MANTECH Publications

Journal of Ceramics and Concrete Technology
Volume 8 Issue 1
ISSN: 2457-0826 (Online)

Effect of Powder of Wollastonite on Soil Stabilization: A Review

Aishwarya A. Maindkar[1], A. I. Dhatrak[2], S.W Thakare[3], P. V. Kolhe[4]

PG Scholar[1], Associate Professor[2,3], PhD Research Scholar[4]

Department of Civil Engineering

GCOE Amravati, Maharashtra, India

Corresponding Author E-mail:- *aishwaryamaindkar@gmail.com*

Abstract

When impure dolostone or limestone is subjected to high temperature and pressure, it will leads to formation of Wollastonite. Wollastonite is a Calcium silicate mineral ($CaSiO_3$) that may contain small traces of other minerals like Iron, Magnesium, and Manganese substituting for Calcium which is available in many location below the ground surface. Wollastonite can frame a progression of strong arrangements in the $CaSiO_3$-$FeSiO_3$ framework or the aqueous combination of stages in the $MnSiO_3$-$CaSiO_3$ framework. Since Wollastonite powder is inexhaustible, bio-degradable, naturally well-disposed and minimal effort material, they have comparable physical and mechanical properties of other added substances like lime. Wollastonite powder has exceedingly potential application as fortifying segment for soil support.

Keywords: *Black cotton soil, Soil stabilization, Wollastonite.*

INTRODUCTION

1.1 General

Black cotton soils are problematic due to the presence of their clay constituent and usually have the potential to show their undesirable engineering properties such as low bearing capacity, high shrinkage and swell characteristics. The shrink-swell behavior of these soils makes them inappropriate for direct engineering applications in its natural form. In order to enhance their engineering performance and to make them more feasible for usage, stabilization of soil may be done physically or chemically.

These soils are well-known for their moisture-holding capacity due to which

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they swell. Due to shrinkage and swelling, a difference in the volume of soil occurs which formulates cracks in the foundation or the building structural system. The cracks reduce the durability and strength of the structure, and may cause failure of structure.

1.2 Soil stabilization

Soil Stabilization is the process of improving the engineering properties of soil and thus making it more stable. It is required when soil available for construction is not suitable for the intended purpose. The term stabilization is generally used for processes which alter the soil material itself for improvement of properties. A cementing material or a chemical is added to natural soil for the purpose of stabilization.

Soil Stabilization is used to reduce the permeability and compressibility of the soil mass in earth structure and to increase its shear strength. Soil stabilization may be adopted to increase the bearing capacity of foundation soils. However, the main use of stabilization is to improve the natural soils for different constructions.

In order to make the expansive soils to achieve geotechnical engineering for design requirements, the process of soil stabilization can be applied to improve the strength characteristics of expansive soil.

1.3 Wollastonite Powder

Wollastonite is a chemically simple mineral named in honor of English mineralogist and chemist Sir W.H. Wollaston (1766–1828). Wollastonite powder is generally a mutual component of thermally altered adulterated limestone. It may also arise when silicon is affected by metamorphisms in sediments that have been altered by contact or contamination by invasive igneous rocks.



Figure 1: Wollastonite mineral and its Powder

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In majority of these cases, it results from the accompanying responses from calcium and silicon by loss of CO_2 $SiO_2 + CaCO_3 = CaSiO_3 + CO_2$ (Silica + limestone = Wollastonite + carbon dioxide)

Thus, Wollastonite is an industrial mineral containing chemicals like calcium, silicon and oxygen. Molecular formula of Wollastonite is $CaSiO_3$ and its approximate theoretical composition consists of 48.28% of CaO and 51.72% of SiO_2. Natural Wollastonite may contain traces or minor amounts of various metal ions such as aluminum, iron, magnesium, potassium and sodium.

Wollastonite is infrequently found in pure form and generally contains other minerals namely calcite, garnet and dropsied as gangue minerals or impurities those removed during extraction process. It possesses properties like lower moisture content and oil absorption with low volatile content. Surface modification of Wollastonite enhances its physical properties. It also results in improved processing and improved dispersion if implemented in resin. Wallostonite find it's plenty of applications which includes ceramics, paints etc.

