EFFECT OF STONE DUST ADMIXTURE ON STRENGTH OF SOIL

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ABSTRACT

This research is an attempt to investigate the effect of stone powder on the strength and compaction properties of C-Ø soil collected from Chandigarh. The basic properties: Unconfined compressive strength, direct shear, compaction and Atterberg limits were determined first. The stone powder was added at specific percentages (20%, 25% and 30%) by weight of soil and mixed with the optimum moisture content obtained from the compaction test. The results revealed that the addition of 25% stone powder increased the maximum dry density whereas decreased optimum moisture content. Further when 20% stone dust powder was added soil strength increases by 6%. Similarly Atterberg limits and Cohesion decreases whereas angle of internal friction increases on increasing the percentage of stone dust.

CERTIFICATE

This is to certify that the work titled "**EFFECT OF STONE DUST ADMIXTURE ON STRENGTH OF SOIL**" submitted by **Arpit Goyal and Neeraj Thakur** in partial fulfilment for the award of degree of B.Tech Civil Engineering of Jaypee University of Information Technology, Waknaghat has been carried out under my supervision. This work has not been submitted partially or wholly to any other University or Institute for the award of this or any other degree or diploma.

Signature of Supervisor	……………………..	Signature of Supervisor	……………………..
Name of Supervisor	……………………..	Name of Supervisor	……………………..
Designation	……………………..	Designation	……………………..
Date	……………………..	Date	……………………..

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Signature of Student	……………………..	Signature of Student	……………………..
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Date	……………………..	Date	……………………..

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1. INTRODUCTION

1.1 Background

In geotechnical engineering practice the soils at a given site are often less than ideal for the intended purpose. It would seem reasonable in such instances to simply relocate the structure or facility. However, considerations other than geotechnical often govern the location of a structure, and the engineer is forced to design for the site at hand. One possibility is to adapt the foundation to the geotechnical conditions at the site. Another possibility is to try to stabilize or improve the engineering properties of the soils at the site. Depending on the circumstances, this second approach may be the most economical solution for the problem.

The concept of stabilization is well established and is used in various applications like improvement of shear strength, load bearing capacity, drainage system etc. The stabilization process aims at increasing the soil strength and reducing its permeability and compressibility. The stabilization processes may include mechanical, chemical, electrical or thermal processes. The process used depends on the type of soil at the site, the time available to execute the project and the stabilization cost compared to the overall cost of the project and to the cost of full replacement of the soil at the site. The engineer may consider one method or several methods together.

One method to improve soils properties is chemical stabilization. Chemical stabilization includes the mixing or injecting of chemical substances into the soil. Portland cement, lime, asphalt, calcium chloride, sodium chloride, and paper mill wastes are common chemical stabilization agents. The effectiveness of these additives depends on the soil conditions, stabilizer properties, and type of construction (i.e., houses, roads, etc.). The selection of a particular additive depends on costs, benefits, availability, and practicality of its application.

In recent years, many attempts have been made to solve the problems posed by industrial wastes. Finding a way for the utilization of these wastes would be an advantageous way of getting free of them. Recent projects illustrated that successful waste utilization could result in considerable savings in construction costs.

This study is performed to obtain geotechnical properties of Stone Dust for its application in strength of soil. The geotechnical properties of soil will be evaluated by performing various laboratory tests to investigate feasibility of using stone dust in soil stabilization. The stabilization of c-Ø soil having properties as mentioned in report by using the waste of aggregates is considered in this thesis study.

1.2 Motivation

Recently, how to utilize resources and how to preserve natural environment have become more serious problems in the world. In considering of increasing amount of the various kinds of industrial waste matter which are by-products from the industrial activity, it is necessary to dispose or utilize them for construction materials. The requirements for utilizing by-products for construction materials are as follows; 1. Production of large amount is possible for a long period of time. 2. The materials are available everywhere. 3. Feasibility of quality control. 4. The materials do not cause environmental pollutions.

The crusher stones are required to use instead of natural gravels, because they are difficult to collect from the reason of environment preservation. Due to the high demand for rubble and aggregates for construction purposes, quarries and aggregate crushers are very common. Out of the different quarry wastes, stone dust is one, which is produced in abundance. Stone dust not only pollutes water, air or land but also their disposal is a great problem. About 20–25% of the total production in each crusher unit is left out as the waste material-stone dust.

Moreover stone dust is cheap and available in commercial quantities at almost every construction site than other industrial wastes like Fly ash. This helps to find an application for industrial waste to improve properties of soil. The improved engineering behaviour of soil by addition of stone dust could act as a good subgrade material and it can also be used to improve soil strength for stronger foundation.

Keeping in mind the above considerations it was decided to use stone dust as soil stabilizer. The main objective of this study is therefore to stabilize the c-Ø soil using stone dust.

2. LITERATURE REVIEW

- **Review 1-** By Rakesh Kumar, Siddhartha Rokade and Satyavir Singh(2010). *"Effect of Mixing Stone dust on engineering properties of expansive soils".* Proceedings of International Conference on Infrastructure Development on Expansive Soils Index-09 ACE Hosur TN 635109.

The expansive soil used was collected from MANIT Campus Bhopal and Stone dust is mixed in different proportions. Optimum moisture content of the soil mixed with stone dust 10%, 20%, 30% and 35% has gradually decreased from 26.50% to 18.00% and maximum dry density gradually increased from 16.80 kN/m^3 to 18.05 kN/m^3. The addition of stone dust in soil sample increases CBR value substantially. The CBR value of soil sample increase 2.5 to 8.2 % when 35% of soil is replaced by stone dust.

- **Review 2-** By Ramadas T.L. , Kumar N. Darga, Aparna G(2010). *"Swelling and Strength Characteristics of Expansive Soil Treated with Stone Dust and Fly Ash*". Indian Geotechnical Conference, IGS Mumbai Chapter & IIT Bombay.

Expansive soil is collected from the Bhimavaram, coastal area in Andhra Pradesh and stone dust is collected from the crusher units in Guntur. When stone dust is added to the expansive soils the Atterberg's limits, OMC, FSI are decreased and MDD, UCS, CBR values are increased. The optimum percentages of stone dust observed is 30% for improving the properties of expansive soils.

- **Review 3-** By Mir Sohail Ali and Shubhada Sunil Koranne(2011). "*Performance Analysis of Expansive Soil Treated With Stone Dust and Fly Ash*". EJGE Vol. 16 Bund. I.

Expansive soil is collected from the Jatwada, Aurangabad in M.S, India and stone dust is collected from the crusher units near to Aurangabad. After addition of stone dust admixture to the expansive soil the Atterberg's limits, OMC, FSI are decreased and MDD, UCS, CBR values are increased. The optimum percentages of stone dust admixture is observed in between 20% to30% respectively for improving the properties of expansive soil.

3. EXPERIMENTAL WORK

3.1 Purpose

The purpose of the experimental work is to investigate the effects of addition of stone dust on Atterberg limits, Direct Shear Test, Maximum Dry Density, Optimum Moisture Content, Unconfined Compressive Strength and California bearing ratio of C-Ø soil.

3.2 Material

Soil used is a C-Ø soil collected from Chandigarh and stone dust used is waste generated from Los Angles Abrasion testing machine which is similar to the aggregate waste from crusher units. Aggregate waste was passed through 300 micron sieve before usage.

3.3 Preparation of specimen

Samples were obtained by mixing a calculated amount of stone dust to obtain a sample with predetermined percentage of stone dust varying at an interval of 5% by dry weight of the soil.

3.4 Testing Procedure

3.4.1 Liquid Limit test

It is defined as water content at which soil is practically in liquid state but has infinitesimal resistance against flow.

APPARATUS

- Mechanical liquid limited Device
- Grooving Tool
- Porcelain Evaporating Dish
- Balance
- Oven
- Containers

SOIL SAMPLE

A sample weighing about 120 gm shall be taken from the thoroughly mixed portion of material passing 425- micron IS Sieve. If this is done stones are present, only the material passing 425- micron IS sieve shall be used for the test, this can be obtained by rubbing the wet soil through the sieve until a sufficient quantity of the size passing 425-micron IS sieve is obtained.

ADUSTMENT OF THE MECHNICAL DEVICE

The liquid limited device shall be inspected to determine that it is clean, dry and in good working order, that the cup fall freely and it does not have too much side play at its hinge. The grooving tool shall also be inspected to determine that it is clean and dry.

Using the gauge on the handle of the grooving tool or a separate gauge and by means of the adjustment plate of the mechanical liquid limited device, the height through which the cup is lifted and dropped shall be adjusted so that the point on the cup which comes in contact with the base falls through exactly one centimetre for one revolution of the handle. The adjustment plate shall then be secured by tightening the screw.

PROCEDURE

1) A bout 120 gm of the soil sample passing 425-micron IS sieve shall be mixed thoroughly with distilled water in the evaporating dish or on the flat glass plate to from a uniform paste.

2) The soil should then be re-mixed thoroughly before the test. A portion of the paste shall be placed in the cup above the spot where the cup rests on the base, squeezed down and spread, with as few strokes of the spatula as possible and at the same time trimmed to a depth of one centimetre at the point of maximum thickness, returning the excess soil to the dish. The soil in the cup shall be decided by firm strokes of the grooving tool along the diameter through the centre line of the cam follower so that a clean, sharp groove of the proper dimensions is formed. The cup shall be filled and dropped by turning the crank at the rate of two revolutions per second until the two halves of the soil cake come in contact with bottom of the groove along a distance of about 12 mm. This length shall be measured with the end of the grooving tool or a ruler. The number of drops required to cause the groove close for the length of 12 mm shall be recorded.

3) A little extra of the soil mixture shall be added to cup and mixed with the soil in the cup. The pat shall be made in the cup and the test repeated as in no case shall dried soil be added to the thoroughly mixed soil that is being tested. The procedure given in and in this clause shall be repeated until two consecutive runs give the same under of drops for closure of the groove.

4) A representative slice of soil approximately the width of the spatula extending from about edge to the soil cake at right angle to the groove and including that portion of the groove in which the soil flowed together, shall be taken in a suitable container and its moisture content expressed as a percentage of the oven dry weight. The remaining soil in the cup shall be transferred to the evaporating dish and the cup and the grooving tool cleaned thoroughly.

5) The operation specified in shall be repeated for at least three more additional trails (minimum of four in all), which the soil collected in the evaporating dish or flat glass plate, to with sufficient water has been added to bring the soil to a more fluid condition. In each case the number of blows shall be recorded and the moisture content determined as before.

DETERMINATION

A flow curve shall be plotted on a semi logarithmic graph representing water content on the arithmetical scale and the number drops on the logarithmic scale. The flow curve is a straight line drawn as nearly as possible through the four or more plotted points. The moisture content corresponding to 25 drops as read from the curve shall be rounded off to the nearest whole number and reported as the liquid limit of the soil.

3.4.2 Plastic Limit test

It is defined as the moisture content at which soil begins to behave as a plastic material.

APPARATUS

- Porcelain Evaporating Dish
- Flat glass Plate
- Spatula
- Palette Knives
- Surface for Rolling
- Containers
- Balance
- Oven
- Rod

SOIL SAMPLE

A sample weighing about 20 gm from the thoroughly mixed portion of the material passing 425- micron IS Sieve, obtained in accordance with shall be taken.

TEST PROCEDURE

1) The soil sample shall be mixed thoroughly with distilled water in an evaporating dish or on the flat glass plate till the soil mass becomes plastic enough to be easily moulded with fingers.

2) A ball shall be formed with about 8 gm of this plastic soil mass and rolled between the fingers and the glass plate with just sufficient pressure to roll the mass into a thread of uniform diameter throughout its length.

3) The rate of rolling shall be between 80 and 90 strokes/min counting a stroke as one complete motion of the hand forward and back to the starting position again.

4) The rolling shall be done till the threads are of 3mm diameter.

5) The soil shall then be kneaded together to a uniform mass and rolled again.

6) This process of alternate rolling and kneading shall be continued until the thread crumbles under the pressure required for rolling and the soil can no longer be rolled into a thread.

7) The crumbling may occur when the thread has a diameter greater than 3 mm.

8) This shall be considered a satisfactory end point, provided the soil has been rolled into a thread 3mm in diameter immediately before. At no time shall an attempt be made to produce failure at exactly 3 mm diameter by allowing the thread to reach 3mm, then reducing the rate of rolling or pressure or both, and continuing the rolling without further deformation until the thread falls apart.

9) Container and the moisture content determined as described.

DETERMINATION

The moisture content (%) at which the soil when rolled into threads of 3mm in diameter, will crumble gives the Plastic Limit.

PLASTICITY INDEX:

The plasticity index is calculated as the difference between its liquid limit and plastic limit.

$$\text{Plasticity index } (I_p) = \text{Liquid limit } (w_L) - \text{Plastic limit } (w_p)$$

3.4.3 Shrinkage Limit

The maximum water content expressed as percentage of oven dry weight at which any further reduction in water content will not cause a decrease in volume of the soil mass, the soil mass being initially of soil in its undisturbed state.

APPARATUS

- Evaporating Dish
- Spatula
- Shrinkage Dish
- Glass Cup
- Glass plates
- Oven
- Sieve 425-microm
- Balances
- Mercury

SOIL SAMPLE

1) Preserve the undisturbed soil sample received from the field in its undisturbed state.

2) Trim from the undisturbed soil sample soil pats approximately 45 mm in diameter and 15 mm in height. Round off their edges to prevent the entrapment of air during mercury displacement.

PROCEDURE

1) Keep the specimen as prepared in a suitable small dish and air dry it then dry the specimen in the dish to constant weight in an oven at 105 to 110ºc.

2) Remove the specimen from the oven and smoothen the edges by sand papering. Brush off the soil dust from the specimen by a soft paint brush. Place the specimen again in the cleaned dish and dry it in an oven to constant weight. Cool the oven dry weight of the specimen Wus

3) Determine the volume Vus of the oven dry specimen of as described

4) Determine the specific gravity of the soil.

DETERMINATION

Shrinkage Limit (Undisturded soil) (wsu)--- Calculate the shrinkage limit (undisturbed soil) using the following formula:

$$wsu = (Vos / Wos \quad G)x100$$

Where

wsu = shrinkage limit

Vos = volume of oven dry specimen in ml

Wos = weight of oven dry specimen in gm

G = specific gravity

Volumetric Shrinkage (Volumetric Change) (Vs) ---- Calculate the volumetric shrinkage using the following formula:

$$Vs = (w1 – w2) R$$

Where

w1 = given moisture content in percent

ws = shrinkage limit

R = shrinkage ratio

Shrinkage Ratio (R)--- Calculate the shrinkage ratio using the following formula:

$$R = Wo / Vo$$

Where

Wo = weight of oven dry pat in gm

Vo = volume of oven dry soil pat in ml

Shrinkage Index (Ip) - Calculate the shrinkage index using the following formula:

$$Is = Ip - ws$$

Where

Ip = plasticity index

3.4.4 Specific Gravity by density bottle method

Specific gravity is defined as the ratio of the weight of an equal Volume of distilled water at that temperature both weights taken in air.

