SOIL STABILIZATION TO IMPROVE STRENGTH AND MITIGATE COLLAPSE SUSCEPIBILITY THROUGH WASTE MARBLE DUST

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Research and Development work titled

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The completion of this project was indeed a determined task which demanded dedicated efforts from DEAN CE wing, HOD geotechnical department, our supervisor and all geotechnical and transportation laboratory staff whom we owe the timely completion of this assignment. We worked whole heartedly as a team with keen interest and dedication. Asst prof Dr Abdul Waheed (our syndicate supervisor), was the main motivator behind this study. He contributed valuable ideas and accepted our views/ suggestions in an extremely encouraging manner. Through his excellent directives and initiatives; we accomplished the objectives of this research. It has been a real honor to have worked and learn under his able guidance indeed.

ABSTRACT

The soils that can rapidly settle or collapse the ground is known as collapsible soils. They have caused major structural damages all over the World. These soils show excellent strength and stiffness properties in dry conditions but undergo a sudden reduction in volume when exposed to water. Most of the buildings in Risalpur region show severe signs of distresses in the form of extensive cracking and differential settlements. The present study focused on mitigation of collapse susceptibility using chemical means by varying percentages (5%, 10% and 15%) of waste marble dust. The target soil layer for improvement was at 4 ft which relates to the depth of shallow and deep foundations. The detailed program of investigations included laboratory tests; including basic tests to estimate index properties and classification of soil, moisture density relationship, Unconfined Compression Test and California bearing ratio soaked as well as unsoaked under different loading conditions. To evaluate the effectiveness of marble dust as a soil stabilizer number of Laboratory tests were done. The research described that geotechnical parameters of collapsible soil of Risalpur is improved substantially by increasing the quantity of waste marble dust but up to a particular level of 10%. Significant Plasticity index reductions occurred with Marble dust treatment. Results showed that plasticity was reduced by 15 to 30% and strength increased by 25 to 50 %. The highest strength were achieved at 10 % waste marble dust after 7 days curing. Also we found that with addition of waste marble dust the swell index of the soil was reduced. Concurrently the moisture acceptance from the surrounding was greatly reduced by the soil when compacted at 65 blows with addition of waste marble dust. However the soil properties to be used as subgrade or sub base material are also analyzed which shows that with addition of waste marble dust the California bearing ratio value is also improved.

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LIST OF ABBREVIATIONS

AASHTO	American Association of State Highway and Transportation Officials
ASTM	American Society for Testing and Materials
CBR	California bearing Ratio
CP	Collapse potential
Fig	Figures
MCE	Military College of engineering
MD	Marble dust
MDD	Maximum dry density
WMD	Waste Marble dust
MWP	Marble waste powder
OMC	Optimum moisture content
UCS/UCC	Unconfined compression strength
TDAP	Trade development authority of Pakistan

CHAPTER 1

INTRODUCTION

1.1 General

Ground settlement can harm man-made structures, like, foundation, asphalt, concrete, services and plumbing works. Structures built on whether collapsible or expansive soils are vulnerable to destruction and failure. Collapsible soils are delicate soils that show huge decrease in volume after wetting. These soils are discovered everywhere throughout the world in any case, parched to semiarid weather conditions favor their development. (Al-Rawas 2000) Risalpur, which is a small military cantonment in district Nowshehra generally lies in the collapsible strata of soil causing auxiliary harm and destruction to structures. By successful completion of this study the soil might be stabilized by utilizing least expensive and locally accessible materials WMD with the objective that we can limit the settlement of foundation as well as structural impairments.

1.2 Problem Statement

Stabilization of soil offers in fact practical and monetarily worthwhile solution for some designing/engineering issues particularly collapse susceptibility of silty clayey soils. Rice husk, cement, coir fibre sand and lime are usually used for treatment of collapsible soils. Most of the answers in geotechnical engineering are precisely for that location, and solution advisable for a specific area can never be applied on other area. Collapsible soils basically have a metastable structure which shows high strength and stiffness at normal water content conditions. On the other hand upon wetting it suffers a sudden plastic deformation, i.e. collapse, which could be severe in some case. This leads to serious engineering problems if not taken into consideration during the design phase. This study is therefore aimed at planning out an everlasting and monetarily durable choice to the problem of collapse susceptibility of this CL-ML soil of Risalpur by improving its capacity to required level. The marble industry in vicinity which is producing tons of waste in the process of wash cuttings/grinding forming sludge each day which causes health hazards and environmental issues. This WMD could be used properly to improve soil properties. Therefore waste marble dust which is locally available in abundance is used as stabilizer for this project. This study specifically assesses the stabilizing impacts of waste marble dust on Risalpur soil which we can grade as a typical collapsible soil.

1.3 Scope

The Scope of this research mainly includes Risalpur soil characterization, waste marble dust characterization, drying of WMD, ascertaining the strength properties of unstabilized soil by performing moisture density relationship, UCS and CBR tests, mixing the WMD in soil with variation of 5%, 10% and 15%, ascertaining the strength properties of stabilized soil by performing moisture density relationship, UCS and CBR tests and comparing the outcomes and deducing conclusions.

1.4 Research Objectives

The principle target and sole objective of this Research is the portrayal and stabilization of Risalpur soil. The investigation will be explicitly engaged at:-

- Soil Characterization including classification and strength parameters.
- Waste Marble dust Characterization
- Ascertaining the possibility of soil stabilization by adding waste marble dust.

1.5 Methodology of Research Work

Characterization of soil was typically done by evaluating its consistency limits, gradation, and chemical composition. Mainly, the effect of moisture on the subgrade foundation soil has been studied by comparing the California bearing ratio (CBR) and unconfined compressive strength (UCS) values of treated and untreated soil. Briefly the methodology is bulleted below however it is explained in detail in chapter 3.

1.5.1 Soil Characterization

- Atterberg limits
- Grain size distribution
- Specific gravity of soil

1.5.2 Waste marble dust characterization.

- Atterberg limits
- Grain size distribution
- Finness modulus of waste marble dust

1.5.3 Determination of optimum moisture content and maximum dry density.

- Moisture-density relationship for virgin soil
- Moisture-density relationship for 5 % Mixture of Marble Dust

- Moisture-density relationship for 10 % Mixture of Marble Dust
- Moisture-density relationship for 15 % Mixture of Marble Dust

1.5.4 Fabrication and testing of samples at room temperature

- Three different trials of Unconfined compression test on soil, 5 % mix, 10% mix and 15 % mix
- CBR unsoaked test on soil, 5 % mix, 10% mix and 15 % mix with 0, 3 and 7 days curing.
- CBR Soaked test on soil, 5 % mix, 10% mix and 15 % mix with 96 hrs soaking.

The Lab test Matrix is given in Table 1.1

Table 1.1 Lab testing program

<table>
<tr><th rowspan="2">Ser</th><th rowspan="2">Test Name</th><th colspan="12">No of tests</th></tr>
<tr><th colspan="3">0%MWP + soil</th><th colspan="3">5%MWP + soil</th><th colspan="3">10%MWP + soil</th><th colspan="3">15%MWP + soil</th></tr>
<tr><td>1</td><td>Atterberg limits for soil and Waste marble dust</td><td colspan="12">1</td></tr>
<tr><td>2</td><td>Gradation of Soil and Waste marble dust</td><td colspan="12">1</td></tr>
<tr><td>3</td><td>Fineness modulus of Waste Marble dust</td><td colspan="12">1</td></tr>
<tr><td>4</td><td>OMC-MDD</td><td colspan="3">1</td><td colspan="3">1</td><td colspan="3">1</td><td colspan="3">1</td></tr>
<tr><td>5</td><td>UCS</td><td colspan="3">3</td><td colspan="3">3</td><td colspan="3">3</td><td colspan="3">3</td></tr>
<tr><td>6</td><td>CBR soaked</td><td colspan="3">1</td><td colspan="3">1</td><td colspan="3">1</td><td colspan="3">1</td></tr>
<tr><td rowspan="3">7</td><td rowspan="3">CBR unsoaked</td><td colspan="12">Curing Period (days)</td></tr>
<tr><td>0</td><td>3</td><td>7</td><td>0</td><td>3</td><td>7</td><td>0</td><td>3</td><td>7</td><td>0</td><td>3</td><td>7</td></tr>
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1.6 Literature Review

The studies conducted on the subject were thoroughly evaluated. The previous efforts are elucidated in chapter 2.

1.7 Research testing program

The methods, procedures adapted in soil characterization, material selection, soil stabilization and lab test results are discussed in chapter 3.

1.8 Result analysis

The results inferred from lab tests are discussed in chapter 4.

1.9 Conclusions and recommendations

The deduced efforts after analysis of soil stabilization are pen down in chapter 5.

CHAPTER 2

LITERATURE REVIEW

2.1 General

The stability of a particular structure depends upon the strength of its foundation, thus foundation soil has a direct influence on the success of any construction project. Loss of soil support; causing settlement of structure may result in cracking, leading to both structural and foundation failure. Thus the underlying soil should be durable enough to take the load of the structure for the anticipated service life. When the foundation soils do not possess the required strength, some corrective measures in the form of the soil treatment are imminent.

For over 70 years collapsible soils are being studied which resulted in an enormous and vast literature. As their name demonstrates, these soils can show huge volume change when exposed to moisture or water content, with or without additional loading, in this manner presenting huge difficulties to the geotechnical engineering projects. (Rogers 1995) provided a compilation of the major characteristics of collapsible soils.

2.2 Classification of Collapsible Soils

Number of soils can be included in collapsible soils category including those which are compacted, for example colluvial deposits, Aeolian deposits, Loess, volcanic tuff, residual deposits, and alluvial deposits. A notable Aeolian deposits, known to frequently show collapse susceptibility, is loess a yellow to reddish brown silt size soil, which is portrayed by moderately low density and consistency, yet considerable quality and solidness in the dry state. Aeolian deposits with a particular tendency to collapse are regularly found in dry regions where the water table is deep. Aeolian deposits with critical inclination to crumple or collapse are regularly found in dry areas where the water table is low. Crumbling/ collapsing behavior has additionally been accounted for some alluvial deposits, explicitly where loose sediments are deposited through water. Alluvial-type collapsible soils are predominantly shaped by flash flood or mudflows (flotsam and jetsam streams) which originate from huge precipitation in unpredictable intervals. Under these conditions, free and metastable structures are actuated because of particles which are kept abruptly and locally. Also, alluvial deposits are ineffectively evaluated and may contain clay in a considerable amount, which assumes a significant job in restricting particles in the dry state. High void proportion, precarious structures can be additionally produced in colluvial stores, for example depositions which are formed and then afterward transported by gravity. Collapsible colluvial and alluvial soil deposits are normally found where breakdown settlements of 2' to 3' are normal, and settlements up to 15' have been reported. In residual soils, which can contain molecule size fractions ranging from clay and silt to huge sections of rock, a shaky and high void ratio structure can on the other hand be shaped by filtering of the solvent and fine material which is between large particles and gives cementation. Soils which are derived from gypsum, sodium-rich montmorillonite, volcanic tuff, dispersive clays and non-cohesive sands which are cemented by soluble salts can be classified as other types of soil which show collapsible behavior upon application of water content. The collapse susceptibility potential is calculated by the change in depth after the application of moisture content and load. (Jennings and Knight 1975) has deduced some collapse potential values through his research which are displayed in table 2.1. Collapsible soil structures are highlighted in figure 2.1.

Table 2.1 Values of Collapse potential

Value of Collapse Potential	
Volume change in percentage	Seriousness of the problem
0 - 1	Without problem
1 -5	Moderate trouble
5 - 10	Trouble
10 -20	Severe trouble
> 20	Very severe trouble

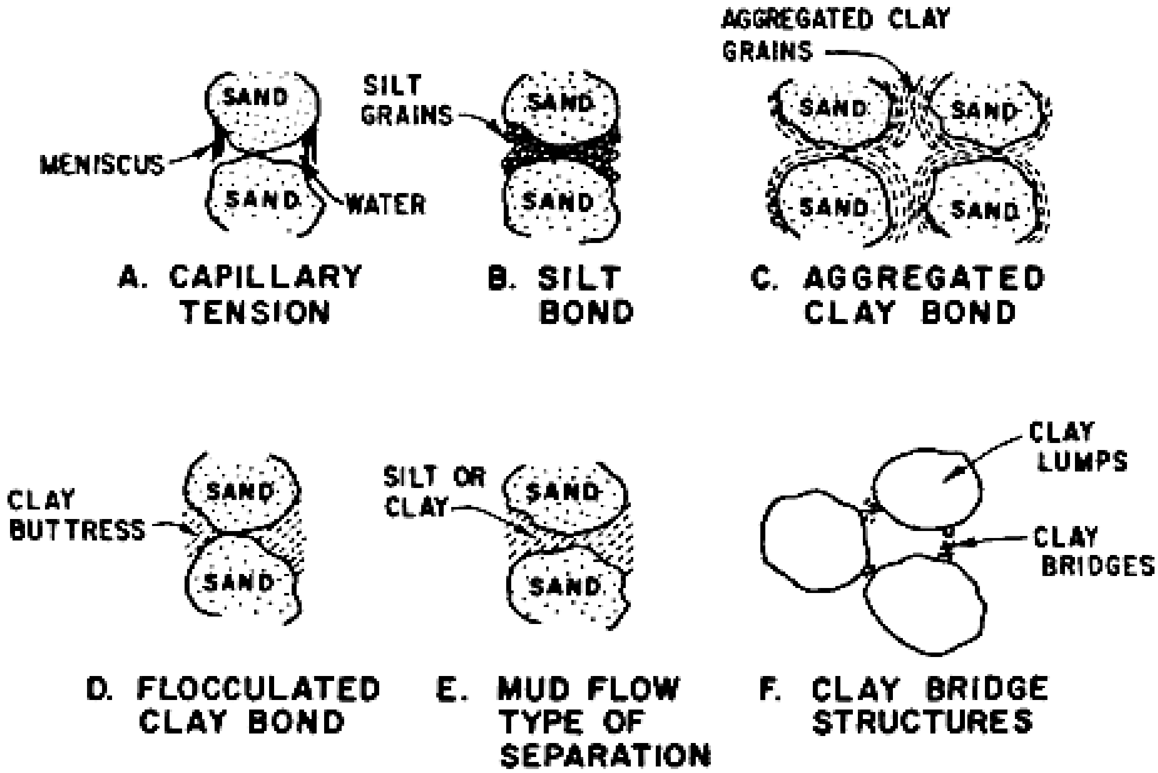


Figure 2.1 Typical collapsible soil structures

2.3 Types of Collapsible Soils

Collapsible soils are soils which have the tendency to undergo large volumetric strains when saturated. Loess is that type of soil which is characterized by comparatively lesser denseness and cohesive properties, hardness and significant strength in the dry state, however is vulnerable to notable abnormalities because of wetting. These are unsaturated soils which have a tendency to deform and completely change the particle structure while coming in contact with water, with or without loading. These soils normally consist of silts and fine sand size particles. Collapsible soils are mainly found in dry to semidry regions (Al-Rawas 2000). The abundantly found and mostly known types of collapsible soil are:

2.3.1 Loess soils

Geologically loess is a silty soil which is recently deposited and is normally brown or yellowish colored in shading and comprising of small mineral particles transpoted by wind to the spots where they currently lie. It is a result of past cold climatic scenarios in that region. These are sedimentary deposited mineral particles brought by wind which in comparison with sand are finer yet they are coarser than clay or silt. In some parts of the world loess generally offers a very fertile top layer of the soil. These deposits are generally few meters thick. “Cat Steps” is one of the key attributes of these deposits. The soil is very scarce in clay particles to hold it together. The primary source of this soil is quartz crystals which slide effectively against one another, and is hence extremely dependent upon disintegration.(El Howayek et al. 2011)

2.3.2 (Wind eroded) Aeolian deposits

These soils have a free open, meta-structure bonded by solidifying agents which after wetting, become powerless and may break down causing breakdown. These soils are made fundamentally out of quartz alongside feldspar and clay minerals.(El Howayek et al. 2011) (Bell and Bruyn 1997) deliberately highlighted that by increasing the clay particles in a soil sample it would decrease its collapse potential

2.3.3 Water (Alluvial) deposits

Alluvial fans, flash floods and mud slip are present in water deposits. The structure is generally open and permeable. During deposition the soil particles are cemented together by the cementitious agents. These deposits are often found in a saturated state at water beds. After drying, they become hard and less compressible achieving moderately less density. If these depositions are by chance exposed to water in any case i-e loaded or unloaded they would undergo settlement. (El Howayek et al. 2011)

2.3.4 Residual soils

These soils are found in variety of molecular sizes i-e clay to pebbles. The breakdown structure is created because of the washing off of the solvent and colloidal (suspension matter some place b/w size of a particle and a grain of sand) matter from the remaining soil. This draining impact of the solvent and fine materials brings about permeable and insecure structure. (El Howayek et al. 2011)

2.3.5 Colluvial deposits

These are free groups of silt that have been or developed at base of a poor quality slope or against a hindrance on that slope, shipped by gravity. These soils are saved with the passage of time essentially through the activity of gravitational power as in avalanches. (El Howayek et al. 2011)

2.3.6 Volcanic tuff

When volcanoes burst out, melted rocks in the form of magma/lava erupts out of it, hot gasses are spread into air and the clouds of ashes are seen everywhere. These clouds can travel several kilometers. These ashes and debris pours down along the walls of the volcanoes and assembles in incredible pyroclastic streams. When this ash with the passage of time cools, solidifies and forms rocks, this material is called volcanic tuff. Geologists named the material which ejects out of volcano as tephra. That can incorporate little debris particles or huge rocks. The particles which are smaller than 2 mm in breadth are termed as Ash. Furthermore, when this debris is compacted down into rock, at that point you get volcanic tuff. Tuff can vary in its chemistry, texture and mineral properties. Some tuff is extremely delicate and can be handily burrowed with hand instruments. Other tuff has been held under constant pressure and established together to the point that it's as hard as obsidian. Volcanic tuff would always be found on earth till the time volcanism would occur on the surface of earth. (El Howayek et al. 2011)

2.4 The Collapse Mechanism

When the following points happen collapse would occur:- (Schwartz 1985)

- Soil should be composed of collapsible material.
- Partial or complete saturation must take place.
- There will be an increase in the water content which will trigger the collapse.
- An increase in overburden pressure must take place.

When the above conditions are met the collapse mechanism can be divided into further 3 phases

2.4.1 PHASE – 1

In this particular phase the original microstructure of the soil is destroyed due to increase in either moisture content or applied load. The aggregates and micro aggregates starts disintegrating, clay films, bridges and buttresses starts breaking and the intensity of the disintegration of carbonates and their relocation in soil increases. This is the point when minor changes tend to take place internally and cannot be significantly noted.

2.4.2 PHASE – 2

Deterioration of the microstructure proceeds, while the amount of carbonates start decreasing, other elements of the soil compresses and the complete volume of soil diminishes.

2.4.3 PHASE – 3

After the destruction of the basic structural design a anew microstructure is formed, The coating if clay particles is completely destroyed and removed.

2.5 Geological Conditions of the Site

Risalpur lies in a hot semiarid region of Pakistan with a soil being loamy and clayey, non-calcareous soil of alluvial or loess plain deposits. (Wikipedia) It also has some unconsolidated surficial deposits of silt, sand and gravel. The southern part of Risalpur comprises of Cambrian rocks that are foliated clay, slate and limestone. The highest temperature ranges between 40-50 C and average annual precipitation is 13.6 inches (345.44 ml). The average rain fall in Risalpur area is less than the potential evaporation (weatherreport.com). The soil composition and environmental conditions favors formation of collapsible soil deposits. The generalized soil map of Pakistan is given in fig 2.2 which can be checked on (Pakistan 1993)

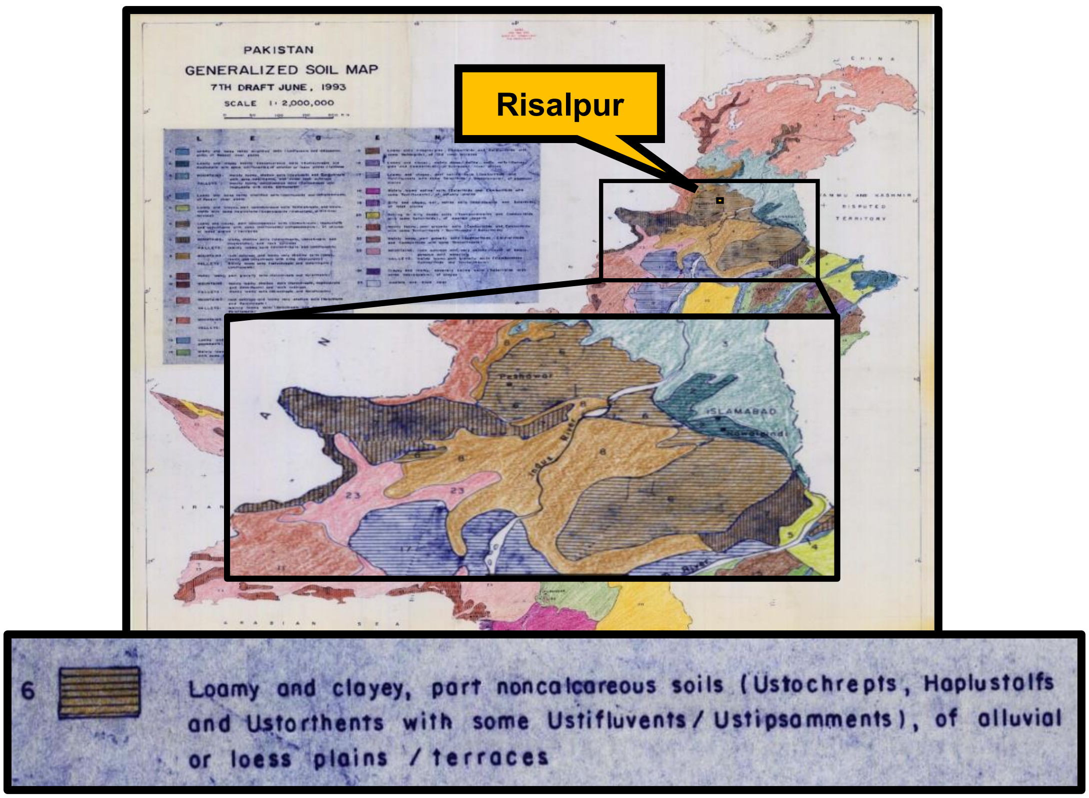


Figure 2.2 Soil types of KPK Pakistan

2.6 Findings of the Previous Research

Soil characterization and evaluation of collapse potential of Risalpur soil was carried out by Engr Tariq , Engr Mir Alam Din and their teams in 2012 and 2014 respectively. This research lays its foundation on the findings and recommendations of previous research, therefore major findings of both of them are listed below:-

- The Risalpur soil up to 20 feet (the depth of investigation) is collapsible, however the magnitude of collapse generally decreases with depth.
- The collapse at the depth of 4 feet is severe; this is the definite depth of shallow foundations of that particular area.
- The collapse of unconfined compression test (UCC) specimens under soaked conditions indicate the severe collapse potential of soil at the depth of investigation (4 feet). That is why probability of structural damages due to differential settlements occurs if foundation gets inundated either in part or as a whole.
- Excessive deformations of UCC specimen due to soaking indicates that foundation can fail quickly when exposed to water, therefore major structural damages are expected if foundation gets inundated.
- The soil regains its strength when it gets dried after flooding. This indicates presence of cementing material which re-precipitates at particle contact on drying.
- Cement and lime are generally the most alluring stabilizers of soil yet cement's use as a stabilizer is not that ideal due to the expanding cost and ecological concerns like the CO2 discharge. The emission of CO2 can also be related to Lime production. Due to the presence of sulfate the swelling may increase due to the production of swelling minerals, for example, ettringite and thaumasite. Over the past years, the industrial waste materials like baggasee ash, ceramic dust, fly ash, blast furnace slag and rice husk are used as stabilizers for clayey or silty soils. These waste items represent a genuine ecological issue if not discarded appropriately. Their utilization fills two needs; firstly its use as additive construction material and secondly the disposal of waste material.

2.7 Soil Stabilization

Stabilization can increase the strength properties of a soils and/or control the shrink-swell potential, resulting into improved characteristics to support the roads, pavements and foundations. Various methods are there to stabilize soil, However, Soil stabilization through waste marble dust have been discussed in this research.

