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Geotechnical Properties of Soil Stabilized with Wollastonite

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Abstract: **In general, the engineering performance of soil is influenced by its properties. In turn, the type of foundation suitable for the imposed load is decided based on the properties of soil. During predestined situation, certain site cannot be ignored and it requires some techniques to modify the properties of soil to make it suitable for the required load carrying behaviour. There are many chemical or mechanical methods exist for the treatment of available mass of soil to improve or maintain its engineering properties. The most obvious purpose of this one is strength improvement. The most common admixture materials available for stabilisation includes Lime, fly ash, Stone Dust, Saw Dust, Groundnut Shell Ash, Disposed Solid Waste, Chemical Admixtures and cement. In this research, the properties of a red soil and its reaction with a additive material have been found out by conducting various tests like Standard Proctor compaction test, California Bearing Ratio test, etc. The additive materials for enhancing the properties of soil been decided as Wollastonite, as the research under this heading is less in number. Wollastonite is a Calcium silicate mineral ($CaSiO_3$) that may contain small traces of Iron, Magnesium, and Manganese substituting for Calcium which is available in many location below the ground surface and find its applications in many engineering industries, etc. It is a product of impure limestone when subjected to high temperature. It has the property of low moisture and oil absorption with low volatile content. It is primarily used in ceramics and tile factories, which also has the chemical properties which is very similar to cement. Because of this similarity wollastonite can be used to enhance the properties of the soil. Initially the test results for red soil without Wollastonite had been obtained. Later the test results for the soil added with Wollastonite was obtained and the comparison had been done. The results shows that Wollastonite, can be effectively utilised for the improving the strength characteristics of soil.**

Keywords ***: Wollastonite, Liquid Limit, Standard Proctor Compaction, California Bearing Ratio.***

1. INTRODUCTION

Soil, the major constituent on the land surface is being found in a vast variety. The soil the most important and yet most neglected one in construction project. All structures, buildings, bridges, dams and even life itself is based on the soil. The soil is the natural foundation that supports all structures and foundation. Soil stabilization significantly changes the characteristics of a soil to produce long-term permanent strength and stability, particularly with respect to the action of water and frost.

Red soil is one such found among them. It is a group of sol that develops in warm temperature conditions that have thin organic and inorganic mineral layers overlying a yellowish brown leached layer resting on an alluvial soil of red layer. It is the second largest group of soil covering a large part of the area (3.5 lakh sqkm. which is about 10.6 percent of the total geographical area of the country). The characteristic texture of the red soil varies from sandy to clay, the majority being loam. The other characteristics include porous and fertile structure. Working in peat, gravel, clay, sand, silt, or loam soil understanding the properties of the soil help us to make good construction decisions leading to the success of the project.

Wollastonite is a Calcium silicate mineral ($CaSiO_3$) that may contain small amount of Iron, Magnesium, and Manganese substituting for Calcium, which is usually white in colour. When impure limestone is subjected to high temperature it will form. It has the property of low moisture and oil absorption with low volatile content. It is primarily used in ceramics and tile factories, which also has the chemical properties which is very similar to cement. Because of this similarity wollastonite can be used as a stabilizing agent.

K. J. Osinubi,et.al stabilized the soil using Ordinary Portland cement(OPC) / locust bean waste ash (LBWA) in stepped concentration of 0, 2, 4, 6 and 8% each by dry weight of soil, was used to treat the soil. Compaction was carried out using British Standard light (BSL) energy and the three criteria for the evaluation of strength (i.e., UCS, CBR and Durability) were considered. The UCS values of specimens treated with 6% OPC / 6% LBWA increased from 178, 381 and 760kN/m^2 for the natural soil to 986, 1326 and 1348kN/m^2 when cured for 7, 14 and 28 days, respectively. The CBR value of 5% of the natural soil increased and peaked at 42% for 6% OPC / 6% LBWA treatment, while the durability in terms of resistance to loss in strength increased from 13% for the natural soil to 58%. The strength and durability values also increased with curing ages.