APPARATUS

- Two density bottles of approximately 50 ml capacity with Stoppers
- A balance accurate to 0.001gm

TEST PROCEDURE

1) The complete density bottle with stopper shall be dried and cooled and weighed to the nearest 0.001 gm.
2) A 5 to 10gm Sub sample shall be obtained and transferred to the density bottle.
3) The bottle and contents together with the stopper shall be weighed to the nearest 0.001 gm.
4) Sufficient air- free distilled water shall be added so that the soil in the bottle is just covered.
5) Air bubbles from the bottle are removed and further air-free liquid added until the bottle is full.
6) The bottle is wiped dry and the whole weighed to the nearest 0.001gm.
7) Remove the soil from bottle.
8) Bottle is cleaned, wiped and dried again.
9) Now air-free liquid is added until the bottle is full.
10) The bottle is wiped dry and the whole weighed to the nearest 0.001gm.
11) Two determinations of the specific gravity of the same soils sample shall be made.

DETERMINATION

The specific gravity of the soil particles G is calculated using the following equation

$$G = \frac{m2 - m1}{(m4 - m1) - (m3 - m2)}$$

Where

m1 = Mass of density bottle in gm

m2 = mass of bottle and dry soil in gm

m3 =mass of bottle, soil and water in gm

m4 = mass of bottle when full of water only in gm

3.4.5 Grain Size analysis by Sieve Analysis

APPARATUS

- Balance
- I.S sieves
- Mechanical Sieve Shaker

PROCEDURE

1) The proportion of soil sample retained on 75 micron I.S sieve is weighed and recorded weight of soil sample is as per I.S 2720.
2) I.S sieves are selected and arranged in the order as shown in the table in Appendix A.
3) The soil sample is separated into various fractions by sieving through above sieves placed in the above mentioned order.
4) The weight of soil retained on each sieve is recorded.
5) The moisture content of soil if above 5% it is to be measured and recorded.
6) No particle of soil sample shall be pushed through the sieves.

DETERMINATION

Draw graph between log sieve size vs % finer. The graph is known as grading curve. Corresponding to 10%, 30% and 60% finer, obtain diameters from graph are designated as D_{10}, D_{30}, D_{60}.

3.4.6 Maximum Dry Density and Optimum Moisture Content using Light Compaction

APPARATUS

- Cylindrical metal mould of 100 mm diameter and 1000 cm^3
- Balances
- Oven
- Container
- Hammer of 2.6kg
- Mixing Tools

PROCEDURE

1) A 5 kg sample of air dried soil passing the 19 mm IS test sieve shall be taken. The sample shall be mixed thoroughly with a suitable amount of water depending on the soil type.
2) The mould of 1000 cm^3 capacity with base plate attached shall be weighed to the nearest 1gm (m1). The mould shall be placed on a solid base, such as a concrete floor or plinth and the moist soil shall be compacted into the mould, with the extension attached, in three layers of approximately equal mass, each layer being given 25 blows from the 2.6 Kg rammer dropped from a height of 310 mm above the soil.
3) The blows shall be distributed uniformly over the surface of each layer. The operator shall ensure that the tube of the rammer is kept clear of soil so that the rammer always falls freely.
4) The amount of soil used shall be sufficient to fill the mould, leaving not more than about 6 mm to be struck off when the extension is removed.
5) The extension shall be removed and the compacted soil shall be levelled off carefully to the top of the mould by means of the straightedge. The mould and soil shall then be weighed to 1gm (m2).
6) The compacted soil specimen shall be removed from the mould and placed on the mixing tray. The water content of a representative sample of the specimen shall be determined.
7) The remainder of the soil specimen shall be broken up, rubbed through the 19 mm IS test sieve, and then mixed with the remainder of the original sample. Suitable increments of water shall be added successively and mixed into the sample, and the above procedure from operation shall be repeated for each increment of water added.
8) Observation table is shown in Appendix A.

DETERMINATION

Graph is plotted between Water content on abscissa and Dry Density on ordinate. The maximum value of Dry density gives Maximum dry density and the corresponding water content gives Optimum Moisture Content.

3.4.7 Unconfined Compressive Strength Test of soil

Unconfined Compressive strength is the load per unit area at which an unconfined cylindrical specimen of soil will fail in the axial compression test.

APPARATUS

- Compression Device
- proving Ring
- Deformation Dial Gauge
- Timer
- Oven
- Weighing Balances
- Sample Extractor
- Mixing Tool

PREPARATION OF TEST SPECIMEN:

Specimen Size:

The specimen for the test shall have a minimum diameter of 38 mm and the Largest particle contained within the test specimen shall be smaller than 1/8 of the specimen diameter. The height to diameter ratio shall be within 2 to 2.5

Undisturbed Specimens:

- Undisturbed specimens shall be prepared from large undisturbed samples or samples secured in accordance with IS: 2132:1986.
- When samples are pushed from the drive sampling tube the ejecting device shall be capable of ejecting the soil core from the sampling tube in the same direction of travel.
- The specimen shall be handled carefully to prevent disturbance, change in cross section, or loss of water. If any type of disturbance is likely to be caused by the ejection device the sample tube shall be split lengthwise or be cut off in small sections to facilitate removal of the specimen without disturbance. If possible carved specimen should be prepared in a humid room to prevent, as far as possible, change in water content of the soil.
- The specimen shall be of uniform circular cross section with ends perpendicular to the axis of the specimen.
- Representative sample cutting taken from the tested specimen shall be used for the determination of water content.

PROCEDURE

- The initial length diameter and weight of the specimen shall be measured and the specimen placed on the bottom plate of the loading device .The upper plate shall be adjusted to make contact with the specimen.
- The deformation dial gauge shall be adjusted to a suitable reading preferably in multiples of 100 Force shall be applied so as to produce axial strain at a rate of 0.5 to 2 percent per minute causing failure with 5 to 10. The force reading shall be taken at suitable intervals of the deformations dial reading.
- The specimen shall be compressed until failure surfaces have definitely developed or the stress strain of 20% is reached.
- The water content of the specimen shall be determined in accordance with using samples taken from the failure zone of the specimen.

DETERMINATION

Graph is plotted between Axial Strain on abscissa and Axial Stress on ordinate. The maximum value of Axial Stress gives Unconfined Compressive strength of soil.

3.4.8 Direct Shear test

APPARATUS

- The shear box grid plates, porous stones, base plates and loading pad and water jacket shall confirm to IS: 11229-1985.
- Loading frame
- Weights – for providing the required normal loads, if necessary.
- Proving Ring
- Micrometre dial-gauges – accurate to 0.01 mm; one suitably mounted to measure horizontal movement and the other suitably mounted to measure the vertical compression of the specimen.
- Sample trimmer or core cutter
- Stop cock
- Balance of 1 kg capacity, sensitive to 0.1 g
- Spatula and a straight edge

PREOCEDURE

The shear box with the specimen, plane grid plate over the base plate at the bottom of the specimen, and plane grid plate at the top of the specimen should be fitted into position in the load frame. The serration of the grid plates should be at right angles to the direction of shear. The loading pad should be placed on the top grid plate. The water jacket should be provided so that the sample does not get rate of longitudinal displacement/shear stress application so adjusted that no drainage can occur in the sample during the test. The test may now conduct by applying horizontal shear load to failure or to 20% longitudinal displacement, which ever occur first. The shear load readings indicated by the proving ring assembly and the corresponding longitudinal displacement should be noted at regular intervals. If necessary, the vertical compression, if any of the soil specimens may be measured to serve as a check to ensure that drainage has not taken place from the soil specimen. At the end of the test, the specimen should be removed from the box and the final moisture content measured.

DETERMINATION

The maximum shear stress & the corresponding longitudinal displacement and applied normal stress should be recorded for each test and the results should be presented in the form of a graph in which the applied normal stress in plotted as abscissa and the maximum shearing stress is plotted as ordinate to the same scale. The angle which the resulting straight line makes with the horizontal axis and the intercept which the straight line makes with the vertical axis shall be reported as the angle of shearing resistance and cohesion intercept respectively.

3.5 Tests performed on soil and results

1) Grain Size Analysis
2) Liquid Limit test
3) Plastic limit test
4) Specific Gravity test
5) Light Compaction test
6) Unconfined Compressive Strength
7) Direct shear test
8) Shrinkage limit

3.5.1 Grain Size Analysis

Observation are shown in Table 1 Appendix A

Fig 1. Grain Size Analysis of soil

From Fig 1 following results are observed:-

D_{10} = 0.07

D_{30}= 0.18

D_{60}= 0.6

C_U= 8.57

C_C= 0.77

Hence it can be concluded that soil used is SM-SC i.e. poorly graded sand with silty and clayey fine.

3.5.2 Liquid Limit test

Observation are shown in Table 2 Appendix A

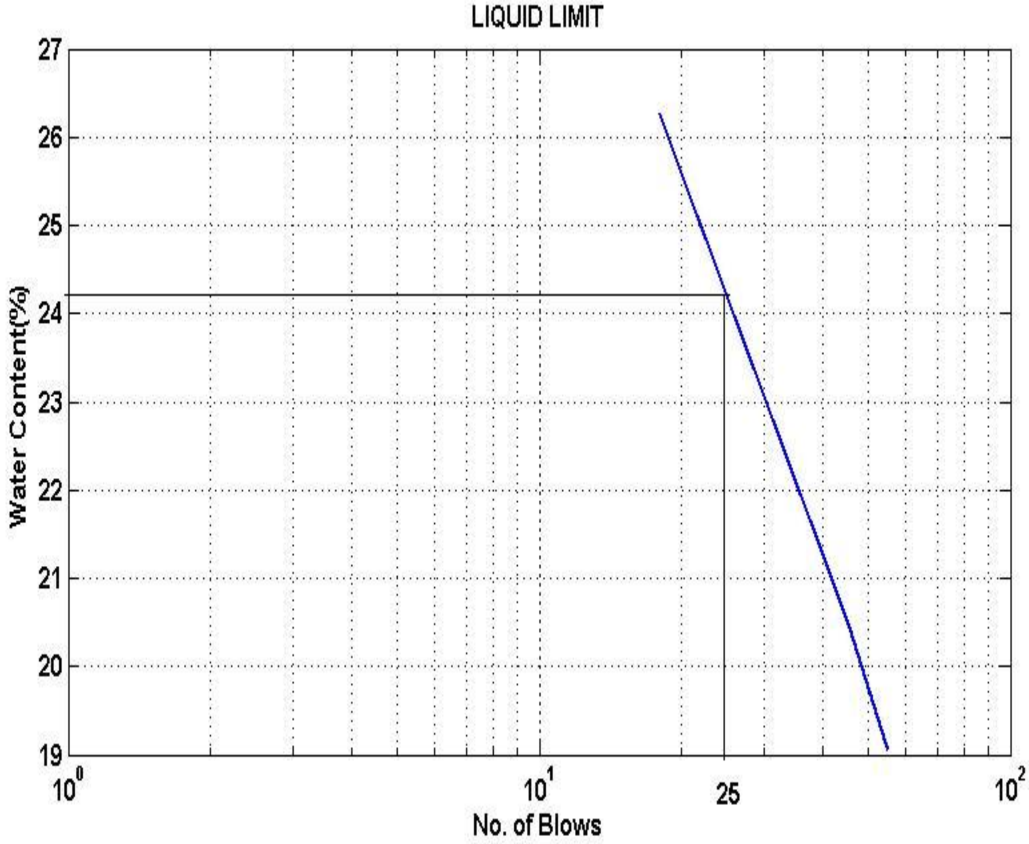

Fig 2. Liquid Limit of soil

From fig 2 it can be concluded that Liquid limit of soil is 24.1%

3.5.3 Plastic Limit test

Observation are shown in Table 3 Appendix A

From the experiment Plastic limit of soil comes out to be 21.95%

Hence Plastic Index= Plastic Limit – Liquid Limit

PI= 24.1 % – 21.95%

PI= 2.15%

3.5.4 Specific Gravity Test

Observation are shown in Table 4 Appendix A

From the experiment Specific Gravity of Soil is 2.296

3.5.5 Light Compaction Test

Observation are shown in Table 5 Appendix A

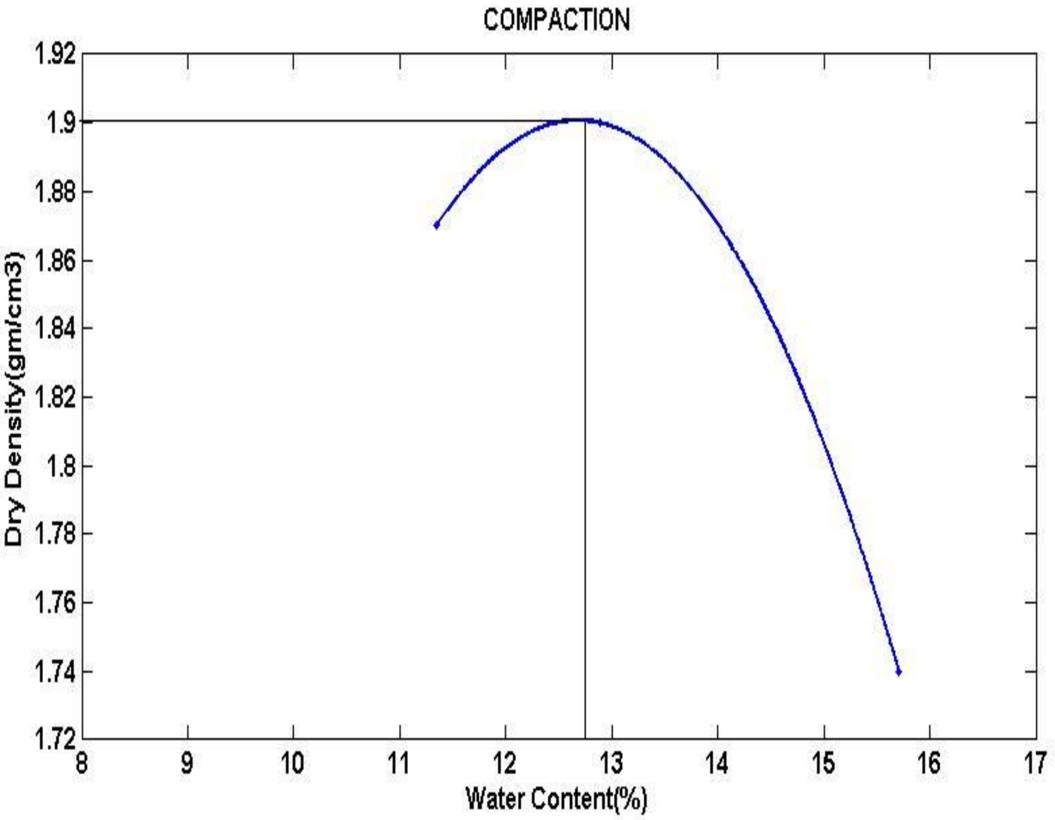

Fig 3. Density- moisture content relationship of soil

It is concluded from the fig 3 that Maximum Dry Density of 1.9 gm/cm^3 is obtained at an optimum moisture content of 12.89%