2.7.1 Marble Sources in Pakistan

> *"From Shahjahan's Taj Mahal in Agra to Aurangzeb's Badshahi Mosque, the subcontinent is laden with monuments that stand in testimony to the magnificence of the material used in their making: marble."* (Hussain 2017)

Marble being a natural stone has astounded individuals with its interesting magnificence and particular characteristics since the unfolding of the world. At the point when cut and cleaned this one of a kind stone can be utilized for an incredible assortment of stuff: mosaics, variety of kinds of tiles, design boards, sills of windows, facing stones, sections, step tracks, as enhancing stone, for indoor and open air furniture, embellishment highlights and some more. Pakistan's marble assets are spread to a great extent across three regions: KP, Baluchistan and Punjab. Some quarries also exist in parts of Sindh and Gilgit-Baltistan. A study issued in 2010 by the Trade Development Authority of Pakistan (TDAP) gauges marble and onyx reserves to be in excess of 300 billion tons while granite reserves are evaluated to be 1,000 billion tons. In comparison, marble reserves in India are assessed to be 1,931 million tons. Marble and onyx reserves are located to a great degree in Mohmand Agency, Wazirstan, Chagai, Khuzdar, Chitral, Parachinar, Azad Kashmir, Buner, Swat, Lasbela, Gilgit, Hunza, Swabi, Bajour and Mardan. (Hussain 2017)

2.7.2 Waste Marble Dust

During the water cutting, grinding or polishing of marble slabs, marble waste powder is obtained. The quick advancement of commercial businesses of marble produces dangerous waste material. It turns into a significant issue to the individuals who are surrounded by it and in addition it goes as a poison in order to impact indigenous ecological habitat of the Earth. It has been seen that marble dust is an effective waste material in soil stabilization methodology which upgrades the compaction characteristics, subgrade qualities, swelling attributes and compressibility attributes. The motivation behind present study is to see the impact of industrial wastes (marble dust), in improving the UC quality of silty or clayey soil. If these characteristics are understood well it would boost the usage of WMD in its utilization as soil stabilizer where it is found in abundance. This study additionally impacts at the usage of this industrial waste in order to save the environment from its repercussions.

2.7.3 Soil Stabilization with Marble Dust

Sabat and Nanda; investigated to improve the strength of an expansive soil with the help of Rick husk-Ash and further added marble dust into it and concluded that the addition of marble dust acts as a catalyst in its stabilization. He narrated that with the addition of marble dust the strength increases while the swelling potential decreases and WMD made the soil and rice husk ash mixture durable. The optimum ratio of its usage which he concluded is as under:- (Sabat and Nanda 2011)

Waste Marble dust: Soil: Rice husk ash :: 20: 70: 10.

Rehman Ali; used bagasse Ash and marble dust for the improvement of expansive soils. Various laboratory tests were conducted on unstabilized and stabilized soils. The results were analyzed and concluded that Marble dust has a significant impact on the characteristics of this soil. (R.ALI 2012)

Bhavser and patel; evaluated swelling characteristics of collapsible and extensive soils in its normal as well as when mixed in different percentages of marble dust (from 30 to 50%). Positive impact was deduced when the effect of marble powder on black cotton soil was measured. It gives optimum improvement in the swelling potential and contraction properties of black cotton soil. (Bhavsar and Patel 2014)

Abdulla and Majeed; investigated the soil of Erbil and Bastora Airport with a CL soil at Erbil Airport and a CH soil at Bastora. Various percentages such as 10%, 20% and 30% of marble waste powder was added by weight to soil. The outcomes exhibit that increasing the percentage of marble dust decreases the liquid limit, plastic limit, plasticity index and swelling potential. (Abdulla and Majeed 2014)

Gupta and Sharma; used waste material e.g. marble dust and fly Ash to evaluate its effect on the sub grade characteristics of dark cotton soil. 200% CBR strength was improved with addition of 15 % addition of waste marble dust (WMD). (Gupta and Sharma 2014)

Singh and yadav; inspected the effect of marble dust in 0% to 40% on record properties of dark cotton soil. The test results showed a tremendous change in consistency limits of the samples having waste marble dust. The decrease from 57.67% to 33.9% as recorded in liquid limrit. With the expansion of marble dust plasticity index came from 28.35% to 16.67% showing reduction and shrinkage limit went from 8.06% to 18.39% showing and increase. Additionally, the swell potential was reduced from 66.6% to 20.0%. (Singh and Yadav 2014)

Altug saygili; investigated the impact of WMD on clayey soils. He added WMD in percentages of 0, 5, 10, 20 and 30 by the total weight of soil. Properties like physical synthetic and mechanical were tested for both soil and WMD. The results outcomes demonstrated that with the addition of WMD to soil, the shear strength was improved whereas the swell potential was greatly reduced. Because of the presence of high calcium WMD has a positive role in stabilizing the soil in the presence of water. Acquired outcomes demonstrated that WMD addition in soil samples will decrease the cost effects of constructing mega projects on those soils which give away problems such as expansion, collapse etc. and finding new zones to utilize WMD which will reduce the ecological contamination/pollution. (Saygili 2015)

V. Keshavan and his team; the clay soil has a destitute supporting capacity and enormous variation in its properties on application of moisture content. Such soils are not at all suitable to construct civil engineering projects over them. Different percentages such as 0%, 25%, 50%, and 75% of marble dust by weight of unstabilized soil was added to the soil and effect was deduced. Shrinkage limit went from 4.366% to 40.88% showing 800% increase. The liquid limit came from 38.6% to 17.33% showing 122% decrease. 333% decrease in Plasticity index was noted when it came from 13.6% to 3.13%. (V.Keshavan et al, 2017)

Bansal and Sidhu; aesthetically added the waste marble dust in soil varying it by 10% from 0 to 30%. The Liquid limit showed reduction from 31.70% to 25% while the plastic charge went on an increase from 17.69% to 19.26%. It was further noted that optimum moisture content of the soil decreased from 18% to 14.10% and the maximum dry density showed an increase from 1.738gm/cc to 1.884gm/cc. Furthermore CBR Value increased by 350 % from 2.46% to 6.07%. (Bansal and Sidhu 2016);

Muthu Kumar and Tamilarsan; made different samples of soil by mixing marble dust in it. He added marble dust in different percentages of 5% to 25% with an interval of 5%. He deduced the results that with increase of marble dust powder in soil, the liquid limit value shows a decrease from 70% to 55% constantly by addition of 5 to 25% of marble powder. The plastic limit value showed a 25 % increase approximately. It was further noticed that the Optimum moisture Content (OMC) of clay showed an increase from 18% to 24% and the maximum dry density (MDD) increases up to 10% addition of WMD and then reduces with further addition of WMD to soil. (Muthu Kumar and Tamilarasan 2015)

Mishra; used quarry dust in percentages of 20, 30 and 40 and mixed it with soil to stabilize by the adhesive and lime. The increase in OMC from 23% to 25.1% was observed while increasing the amount of quarry dust and MDD diminishes from 1.83gm/cc to 1.71gm/cc. UCS increases up to a required 30% with optimum strength value of 19.60 kg/m2. Increase in plastic and liquid limit was also observed but it was not that significant. Swell potential of the soil was decreased from 85% to 45%. (Mishra and Mishra 2015)

Gupta and Sharma; reviewed an already stabilized soil with sand and fly ash by replacing soil with adverse severity of WMD from 0% to 20% which shows that 15% addition of WMD to soil gives the optimum results. The optimum ratio of its usage which he concluded is as under:-

Marble dust: Sand-Fly ash: Soil: as 13.20%: 22.44%: 52.36%:

The increase of 200% was observed in CBR soaked when sand-fly ash was added with the optimum percentage shown above. (Gupta and Sharma 2014)

2.7.4 Marble stabilization mechanism

Marble powder classified as dolomite is a natural agglomerate of calcium magnesium carbonate, white in color has a rock forming material that contains extraordinary affinity for water absorption and dispersion. The general understanding about the response instrument of lime-rewarded soils is that when lime is added to a soil it separates/ dissociates with the presence of moisture content into $Ca2+$ and $OH-$. Following this separation, one of two things occurs, either the overabundance of $Ca2+$ particles replace the cations of different components present at the sites of exchange in soil, or these particles are consumed by the soil if there are other unattached anions on the surfaces of soil particles (aside from $OH-$ particles). Both of these reactions can be classified as cation exchange reaction. It has already been accepted that the marble dust-soil reaction is categorized as cation exchange reaction. This response brings about the flocculation and coagulation of the soil particles with subsequent decrease in the measure of clay size materials and thus the surface area of the soil, which represents the reduction in plastic behavior of soil. Both inside floccules and between the soil particles including the floccules there are voids which are related to the high moisture contents which were recorded during Atterberg limit tests. (Fujii and Murakami 2008)

2.7.5 Water Requirements

Pragmatic confinements on vulnerability of soil to Marble dust stabilization deduced from the water prerequisites during the compaction and solidifying period. The framework must contain enough water for hydration of Marble residue, soil constituents and for the soil workability. Water acts as a lubricant while working with the soil. Distilled water shall be used which would be clean and free from harmful minerals ingredients and salts. Water fit to drink can be categorized as satisfactory. 15 % of MWD is needed by well graded soil for stabiliztion which contains coarse sand, gravel, and fine sand with or without the presence of small amounts of silt or clay. Further it is shown that increase in curing periods shows increase in strength of soil. The best and optimum CBR values are often found at 7 days curing period. (Ueno et al. 2015)

2.7.6 Effects Of Marble Dust on Properties of Stabilized Soil

2.7.6.1 Volume Changes:

It is generally observed that an increase in Marble dust content tends to reduce the shrinkage of clay due to the irregular cohesion and coarser grains of MWP than soil. It is however be understood that in order to cut down this shrinkage potential, an optimum amount of Marble Dust is to be added in the soil. High amount of MWP will increase the characteristics but will decrease the strength after an optimum limit. (Sabat and Nanda 2011)

2.7.6.2 Thermal Expansion

In the tropics where the temperatures are high (like Risalpur), the thermal expansion is an important physical property of soil. Several studies shows that MWP contains calcium carbonate which expands on the application of heat. (Saygili 2015)

2.7.6.3 Collapsible Potential

There is an increase in the optimum moisture content of the soil with an increase in addition of percentage of Marble dust. It thus automatically reduces the collapsible potential of soil and tends to require more water content for collapse to happen.(Saygili 2015)

2.7.6.4 Strength Characteristics

The compressive strength, flexural strength and modulus of elasticity of soil treated with Marble dust increases.(Minhas and Devi 2016)

2.7.7 Laboratory Testing

Basic tests to evaluate the compressive strength and moisture-density relations are followed as given below:-

- Standard Test Method for Unconfined Compressive Strength of Cohesive Soil, ASTM D2166 (ASTM 2003)
- Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort, ASTM (D698 2012)/ AASHTO T99
- Standard Test Method for California Bearing Ratio (CBR) of Laboratory-Compacted Soils, ASTM D1883 (D 2016)

The test specimens prepared in the Laboratory should show, from a more minor perspective, the means and procedures really utilized in development of projects. Crushing grinding and sieving for the homogenization of non-cohesive soils by evacuating the large particles, is the preliminary step in making a specimen which would be tested in the laboratory. Proper addition of marble dust in required percentages to the soil and then its compaction at optimum moisture content and achieving maximum dry density as per the desired levels and then proper curing to prevent the moisture loss in cured samples are the steps followed in samples preparation.

CHAPTER 3
EXPERIMENTAL PROGRAM

3.1 General

The aim of this study was to analyze the possibility of using waste marble dust, obtained by drying the sludge. The experimental program mainly emphasized on three main objectives: the first part is the characterization of Soil sample through different lab tests by checking its consistency limits and gradation. The second part was to analyze the characterization of marble dust which was obtained by drying the marble waste sludge obtained during the crushing, cutting and polishing of Marble blocks. The third part presents a comparison of the effects of the marble dust on soil properties. Various tests were performed such as OMC and MDD, UCS, CBR etc. to find out the engineering properties of Risalpur soil in stabilized and unstabilized condition. Marble dust was added in varying percentages (5, 10, 15%) along with varying curing periods of (0,3,7) days to the soil sample to determine its strength characteristics.

3.2 Materials

3.2.1 Soil

The soil used in the research was collected from general area Risalpur within MCE premises. Details are covered in section 3.3 of this chapter.

3.2.2 Waste Marble Dust

In this study, the waste marble dust (WMD) was obtained from sludge drain of marble factory. Marble sludge, which is a waste material/constituent formed as a byproduct of water jet cutting of marble blocks in marble industry, was taken from native marble cutting plants. Marble is mainly composed of calcium carbonate (typically 88.5%) ad it significantly helps in stabilization of soil.

3.2.2.1 Preparation of Waste Marble Dust (WMD)

Marble sludge was in semisolid form with lumps. It was sundried for 2 days; and further dried at 105°C for 24 hrs in an oven to remove complete moisture. The dried sludge was pulverized and the undesirable particles were removed. Finally, the marble powder was taken by passing the powder through no 10 sieve. Marble dust was then passed by No 10 sieve and the gradation was carried out, Atterberg limits were calculated and the WMD was characterized.

3.2.2.2 Particle Size Analysis

Sieve analysis of the WMD was carried out and plotted on the curve shown in Fig3.1. The particle size distribution curve, presented in Figure 3.1. The uniformity and Curvature coefficients were calculated which are 3.66 and 1.75 respectively. On the basis if these calculation it can be stated that Cu is less than 6 so can be regarded that particles are poorly graded. The Results are shown in Table 3.1.

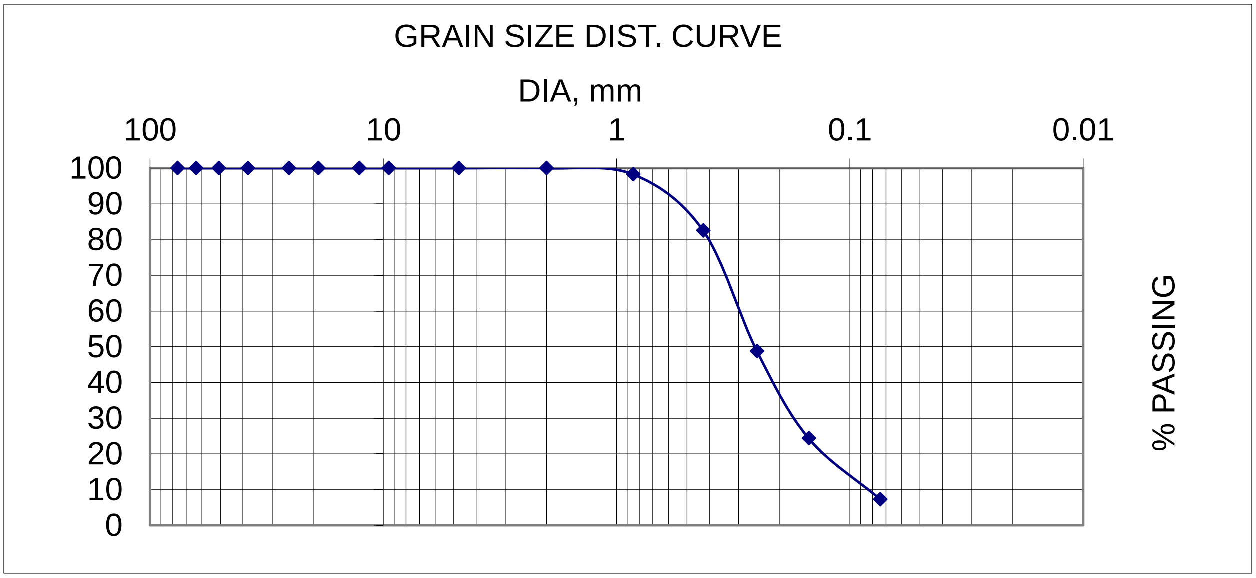


Fig 3.1 Particle size distribution of WMD

Table 3.1 Curvature and uniformity coefficients if WMD

Percentage passing	Dia in mm of sieve	Cu	Cc
D10=	0.082	3.65853659	1.174797
D30=	0.17		
D60=	0.3		

3.2.2.3 Physical Properties

The Bulk density and the absolute density of WMD which was calculated in Laboratory came out to be 610 kg/m3 and 2690 kg/m3 respectively.

3.3 Soil Sample Collection

The soil sample taken for the present study were collected from general area near to the “structures lab” of Military college of engineering, Risalpur at a depth of 4’. The soil sample was taken in a disturbed form. The place is having a latitude 34°02'59.1"N and longitude 71°59'21.4"E. The sample is mainly brownish in appearance.

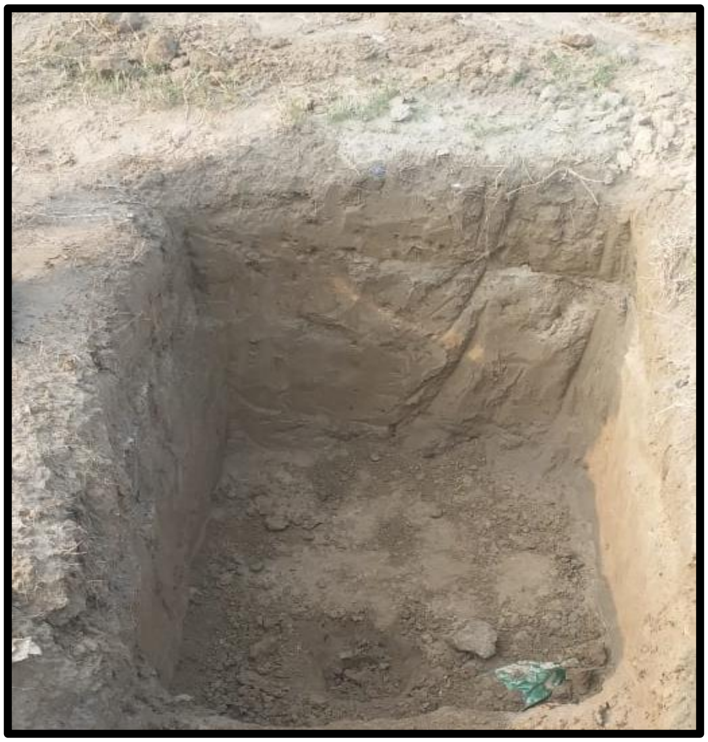


Fig 3.2 Soil sample site view

3.4 Soil Characterization

Soil characterization was carried out to determine the attributes of untreated soil and to create the possibility of soil stabilization using Marble Dust as an Admixture. The process covered following:

3.4.1 Grain Size Distribution

ASTM D 2487-00 was followed for sieve analysis i-e Grain size distribution of soil. 300g soil sample was taken for sieving. The sample was pulverized and passed through number 10 sieve. The percentage of soil passing from a particular sieve was plotted against that sieve. The grain distribution curve is given in Fig 3.3

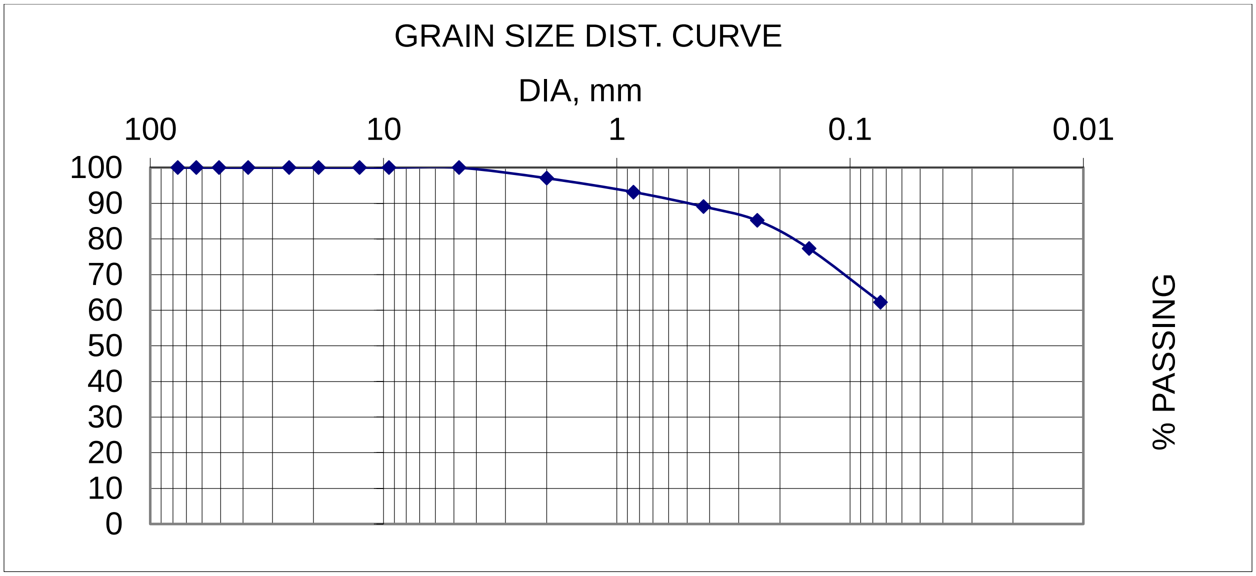


Fig 3.3 Distribution of Grain size curve of Soil

3.4.2 Atterberg's Limits

ASTM D 4318-00 was studied to conduct Atterberg limits test. The sample passing no 40 sieve was taken to carry out liquid limit and plastic limit test. For Classification purpose these tests were needed alongside soil gradation analysis, on behalf of which the soil was classified as CL-ML.

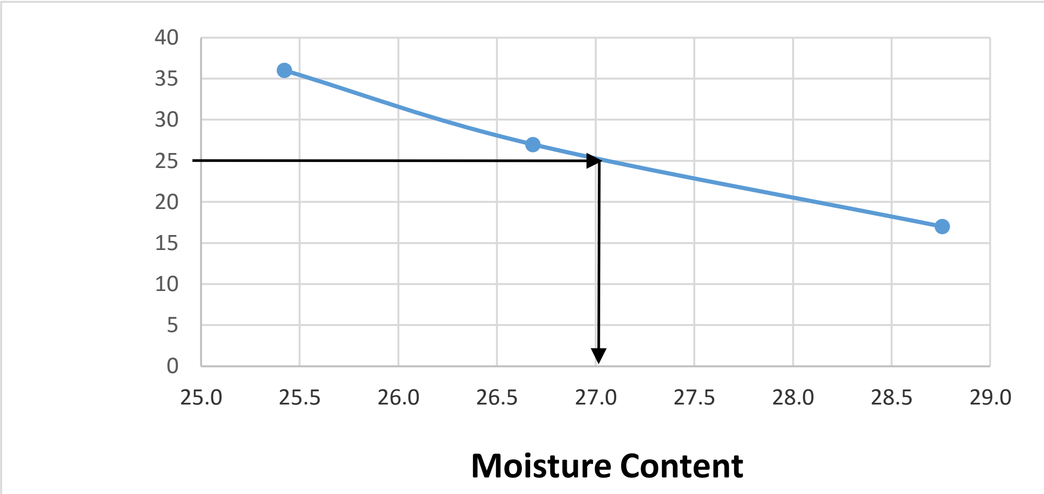


Fig 3.4 LL Chart of Soil

3.4.3 Moisture – Density Relationship of Untreated Soil

ASTM D 1557-02 was used to establish the moisture - density relationship for the soil. Standard compaction effort (5.5 pound hammer and 12 inch fall) and 4 inches diameter mould was used to establish the relation. Compaction of soil was done in three layer with 25 blows of the hammer in each layer. The result is shown in fig 3.4.

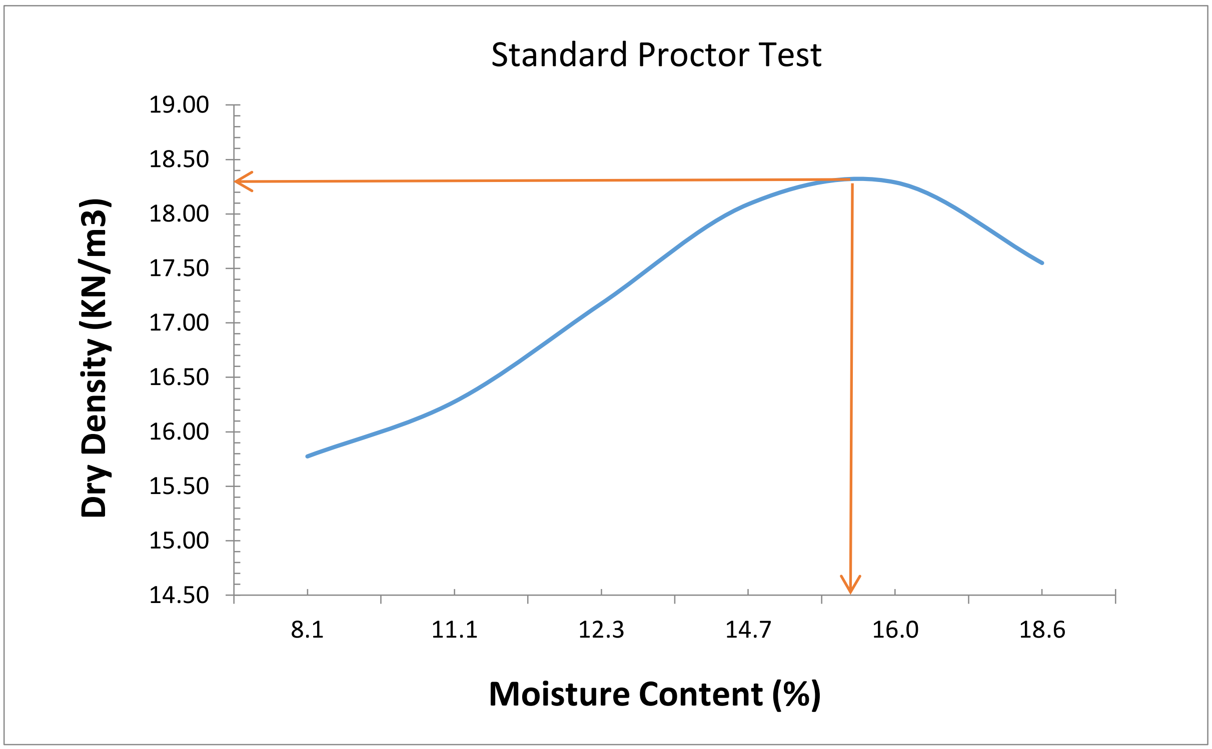


Fig 3.5 OMC-MDD graph of Soil Sample

3.5 Soil Stabilization

Various tests like the relationship of moisture-density, UCS (unconfined compressive strength) and CBR test are performed. The type of soils present in Risalpur are generally weak because of its collapse properties. Thus to increase various properties of such soil there is a need to stabilize it. The stabilizer material used for the study was waste marble dust. Experimental tests such as OMC-MDD, UCS, California bearing ratio (soaked and unsoaked) test were carried out for both natural soil and with the addition of waste marble dust with three different percentages (5%, 10%, and 15%).