K. Suresh, et.al studied the effect of stone dust and Polypropylene fibers on engineering and strength properties of the Black Cotton Soils. The properties of stabilized soil such as compaction characteristics, unconfined compressive strength and California bearing ratio were evaluated and their variations with content of stone dust and fibers are evaluated.

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Addition of either Optimum percentage of stone dust (3%) and Optimum Percentage of fibers (0.6%) or Optimum percentage of its combination to the Black Cotton Soil has improved the strength characteristics of sub grade.

Parampreet kaur, et.al studied the improvement of soil using lime. The most common improvements through stabilization includes better soil gradation, reduction of plasticity index, and increase in strength and durability.
Addition of optimum percentage of lime (6%) to the soil increases the compressive strength of the soil and it also increases the maximum dry density.

2. MATERIALS

2.1 SOIL

The soil used in this study has been collected at the village near annur located at Coimbatore. Various experimental investigation were carried out to find the properties of the soil. The properties of the red soil are presented in Table 1.

Table 1: Properties of Red Soil

SL.NO	PROPERTIES	RESULT
1	Natural Moisture Content	13.72%
2	Specific Gravity	2.66
3	Seive Analysis % Of Gravel % Of Coarse Sand % Of Medium Sand % Of Fine Sand % Of Clay and Silt	 0% 8.4% 35.4% 46.4% 9.8%
4	Free Swell Index	0
5	Liquid Limit (w_L)	24.5%
	Plastic Limit (wP)	71.3%
	Shrinkage Limit (wS)	30.2%
	Flow Index (If)	30
	Plasticity Index (Ip)	0
	Toughness Index(IT)	0
6	Optimum Moisture Content	9%
	Dry Density	1.74g/cc
7	Unconfined Compressive Strength (q_u)	14.67 kN/m^2
	Cohesion (C)	7.34 kN/m^2

2.2 WOLLASTONITE

Wollastonite used in this study has been collected from Wolkam Chemicals which is located in Rajasthan. The physical and chemical properties of Wollastonite are presented in Table 2.

Table 2: Physical and Chemical Properties of Wollastonite (with reference to internet source)

SL.NO	PROPERTIES	WOLLASTONITE
1	Appearance	White
2	Form	Powder
3	Hardness(Moths)	4.5 - 5.5
4	pH	8.9 – 9.7
5	Melting Point(^{o}c)	1540
6	CaO	43 – 47%
7	SiO_2	48 – 53%
8	Sedimentation	45 – 75
9	Whiteness	87 – 92

3. PREPARATION OF SAMPLES

In this study, the wollastonite of various percentages such as 5%, 10%, 15%, 20% was mixed with the soil then the samples were undertaken for various experimental investigation.

3.1. METHODS

3.1.1. ATTERBERG'S CONSISTENCY LIMIT

The Atterberg limit test was applied to obtain the liquid limit of the soil sample and wollastonite added soil. The liquid limit test was conducted as per IS: 2720(part 5) – 1985 procedure. The liquid limit of the samples are presented in Table 3.

Table 3: Liquid Limit

SL.NO	SOIL SAMPLE	LIQUID LIMIT
1	Soil Sample	25.5%
2	Soil Sample + 5% Wollastonite	26.5%
3	Soil sample + 10% Wollastonite	28%
4	Soil Sample + 15% Wollastonite	30%
5	Soil Sample + 20% Wollastonite	27.5%

3.1.2: STANDARD PROCTOR COMPACTION TEST

Standard proctor Compaction test was conducted to determine the Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) of the soil sample and Wollastonite added samples. The test was conducted as per IS: 2720 (part 8) – 1980. The OMC and MDD of the sample are presented in Table 4.

Table 4: Proctor Compaction

SL.NO	SOIL SAMPLE	OMC (%)	MDD (g/cc)
1	Soil Sample	9	1.74
2	Soil Sample + 5% Wollastonite	8	1.78
3	Soil sample + 10% Wollastonite	6	1.82
4	Soil Sample + 15% Wollastonite	4	1.85
5	Soil Sample + 20% Wollastonite	4	1.8

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3.1.3: UNCONFINED COMPRESSION TEST

Unconfined Compression test was conducted to determine the unconfined compressive strength, which is used to find out the shear strength of the soil sample. The test was conducted as per IS: 2720(part 10) – 1991. The shear strength of the soil sample and soil sample added with wollastonite are presented in Table 5.