LITERATURE REVIEW

The review of available literature, based on studies carried out with the use of Wollastonite to improve properties of soil along with their concluding remarks is presented below:

2.1 Geotechnical Properties of Soil Stabilized with Wollastonite

Mohanalakshmi et al. (2016) studied the properties of a red soil and its reaction with a Wollastonite conducting various tests like Standard Proctor compaction test, California Bearing Ratio test, etc.

Red soil was collected at Annur and the properties of red soil (unaltered) were found. Wollastonite was then added to the red soil and properties and strength of soil was found by conducting various experimental investigations. Table 1, Table 2, Table 3 and Table 4 show the results for consistency limit, OMC and MDD, UCS and CBR values of red soil stabilized with Wollastonite.

The results showed that due to addition of 15% Wollastonite, properties like UCC, California Bearing Ratio (CBR) and Dry density increased and further addition of Wollastonite decreased these properties.

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Table 1: Consistency Limits of red soil stabilized with Wollastonite

Sr. 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%

Table 2: OMC and MDD of red soil stabilized with Wollastonite

Sr. 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

Table 3: Unconfined Compressive Strength of red soil stabilized with Wollastonite

Sr. 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	0.32

Table 4: California bearing ratios of red soil stabilized with Wollastonite

Sr. No.	Soil sample	CBR Values
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

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The liquid limit increased up to addition of 15% of Wollastonite and decreased after 15%. So the optimum level was 15%.

Unconfined Compression test results showed that the shear strength of the soil increased compared to the normal soil by adding Wollastonite up to 15% and then decreased after 15%. So the optimum dose was 15%. Shear strength of soil due to addition of Wollastonite as shown in Figure 2.

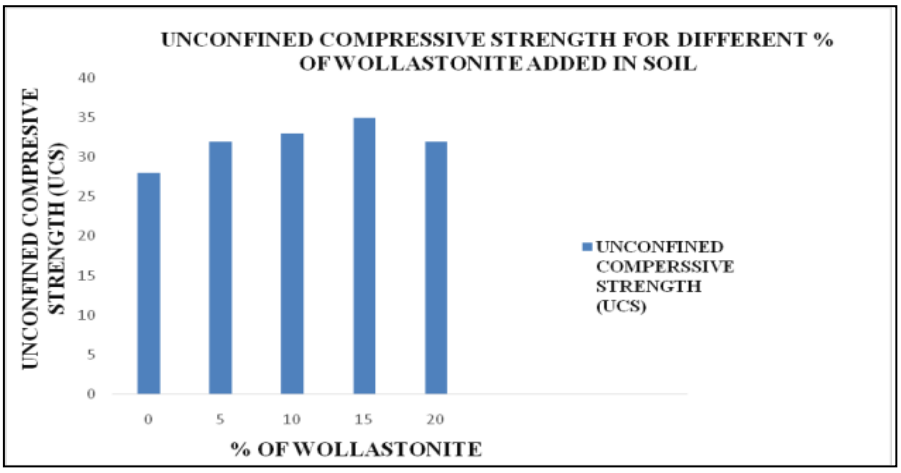


Figure 2: Effect of various% of Wollastonite on unconfined compressive strength (UCS)

Results of California Bearing Ratio tests showed that the CBR value of the Wollastonite added soil increased compared to the normal soil sample as shown in Figure 3.

