STABLIZATTION OF CLAYEY SOIL USING STEEL SLAG AND MARBLE DUST

A DISSERTATION REPORT

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CERTIFICATE

Certify that this project report entitled '**STABLIZATTION OF CLAYEY SOIL USING STEEL SLAG AND MARBLE DUST'** submitted individually **GURPREET SINGH** student of civil engineering, Lovely Professional University carried out then the work under my supervision for the award of degree. This report has not been submitted to any other university/institution for the award of any degree.

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DECLARATION

I hereby declare that the dissertation report titled **"STABILIZATION OF CLAY SOIL USING STEEL SLAG AND MARBLE DUST"** is an authentic record of my own research work carried out as a requirement for the preparation of M-Tech dissertation for the award of Masters of Technology Degree in Geotechnical Engineering from Lovely Professional University, Phagwara, Punjab, under the guidance of Mr HARDEEP SINGH. All the information furnished in this report is based upon my intensive work and is completely genuine to the best of my knowledge. And no part of the uncited work in this report has ever been published before in any journal or presented for the award of any degree or honour.

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CHAPTER 1

1.1 INTRODUCTION

Soil consists of air, water and sold particles which are generated by the disintegration of rocks and t is on the top of the earth layers. It is a construction material at very low cost than other materials available in most of the countries and its properties are not same and changes from place to place, especially in case of clayey soil. There are engineering problems due to low strength, low bearing capacity and water holding capacity and high compressibility in clay. Therefore, clayey soils are not good enough for construction like pavements, embankments, foundations etc. So there is big need to treat clayey soil. Stabilization is a good process for improving in properties of clay by using different type of stabilizing agents. Sol stabilization is an important for poor soil and not good enough for any construction. In soil stabilization process the poor soil is treated to stable by maintains or improves performance of the soil as a good construction material. Stabilizing agents are used to stable the soil and they improve the strengths parameters of sub grade material or soil. Improves in the California Bearing Ratio (CBR), is one of the main advantage of the stabilization. For improves the on-site material (soil) for construction, such as solid and strong sub base and base course stabilization is necessary. In most of the countries, the stabilization is used to construct the entire road. By utilizing the binding properties of clay soil, stabilizing was done. There are many technologies for soil stabilization and depend upon the type of soil and site conditions. Cost factor also affects the adopting method of stabilization.

Shear strength is main property of soil and important for every type of structure on soil. Clayey soils have low shear strength in wet condition and undesirable engineering properties. Clayey soil is subjected to change in volume when it is in contact with water or increase in water content. These problems of clayey soil can damage or harmful to civil engineering construction. So to achieved desire properties this soil should be treated first and the able to construction. Different methods for improve in engineering properties are chemical stabilization, densification, reinforcement and reduction in pore water pressure. Stabilized soils are more useful as a construction material. The treatment of clayey soil with the use of steel slag and waste marble dust is not very tough, it is economical and pollution controlling.

The treatment of clayey soil with the use of sugarcane steel slag and marble dust powder is not very tough, it is economical and pollution controlling.

1.1.1 EXPANSIVE SOIL

Expansive soil is a type of soil that is known as a low weight aggregate with a circular structure, consisting porous inner, and a hard and frictional outer layer. It is a soil that is undergoes large Changes in volume (shrinkage and swelling) which occur due change in water content. There are deep cracks in expensive minerals in drier years and seasons and that type of soil also known as vertisoil. This shrink swell capacity of this soil is due to presence of montmorillonite and bentonite. All clays including mineral sheets packaged into layers, and can be grouped as either 1:1 or 2:1. These ratios give in the proportion of tetrahedral sheets to octahedral sheets. Octahedral sheets are trapped between two tetrahedral sheets in 2:1 clays, while 1:1 clays have sheets in related pairs. Crystal lattice in a 2:1 ratio available in the expensive soil and there are 2:1 non-expansive clays.

Expansive soil has another important factor, its vulnerability to physical changes, with arability or presence of amount of water. For example, in a wet or rainy season, the clay is tends to swelling, and when dry season, it tends to shrink and generate cracks. Montmorillonite has the maximum swelling potential in clay or expensive soil.

1.1.2 PROBLEMS WITH CLAYEY SOIL

The soils have a rich content of clay minerals, behave like sponges and absorb more quantities of water when it have increase in water content, causing the clay mineral to change in volume. When the water escaped (dries) from clay mineral, and then it tends to shrinks or decrease in volume. The type of Clays that have sodium when in contact with water, expand as more as a thousand percent. Because the other soils are not having clay minerals, then the expansion in that soils typically less as compared to pure clay. However, when the volume changes occur in clay than the structures may be damaged. There can be cracks in structures and foundations when expansion in clay and also roads are affected. The main sign of expanding soil or volume change in clay beneath a structure may be displacing of doors and windows. Non-load-bearing walls, in structures heaving low weight to resist the pressure generated by expansion, typically crack earlier than load-bearing walls do. When water escape from clay (drying), expansive soil decreased in volume (shrinks), generating deep, large, cracks or "soil boil" texture in surface exposures. Soil boil textures are the outcomes of again and again shrink/swell cycles. In more cases, cracks arises by drying clay can be good enough to copy earth fissures. However, cracks due to drying clay are not as deep or long as earth fissures. In India clay or expensive soil are present in many regions. The second disadvantage of increase in water content is reducing the shear strength of clayey soil and which is not good for structures on it. The wet clay cannot take loads properly from structures and reasons of failure of structures and pavements also.

