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AN EXPERIMENTAL STUDY OF SOIL STABILISATION WITH MARBLE DUST AND SODIUM SILICATE AS BINDER

SABHA ANJUM[1], ASHISH KUMAR[2]

1.M. Tech Student, Department Civil Engineering, RIMT University Mandi Gobindgarh, Punjab India
2.Assistant Professor, Department Civil Engineering, RIMT University, Mandi Gobindgarh, Punjab India

ABSTRACT

Soil stabilization is the alteration of soil to enhance their physical properties. The process of soil stabilization helps to achieve the required properties in a soil needed for the construction work. Weak soil generally swells and shrinks depending upon the presence of moisture content. Stabilization can increase the shear strength of a soil and control shrinkage properties of a soil and thus improving the load bearing capacity of a soil. In this project clayey soil is collected.

Generally, clayey soils are problematic soil having poor strength and low bearing capacity. The weak soil mixed with different percentage of marble dust with sodium silicate as binder. The different percentage of 5%, 10%, 15% and 20% of marble dust and 2.5%, 5%, 7.5% and 10% of sodium silicate is mixed with weak soil. Liquid limit test, Plastic limit test, Standard proctor test, direct shear test and California Bearing Ratio (CBR) test were conducted on soil stabilization. Finally, the Engineering properties of soil to be improved.