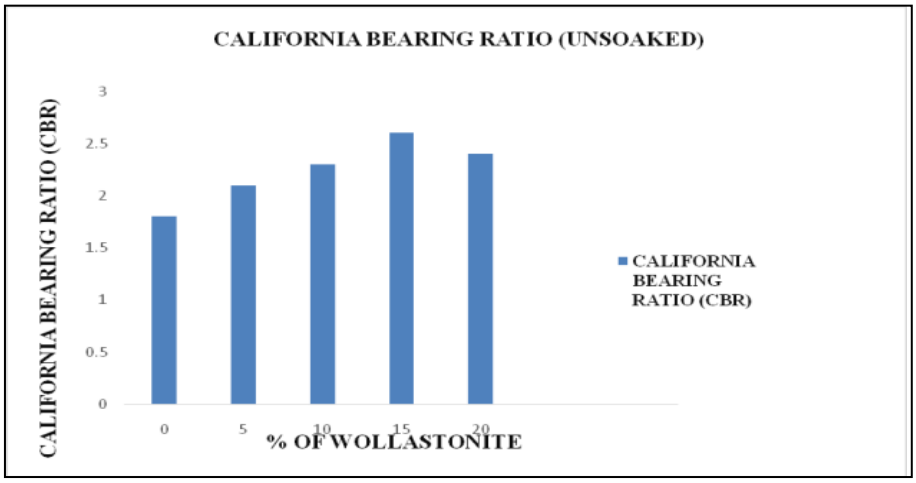


Figure 3: Effect of various % of Wollastonite on California bearing ratio (CBR)

Thus, for 15% addition of Wollastonite, strength, liquid limit, CBR value increased and OMC decreased. Hence it was concluded that 15% addition of Wollastonite was the optimum value.

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2.2 Stabilization and Characterization of Soil using Wollastonite Powder

Nikhil et. al. in 2020 carried out investigations into the improvement of strength characteristics of expansive soils using Wollastonite powder as an additive to reduce the cost.

Table 5 and Table 6 shows the results of investigations. From the compaction test, it was detected that Maximum Dry-density decreased whereas Optimum Moisture content of soils increased with increase in dosage of admixture.

The Unconfined compressive strength values of soils treated with Wollastonite Powder increased up on addition of 12.5% Wollastonite powder and then, a slight decrease was observed. Thus, the results showed that, Wollastonite powder was effective additive for soil.

Table 5: Compaction Characteristics of S1 Sample

Soil	Wollastonite %	MDD (g/cc)	OMC (%)
Soil Sample S1	S1 + 0%	1.64	16.9
	S1 + 5%	1.63	18.4
	S1 + 7.5%	1.61	19.2
	S1 + 10%	1.59	21.5
	S1 + 12.5%	1.58	23
	S1 + 15%	1.57	24.2

Table 6: Compaction Characteristics of S2 Sample

Soil	Wollastonite %	MDD (g/cc)	OMC (%)
Soil Sample S2	S2 + 0%	1.71	18.5
	S2 + 5%	1.70	19.4
	S2 + 7.5%	1.69	21
	S2 + 10%	1.68	22.5
	S2 + 12.5%	1.67	23.8
	S2 + 15%	1.66	25

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Figure 4 and Figure 5 shows Compaction curves for untreated and treated soil sample S1 and soil sample S2 respectively.

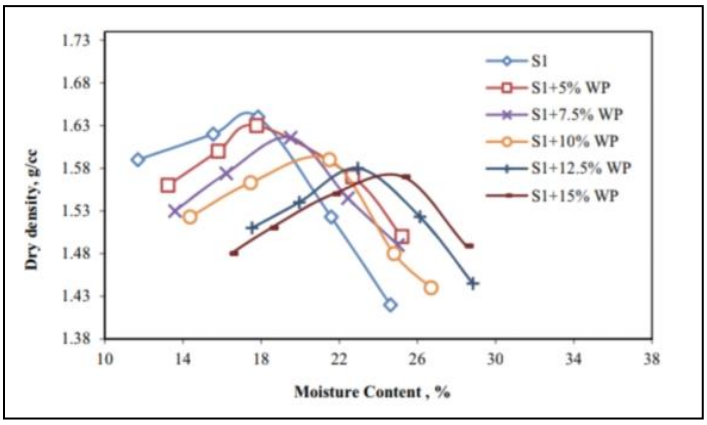


Figure 4: Compaction curves for untreated and treated soil sample S1.

