%)
16	63.27
21	62.14
30	58.63
39	55.86
35	56.23

LIQUID LIMIT----50.52%

No. of Blows	Water Content (w%)
15	61.27
22	59.13
25	58.09
29	56.87
36	54.19

3 SHRINKAGE LIMIT

- 3.1 Shrinkage limit for (100% MP & 0% Clay)
- 3.2 Shrinkage limit for (90% MP & 10% Clay)
- 3.3 Shrinkage limit for (80% MP & 20% Clay)
- 3.4 Shrinkage limit for (70% MP & 30% Clay)
- 3.5 Shrinkage limit for (60% MP & 40% Clay)
- 3.6 Shrinkage limit for (55% MP & 45% Clay)
- 3.7 Shrinkage limit for (50% MP & 50% Clay)
- 3.8 Shrinkage limit for (45% MP & 55% Clay)
- 3.9 Shrinkage limit for (40% MP & 60% Clay)
- Shrinkage limit for (35% MP & 65% Clay)**
- 3.10 Shrinkage limit for (30% MP & 70% Clay)
- 3.11 Shrinkage limit for (20% MP & 80% Clay)
- 3.12 Shrinkage limit for (10% MP & 90% Clay)
- 3.13 Shrinkage limit for (00% MP & 100% Clay)

4 Observations for Shrinkage Limit

A	Water content of wet soil paste	100%MP	10%Clay+ 90%MP	20%Clay+ 80%MP
1.	Shrinkage Dish no.	E	B	D
2.	Mass of shrinkage dish(Empty)	8.87 gm	9.17 gm	8.18 gm
3.	Mass of shrinkage dish + Wet soil paste	41.23 gm	41.70 gm	40.81 gm

4.	Mass of shrinkage dish + dry soil paste	29.86 gm	31.02 gm	29.78 gm
5.	Mass of dry soil paste	20.99 gm	21.85 gm	21.6 gm
6.	Mass of water	11.37 gm	10.68 gm	11.04 gm
7.	Water content of soil paste (w)	54.16 %	48.87 %	51.11 %
B	Volume of wet soil paste			
1.	Mass of evaporating dish	50.65	50.65	50.65
2.	Mass of mercury filling shrinkage dish + evaporating dish	315.44	310.04	310.4
3.	Mass of mercury filling shrinkage dish	264.79	259.39	259.75
4.	Volume of wet soil paste(V)	19.47 cm ³	19.07 cm ³	19.0799cm ³
C	Volume of dry soil paste			
1.	Mass of mercury equivalent to vol of (shrinkage dish-dry paste) + evaporating dish	125.57	116.53	123.13
2.	Mass of mercury equivalent to vol of	74.86	65.88	72.48

	(shrinkage dish-dry paste)			
3.	Mass of mercury displaced by dry paste	189.93	193.51	187.27
4.	Volume of dry paste(V_d)	13.96 cm ³	14.23 cm ³	13.769cm ³
D	Calculation:-			
1.	Shrinkage limit $w_s = (w - V - V_d)/M_d * 100$	27.90	26.72	26.43
2.	Shrinkage ratio $sr = M_d / (V_d * P_w)$	1.5036	1.5235	1.5687

5

6

7

8

9 **TABLE 3:2**

10 **Observations for Shrinkage Limit**

A	Water content of wet soil paste	30%Clay+ 70%MP	40%Clay+ 60%MP	45%Clay+ 55%MP
1.	Shrinkage Dish no.	C	A	D
2.	Mass of shrinkage dish(Empty)	9.24 gm	9.48 gm	8.18 gm
3.	Mass of shrinkage dish + Wet soil paste	42.02 gm	41.27 gm	41.42 gm
4.	Mass of shrinkage dish + dry soil paste	30.82 gm	29.87 gm	31.2 gm
5.	Mass of dry soil paste	21.58 gm	20.42 gm	23.02 gm
6.	Mass of	11.2 gm	11.4 gm	10.22 gm

	water			
7.	Water content of soil paste (w)	51.899 %	55.82 %	44.41 %
B	Volume of wet soil paste			
1.	Mass of evaporating dish	50.65	50.65	50.65
2.	Mass of mercury filling shrinkage dish + evaporating dish	315.72	317.03	310.4
3.	Mass of mercury filling shrinkage dish	265.07	266.38	259.75
4.	Volume of wet soil paste(V)	19.49cm ³	19.586 cm ³	19.099 cm ³
C	Volume of dry soil paste			
1.	Mass of mercury equivalent to vol of (shrinkage dish-dry paste) + evaporating dish	128.00	139.17	116.7
2.	Mass of mercury equivalent to vol of (shrinkage	77.35	88.52	66.05

	dish-dry paste)			
3.	Mass of mercury displaced by dry paste	187.72	177.86	193.7
4.	Volume of dry paste(V_d)	13.8 cm ³	13.08 cm ³	14.25 cm ³
D	Calculation:-			
1.	Shrinkage limit $w_s = (w - (V - V_d)/M_d) * 100$	25.53	23.95	23.34
2.	Shrinkage ratio $sr = M_d / (V_d * P_w)$	1.563	1.561	1.615

TABLE 3:5
Observations for Shrinkage Limit

A	Water content of wet soil paste	90%Clay+ 10%MP	100%Clay
1.	Shrinkage Dish no.	B	A
2.	Mass of shrinkage dish(Empty)	9.17 gm	9.45 gm
3.	Mass of shrinkage dish + Wet soil paste	41.45 gm	42.97 gm
4.	Mass of shrinkage dish + dry soil paste	30.83 gm	31.73 gm
5.	Mass of dry soil paste	21.71 gm	22.28 gm
6.	Mass of water	10.62 gm	11.25 gm
7.	Water content of soil paste (w)	48.92 %	50.45 %
B	Volume of wet soil paste		
1.	Mass of evaporating dish	50.65	50.65
2.	Mass of mercury filling shrinkage dish + evaporating dish	310.04	317.03
3.	Mass of mercury filling shrinkage dish	259.39	266.38
4.	Volume of wet soil paste(V)	19.07 cm ³	19.586 cm ³

C	Volume of dry soil paste		
1.	Mass of mercury equivalent to vol of (shrinkage dish-dry paste) + evaporating dish	143.75	153.1
2.	Mass of mercury equivalent to vol of (shrinkage dish-dry paste)	93.1	102.45
3.	Mass of mercury displaced by dry paste	166.29	163.93
4.	Volume of dry paste(V_d)	12.227 cm ³	12.053 cm ³
D	Calculation:-		
1.	Shrinkage limit $w_s = (w - (V - V_d)/M_d) * 100$	17.3999	16.64
2.	Shrinkage ratio $sr = M_d / (V_d * P_w)$	1.7755	1.8485