3.5.1 Moisture Density Relation

The aim of this test was to find the maximum dry density (MDD) and optimum moisture content (OMC) of natural as well as mix specimen as per ASTM D698 / AASHTO T99. The mix specimen is prepared by different percentages (5%, 10%, and 15%) of waste marble dust in soil. The test results of specimens are shown below in Table 3.1.

Table 3.2 Effect of waste marble dust on OMC / MDD

% of Marble Dust With Natural Collapsible Soil	MDD (KN/m3)	OMC (%)
Natural Soil + 0 % MD (Marble Dust)	18.345	15.70
N.S + 5 % MD (Marble Dust)	18.196	16.4
N.S + 10 % MD (Marble Dust)	18.032	17.27
N.S + 15 % MD (Marble Dust)	17.853	18.226

3.5.2 Unconfined Compressive Strength Test (UCS)

The aim of testing is to investigate the effect of inclusion of waste marble dust in soil. The unconfined compressive strength of collapsible soil by loading axially a cylindrical specimen and the tests are performed directly after collecting the sample in unsoaked condition, however the results and previous investigations show that, the results are enhanced and optimized if samples are cured for 14 days due to continuous hydration. The observation and calculation of UCS test is shown below in table 3.2. Tests were performed on the basis of Standard Test Method for Unconfined Compressive Strength of Cohesive Soil, ASTM D2166. Three samples were made for each combination and the results were obtained on an average. Pictorial view of the tests is shown in fig 3.5. Details of the test are attached as Annex whereas the average value is shown in the table 3.2.

Fig 3.6 UCC test pictorial view

Table 3.3 Effect of marble dust on UCS

% of Marble Dust With Natural Collapsible Soil	Unconfined Compressive Strength, qu (KN/m2)	MC (%)	(%) variation
Natural Soil + 0 % MD (Marble Dust)	101.01	12.32	-

N.S + 5 % MD (Marble Dust)	146.12	16.21	44.55
N.S + 10 % MD (Marble Dust)	202.01	14.01	99.88
N.S + 15 % MD (Marble Dust)	187.31	14.29	85.29

3.5.3 California Bearing Ratio Test (CBR)

The CBR test were conducted on the soil sample with 3 varying percentages of marble dust powder. Waste marble dust was added to soil in percentages of (5%, 10%, 15%) respectively. This test is utilized to assess the potential quality of subgrade, sub base, and base course material, including reused materials for its use in road pavements and landing strips. CBR value observed in this test is the basis of numerous flexible pavements design method. For applications where the impact of water content compaction on CBR is obscure or where it is wanted to represent its impact, CBR value is calculated for a different range of water content, as a rule the range of water content allowed for field compaction by utilizing the organization's specifications of field compaction.

In accordance with standard method of AASHTO Designation: T 193-99 (2003) tests were carried out. For each specimen 3 moulds were prepared with 10, 30, and 65 blows. A total of 48 moulds were prepared for soaked and unsoaked CBR. The test was further done in two parts as below

3.5.3.1 Unsoaked testing

In this test a total of 36 moulds were prepared. 9 each for natural soil, 5 % Mix, 10% Mix, and 15 % Mix. The specimen were tested at 0, 3 and 7 days curing strength. Soil was compacted in a layer in accordance with the OMC – MDD result, i.e. optimum moisture content was taken from the proctor result. The generic formula used for calculating CBR % is (Aashto 1993)

CBR % = (Stress at that point/ Standard stress) * 100

Standard stress at 0.1 inches penetration = 1000 psi

Standard stress at 0.2 inches penetration = 1500 psi

Pictorial view of the tests are shown in Fig 3.6. Details of the test are attached as Annex whereas the comparison of CBR value on the basis of curing period is shown in table 3.3.

Fig 3.7 Pictorial view of CBR Unsoaked

Table 3.4 Effect of marble dust on CBR (Unsoaked) values with different curing periods

Varying Percentages of Marble Dust	CBR VALUE					
	UnSoaked Value (0 days Curing)					
	At Penetration of					
	0.1 inches			0.2 inches		
	10 blows	30 blows	65 blows	10 blows	30 blows	65 blows
0 %	1.70	5.10	8.50	2.50	5.60	9.80
5%	2.40	5.60	9.10	3.40	6.40	10.20
10%	5.80	8.60	12.00	7.40	9.60	13.10
15%	4.70	7.00	10.80	5.90	8.00	11.60
	CBR VALUE					

Varying Percentages of Marble Dust	UnSoaked Value (3 days Curing)					
	At Penetration of					
	0.1 inches			0.2 inches		
	10 blows	30 blows	65 blows	10 blows	30 blows	65 blows
0 %	2.40	5.80	8.70	3.00	6.40	10.60
5%	2.80	5.80	10.10	3.80	6.70	11.10
10%	6.60	10.40	13.30	8.00	11.10	15.20
15%	5.80	7.80	11.60	6.50	8.70	12.40
Varying Percentages of Marble Dust	CBR VALUE					
	UnSoaked Value (7 days Curing)					
	At Penetration of					
	0.1 inches			0.2 inches		
	10 blows	30 blows	65 blows	10 blows	30 blows	65 blows
0 %	3.90	5.60	9.50	4.90	6.50	11.00
5%	3.00	6.60	10.40	4.20	7.00	11.50
10%	7.10	10.90	14.30	8.10	11.70	16.00
15%	6.60	8.50	12.10	7.30	9.60	12.80

3.5.3.2 Soaked testing

In this test a total of 12 moulds were prepared. 3 each for natural soil, 5 % Mix, 10% Mix, and 15 % Mix. The specimen were tested after 96 hours of soaking. Soil Mixtures were compacted in a layer in accordance with the OMC – MDD results, i.e. optimum moisture content was taken from the proctor results. Further to this the swell index was also taken into account as to see if the risalpur soil shows any tendency to swelling or not upon application of water. Variation of Water acceptance was also compared.

Pictorial view of the tests are shown in Fig 3.7. The values obtained for the swell potential though quite minute but is calculated, the CBR and the moisture content obtained after 4 days of soaking are shown in table3.4.

Table 3.5 Effect of marble dust on CBR (Soaked) values

Varying Percentages of Marble Dust	MC %			Average Swell Index	CBR VALUE					
					Soaked Value (96 hours of Soaking)					
					At Penetration of					
	Blows				0.1 inches			0.2 inches		
	10	30	65		10 blows	30 blows	65 blows	10 blows	30 blows	65 blows
0 %	22.8	20.0	16.9	0.07	0.3	1.9	5.5	0.4	2.2	5.8
5%	21.2	17.2	15.7	0.05	0.4	2.3	5.0	0.5	2.6	6.1
10%	17.7	16.7	15.4	0.03	0.8	3.1	5.6	0.9	3.8	7.1
15%	17.3	16.3	15.7	0.02	0.5	3.1	4.8	0.6	4.2	6.2

Fig 3.8 Pictorial view of CBR Soaked

CHAPTER 4

TEST RESULTS AND DISCUSSIONS

4.1 General

Collapsible soil of Risalpur locality represents a persistent issue to the staging of overlying structures. To the point and deliberate analysis was meant to propose and devise a plan portraying to recommend the medicinal measures to improve the quality and strength attributes of this soil. A keen assessment of this collapse potential up to a profundity of 4 feet was done by an syndicate ex OD-86, as a component of their last year venture (FYP). A variety of conclusions are drawn from different tests conducted in this research which are explained in this chapter and are analyzed.

Mitigation of collapse potential was evaluated using Marble waste powder which is obtained as a byproduct of polishing and grinding of marble stones or tiles. The results were nearly matching to those soils which were treated with lime as a stabilizer. Soil responded well to both this stabilizing agents however it showed an optimum increase in its strength with 10% Marble powder. With further addition of MWP the strength went on decreasing.

4.2 Soil Characterization

Different test results for unstabilized soil are summed up in table 4.1 and point by point conversation on test results is given in ensuing sections. The Atterberg Limits and fineness test conducted on Marble Dust are shown in Table 4.2

Aftereffects of all the tests show that soil showed relatively good strength which was reduced upon application of water. The previous research conducted by Engr Mir Alam Din and his syndicate in 2014 showed that the Unconfined Compression strength of soil when exposed to capillary soak for just twenty four hours was reduced from 36 psi to 0 psi. In this way adjustment measures are required for the improvement of strength/ volumetric firmness.

Table 4.1 Summary of soil characterization results

Ser	Property	Value
1.	Free swell Index	0.07%
2.	Liquid limit	27%
3.	Plastic Limit	22.059%
4.	Plasticity index	4.9%

5.	Specific gravity	2.67
6.	Maximum dry density	18.34 KN/m3
7.	OMC	15.7%
8.	CBR value	11.00%
9.	UCC value	101.08 KN/m2
10.	Soil classification	CL-ML
11.	Grain size distribution	Sand (37.8%), Silt and Clay (62.2%)

Table 4.2 Marble Dust index Properties

Ser	Property	Value
1.	Fineness Modulus	0.46
2.	Liquid limit	22.20%
3.	Plastic Limit	18.79%
4.	Plasticity index	3.4%

4.3 Waste Marble Dust Stabilization

4.3.1 Optimization of Marble powder contents

Three soil-Marble Dust powder mixtures were prepared by adding 5%, 10%, and 15% Marble dust by weight of soil. Each mix was tested for optimum moisture requirement and maximum dry density as discussed in section 3.5.1.

The results for moisture-density relation, and UCC at different Marble Dust contents are shown in Subsequent paragraphs. It can be seen that the strength gain is significant with maximum gain at 10% Marble Dust content. Further to this additional samples were prepared and tested for CBR (soaked and unsoaked) as discussed in section 3.5.3 at the same 5%, 10% and 15% Marble dust Mixtures. It also showed an optimum strength at 10 % Marble Dust Content.

Strength and Durability analysis of these mixes are explained in detail in the following paragraphs

4.4 Moisture Density Relationship

This was the initial and starting test conducted in order to ascertain the OMC and MDD. The results shows that the Maximum Dry Density (MDD) decreases and Optimum Moisture Content (OMC) increases while increasing the percentage of marble dust. When compared with the untreated soil, 15% addition of Marble dust increased the OMC by 16.09% due to the reason of change in liquid limit and plasticity index. The OMC went on an increase from 15.7% shown in 3.4.3 to 18.226%. Marble dust addition in soil optimizes the Plasticity index by increasing it and and decreasing the swelling potential of soil. Due to the presence of clayey particles these are extremely useful to control the volume change, however it shall be known that Risalpur soil does not show high amount of swell potential. The Results of OMC - MDD are as Shown below:-

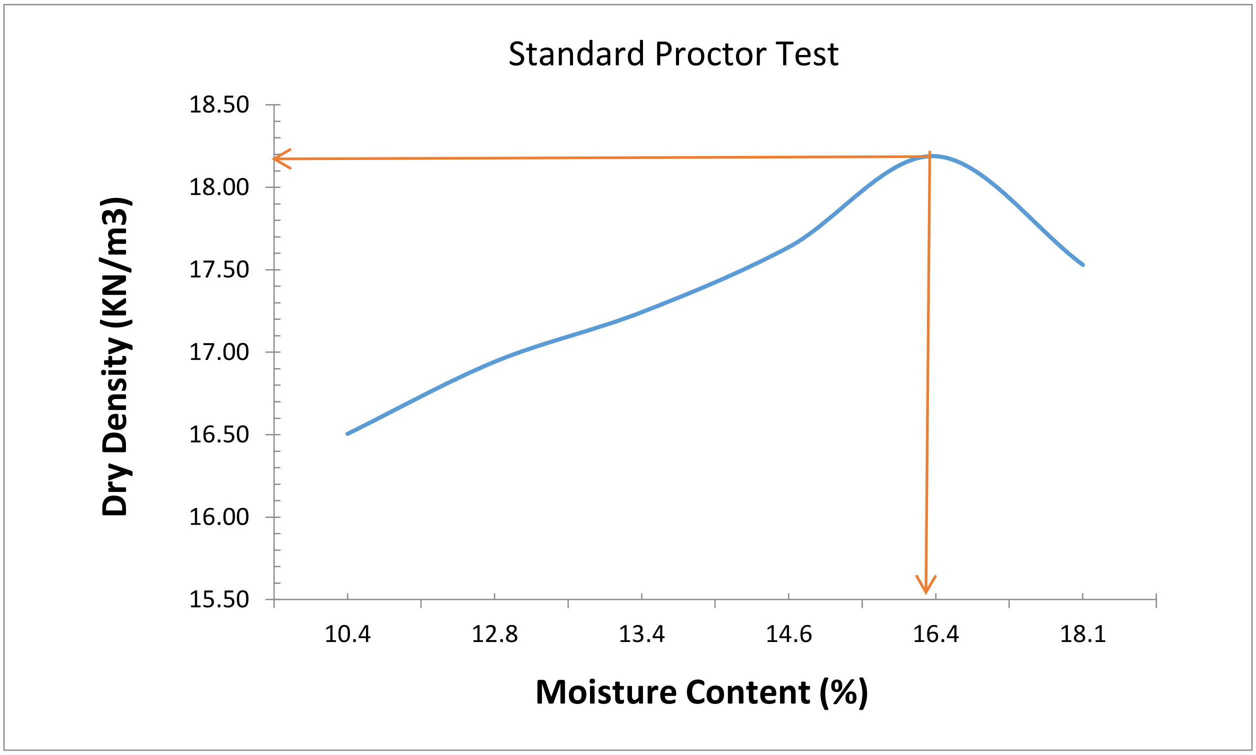


Figure 4.1 OMC-MDD chart 5 % Marble Dust

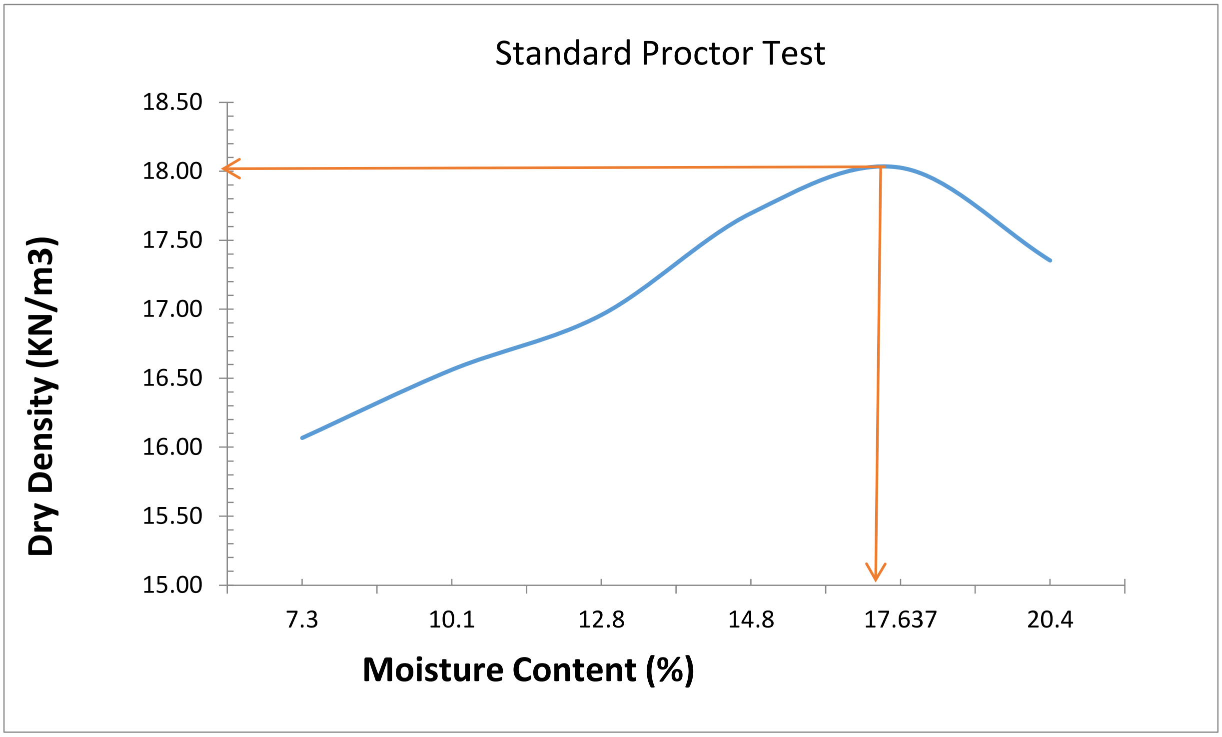


Figure 4.2 OMC-MDD chart 10 % Marble Dust

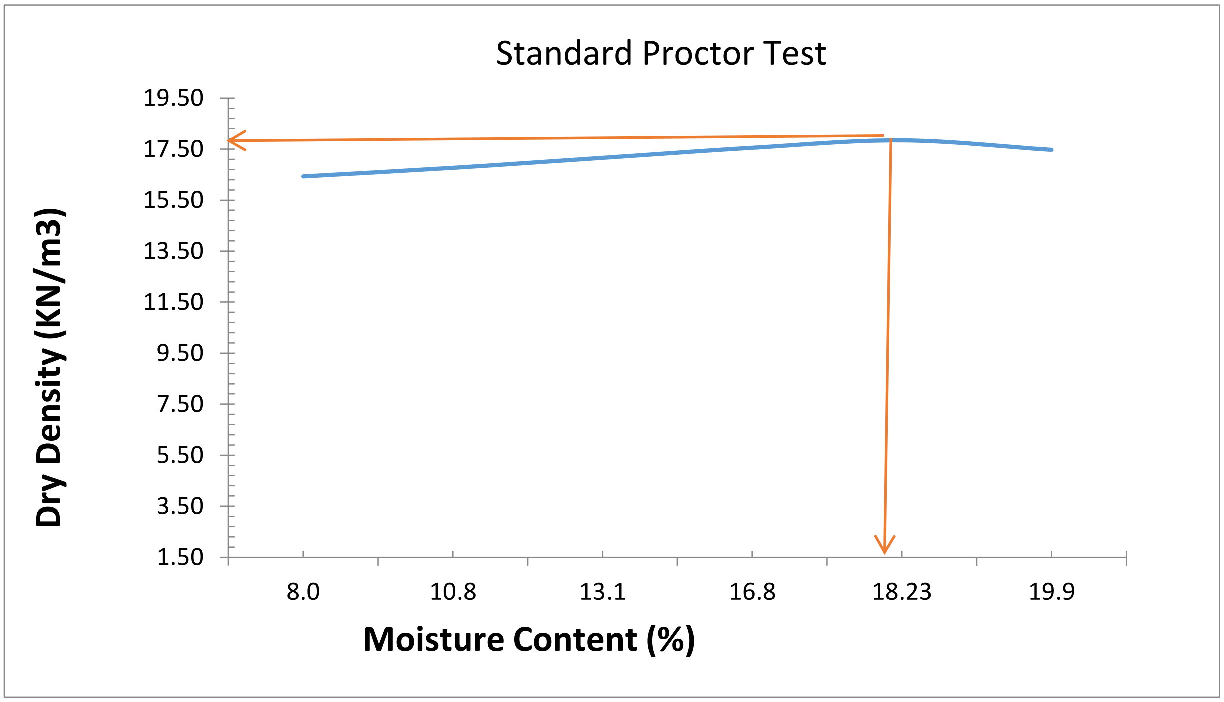


Figure 4.3 OMC-MDD chart 15 % Marble Dust

4.5 Unconfined Compression Test

The Unconfined pressure test were led on the Soil Mix with 3 differing rates of marble dust powder. Marble dust were added to soil in varying percentages (5, 10, 15%) respectively. The optimum strength value of UCC on average was acquired as 202.017 KN/m2 at 10 % addition of Marble Dust. The UCC esteem demonstrated an expansion from 101.08 KN/m2 to 202.017 KN/m2. The test outcomes are shown in the Table 4.2.The stress strain charts for soil test treated with changing rates of marble dust are spoken to in Figures below. The increase in the UCC value shall be credited to the steady arrangement of compounds like CaH2O4Si which is cementitious in nature because of the response of calcium carbonate which is present in WMD, water and soil.

Table 4.3 Effect of marble dust on UCC values

Varying Percentages of Marble Dust	**Unconfined Compressive strength qu in KN/m^2**			
	Trial 1	**Trial 2**	**Trial 3**	**Average**
0%	101.008	107.873	95.124	101.008
5%	136.3	147.1	153.964	146.119
10%	211.823	193.191	202.017	202.017
15%	185.345	198.094	180.442	187.307

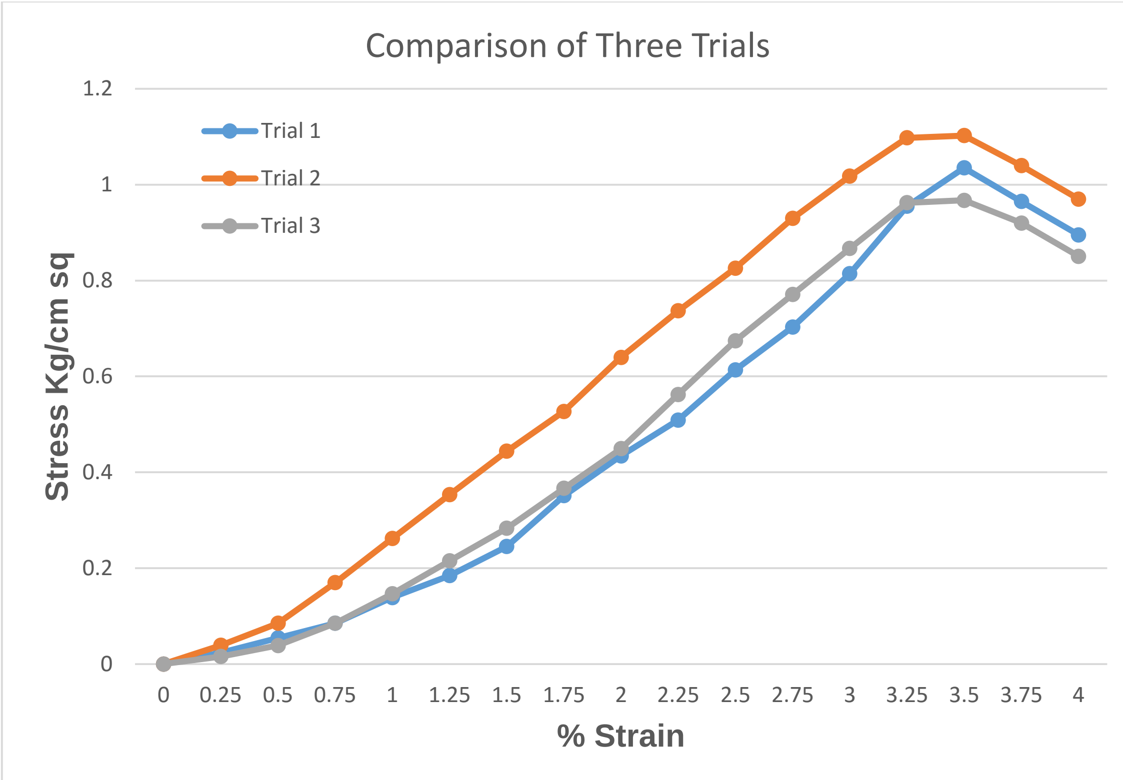


Figure 4.4 Stress-strain variation curve 0 % Marble Dust (Untreated Soil)