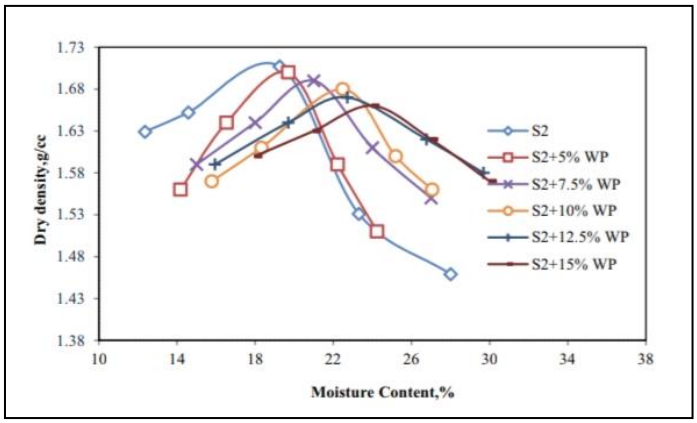


Figure 5: Compaction curves for untreated and treated soil sample S2.

Figure 6 and Figure 7 shows Stress vs Strain characteristics for untreated and treated Soil sample S1 and soil sample S2 respectively at 28 days of curing

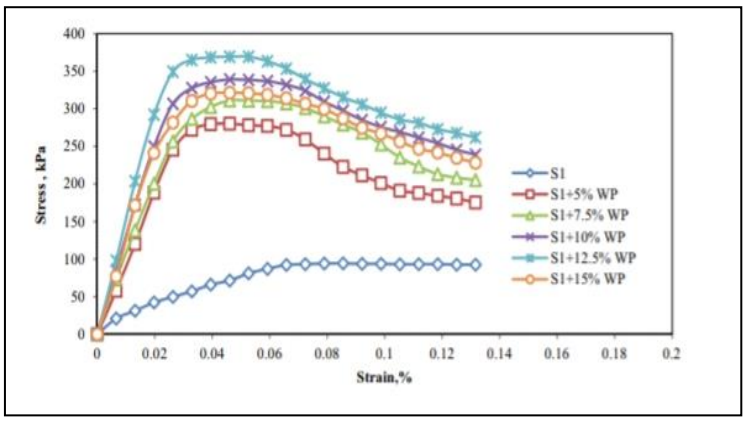


Figure 6: Stress vs Strain characteristics for untreated and treated Soil sample S1 at 28 days of curing.

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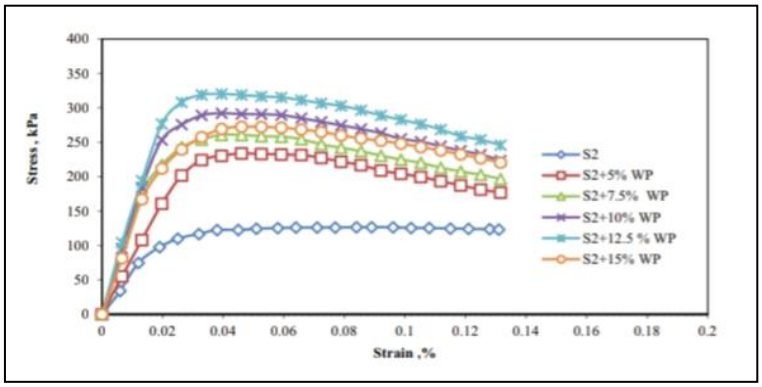


Figure 7: Stress vs Strain characteristics for untreated and treated Soil sample S2 at 28 days of curing.