4 OMC & Maximum Dry density test (Standard Procter test)

- 4.01 OMC & Maximum Dry density for (100% MP& 0% Clay)
- 4.02 OMC & Maximum Dry density for (90% MP & 10% Clay)
- 4.03 OMC & Maximum Dry density for (80% MP & 20% Clay)
- 4.04 OMC & Maximum Dry density for (70% MP & 30% Clay)
- 4.05 OMC & Maximum Dry density for (60% MP & 40% Clay)
- 4.06 OMC & Maximum Dry density for (55% MP & 45% Clay)
- 4.07 OMC & Maximum Dry density for (50% MP & 50% Clay)
- 4.08 OMC & Maximum Dry density for (45% MP & 55% Clay)
- 4.09 OMC & Maximum Dry density for (40% MP & 60% Clay)
- 4.10 OMC & Maximum Dry density for (35% MP & 65% Clay)
- 4.11 OMC & Maximum Dry density for (30% MP & 70% Clay)

- 4.12 OMC & Maximum Dry density for (20% MP & 80% Clay)
- 4.13 OMC & Maximum Dry density for (10% MP & 90% Clay)
- 4.14 OMC & Maximum Dry density for (00% MP & 100% Clay)

5 SHEAR PARAMETERS BY (DIRECT SHEAR TEST)

- 5.01 Shear parameters (C- ϕ) for (100% Mp & 0% Clay)
- 5.02 Shear parameters (C- ϕ) for (90% Mp & 10% Clay)
- 5.03 Shear parameters (C- ϕ) for (80% Mp & 20% Clay)
- 5.04 Shear parameters (C- ϕ) for (70% Mp & 30% Clay)
- 5.05 Shear parameters (C- ϕ) for (60% Mp & 40% Clay)

- 5.06 Shear parameters (C- ϕ) for (55% Mp & 45% Clay)
- 5.07 Shear parameters (C- ϕ) for (50% Mp & 50% Clay)
- 5.08 Shear parameters (C- ϕ) for (45% Mp & 55% Clay)
- 5.09 Shear parameters (C- ϕ) for (40% Mp & 60% Clay)
- 5.10 Shear parameters (C- ϕ) for (35% Mp & 65% Clay)
- 5.11 Shear parameters (C- ϕ) for (30% Mp & 70% Clay)
- 5.12 Shear parameters (C- ϕ) for (20% Mp & 80% Clay)
- 5.13 Shear parameters (C- ϕ) for (10% Mp & 90% Clay)
- 5.14 Shear parameters (C- ϕ) for (00% Mp & 100% Clay)

S. No.	Sample	Area Of Specimen	Normal Load (KN) V	Shear Load (KN) H	Shear Stress t (KN/m ²)	Normal Stress (KN/m ²)	Moisture Content w (%)	Density (gm/cc)	Shear parameters	
									c	ϕ
1	100% MP+0% Clay	36x10 ⁻⁴ m ²	1	0.13	36.11	277.77				
			2	0.24	66.66	555.55	18.34	1.532	6	12°
			3	0.35	97.22	833.33				
2	90%MP+10%Clay	36x10 ⁻⁴ m ²	1	0.3	83.33	277.77				
			2	0.53	147.22	555.55	18.03	1.535	18	13°
			3	0.75	208.33	833.33				
3	80%MP+20%Clay	36x10 ⁻⁴ m ²	1	0.39	108.33	277.77				

			2	0.67	186.11	555.55	17.68	1.559	3 6	14°
			3	0.92	255.55	833.33				
4	70%MP+ 30%Clay	36×10^{-4} m ²	1	0.44	122.22	277.77			5 0	15°
			2	0.7	194.44	555.55	18.08	1.576		
			3	0.98	272.22	833.33				

1. LIQUID LIMIT

Fig 1.01 CHART 1.01 Liquid limit for (100%MP & 0% Clay) CHART 1.02 Liquid limit for (90% MP & 10% Clay)

Fig 1.02 CHART 1.03 Liquid limit for (80% MP & 20% Clay) CHART 1.04 Liquid limit test for (70% Mp & 30% Clay)

Fig 1.03 CHART 1.05 Liquid limit test(60% Mp & 40% Clay)CHART 1.06 Liquid limit test for (55% Mp & 45% Clay)

Fig 1.04 CHART 1.07 Liquid limit test for (50% Mp & 50% Clay) CHART 1.08 Liquid limit test for (45% Mp & 55% lay)

Fig 1.05 CHART 1.09 Liquid limit test for (40% Mp & 60% Clay) CHART 1.10 Liquid limit test for (35% Mp & 65% Clay)

Fig 1.06 CHART 1.11 Liquid limit test for (30% Mp & 70% Clay)CHART 1.12 Liquid limit test for (20% Mp & 80% Clay)

Fig 1.07 CHART 1.13 Liquid limit test for (10% Mp & 90% Clay)