3.5.6 Unconfined Compressive Strength

Observation are shown in Table 6 Appendix A

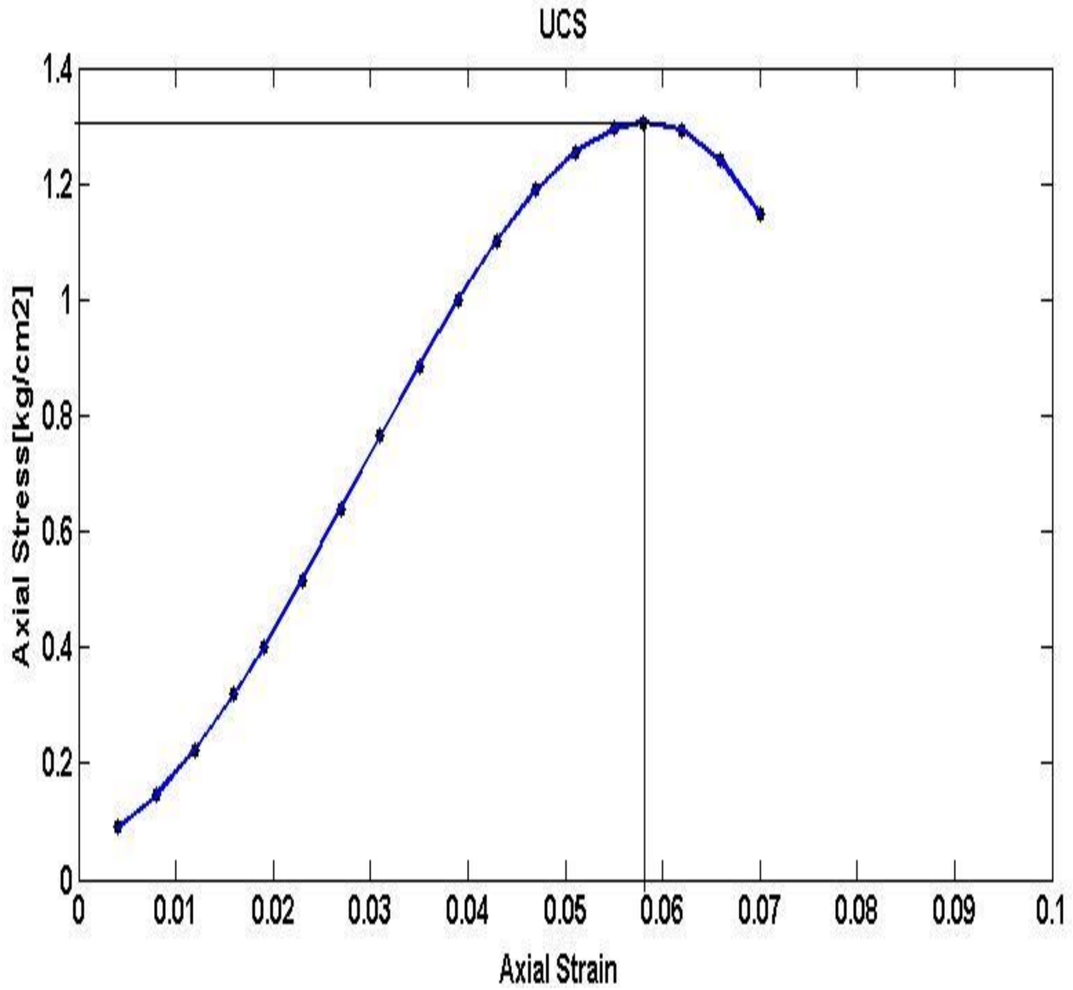

Fig 4. Compressive strength of soil

From fig 4 it can clearly be seen that Unconfined Compressive Strength of soil is

1.32 kg/cm^2 or 132 kPa.

3.5.7 Direct Shear Test

Observation are shown in Table 7 Appendix A

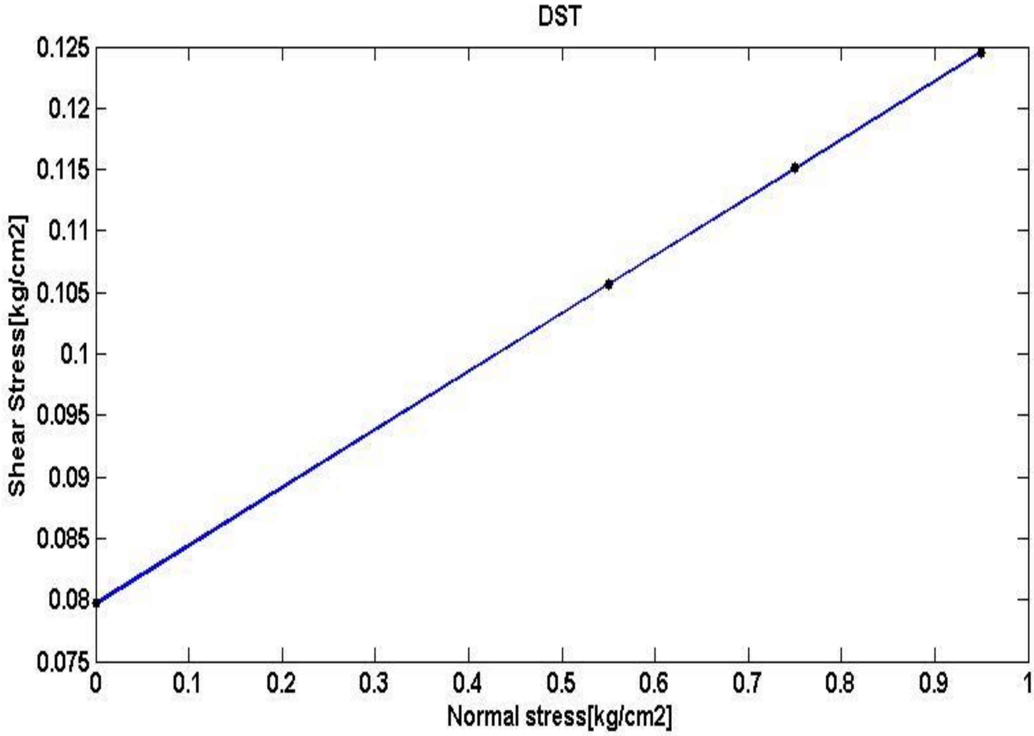

Fig 5. Direct Shear Test

From fig 5 it can be concluded that soil have following properties

Cohesion (c) = 0.08 kg/cm^2

Angle of Internal Friction (Ø) = 2.29 ^{0}

3.5.8 Shrinkage Limit Test

Observation are shown in Table 8 Appendix A

From the Experiment, following results are obtained:-

Property	Sample 1	Sample 2
Shrinkage Limit(%)	22.6	23.77
Shrinkage ratio	1.3	1.06
Volumetric Shrinkage	0.56	0.46
Shrinkage index	1.92	1.92

All the test results of soil are comprised below:-

S.NO.	PROPERTIES	RESULT	
1.	Liquid Limit	24.1%	
2.	Plastic Limit	21.95%	
3.	Plastic Index	2.15%	
4.	Specific Gravity	2.296	
5.	Maximum Dry density	1.9gm/cm^3	
6.	Optimum Moisture Content	12.89%	
7.	Unconfined Compressive Strength	1.32kg/cm^2	
8.	Direct Shear Test	C (kg/cm^2)	Ø
		0.08	2.29^0
9.	Shrinkage Limit	23.18%	

3.6 Test performed on Stone Dust and results

1) Specific Gravity
2) Grain Size Analysis

3.6.1 Specific Gravity Test

Observation are shown in Table 9 Appendix A

From the experiment Specific Gravity of Soil is 2.652

3.6.2 Grain Size Analysis

Observation are shown in Table 10 Appendix A

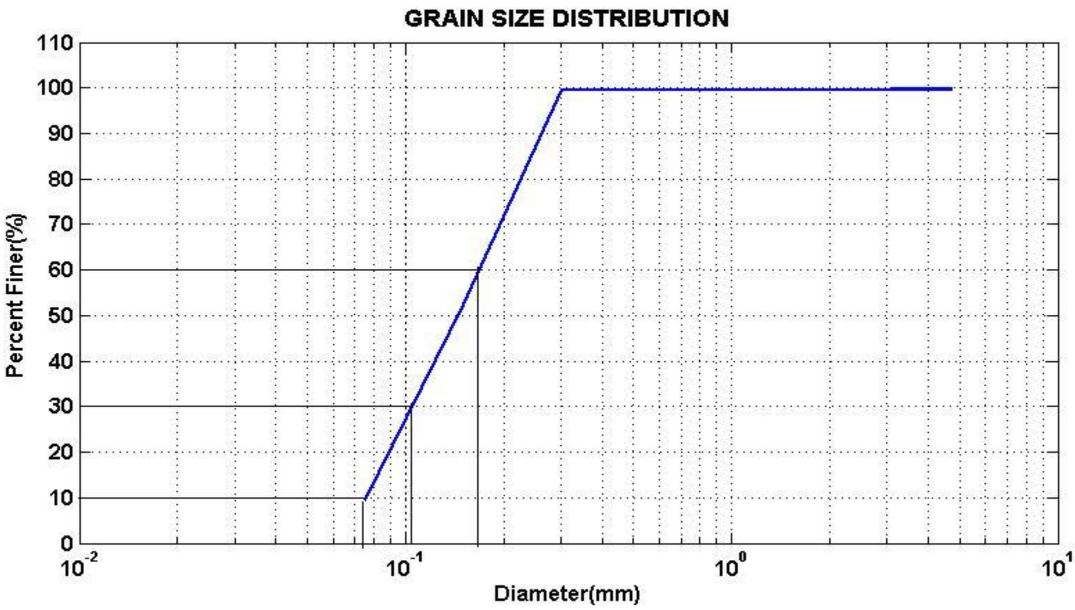

Fig 6. Grain Size Analysis of Stone dust

From Fig 6 following results are observed:-

D_{10} = 0.079

D_{30}= 0.12

D_{60}= 0.18

C_U= 2.28

C_C= 1.01

Hence it can be concluded that soil used is poorly graded sand .

3.7 Tests Performed on soil mixed with different proportion of Stone Dust

1) Light Compaction Test
2) Unconfined Compressive Strength Test
3) Direct Shear Test
4) Liquid Limit Test
5) Plastic Limit Test

3.7.1 Light Compaction Test

- Observations with soil mixed with 20% Stone Dust are shown in Table 11 Appendix A

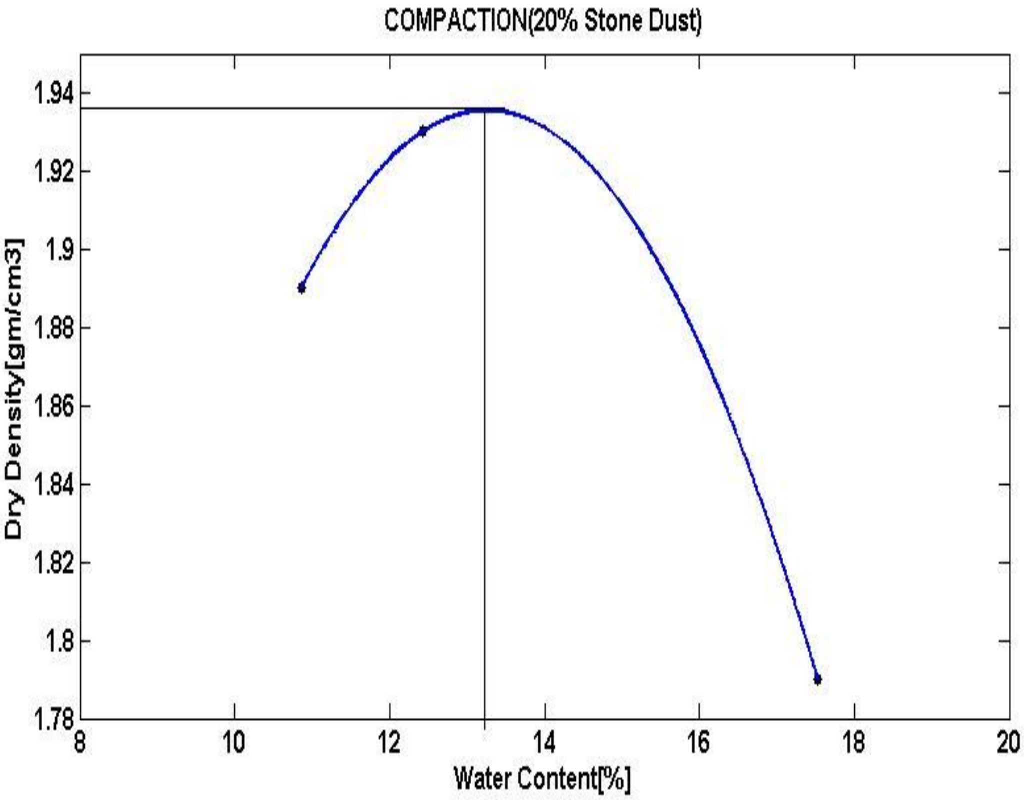

Fig 7. Density- moisture content relationship of soil with 20%stone dust

It is concluded from Fig 7 that Maximum Dry Density of 1.935 gm/cm^3 is obtained at an optimum moisture content of 12.8% when soil is mixed with 20% stone dust.