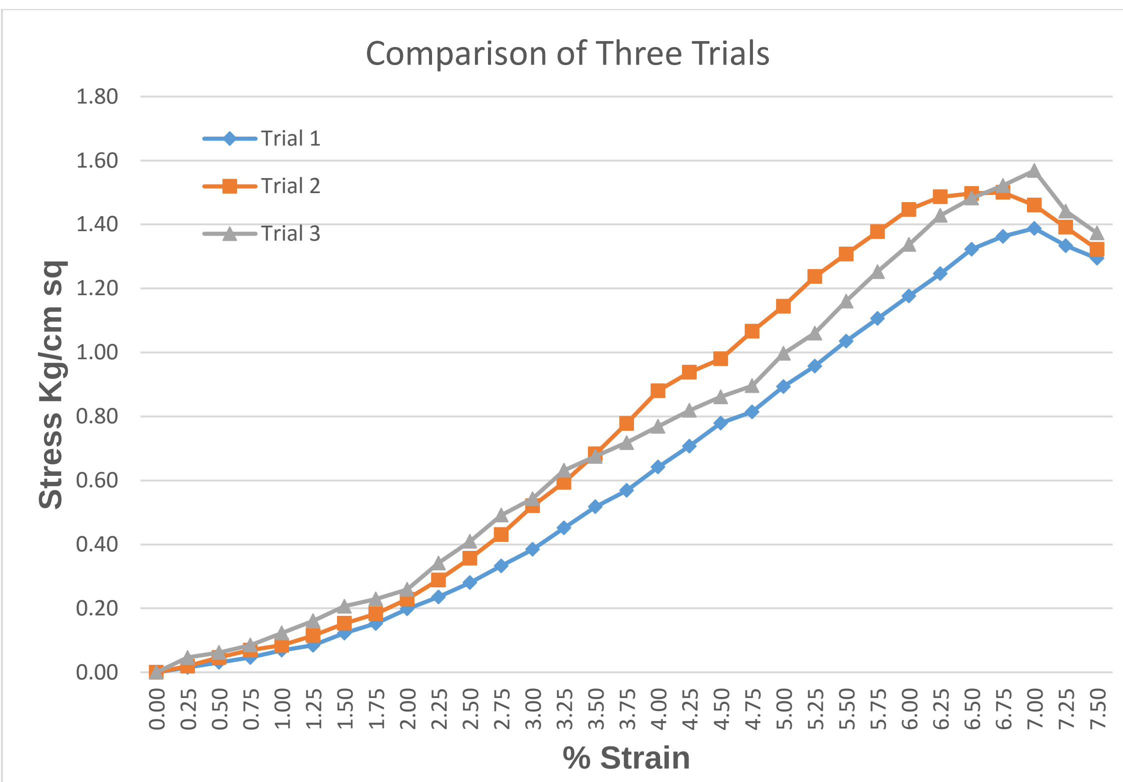


Figure 4.5 Stress-strain variation curve 5 % Marble Dust

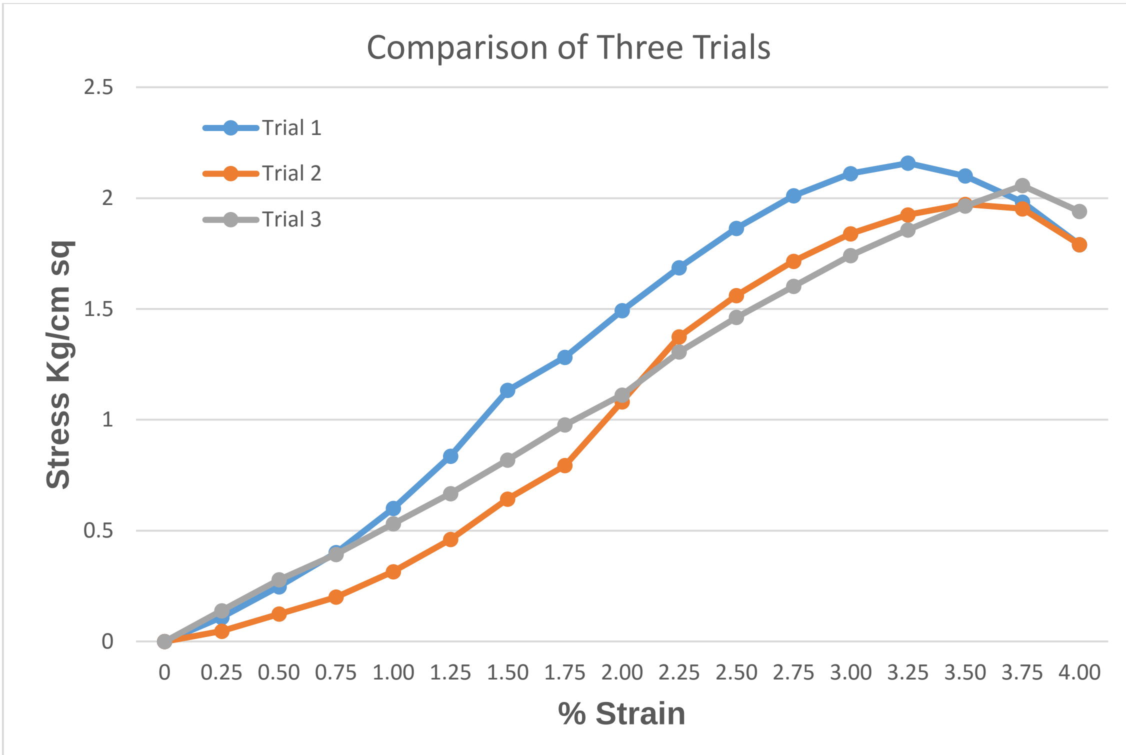


Figure 4.6 Stress-strain variation curve 10 % Marble Dust

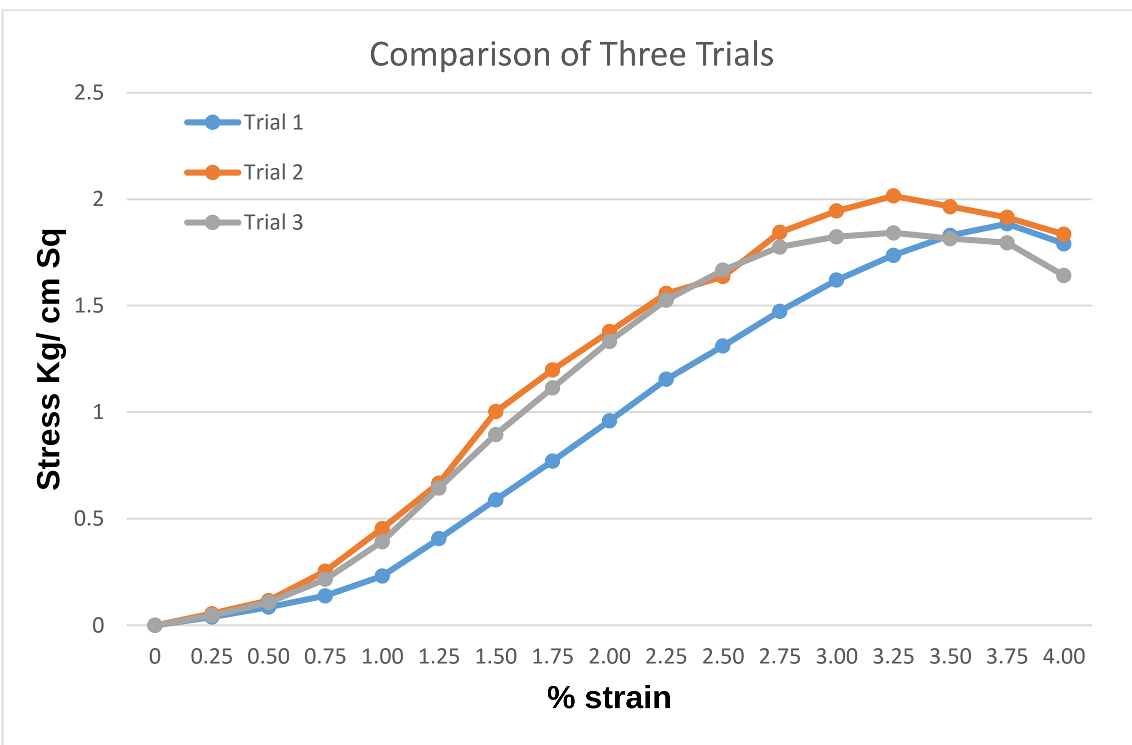
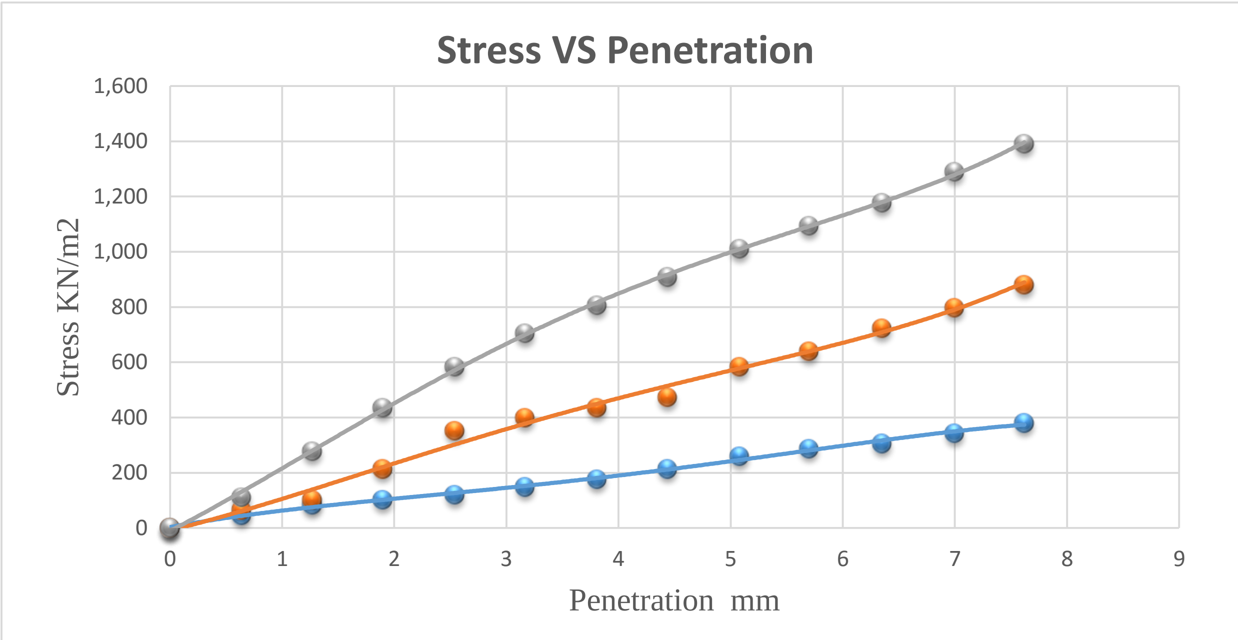


Figure 4.7 Stress-strain variation curve 15 % Marble Dust

With increasing curing period marble dust- clay reaction improves the pore size distribution by cementation process. Hence higher strengths were achieved at higher curing periods but there is no significant increase in strength after 14 days. Due to the addition of marble dust the pores in the clay matrix are reduced by compensation of graded material and large surface area. When the curing process starts it becomes way more difficult for the moisture content to enter into the clay matrix and shall induce swelling into the sample.

4.6 California Bearing Ratio (Unsoaked)

The California bearing ratio test were led on the soil sample with 3 varied rates of marble dust powder. Marble dust were added to soil in differing rates of 5, 10 and15%. The test outcomes are described in the 3.5.3.1. CBR value rises up to 10% increase of marble powder and afterward diminishes. The most optimized estimation of CBR for 10% addition of marble dust without curing was acquired as 12% and 13.1% for 65 blows at 0.1 and 0.2 inches penetration respectively. The CBR value demonstrated an expansion from 8.5% to 12% and 9.8 to 13.1 with 10% addition of marble powder at 0.1 and 0.2 inches penetration respectively. The results can be compared from tables appeared in Table 3.3. The load penetration charts for the CBR test led on a virgin soil sample and its comparison with dry density is shown in Figure 4.8. CBR can be calculated in accordance with 3.5.3.1. The arrangement of a cation trade response, trailed by a period subordinate pozzolanic response were accountable for the increase in CBR value. The decrease in the CBR value when the marble dust surpasses the ideal rate shows that abundance of marble dust can't be spent in the marble dust-soil stabilization.



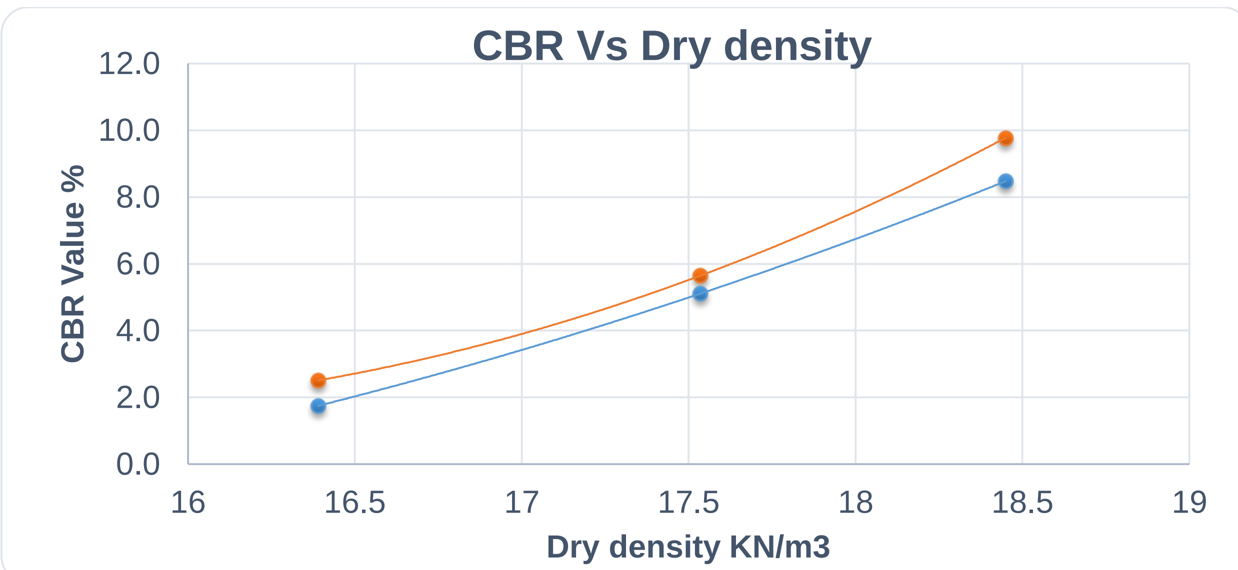
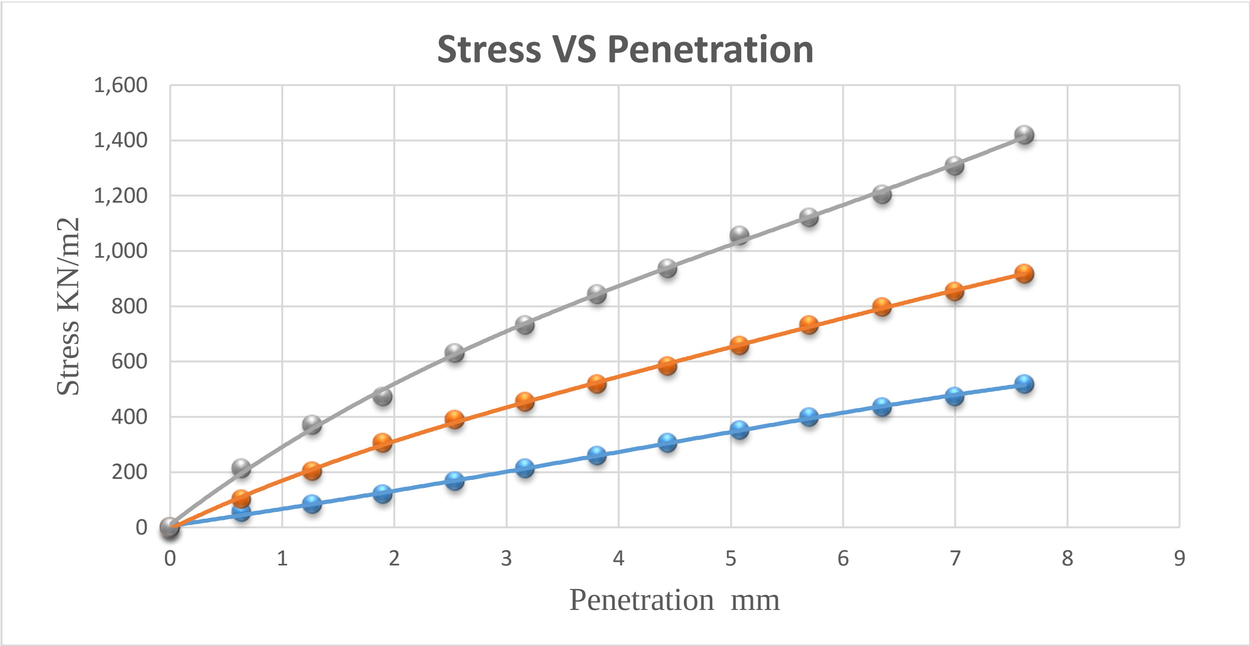


Figure 4.8

(a). Load Penetration Graph of Virgin Soil without Curing

(b). CBR vs Dry density of Virgin Soil without Curing



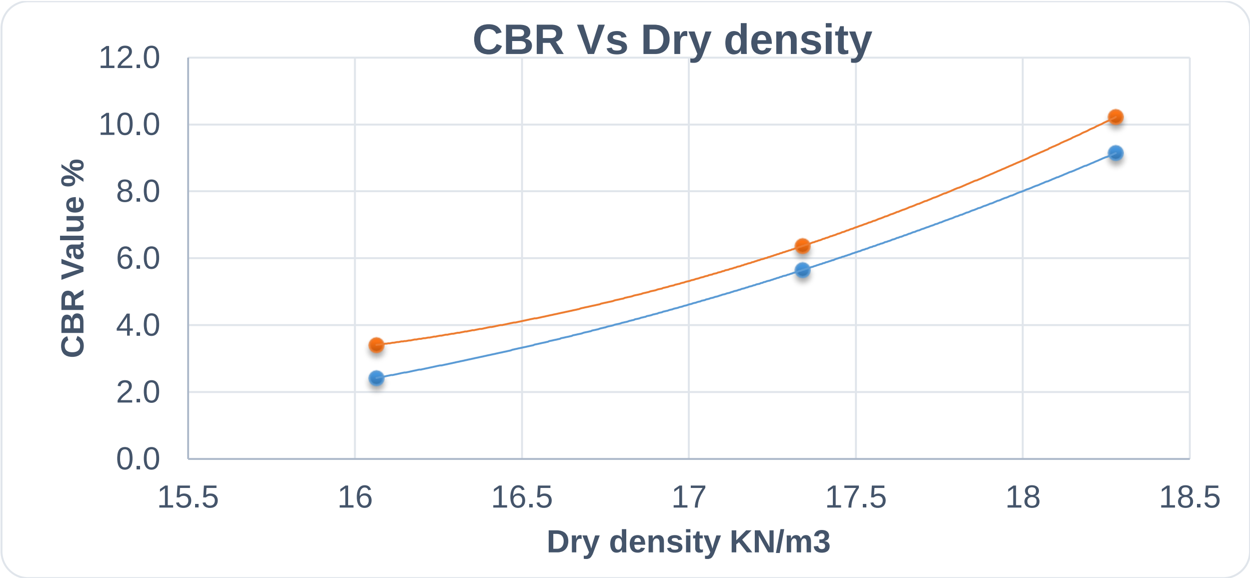
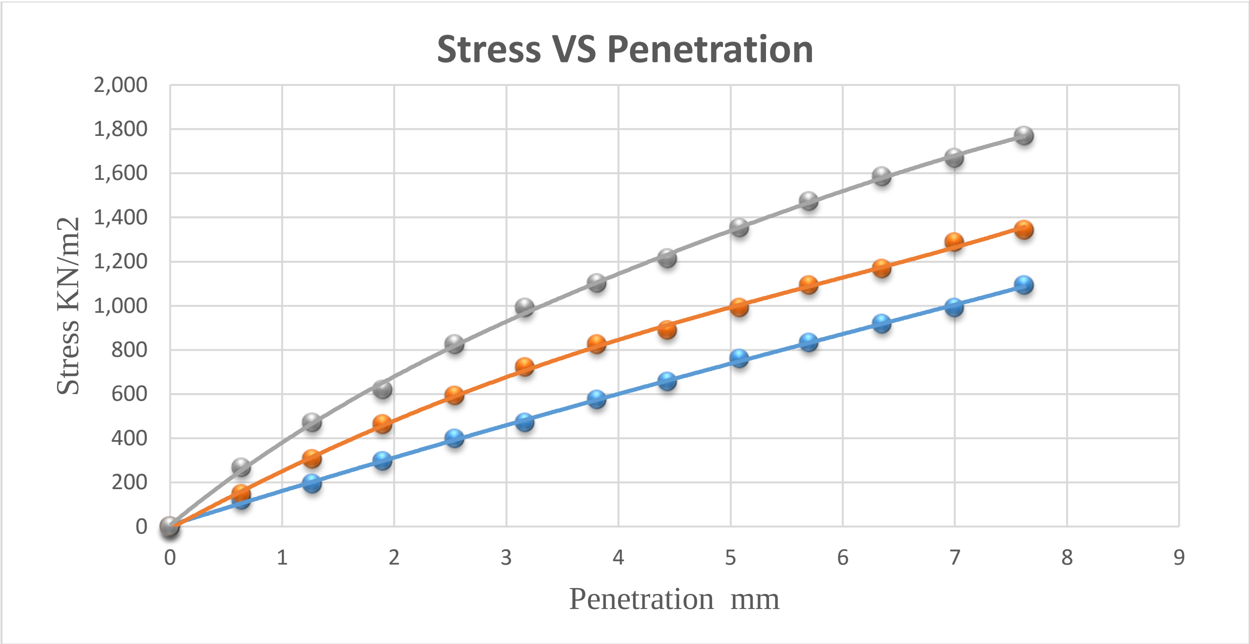


Figure 4.9

(a). Load Penetration Graph of 5% Marble dust mix without Curing

(b). CBR vs Dry density of 5% Marble dust mix without Curing



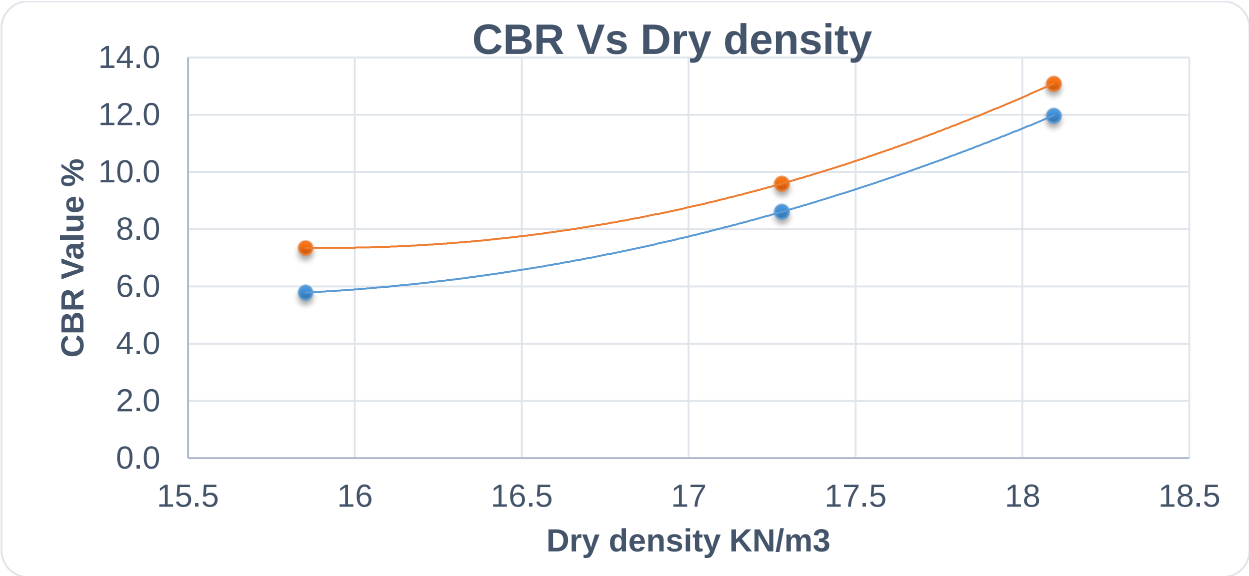
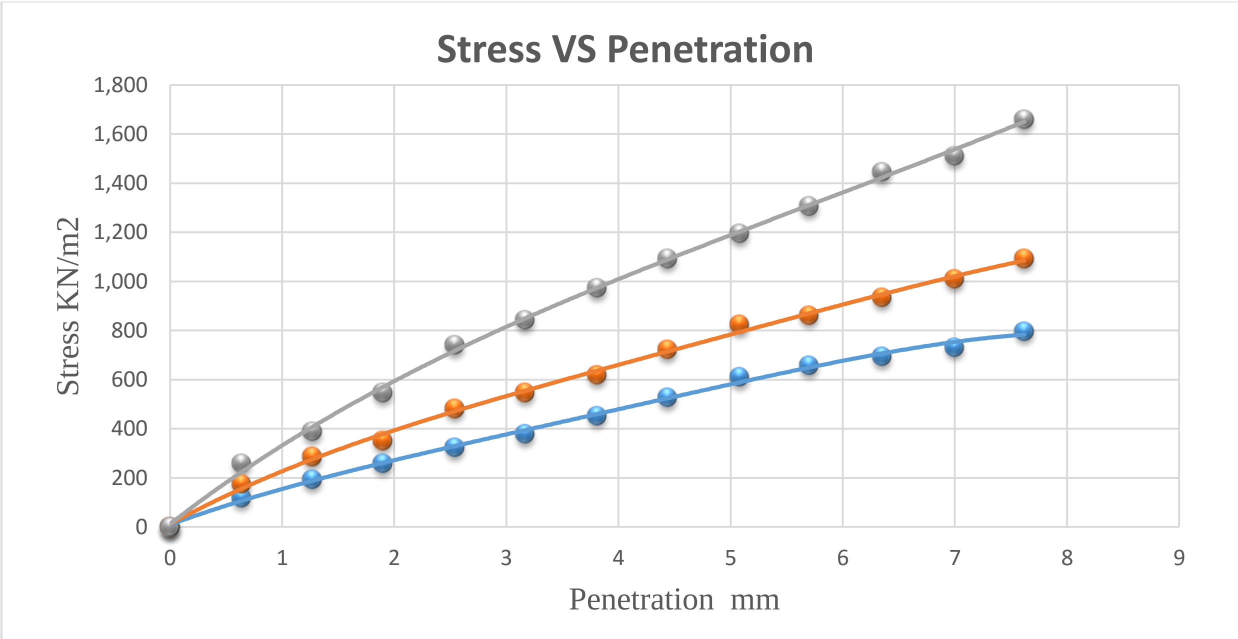