Table 5: Unconfined Compressive Strength (UCS)

SL.NO	SOIL SAMPLE	UCS
1	Soil Sample	0.028
2	Soil Sample + 5% Wollastonite	0.032
3	Soil sample + 10% Wollastonite	0.033
4	Soil Sample + 15% Wollastonite	0.035
5	Soil Sample + 20% Wollastonite	0.032

3.1.4: CALIFORNIA BEARING RATIO TEST (UNSOAKED CONDITION)

California Bearing ratio test was conducted to determine the CBR value of the soil sample and Wollastonite added soil sample. The test was conducted as per IS: 2720 (part 16) – 1987. The CBR value of the sample are presented in Table 6.

Table 6: California Bearing Ratio (CBR) value

SL.NO	SOIL SAMPLE	CBR VALUE
1	Soil Sample	1.8
2	Soil Sample + 5% Wollastonite	2.1
3	Soil sample + 10% Wollastonite	2.3
4	Soil Sample + 15% Wollastonite	2.6
5	Soil Sample + 20% Wollastonite	2.4

4. RESULT AND DISSCUSSION

The liquid limit of the soil get increased by addition of 5%, 10%, 15%, 20% of Wollastonite. The liquid limit increased upto addition of 15% 0f wollastonite and get decreased after 15%. So the optimum level is 15%. The addition of wollastonite and changes in liquid limit is shown in Figure 1.

Standard Proctor Compaction test shown that addition of wollastonite increases the maximum dry density of the red soil which is shown in Figure 2 .

Addition of wollastonite decreases the optimum moisture content of the red soil which is shown in Figure 3.

Unconfined Compression test shows that the shear strength of the soil get increased then the normal soil by adding wollastonite upto 15% and then get decreased after 15%. So the optimum level is 15%. The addition of wollastonite and the increase in shear strength is shown in Figure 4.

California Bearing Ratio test shows that the CBR value of the wollastonite added soil is increased than the normal soil sample. The addition of wollastonite and the incresase in CBR value is shown in Figure 5.

Comparison of all test results has been shown in Figure 6. It is clear from the graph that upto 15% addition of wollastonite, strength, liquid limit, CBR value are increased and OMC get decreased. After 15% strength and other factors get decreases. Hence it could be decided that 15% addition of wollastonite is the optimum value.

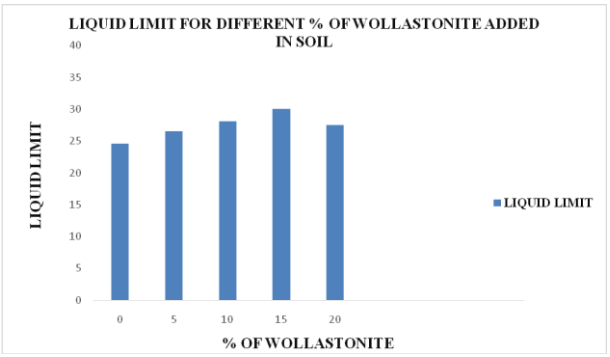

Figure 1: Comparison of various % of wollastonite and its liquid limit

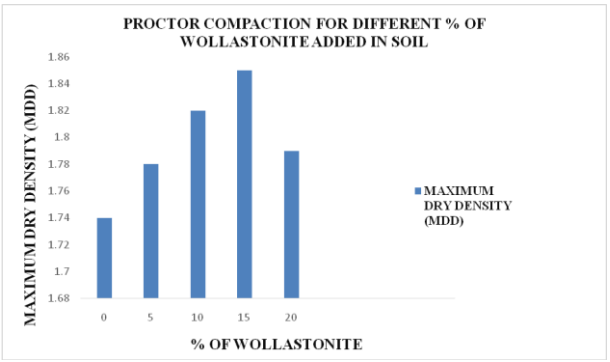

Figure 2: Comparison of various % of wollastonite and its maximum dry density (MDD)

