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Effect of Marble Dust and Silica Fume on Engineering Properties of Clayey Soil

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Abstract*— This paper aims at studying the effects of silica fume and marble dust powder as admixtures in clayey soil to improve the engineering properties of soil. Silica fume and marble dust powder form a major percentage of waste materials originated by silicon industry and marble industry respectively. Based on Indian Standard guidelines Standard Proctor Test was conducted to determine the maximum dry density and optimum moisture content at varied percentages of waste admixtures (silica fume and marble dust powder) in the soil. An increase of OMC from 16.01% to 27% and decrease of MDD from 1.52g/cm^3 to 1.47g/cm^3 when the percentage of silica fume are used as 8, 16, & 24% respectively. When the percentage of marble dust powder are used as 12, 18 & 24% , there is decreased of OMC from 15.86% to 14.92% and an increase of MDD from 1.65g/cc to 1.72 g/cc. There is increase of OMC from 16.32% to 22.38% and decrease of MDD from 1.69g/cc to 1.61 g/cc when the percentage of Silica fume varied from 5 to 15 % @ interval of 5% and marble dust is fixed at 18%.

Keywords *:- Clayey soil, Marble dust powder, Silica fume, standard proctor test.*

I. INTRODUCTION

Clayey soil exhibits an unusual behavior of excessive swelling and shrinking with in and out of water respectively, which form the clay soil useless for the engineering applications because of possibility of excessive settlement of structures standing on it. Of all the available soils, behavior of clayey soil is very uncertain because of its fine grained composition with clay mineral fraction and very high water retention capacity due to cation exchange property. It is prone to considerable settlement due to its swelling and shrinkage behavior. It leads more damage to the pavements and light buildings than any other natural hazard including flood and earthquake.

During the last few years' damage due to swelling action has been clearly observed in the semiarid regions in the form of cracking and breakup of pavements, roadways, building foundations, channel, reservoir linings, irrigation systems, water lines, and sewer lines. To overcome this issue, several methods of soil stabilization are studied so that the soil can be easily used for various engineering applications. Soil stabilization techniques are used to enhance the properties of soil like shear strength, bearing capacity, reducing expansive characteristics, etc. Many waste materials are used to modify the characteristics of clayey soil. Traditionally the soils are stabilized by lime, cement, bitumen, etc. In recent year the uses of waste materials like fly ash, plastic, rice- husk ash, slag, polyester fiber , etc are gaining importance for soil stabilization. In this study, attempts are made to find the effect of silica fume and marble dust powder on engineering characteristics of clayey soil.

Silica fume also known as micro-silica is a by-product resulting reduction of high purity quartz with coal in an electric arc furnace in the manufacture of silicon or Ferro-silicon alloy. It is an air borne material and has spherical shape. Nearly one lakh ton of micro silica is produced every year worldwide.

Marble dust powder is the by-product of the marble industry which is produced during cutting and grinding of marble. The waste generation is approximately 40% of the total marble handled per year. It makes relevance because every year about 5-6 million ton of marble is manufactured all over the world. Out of this huge amount of marble dust produced only some part of it used for commercial applications and the remaining part is a waste.

II. LITERATURE REVIEW

Stabilization methods are required to make the soil suitable for construction purposes. The main objective of stabilization is to increase the strength and stability of soil and to reduce the construction cost by making best use of the locally available material. Many research works have been done on clayey soil to maintain its engineering properties for construction purposes by the different researchers.

Bharathan et al., (2017) examined the effect of silica fume & cement on clayey soil. The fixed ratio of cement 10% added by varying the percentage of silica fume from 5% to 20% at interval of 5% with clayey soil. The results showed that the increase in silica fume upto 15% increases both unconfined compressive strength and California bearing ratio.

Saxena et al., (2017) studied the effect of marble dust powder and fine sand on properties of Expansive soil. The expansive soil was mixed with marble dust powder and sand from 30% to 50% and 20% to 40% respectively at an interval of 10%. From the analysis of test results it was found that , liquid limit, plasticity index , optimum moisture content , permeability and cohesion decreased and plastic limit, shrinkage limit, maximum dry density, California bearing ratio and angle of internal friction increases with increase in marble powder content.

Patel et al., (2017) studied the use of waste marble powder to improve the characterstics of black cotton soil. The proportion of marble powder used was 20% to 60% . The test results showed a significant change in consistency limits of sample containing marble dust powder. The liquid limit would decrease from 31.3% to 23.5%. The plasticity index decreased from 11.57% to 4.35%. The CBR test increases from 10.36 to 27.19. From this laboratory investigation it was concluded that the waste material like marble powder generated from stone industries has a potential to modify the characteristics of expansive clay soil.