1.1.3 STABILIZATION

Stabilization of soil is a method of modifying the properties of a poor soil to improve its engineering performance. In stabilization the best way of an existing soil is amplify by improving the main property of soil i.e. Shear strength of the soil related to the desired needs so as to approaches the constructional standard. Stabilization of soil is used for a different type of engineering works and it is the most common method being in the construction of road and air field pavement, where the construction is totally depend on locally available materials. The stabilization method is adopted more where the soil present at site of construction is cannot be replaced. However, stabilization of soil is the process of improving soil properties but it can be achieved by different methods according to the demand or need. The stabilization methods of soil can be divided into two different types. These are as follows

1. Method of stabilization in which the improvement of soil can be done without adding any admixture or stabilizing agent, and
2. Method of stabilizing in which the improvement of soil is done by adding an admixture.

The methods of drainage and compaction includes in the method of improvement in which the property of the soil is changes without adding any admixture. The main stabilization methods without using admixtures are cement stabilization, mechanical stabilization, bitumen stabilization, lime stabilization, and chemical stabilization.

When the above mentioned methods are not needed or applicable, the admixtures are used for stabilization the soil. There are many admixtures used for stabilization heaving different properties which helps to improve the engineering performance of soil for example sugarcane bagasse ash, lime, silica, marble dust, glass powder etc.

1.1.4 ADMIXTURES USED

STEEL SLAG

Steel slag is more attractive to reuse and recycle in industrial wastes rather than disposing them off. Steel slag is conversion of iron to steel, is one of the most industrial wastes having a large percentage in disposed off landfills and on dumpsites.

MARBLE DUST

Marble dust is produced from marble producing industries through the cutting, polishing and smoothening of marble tiles. These processes are done by spraying water over it.So the waste marble is discarded as slurry, which on drying gets transported by wind and cause problems to humans and society. These wastes are also produced from buildings under construction where tiles are laid and polished. Thus the effective utilization of this waste is of high importance, and has been used as cement replacement additive in concrete blocks. Studies relating to utilization of marble improve soil properties have also been evolving in the recent years.

CHAPTER 2

2.1 TERMINOLOGY

Nomenclatures

Gs Specific gravity

M1	Mass of empty container, kg
M2	Mass of container and wet sample, kg
M3	Mass of container and dry sample, kg
m1	Mass of specific gravity jar, kg
m2	Mass of specific gravity jar with 500 g of soil sample, kg
m3	Mass of specific gravity jar with water and soil sample, kg
m4	Mass of specific gravity jar filled with water, kg

Greek Symbols

γ Density, kN/m3

γ-max Maximum density, kN/m3

ABBREVIATIONS

CBR	California bearing ratio
LL	Liquid Limit
MC	Moisture content
MDD	Maximum Dry Density
OMC	Optimum Moisture Content
PL	Plastic Limit
PI	Plasticity Index
UCS	Unconfined compressive strength
SS	Steel slag
MD	Marble dust.

CHAPTER 3

3.1 REVIEW OF LITRATURE

Saurabh Kumar et al. (2016) In this project, strength characteristics of clayey soil with steel slag have been studied. The following conclusions can be made based on the test results. With the addition of slag percentage in the soil the maximum dry density in increasing order and the optimum moisture content start decreasing at both slag passed through 180 μ and 300 μ sieves. The MDD result shows the increasing trend for soil slag mixture and OMC results shows the decreasing trend for soil slag mixture. In UCS, the unconfined compressive strength of soil slag mixture having increasing trend. There are many factors like gradation, carbon content, iron content and fineness etc., mainly control the Strength of soil treated with steel slag. Samples are fails by vertical cracks and sudden failure. The result of Plastic Limit increases at upto 8% of steel slag mixture with parent soil and start decreasing after 8% of steel slag mixture. And Liquid Limit results start decreasing for steel slag mixture with parent soil. Due to friction between particles of steel slag, Liquid Limit result has been decreasing. Plasticity index is in reducing manner for slag passed through 180 μ and 300 μ sieves.