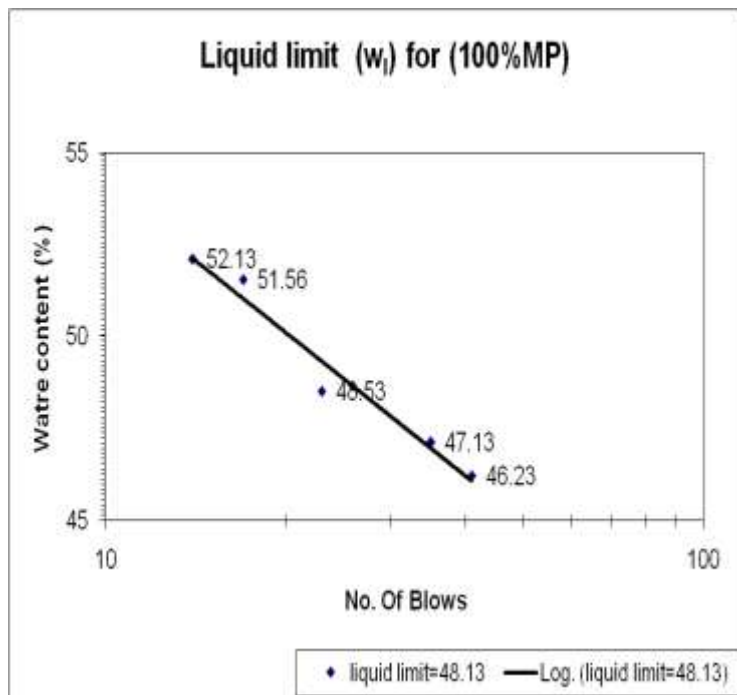


CHART 1.02

CHART 1.03

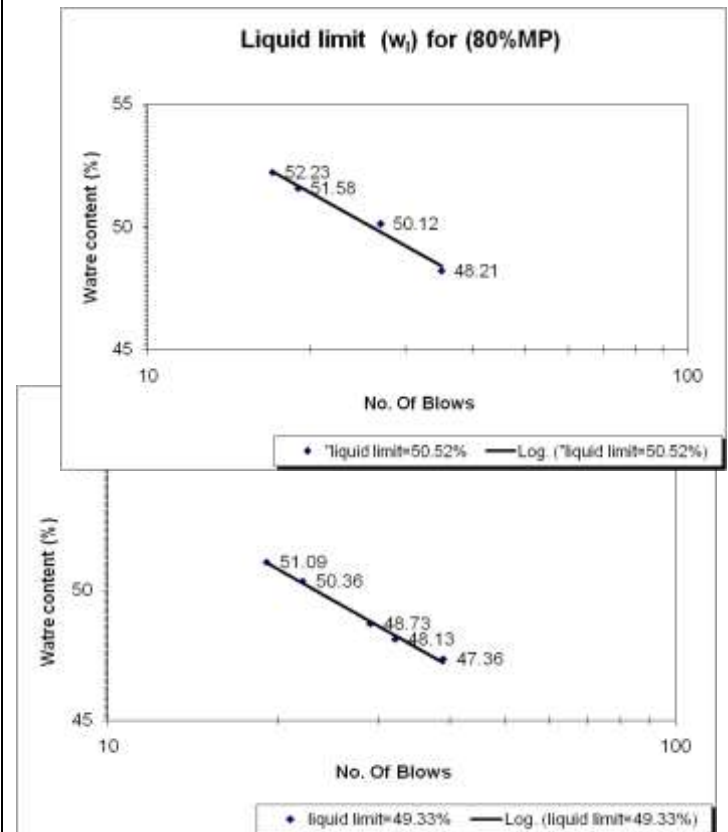


CHART 1.04

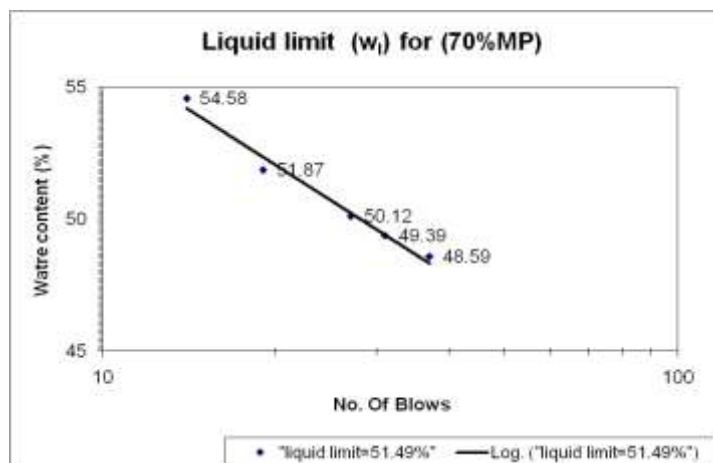


CHART 1.05

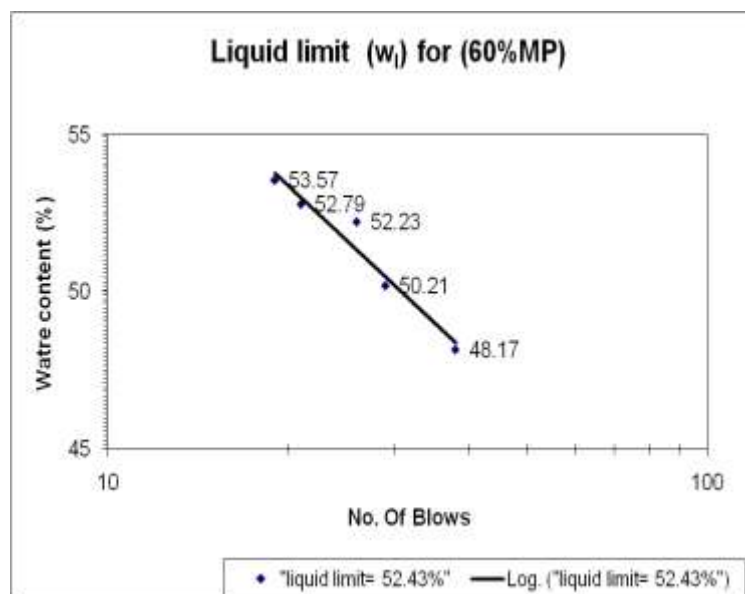


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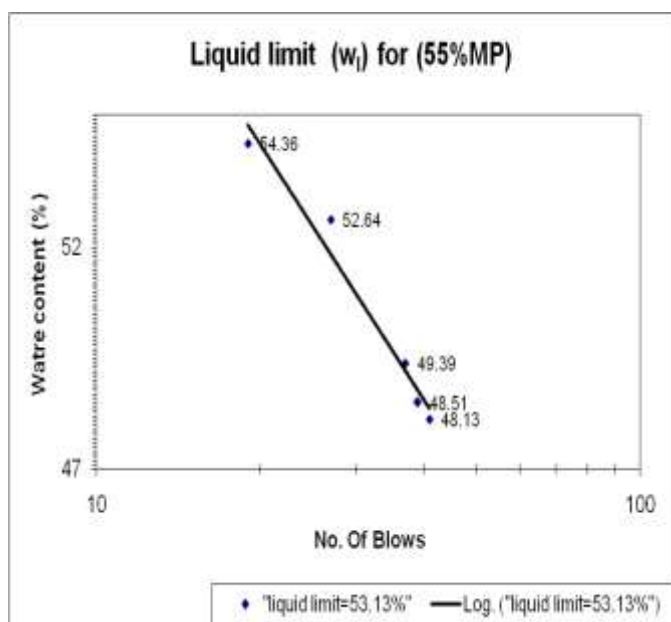


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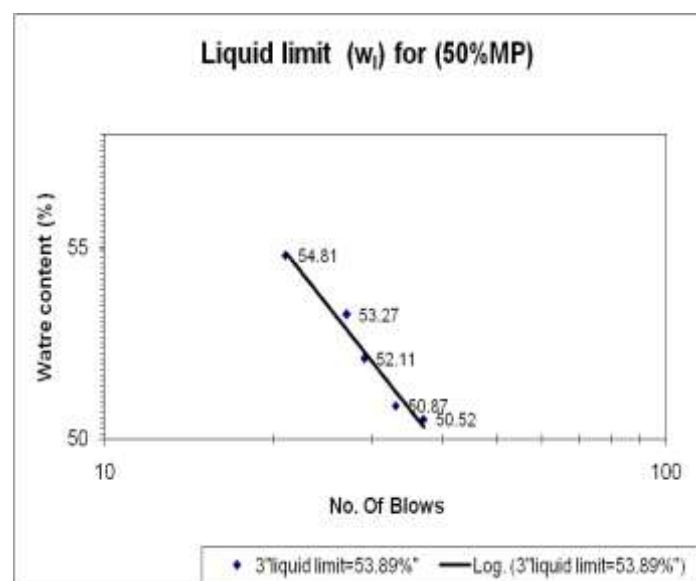