KEYWORDS: *Stabilization, Marble dust, Sodium silicate, clayey soil.*

I. INTRODUCTION

Previously, Various sorts of soil qualities were improved using the soil stabilisation technology. It was built to help civil engineering projects with unsteady soil. Historically, lime, bitumen, aggregates, and other materials were used for stabilisation. However, waste materials to stabilise the land, industries and factories are currently being used. Because it contribute to dumping and other environmental problems. The size of the parties, bearing capacity, and drainage conditions define the soil's qualities. Civil engineers have a bigger job than designing safe and cost-effective structures. The impact of mixing sodium silicate with residual marble dust from the industry on the engineering attributes of stabilised soils will also be studied. Clayey soils, in general, are problematic soils with low strength and bearing capability. Engineers encounter numerous challenges as a result of such soil. Clayey soils are not strong enough to handle the loads placed on them by the structure during construction or during its service life. As a result, this type of soil must be stabilised. The soil Marble dust and sodium silicate as a binder are used to stabilise this project. Marble dust, fly ash, and blast furnace slag are examples of industrial waste have become more popular as stabilising elements in recent years. The study also looks towards lowering the cost of stabilisation materials. Traditional materials such as clay, sand, stone, and gravel are commonly used in highway construction and foundation work. Traditional building materials are derived from existing natural resources, and their continued use harms the environment Nonetheless, high concentration polluting gases (carbon monoxide, sulphur dioxide, etc.) are invariably discharged to the atmosphere by machineries during the process of acquiring and transporting diverse raw materials. Exposure to poisonous gases released into the environment causes significant contamination of the air, water, soil, flora, fauna, and aquatic life, ultimately affecting human health and living situations. To maximise the use of by-products, it is necessary to discover functional substitutes or partially replacement additives for typical construction materials in the construction sector due to high transportation costs and environmental implications Considering the importance of energy conservation and resource conservation, efficient recycling of all solid wastes (fly ash, slag, marble dust, and so on) has become a global concern, necessitating extensive research and development work to explore newer applications and maximise the use of existing technologies for a sustainable and environmentally sound management. Industrial wastes (by-products) can be used alone or in combination with natural resources to increase efficiency and protect the environment from waste deposits [2]. The building industry's growing demand for marble products increases waste marble dust production. During the cutting of marble blocks, the marble dust and water combine to form waste marble mud, with roughly 22% of the marble being turned into dust Although notified sites have been established for dumping, the marble cutting plants are dumping the waste marble powder in any neighbouring pit or vacant spaces near their facility. This results in significant environmental and dust pollution, as well as the occupation of a large amount of land. Compaction alone is insufficient to improve soil qualities, especially in arid and semi-arid areas. Lime and sodium silicate stabilisation can be used to improve the strength and minimise the sensitivity of weak clay deposits to water changes. Sodium silicates have a significant impact on soil parameters, These stabilisers help to increase the dry density of the subgrade soil, improving its stability and load bearing capacity, by reducing soil flexibility capability. The practise of altering soil to improve its physical properties is known as soil stabilisation. The soil stabilisation technique assists in acquiring the needed properties of a soil for construction. The amount of moisture in weak soil causes it to expand and compress. Stabilization can improve a soil's load bearing capability by increasing its shear strength and controlling its shrinkage qualities. Clayey dirt is obtained in this research. Clayey soils, in general, are difficult to work with because of their low strength and bearing capacity. As a binder, the poor soil was mixed with varied amounts of sodium silicate. Weak soil is combined with various concentrations of sodium silicate (2.5 percent, 5%, 7.5 percent, and 10%). Liquid limit tests, plastic limit tests, conventional proctor tests, direct shear tests, and California Bearing Ratio (CBR) experiments were conducted on soil stabilisation. Finally, soil engineering properties will be enhanced. Sodium silicate is a colourless or white powder that dissolves readily in water to form an alkaline solution. The sodium silicate chemical belongs to the Sodium Meta silicate family. The addition of sodium silicate to soil improves its strength and durability. Ground improvement refers to a variety of techniques for modifying soil properties in order to increase engineering performance A variety of engineering projects use ground improvement techniques, including road and airport pavement building. The major goal is to improve soil strength and stability while lowering building costs by making the most of locally accessible materials. Industry-generated waste materials, which pose a significant disposal challenge, can be advantageously utilised to improve soil stability Marble dust is one such waste product. Marble dust is manufactured when marble stone is cut and polished. Every year, around 5-6 million tonnes of marble slurry are generated. Many researchers have discovered that marble dust powder has a significant lime concentration, which aids in stabilisation. Okagbue and Onyeobi (1999) discussed the use of marble dust powder in various quantities to improve red tropical soils. Unconfined compressive strength and CBR rose by 30 to 46 percent and 27 to 55 percent, respectively, whereas plasticity was reduced by 20 to 33 percent. At 8% marble dust, the greatest unconfined compressive strength and CBR were attained. Altug Saygili looked into the feasibility of using discarded marble dust in clayey soil stabilisation. By weight, marble dust was added in amounts of 5%, 10%, 20%, and 30%. The ideal moisture content is somewhere between 16.5 and 15.5 percent. The addition of waste marble dust to the soil raised the unconfined compressive strength values from 110kpa to 220kpa (5 percent addition) (30 percent addition). Parte Shyam Singh and Yadav R investigated the effects of adding marble dust to black cotton soil in various proportions (10,20,30,40,50 percent). The liquid limit value decreased from 57.67 to 33.9 percent, but the shrinkage limit value grew from 8.06 to 18.39 percent. The free swell differential was reduced from 66.6 percent to 20.0 percent. Muthu Kumar and Tamilarasan discovered that adding marble dust to expansive soil in various percentages (5,10,15,20,25 percent) increased unconfined compressive strength values. The increase was seen from 93 kN/m2 with no marble dust addition to 215 kN/m2 with 15% marble dust addition.

II. OBJECTIVE

- To look into the idea of using leftover marble dust to help stabilise troublesome soils (especially swelling clays).
- To determine the physical, mechanical, and chemical characteristics of soil and marble dust samples
- To examine the qualities and applicability of soil before and after using sodium silicate as a binder to stabilise marble dust.
- Reduce the soil's elasticity to make it more stable.
- To improve the California Bearing Ratio (CBR) of the soil.
- To determine the strength of soil using various marble percentages (5, 10, 15, and 20 percent). In poor soil , there is 2.5 percent, 5 percent, 7.5 percent, and 10% sodium silicate.

III. MATERIALS AND METHODS

Soil sample

A sample of soil for this investigation was gathered at a depth of 1.5 metres in Rajouri, Jammu and Kashmir. The coordinates of the location are 9.9252° N and 78.1198° E. The sample has a predominantly blackish look. A sample of disturbed soil was taken.