Chayan et al., (2014) studied Influence of Micro Silica on Sub Grade Characteristics of Expansive Soil. Number of laboratory tests were conducted and it was proven that the material is good agent of stabilization of expansive soils for sub-grade modification.

Negi et al., (2013) Effect of Silica Fume on Index Properties of Black Cotton Soil. A series of laboratory experiments have been conducted on samples with 0%, 5%, 10%,15% and 20% of Silica Fume by weight of dry soil. The test results showed a significant change in consistency limits of samples containing Silica fume. The Liquid limit would increased by 54% to 57% and Plastic limit would decreased by 27.07% to 26.29% with increasing Silica fume contents from 5% to 20% .

III. MATERIAL AND METHODOLOGY

The purpose of this study was to investigate the effects on clayey soil by addition of silica fume and waste marble dust powder. The effects were studied by taking measurements of compaction characterstics by conducting light compaction test.

Material

Silica Fume

Silica fume is also known as micro-silica. It is a product resulting reduction of high purity quartz with coal in an electric arc furnace in the manufacture of silicon or Ferro-silicon alloy. Silica fume rises as an oxidized vapour. It cools, condenses and is collected. It is fine grey coloured powder sometime similar to Portland cement or some flashes. Condensed silica fume is essentially silicon-dioxide (more than 90%) in non-crystalline form. It is an air borne material and has spherical shape. It is extremely fine with a particle size less than 0.1 micron and specific surface area of about 20,000m²/kg. Nearly 1lakh tons of micro silica is produced every year world wide.

Fig.1 Silica Fume

The chemical properties of silica fume are given below,

S.No	Parameters	Mass(%)
01.	Silica as SiO_2,	89.9
02.	Sulphur Content as SO_3	0.58
03.	Lime as CaO	7.85
04.	Magnesia as MgO	4.03
05.	Alumina as Al_2O_3	Nil
06.	Iron Oxide as Fe_2O_3	Nil
07.	colour	gray

Table-1 Properties of silica fume

Marble dust powder

Marble dust powder is obtained as a waste product from marble industry. It produced during cutting and grinding of marble. The waste is generated from the industries in the form of both solid and slurry. The solid waste is produced on the mine sites or at the processing units and slurry is in the semi- liquid form generates during sawing and polishing operations. The generation of waste marble dust is approximately 30-40% of the total marble handled per year. It makes relevance because every year about 68 million ton of marble is manufactured all over the world.

Fig.2 Marble Dust Powder

The various chemical properties of marble dust powder are given below,

S.No	Oxide Compound	Mass(%)
01.	SiO_2	28.35
02.	Al_2O_3	0.42
03.	Fe_2O_3	9.70
04.	CaO	40.45
05.	MgO	16.25
06.	Density	2.80
07.	Colour	White

Table-2 Properties Of Marble Dust Powder

Clayey soil

For this study , clayey soil sample was collected from R.S.Pura region, Jammu. The soil sample was collected by method of disturbed sampling after removing the top soil at 500 mm depth and transported in sacks to the laboratory. The soil was air dried, pulverized and sieved with 4.75 mm Indian Standard as required for laboratory test. The soil is classified as clay of high plasticity. The physical characteristics and index properties of clayey soil sample are presented in table;

S.No.	Particulars	Results
1	Grain size analysis	
	Sand	15 %
	Clay and silt	85 %
	Classification	CH
2	Specific gravity (G)	2.70
3	**Atterberg limits**	
	Liquid limit	51.91 %
	Plastic limit	26.76 %
	Plasticity Index	25.15 %
4	**Compaction characteristics**	
5	Maximum dry density (MDD)	1.52g/cm^3
6	Optimum moisture content (OMC)	16.01 %