CHART 1.08

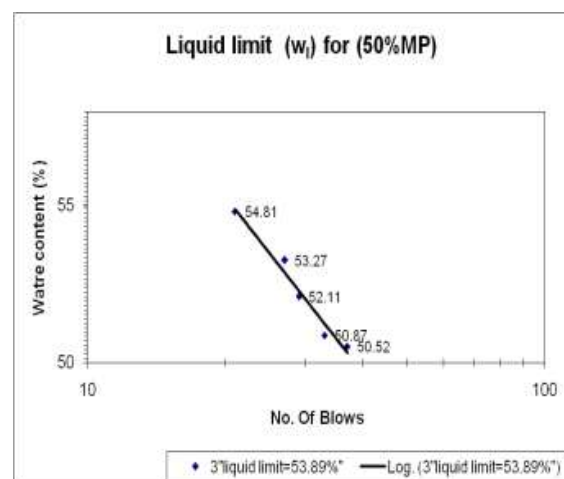


CHART 1.9

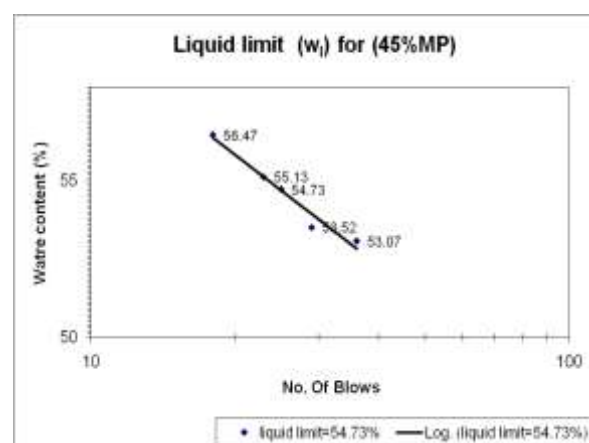


CHART 1.10

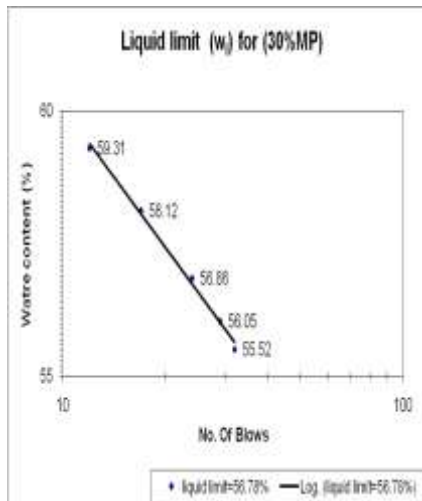


CHART 1.11

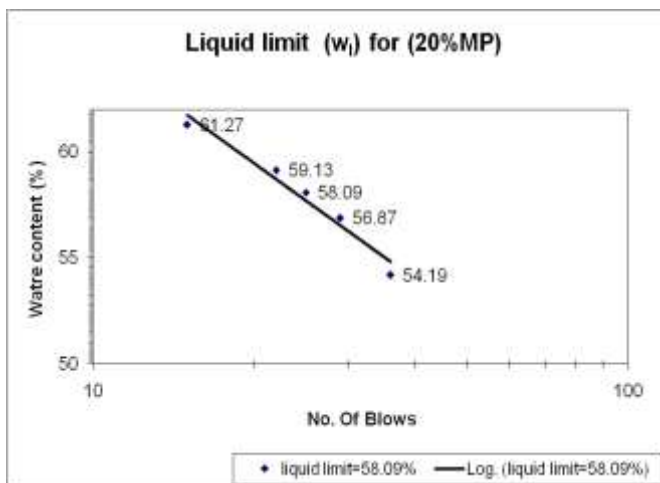


CHART 1.12

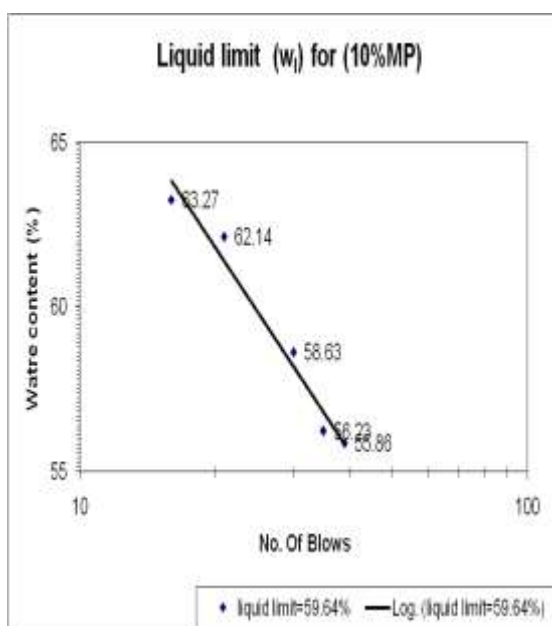


CHART 1.13

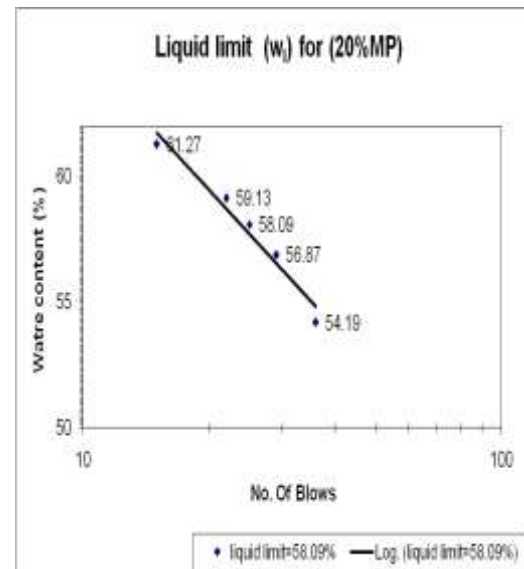
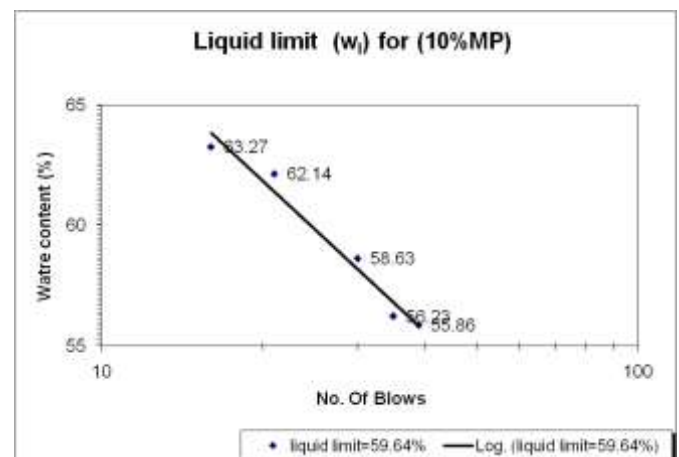