Silicate of sodium

Colorless clear solids, white granules, and water soluble sodium silicate Soda ash and silica sand are combined chemically to create it. The chemical sodium silicate is made up of sodium oxide and silicon dioxide. It's been employed in a variety of manufacturing, industrial, and agricultural applications. Because of its low cost, non-toxic, and ecologically benign nature, certain manufacturers prefer it as an adhesive material.

Table: The chemical make-up of sodium silicate

Chemical formula	(Na2)Sio2
Appearence	Thick liquid
Color	Clear to musty white
Odor	Odourless or musty odor
Ph	10-15
Density	1.4-1.6 g/cubic cm
Water solube	100%

Marble dust

The marble dirt shown in figure, had been produced from reducing and sharpening of marble stones. The predominant component of marble dirt (85 percent) is calcium carbonate, which helps to stabilise the soil. Figure 3.illustrates the sieve distribution of marble powder. Marble dust is produced during the cutting and polishing of marble stones. For this study, marble dust was obtained from Astrra chemicals in Ambattur, Chennai. Marble dust is mostly composed of calcium carbonate (88.5 percent), which aids in soil stabilisation. Marble is made up of recrystallized carbonate minerals such as calcite and dolomite.. When marble is cut, fine particles smaller than 2 mm are created. Brick, construction materials, infiltration, and ceramic processes all employ marble dust. Increasing the use ratio of such trash appears to be a solution to environmental issues as well as a cost-cutting measure.

Table: Marble dust chemical composition

CaO	54.4
Sio3	2.41
SO3	0.51
MgO	0.44
Al2O3	0.29
Fe2O3	0.06
K20	0.02
Mn2O3	0.01
TiO2	0.01
Loss on ignition at 1000*C	42.81
Na2O	0.02

METHODOLOGY

The material has been gathered based on the title we have chosen. Then we look at codal provisions like IS 1498-1970 and IS 2720. (part-2, 4, 5, 7, 13 & 16). For the experiment, a soil sample is taken from a certain location. The dirt is oven dried before being sieved through several sieve sizes (425, 90, 4.75mm) for the appropriate test. The marble dust and sodium silicate are combined in various amounts with the soil sample. The soil mixture is then transferred to the container and dried in an oven at 110°C for 24 hours before being examined for experimental purposes. The qualities of the virgin soil sample were determined by tests. Table 1 shows the outcomes of the testsTo measure the strength properties of the soil sample, marble dust was applied in varied amounts (3,6,9,12,15 percent) with varying curing periods (3,7,14) days.

Table: Virgin soil sample properties

S1.NO	DESCRIPTION	RESULTS
1	Free swell index	55%
2	Liquid limit	61%
3	Plastic limit	27.19%
4	Plasticity index	33.14%
5	Shrinkage limit	3.5%
6	Specific gravity	2.67
7	Maximum dry density	1.66g/cc
8	OMC	16.91%
9	CBR value	5.18%
10	UCC value	95.2Kn/m2
11	Grain size distribution Sand Silt +Clay	 35% 61%

According to IS;2720 part XL, a free swell index value of 55 percent, which is higher than 50 percent, shows that the soil is highly expansive. According to IS:2720 Part 5, a liquid limit value of 58 percent or above indicates that the soil is very compressible. The shrinkage limit value of 3.5 percent, which is less than 11 percent, places the degree of soil expansion in the critical region. The clay mineral included is kaolinite, which has a specific gravity of 2.67. According to the plasticity chart, a plasticity index value of 33.8 that is over the A-line signifies clay with a high compressibility. The virgin soil sample's CBR value was 5.18 percent, which is within the acceptable range. According to IS IS: 2720 (part16)-1987, 5-6 percent of the soil was classed as fair. According to The obtained UCC value of 95.2kN/m2, which is in the range 50-100kN/m2, can be classified as clay of firm consistency according to IS: 2720 (part10)-1991.