Table-3 Engineering Properties Of Clayey Soil

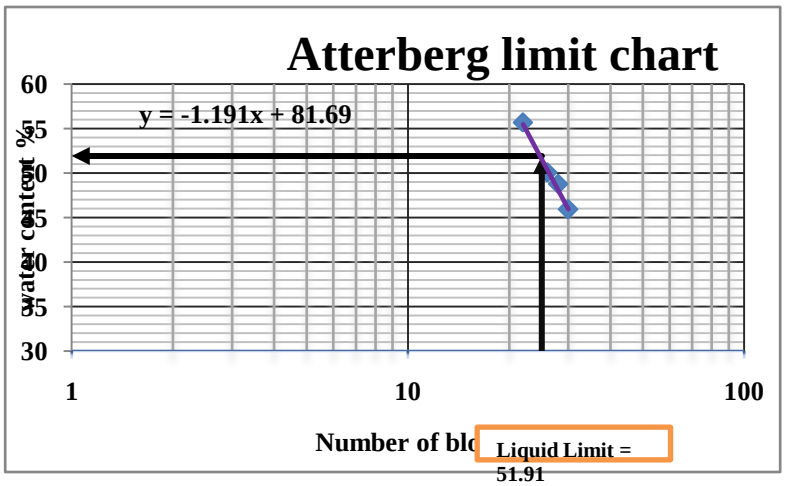

Fig.3 Atterberg's limit chart

IV.Results and Discussions

The light compaction test as per IS 2720 : Part 7 : 1980 has been conducted on untreated and treated clayey soil sample. The test results obtained from the experiment work are briefly discussed below;

S.No	Composition	Proportions(%)	MDD(g/cm^3)	OMC(%)
1.	Clayey Soil	100 : 00 : 00	1.52	16.01
2.	Clayey Soil : Marble Dust	88 : 12 : 00	1.65	15.86
		82 : 18 : 00	1.72	15.02
		76 : 24 : 00	1.77	14.92
3.	Clayey Soil : Silica Fume	92 : 8 : 00	1.51	19.02
		74 : 16 : 00	1.49	24
		76 : 24 : 00	1.47	27.01
4.	Clayey Soil : MD : SF	77 : 18 : 5	1.69	16.32
		72 : 18 : 10	1.66	18.21
		67 : 18 : 15	1.61	22.38

Table-4 Light Compaction Test Results

The fig.4 and fig.5 explained about the variation of MDD and OMC with the different proportion of marble dust.

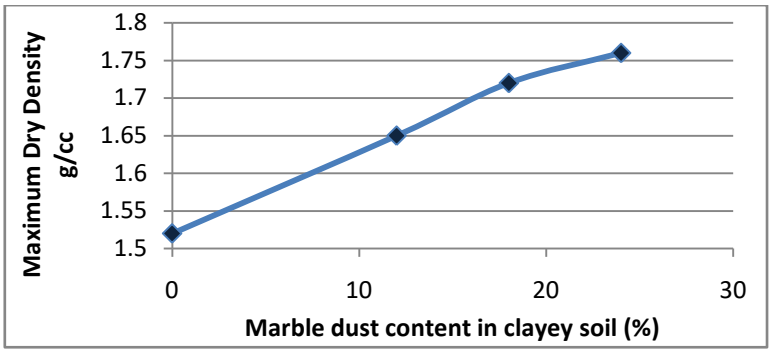

Figure-4: Varioation Of MDD With Different Percentage Of Marble Dust Powder.

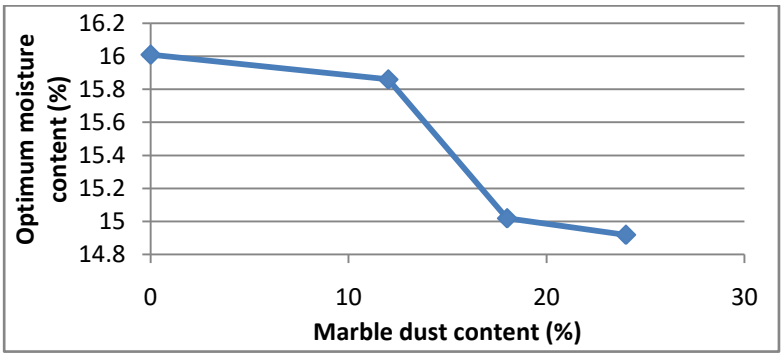

Figure-5: Variation Of OMC With Different Percentage Of Marble Dust.

The figure-6 and figure-7 explained about the variation of MDD and OMC with the different percentages of silica fume.

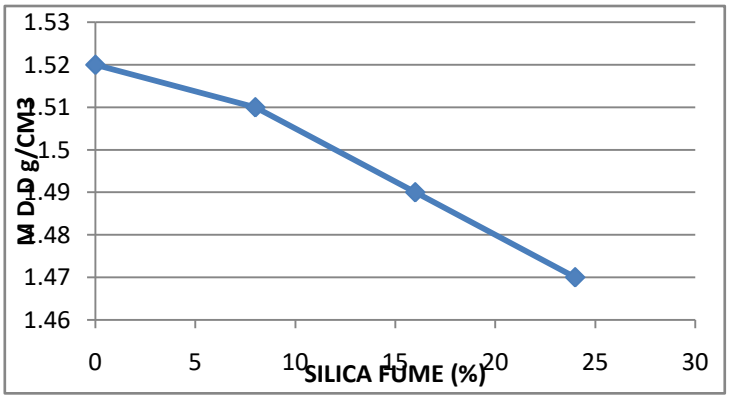

Figure-6: Variation Of MDD With Different Percentages Of Silica Fume.