Figure 4.10

(a). Load Penetration Graph of 10% Marble dust mix without Curing

(b). CBR vs Dry density of 10% Marble dust mix without Curing



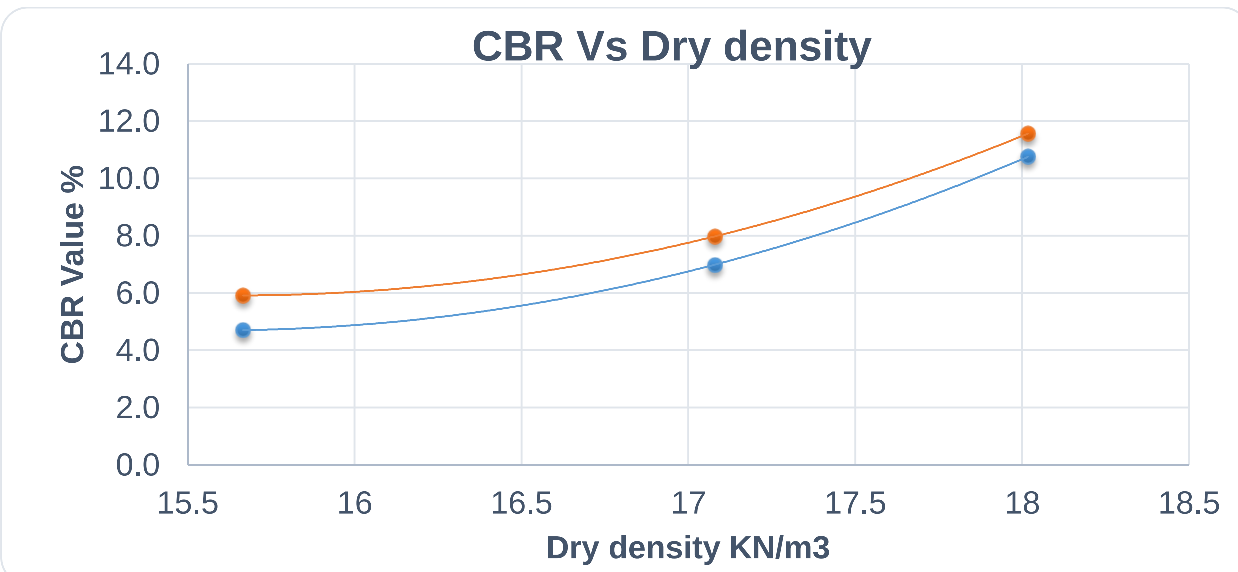


Figure 4.11

(a). Load Penetration Graph of 15% Marble dust mix without Curing

(b). CBR vs Dry density of 15% Marble dust mix without Curing

Figure 4.9 shows the load-penetration graph for soil sample added with 5 % marble dust without curing. The most optimized estimation of CBR for 5% addition of marble dust without curing was acquired as 9.1% and 10.2% for 65 blows at 0.1 and 0.2 inches penetration respectively. A steady rise in CBR value for varying percentage addition of marble dust were clearly shown in the graph. Similarly in Figure 4.10 it can be clearly observed that with 10% addition of marble dust without curing the sample the CBR value increases to 12% and 13.1% for 65 blows at 0.1 and 0.2 inches penetration respectively. Figure 4.11 shows the values of CBR for 15% addition of marble dust without curing was acquired as 10.8% and 11.6% for 65 blows at 0.1 and 0.2 inches penetration respectively. The reduction of CBR values shows that soil reduces its strength when further Marble dust is added. Furthermore it has been clearly observed that with increase in addition of Marble dust the dry density decreases.

The results show an increase in CBR values when the samples are cured for some days. There was no significant increase after 7 days of curing. However the increments were found to be maximum for 10 % marble dust sample. Figure 4.12 shows the load-penetration graph for soil sample treated with 10% of marble dust with 3 days curing period. The CBR value acquired was 13.3% and 15.2% for 65 blows at 0.1 and 0.2 inches penetration respectively.

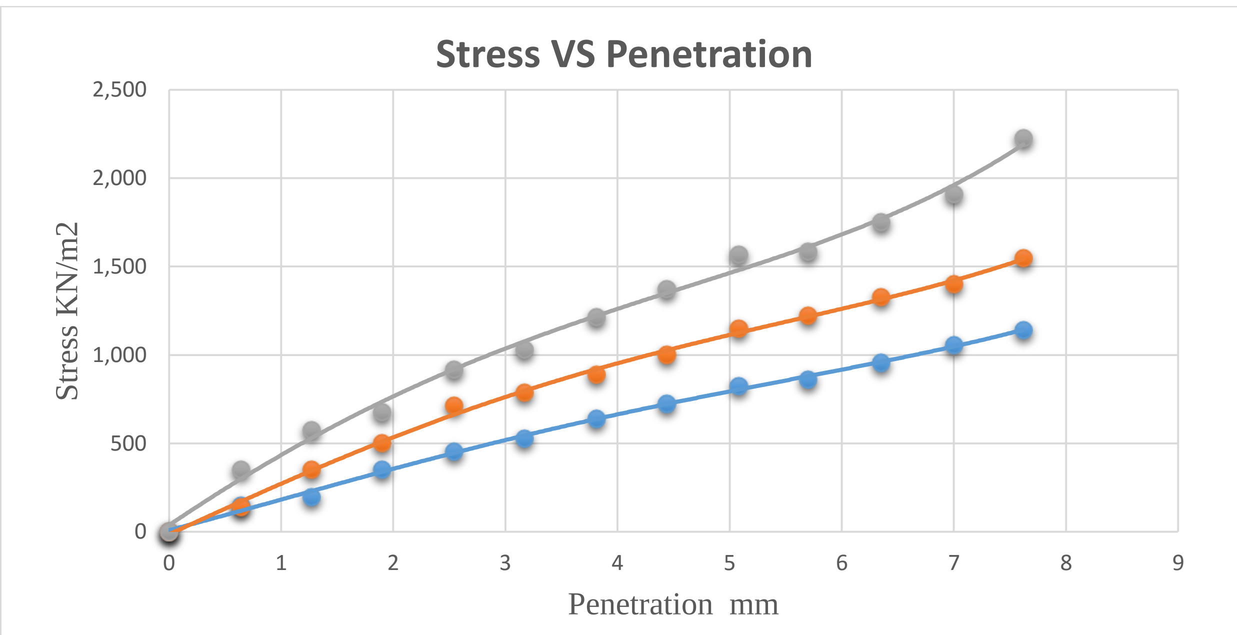


Figure 4.12 Load Penetration Graph of 10% Marble dust mix with 3 days curing period

Figure 4.13 shows the load-penetration graph for soil sample treated with 10% of marble dust with 7 days curing period. The CBR value acquired was 14.3% and 16% for 65 blows at 0.1 and 0.2 inches penetration respectively. 16% is the maximum value recorded however this can be improved by increasing the curing period. Strength increase during curing is due to formation of cementing gel material followed by pozzolanic reactions which take place over a period of time.

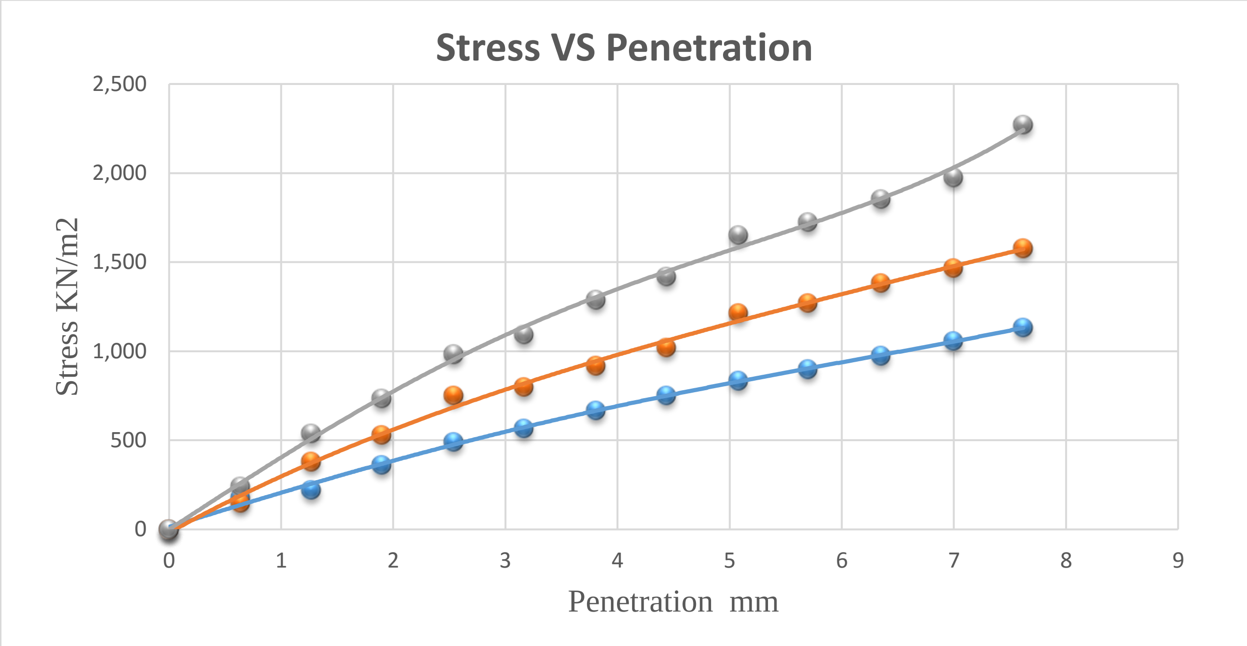
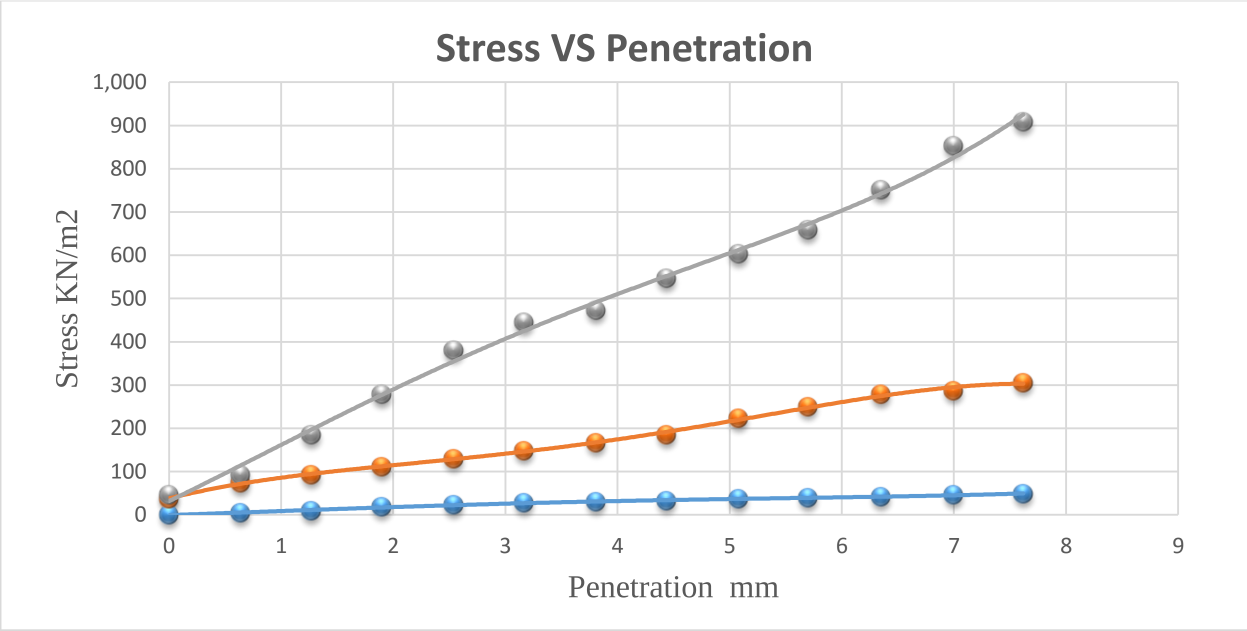


Figure 4.13 Load Penetration Graph of 10% Marble dust mix with 7 days curing period

4.7 California Bearing Ratio (Soaked)

CBR test unsoaked was conducted for evaluating the suitability of Waste Marble dust stabilization of Risalpur soil. The test results of UCS showed optimized results for 10 % Waste Marble Mixture. Further confirmation was done by conducting the CBR soaked test on all the samples. The results of unstabilized soil were compared with the varied percentages of WMD and it showed an increase in the CBR value but was not that significant as in case of Unsoaked CBR as shown in 3.5.3.2. It was observed that the CBR value for 1 inch penetration was less than CBR value for the 2 inches penetration. The specimen was also covered with a surcharge mass in the test to simulate the effect of overlying materials. Test results obtained show that CBR value increases with increase in waste marble powder in soil up to 10 % waste marble dust and then reduces with further increase of WMD. The addition of marble dust in soaked condition improved the CBR value by about 22.4 %. The stress vs. penetration graphs and CBR vs. dry density graphs for both unstabilized soil and 10 % waste marble mix sample are shown in Fig 4.14 and 4.15 respectively.



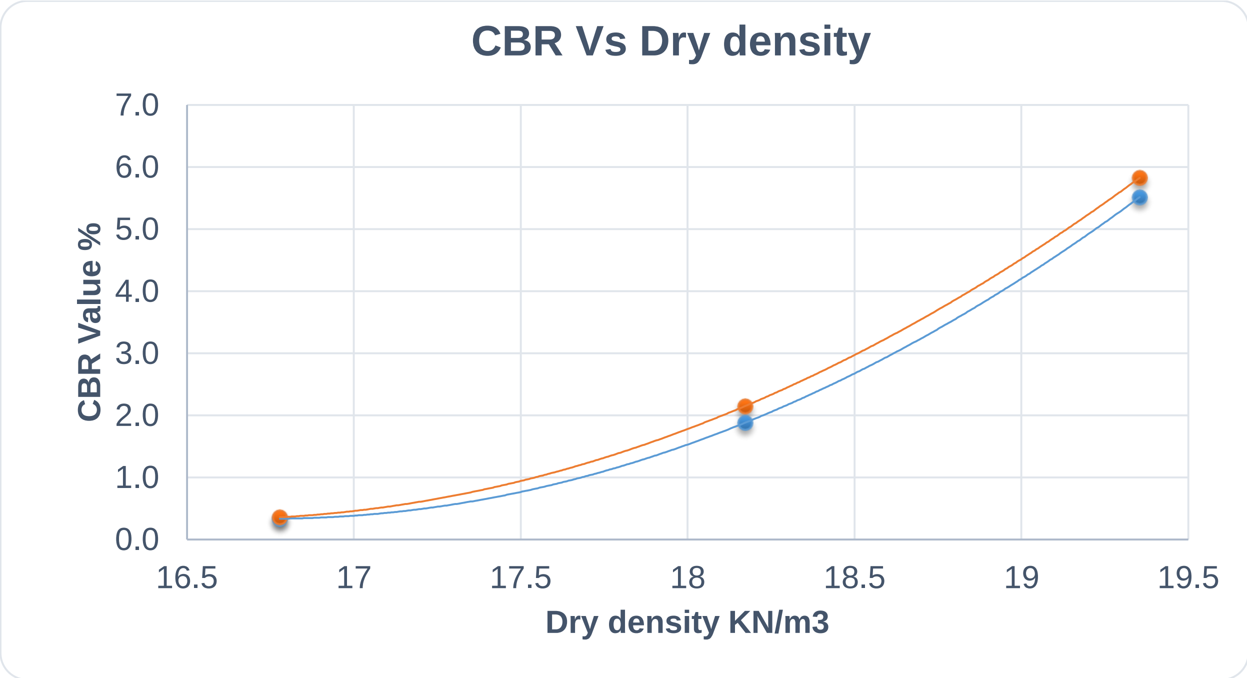
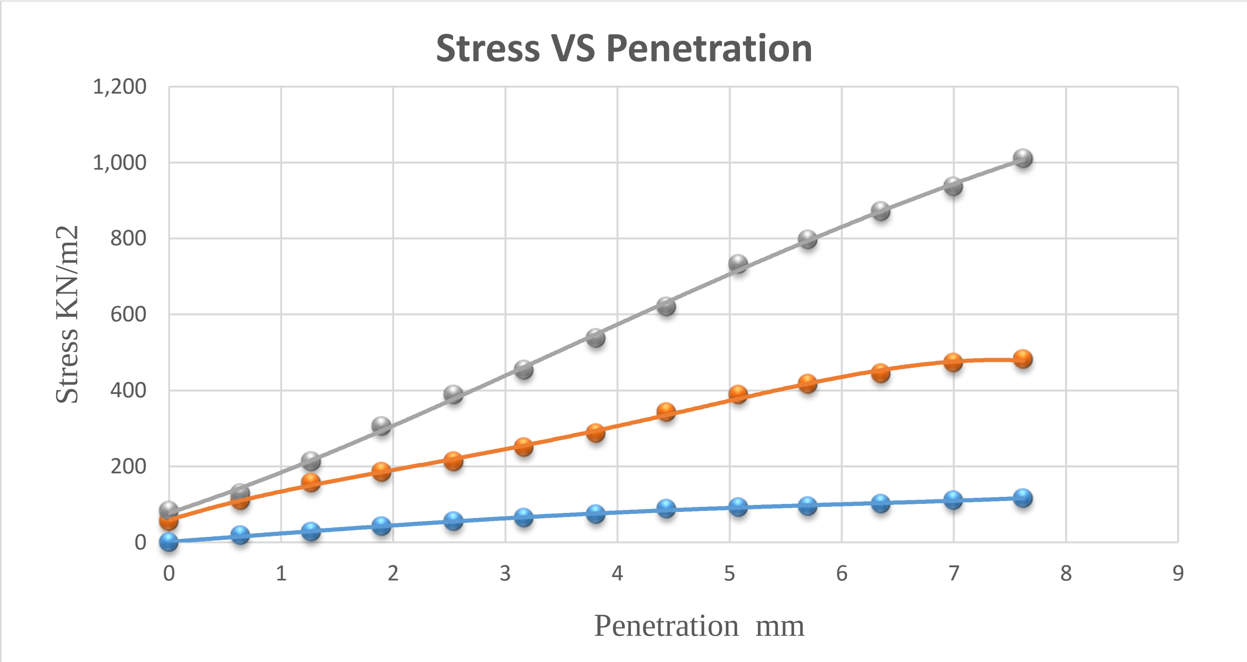


Figure 4.14

(a). Load Penetration Graph of soil Soaked for 96 hours.

(b). CBR vs Dry density of soil Soaked for 96 hours.



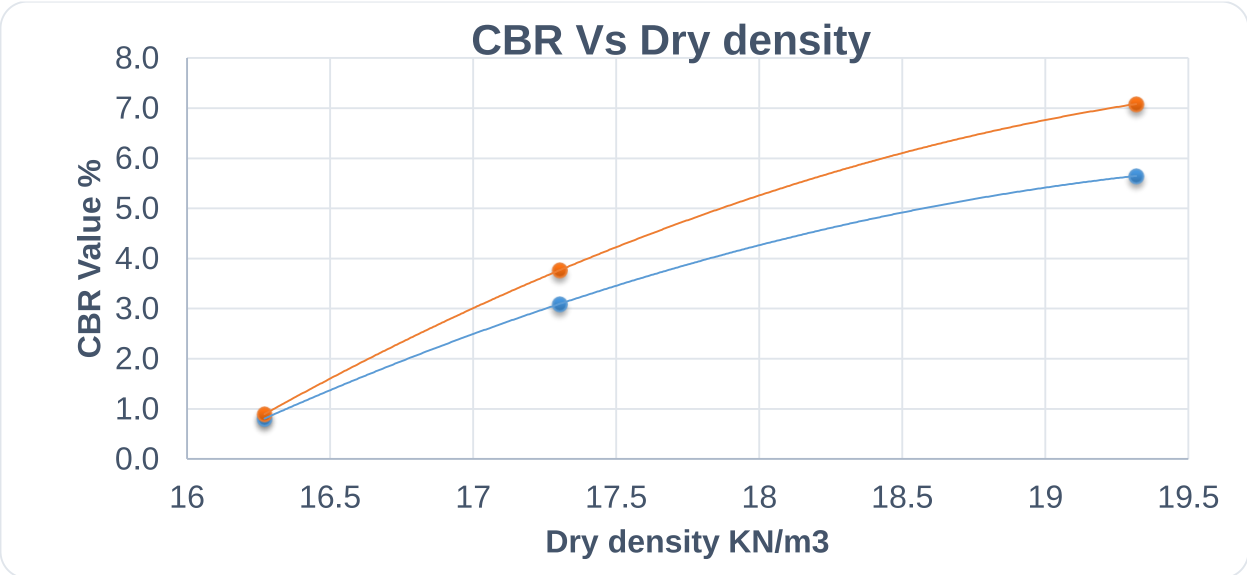


Figure 4.15

(a). Load Penetration Graph of 10 % Marble Mix Soaked for 96 hours.

(b). CBR vs Dry density of 10 % Marble Mix Soaked for 96 hours.

Further to CBR value it has been noted that when the number of blows and marble dust content were increased the acceptance of water content by the sample was reduced. Similarly the value of swell percentage if compared is also reduced when the quantity of marble dust is increased in soil samples. The comparison of swell percentage and water penetration in the sample are shown in fig 4.16 and fig 4.17 respectively.