Faisal Shalabi I. et al. (2016) The increase in steel slag aggregate content decreases the plasticity and increases the maximum dry density of the clay soils. Based on large scale consolidated undrained shear strength tests, the cohesion intercept of the clay soil decreases with the increase in steel slag content while opposite behaviour is expected for the angle of internal friction. . Presence of steel slag as a stabilization material improves the swelling potential of the clay soils. Both, percentage of free swell and swell pressure decrease almost linearly with the increase in steel slag content. Unconfined compressive strength of the treated clay soils with steel slag depends on the initial compaction conditions of the soil. While the zero slag compacted soil shows a decrease in UCS with the increase in slag content, the compacted soil at different steel slag content shows almost a slight change in UCS with slag content. CBR value of the treated clay soil was found to increase with the increase in steel slag content, and it is in a reverse relation with the free swell value.

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Ayesha Rehman et al. (2014) determine strength of brick using marble dust. This study investigated the utilization for mechanical waste for example, such that marble dust (MD) and. Steel slag (SS) to process unfired, Ecological inviting blocks. Different mixtures holding gypsum, lime and. Md or ss were prepared, in distinctive proportions in the research center. Those setting time, compressive strength, water. Absorption Furthermore immersion coefficient about examination blocks were dead set. These blocks achieved compressive. Quality better than traditional blazed mud blocks over under 7 times. However, water absorption of every last one of. Furthermor Similarly as mud substitute will be guaranteeing to making nature's domain friendly, low cosset blocks Hosting addition. Quality for use Previously, development industry. Further testing about block mixtures and water absorption properties is. Required When business preparation.

Isaac Akinwumi (2014) This study provides experimental insights that show that pulverized steel slag was beneficially used to improve the plasticity, uncured strength and drainage characteristics of the lateritic soil without any adverse swell behaviour observed. The improvement in the uncured strength of the soil was limited to the application of 8% steel slag to the soil. Addition of 8% of steel slag to the soil increased its unsoaked CBR by 40% and its unconfined compressive strength by 66.7 kN/m2, while the liquid limit, plastic limit and plasticity index were reduced by 6.3%, 4.0% and 2.3%, respectively. Cation exchange between the soil and the steel slag was identified as the major factor that influenced the modification of the engineering properties of the soil by the addition of steel slag. It influenced the reduction in the di_used water layer and led to the agglomeration of clay-size particles in the soil-slag mixtures. Steel slag (instead of being disposed-o_) is recommended for use as a low-cost modifier or stabilizer, of local soils with similar engineering properties as that used in this study, for subgrade improvement or constructing a subgrade capping layer during road construction.

Tarkeshwar Pramanik et al. (2016) The Rapid growth of industries of marble produce and the production of steel creates hazardous waste materials by a large extent which cause a big problem to the humans surrounding them as well as acts as a pollutant affecting the ecological system of the environment. Keeping this objective in mind, the Marble Dust and GGBS can be used as soil stabilization materials in different proportion. In this paper, sandy clayey soil was stabilised using the combination of Marble Dust and GGBS in different proportion (i.e.0%+0%, 5%+5%, 10%+10%, 15%+15% & 20%+20%) and the Characteristic behaviour (i.e. OMC, MDD, UCS, CBR & Permeability) of modified soil in the laboratory was studied. The series of test has been conducted in laboratory and it is found that Marble Dust and GGBS (15%+15%) is sufficient to increases the California bearing ratio in unsoaked and soaked condition value up to 195% and 100% approximately.

Gupta R.C. (2012) This research was done on the engineering behavior of Clay when stabilized with Copper Slag. The absolute maximum dry density was 1.937 gm/cm3 for the combination of 50% Clay and 50% Copper slag. The maximum dry density was higher than 1.87 gm/cm3 for the combination of 70% Clay with 30% Copper slag to 30% clay with 70% copper slag. In the Tri-axial test, the angle of shearing resistance was 48° for the combination of 50% Clay and 50% Copper slag. Theangle of shearing resistance. Higher than 40° for the combination of 80% Clay with 20% Copper slag to 40% clay with 60% copper slag. The combination of 70% Clay with 30% Copper slag to 30% clay with 70% copper slag was most satisfactory combination to get good soil stabilizations.

Kiran Biradar.B et al. (2014) This reserch describes a study carried out to check theimprovements in the properties of Clayey soil with the additionof Fly ash and Steel slag. Fly ash and Steel slag are blended withunmodified soil in varying percentages to obtain the optimumpercentage of admixture required for the soil stabilization. Inthiscomparative study laboratory tests such as Atterberg's limit,Compaction test and CBR test were carried out for bothmodified and unmodified clayey soil. Liquid limit of the modified soil is reduced by 22.96% for Steel slag and 17.19% for Fly ash, when blended with the unmodified soil. Plasticity index of the modified soil is decreased by 65.76% for Steel slag and 25.67% for Fly ash. Maximum dry density of the modified soil is increased by 9.20% for (40%) Steel slag and it is decreased by 19.62% for (50%) of Fly ash. Optimum moisture content of the modified soil is reduced by 39.24% for Steel slag and it is increased by 35.44% for Flyash. CBR (Soaked) for the modified Soil is increased by 180% for (40%) Steel slag and 65% for (30%) Fly ash. CBR (Unsoaked) for the modified Soil is increased by 122% for (40%) Steel slag and 45% for (30%) Fly ash. It is observed that addition of Steel slag to clayey soil
results in attainment of higher CBR value than the Fly ash.