- Observations with soil mixed with 25% Stone Dust are shown in Table 12 Appendix A

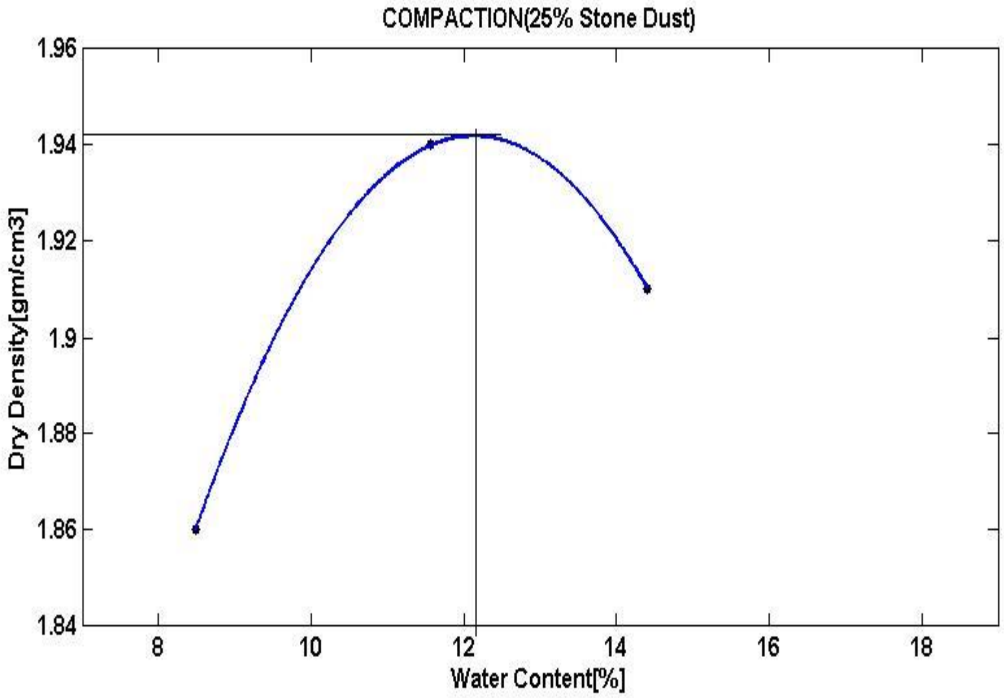

Fig 8. Density- moisture content relationship of soil with 25% stone dust

It is concluded from Fig 8 that Maximum Dry Density of 1.941 gm/cm^3 is obtained at an optimum moisture content of 12.2% when soil is mixed with 25% stone dust.

- Observations with soil mixed with 30% Stone Dust are shown in Table 13 Appendix A

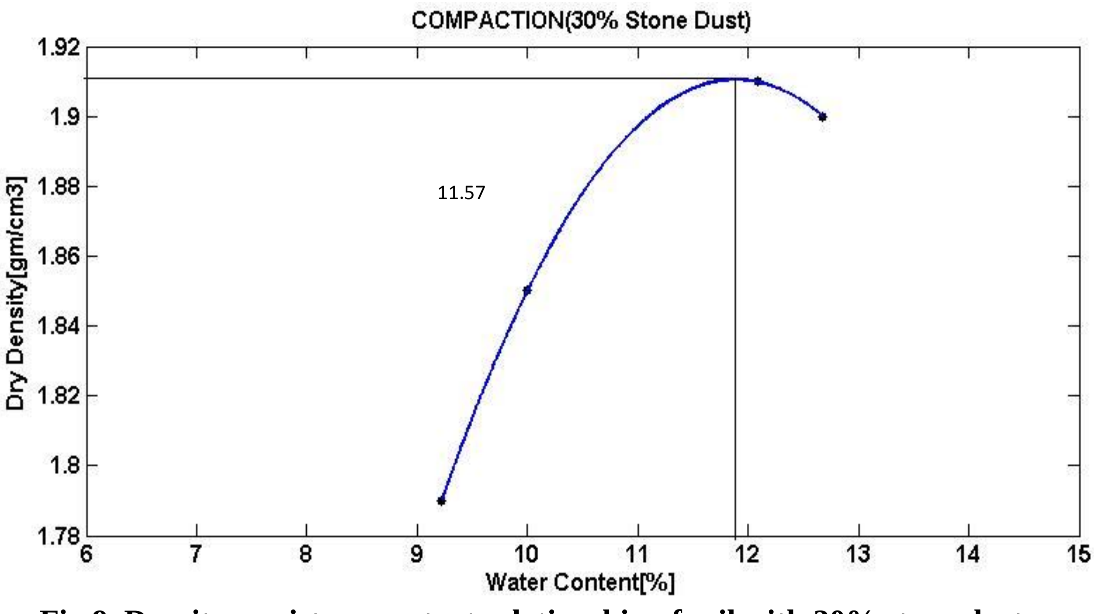

Fig 9. Density- moisture content relationship of soil with 30% stone dust

It is concluded from Fig 9 that Maximum Dry Density of 1.91 gm/cm^3 is obtained at an optimum moisture content of 11.9% when soil is mixed with 30% stone dust.

- Observations with soil mixed with 35% Stone Dust are shown in Table 14 Appendix A

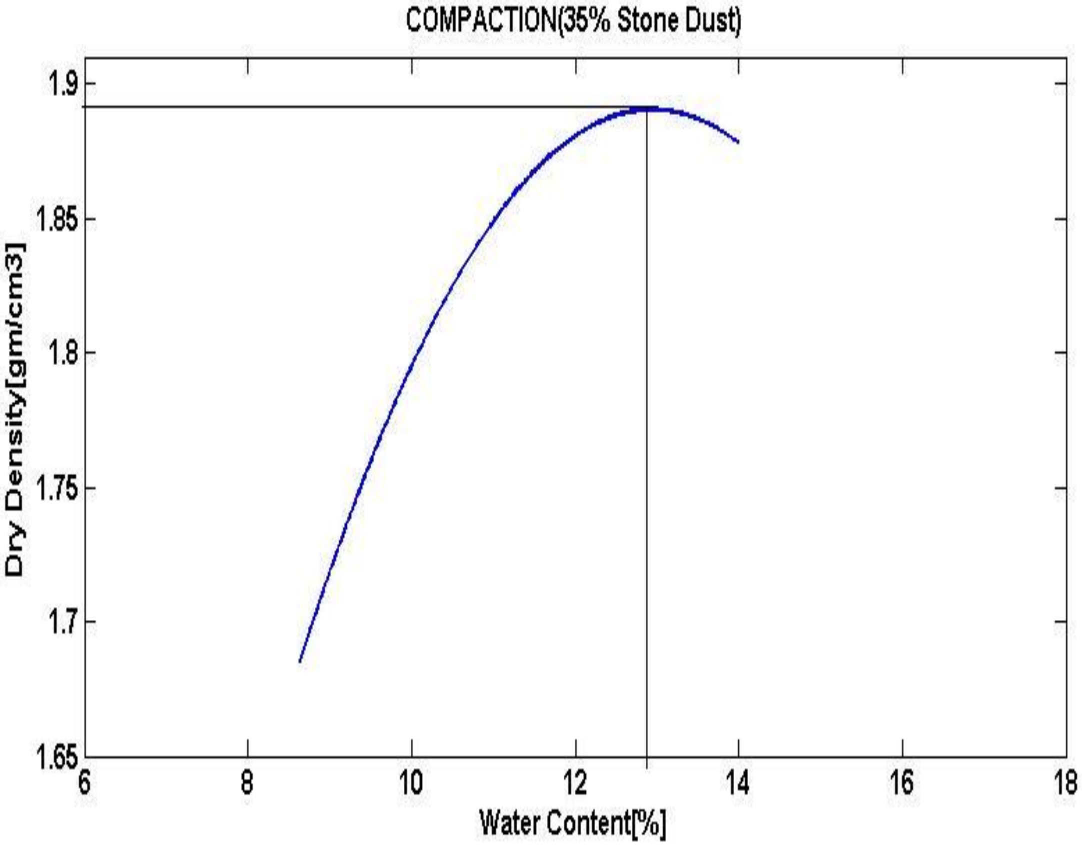

Fig 10. Density- moisture content relationship of soil with 35% stone dust

It is concluded from the above graph that Maximum Dry Density of 1.89 gm/cm^3 is obtained at an optimum moisture content of 12.9% when soil is mixed with 35% stone dust.

3.7.2 Unconfined Compressive Strength Test

- Observations with soil mixed with 20% Stone Dust are shown in Table 15 Appendix A

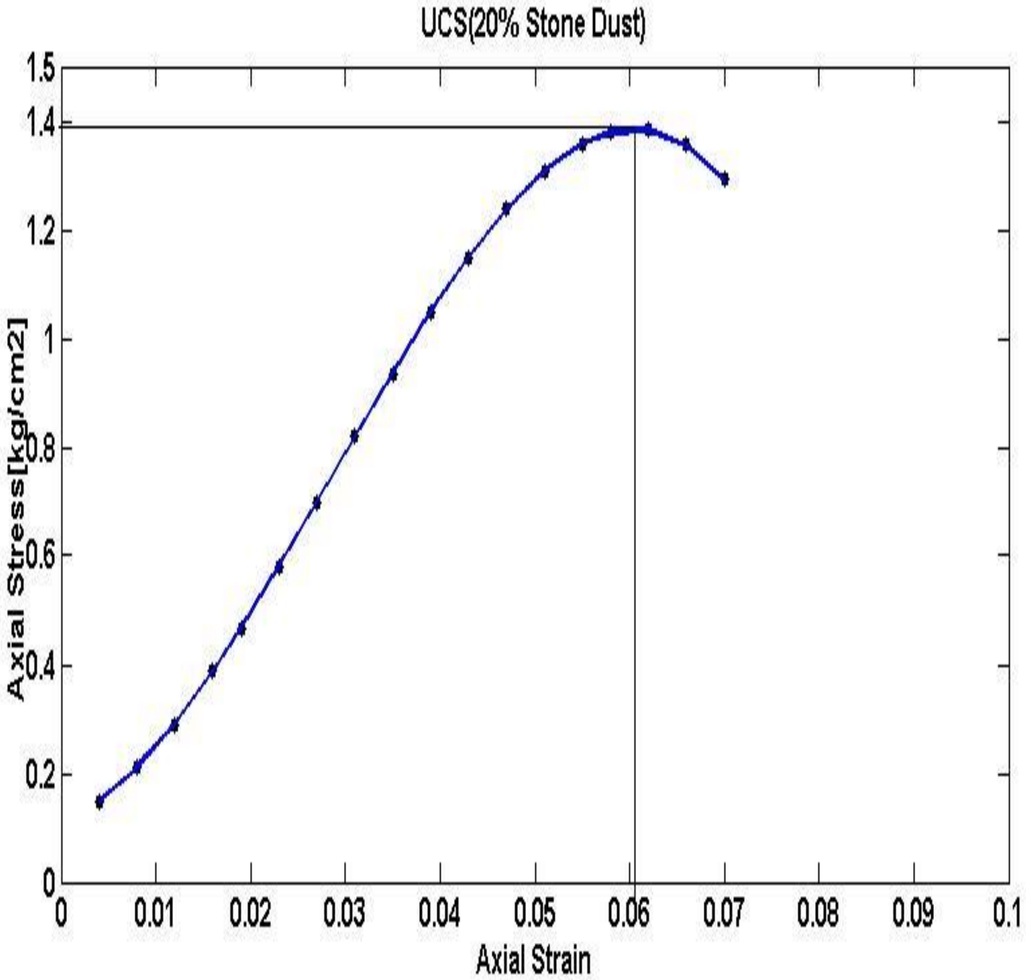

Fig 11. Compressive Strength of soil with 20% stone dust

From Fig 11 it can clearly be seen that Unconfined Compressive Strength of soil is 1.4 kg/cm^2 or 140 kPa when it is mixed with 20% stone dust.

- Observations with soil mixed with 25% Stone Dust are shown in Table 16 Appendix A

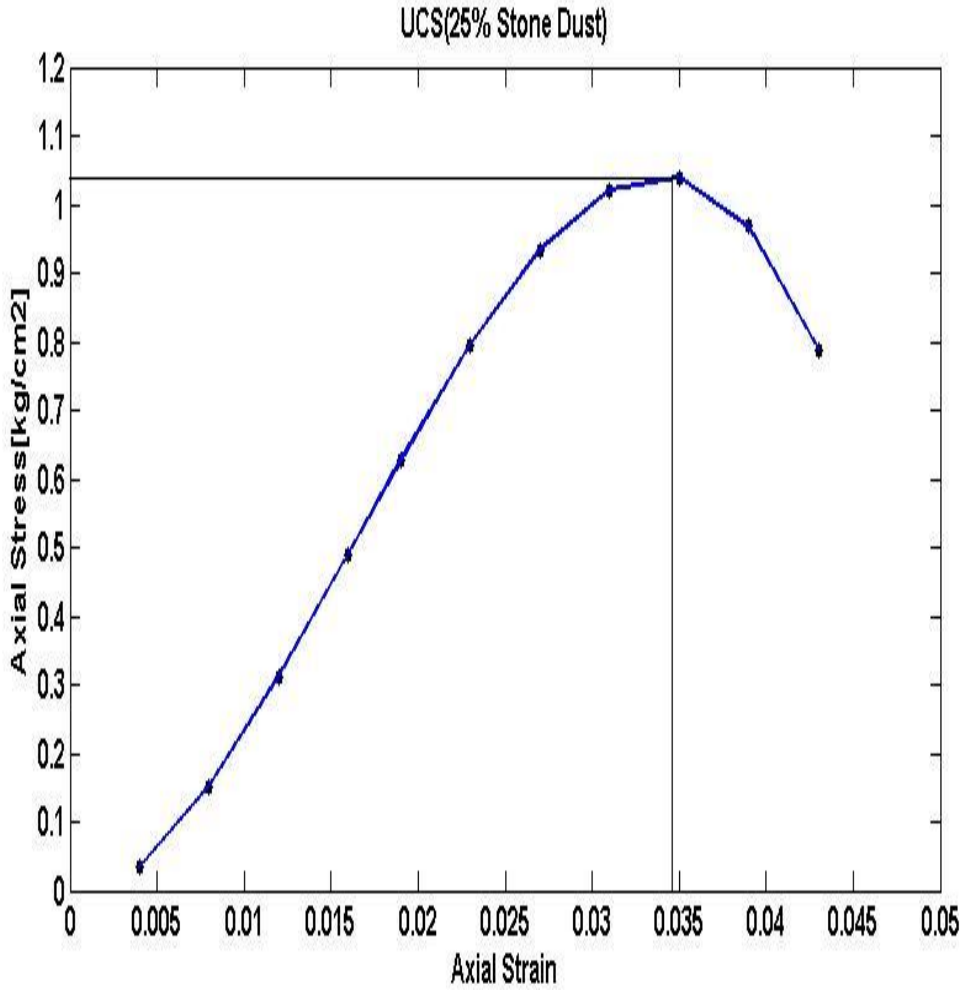

Fig 12. Compressive Strength of soil with 25% stone dust

From Fig 12 it can clearly be seen that Unconfined Compressive Strength of soil is 1.04 kg/cm^2 or 104 kPa when it is mixed with 25% stone dust.