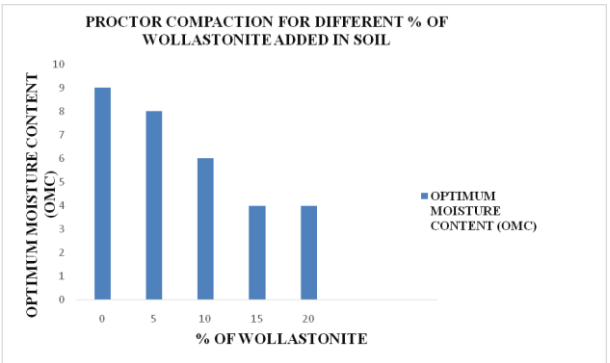

Figure 3: Comparison of various % of wollastonite and its optimum moisture content (OMC)

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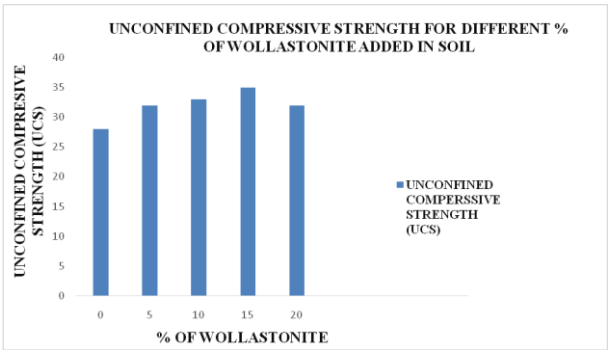


Figure 4: Comparison of various% of wollastonite and its unconfined compresive strength (UCS)

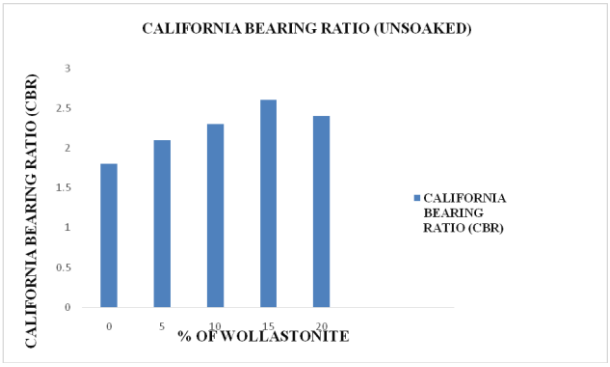
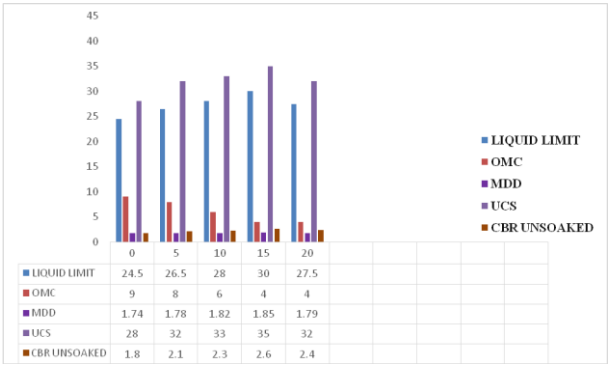


Figure 5: Comparison of various % of wollastonite and its california bearing ratio (CBR)



	0	5	10	15	20
LIQUID LIMIT	24.5	26.5	28	30	27.5
OMC	9	8	6	4	4
MDD	1.74	1.78	1.82	1.85	1.79
UCS	28	32	33	35	32
CBR UNSOAKED	1.8	2.1	2.3	2.6	2.4

Figure 6: Overall comparison of various % of wollastonite with liquid limit, OMC, MDD,UCS and CBR value.

5. CONCLUSION

The main objective of this paper is to study the effect of wollastonite on geotechnical properties of soil.

Based on this experimental stud , the following observations are drawn.

1. Addition of wollastonite improves the properties of the red soil.
2. Increase of MDD by the addition of wollastonite enhances the strength of the red soil.
3. Improvement of Unconfined Compressive Strength results in the reduction of difficulties in foundation work.
4. The addition of wollastonite to the red soil lead to the reduction of OMC and increase of MMD.

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