The several tests have been performed, details of equipment's used and the procedure have been described in the following sections.

Various Tests Executed on Soil Sample

* Standard Proctor Test
* Direct Shear Test
* California Bearing Ratio Test
* Unconfined Compressive Strength Test

Index Properties

%of marble dust	%of Na2Sio3	Liquid limit	Plastic limit	Plasticity index	Group(IS1498_1970)
5%	2.5%	57	44	27.1	CH
5%	10%	53.24	50	24.7	CI
10%	7.5%	50	50	21.9	CI
10%	10%	38.46	50	13.98	CL
15%	7.5%	33.33	49.9	9.73	CL
15%	10%	30	38.89	7.3	ML
20%	5%	50	50	21.9	CI

The liquid limit and plastic limit lowers with the addition of marble dust up to 15% and Na2SiO3 up to 10%, as shown in the table, and the value increases beyond this limit. The soil group moves from CH to ML according to IS 1498-1970.

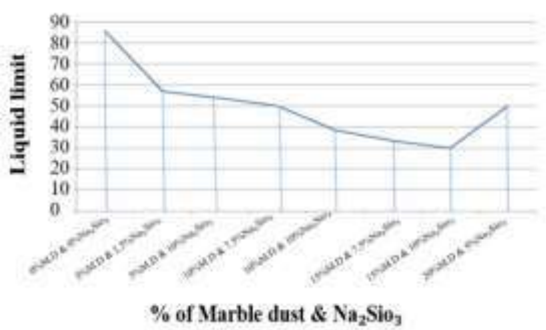

Fig: Plastic limit result with varying % of Marble dust &Na

B. Standard Proctor Test : The maximum dry density can be determined from the table, and it increases with the addition of marble dust up to 15% and Na2SiO3 up to 10% before declining point.

%of marble dust	%of Na2Sio3	MDD(gm/cc)	OMC
5%	2.5%	1.465	20%
5%	10%	1.505	20%
10%	7.5%	1.669	16%
10%	10%	1.759	16%
15%	7.5%	1.887	16%
15%	10%	1.999	12%
20%	5%	1.497	20%

C. Direct Shear Test

Table. The shear strength of a sample with different percentages of marble dust and Na2SiO3 was determined.

%of marble dust	%of Na2Sio3	Shear stress at failure(kg/m3)
5%	2.5%	0.119
5%	10%	0.183
10%	7.5%	0.202
10%	10%	0.229
15%	7.5%	0.257
15%	10%	0.293
20%	5%	0.128

The shear stress may be calculated using the table, and it increases with the addition of marble dust up to 15% and Na2SiO3 up to 10% before decreasing beyond this point.

D. California Bearing Ratio Test

Table: Shear strength of sample with different percentages of marble dust and Na2SiO3 was determined.

%of marble dust	%ofNa2Sio3	CBR value @ 2.5mm penetration
5%	2.5%	3.86
5%	10%	4.17
10%	7.5%	9.97
10%	10%	10.53
15%	7.5%	11.83
15%	10%	16.24
20%	5%	7.03

The CBR value at 2.5mm penetration increases with the addition of marble dust up to 15% and Na2SiO3 up to 10%, and drops beyond this limit, as shown in the table.

E. Unconfined Compressive Strength

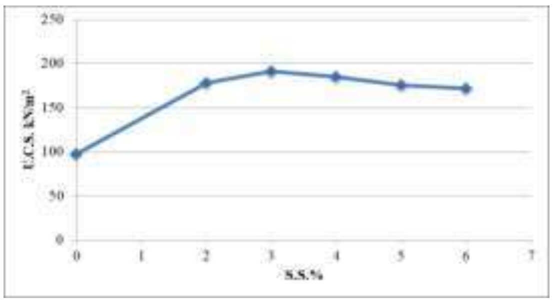

Figure. Effect of sodium silicate on U.C.S.

reases in sodium silicate will improve soil compressive strength. The increase is caused by the activity of water stabilisers in conjunction with an increase in S.S. and soil moisture content. The ideal value of U.C.S. for 3 percent sodium silicate is 191.11 kN/m2.