CHART 1.14



2 PLASTIC LIMIT

CHART showing variation in Plastic limit with change in MP fraction

3 SHRINKAGE LIMIT

CHART showing variation in Shrinkage limit with change in MP fraction

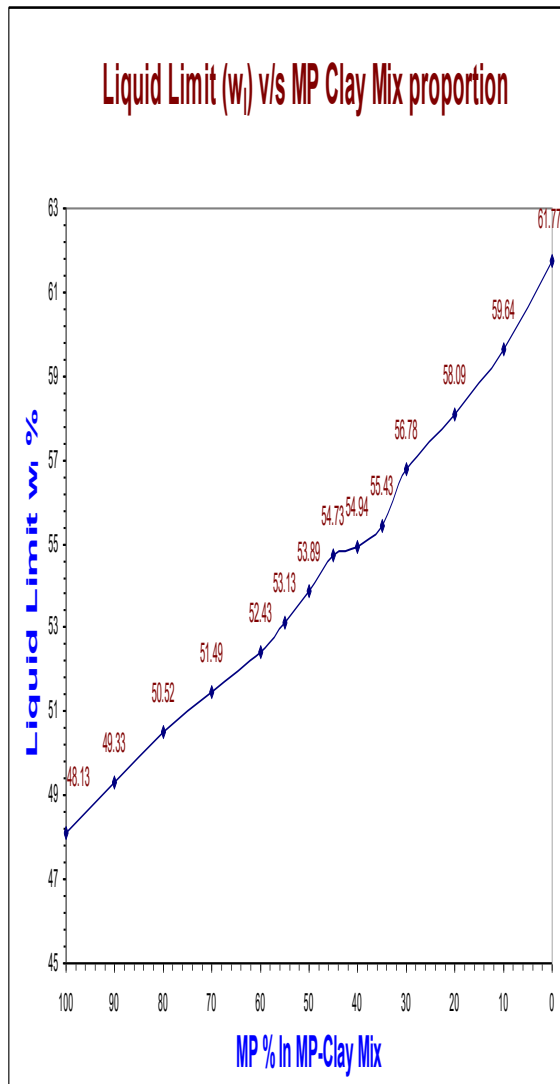
DESCRIPTION OF WORK AND COMPUTATION OF RESULTS

✓ INDEX PROPERTIES

• Liquid Limit

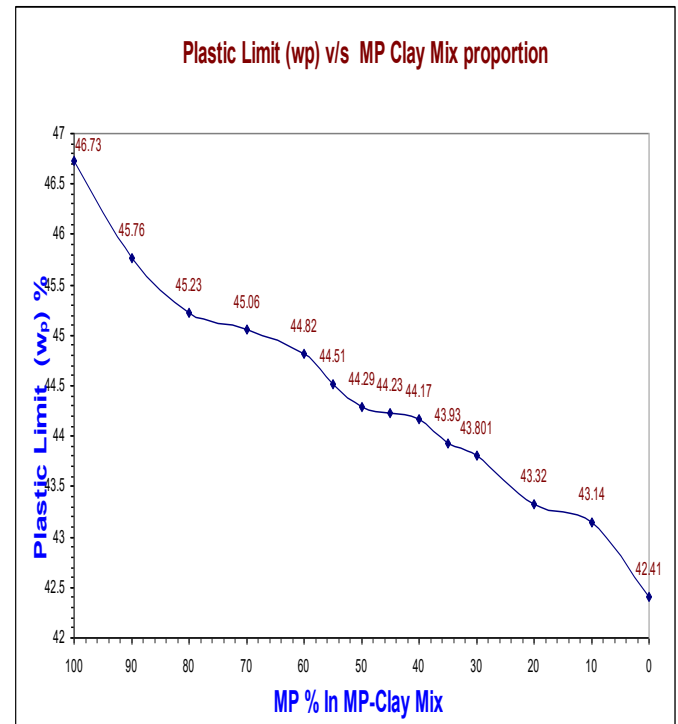
Shown in the figure ahead the liquid limit goes on increasing with increase in clay content in the marble powder-clay mix. It varies from 48.13 % (for 100% MP) to 61.77% (for 100 % Clay). A

possible explanation to this increasing liquid limit can be that at Liquid limit there is no role of friction angle due to over saturation of sample and cohesion value governs the amount of water required to make the soil flow i.e. reach the liquid limit. Hence MP has poor cohesion



Plastic Limit:

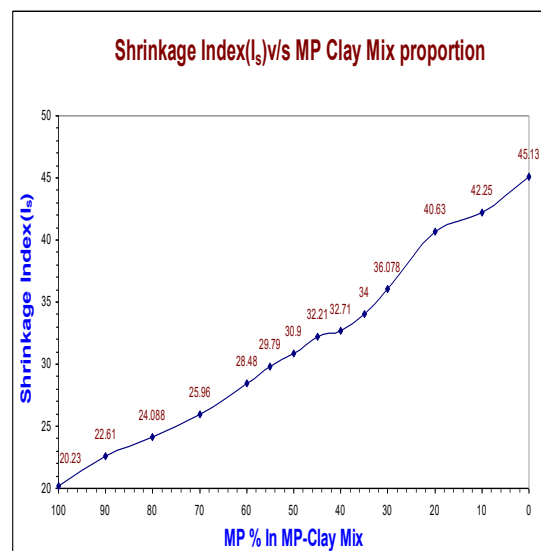
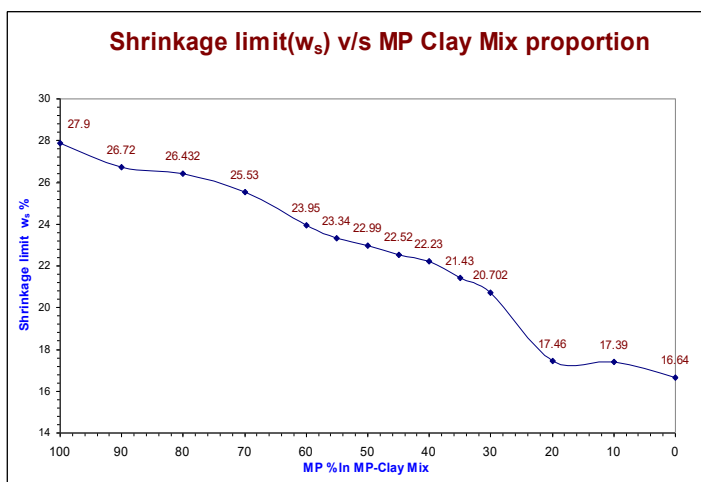
As shown in figure 4.2 the Plastic Limit goes on decreasing with the increase in clay content. It varies from 46.73 (for 100 % MP) to 42.41 % (for 100 % clay). It occurs possibly due to the fact that since MP is finer than clay so due to greater specific surface it requires more water to bring the sample in plastic state. Since MP is found to be non-plastic in various experiments, for the same reason the value of Plastic limit in the experiments done are quite near to the liquid limit values.