- Observations with soil mixed with 30% Stone Dust are shown in Table 17 Appendix A

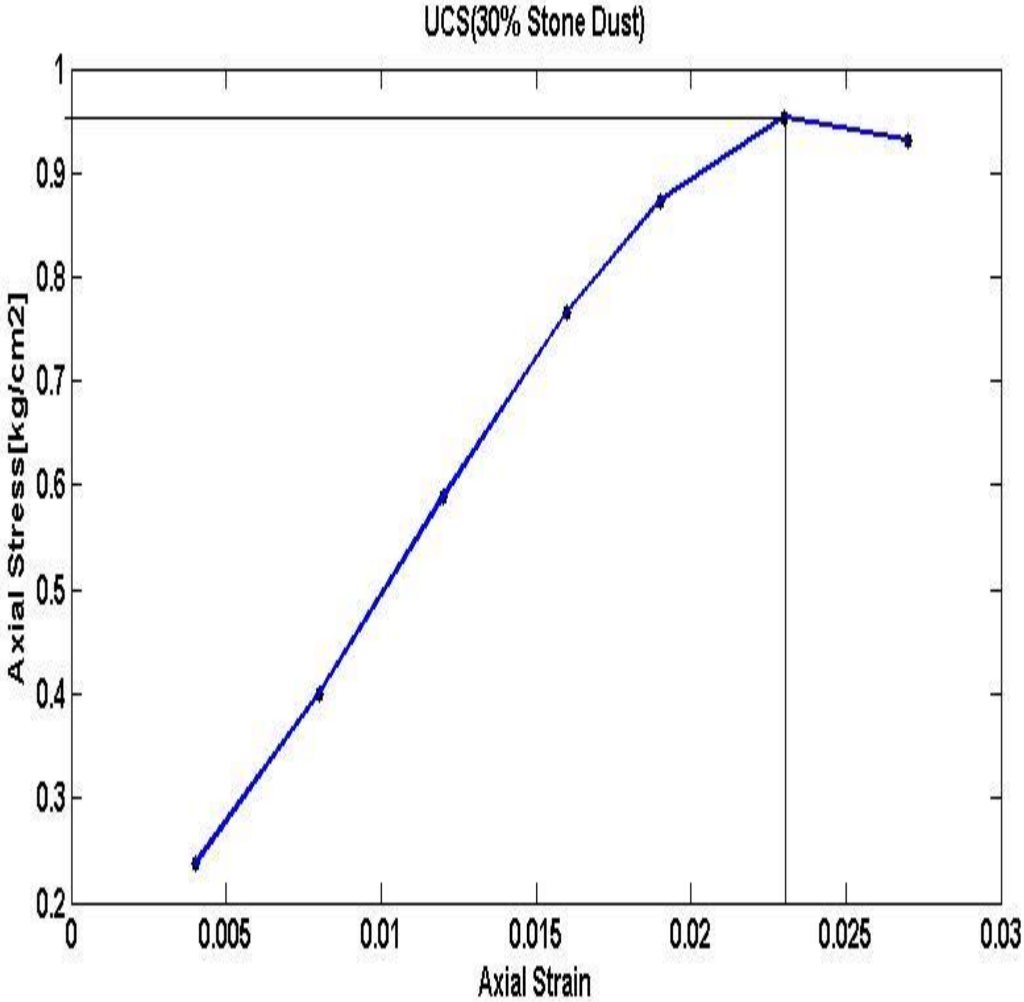

Fig 13. Compressive Strength of soil with 30% stone dust

From Fig 13 it can clearly be seen that Unconfined Compressive Strength of soil is 0.96 kg/cm^2 or 96 kPa when it is mixed with 30% stone dust.

3.7.3 Direct Shear Test

- Observations with soil mixed with 20% Stone Dust are shown in Table 18 Appendix A

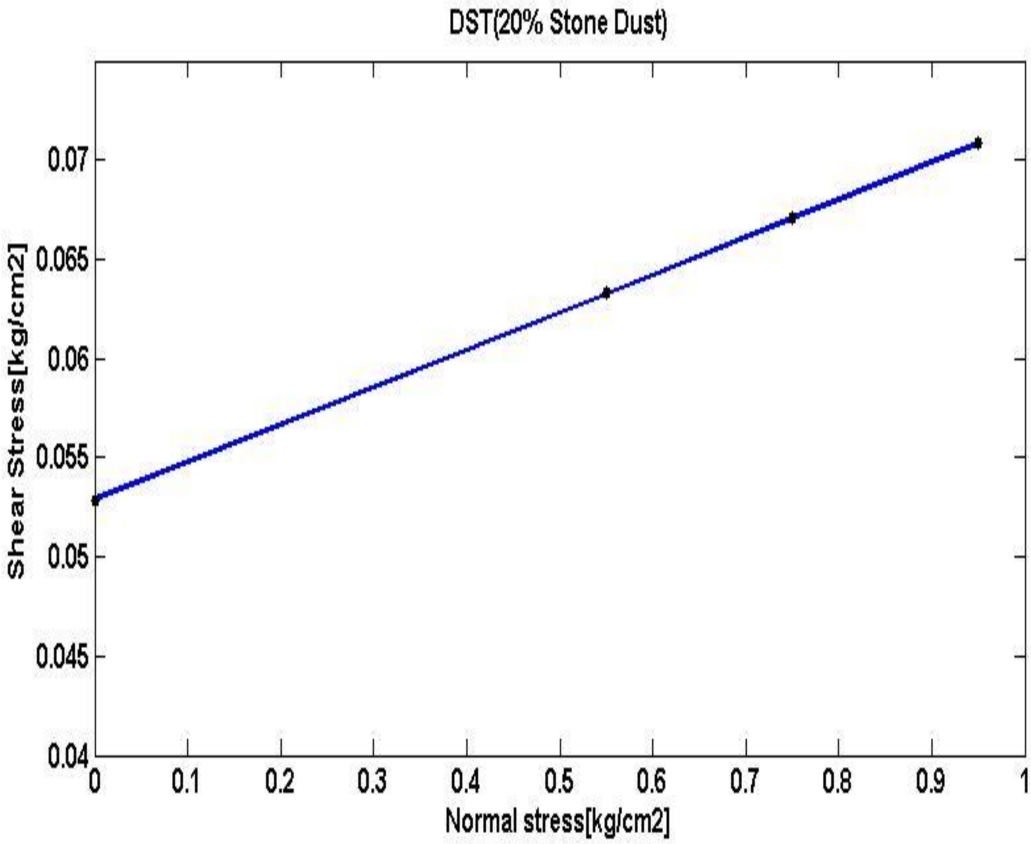

Fig 14. Direct Shear Test with 20% of soil

From fig 14 it can be concluded that soil have following properties

Cohesion (c) = 0.053 kg/cm^2

Angle of Internal Friction (Ø) = 3.91 ^{0}

- Observations with soil mixed with 25% Stone Dust are shown in Table 19 Appendix A

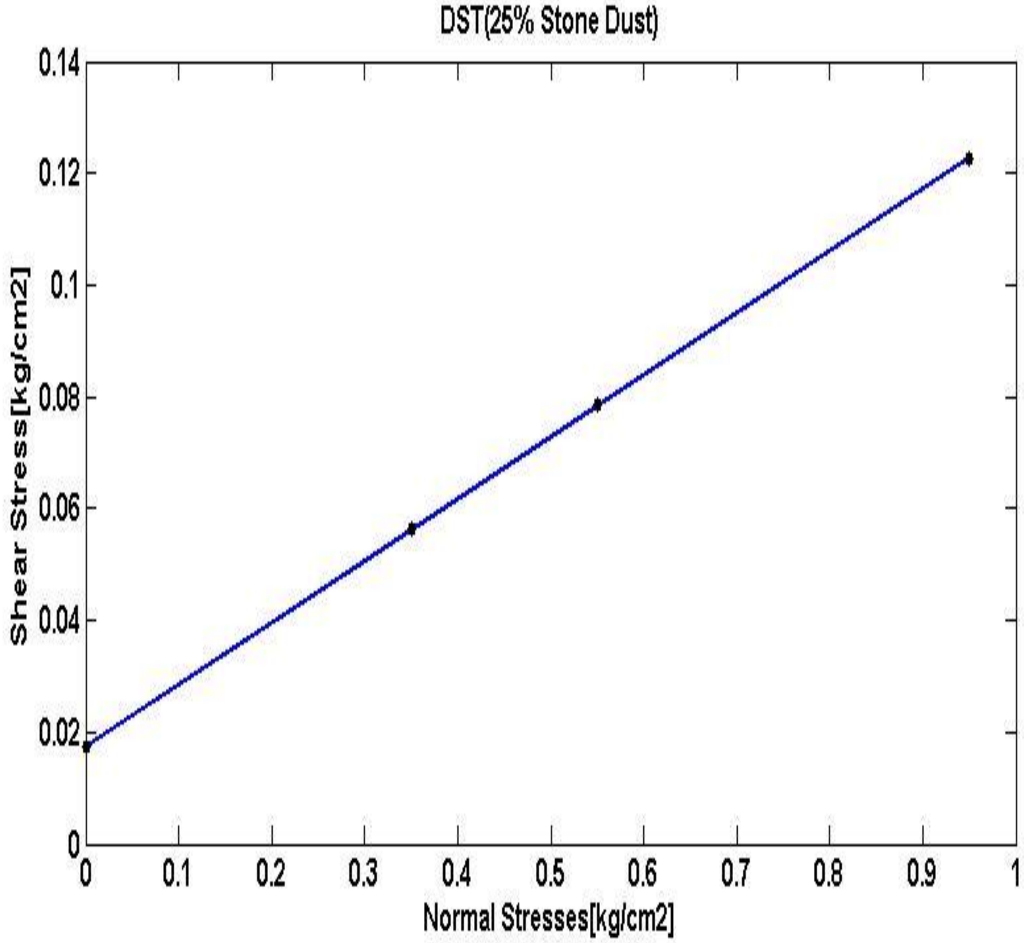

Fig 15. Direct Shear Test with 25% of soil

From fig 15 it can be concluded that soil have following properties

Cohesion (c) = 0.019 kg/cm^2

Angle of Internal Friction (Ø) = 6.164 ^{0}

3.7.4 Liquid Limit Test

- Observations with soil mixed with 20% Stone Dust are shown in Table 20 Appendix A

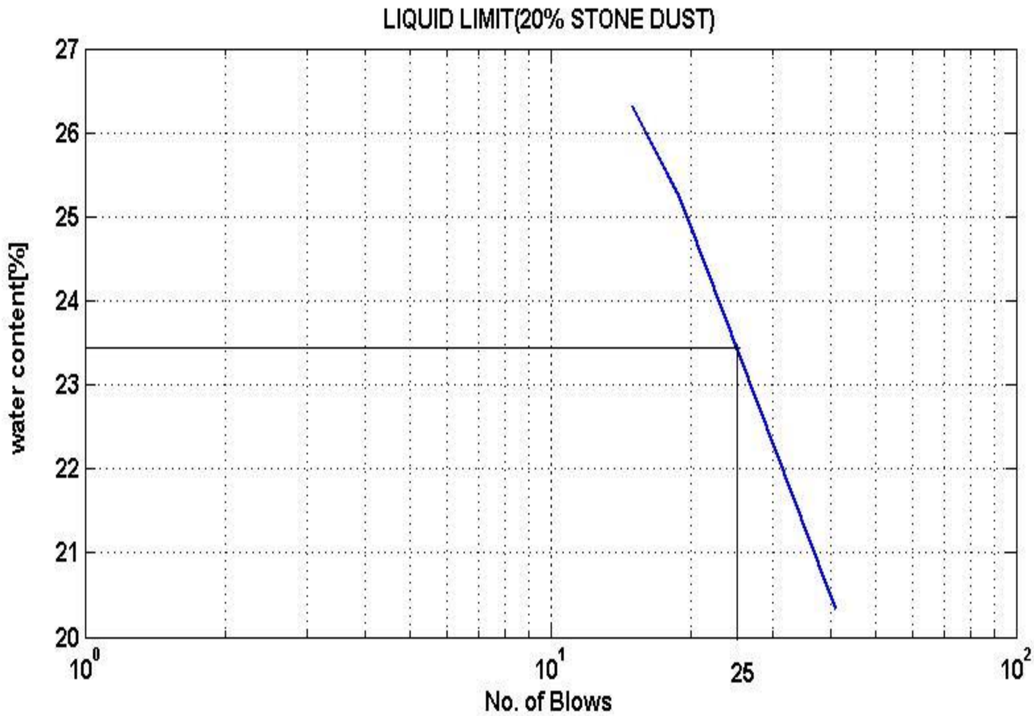

Fig 16. Liquid Limit of soil with 20% stone dust

From fig 16 it can be concluded that Liquid limit is 23.4%.

- Observations with soil mixed with 25% Stone Dust are shown in Table 21 Appendix A

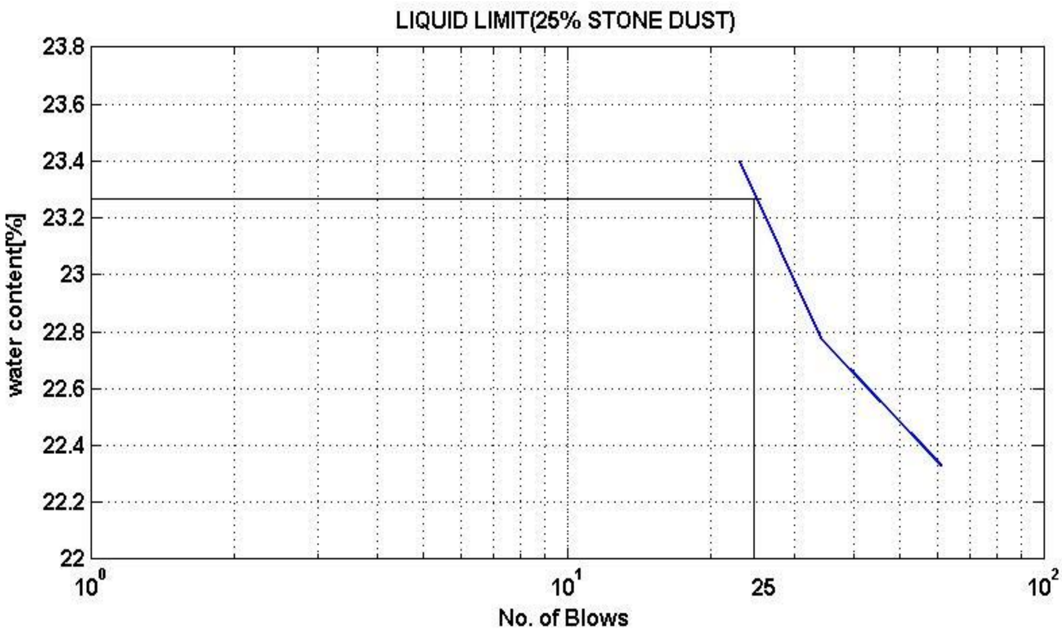

Fig 17. Liquid Limit of soil with 25% stone dust

From fig 17 it can be concluded that Liquid limit is 23.25%.