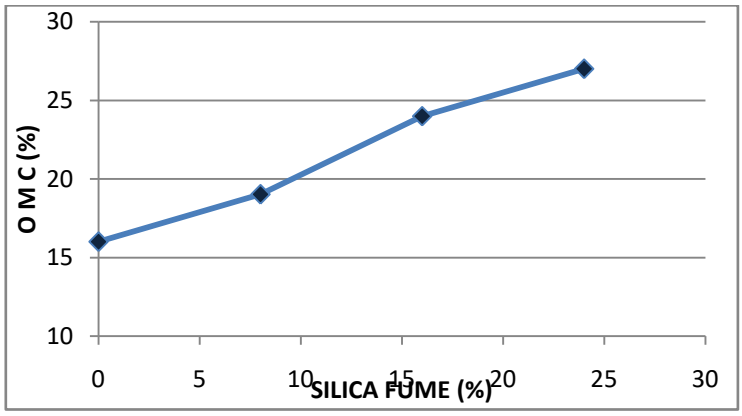

Figure-7: Variation Of OMC With Different Percentages Of Silica Fume.

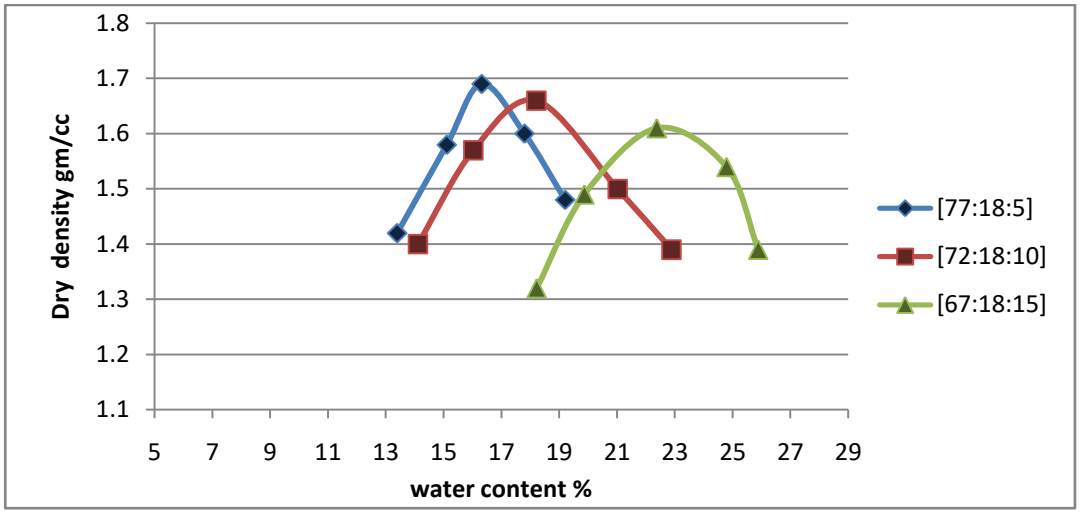

Figure-8: MDD And OMC for Various Percentages of Clayey Soil Mixed with Marble Dust And Silica Fume.

The variation of optimum moisture content (OMC) and maximum dry density (MDD) with different percentages of marble dust and silica fume is shown in figure-8.

IV. CONCLUSIONS

From this research work, the following results were obtained

- The use of waste marble dust powder and silica fume may reduce the disposal problem and preserve the ecological system.
- With the addition of marble dust to clayey soil the maximum dry density increases from 1.52g/cm^3 to 1.77g/cm^3 and optimum moisture content of soil decreases from 16.01% to 14.92%.
- While adding silica fume to clayey soil sample , the optimum moisture content increases from 16.01% to 27 % and maximum dry density decreases from 1.52g/cm^3 to 1.47 g/cm^3
- When percentage of marble dust fixed at 18% with clayey soil and content of silica fume varies from 0 to 15% at the interval of 5%, the optimum moisture content increases from 16.32% to 22.38% and maximum dry density decreases from 1.69g/cm^3 to 1.61g/cm^3.

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