Shrinkage Limit:

As shown in figure ahead the Shrinkage Limit goes on decreasing with the increase in clay content. It varies from 27.9 (for 100 % MP) to 16.64 % (for 100 % clay). The CHART represents that Shrinkage Limit at 100% clay content is lesser than that at 100% MP. It means Shrinkage/Volume change increases as the clay content in the MP-Clay mix increases. But in field it is seen that 100% MP deposits have more shrinkage cracks on drying. An experiment was performed to see this paradox.

Two small shrinkage dishes were filled with 100% MP and 100% Clay at almost same water content and it was found that marble powder sample shrinks lesser than the Clay sample, but it shows more shrinkage cracks (see PLAT F). This paradox can be explained by their cohesion value. As clay has greater value of cohesion, which imparts the ability to sustain some tensile stress generated due to shrinkage if sample.



Plasticity Index:

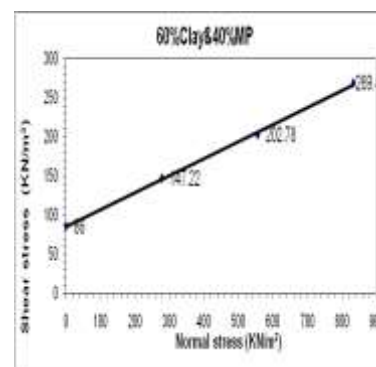
It has been discovered that the liquid and plastic limits of a soil are both affected by the type and amount of clay present. The plasticity index, on the other hand, is primarily determined by the amount of clay present. The soil plasticity index is a measure of the amount of clay in the soil. As shown in figure the Plasticity Index goes on increasing with the increase in clay content in MP-Clay mix. It varies from 1.42 (for 100 % MP) to 19.36 (for 100 % clay). It shows that the plastic characteristics are increasing with increase in clay content.

SHEAR STRENGTH PARAMETERS:

Angle of Shearing Resistance:

- As the figure 4.10 shows that value of shear angle increases from 12° at 100% MP to 16° at 65%MP and also at 50% MP then decrease to 3° at 100% Clay. It has maximum value between 55-50%MP content. This behavior indicates that the mix proportion has good inter particle bonding in this range. **Shrinkage Index:**

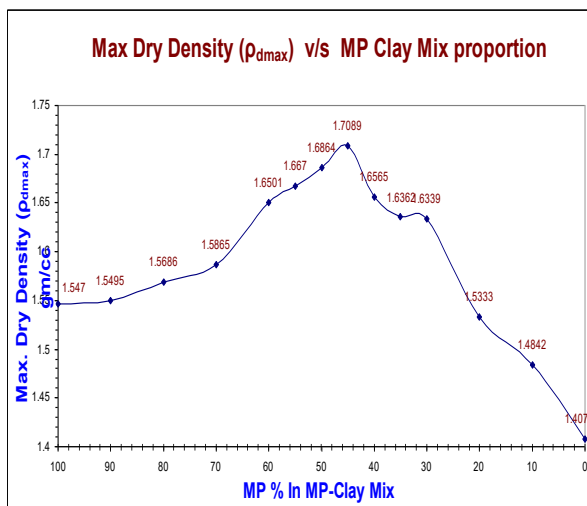
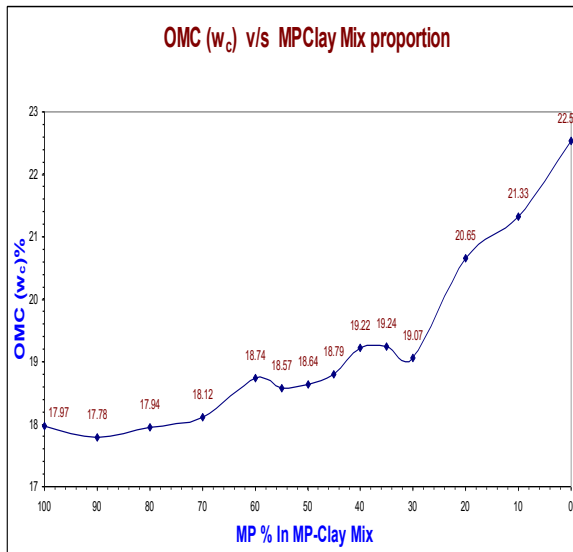
As the figure ahead shows the shrinkage index goes on increasing with increase in clay content in MP-Clay mix. It varies from 20.23 at 100% MP to 45.13 at 100% Clay. Shrinkage index is directly proportional to the percentage of clay size fraction present in the soil. It can be used as an indicator for the amount of clay present.



COMPACTION CHARACTERISTICS:

Optimum Moisture Content:

As shown in the figure, OMC increases gradually with increase in clay content till 30% MP and 70% Clay mix. Then there is a sharp increase in OMC between 70% to 100% Clay content. It has maximum value 22.54% at 100% Clay and minimum value 17.78% at 90%MP and 10% Clay mix. This happens due to more adsorption of water by clay particles as they are charged.



SHEAR PARAMETERS BY (DIRECT SHEAR TEST)

Fig 5.01 CHART 5.01 Shear parameters (C- ϕ) for (100% Mp & 0% Clay)

CHART 5.02 Shear parameters (C- ϕ) for (90% Mp & 10% Clay)

Fig 5.02 CHART 5.03 Shear parameters (C- ϕ) for (80% Mp & 20% Clay)

CHART 5.04 Shear parameters (C- ϕ) for (70% Mp & 30% Clay)

Fig 5.03 CHART 5.05 Shear parameters (C- ϕ) for (60% Mp & 40% Clay)

CHART 5.06 Shear parameters (C- ϕ) for (55% Mp & 45% Clay)

Fig 5.04 CHART 5.07 Shear parameters (C- ϕ) for (50% Mp & 50% Clay)

CHART 5.08 Shear parameters (C- ϕ) for (45% Mp & 55% Clay)

Fig 5.05 CHART 5.09 Shear parameters (C- ϕ) for (40% Mp & 60% Clay)

CHART 5.10 Shear parameters (C- ϕ) for (35% Mp & 65% Clay)

Fig 5.06 CHART 5.11 Shear parameters (C- ϕ) for (30% Mp & 70% Clay)

CHART 5.12 Shear parameters (C- ϕ) for (20% Mp & 80% Clay)

Fig 5.07 CHART 5.13 Shear parameters (C- ϕ) for (10% Mp & 90% Clay)

CHART 5.14 Shear parameters (C- ϕ) for (00% Mp & 100% Clay)