Kalpana Patel and Adarsh Patel (2016) As steel industry releases waste with some good engineering properties so, we can use this type of waste with soil which has low strength and does not have good engineering properties. Various techniques are available like soil stabilization, providing reinforcement etc. to improve load bearing capacity of soil. Soil stabilization is one of the modification techniques used to improve the geotechnical properties of soil and has become the major practice in construction engineering which enables the effective utilization of industrial wastes as a stabilizer. Steel Mill Scale (SMS) increased the MDD of black cotton soils by about 19%. The increase is within the range of 1720 to 1920kg/m3 which is considered satisfactory to excellent. Steel Mill Scale reduced the OMC of black cotton soils by about 28%. The strength characteristics of the soilsteel mill scale mixtures improved as the swelling potential was reduced by about 60%. Steel mill scale also increased the Un-soaked CBR of black cotton soils by about 16%. The increase in strength shows a potential for future usage. The addition of steel mill scale reduced the Soaked CBR of black cotton soils by about 75%. Steel Mill Scale increased the unconfined compressive strength of black cotton soils by about 53% at 5% Steel Mill Scale content.

Divya Devarajan and Aswathy Sasikumar (2014) The current study is to observe the variation in geotechnical properties of soil treated with 0% to 20% marble dust. The change in properties like liquid limit, plastic limit, optimum moisture content, maximum dry density and unconfined compressive strength has beenrecorded. From the study conducted, marble dust can be used as an effective soil stabilizer. The time that of characteristics improved untreated soil with optimum content ranging between 10% and 15% marble addition. Also the consistency limit were improved with addition of marble dust making it a silt low plasticity. The compaction characteristic also indicated an increase maximum dry density and reduced optimum moisture content. All the results indicate that marble dust can be effectively utilized as a stabilizer to improve properties of soil.

Elizabeth Siby.K and Betsypaul K. (2014) Eggshell powder has not been commonly used as a stabilizing material in most parts of the world. Marble dust are the wastes/dust produced during cutting and polishing of marble. This project aims at determining the geotechnical properties of eggshell powder and marble dust stabilized clay with a view to determine its suitability as a substitute for conventional lime stabilized clay. The main aim of the project is to compare the stabilizing potential of eggshell powder and marble dust which is easily obtained as a waste material with that of artificially synthesized lime. Lime is produced by burning of lime stone in kilns, which is harmful to the environment. It needs more cost to burn lime stone so as to obtain lime used for stabilization. Thus eggshell powder and marble dust could be a good replacement for industrial lime since it contains lime content in it. The effect of eggshell powder and marble dust on the index and engineering properties of clay will be analyzed individually and in combination. The project is aimed at determining the optimum percentage of combination of eggshell powder and marble dust in clay which can effectively replace conventional lime.

Amandeep Varma and Avtarpreet Singh (2017) Strength improvement of soil means that to improve the properties of soil. Some waste material are used to improve the soil such materials are fly ash, marble dust. Fly ash is the ash produced by burning of pulverized coal in thermal power plants. Marble industries are producing larger amount of marble dust. The rapid growth of marble dust creates a big problem on environment as it acts as a pollutant and disturbs the ecological system. Hence both material are cheap by cost. The object to carry out this study was to evaluate the effect of materials i.e marble dust and fly ash mixed with soil of clayey type. The physical as well as chemical characteristics of soil was improved by addition of such those materials. Whereas some expecting properties are index properties, compaction characteristics and strength characteristics. In the research marble dust is added in range of 5–20 % in corporation with fly ash 10-30%. Laboratory studies were performed to identification the Atterberg limits, proctor test, Unconfined compression strength, triaxial test. It was found that addition of 20% fly ash in soil shows maximum strength value increases 114.42% Unconfined compression strength(UCS). Further addition of fly ash has negative effects on these properties. Triaxial test is performed to calculate shear strength parameters of mixed soil i.e soil, fly ash and marble dust. It was found that cohesion character („c‟) went down and angle of internal friction (φ) goes up by addition of marble dust in soil and optimized fly ash. Test result depicts marble dust and fly ash improves strength characteristics of soil along with those use of materials is economical and also solves the problem of environment.

Ismail Zorluer and Ismail Muratoglu (2014) In this study, marble dust had been used as an additive material in clay soil. Marble dust is a waste of the marble industry and despite its recycling in various industries, there is still a significant amount of marble dust left as waste.

In this study, soil specimens were sampled from different locations in the ANS campus of Afyon Kocatepe University. These specimens were mixed with waste marble dust at ratios of 5%, 10% and 15%. Geotechnical experiments were carried out on specimens. Test results shows that marble dust have affected consolidation characteristics of clay soils. Especially, swelling index and consolidation index of specimens were decreased. This decrease is important in point of swelling potential of clay soils.