IV. RESULTS

The samples' ideal moisture content ranged from 16.5 to 15.5 percent, decreasing as the proportion of marble dust was increased. The maximum dry unit weight values ranged from 17.1 to 18.0 KN/m3, increasing as the quantity of marble dust added increased. Unconfined compression tests are performed on samples that have been cured for 7 and 28 days. Shown in Fig. 1 and Fig. 2

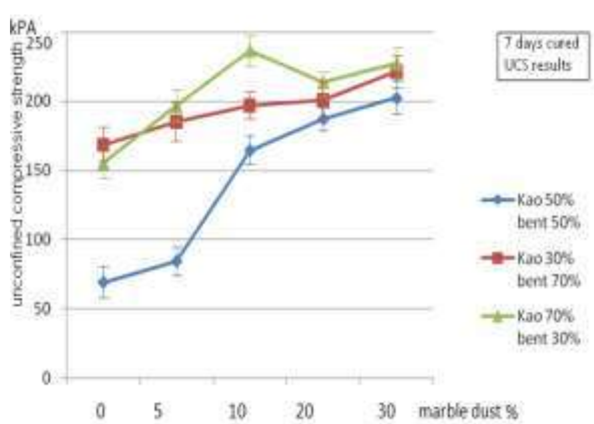

Fig.1. 7 day's cured samples unconfined compressive test results

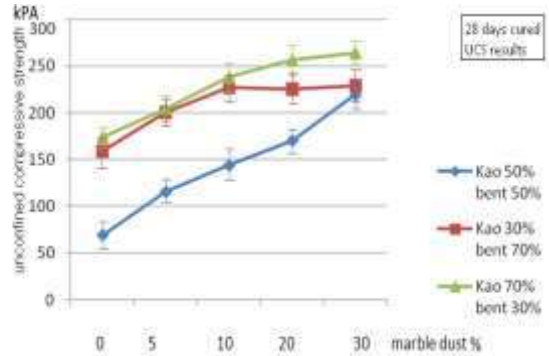

Fig. 2. 28 days cured samples unconfined compressive test results

The addition of waste marble dust to clay samples boosted the unconfined compressive strength values. As shown in Figures 3 and 4, increasing the proportion of leftover marble dust reduced the swelling potential of the clay specimens tested. The good performance of stabilised samples containing waste marble dust will reduce swelling concerns in highly swelling (active) bentonite clays, especially at high marble dust contents and lengthy curing times. As shown in Figures 5 and 6, direct shear tests were performed on samples cured for 7 and 28 days (applied normal stresses were 20, 40, and 80 kPA.Using the cation exchange process, waste marble dust addition showed greater performance in problematic soils during the physical tests detailed above. Cations of other elements present in the problematic soil were replaced by excess Ca2+ ions supplied by waste marble dust added to the matrix.