CHART 5.1

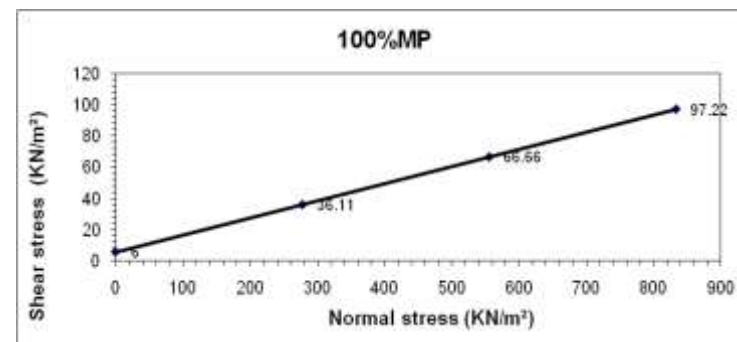


CHART 5.2

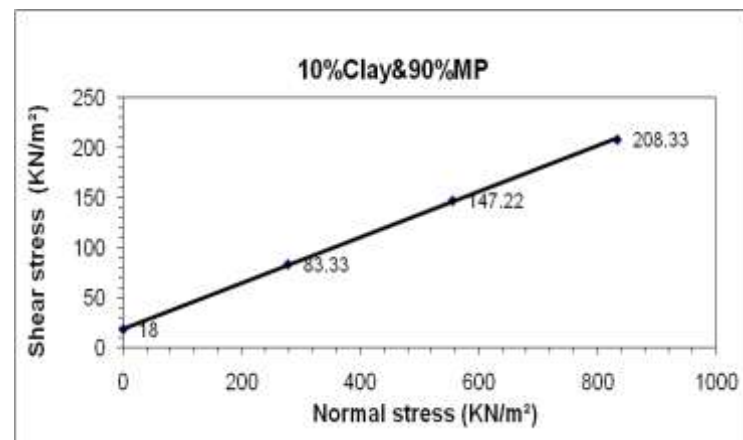


CHART 5.3

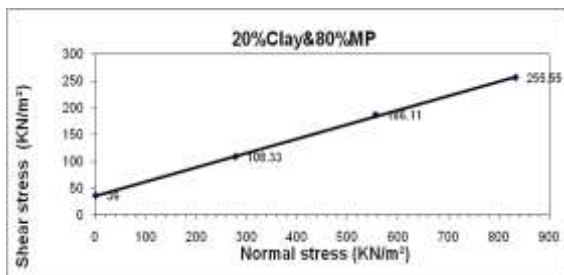


CHART 5.4

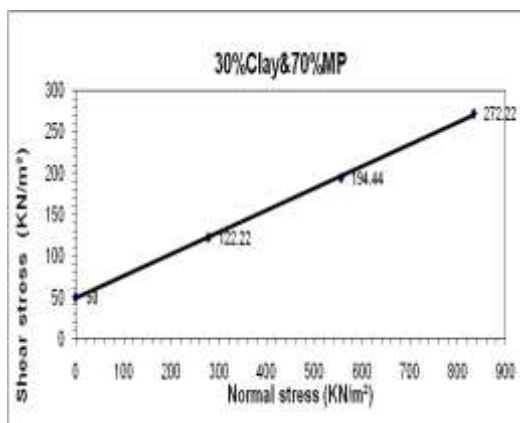


CHART 5.5

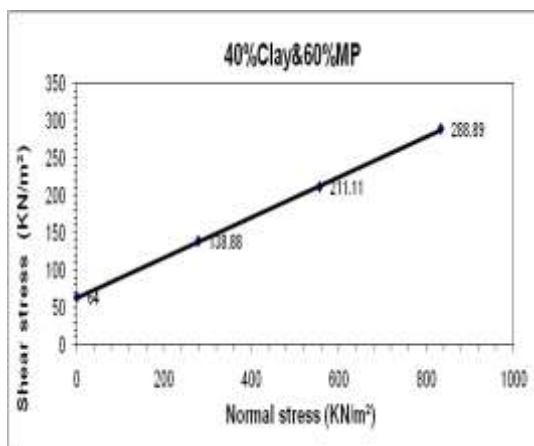


CHART 5.6

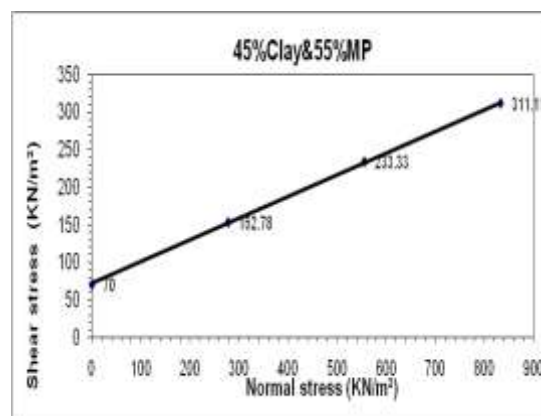


CHART 5.7

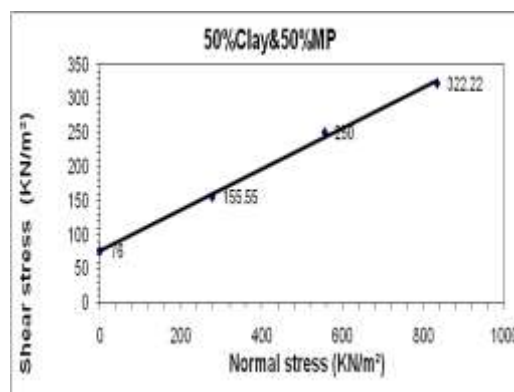
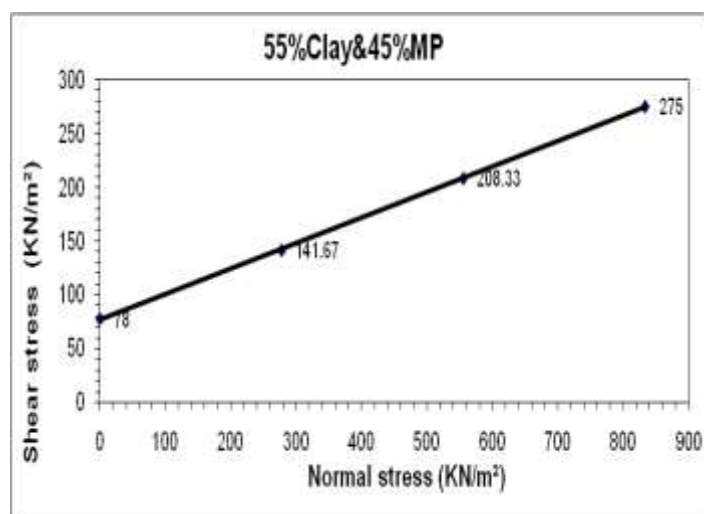