Marble dust affects the properties of clay like strength, swelling potential, freeze-thaw strength. This case was expressed at previous studies. In this study, consolidation characteristic of clay were affected from waste marble dust. Compression index (cc) and expansion index (ce) of specimens decreases when the amount of the added marble dust increases. Furthermore, void ratio decreases with increasing of marble dust. This result shows that consolidation settlement reduced when marble dust mixed to clay soil. Use of marble dust in soil stabilization, provide the protection of the environment. In addition, it is gained an economical material for soil stabilization.

Ismail Zorluer and Suleyman Gucek (2014) The objective of this study is to investigate the beneficial reuse of marble dust and fly ash in soil stabilization. Tests were performed on clay soil mixtures amended with marble dust and fly ash. Marble dust was used as an activator due to fly ash being inadequate for self-cementing.Reuse of suitable waste materials in soil stabilization can provide significant cost saving and environmental protection. A laboratory study was conducted to investigate the availability of marble dust and fly ash in clay soils. For this purpose, unconfined compressive strength, CBR, F-T, unconfined compressive strength after F-T, and swelling tests were performed. In addition, SEM analyses were performed for microstructural textures. The objective of this study is to investigate the beneficial reuse of marble dust and fly ash in soil stabilization. Tests were performed on clay soil mixtures amended with marble dust and fly ash. Marble dust was used as an activator due to fly ash being inadequate for self-cementing.

Adarsh Minhas and Veena Uma Devi (2016) This research aims to study the effect of marble powder on the stabilization of alluvial soils. The term soil soil stabilization means the improvement of stability or bearing power of soil by the use of controlled compaction; proportioning or the addition of suitable admixtures or stabilizers. As soil stabilization the alluvial soil is necessary as long as their volume changes due to variation in water content. Generally it expands throughout the rainy season owing to the addition or intake of water or shrinks in winter. Therefore, it is very important to replace the weak soil accompanied by the stabilized one. Although no. of studies has been accomplished on use of marble dust as a soil stabilization material.

Final conclusion of this report is that the OMC becomes steadiness with the addition of all the percentages of marble powder i.e (5,10,15%). There is no change in OMC with the addition of marble powder in given soil sample. When there was no mix in the soil the OMC becomes 8%. But by the addition of marble powder in the soil sample the OMC got up to 12%. This shows some variation in OMC due to the addition of marble powder. All in three cases (5,10,15%) of marble dust to the alluvial soil shows same variation in OMC. Generally OMC depends on the specific surface (particles surface area per weight). It varies from material to material. If specific surface of admixtures is same as that of soil, OMC will remain constant. But in maximum dry density (MDD) decreases with the addition of marble dust. This is because of presence of mixing that is soil and marble dust has different specific gravity than the natural soil. Another conclusion of CBR test results, there was a prominent improvement seen when natural soil is replaced by the addition of marble dust. It was noticed that bearing capacity of soil decreases if furthermore marble powder is added.

CHAPTER 4

4.1 RATIONALE AND SCOPE OF THE STUDY

- Much research has been done using marble dust as a stabilizer in different clays.
- Very Few studies are found marble in clay.
- But no study has been done using both steel slag and marble dust as stabilizers in clay.
- By using this combination of both steel slag and marble dust in clay, positive results are expected.
- This study gives huge advantage to waste management system of state or country where it carried out and solves the problem of disposal of those two materials.

CHAPTER 5

5.1 OBJECTIVES OF STUDY

- To improve the liquid limit, plastic limit, plasticity index, such as improves the index properties of clayey soil. By improve that values the problems of shrinkage and swelling of clay when it contact with water or increase in moisture content can be solved.
- To improvement in sub grade characteristics of CBR of clay. It helps to improve in bearing capacity of clay soil under the application of loads from structure on it.
- To overcome uneven volume changes of clay without any warning.
- To improve in dry density at different water content and obtain the maximum or improved dry density at optimum moisture content (OMC)
- To Improvement in Unconfined compressive strength (UCS) clay.
- The main objective of this study is to improve the overall performance of clay by using two waste materials i.e. steel slag and marble dust as stabilizers.

CHAPTER 6

6.1 MATERIALS

The materials used in carrying out this study were clay soil, waste steel slag and marble dust. The soil sample was provided from the Amritsar (Punjab) district in the city of beas, in north India. These marble components are matching with lime's components. So, stabilize to clay soil with the help of marble dust.