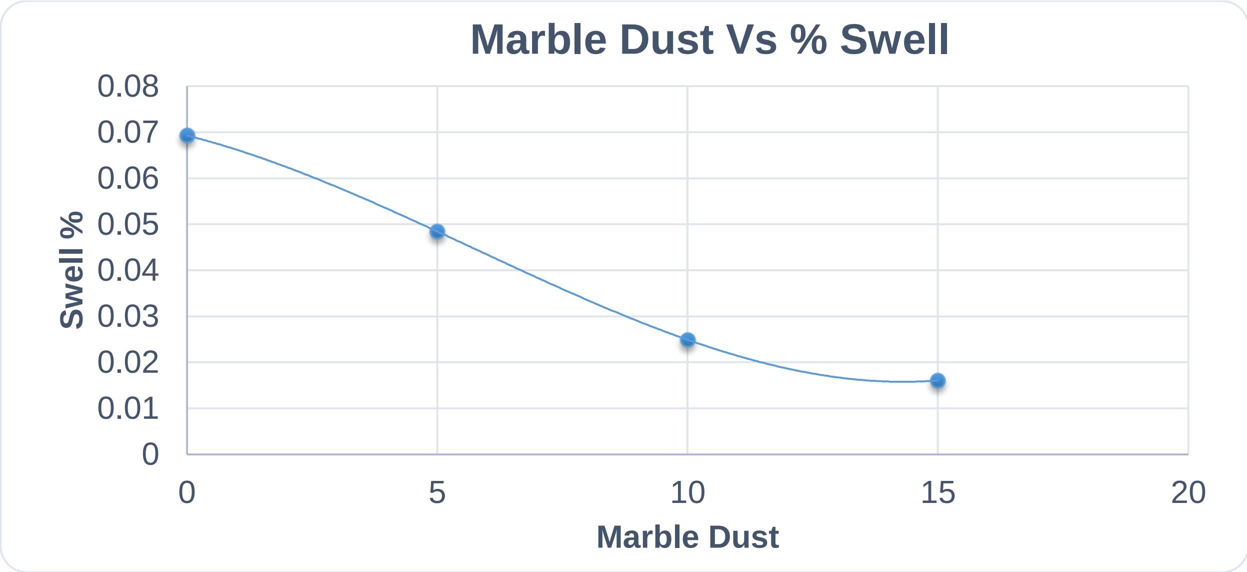


Figure 4.16 Impact of Marble dust on swell potential

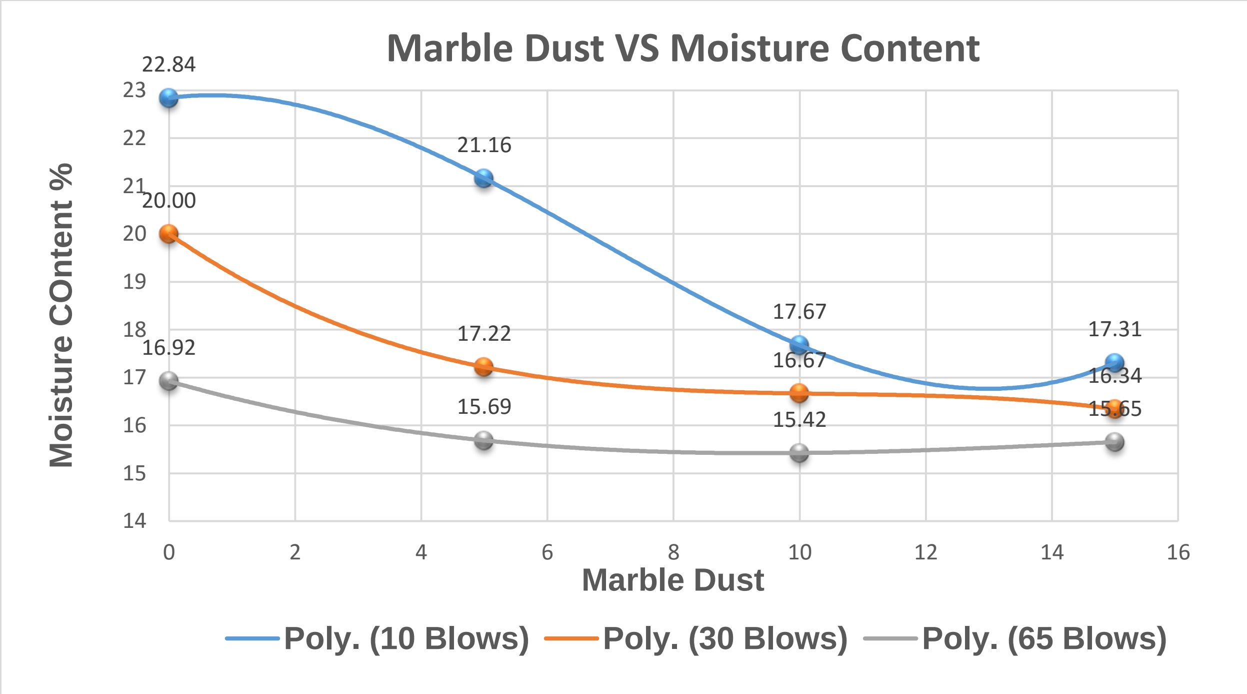


Figure 4.17 Influence of Marble dust on Moisture Penetration with differing rate of compaction

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Marble powder’s appropriateness as stabilizer to increase the physical properties and strength of weak CL-ML soil has been studied with the help of a series of the laboratory tests. Samplesof soil and marble dust were collected from general area Risalpur, Pakistan and were tested to determine their properties such as optimum moisture content, size distribution of particles, dry density, UCS strength, swelling potential and California bearing ratios. The properties of soil samples were determined without and with the addition of 5%, 10%, and 20% marble powder by total weight of the samples. Conclusions which are deduced from the discussions are as follows:

- With addition of waste marble dust the percentage of coarser particles was increased and the surface area was reduced, thereby reducing the LL of the soil. The LL was reduced by 22.7%.
- The MDD is decreased while the OMC is improved regardless of the quantity of Waste marble dust additon to soil. The decrease in dry density of soil by addition of waste marble dust may be due to low specific gravity of waste marble dust, mechanical action.
- The UCS of the soil increased up to 10% addition of Waste marble dust. Further addition of Waste marble dust decreased this strength of the soil. On an average 100% increase in UCS of the virgin soil was calculated. This was due to the densification of particles and hence it gives more strength to the soil.
- The CBR value demonstrated an increase from 8.5% to 12% and 9.8 to 13.1 with 10% addition of marble powder at 2.5 and 5 mm penetration respectively. The percentage increase in CBR value for 10% addition of waste marble dust without curing was acquired as 41.18% and 33.67% for 65 blows at 2.5 and 5 mm penetration respectively. Further addition of waste marble dust reduces the CBR value. The maximum CBR value was obtained as 16% at 7 days curing period for 10% addition of waste marble dust.
- The Soaked CBR test of soil also showed an increase up to 10% addition of Waste marble dust. Further addition of Waste marble dust decreased the soaked CBR of the soil. The

percentage increase in CBR soaked value for 10% addition of waste marble dust was attained as 12% and 22.4% for 65 blows at 2.5 and 5 mm penetration respectively.

- The stabilization of Risalpur soil with waste marble dust which is abundant in this area and represents an environmentally friendly process from biological, technical and economical points of view.
- Mainly the improvement in soil came due to the physiochemical processes which include blending, densification and cat ion exchange reactions.

5.2 Recommendations

- Soil improvement and stabilization shall be undertaken as an integral part in the future construction projects in Risalpur and surrounding areas.
- Water should be added to the sample after mixing of stabilizer with soil but if water is added while mixing it should be lesser than the optimum moisture content of the sample, so that the moisture lost while mixing can be accounted for and pertinent moisture content is achieved while compacting.
- A very significant factor in soil stabilization is the mixing time of samples. To achieve the optimum results in unconfined compressive strength optimum degree of mixing time is required. Therefore mixing time shall be increased to achieve best results.
- Other types of waste material like ceramic dust, stone quarry and rubber etc. also need be tried to know its effect on Risalpur soil.
- UCS strength was not checked in soaked condition so this soil is required to be tested in soaked condition for UCS strength.

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ANNEX

Fineness Modulus of Waste Marble Dust ASTM C136,			
Testing Sieve	Mass Retained	Cumulative Mass Retained	Cumulative Percentage Retained
No	grams	grams	%
10	0	0	0.00
40	0	0	0.00
60	7.2	7.2	7.39
100	30.4	37.6	38.60
200	27.1	64.7	66.43
Pan	32.7	97.4	100.00
Sum Cumulative Percentage Till No 100 Sieve =			45.99
	Fineness Modulus =	Sum Cumulative Percentage Retained Till No 100 Sieve /100	
	Fineness Modulus =	0.46	

CONSISTENCY LIMITS OF SOIL						
	LIQUID LIMIT			PLASTIC LIMIT		
NO. OF BLOWS	17	27	36	Trial 1	Trial 2	Trial 3
MASS OF WET SOIL+CAN	33.00	61.80	40.60	16.50	17.95	16.77
MASS OF DRY SOIL+CAN	28.60	51.10	34.60	15.60	16.40	15.80
MASS OF CAN	13.30	11.00	11.00	11.59	9.08	11.50
MASS OF WATER	4.40	10.70	6.00	0.90	1.55	0.97
MASS OF SOLIDS	15.30	40.10	23.60	4.01	7.32	4.30
WATER CONTENT	28.8	26.7	25.4	22.4	21.2	22.6

CONSISTENCY LIMITS OF WASTE MARBLE DUST				
	LIQUID LIMIT			PLASTIC LIMIT
NO. OF BLOWS	17	23	40	
MASS OF WET SOIL+CAN	42.03	27.00	34.70	17.30
MASS OF DRY SOIL+CAN	35.97	24.03	30.90	16.00

MASS OF CAN	10.60	10.80	12.39	9.08
MASS OF WATER	6.06	2.97	3.80	1.30
MASS OF SOLIDS	25.37	13.23	18.51	6.92
WATER CONTENT	23.9	22.4	20.5	18.8

GRADATION OF SOIL					
SIEVE NO.	**SIEVE**	**MASS OF SOIL**	**CUMULATIVE**	**CUMULATIVE %**	**%**
	Dia	**RETAINED**	**MASS RETAINED**	**RETAINED**	**PASSING**
	mm	**gm**	**gm**	**gm**	
3"	76.2	0	0	0.0	100.0
2-1/2"	63.5	0	0	0.0	100.0
2"	50.8	0	0	0.0	100.0
1-1/2"	38.1	0	0	0.0	100.0
1"	25.4	0	0	0.0	100.0
3/4"	19	0	0	0.0	100.0
1/2"	12.7	0	0	0.0	100.0
3/8"	9.5	0	0	0.0	100.0
4	4.75	0	0	0.0	100.0
10	2	8.8	8.8	3.0	97.0
20	0.85	11.6	20.4	6.8	93.2
40	0.425	12.2	32.6	10.9	89.1
60	0.25	11.6	44.2	14.8	85.2
100	0.15	23.5	67.7	22.7	77.3
200	0.074	45	112.7	37.8	62.2
pan		185.6	298.3	100.0	0.0

GRADATION OF WASTE MARBLE DUST					
SIEVE NO.	**SIEVE**	**MASS OF SOIL**	**CUMULATIVE**	**CUMULATIVE %**	**%**
	Dia	**RETAINED**	**MASS RETAINED**	**RETAINED**	**PASSING**
	mm	**gm**	**gm**	**gm**	
3"	76.2	0	0	0.0	100.0
2-1/2"	63.5	0	0	0.0	100.0
2"	50.8	0	0	0.0	100.0
1-1/2"	38.1	0	0	0.0	100.0

1"	25.4	0	0	0.0	100.0
3/4"	19	0	0	0.0	100.0
1/2"	12.7	0	0	0.0	100.0
3/8"	9.5	0	0	0.0	100.0
4	4.75	0	0	0.0	100.0
10	2	0	0	0.0	100.0
20	0.85	5	5	1.7	98.3
40	0.425	46	51	17.5	82.5
60	0.25	98.4	149.4	51.2	48.8
100	0.15	71.2	220.6	75.6	24.4
200	0.074	49.7	270.3	92.7	7.3
pan		21.4	291.7	100.0	0.0

OMC MDD RELATIONSHIP OF UNSTABILIZED SOIL

ASTM D 698 (Standard), ASTM D 1557 (Modified)

Density	**Trail No**					
Determination No	1	2	3	4	5	6
Mass of mould + compacted soil M 1(g)	3398	3497	3614	3753.4	3800	3760.0
Mass of mould (M 2) g	1759.0	1759.0	1759.0	1759.0	1759.0	1759.0
Volume of Mould (Cubic Cm)	943	943	943	943	943	943
Mass of compacted soil (g) M3	1639	1738	1855	1994	2041	2001
Wet Density (gm/Cc) ɣwet	1.74	1.8	2.0	2.1	2.2	2.1
Dry density (ɣdry)	1.61	1.66	1.75	1.84	1.87	1.79
Dry density (ɣdry)	15.77	16.28	17.18	18.09	18.29	17.55
Moisture Content	**Trail No**					
Determination No	1	2	3	4	5	6
Mass of container + wet soil = M1 (g)	59.5	50.6	46.2	59.0	42.7	52.3
Mass of container + Dry soil = M2 (g)	56.6	47.7	42.3	53.9	38.4	45.8
Mass of Container (M3)	20.6	21.2	10.6	19.1	11.6	10.8
Mass of water = M1 – M2 (g)	2.9	2.9	3.9	5.1	4.3	6.5
Mass of Dry soil = (M2 – M3) (g)	36.0	26.5	31.7	34.8	26.8	35.0
Water content = W = WW	8.1	11.1	12.3	14.7	16.0	18.6

Optimum Moisture Content (%)	**15.700**
Maxuimum Dry Density (gm/cm3)	**1.870**
Maxuimum Dry Density (KN/m3)	**18.345**

OMC MDD RELATIONSHIP OF 5 % MIX

ASTM D 698 (Standard), ASTM D 1557 (Modified)

Density	**Trail No**					
Determination No	1	2	3	4	5	6
Mass of mould + compacted soil M 1(g)	3511	3597.2	3640	3702	3795.5	3749.0
Mass of mould (M 2) g	1759.0	1759.0	1759.0	1759.0	1759.0	1759.0
Volume of Mould (Cubic Cm)	943	943	943	943	943	943
Mass of compacted soil (g) M3	1752	1838	1881	1943	2037	1990
Wet Density (gm/Cc) ɣwet	1.86	1.9	2.0	2.1	2.2	2.1
Dry density (ɣdry)	1.68	1.73	1.76	1.80	1.85	1.79
Dry density (ɣdry)	16.51	16.94	17.24	17.64	18.19	17.53
Moisture Content	**Trail No**					
Determination No	1	2	3	4	5	6
Mass of container + wet soil = M1 (g)	47.8	40.9	75.1	46.0	87.9	62.1
Mass of container + Dry soil = M2 (g)	44.3	37.5	68.7	41.5	78.4	54.5
Mass of Container (M3)	10.6	11.0	21.1	10.6	20.6	12.4
Mass of water = M1 – M2 (g)	3.5	3.4	6.4	4.5	9.5	7.6
Mass of Dry soil = (M2 – M3) (g)	33.7	26.5	47.6	30.9	57.8	42.1
Water content = W = WW	10.4	12.8	13.4	14.6	16.4	18.1

Optimum Moisture Content (%)	**16.40**
Maxuimum Dry Density (gm/cm3)	**1.855**
Maxuimum Dry Density (KN/m3)	**18.196**

OMC MDD RELATIONSHIP OF 10% MIX

ASTM D 698 (Standard), ASTM D 1557 (Modified)

Density	Trail No					
Determination No	1	2	3	4	5	6
Mass of mould + compacted soil M 1(g)	3417.3	3512.6	3598	3713	3798	3768.0
Mass of mould (M 2) g	1759.0	1759.0	1759.0	1759.0	1759.0	1759.0
Volume of Mould (Cubic Cm)	943	943	943	943	943	943
Mass of compacted soil (g) M3	1658	1754	1839	1954	2039	2009
Wet Density (gm/Cc) ɣwet	1.76	1.9	2.0	2.1	2.2	2.1
Dry density (ɣdry)	1.64	1.69	1.73	1.80	1.84	1.77
Dry density (ɣdry)	16.07	16.56	16.96	17.70	18.03	17.35
Moisture Content	**Trail No**					
Determination No	1	2	3	4	5	6
Mass of container + wet soil = M1 (g)	38.7	39.8	72.1	29.9	89.8	69.9
Mass of container + Dry soil = M2 (g)	36.8	37.2	66.3	27.2	79.2	61.7
Mass of Container (M3)	10.9	11.5	20.9	9.0	19.1	21.5
Mass of water = M1 – M2 (g)	1.9	2.6	5.8	2.7	10.6	8.2
Mass of Dry soil = (M2 – M3) (g)	25.9	25.7	45.4	18.2	60.1	40.2
Water content = W = WW	7.3	10.1	12.8	14.8	17.637	20.4

Optimum Moisture Content (%)	**17.270**
Maxuimum Dry Density (gm/cm3)	**1.838**
Maxuimum Dry Density (KN/m3)	**18.032**

OMC MDD RELATIONSHIP OF 15% MIX

ASTM D 698 (Standard), ASTM D 1557 (Modified)

Density	**Trail No**					
Determination No	1	2	3	4	5	6
Mass of mould + compacted soil M 1(g)	3465	3545	3625.5	3731	3788	3774.0
Mass of mould (M 2) g	1759.0	1759.0	1759.0	1759.0	1759.0	1759.0
Volume of Mould (Cubic Cm)	943	943	943	943	943	943
Mass of compacted soil (g) M3	1706	1786	1867	1972	2029	2015
Wet Density (gm/Cc) ɣwet	1.81	1.9	2.0	2.1	2.2	2.1
Dry density (ɣdry)	1.68	1.71	1.75	1.79	1.82	1.78
Dry density (ɣdry)	16.43	16.77	17.16	17.55	17.85	17.47
Moisture Content	**Trail No**					
Determination No	1	2	3	4	5	6
Mass of container + wet soil = M1 (g)	46.7	51.9	46.0	46.7	117.9	55.3
Mass of container + Dry soil = M2 (g)	44.1	47.9	41.8	41.5	102.9	47.9
Mass of Container (M3)	11.6	10.8	9.8	10.6	20.6	11.0
Mass of water = M1 – M2 (g)	2.6	4.0	4.2	5.2	15.0	7.4
Mass of Dry soil = (M2 – M3) (g)	32.5	37.1	32.0	30.9	82.3	36.9
Water content = W = WW	8.0	10.8	13.1	16.8	18.23	19.9

Optimum Moisture Content (%)	**18.226**
Maxuimum Dry Density (gm/cm3)	**1.820**
Maxuimum Dry Density (KN/m3)	**17.853**

UCC RESULT UNSTABILIZED SOIL TRIAL NO 1

Deformatiom		Axial Strain	strain %	Area	Proving	Load	Axial Load
DR	Deformation			AC	Ring dial	Kg	Kg/Cm2
	(mm)			cm2	Reading		
0	0	0	0	19.63	0	0	0
25	0.25	0.003	0.25	19.68	3	0.46	0.02
50	0.5	0.005	0.50	19.73	7	1.07	0.05
75	0.75	0.008	0.75	19.78	11	1.68	0.08
100	1	0.010	1.00	19.83	18	2.75	0.14
125	1.25	0.013	1.25	19.88	24	3.66	0.18
150	1.5	0.015	1.50	19.93	32	4.88	0.24
175	1.75	0.018	1.75	19.98	46	7.02	0.35
200	2	0.020	2.00	20.04	57	8.70	0.43
225	2.25	0.023	2.25	20.09	67	10.22	0.51
250	2.5	0.025	2.50	20.14	81	12.36	0.61
275	2.75	0.028	2.75	20.19	93	14.19	0.70
300	3	0.030	3.00	20.24	108	16.48	0.81
325	3.25	0.033	3.25	20.29	127	19.38	0.95
350	3.5	0.035	3.50	20.35	138	21.06	1.03
375	3.75	0.038	3.75	20.40	129	19.69	0.96
400	4	0.040	4.00	20.45	120	18.31	0.90

Wt of Sample	408
Dia(cm)	5
hight(Cm)	10
Area(cm2)	19.63
V0lume(cm3)	196.3
density(gm/cm3)	2.08

MC %	14.2
qu (kg/cm2)	1.03
C=qu/2	0.517488911

UCC RESULT UNSTABILIZED SOIL TRIAL NO 2

Deformatiom		Axial Strain	strain %	Area	Proving	Load	Axial Load
DR	Deformation			AC	Ring dial	Kg	Kg/Cm2
	(mm)			cm2	Reading		
0	0	0	0	19.63	0	0	0
25	0.25	0.003	0.25	19.68	3	0.46	0.02
50	0.5	0.005	0.50	19.73	7	1.07	0.05
75	0.75	0.008	0.75	19.78	11	1.68	0.08
100	1	0.010	1.00	19.83	18	2.75	0.14
125	1.25	0.013	1.25	19.88	24	3.66	0.18
150	1.5	0.015	1.50	19.93	32	4.88	0.24
175	1.75	0.018	1.75	19.98	46	7.02	0.35
200	2	0.020	2.00	20.04	57	8.70	0.43
225	2.25	0.023	2.25	20.09	67	10.22	0.51
250	2.5	0.025	2.50	20.14	81	12.36	0.61
275	2.75	0.028	2.75	20.19	93	14.19	0.70
300	3	0.030	3.00	20.24	108	16.48	0.81
325	3.25	0.033	3.25	20.29	127	19.38	0.95
350	3.5	0.035	3.50	20.35	138	21.06	1.03
375	3.75	0.038	3.75	20.40	129	19.69	0.96
400	4	0.040	4.00	20.45	120	18.31	0.90

Wt of Sample	408
Dia(cm)	5
hight(Cm)	10
Area(cm2)	19.63
V0lume(cm3)	196.3
density(gm/cm3)	2.08

MC %	14.2
qu (kg/cm2)	1.03
C=qu/2	0.517488911

UCC RESULT UNSTABILIZED SOIL TRIAL NO 3

Deformatiom		Axial Strain	strain %	Area	Proving	Load	Axial Load
DR	Deformation			AC	Ring dial	Kg	Kg/Cm2
	(mm)			cm2	Reading		
0	0	0	0	19.63	0	0	0
25	0.25	0.003	0.25	19.68	2	0.31	0.02
50	0.5	0.005	0.50	19.73	5	0.76	0.04
75	0.75	0.008	0.75	19.78	11	1.68	0.08
100	1	0.010	1.00	19.83	19	2.90	0.15
125	1.25	0.013	1.25	19.88	28	4.27	0.21
150	1.5	0.015	1.50	19.93	37	5.65	0.28
175	1.75	0.018	1.75	19.98	48	7.32	0.37
200	2	0.020	2.00	20.04	59	9.00	0.45
225	2.25	0.023	2.25	20.09	74	11.29	0.56
250	2.5	0.025	2.50	20.14	89	13.58	0.67
275	2.75	0.028	2.75	20.19	102	15.57	0.77
300	3	0.030	3.00	20.24	115	17.55	0.87
325	3.25	0.033	3.25	20.29	128	19.53	0.96
350	3.5	0.035	3.50	20.35	129	19.69	0.97
375	3.75	0.038	3.75	20.40	123	18.77	0.92
400	4	0.040	4.00	20.45	114	17.40	0.85

Wt of Sample	398.5
Dia(cm)	5
hight(Cm)	10
Area(cm2)	19.63
V0lume(cm3)	196.3
density(gm/cm3)	2.03
MC %	13.1
qu (kg/cm2)	0.97
C=qu/2	0.483739634

UCC RESULT STABILIZED 5% MIXTURE TRIAL NO 1

	Axial Strain	strain %	Area	Proving	Load	Axial Load
Deformation			AC	Ring dial	Kg	Kg/Cm2
(mm)			cm2	Reading		
0.00	0.00	0.00	19.63	0.00	0.00	0.00
0.25	0.00	0.25	19.68	2.00	0.31	0.02
0.50	0.01	0.50	19.73	4.00	0.61	0.03
0.75	0.01	0.75	19.78	6.00	0.92	0.05
1.00	0.01	1.00	19.83	9.00	1.37	0.07
1.25	0.01	1.25	19.88	11.00	1.68	0.08
1.50	0.02	1.50	19.93	16.00	2.44	0.12
1.75	0.02	1.75	19.98	20.00	3.05	0.15
2.00	0.02	2.00	20.04	26.00	3.97	0.20
2.25	0.02	2.25	20.09	31.00	4.73	0.24
2.50	0.03	2.50	20.14	37.00	5.65	0.28
2.75	0.03	2.75	20.19	44.00	6.71	0.33
3.00	0.03	3.00	20.24	51.00	7.78	0.38
3.25	0.03	3.25	20.29	60.00	9.16	0.45
3.50	0.04	3.50	20.35	69.00	10.53	0.52
3.75	0.04	3.75	20.40	76.00	11.60	0.57
4.00	0.04	4.00	20.45	86.00	13.12	0.64
4.25	0.04	4.25	20.51	95.00	14.50	0.71
4.50	0.05	4.50	20.56	105.00	16.02	0.78
4.75	0.05	4.75	20.61	110.00	16.79	0.81
5.00	0.05	5.00	20.67	121.00	18.46	0.89
5.25	0.05	5.25	20.72	130.00	19.84	0.96
5.50	0.06	5.50	20.78	141.00	21.52	1.04
5.75	0.06	5.75	20.83	151.00	23.04	1.11
6.00	0.06	6.00	20.89	161.00	24.57	1.18
6.25	0.06	6.25	20.94	171.00	26.09	1.25
6.50	0.07	6.50	21.00	182.00	27.77	1.32
6.75	0.07	6.75	21.06	188.00	28.69	1.36
7.00	0.07	7.00	21.11	192.00	29.30	1.39
7.25	0.07	7.25	21.17	185.00	28.23	1.33
7.50	0.08	7.50	21.23	180.00	27.47	1.29

Wt of Sample	407.9
Dia(cm)	5
hight(Cm)	10
Area(cm2)	19.63
V0lume(cm3)	196.3
density(gm/cm3)	2.08