- Observations with soil mixed with 30% Stone Dust are shown in Table 22 Appendix A

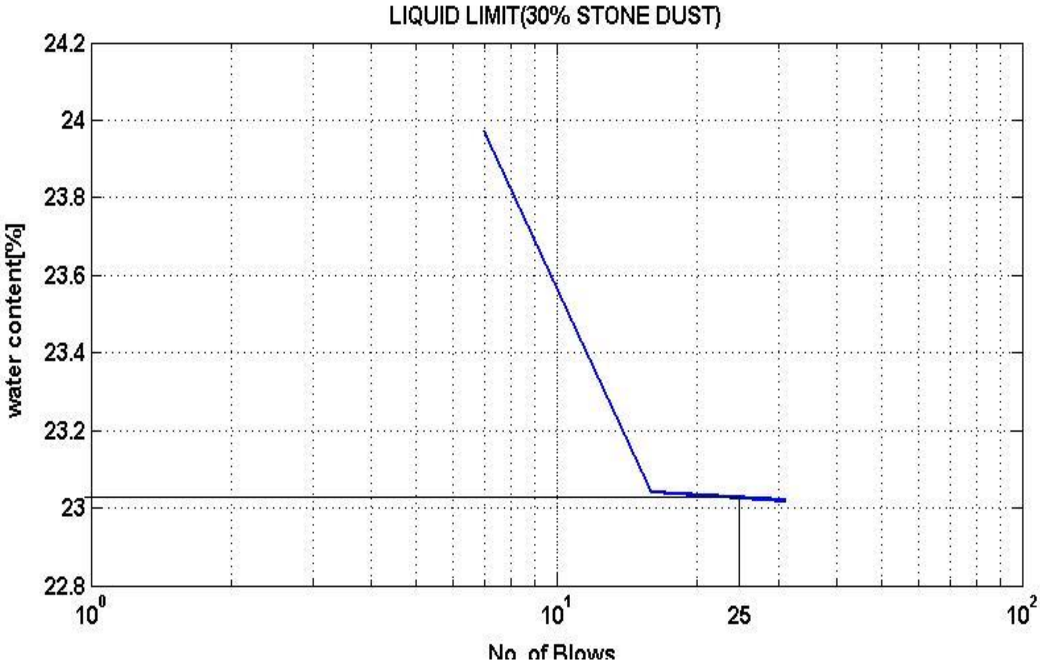

Fig 18. Liquid Limit of soil with 30% stone dust

From fig 18 it can be concluded that Liquid limit is 23.01%.

- Observations with soil mixed with 35% Stone Dust are shown in Table 23 Appendix A

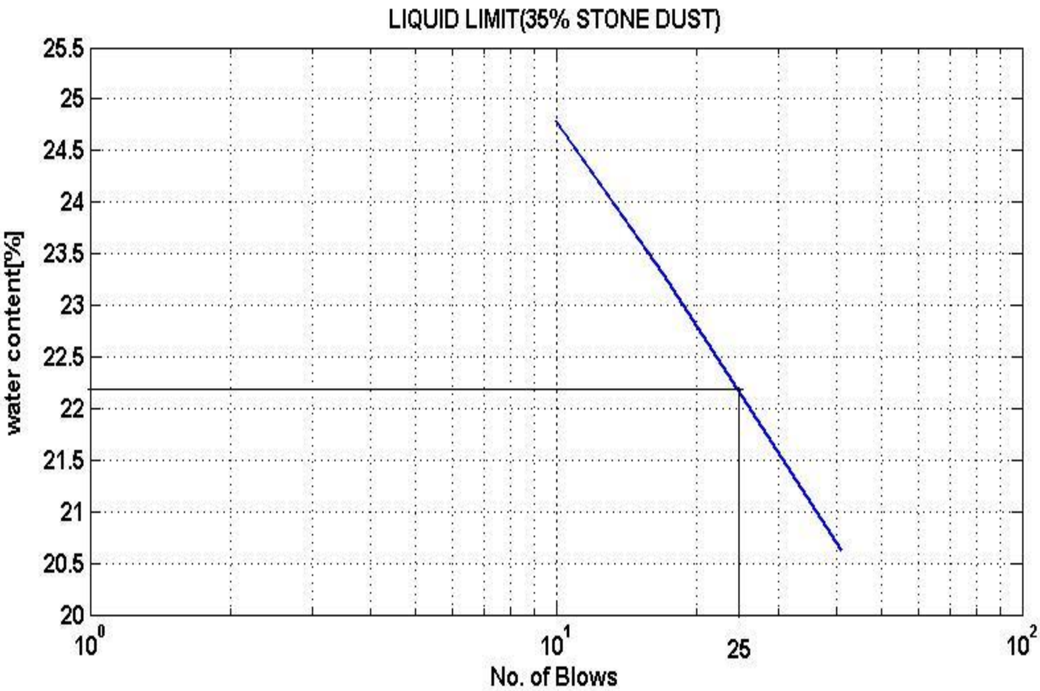

Fig 19. Liquid Limit of soil with 35% stone dust

From fig 19 it can be concluded that Liquid limit is 22.2%.

3.7.5 Plastic Limit Test

- Observations with soil mixed with 5% Stone Dust are shown in Table 24 Appendix A

  From the experiment Plastic limit comes out to be 18.6%

- Observations with soil mixed with 10% Stone Dust are shown in Table 25 Appendix A

  From the experiment Plastic limit comes out to be 15.38%

- Observations with soil mixed with 20% Stone Dust are shown in Table 26 Appendix A

  From the experiment Plastic limit comes out to be 9.09%

  Hence Plastic Index= Plastic Limit – Liquid Limit

  PI= 23.4 % – 9.09%

  PI= 14.31%

- Observations with soil mixed with 25% Stone Dust are shown in Table 27 Appendix A

  From the experiment Plastic limit comes out to be 5.84%

  Hence Plastic Index= Plastic Limit – Liquid Limit

  PI= 23.25 % – 5.84%

  PI= 17.41%

All the above test results are comprised below:-

S.NO.	PROPERTIES		STONE DUST MIXED BY WEIGHT OF RAW SOIL			
			20%	**25%**	**30%**	**35%**
1.	Maximum Dry Density (gm/cm^3)		1.935	1.941	1.91	1.89
2.	Optimum Moisture Content (%)		12.8	12.2	11.9	12.9
3.	Unconfined Compressive strength(kg/cm^2)		1.4	1.04	0.96	--
4.	Direct Shear Test	C (kg/cm2)	0.053	0.019	--	--
		∅	3.91^0	6.164^0	--	--
5.	Liquid Limit (%)		23.4	23.25	23.01	22.2

S.NO.	PROPERTIES	STONE DUST MIXED BY WEIGHT OF RAW SOIL			
		5%	**10%**	**20%**	**25%**
5.	Plastic Limit (%)	18.6	15.38	9.09	5.84

4. RESULTS AND DISCUSSION

4.1 Effect of Stone Dust on Maximum Dry Density and Optimum Moisture Content

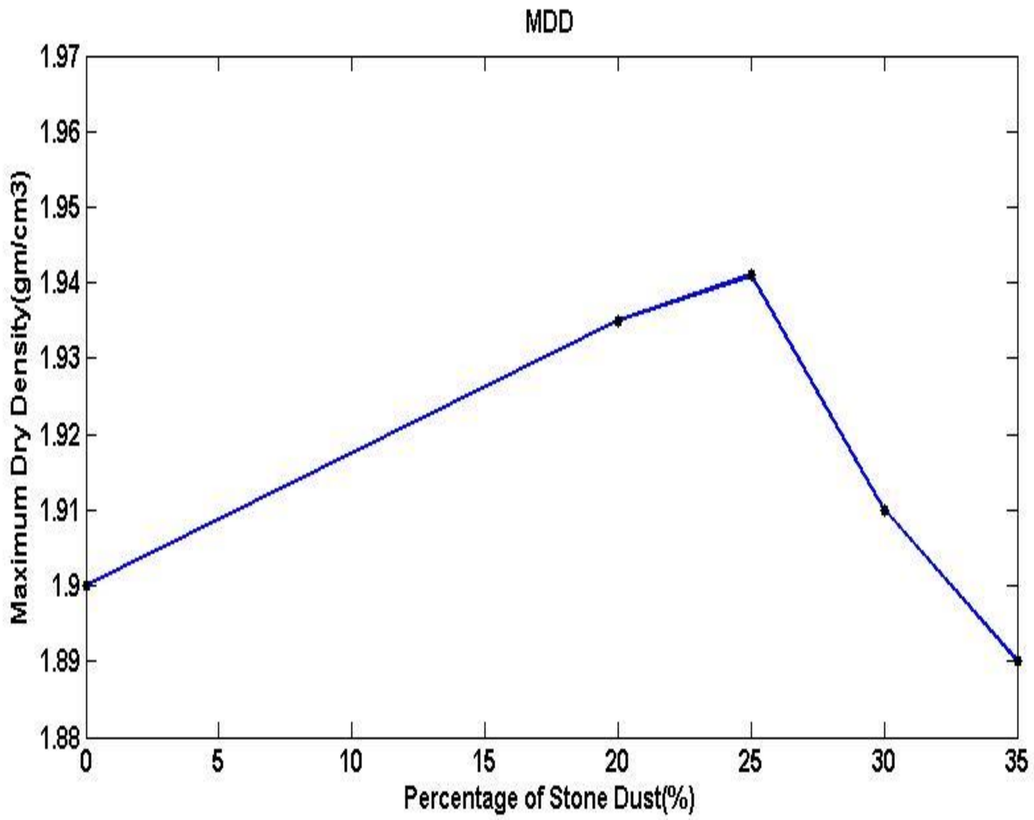

Fig 20. Variation of maximum Dry density with % of stone dust

From Fig 20 it can be seen that initially there is increase in maximum dry density with increase in percentage of stone dust but later it decreases. This is attributed to the high specific gravity of quarry dust (2.652) as compared to soil (2.296) in soil quarry dust mixes.

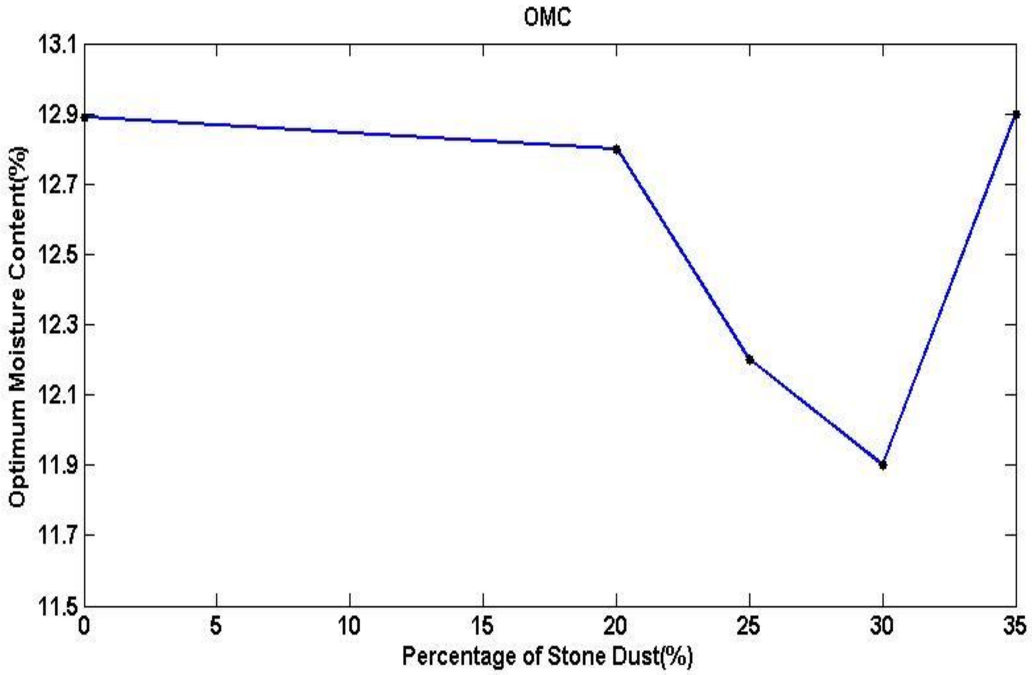

Fig 21. Variation of optimum moisture content with % of stone dust

From Fig 21 it can be seen that initially there is decrease in optimum moisture content with increase in percentage of stone dust but later it increases. This is attributed to the reduction in clay content of soil by replacement with quarry dust mixes which have less attraction for water molecules.

From above graphs it can also be observed that when soil is replaced with 25% stone dust it yielded maximum dry density of 1.94 gm/cm^3 at optimum moisture content of 11.57% and on further increasing the percentage of stone dust maximum dry density decreases and optimum moisture content increases.

The above observation is quite obvious. The coarse grained stone dust requires less water and is likely to have higher dry density on compaction. Thus the compressibility of the stone dust mixed soil has improved.

4.2 Effect of Stone Dust on Unconfined Compressive Strength

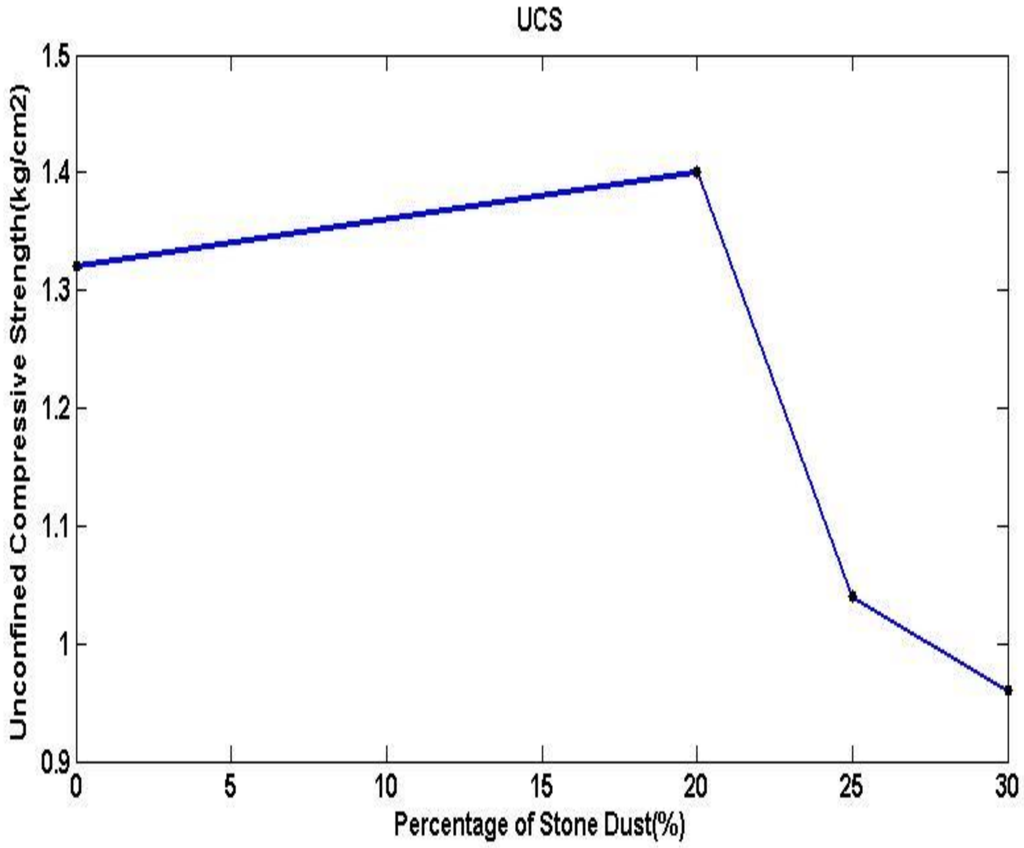

Fig 22. Variation on Compressive Strength with % of stone dust

From Figure 22 it can be seen that the unconfined compressive strength of soil sample have increased with the percentage of stone dust up to addition of 20% stone dust and later it decreases. The UCS value at 20% addition of stone dust to the soil is 140 kPa. As compared to the untreated soil, the percentage increase in UCS at 20% addition of stone dust to the soil is 6%.