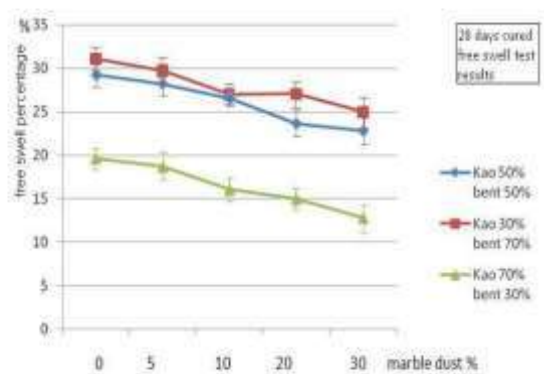

Fig 3. 28 days cured free swell test results

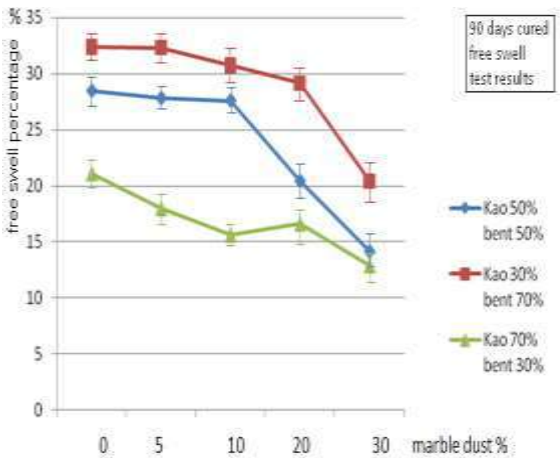

Fig. 4. 90 days cured free swell test results

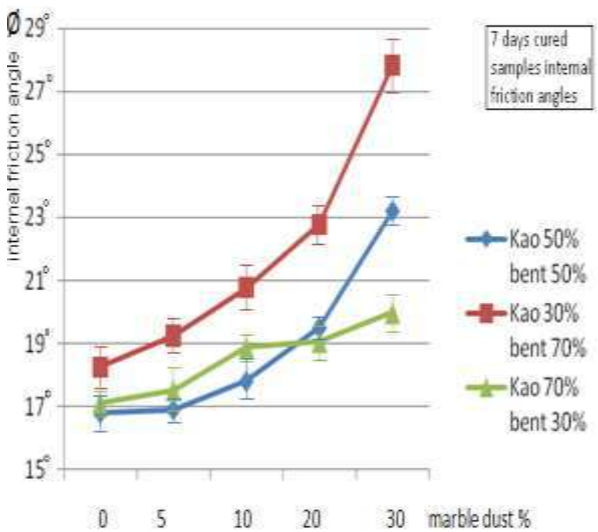

Fig. 5. 7 days cured samples internal friction angles

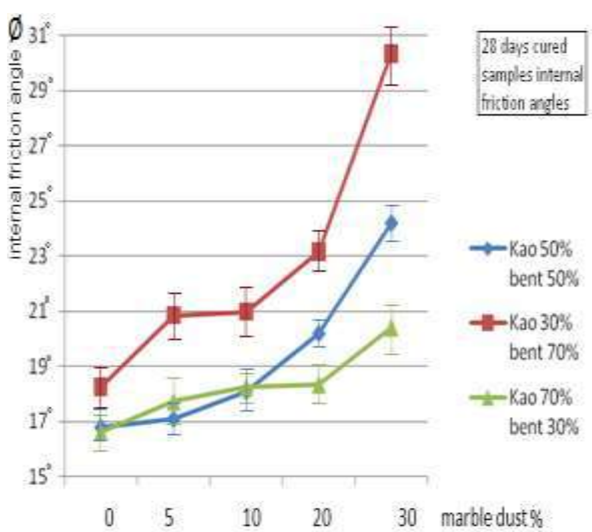

Fig. 6. 28 days cured samples internal friction angles

Tested samples are analyzed in SEM (Scanning Electron Microscopy) and EDS (Energy-dispersive X-ray spectroscopy) are used to study the tested samples, and the physical improvement achieved is examined micro structurally (Fig. 7, Fig. 8 and Fig. 9). With increasing curing time and waste marble powder percentage, gaps are filled with newly constituted cementations minerals with pozzolanic reactions with the help of high calcium content in waste marble dust, as observed in SEM photos and EDS data.