Figure 8 and Figure 9 shows Variation of UCS values of S1 and S2 with increase in % of Wollastonite powder

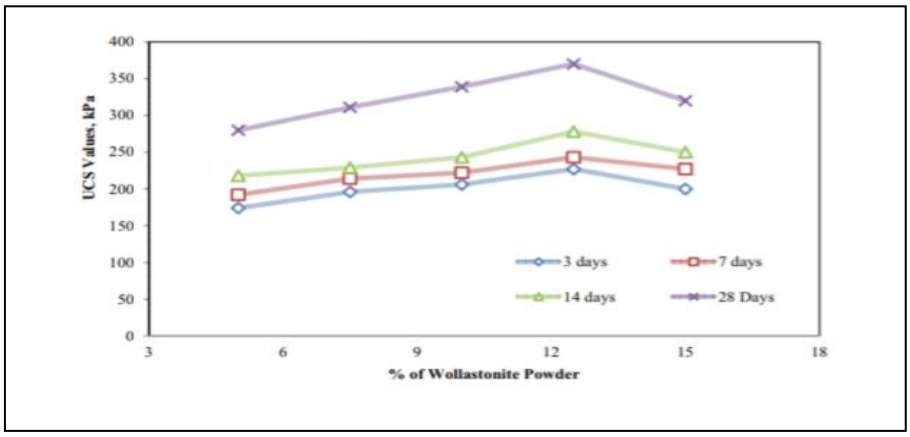


Figure 8: Variation of UCS values of S1 with increase in % of Wollastonite powder

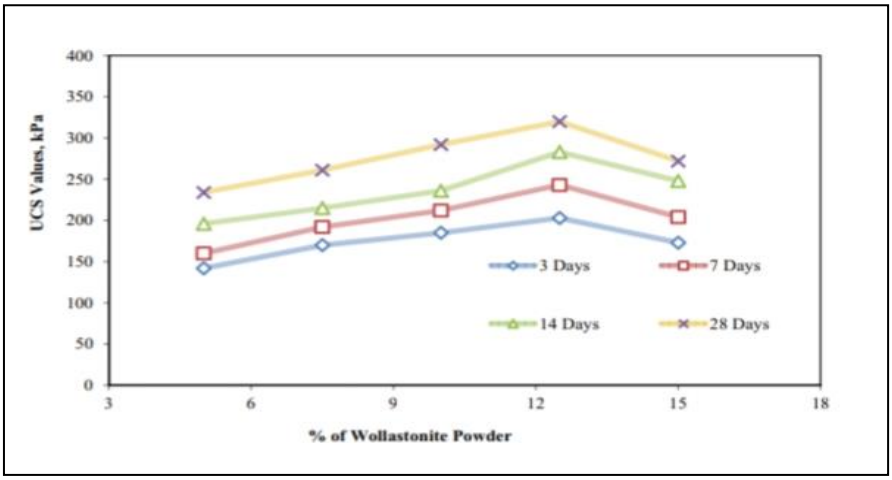


Figure 9: Variation of UCS values of S2 with increase in % of Wollastonite powder.

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It was concluded that,

1. From the compaction tests, it was detected that Maximum Dry density was decreased whereas Optimum Moisture content of soils increased with increase in dosage of admixture.

2. The Unconfined compressive strength values of soils treated with WP increased up on addition of 12.5% Wollastonite powder then, a slight decrease was observed. However, this value was higher than the untreated soil up on 15% addition of Wollastonite powder. Peak stress was observed to 393.6% and 253.9% as compared to untreated soils on addition of 12.5% Wollastonite powder at 28 days of curing.

3. Wollastonite powder was effective additive for soil, which could boost stability and condense the cost of process in addition to improve strength and properties.

CONCLUSIONS

From the research work on use of eco-friendly (Wollastonite) in geotechnical engineering to modify the characteristics of soil, following concluding remarks can be done:

- The soil stabilization with using Wollastonite powder is effective in improving strength properties of soil.
- The curing period plays an important role in strength gain of soil stabilized with Wollastonite.
- The addition of Wollastonite to the soils leads to the reduction of OMC and increase of MMD.
- Increase of MDD by the addition of Wollastonite enhances the strength of the soil.
- Wollastonite stabilization depends upon various factors like Curing period, percentages of Wollastonite etc.
- The eco friendly materials like Wollastonite in stabilization of soil may achieve the overall economy and becomes eco-friendly approach for soil stabilization compared to conventional methods.

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