Though the increase in strength is marginal with the addition of stone dust, there is a good control over the plasticity characteristics of clay. Consistency of Soil decreases from stiff to medium consistency.

Due to lack of cohesion i.e. soil percentage the bonding between soil -quarry dust mixes loses its strength. UCS samples were unable to stand without a support and resulted decrease in UCS values.

4.3 Effect of Stone Dust on Shear Strength Parameters c and Ø

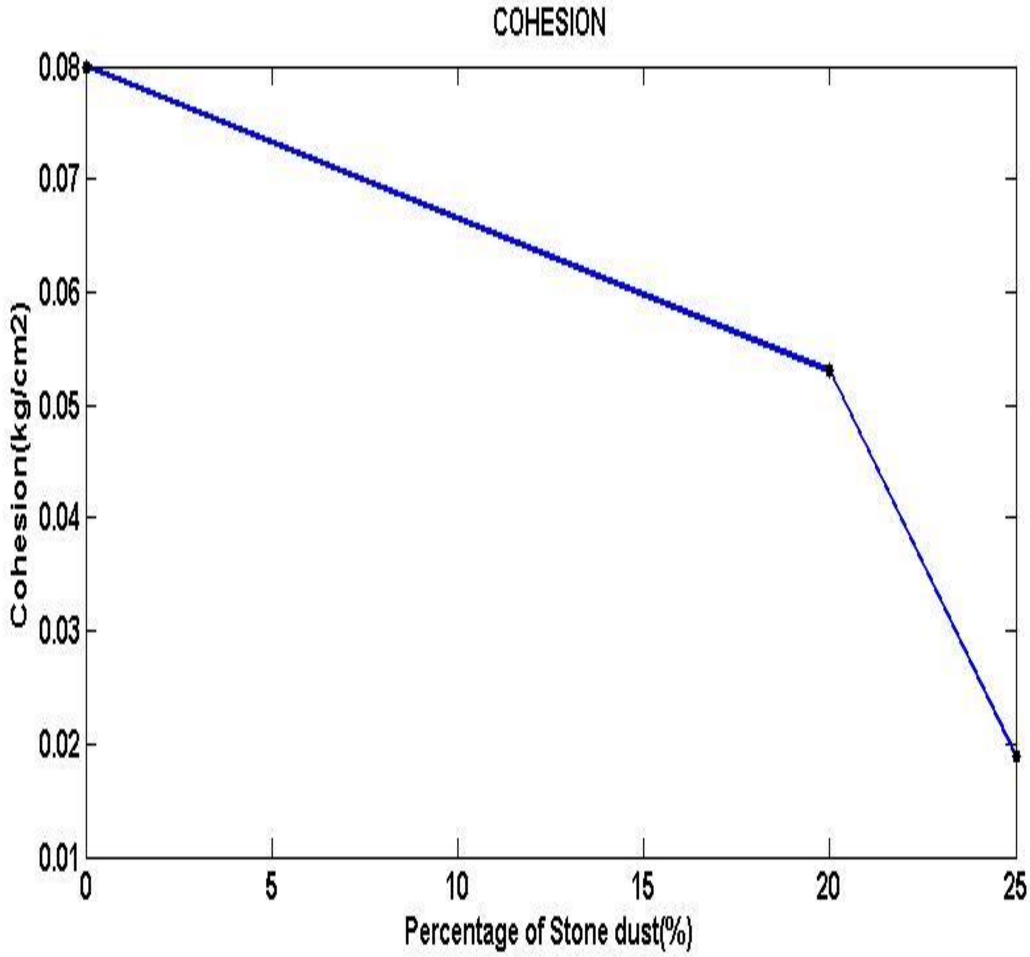

Fig 23. Variation on cohesion with % of stone dust

From figure 23 it has been found that with the increase in the percentage quarry dust, the cohesion of the soil goes on decreasing. This is attributed to the reduction in clay content of soil with increase in quarry dust percentage.

With the addition of stone dust Cohesion decrease and at 25% addition of stone dust cohesion is found out to be 0.019 kg/cm^2.

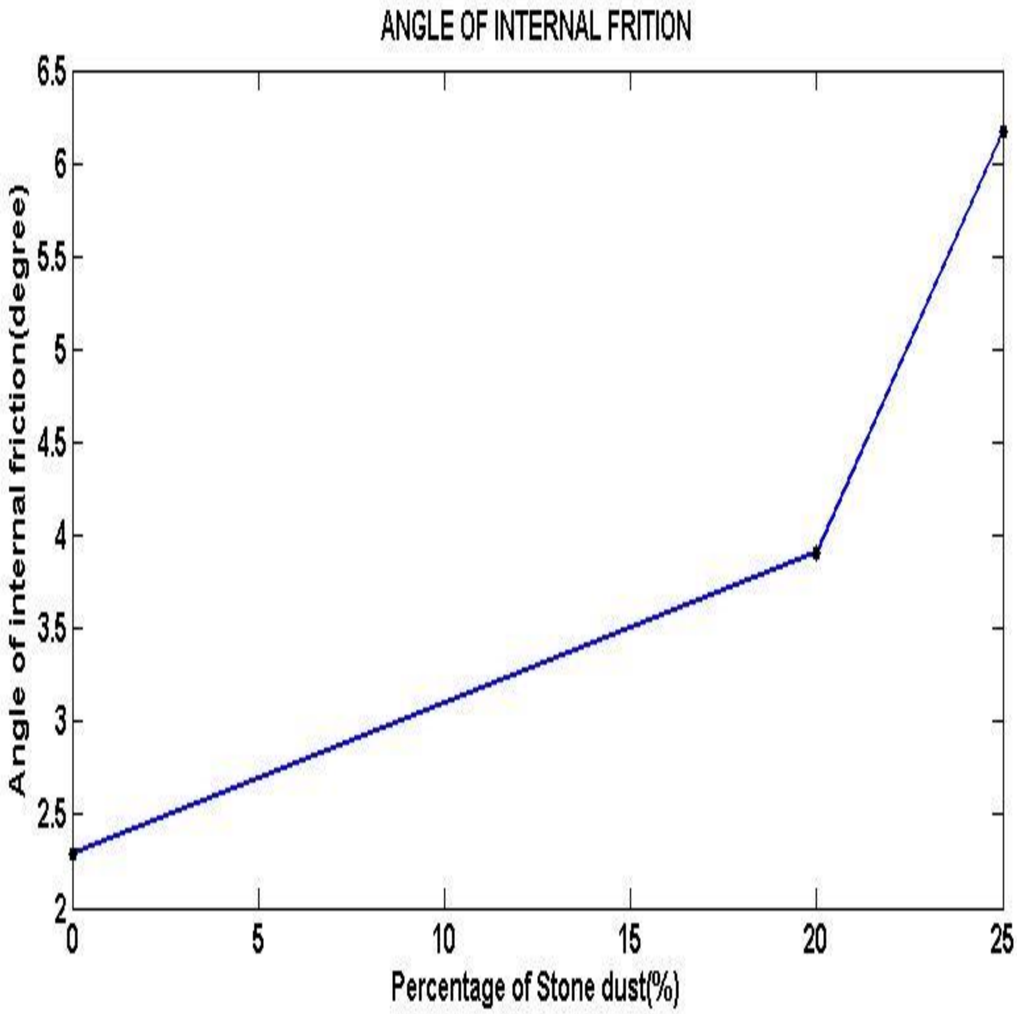

Fig 24. Variation on Angle of Internal Friction with % of stone dust

From figure 24 it has been found that with the increase in the percentage of quarry dust, the angle of internal friction of the soil goes on increasing. This is attributed to the reduction in clay content of soil with increase in quarry dust percentage, quarry dust mixes have higher angle of internal friction values than the soil.

With the addition of stone dust angle of internal friction increase and at 25% addition of stone dust angle of internal friction is found out to be 6.164^o.

4.4 Effect of Stone Dust on Liquid Limit and Plastic Limit of soil

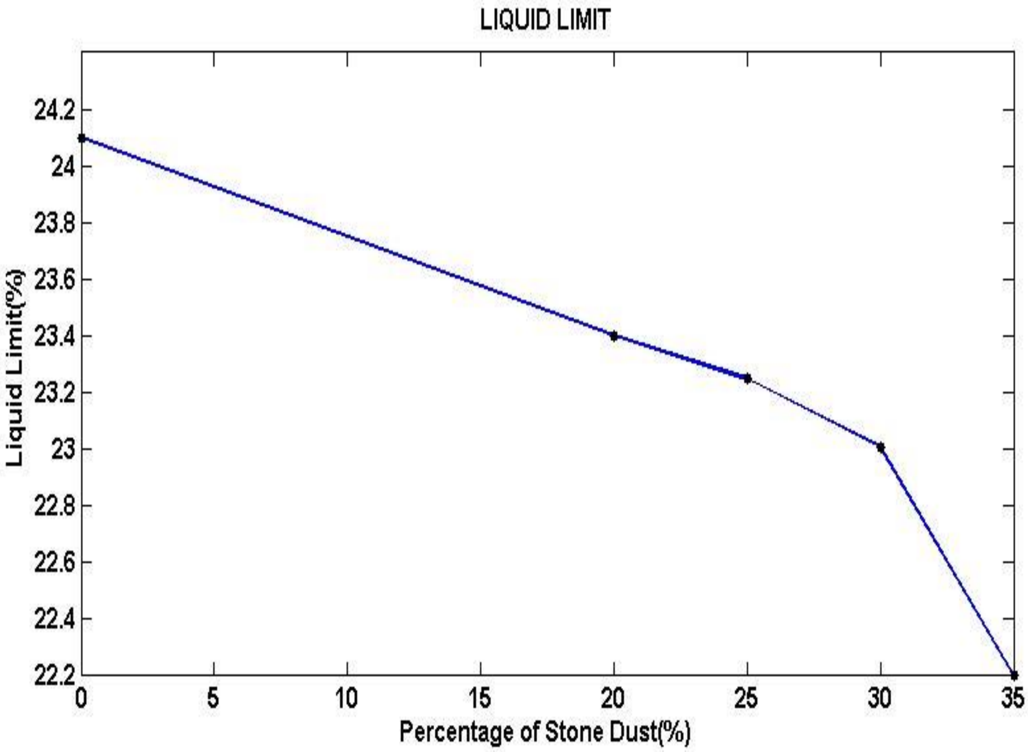

Fig 25. Variation on Liquid Limit with % of stone dust

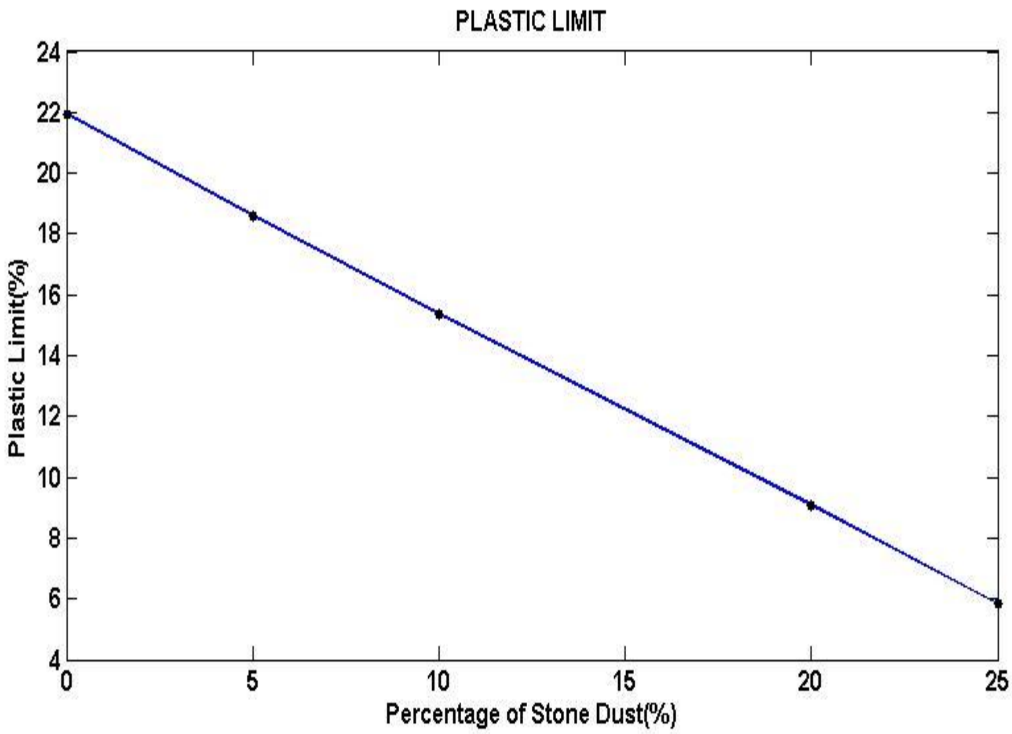

Fig 26. Variation on Plastic Limit with % of stone dust

From figure 25 and 26 it is observed that as the percentage of admixture increases, there is a marked reduction in liquid limit and plastic limit of soil tested. From this, it can be deduced that the flow characteristics and plastic characteristics of the soil sample are gradually decreasing with increase in the percentage of stone dust. This reduced plasticity of soil is very much required to avoid the failure patterns in the road construction over the sub grade soils.

The liquid limit at 35% addition of stone dust shows the value 22.1% and Plastic limit at 25% addition of stone dust as 5.84%.

5. CONCLUSION

In this research, several tests were carried out using stone powder as additives for C-Ø soil collected from Chandigarh. The main objective of the research was to improve the strength and bearing capacity of the soil. The main tests carried out were Unconfined Compressive Strength test, direct shear, standard compaction and Atterberg Limits. The additive is mixed with the soil at percentages of 20%, 25%, 30% and 35% by weight. The following conclusions can be withdrawn:

- The optimum percentages stone dust admixture is observed in between 20% to 25% for improving the properties of soil.

- Maximum dry density increases whereas Optimum moisture content decreases on increasing the percentage of stone dust. Using 25% stone dust powder yielded maximum dry density of 1.941 gm/cm^3 at an optimum moisture content of 12.2%.