V. DISCUSSION

Marble dust in various ratios and sodium silicate as a binder were used to get index properties of the soil. The soil sample was tested for liquid limit and plastic limit in accordance with IS 2720-1985.The liquid limit and plastic limit lowers with the addition of marble dust up to 15% and Na_2SiO_3 up to 10%, as shown in the table, and the value increases beyond this limit. The soil group moves from CH to ML according to IS 1498-1970. plastic limit of soil reduces from 50 percent to 38.89 percent when the percent of marble dust and Na_2SiO_3 is increased, and slightly increases when the percent of marble dust and Na_2SiO_3 is increased.By adding sodium silicate into the soil sample, the standard proctor test evaluates for M.D.D. and O.M.C. After mixing 2 percent, 3 percent, 4 percent, 5 percent, and 6 percent The M.D.D. and O.M.C. of sodium silicate in the soil at varied water concentrations were determined. The O.M.C percentage is linked to the sodium silicate ratio. With the addition of 4 percent sodium silicate, the O.M.C percent does not change, although it does fall after that. Due to the reduction of vacancies in the soil, With the addition of sodium silicate, the O.M.C. decreases. The different sodium silicate ratios affect the maximum dry density. When sodium silicate and water are combined, the dry density rises. Compaction is the process of eliminating air gaps in soil to make it denser. Dry density is used to determine the degree of compaction. At optimum moisture content, the dry density is at its highest. The soil sample is sieved at 4.75mm and combined with various percentages of marble dust and Na2SiO3. By utilising a rammer, the sample is compacted into three equal layers. 1980, according to IS2720.A CBR test was performed to determine the appropriateness of a subgrade The soil is mixed with varying ratios of marble dust and sodium silicate, compacted in a mould, and then loaded, with readings taken at 2.5, 5, 7.5, 10, and 12.5mm penetrations. A soil sample comprising 5 different percentages of marble dust powder was used in the California bearing ratio test. Marble dust was mixed into the soil in various percentages (3,6,9,12,15 percent). The results of the tests are shown in Table. The CBR value climbs until 9 percent marble dust is added, then drops. For a 9 percent addition of marble dust, the maximum CBR value was 8.83 percent. With the addition of 9% marble dust, the CBR value increased from 5.19 percent to 8.83 percent. The CBR value lowers when the marble dust concentration exceeds the optimum, suggesting that the excess marble dust is not used up in the marble dust-soil reaction.

VI. CONCLUSION

The impact of various amounts of marble dust in soft soils is investigated. The experiment involves using different marble dust percentages by the weight of soils: 5%, 10%, 15%, 20%, and 25%. To compare the varied marble dust percentages to the untreated (control) soils, a comparison was done. We draw the following conclusions based on the findings of this study:

* When marble dust was added to soft soils, the maximum dry density (MDD) increased considerably when compared to untreated soils. Soils containing 10% marble dust had the highest MDD value and were therefore less prone to deformation. However, statistical analysis revealed that the marble dust applied to the soils had no meaningful effect.

* When compared to untreated soils, statistical analysis revealed that adding marble dust to soils considerably increased CBR. When exposed to heavy loads, the soils have a much higher bearing ratio. The results showed that the CBR values increased as the percentages of marble dust increased. Furthermore, these increases were really considerable. The soils that had been treated with 25% marble dust had the greatest CBR value. * Adding marble dust to soils not only helps to decrease trash in landfills and protects the environment, but it may also be a good way to improve the long-term performance of poor soils. However, it is important to note that the limits of this study include the types of soil and marble dust that were influenced, and the findings are only applicable to the soils and marble dust acquired from the Al-marj region of Libya. uenced the interpretation of the research findings. We noticed Researchers measured the effects of marble dust and sodium silicate on soil characteristics in a series of laboratory tests on soil samples

The following conclusions were reached based on the findings:

*The liquid and plastic limits of the soil are reduced by When marble dust and Na2SiO3 are added, the percentage increases to up to 15% and beyond.
* According to IS1498-1970, the soil group can be changed from CH to ML with the addition of marble dust and Na2SiO3. The MDD increases when 15 percent marble dust and 10% Na2SiO3 are added.
* The CBR value has enhanced with the addition of marble dust and Na2SiO3. Based on these findings, it has been determined that 15% marble dust and 10% Na2SiO3 should be added.
* Addition of The addition of sodium silicate and marble dust increases the maximum dry density of soil, but it decreases the O.M.C. of soil.
* The U.C.S. of soil is improved by adding sodium silicate and marble dust.
* The ideal sodium silicate and marble dust proportions to stabilise soil have been determined to be 3% and 2% together.

CONFLICT OF INTEREST

The author declares that they have no conflicts of interest.

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