Table 1: chemical properties of marble dust

Oxide compounds	Marble dust percent by weight
Si o_2	26.53
Mg o	18.31
Ca o	38.45
Fe_2 o_3	13.70
Al_2 o_3	0.39
Density	2.83(gm/cm^3)

Table 4: Typical chemical composition of steel slag

Oxide compound	Mass percentage
Calcium oxide (CaO)	34% – 43 %
Silicon dioxide (SiO_2)	27% – 38%
Aluminum oxide (Al_2O_3)	7% – 12%
Magnesium oxide (MgO)	7% – 15 %
Iron (FeO or Fe_2O_3)	0.2% – 1.6%
Sulphur (S)	1.0% – 1.9%
Manganese oxide (MnO)	0.15% – 0.76%

Due to those properties it can be used for stabilization of clayey soil. The stabilization of clayey soil with steel slag automatically solves the problem of disposal and it good for environment. It is used as a cheap material and very important for economy in the construction.

The marble dust is so economical and only some are recycled. The marble dust was collected and converts into the powdered form. Marble dust is fine and rich in density. Then it can be used as the stabilized agent for clayey soil. The waste marble dust can crushed into desirable proportion for addition in clay. Some cities and town have poor solid waste management, which creates seriously environmental problems. So with using of marble dust powder for stabilizing clay, the problems arise from marble dust decreased and it became a cheap material as a stabilizing agent..

6.2 RESEARCH METHODOLOGY

6.2.1 Laboratory tests and analysis

Different tests and analysis were taken out to determine the effects of the steel slag and marble dust on the clay soil i.e. particle size distribution analysis, specific gravity test, Atterberg limits test, compaction test and California Bearing Ratio test (CBR)were attempt to the determination the effect of mixture. With the help of these tests, the required proportions and SCBA for effective stabilization of the clay soil was examined.

6.2.2 Particle size distribution analysis

To find the size of particles in terms of percentage by weight of the soil the sieve analysis test carried out by passing it through each sieve. The first step of this test is to oven drying the clay soil sample for 24 hours allowing it to cool. The sieves were set according to the aperture size and the reweighed shaken safely for 10minutes. The sieve was undisturbed for the sample to settle, the sample retained on each sieves was weighed and noted and the corresponding calculations made. A graph of the percentage passing was prepared against the sieve sizes.

6.2.3 Natural moisture content

This test was carried to determine the quantity of moisture content present in the soil as a percentage of dry mass of soil sample. The empty container was weighed (and represented as *M1*) after which some amount of wet sample was placed therein and weighed (represented as *M2*). Thereafter, it subjected to oven dry for 24 hours, removed and weighed (represented as

M3). The moisture content (MC) was determined as a percentage of dry soil mass using the mathematical equation MC= $\frac{M2-M3}{M3-M1} \times 100\%$

6.2.4 Specific gravity test

The specific gravity of a soil sample is the weight in air of a given volume of soil particles to the weight in air of an equal volume of clean water. The procedure for its calculation involved emptying, drying and weighing the specific gravity jar (in*m1*) into which 500 g of the soil sample was given and weighed (in*m2*). Water was then added to the sample in the pycnometer (jar) till the sample particles were in suspension. This was free to stand for 30 minutes and weighed as (*m3*). Thereafter, the jar was withdrawn and cleaned. After that, the jar was filled with water and weight was determined as (*m4*). The specific gravity (*Gs*) was determined by using mathematical equation

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

6.2.5 Atterberg limits tests

The Atterberg limits are determined to measure the nature of fine-grained soil, related to the water content of the soil; it may found in four states: solid, semi-solid, plastic and liquid. In single state, the Behaviour, Consistency and Engineering properties of a soil is distinct. Thus, the difference between each state can be measure based on a variation in the soil's behaviour. The Atterberg limits can be used to difference between silt and clay, and it can difference between various types of silts and clays. The various Atterberg limits are liquid limit, shrinkages limit and plastic limit test. The procedure for obtained the liquid limit (LL) involved measuring out some weight of soil sample. It was then placed in the Casagrande'sapparatus, leveled and split with the grooving tool. The number of blows noted at which the split part became closed. A portion of this soil was collected in container to find its moisture content. The experiment was repeated till here is increasing the amount of water added. Then, the graph between the moisture content (MC) and the corresponding number of blows were plotted. The moisture content related to 25 blows was assumed as the liquid limit of the soil.

The test to calculated the plastic limit (PL) involved moulding and rolling the well mixed sample with the makes a threadlike shaped stick of about 3 mm diameter. The plastic limit was shown by the moisture content related to the point at which the stick first crumbled. Then, the plasticity index (PI) was calculated by using

PI= LL-PL

6.2.6 Compaction test

This test calculates the maximum dry density (γ-max) and optimum moisture content (W opt.) of the soil with and without mixtures of stabilizers. The outcomes are after used in the preparation of CBR sample. Compaction tests gives main information about the soil quality or performance at a site which can be used to calculate the most favourable structures sites, the maximum load of the soil can withstand and the sensitive of the site for building. In order to find the effect of steel slag on clay soil throughout. After that a graph was plotted between the dry density and water content to obtain the maximum dry density at optimum moisture content.