Total Mass Wet (M1)	(g)	40.60
Total Mass Dry (M2)	"	38.00
Mass of Container (M3)	"	21.50
Mass of water = M1 – M2	"	2.60
Mass of Dry soil = (M2 – M3)	"	16.50
Moisture content	%	15.76

qu (kg/cm2)	1.39
C=qu/2	0.693871141

UCC RESULT STABILIZED 5% MIXTURE TRIAL NO 2

Deformatio m		Axial Strai n	strai n %	Area	Proving	Load	Axial Load
DR	Deformatio n			AC	Ring dial	Kg	Kg/Cm 2
	(mm)			cm2	Reading		
0.00	0.00	0.00	0.00	19.63	0.00	0.00	0.00
25.00	0.25	0.00	0.25	19.68	2.50	0.38	0.02
50.00	0.50	0.01	0.50	19.73	6.00	0.92	0.05
75.00	0.75	0.01	0.75	19.78	9.00	1.37	0.07
100.00	1.00	0.01	1.00	19.83	11.00	1.68	0.08
125.00	1.25	0.01	1.25	19.88	15.00	2.29	0.12
150.00	1.50	0.02	1.50	19.93	20.00	3.05	0.15
175.00	1.75	0.02	1.75	19.98	24.00	3.66	0.18
200.00	2.00	0.02	2.00	20.04	30.00	4.58	0.23
225.00	2.25	0.02	2.25	20.09	38.00	5.80	0.29
250.00	2.50	0.03	2.50	20.14	47.00	7.17	0.36
275.00	2.75	0.03	2.75	20.19	57.00	8.70	0.43
300.00	3.00	0.03	3.00	20.24	69.00	10.53	0.52
325.00	3.25	0.03	3.25	20.29	79.00	12.06	0.59
350.00	3.50	0.04	3.50	20.35	91.00	13.89	0.68
375.00	3.75	0.04	3.75	20.40	104.00	15.87	0.78
400.00	4.00	0.04	4.00	20.45	118.00	18.01	0.88
425.00	4.25	0.04	4.25	20.51	126.00	19.23	0.94
450.00	4.50	0.05	4.50	20.56	132.00	20.14	0.98
475.00	4.75	0.05	4.75	20.61	144.00	21.97	1.07
500.00	5.00	0.05	5.00	20.67	155.00	23.65	1.14
525.00	5.25	0.05	5.25	20.72	168.00	25.64	1.24
550.00	5.50	0.06	5.50	20.78	178.00	27.16	1.31
575.00	5.75	0.06	5.75	20.83	188.00	28.69	1.38
600.00	6.00	0.06	6.00	20.89	198.00	30.21	1.45
625.00	6.25	0.06	6.25	20.94	204.00	31.13	1.49
650.00	6.50	0.07	6.50	21.00	206.00	31.44	1.50
675.00	6.75	0.07	6.75	21.06	207.00	31.59	1.50
700.00	7.00	0.07	7.00	21.11	202.00	30.83	1.46
725.00	7.25	0.07	7.25	21.17	193.00	29.45	1.39
750.00	7.50	0.08	7.50	21.23	184.00	28.08	1.32

Wt of Sample	405.1
Dia(cm)	5
hight(Cm)	10
Area(cm2)	19.63
V0lume(cm3)	196.3
density(gm/cm3)	2.06

Total Mass Wet (M1)	(g)	55.30
Total Mass Dry (M2)	"	50.50
Mass of Container (M3)	"	20.90
Mass of water = M1 – M2	"	4.80
Mass of Dry soil = (M2 – M3)	"	29.60
Moisture content	%	16.22

qu (kg/cm2)	1.50
C=qu/2	0.750090791

UCC RESULT STABILIZED 5% MIXTURE TRIAL NO 3

Deformatio m		Axial Strai n	strain %	Area	Proving	Loa d	Axial Load
DR	Deformatio n			AC	Ring dial	Kg	Kg/Cm 2
	(mm)			cm2	Reading		
0.00	0.00	0.00	0.00	19.63	0.00	0.00	0.00
25.00	0.25	0.00	0.25	19.68	6.00	0.92	0.05
50.00	0.50	0.01	0.50	19.73	8.00	1.22	0.06
75.00	0.75	0.01	0.75	19.78	11.00	1.68	0.08
100.00	1.00	0.01	1.00	19.83	16.00	2.44	0.12
125.00	1.25	0.01	1.25	19.88	21.00	3.20	0.16
150.00	1.50	0.02	1.50	19.93	27.00	4.12	0.21
175.00	1.75	0.02	1.75	19.98	30.00	4.58	0.23
200.00	2.00	0.02	2.00	20.04	34.00	5.19	0.26
225.00	2.25	0.02	2.25	20.09	45.00	6.87	0.34
250.00	2.50	0.03	2.50	20.14	54.00	8.24	0.41
275.00	2.75	0.03	2.75	20.19	65.00	9.92	0.49
300.00	3.00	0.03	3.00	20.24	72.00	10.99	0.54
325.00	3.25	0.03	3.25	20.29	84.00	12.82	0.63
350.00	3.50	0.04	3.50	20.35	90.00	13.73	0.67
375.00	3.75	0.04	3.75	20.40	96.00	14.65	0.72
400.00	4.00	0.04	4.00	20.45	103.00	15.72	0.77
425.00	4.25	0.04	4.25	20.51	110.00	16.79	0.82
450.00	4.50	0.05	4.50	20.56	116.00	17.70	0.86
475.00	4.75	0.05	4.75	20.61	121.00	18.46	0.90
500.00	5.00	0.05	5.00	20.67	135.00	20.60	1.00
525.00	5.25	0.05	5.25	20.72	144.00	21.97	1.06
550.00	5.50	0.06	5.50	20.78	158.00	24.11	1.16
575.00	5.75	0.06	5.75	20.83	171.00	26.09	1.25
600.00	6.00	0.06	6.00	20.89	183.00	27.93	1.34
625.00	6.25	0.06	6.25	20.94	196.00	29.91	1.43
650.00	6.50	0.07	6.50	21.00	204.00	31.13	1.48
675.00	6.75	0.07	6.75	21.06	210.00	32.05	1.52
700.00	7.00	0.07	7.00	21.11	217.00	33.11	1.57
725.00	7.25	0.07	7.25	21.17	200.00	30.52	1.44
750.00	7.50	0.08	7.50	21.23	191.00	29.15	1.37

Wt of Sample	401.8
Dia(cm)	5
hight(Cm)	10
Area(cm2)	19.63
V0lume(cm3)	196.3
density(gm/cm3)	2.05

Total Mass Wet (M1)	(g)	45.8
Total Mass Dry (M2)	"	40.9
Mass of Container (M3)	"	11.5
Mass of water = M1 – M2	"	4.9
Mass of Dry soil = (M2 – M3)	"	29.4
Moisture content	%	16.667

qu (kg/cm2)	1.57
C=qu/2	0.784218946

UCC RESULT STABILIZED 10% MIXTURE TRIAL NO 1

Deformatiom		Axial Strain	strain %	Area	Proving	Load	Axial Load
DR	Deformation			AC	Ring dial	Kg	Kg/Cm2
	(mm)			cm2	Reading		
0	0	0	0	19.63	0	0	0
25	0.25	0.003	0.25	19.68	14	2.14	0.11
50	0.5	0.005	0.50	19.73	32	4.88	0.25
75	0.75	0.008	0.75	19.78	52	7.94	0.40
100	1	0.010	1.00	19.83	78	11.90	0.60
125	1.25	0.013	1.25	19.88	109	16.63	0.84
150	1.5	0.015	1.50	19.93	148	22.58	1.13
175	1.75	0.018	1.75	19.98	168	25.64	1.28
200	2	0.020	2.00	20.04	196	29.91	1.49
225	2.25	0.023	2.25	20.09	222	33.88	1.69
250	2.5	0.025	2.50	20.14	246	37.54	1.86
275	2.75	0.028	2.75	20.19	266	40.59	2.01
300	3	0.030	3.00	20.24	280	42.73	2.11
325	3.25	0.033	3.25	20.29	287	43.80	2.16
350	3.5	0.035	3.50	20.35	280	42.73	2.10
375	3.75	0.038	3.75	20.40	265	40.44	1.98
400	4	0.040	4.00	20.45	240	36.62	1.79

Wt of Sample	403.3
Dia(cm)	5
height(Cm)	10
Area(cm2)	19.63
V0lume(cm3)	196.3
density(gm/cm3)	2.05

Total Mass Wet (M1)	(g)	52.90
Total Mass Dry (M2)	"	49.00
Mass of Container (M3)	"	20.60
Mass of water = M1 – M2	"	3.90
Mass of Dry soil = (M2 – M3)	"	28.40
Moisture content	%	13.73

qu (kg/cm2)	2.16
C=qu/2	1.07901509

UCC RESULT STABILIZED 10% MIXTURE TRIAL NO 2

Deformatiom		Axial Strain	strain %	Area	Proving	Load	Axial Load
DR	Deformation			AC	Ring dial	Kg	Kg/Cm2
	(mm)			cm2	Reading		
0	0	0	0	19.63495408	0	0	0
25	0.25	0.003	0.25	19.68	6	0.92	0.05
50	0.5	0.005	0.50	19.73	16	2.44	0.12
75	0.75	0.008	0.75	19.78	26	3.97	0.20
100	1	0.010	1.00	19.83	41	6.26	0.32
125	1.25	0.013	1.25	19.88	60	9.16	0.46
150	1.5	0.015	1.50	19.93	84	12.82	0.64
175	1.75	0.018	1.75	19.98	104	15.87	0.79
200	2	0.020	2.00	20.04	142	21.67	1.08
225	2.25	0.023	2.25	20.09	181	27.62	1.38
250	2.5	0.025	2.50	20.14	206	31.44	1.56
275	2.75	0.028	2.75	20.19	227	34.64	1.72
300	3	0.030	3.00	20.24	244	37.23	1.84
325	3.25	0.033	3.25	20.29	256	39.07	1.92
350	3.5	0.035	3.50	20.35	263	40.13	1.97
375	3.75	0.038	3.75	20.40	261	39.83	1.95
400	4	0.040	4.00	20.45	240	36.62	1.79

Wt of Sample	404.4
Dia(cm)	5
hight(Cm)	10
Area(cm2)	19.63
V0lume(cm3)	196.3
density(gm/cm3)	2.06

Total Mass Wet (M1)	(g)	70.10
Total Mass Dry (M2)	"	64.00
Mass of Container (M3)	"	21.10
Mass of water = M1 – M2	"	6.10
Mass of Dry soil = (M2 – M3)	"	42.90
Moisture content	%	14.22

qu (kg/cm2)	1.97
C=qu/2	0.986228866

UCC RESULT STABILIZED 10% MIXTURE TRIAL NO 3

Deformatiom		Axial Strain	strain %	Area	Proving	Load	Axial Load
DR	Deformation			AC	Ring dial	Kg	Kg/Cm2
	(mm)			cm2	Reading		
0	0	0	0	19.63	0	0	0
25	0.25	0.003	0.25	19.68	18	2.75	0.14
50	0.5	0.005	0.50	19.73	36	5.49	0.28
75	0.75	0.008	0.75	19.78	51	7.78	0.39
100	1	0.010	1.00	19.83	69	10.53	0.53
125	1.25	0.013	1.25	19.88	87	13.28	0.67
150	1.5	0.015	1.50	19.93	107	16.33	0.82
175	1.75	0.018	1.75	19.98	128	19.53	0.98
200	2	0.020	2.00	20.04	146	22.28	1.11
225	2.25	0.023	2.25	20.09	172	26.25	1.31
250	2.5	0.025	2.50	20.14	193	29.45	1.46
275	2.75	0.028	2.75	20.19	212	32.35	1.60
300	3	0.030	3.00	20.24	231	35.25	1.74
325	3.25	0.033	3.25	20.29	247	37.69	1.86
350	3.5	0.035	3.50	20.35	262	39.98	1.96
375	3.75	0.038	3.75	20.40	275	41.97	2.06
400	4	0.040	4.00	20.45	260	39.68	1.94

Total Mass Wet (M1)	**(g)**	**57.20**
Total Mass Dry (M2)	**"**	**52.50**
Mass of Container (M3)	**"**	**19.10**
Mass of water = M1 – M2	**"**	**4.70**
Mass of Dry soil = (M2 – M3)	**"**	**33.40**
Moisture content	**%**	**14.07**

Wt of Sample	**406.1**
Dia(cm)	**5**
hight(Cm)	**10**
Area(cm2)	**19.63**
V0lume(cm3)	**196.3**
density(gm/cm3)	**2.07**

qu (kg/cm2)	**2.06**
C=qu/2	**1.028556327**

UCC RESULT STABILIZED 15% MIXTURE TRIAL NO 1

Deformation			AC	Ring dial	Kg	Kg/Cm2
(mm)			cm2	Reading		
0	0	0	19.63	0	0	0
0.25	0.003	0.25	19.68	5	0.76	0.04
0.5	0.005	0.50	19.73	11	1.68	0.09
0.75	0.008	0.75	19.78	18	2.75	0.14
1	0.010	1.00	19.83	30	4.58	0.23
1.25	0.013	1.25	19.88	53	8.09	0.41
1.5	0.015	1.50	19.93	77	11.75	0.59
1.75	0.018	1.75	19.98	101	15.41	0.77
2	0.020	2.00	20.04	126	19.23	0.96
2.25	0.023	2.25	20.09	152	23.20	1.15
2.5	0.025	2.50	20.14	173	26.40	1.31
2.75	0.028	2.75	20.19	195	29.76	1.47
3	0.030	3.00	20.24	215	32.81	1.62
3.25	0.033	3.25	20.29	231	35.25	1.74
3.5	0.035	3.50	20.35	244	37.23	1.83
3.75	0.038	3.75	20.40	252	38.46	1.89
4	0.040	4.00	20.45	240	36.62	1.79

Total Mass Wet (M1)	**(g)**	**31.40**
Total Mass Dry (M2)	**"**	**28.60**
Mass of Container (M3)	**"**	**9.08**
Mass of water = M1 – M2	**"**	**2.80**
Mass of Dry soil = (M2 – M3)	**"**	**19.52**
Moisture content	**%**	**14.34**

Wt of Sample	**399.2**
Dia(cm)	**5**
hight(Cm)	**10**
Area(cm2)	**19.63**
V0lume(cm3)	**196.3**
density(gm/cm3)	**2.03**

qu (kg/cm2)	**1.89**
C=qu/2	**0.942531616**

UCC RESULT STABILIZED 15% MIXTURE TRIAL NO 2

Deformatiom		Axial Strain	strain %	Area	Proving	Load	Axial Load
DR	Deformation			AC	Ring dial	Kg	Kg/Cm2
	(mm)			cm2	Reading		
0	0	0	0	19.63495408	0	0	0
25	0.25	0.003	0.25	19.68	7	1.07	0.05
50	0.5	0.005	0.50	19.73	15	2.29	0.12
75	0.75	0.008	0.75	19.78	33	5.04	0.25
100	1	0.010	1.00	19.83	59	9.00	0.45
125	1.25	0.013	1.25	19.88	87	13.28	0.67
150	1.5	0.015	1.50	19.93	131	19.99	1.00
175	1.75	0.018	1.75	19.98	157	23.96	1.20
200	2	0.020	2.00	20.04	181	27.62	1.38
225	2.25	0.023	2.25	20.09	205	31.28	1.56
250	2.5	0.025	2.50	20.14	216	32.96	1.64
275	2.75	0.028	2.75	20.19	244	37.23	1.84
300	3	0.030	3.00	20.24	258	39.37	1.94
325	3.25	0.033	3.25	20.29	268	40.90	2.02
350	3.5	0.035	3.50	20.35	262	39.98	1.96
375	3.75	0.038	3.75	20.40	256	39.07	1.91
400	4	0.040	4.00	20.45	246	37.54	1.84

Wt of Sample	**398**
Dia(cm)	**5**
hight(Cm)	**10**
Area(cm2)	**19.63**
V0lume(cm3)	**196.3**
density(gm/cm3)	**2.03**

Total Mass Wet (M1)	**(g)**	**35.80**
Total Mass Dry (M2)	**"**	**32.90**
Mass of Container (M3)	**"**	**12.39**
Mass of water = M1 – M2	**"**	**2.90**
Mass of Dry soil = (M2 – M3)	**"**	**20.51**
Moisture content	**%**	**14.14**

qu (kg/cm2)	**2.02**
C=qu/2	**1.007582035**

UCC RESULT STABILIZED 15% MIXTURE TRIAL NO 3

Deformatiom		Axial Strain	strain %	Area	Proving	Load	Axial Load
DR	Deformation			AC	Ring dial	Kg	Kg/Cm2
	(mm)			cm2	Reading		
0	0	0	0	19.63	0	0	0
25	0.25	0.003	0.25	19.68	6	0.92	0.05
50	0.5	0.005	0.50	19.73	14	2.14	0.11
75	0.75	0.008	0.75	19.78	28	4.27	0.22
100	1	0.010	1.00	19.83	51	7.78	0.39
125	1.25	0.013	1.25	19.88	84	12.82	0.64
150	1.5	0.015	1.50	19.93	117	17.85	0.90
175	1.75	0.018	1.75	19.98	146	22.28	1.11
200	2	0.020	2.00	20.04	175	26.71	1.33
225	2.25	0.023	2.25	20.09	201	30.67	1.53
250	2.5	0.025	2.50	20.14	220	33.57	1.67
275	2.75	0.028	2.75	20.19	235	35.86	1.78
300	3	0.030	3.00	20.24	242	36.93	1.82
325	3.25	0.033	3.25	20.29	245	37.39	1.84
350	3.5	0.035	3.50	20.35	242	36.93	1.81
375	3.75	0.038	3.75	20.40	240	36.62	1.80
400	4	0.040	4.00	20.45	220	33.57	1.64

Wt of Sample	394
Dia(cm)	5
hight(Cm)	10
Area(cm2)	19.63
V0lume(cm3)	196.3
density(gm/cm3)	2.01

Total Mass Wet (M1)	(g)	45.10
Total Mass Dry (M2)	"	40.80
Mass of Container (M3)	"	10.90
Mass of water = M1 – M2	"	4.30
Mass of Dry soil = (M2 – M3)	"	29.90
Moisture content	%	14.38

qu (kg/cm2)	1.84
C=qu/2	0.921110443

CBR RESULT SOAKED UNSTABILIZED SOIL

Penetration		10Blows		30Blows		65Blows	
mm	in	DR	Stress	DR	Stress	DR	Stress
0	0	0	0.0	4	5.4	5	6.7
0.64	0.025	0.5	0.7	8	10.8	10	13.5
1.27	0.05	1	1	10	13.5	20	26.9
1.9	0.075	2	2.7	12	16.1	30	40.4
2.54	**0.1**	**2.5**	**3.4**	**14**	**18.8**	**41**	**55.1**
3.17	0.125	3	4.0	16	21.5	48	64.6
3.81	0.15	3.25	4.4	18	24.2	51	68.6
4.44	0.175	3.5	4.7	20	26.9	59	79.4
5.08	**0.2**	**4**	**5.4**	**24**	**32.3**	**65**	**87.4**
5.7	0.225	4.25	5.7	27	36.3	71	95.5
6.35	0.25	4.5	6.1	30	40.4	81	108.9
7	0.275	5	6.7	31	41.7	92	123.7
7.62	0.3	5.25	7.1	33	44.4	98	131.8

Moisture Content				
	10 blows	30 blows	65 blows	Avergae
W1	31.3	52.9	34.3	
W2	27.6	46	31	
W3	11.4	11.5	11.5	
Ww	3.7	6.9	3.3	
Ws	16.2	34.5	19.5	
M.C %	**22.8**	**20.0**	**16.9**	**19.9**

Density	*10 Blows*	*30Blows*	*65 Blows*
W1	11672.8	11899	12033
W2	7211	7178	7134
W3	4461.8	4721	4899
Voulme	2123	2123	2123
Wet Den	2.1	2.2	2.3
Dry Den g/Cm3	1.7	1.9	2.0
Dry Den KN/m3	**16.8**	**18.2**	**19.4**

10Blows	30Blows	65Blows
Stress in KN/m^2		
0.0	37.1	46.4
4.6	74.2	92.7
9.3	92.7	185.5
18.5	111.3	278.2
23.2	129.8	380.2
27.8	148.4	445.1
30.1	166.9	472.9
32.5	185.5	547.1
37.1	222.6	602.8
39.4	250.4	658.4
41.7	278.2	751.1
46.4	287.5	853.2
48.7	306.0	908.8

CBR RESULT SOAKED 5% MIXTURE

Penetration		10Blows		30Blows		65Blows	
mm	in	DR	Stress	DR	Stress	DR	Stress
0	0	0	0.0	5	6.7	8	10.8
0.64	0.025	1	1.3	9	12.1	12	16.1
1.27	0.05	1.75	2	13	17.5	20	26.9
1.9	0.075	2.5	3.4	15	20.2	31	41.7
2.54	**0.1**	**3**	**4.0**	**17**	**22.9**	**37**	**49.8**
3.17	0.125	4.5	6.1	19	25.6	44	59.2
3.81	0.15	4.75	6.4	23	30.9	51	68.6
4.44	0.175	5	6.7	26	35.0	61	82.0
5.08	**0.2**	**5.25**	**7.1**	**29**	**39.0**	**68**	**91.5**
5.7	0.225	5.5	7.4	33	44.4	76	102.2
6.35	0.25	5.75	7.7	36	48.4	87	117.0
7	0.275	6	8.1	41	55.1	96	129.1
7.62	0.3	6.25	8.4	43	57.8	103	138.5

Density	*10 Blows*	*30Blows*	*65 Blows*
W1	11244	12875	13423
W2	7035	8475	8665
W3	4209	4400	4758
Volume	2123	2123	2123
Wet Den	2.0	2.1	2.2
Dry Den g/Cm3	1.6	1.8	1.9
Dry Den KN/m3	**16.0**	**17.3**	**19.0**

10Blows	30Blows	65Blows
Stress in KN/m^2		
0.0	46.4	74.2
9.3	83.5	111.3
16.2	120.6	185.5
23.2	139.1	287.5
27.8	157.6	343.1
41.7	176.2	408.0
44.0	213.3	472.9
46.4	241.1	565.7
48.7	268.9	630.6
51.0	306.0	704.8
53.3	333.8	806.8
55.6	380.2	890.3
58.0	398.8	955.2

Moisture Content				
	10 blows	**30 blows**	**65 blows**	**Avergae**
W1	48	41.1	34.8	
W2	41.8	36.4	31.6	
W3	12.5	9.1	11.2	
Ww	6.2	4.7	3.2	
Ws	29.3	27.3	20.4	
M.C %	**21.2**	**17.2**	**15.7**	**18.0**

CBR RESULT SOAKED 10% MIXTURE

Penetration		10Blows		30Blows		65Blows	
mm	in	DR	Stress	DR	Stress	DR	Stress
0	0	0	0.0	6	8.1	9	12.1
0.64	0.025	2	2.7	12	16.1	14	18.8
1.27	0.05	3	4	17	22.9	23	30.9
1.9	0.075	4.5	6.1	20	26.9	33	44.4
2.54	**0.1**	**6**	**8.1**	**23**	**30.9**	**42**	**56.5**
3.17	0.125	7	9.4	27	36.3	49	65.9
3.81	0.15	8	10.8	31	41.7	58	78.0
4.44	0.175	9.5	12.8	37	49.8	67	90.1
5.08	**0.2**	**10**	**13.5**	**42**	**56.5**	**79**	**106.3**
5.7	0.225	10.25	13.8	45	60.5	86	115.7
6.35	0.25	11	14.8	48	64.6	94	126.4
7	0.275	12	16.1	51	68.6	101	135.8
7.62	0.3	12.5	16.8	52	69.9	109	146.6

Density	*10 Blows*	*30Blows*	*65 Blows*
W1	10389	11786	12861
W2	6244	7416	8034
W3	4145	4370	4827
Volume	2123	2123	2123
Wet Den	2.0	2.1	2.3
Dry Den g/Cm3	1.7	1.8	2.0
Dry Den KN/m3	**16.3**	**17.3**	**19.3**

Moisture Content				
	10 blows	**30 blows**	**65 blows**	**Avergae**
W1	35.8	31.6	34.6	
W2	32	28.6	31.5	
W3	10.5	10.6	11.4	
Ww	3.8	3	3.1	
Ws	21.5	18	20.1	
M.C %	**17.7**	**16.7**	**15.4**	**16.6**

10Blows	30Blows	65Blows
Stress in KN/m^2		
0.0	55.6	83.5
18.5	111.3	129.8
27.8	157.6	213.3
41.7	185.5	306.0
55.6	213.3	389.5
64.9	250.4	454.4
74.2	287.5	537.9
88.1	343.1	621.3
92.7	389.5	732.6
95.1	417.3	797.5
102.0	445.1	871.7
111.3	472.9	936.6
115.9	482.2	1010.8

CBR RESULT SOAKED 15% MIXTURE

Penetration		10Blows		30Blows		65Blows	
mm	in	DR	Stress	DR	Stress	DR	Stress
0	0	0	0.0	7	9.4	11	14.8
0.64	0.025	1.25	1.7	12	16.1	14	18.8
1.27	0.05	1.75	2	16	21.5	23	30.9
1.9	0.075	2.75	3.7	20	26.9	33	44.4
2.54	**0.1**	**3.5**	**4.7**	**23**	**30.9**	**36**	**48.4**
3.17	0.125	5	6.7	29	39.0	41	55.1
3.81	0.15	5.25	7.1	35	47.1	50	67.3
4.44	0.175	6	8.1	42	56.5	60	80.7
5.08	**0.2**	**6.5**	**8.7**	**47**	**63.2**	**69**	**92.8**
5.7	0.225	7	9.4	52	69.9	77	103.6
6.35	0.25	7.25	9.8	57	76.7	85	114.3
7	0.275	7.75	10.4	61	82.0	94	126.4
7.62	0.3	8	10.8	64	86.1	102	137.2

Density	*10 Blows*	*30Blows*	*65 Blows*
W1	11720	12059	11887
W2	7287	7463	7048
W3	4433	4596	4839
Volume	2123	2123	2123
Wet Den	2.1	2.2	2.3
Dry Den g/Cm3	1.8	1.9	2.0
Dry Den KN/m3	**17.5**	**18.2**	**19.3**

10Blows	30Blows	65Blows
Stress in KN/m^2		
0.0	64.9	102.0
11.6	111.3	129.8
16.2	148.4	213.3
25.5	185.5	306.0
32.5	213.3	333.8
46.4	268.9	380.2
48.7	324.6	463.7
55.6	389.5	556.4
60.3	435.9	639.9
64.9	482.2	714.1
67.2	528.6	788.2
71.9	565.7	871.7
74.2	593.5	945.9