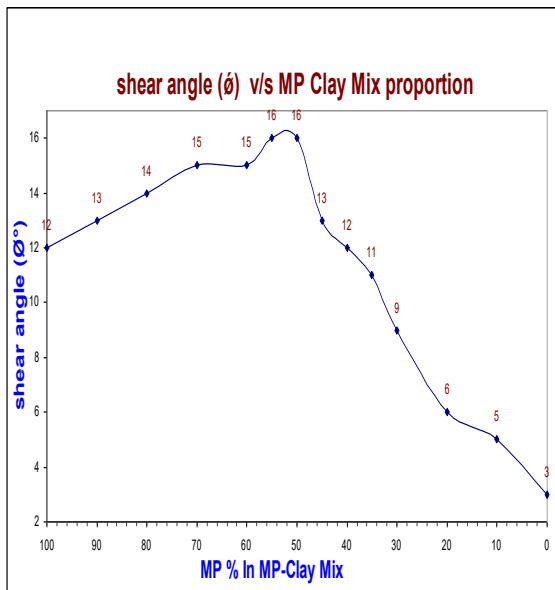
CHART 5.8



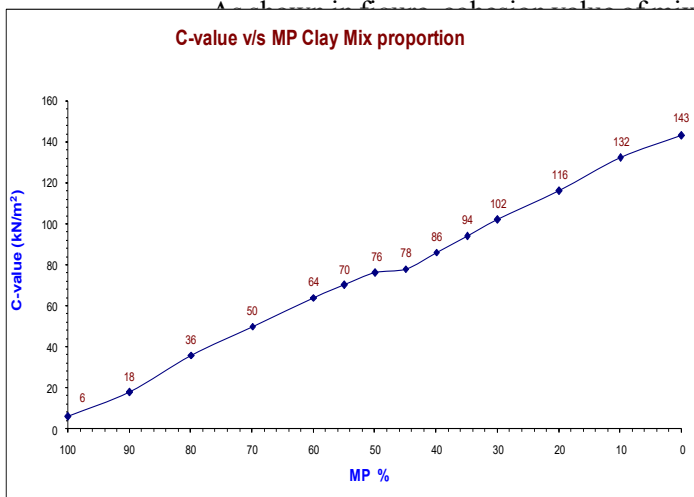
• **Maximum Dry Density:**

As shown in figure, maximum dry density increases with increase in MP to some extent and then decreases. It has minimum value 1.408 gm/cc at 100% Clay and maximum value 1.705 gm/cc at 45% MP & 55% Clay mix. The CHART shows that

between sample 40%MP & 60%Clay and sample 65% MP & 35% Clay, the mix proportions show adequate maximum dry density.



Cohesion Value:



4.31 Complete test result for different mix proportion.

TABLE 4.32

Variations in Attebergs limit, OMC, Maximum dry density & shear parameters with change in Mix proportion

S. No.	Sample (Clay+MP)	OMC (w _c) %	Max. dry density (γ _{d max})	Liquid Limit (w _L) %	Plastic Limit (w _p) %	Shrinkage Limit (w _s) %	Shear parameters c K N/m ²
1	100% MP	17.97	1.547	48.13	46.73	27.9	6
2	10%Clay+90%MP	17.78	1.5495	49.33	45.76	26.72	18
3	20%Clay+80%MP	17.94	1.5686	50.52	45.23	26.432	36
4	30%Clay+70%MP	18.12	1.5865	51.49	45.06	25.53	50
5	40%Clay+60%MP	18.74	1.6501	52.43	44.82	23.95	64
6	45%Clay+55%MP	18.57	1.667	53.13	44.51	23.34	70
7	50%Clay	18.	1.653	53	44.	22.	76

	ay+50 %MP	64	864	.8 9	29	99	
8	55%Cl ay+45 %MP	18. 79	1.7 089	.7 3	44. 23	22. 52	78
9	60%Cl ay+40 %MP	19. 22	1.6 565	.9 4	44. 17	22. 23	86
10	65%Cl ay+35 %MP	19. 24	1.6 362	.4 3	43. 93	21. 43	94
11	70%Cl ay+30 %MP	19. 07	1.6 339	.7 8	43. 801	20. 702	10 2
12	80%Cl ay+20 %MP	20. 65	1.5 333	.0 9	43. 32	17. 46	11 6
13	90%Cl ay+10 %MP	21. 33	1.4 842	.6 4	43. 14	17. 39	13 2
14	100% Clay	22. 54	1.4 078	.7 7	42. 41	16. 64	14 3

Dhaka Clay but MDD increased with increasing % of cement content both Dhaka Clay and River Sand

- ✓ Optimum Moisture Content decreased with increasing (0-6) % of cement content but it increased for 8% of cement content
- ✓ OMC increased linearly with increasing % of lime content
- ✓ It was also found that liquid limit also same CHARTically between previous study and our study for lime content but liquid limit (LL) varied for cement content.
- ✓ Maximum dry density (MDD) almost remained same between our study and previous study
- ✓ Optimum moisture content (OMC) varies previous study than our study for both lime and cement content.
- ✓ Marble Powder has low plasticity Index and higher value of shrinkage Limit as compare to clay. Hence it almost non-plastic and has less shrinkage as compare to clay. So it can be used to fill low-lying areas with mixing some amount of clay as additive to impart cohesion.
- ✓ Compaction characteristics of MP-Clay Mix proportions show that in the range between 45%MP & 55% Clay to 60% MP & 40% Clay give better dry density to use Marble Powder as land filling material.
- ✓ Its Shear strength parameters show that it is better to use MP-Clay mix in above-mentioned range in back filling for retaining wall as it has got adequate shearing strength

CONCLUSIONS AND SUGGESTIONS FOR FUTURE WORK

5.1. CONCLUSIONS

After conducting tests following conclusion is drawn for mixing Clay in Marble slurry as additive to stabilize it for filling purpose

- ✓ It was found that Liquid limit also are same for lime content but plastic limit varied with increasing % of lime content for Dhaka clay [Soil A] but the liquid limit change with increasing % of cement both Dhaka clay [Soil A] and River sand [Soil B].
- ✓ It was found that Maximum Dry Density (MDD) decreased with the increase in % of lime content for

5.2 Environmental Damage Due to marble Slurry

Marble slurry is environmentally hazardous in following way

The porosity and permeability of topsoil is reduces tremendously and in due course of time, it results in water logging problem.

- ✓ The fine marble dust reduces the fertility of the soil by increasing its alkalinity.
- ✓ It causes respiratory ailments in the nearby residential areas.
- ✓ It causes contamination of underground water resources.
- ✓ Adverse effect on the landscape beauty or the area. Disposal on land results in the formation of ugly mosquito breeding lagoons. Etc...

5.3. SUGGESTIONS FOR FUTURE WORK

There is lot of research is to be done in the field of Marble slurry , I suggest some of future work that could be done

- ✓ It is suggested that further study & experimentation should be done on Marble Powder / Slurry to examine its feasibility as soil sub grade material in road construction.
- ✓ Further study & experimentation should be performed to determine any procedure or method to produce cementing property in Marble Slurry / Powder.
- ✓ Further study and experimentation should be performed to examine the feasibility of use of marble Slurry / Powder as ingredient or admixture in concrete mix to impart workability.

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CHART 1.14