6.2.7 California bearing ratio test (CBR)

The California Bearing Ratio Test (CBR) is a penetration test, used for obtain the bearing capacity of sub grade soil for safe pavements. It is performed on natural or compacted soils under soaked or un-soaked conditions and the outcomes are relates with the curves of standard tests to shows the soil strength. The test is carried out by determining the pressure required to penetrate a soil sample with a plunger of standard area which is then split by the pressure required to achieve an equal amount of penetration on a standard crushed rock material. In order to perform this test, the addition used under the compaction test was used again in this test. Around 6 kg of dry soil was mixed thoroughly with calculated quantity of water related to its OMC. The soil was compacted in CBR moulds, in each in 3 layers and subjected 25 blows each using the standard rammer. The top surface of the sample was scraped and levelled after compacting the last layer. Needed surcharge mass was then taken on the soil surface to equal the actual or estimated mass of construction. The loading was applied at the rate or standard rate of 1.25 mm/min. Note the readings at the following penetrations for the top and bottom layers namely 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0, 5.5, 6.0, 6.5 and 7.0. The readings of the load at penetration of 2.5 mm and 5.0 mm were shown as percentages of standard loads of 70 kg/cm and 150 kg/cm respectively. The higher value out of these two was assumed as the CBR. The CBR values were calculated by using Eqs.

CBR_at_2.5_mm_penetration = $\frac{Actual\ load\ in\ kg/cm\ taken\ by\ soil}{Standard\ load\ at\ 2.5mm\ penitration\ in\ kg/cm}$

CBR_at_5.0_mm_penetration = $\frac{Actual\ load\ in\ taken\ by\ soil}{Standard\ load\ at\ 5.0\ mm\ penitration\ in\ kg/cm}$

CHAPTER 7

7.1 LABORATARY INVESTIGATION

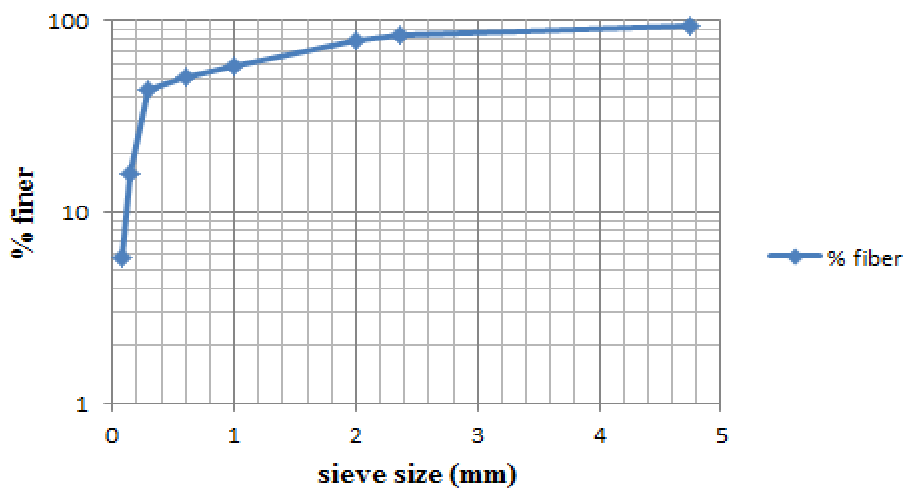
7.1.1 Particle size distribution analysis

Table.3 shows proportions of the particle size distribution analysis with the corresponding percentages retained in each the sieve.

Table 3. Particle Size Distribution Analysis

Sr.no	Sieve diameter (mm)	Mass retained (kg)	% retained	% passing
1	4.75	0.056	5.6	94.4
2	2.36	0.102	10.2	84.2
3	2	0.052	5.2	79
4	1	0.214	21.4	57.6
5	0.600	0.064	6.4	51.2
6	0.300	0.074	7.4	43.8
7	0.150	0.278	27.8	16
8	0.075	0.102	10.2	5.8
9	PAN	0.058	5.8	0

Fig.1 Particle Size Distribution Chart



7.1.2Natural moisture content

The clay soil used for this research work had natural water content sample 4.67% as giver in Table 4.

Table.4 Moisture content results

Test sample	Mass of empty can (g) M1	Mass of can + wet soil (g) M2	Mass of can + dry soil (g) M3	Moisture (g)	MC %
1 2 3	45.82 46.01 47.50	96.38 97.8 98.2	94.14 95.51 95.89	2.24 2.29 2.31	4.63 4.62 4.77
Average					4.67

7.1.3Atterberg limits tests

The moisture content values of soil sample are examine by the Atterberg limits test (liquid limit, plastic limit and shrinkage limit) are as shown in Tables 5.1, 5.2 and 5.3. The liquid limit is 37.5, plastic limit is 20.53% and plasticity index is 16.97 of the natural soil sample.