Moisture Content				
	10 blows	**30 blows**	**65 blows**	**Avergae**
W1	34.2	29.4	26.56	
W2	30.6	26.9	24.4	
W3	9.8	11.6	10.6	
Ww	3.6	2.5	2.16	
Ws	20.8	15.3	13.8	
M.C %	**17.3**	**16.3**	**15.7**	**16.4**

CBR RESULT UNSOAKED NON CURED UNSTABILIZED SOIL

Penetration		10Blows		30Blows		65Blows	
mm	in	DR	Stress	DR	Stress	DR	Stress
0	0	0	0.0	0	0.0	0	0.0
0.64	0.025	5	6.7	7	9.4	12	16.1
1.27	0.05	9	12	11	14.8	30	40.4
1.9	0.075	11	14.8	23	30.9	47	63.2
2.54	**0.1**	**13**	**17.5**	**38**	**51.1**	**63**	**84.7**
3.17	0.125	16	21.5	43	57.8	76	102.2
3.81	0.15	19	25.6	47	63.2	87	117.0
4.44	0.175	23	30.9	51	68.6	98	131.8
5.08	**0.2**	**28**	**37.7**	**63**	**84.7**	**109**	**146.6**
5.7	0.225	31	41.7	69	92.8	118	158.7
6.35	0.25	33	44.4	78	104.9	127	170.8
7	0.275	37	49.8	86	115.7	139	187.0
7.62	0.3	41	55.1	95	127.8	150	201.8

Density	*10 Blows*	*30Blows*	*65 Blows*
W1	11194.1	11526	11873.5
W2	7077.8	7122	7240
W3	4116.3	4404	4633.5
Voum	2123	2123	2123
Wet Den	1.9	2.1	2.2
Dry Den g/Cm3	1.7	1.8	1.9
Dry Den KN/m3	**16.4**	**17.5**	**18.4**

Moisture Content	
W1	88.2
W2	78.7
W3	19.36
Ww	9.5
Ws	59.34
M.C %	**16.0**

10Blows	30Blows	65Blows
Stress in KN/m^2		
0.0	0.0	0.0
46.4	64.9	111.3
83.5	102.0	278.2
102.0	213.3	435.9
120.6	352.4	584.2
148.4	398.8	704.8
176.2	435.9	806.8
213.3	472.9	908.8
259.7	584.2	1010.8
287.5	639.9	1094.3
306.0	723.3	1177.7
343.1	797.5	1289.0
380.2	881.0	1391.0

CBR RESULT UNSOAKED NON CURED 5% MIXTURE

Penetration		10Blows		30Blows		65Blows	
mm	in	DR	Stress	DR	Stress	DR	Stress
0	0	0	0.0	0	0.0	0	0.0
0.64	0.025	6	8.1	11	14.8	23	30.9
1.27	0.05	9	12	22	29.6	40	53.8
1.9	0.075	13	17.5	33	44.4	51	68.6
2.54	**0.1**	**18**	**24.2**	**42**	**56.5**	**68**	**91.5**
3.17	0.125	23	30.9	49	65.9	79	106.3
3.81	0.15	28	37.7	56	75.3	91	122.4
4.44	0.175	33	44.4	63	84.7	101	135.8
5.08	**0.2**	**38**	**51.1**	**71**	**95.5**	**114**	**153.3**
5.7	0.225	43	57.8	79	106.3	121	162.7
6.35	0.25	47	63.2	86	115.7	130	174.9
7	0.275	51	68.6	92	123.7	141	189.6
7.62	0.3	56	75.3	99	133.2	153	205.8

Density	*10 Blows*	*30Blows*	*65 Blows*
W1	11093.1	11483.5	11841.5
W2	7051.8	7121	7243
W3	4041.3	4362.5	4598.5
Voum	2123	2123	2123
Wet Den	1.9	2.1	2.2
Dry Den g/Cm3	1.6	1.8	1.9
Dry Den KN/m3	**16.1**	**17.3**	**18.3**

10Blows	30Blows	65Blows
Stress in KN/m^2		
0.0	0.0	0.0
55.6	102.0	213.3
83.5	204.0	370.9
120.6	306.0	472.9
166.9	389.5	630.6
213.3	454.4	732.6
259.7	519.3	843.9
306.0	584.2	936.6
352.4	658.4	1057.2
398.8	732.6	1122.1
435.9	797.5	1205.5
472.9	853.2	1307.6
519.3	918.1	1418.8

Moisture Content	
W1	58.6
W2	53.3
W3	20.6
Ww	5.3
Ws	32.7
M.C %	**16.2**

CBR RESULT UNSOAKED NON CURED 10% MIXTURE

Penetration		10Blows		30Blows		65Blows	
mm	in	DR	Stress	DR	Stress	DR	Stress
0	0	0	0.0	0	0.0	0	0.0
0.64	0.025	13	17.5	16	21.5	29	39.0
1.27	0.05	21	28	33	44.4	51	68.6
1.9	0.075	32	43.0	50	67.3	67	90.1
2.54	**0.1**	**43**	**57.8**	**64**	**86.1**	**89**	**119.7**
3.17	0.125	51	68.6	78	104.9	107	143.9
3.81	0.15	62	83.4	89	119.7	119	160.1
4.44	0.175	71	95.5	96	129.1	131	176.2
5.08	**0.2**	**82**	**110.3**	**107**	**143.9**	**146**	**196.4**
5.7	0.225	90	121.1	118	158.7	159	213.9
6.35	0.25	99	133.2	126	169.5	171	230.0
7	0.275	107	143.9	139	187.0	180	242.1
7.62	0.3	118	158.7	145	195.0	191	256.9

Density	*10 Blows*	*30Blows*	*65 Blows*
W1	11063.1	11493.5	11821.5
W2	7051.8	7121	7243
W3	4011.3	4372.5	4578.5
Voum	2123	2123	2123
Wet Den	1.9	2.1	2.2
Dry Den g/Cm3	1.6	1.8	1.8
Dry Den KN/m3	**15.9**	**17.3**	**18.1**

10Blows	30Blows	65Blows
Stress in KN/m^2		
0.0	0.0	0.0
120.6	148.4	268.9
194.7	306.0	472.9
296.8	463.7	621.3
398.8	593.5	825.3
472.9	723.3	992.3
575.0	825.3	1103.5
658.4	890.3	1214.8
760.4	992.3	1353.9
834.6	1094.3	1474.5
918.1	1168.5	1585.8
992.3	1289.0	1669.2
1094.3	1344.7	1771.2

Moisture Content	
W1	62.3
W2	55.09
W3	12.39
Ww	7.21
Ws	42.7
M.C %	**16.9**

CBR RESULT UNSOAKED NON CURED 15% MIXTURE

Penetration		10Blows		30Blows		65Blows	
mm	in	DR	Stress	DR	Stress	DR	Stress
0	0	0	0.0	0	0.0	0	0.0
0.64	0.025	13	17.5	19	25.6	28	37.7
1.27	0.05	21	28	31	41.7	42	56.5
1.9	0.075	28	37.7	38	51.1	59	79.4
2.54	**0.1**	**35**	**47.1**	**52**	**69.9**	**80**	**107.6**
3.17	0.125	41	55.1	59	79.4	91	122.4
3.81	0.15	49	65.9	67	90.1	105	141.2
4.44	0.175	57	76.7	78	104.9	118	158.7
5.08	**0.2**	**66**	**88.8**	**89**	**119.7**	**129**	**173.5**
5.7	0.225	71	95.5	93	125.1	141	189.6
6.35	0.25	75	100.9	101	135.8	156	209.8
7	0.275	79	106.3	109	146.6	163	219.2
7.62	0.3	86	115.7	118	158.7	179	240.8

Density	*10 Blows*	*30Blows*	*65 Blows*
W1	11069.1	11473.5	11833.5
W2	7077.8	7122	7243
W3	3991.3	4351.5	4590.5
Voum	2123	2123	2123
Wet Den	1.9	2.0	2.2
Dry Den g/Cm3	1.6	1.7	1.8
Dry Den KN/m3	**15.7**	**17.1**	**18.0**

10Blows	30Blows	65Blows
Stress in KN/m^2		
0.0	0.0	0.0
120.6	176.2	259.7
194.7	287.5	389.5
259.7	352.4	547.1
324.6	482.2	741.9
380.2	547.1	843.9
454.4	621.3	973.7
528.6	723.3	1094.3
612.0	825.3	1196.3
658.4	862.4	1307.6
695.5	936.6	1446.7
732.6	1010.8	1511.6
797.5	1094.3	1659.9

Moisture Content	
W1	86.3
W2	76.2
W3	19.1
Ww	10.1
Ws	57.1
M.C %	**17.7**

CBR RESULT UNSOAKED UNSTABILIZED 3 DAYS CURED SOIL

Penetration		10Blows		30Blows		65Blows	
mm	in	DR	Stress	DR	Stress	DR	Stress
0	0	0	0.0	0	0.0	0	0.0
0.64	0.025	7	9.4	11	14.8	17	22.9
1.27	0.05	13	17	13	17.5	35	47.1
1.9	0.075	16	21.5	25	33.6	54	72.6
2.54	**0.1**	**18**	**24.2**	**43**	**57.8**	**65**	**87.4**
3.17	0.125	19	25.6	48	64.6	81	108.9
3.81	0.15	24	32.3	55	74.0	84	113.0
4.44	0.175	29	39.0	60	80.7	104	139.9
5.08	**0.2**	**33**	**44.4**	**71**	**95.5**	**118**	**158.7**
5.7	0.225	36	48.4	81	108.9	123	165.4
6.35	0.25	41	55.1	93	125.1	131	176.2
7	0.275	48	64.6	99	133.2	142	191.0
7.62	0.3	51	68.6	104	139.9	156	209.8

Density	*10 Blows*	*30Blows*	*65 Blows*
W1	11194.1	11526	11873.5
W2	7077.8	7122	7240
W3	4116.3	4404	4633.5
Voum	2123	2123	2123
Wet Den	1.9	2.1	2.2
Dry Den g/Cm3	1.7	1.8	1.9
Dry Den KN/m3	**16.4**	**17.5**	**18.4**

10Blows	30Blows	65Blows
Stress in KN/m^2		
0.0	0.0	0.0
64.9	102.0	157.6
120.6	120.6	324.6
148.4	231.8	500.8
166.9	398.8	602.8
176.2	445.1	751.1
222.6	510.0	779.0
268.9	556.4	964.4
306.0	658.4	1094.3
333.8	751.1	1140.6
380.2	862.4	1214.8
445.1	918.1	1316.8
472.9	964.4	1446.7

Moisture Content	
W1	88.2
W2	78.7
W3	19.36
Ww	9.5
Ws	59.34
M.C %	**16.0**

CBR RESULT UNSOAKED UNSTABILIZED 7 DAYS CURED SOIL

Penetration		10Blows		30Blows		65Blows	
mm	in	DR	Stress	DR	Stress	DR	Stress
0	0	0	0.0	0	0.0	0	0.0
0.64	0.025	11	14.8	13	17.5	16	21.5
1.27	0.05	16	22	16	21.5	38	51.1
1.9	0.075	23	30.9	29	39.0	55	74.0
2.54	**0.1**	**29**	**39.0**	**42**	**56.5**	**71**	**95.5**
3.17	0.125	33	44.4	53	71.3	86	115.7
3.81	0.15	41	55.1	59	79.4	93	125.1
4.44	0.175	48	64.6	67	90.1	110	148.0
5.08	**0.2**	**55**	**74.0**	**72**	**96.8**	**123**	**165.4**
5.7	0.225	61	82.0	78	104.9	133	178.9
6.35	0.25	67	90.1	83	111.6	139	187.0
7	0.275	73	98.2	89	119.7	147	197.7
7.62	0.3	79	106.3	97	130.5	161	216.5

Density	*10 Blows*	*30Blows*	*65 Blows*
W1	11209.5	11539.5	11901
W2	7077.8	7122	7240
W3	4131.7	4417.5	4661
Voum	2123	2123	2123
Wet Den	1.9	2.1	2.2
Dry Den g/Cm3	1.7	1.8	1.9
Dry Den KN/m3	**16.4**	**17.6**	**18.5**

Moisture Content	
W1	54.4
W2	49.5
W3	19.36
Ww	4.9
Ws	30.14
M.C %	**16.3**

10Blows	30Blows	65Blows
Stress in KN/m^2		
0.0	0.0	0.0
102.0	120.6	148.4
148.4	148.4	352.4
213.3	268.9	510.0
268.9	389.5	658.4
306.0	491.5	797.5
380.2	547.1	862.4
445.1	621.3	1020.1
510.0	667.7	1140.6
565.7	723.3	1233.4
621.3	769.7	1289.0
677.0	825.3	1363.2
732.6	899.5	1493.0

CBR RESULT UNSOAKED 5% MIXTURE 3 DAYS CURED SOIL

Penetration		10Blows		30Blows		65Blows	
mm	in	DR	Stress	DR	Stress	DR	Stress
0	0	0	0.0	0	0.0	0	0.0
0.64	0.025	9	12.1	14	18.8	28	37.7
1.27	0.05	11	15	25	33.6	45	60.5
1.9	0.075	14	18.8	33	44.4	61	82.0
2.54	**0.1**	**21**	**28.2**	**43**	**57.8**	**75**	**100.9**
3.17	0.125	23	30.9	54	72.6	84	113.0
3.81	0.15	31	41.7	61	82.0	96	129.1
4.44	0.175	37	49.8	69	92.8	110	148.0
5.08	**0.2**	**42**	**56.5**	**75**	**100.9**	**124**	**166.8**
5.7	0.225	48	64.6	84	113.0	131	176.2
6.35	0.25	51	68.6	93	125.1	141	189.6
7	0.275	59	79.4	101	135.8	151	203.1
7.62	0.3	63	84.7	114	153.3	161	216.5

Density	*10 Blows*	*30Blows*	*65 Blows*
W1	11029.1	11495.5	11858.5
W2	7051.8	7121	7243
W3	3977.3	4374.5	4615.5
Voum	2123	2123	2123
Wet Den	1.9	2.1	2.2
Dry Den g/Cm3	1.6	1.8	1.9
Dry Den KN/m3	**15.8**	**17.4**	**18.3**

10Blows	30Blows	65Blows
Stress in KN/m^2		
0.0	0.0	0.0
83.5	129.8	259.7
102.0	231.8	417.3
129.8	306.0	565.7
194.7	398.8	695.5
213.3	500.8	779.0
287.5	565.7	890.3
343.1	639.9	1020.1
389.5	695.5	1149.9
445.1	779.0	1214.8
472.9	862.4	1307.6
547.1	936.6	1400.3
584.2	1057.2	1493.0

Moisture Content	
W1	84.6
W2	75.8
W3	21.5
Ww	8.8
Ws	54.3
M.C %	**16.2**

CBR RESULT UNSOAKED 5% MIXTURE 7 DAYS CURED SOIL

Penetration		10Blows		30Blows		65Blows	
mm	in	DR	Stress	DR	Stress	DR	Stress
0	0	0	0.0	0	0.0	0	0.0
0.64	0.025	9	12.1	15	20.2	29	39.0
1.27	0.05	12	16	26	35.0	48	64.6
1.9	0.075	15	20.2	38	51.1	63	84.7
2.54	**0.1**	**22**	**29.6**	**49**	**65.9**	**77**	**103.6**
3.17	0.125	25	33.6	58	78.0	86	115.7
3.81	0.15	33	44.4	64	86.1	99	133.2
4.44	0.175	39	52.5	69	92.8	118	158.7
5.08	**0.2**	**47**	**63.2**	**78**	**104.9**	**128**	**172.2**
5.7	0.225	51	68.6	87	117.0	133	178.9
6.35	0.25	56	75.3	99	133.2	144	193.7
7	0.275	63	84.7	102	137.2	150	201.8
7.62	0.3	67	90.1	110	148.0	158	212.5

Density	*10 Blows*	*30Blows*	*65 Blows*
W1	11067.1	11453.5	11859.5
W2	7051.8	7121	7243
W3	4015.3	4332.5	4616.5
Voum	2123	2123	2123
Wet Den	1.9	2.0	2.2
Dry Den g/Cm3	1.6	1.8	1.9
Dry Den KN/m3	**15.9**	**17.2**	**18.3**

10Blows	30Blows	65Blows
Stress in KN/m^2		
0.0	0.0	0.0
83.5	139.1	268.9
111.3	241.1	445.1
139.1	352.4	584.2
204.0	454.4	714.1
231.8	537.9	797.5
306.0	593.5	918.1
361.7	639.9	1094.3
435.9	723.3	1187.0
472.9	806.8	1233.4
519.3	918.1	1335.4
584.2	945.9	1391.0
621.3	1020.1	1465.2

Moisture Content	
W1	64.5
W2	58.1
W3	19.36
Ww	6.4
Ws	38.74
M.C %	**16.5**

CBR RESULT UNSOAKED 10% MIXTURE 3 DAYS CURED SOIL

Penetration		10Blows		30Blows		65Blows	
mm	in	DR	Stress	DR	Stress	DR	Stress
0	0	0	0.0	0	0.0	0	0.0
0.64	0.025	16	21.5	15	20.2	38	51.1
1.27	0.05	21	28	38	51.1	62	83.4
1.9	0.075	38	51.1	54	72.6	73	98.2
2.54	**0.1**	**49**	**65.9**	**77**	**103.6**	**99**	**133.2**
3.17	0.125	57	76.7	85	114.3	111	149.3
3.81	0.15	69	92.8	96	129.1	131	176.2
4.44	0.175	78	104.9	108	145.3	148	199.1
5.08	**0.2**	**89**	**119.7**	**124**	**166.8**	**169**	**227.3**
5.7	0.225	93	125.1	132	177.5	171	230.0
6.35	0.25	103	138.5	143	192.3	189	254.2
7	0.275	114	153.3	151	203.1	206	277.1
7.62	0.3	123	165.4	167	224.6	240	322.8

Density	*10 Blows*	*30Blows*	*65 Blows*
W1	11074.1	11499.5	11827.5
W2	7051.8	7121	7243
W3	4022.3	4378.5	4584.5
Voum	2123	2123	2123
Wet Den	1.9	2.1	2.2
Dry Den g/Cm3	1.6	1.8	1.8
Dry Den KN/m3	**15.8**	**17.2**	**18.1**

Moisture Content	
W1	45.2
W2	39.89
W3	9.16
Ww	5.31
Ws	30.73
M.C %	**17.3**

10Blows	30Blows	65Blows
Stress in KN/m^2		
0.0	0.0	0.0
148.4	139.1	352.4
194.7	352.4	575.0
352.4	500.8	677.0
454.4	714.1	918.1
528.6	788.2	1029.4
639.9	890.3	1214.8
723.3	1001.5	1372.5
825.3	1149.9	1567.2
862.4	1224.1	1585.8
955.2	1326.1	1752.7
1057.2	1400.3	1910.3
1140.6	1548.7	2225.6

CBR RESULT UNSOAKED 10% MIXTURE 7 DAYS CURED SOIL

Penetration		10Blows		30Blows		65Blows	
mm	in	DR	Stress	DR	Stress	DR	Stress
0	0	0	0.0	0	0.0	0	0.0
0.64	0.025	19	25.6	16	21.5	26	35.0
1.27	0.05	24	32	41	55.1	58	78.0
1.9	0.075	39	52.5	57	76.7	79	106.3
2.54	**0.1**	**53**	**71.3**	**81**	**108.9**	**106**	**142.6**
3.17	0.125	61	82.0	86	115.7	118	158.7
3.81	0.15	72	96.8	99	133.2	139	187.0
4.44	0.175	81	108.9	110	148.0	153	205.8
5.08	**0.2**	**90**	**121.1**	**131**	**176.2**	**178**	**239.4**
5.7	0.225	97	130.5	137	184.3	186	250.2
6.35	0.25	105	141.2	149	200.4	200	269.0
7	0.275	114	153.3	158	212.5	213	286.5
7.62	0.3	122	164.1	170	228.7	245	329.5

Density	*10 Blows*	*30Blows*	*65 Blows*
W1	11093.1	11513.5	11876.5
W2	7051.8	7121	7243
W3	4041.3	4392.5	4633.5
Voum	2123	2123	2123
Wet Den	1.9	2.1	2.2
Dry Den g/Cm3	1.6	1.8	1.9
Dry Den KN/m3	**15.9**	**17.3**	**18.2**

10Blows	30Blows	65Blows
Stress in KN/m^2		
0.0	0.0	0.0
176.2	148.4	241.1
222.6	380.2	537.9
361.7	528.6	732.6
491.5	751.1	983.0
565.7	797.5	1094.3
667.7	918.1	1289.0
751.1	1020.1	1418.8
834.6	1214.8	1650.7
899.5	1270.5	1724.9
973.7	1381.7	1854.7
1057.2	1465.2	1975.2
1131.4	1576.5	2272.0

Moisture Content	
W1	73.9
W2	64.7
W3	12.39
Ww	9.2
Ws	52.31
M.C %	**17.6**

CBR RESULT UNSOAKED 15% MIXTURE 3 DAYS CURED SOIL

Penetration		10Blows		30Blows		65Blows	
mm	in	DR	Stress	DR	Stress	DR	Stress
0	0	0	0.0	0	0.0	0	0.0
0.64	0.025	16	21.5	18	24.2	18	24.2
1.27	0.05	28	38	33	44.4	36	48.4
1.9	0.075	37	49.8	47	63.2	64	86.1
2.54	**0.1**	**43**	**57.8**	**58**	**78.0**	**86**	**115.7**
3.17	0.125	48	64.6	62	83.4	99	133.2
3.81	0.15	55	74.0	70	94.2	110	148.0
4.44	0.175	63	84.7	82	110.3	125	168.1
5.08	**0.2**	**73**	**98.2**	**97**	**130.5**	**138**	**185.6**
5.7	0.225	80	107.6	105	141.2	149	200.4
6.35	0.25	89	119.7	116	156.0	163	219.2
7	0.275	96	129.1	121	162.7	170	228.7
7.62	0.3	102	137.2	131	176.2	183	246.1

Density	*10 Blows*	*30Blows*	*65 Blows*
W1	11098.1	11453	11856.5
W2	7077.8	7122	7243
W3	4020.3	4331	4613.5
Voum	2123	2123	2123
Wet Den	1.9	2.0	2.2
Dry Den g/Cm3	1.6	1.7	1.8
Dry Den KN/m3	**15.7**	**16.9**	**18.0**

Moisture Content	
W1	61.5
W2	55.3
W3	21.5
Ww	6.2
Ws	33.8
M.C %	**18.3**

10Blows	30Blows	65Blows
Stress in KN/m^2		
0.0	0.0	0.0
148.4	166.9	166.9
259.7	306.0	333.8
343.1	435.9	593.5
398.8	537.9	797.5
445.1	575.0	918.1
510.0	649.1	1020.1
584.2	760.4	1159.2
677.0	899.5	1279.7
741.9	973.7	1381.7
825.3	1075.7	1511.6
890.3	1122.1	1576.5
945.9	1214.8	1697.0

CBR RESULT UNSOAKED 15% MIXTURE 7 DAYS CURED SOIL

Penetration		10Blows		30Blows		65Blows	
mm	in	DR	Stress	DR	Stress	DR	Stress
0	0	0	0.0	0	0.0	0	0.0
0.64	0.025	18	24.2	19	25.6	19	25.6
1.27	0.05	29	39	31	41.7	40	53.8
1.9	0.075	41	55.1	49	65.9	68	91.5
2.54	**0.1**	**49**	**65.9**	**63**	**84.7**	**90**	**121.1**
3.17	0.125	56	75.3	71	95.5	101	135.8
3.81	0.15	63	84.7	85	114.3	112	150.6
4.44	0.175	72	96.8	99	133.2	128	172.2
5.08	**0.2**	**81**	**108.9**	**107**	**143.9**	**143**	**192.3**
5.7	0.225	90	121.1	117	157.4	156	209.8
6.35	0.25	99	133.2	123	165.4	169	227.3
7	0.275	104	139.9	135	181.6	178	239.4
7.62	0.3	113	152.0	144	193.7	187	251.5

Density	*10 Blows*	*30Blows*	*65 Blows*
W1	11129.1	11483.5	11898.5
W2	7077.8	7122	7243
W3	4051.3	4361.5	4655.5
Voum	2123	2123	2123
Wet Den	1.9	2.1	2.2
Dry Den g/Cm3	1.6	1.7	1.8
Dry Den KN/m3	**15.8**	**17.0**	**18.1**

Moisture Content	
W1	55.6
W2	50.2
W3	21.5
Ww	5.4
Ws	28.7
M.C %	**18.8**

10Blows	30Blows	65Blows
Stress in KN/m^2		
0.0	0.0	0.0
166.9	176.2	176.2
268.9	287.5	370.9
380.2	454.4	630.6
454.4	584.2	834.6
519.3	658.4	936.6
584.2	788.2	1038.6
667.7	918.1	1187.0
751.1	992.3	1326.1
834.6	1085.0	1446.7
918.1	1140.6	1567.2
964.4	1251.9	1650.7
1047.9	1335.4	1734.1