- Using 20% stone dust powder increases unconfined compressive strength by 6% and further addition of stone dust decreases it.

- Using 25% of stone powder has increased the angle of internal friction (φ) by about 170% and reduced the cohesion by about 76%.

- Liquid and plastic limit of soil decreases on increasing the percentage of stone dust.

- On the basis of this aggregate waste can be recommended as effective stabilizing agents for improvement of soils for the construction of dam, highway and embankments. The use of aggregate waste as stabilizing agents can be economically attractive in regions near to the areas where these waste by-products are obtained. Utilization of aggregate waste in this manner also has the advantage of reusing and industrial waste by-product without adversely affecting the environment or potential land use.

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- IS:2720 Part 4-1985 Grain size analysis.

- IS:2720 Part 7-1980 Water content-dry density relationship using light compaction.

- IS:2720 Part 10-1991 Unconfined compressive strength.

- IS:2720 Part 13-1986 Direct shear test.

APPENDIX A
OBSERVATION TABLES

- Table 1: Grain Size Analysis of soil

Sample weight = 1kg

SIEVE NO	WT OF SIEVE (gm)	WT OF SIEVE + SOIL (gm)	SOIL RETAINED (gm)	%AGE OF SOIL RETAINED	CUMULATIVE %AGE	% FINER
10 mm	503.1	521.5	18.4	1.84	1.84	98.16
4.75 mm	418.6	494.5	75.9	7.59	9.43	90.57
2 mm	402.7	486.1	83.4	8.34	17.77	82.23
1 mm	374.8	504.2	129.4	12.94	30.71	69.29
0.6 mm	362.4	455.8	93.4	9.34	40.05	59.95
0.425 mm	349.9	431.8	81.9	8.19	48.24	51.76
0.3 mm	354.3	413.8	59.5	5.95	54.19	45.81
0.15 mm	358	551.6	193.6	19.36	73.55	26.45
0.075 mm	328.4	471.1	142.7	14.27	87.82	12.18
pan	255.9	375.8	119.9	11.99	99.81	0.19

- Table 2: Liquid Limit of soil

Sample	No. of blows	wt of empty container (gm)	wt of cont + wet soil (gm)	wt of container + dry soil (gm)	water content(%)
1	55	27.85	95.15	84.37	19.07
2	45	28.2	70.2	63.05	20.52
3	18	29	68.9	60.6	26.27

- Table 3: Plastic Limit of soil

Sample	wt of empty container (gm)	wt of cont + wet soil (gm)	wt of container + dry soil (gm)	water content(%)
1	29	34	33.1	21.95

- Table 4: Specific Gravity of soil

Sample	1	2	3
Wt of bottle(gm)	35.5	29.9	33.2
Wt of bottle + soil(gm)	52.2	50.1	51.5
Wt of bottle + soil + water(gm)	95.9	90.6	98.1
wt of bottle + water(gm)	86.2	79.3	88
sp gravity	2.386	2.27	2.232

- Table 5: Light Compaction of soil

Determination	1	2	3
wt of mould(gm)	5550	5550	5550
wt of mould+ soil(gm)	7630	7690	7563
vol of mould(cm^3)	1000	1000	1000
wt of container(gm)	28.8	28.1	26.9
wt of container+ wet soil(gm)	44.5	55.08	49
wt of container+ dry soil(gm)	42.9	52	46
w%	11.35	12.89	15.71
bulk density(gm/cm3)	2.08	2.14	2.013
dry density(gm/cm3)	1.87	1.9	1.74

- Table 6: Unconfined Compressive Strength of soil

LOAD		ΔL(mm)	∑= ΔL/L	$A_f = A_o /1-\sum$ (cm^2)	$\sigma = P_f/A_f$ (kg/cm^2)
DIV	P(Div * 0.263)				
4	1.052	0.3	0.004	10.79	0.1
6	1.578	0.6	0.008	10.84	0.15
9	2.367	0.9	0.012	10.88	0.22
11	2.893	1.2	0.016	10.92	0.26
17	4.471	1.5	0.019	10.96	0.41
22	5.786	1.8	0.023	11	0.53
28	7.364	2.1	0.027	11.05	0.67
33	8.679	2.4	0.031	11.09	0.78
38	9.994	2.7	0.035	11.14	0.9
43	11.309	3	0.039	11.19	1.01
46	12.098	3.3	0.043	11.23	1.08
49	12.887	3.6	0.047	11.28	1.14
53	13.939	3.9	0.051	11.33	1.23
57	14.991	4.2	0.055	11.38	1.32
57	14.991	4.5	0.058	11.41	1.31
57	14.991	4.8	0.062	11.46	1.31
56	14.728	5.1	0.066	11.51	1.28
49	12.887	5.4	0.07	11.56	1.11

- Table 7: Direct shear test of soil

Normal Stress (kg/cm^2)	Shear Stress (kg/cm^2)
0.35	0.053
0.55	0.08
0.95	0.123

- Table 8: Shrinkage Limit

Determination	1	2
mass of empty dish (gm)	24.5	36.2
mass of dish +wet soil(gm)	68.3	75.2
mass of dish +dry soil(gm)	60.1	67.6
w%	39.3	37.84
mass of weighing dish empty(gm)	25.3	25.3
mass of weighing dish +mercury (gm)	606.4	606.4
mass of mercury(gm)	581.1	581.1
vol wet soil pat	42.73	42.73
mass of weighing dish + displaced mercury(gm)	397.1	425.3
mass of mercury displaced(gm)	371.8	400
vol dry soil pat	27.34	29.41

- Table 9: Specific gravity of stone dust

Sample	1	2	3
Wt of bottle(gm)	35.5	29.9	33.2
Wt of bottle + soil(gm)	59.3	57.2	58.6
Wt of bottle + soil + water(gm)	101.1	95.8	105
wt of bottle + water(gm)	86	79.1	89.2
sp gravity	2.736	2.575	2.646

- Table 10: Grain Size analysis of stone dust

Sample weight = 880gm

SIEVE NO	WT OF SIEVE (gm)	WT OF SIEVE + SOIL (gm)	SOIL RETAINED (gm)	%AGE OF SOIL RETAINED	CUMULATIVE %AGE	% FINER
4.75 mm	419.1	420.7	1.6	0.18	0.18	99.82
2mm	402.5	403	0.5	0.06	0.24	99.76
0.45mm	349.8	350.2	0.4	0.05	0.29	99.71
0.3mm	355	355.3	0.3	0.03	0.32	99.68
0.15mm	354.3	770	415.7	47.24	47.56	52.44
0.075 mm	326.6	703.4	376.8	42.82	90.38	9.62
Pan	256.1	335.1	79	8.98	99.36	0.64

- Table 11: Light compaction test of soil with 20% stone dust

Determination	1	2	3
wt of mould(gm)	5550	5550	5550
wt of mould+ soil(gm)	7640	7720	7650
vol of mould(cm^3)	1000	1000	1000
wt of container(gm)	27	26.8	28.3
wt of container+ wet soil(gm)	46.4	61.2	57.8
wt of container+ dry soil(gm)	44.5	57.4	53.4
w%	10.86	12.42	17.53
bulk density(gm/cm3)	2.09	2.17	2.1
dry density(gm/cm3)	1.89	1.93	1.79

- Table 12: Light compaction test of soil with 25% stone dust

Determination	1	2	3
wt of mould(gm)	5550	5550	5550
wt of mould+ soil(gm)	7570	7720	7730
vol of mould(cm^3)	1000	1000	1000
wt of container(gm)	26.5	27	28.3
wt of container+ wet soil(gm)	44.4	51.1	55.3
wt of container+ dry soil(gm)	43	48.6	51.9
w%	8.48	11.57	14.41
bulk density(gm/cm3)	2.02	2.17	2.18
dry density(gm/cm3)	1.86	1.94	1.91

- Table 13: Light compaction test of soil with 30% stone dust

Determination	1	2	3	4
wt of mould(gm)	5560	5560	5560	5560
wt of mould+ soil(gm)	7520	7600	7700	7700
vol of mould(cm^3)	1000	1000	1000	1000
wt of container(gm)	28.8	28	28.6	28
wt of container+ wet soil(gm)	52.5	43.4	52.7	52.9
wt of container+ dry soil(gm)	50.5	42	50.1	50.1
w%	9.22	10	12.09	12.67
bulk density(gm/cm3)	1.96	2.04	2.14	2.14
dry density(gm/cm3)	1.79	1.85	1.91	1.9

- Table 14: Light compaction test of soil with 35% stone dust

Determination	1	2	3	4	5
wt of mould(gm)	5560	5560	5560	5560	5560
wt of mould+ soil(gm)	7390	7540	7650	7700	7700
vol of mould(cm^3)	1000	1000	1000	1000	1000
wt of container(gm)	26.8	26.5	28.5	27.2	27.2
wt of container+ wet soil(gm)	54.5	54.2	58.6	56.3	56.3
wt of container+ dry soil(gm)	52.3	51.7	55.4	52.9	52.9
w%	8.63	9.92	11.9	13.23	14
bulk density(gm/cm3)	1.83	1.98	2.09	2.14	2.13
dry density(gm/cm3)	1.68	1.8	1.87	1.89	1.88

- Table 15: Unconfined compressive strength of soil with 20% stone dust

LOAD		ΔL(mm)	$\sum = \Delta L/L$	$A_f = A_o / 1-\sum$ (cm^2)	$\sigma = P_f/A_f$ (kg/cm^2)
DIV	P(Div * 0.263)				
5	1.315	0.3	0.004	10.79	0.12
10	2.63	0.6	0.008	10.84	0.24
12	3.156	0.9	0.012	10.88	0.29
16	4.208	1.2	0.016	10.92	0.39
20	5.26	1.5	0.019	10.96	0.48
25	6.575	1.8	0.023	11	0.6
29	7.627	2.1	0.027	11.05	0.69
34	8.942	2.4	0.031	11.09	0.81
38	9.994	2.7	0.035	11.14	0.9
43	11.309	3	0.039	11.19	1.01
50	13.15	3.3	0.043	11.23	1.17
55	14.465	3.6	0.047	11.28	1.28
58	15.254	4.2	0.055	11.38	1.34
60	15.78	4.5	0.058	11.41	1.38
61	16.043	4.8	0.062	11.46	1.4
60	15.78	5.1	0.066	11.51	1.37
56	14.728	5.4	0.07	11.56	1.27

- Table 16: Unconfined compressive strength of soil with 25% stone dust

LOAD		ΔL(mm)	∑= ΔL/L	$A_f = A_o /1-\Sigma$ (cm^2)	σ =P_f/A_f (kg/cm^2)
DIV	P(Div * 0.263)				
2	0.526	0.3	0.004	10.79	0.05
6	1.578	0.6	0.008	10.84	0.15
12	3.156	0.9	0.012	10.88	0.29
18	4.734	1.2	0.016	10.92	0.43
28	7.364	1.5	0.019	10.96	0.67
35	9.205	1.8	0.023	11	0.84
40	10.52	2.1	0.027	11.05	0.95
42	11.046	2.4	0.031	11.09	1
44	11.572	2.7	0.035	11.14	1.04
39	10.257	3	0.039	11.19	0.92
35	9.205	3.3	0.043	11.23	0.82

- Table 17: Unconfined compressive strength of soil with 30% stone dust

LOAD		ΔL(mm)	∑= ΔL/L	$A_f = A_o /1-\Sigma$ (cm^2)	σ =P_f/A_f (kg/cm^2)
DIV	P(Div * 0.263)				
10	2.63	0.3	0.004	10.79	0.24
16	4.208	0.6	0.008	10.84	0.39
25	6.575	0.9	0.012	10.88	0.6
32	8.416	1.2	0.016	10.92	0.77
36	9.468	1.5	0.019	10.96	0.86
40	10.52	1.8	0.023	11	0.96
39	10.257	2.1	0.027	11.05	0.93

- Table 18: Direct Shear Test of soil with 20% stone dust

Normal Stress (kg/cm^2)	Shear Stress (kg/cm^2)
0.55	0.105
0.75	0.115
0.95	0.125

- Table 19: Direct Shear Test of soil with 25% stone dust

Normal Stress (kg/cm^2)	Shear Stress (kg/cm^2)
0.55	0.063
0.75	0.067
0.95	0.071

- Table 20: Liquid Limit of soil with 20% stone dust

Sample	No. of blows	wt of empty container (gm)	wt of cont + wet soil (gm)	wt of container + dry soil (gm)	water content(%)
1	41	29.8	44	41.6	20.34
2	19	28	41.9	39.1	25.23
3	15	28	40	37.5	26.32

- Table 21: Liquid Limit of soil with 25% stone dust

Sample	No. of blows	wt of empty container (gm)	wt of cont + wet soil (gm)	wt of container + dry soil (gm)	water content(%)
1	61	27	39.6	37.3	22.33
2	34	27.4	46.8	43.2	22.78
3	23	26.8	44.2	40.9	23.4

- Table 22: Liquid Limit of soil with 30% stone dust

Sample	No. of blows	wt of empty container (gm)	wt of cont + wet soil (gm)	wt of container + dry soil (gm)	water content(%)
1	7	26.8	44.9	41.4	23.97
2	16	29.9	55	50.3	23.04
3	31	26.5	42	39.1	23.02

- Table 23: Liquid Limit of soil with 35% stone dust

Sample	No. of blows	wt of empty container (gm)	wt of cont + wet soil (gm)	wt of container + dry soil (gm)	water content(%)
1	41	27.6	50.4	46.5	20.63
2	17	27.3	43.7	40.6	23.31
3	10	27.5	42.1	39.2	24.79

- Table 24: Plastic Limit of soil with 5% stone dust

Sample	wt of empty container (gm)	wt of cont + wet soil (gm)	wt of container + dry soil (gm)	water content(%)
1	29	34.1	33.3	18.6

- Table 25: Plastic Limit of soil with 10% stone dust

Sample	wt of empty container (gm)	wt of cont + wet soil (gm)	wt of container + dry soil (gm)	water content(%)
1	27.5	33.5	32.7	15.38

- Table 26: Plastic Limit of soil with 20% stone dust

Sample	wt of empty container (gm)	wt of cont + wet soil (gm)	wt of container + dry soil (gm)	water content(%)
1	28.9	37.3	36.6	9.09

- Table 27: Plastic Limit of soil with 25% stone dust

Sample	wt of empty container (gm)	wt of cont + wet soil (gm)	wt of container + dry soil (gm)	water content(%)
1	28	42.5	41.7	5.84

APPENDIX B

EQUIPMENTS AND SAMPLES

- LIGHT COMPACTION TEST

- UNCONFINED COMPRESSIVE STRENGTH TEST

- DIRECT SHEAR TEST

- LIQUID LIMIT TEST

Before Giving the Blows

After Giving the Blows

- PLASTIC LIMIT TEST

Rolling of soil into threads of 3mm diameter

Thread at diameter of 3mm just starts crumbling

- SIEVE ANALYSIS