Table.5.1 liquid limit results

Sample	No. of blows	Mass of wet sample(g)	Mass of dry sample (g)	Moisture (g)	MC %
1 2 3 4 5	52 39 27 19 11	6.52 8.1 11.03 8.65 9.56	4.97 6.05 8.07 6.24 6.50	1.55 2.05 2.96 2.41 2.75	31.18 33.80 36.6 38.6 42.31

The Liquid limit from graph correspond to 25 blows is 37.5.

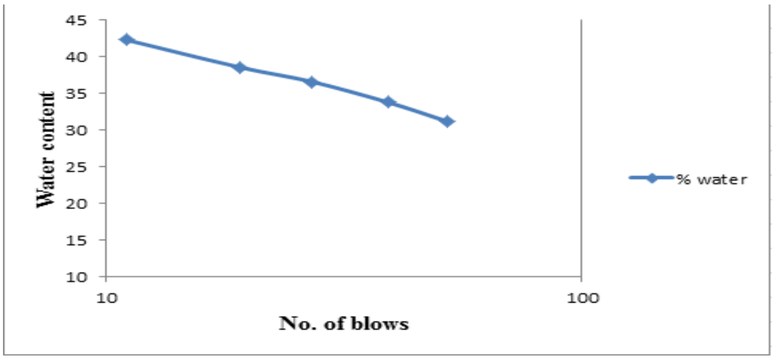
To find the type of clay we use the equation: 0.73(L.L-20) =>0.73(37.5-20) =12.8

And L.L-P.L=37.5-20.53=16.97

The value of plasticity index (16.97) is greater than 12.8 (16.97>12.8) so the type of soil is clay.

Graph is plotted between the No. of blows and water content to find the value of liquid limit which is 37.5.

Fig.2Graph between no. of blows and water content



From the plastic limit test the results are obtain from the readings which are given in table no. 5.2

Table.5.2 Plastic limit results

Sample	Mass of wet sample (g)	Mass of dry sample (g)	Moisture (g)	MC
1	6	1.02	4.98	20.52
2	6.07	1.03	5.04	20.76
3	5.33	0.9	4.43	20.31
Average MC				20.53

7.1.4COMPACTION TEST

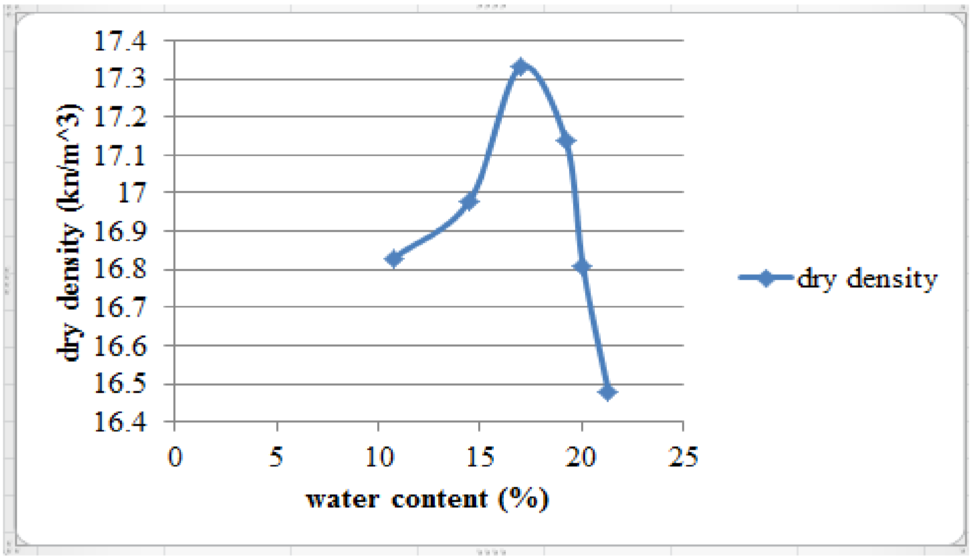
Table 4. Summarizes the compaction test results for the clay soil, from the outcomes the maximum dry density is 17.5 kn/m^3 and the OMC is 17.5%.

Table 6. Summary of MDD and OMC Values

MDD (kN/m3)	OMC (%)
16.63	10.76
16.98	14.48
17.33	16.96
17.14	19.2
16.81	20.04
16.48	21.31

Fig.2 shows the graph between the water content and dry density of soil and from which the maximum dry density obtained at optimum moisture content

Fig.3Graph of Maximum Dry Density at optimum moisture content



7.1.5 Specific gravity

The specific gravity of the clay soil sample was determined as 2.64 as shown in Table 5.

Table 7. Specific gravity

Sr. No.	Masses (Kg)	Test 1	Test 2	Test 3
1 2 3 4 5	Mass of density jar + Water (Full) = *m*4 Mass of density jar + Soil + Water = *m*3 Mass of density jar + Soil = *m*2 Mass of density jar2 = *m*1 Specific gravity	1.515 1.829 1.128 0.628 2.68	1.515 1.831 1.128 0.628 2.71	1.515 1.830 1.128 0.628 2.70
	Average specific gravity (*G*s)	2.69		

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