Journal of Green Engineering (JGE)

Volume-10, Issue-3, March 2020

Sustainable Stabilization of Soil Using Wollastonite Powder

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Abstract

All over the world there are lots of places where clayey soil can be found. Design and construction of any kind of structure or pavement over this expansive and weak kind of soil is quite challengeable and problematic for geotechnical engineers. Enhancing the properties of expansible and weak soil has become a popular research topic in the present scenario, which prevents the need of replacement of the soil and could be established with chemical inclusion and sustainable method of stabilization. The present investigations includes the study on improvement in the characteristics of soil compaction, California Bearing Ratio (CBR) and swell behaviour with the addition of Wollastonite Powder (WP) on two selected soil sample. From the study it was observed that with the addition of optimum amount of 12.5% of wollastonite powder increases the admixture impact ratio on CBR value more than 200 %. In addition, the Free-swell index of wollastonite powder treated soil showed a dropping instance with increase in growth of bonding between soil particles and admixture SEM micrographs also reveal reduction in pore spaces of the treated soil sample and structural change at micro level, which indicates the improvement in strength.

Journal of Green Engineering, Vol. 10_3, 1167–1181.

Alpha Publishers

Keywords: Clayey Soil, Curing period Wollastonite Powder, Stabilization, Sustainable stabilisation

1 Introduction

Clay soils of clearing nature are generally seen as unstable soils in numerous countries, basically where the environment is completely dry to semi-dried. India is one country where the conceivable high swelling of a these soil will cause early damage a road structure. Usually clay soil is an alluvial kind that is no matter how you look at it in northern fields and valleys of the canal. Alluvial soils spread about 46.85 % of India's outright region. Most soils are said to be clayey and silty soils. The quantity of CaO and Fe2O3 in this earth varies for the most part, due to which these kinds of soil has a low CBR regard. This sort of soil thusly needs greater improvement costs similarly as help sustainable environment [1,2].

2 Literature Review

Low- concentration roadways and the present development stage where the removal and substitution of lower subsoils may not be practicality. Subgrade adjustment is normally pertinent for unpaved brief streets, for example, streets or development stages to help permanent streets. The least difficult adjustment forms are compacting and seepage (if moisture depletes out of saturated soil it winds up more grounded). The different procedure is by enlightening degree of molecule estimate and additional enhancement is accomplished by addition of binding agents to the problematic soils [3-5].

The roadway surface's conduct relies upon the quality of the fill material and the asphalt's subgrade. The quality of the subgrade is frequently associated by a standard plunger as far as the California Bearing Ratio (CBR), which is the proportion of testing load to standard load at a particular entrance. Numerous investigations had been achieved to survey the swell-shrinkl for undisturbed clay soil as a component of water content [6-8], Stabilization by Fly-Ash [3, 9-11], by Cement [12], Recycled Asphalt [1], Phosphogypsum [3], GGBS [13], Waste Material [14], Coal Waste [5], Cement Kiln Dust [15].

Other soil enhancement and soil strengthening are done by agricultural waste such as Sugar Cane Baggage Ash [16,17], Groundnut Shell Ash [18], Rice Husk Ash [19], Palm Oil fuel Ash [20] and Dolomite Hydrated Lime [21], Wood Ash [22] Metakaolin [23], Bio-Stabilization [24].

The purpose of this investigation is to explore the usability of wollastonite powder(WP), which is formed when contaminated carbonate sedimentary rock is exposed to greater temperature, in improving bearing capacities of problematic soils. Each component forms almost half of the mineral weight in pure wollastonite i.e. 48.3% of CaO and 51.7% of SiO_2. Wollastonite Powder has highly application as reinforcing component for soil reinforcement.

In this study two types of clay soils were taken, a set of laboratory experiments including compaction test, California Bearing Ratio (CBR) test and Free-Swell Index test was conducted on untreated soil and soil treated with different percentages of wollastonite powder for preserving periods of 4 7 days. Microstructural analysis was performed on untreated and treated soil sample to study the effect of gain in strength in treated soil. The findings of this investigation were analysed and discussed for better understanding of the impact of Wollastonite Powder on sustainable strength characteristics of treated soils.

3 Materials

Two soil samples S1 and S2 were used in this study,that was collected from a construction site in Nellore, Andhra Pradesh and Hubli, Karnataka. These soils were air-dried and pulverised in laboratory. The principal properties of untreated soil used in this study was investigated and observed in detail. All the teste on soil sample were carried out according to the Bureau of India standards [25-33]. In terms of size of particles, both soils were classified as fine-grained soil according to IS classification. Grain size distribution showed 96% and 84% in range of fine grained for both soil S1 and S2. These soil samples were showing high swelling potential as the free-swell index values of soil samples S1 and S2 was observed as 70% and 95% respectively, which are more than 50%. The specific gravity of soil samples was obtained as 2.34 and 2.69 for S1 and S2 respectively. Liquid Limit, Plastic Limit and Shrinkage Limit for soil samples S1 and S2 were obtained as 55%, 28%, 9.4% and 65%, 30%, 7.8% respectively. Maximum Dry Density and Optimum Moisture Content was found out as 1.64 g/cc and 16.9% for soil sample S1 and 1.71 g/cc and 18.5% for soil sample S2. Unconfined compression strength was obtained as 94 kPa and 126 kPa for S1 and S2 respectively. Based on above obtained results the soil is classified as High Compressible (CH) clay with weak consistency and medium consistency.

Wollastonite powder(WP) used for this investigation study was collected from Jaipur, Rajasthan. General properties of wollastonite powder are provided in below Table 1, which provide details of its appearance, hardness and other chemical properties .

Table 1. Properties of wollastonite powder

Properties	**Results**
Appearance	White
Hardness (moths)	4.5-5.5
pH	8.9-9.7
Melting point (^{o}C)	1540
CaO	43-47%
SiO_2	45-75%
Specific gravity	2.8-3.09

3.1 Preparation of soil specimens

In this work, a set of reformed soils sample S1 and S2 with different percentages of WP were prepared to investigate the swelling and strength characteristics of treated soil samples. Based on the requirement of dosage of admixture the percentages of wollastonite powder was taken as 5%, 7.5%, 10%, 12.5% and 15%, for curing periods of 4 and 7 days. The soil samples are prepared with varying percentages of wollastonite powder by weight of specimen. Prepared soil samples were cured with utmost care to avoid unnecessary errors at time of sample testing.

4 Testing Procedure

Light compaction test was used in finding Water content and Dry density relationship of soil in accordance to IS-2720/7-1980. This test was carried out to determine the compaction characteristics of soil samples treated with varying percentages of wollastonite powder. Variation of MDD and OMC with different dosages of wollastonite powder for soil sample S1 and S2 are provided in Figure 1 – Figure 2, respectively.

CBR test was conducted on basis of IS : 2720 (Part 16) –1987. Test sample was prepared from MDD and OMC obtained from compaction test. The prepared soil specimen was cured by placing the specimen over wet sack bag and keeping surcharge load on top of the specimen. At the end of each curing day the sample was tested using universal testing machine at constant rate of load. Load vs penetration plots are made and further discussion was carried out.

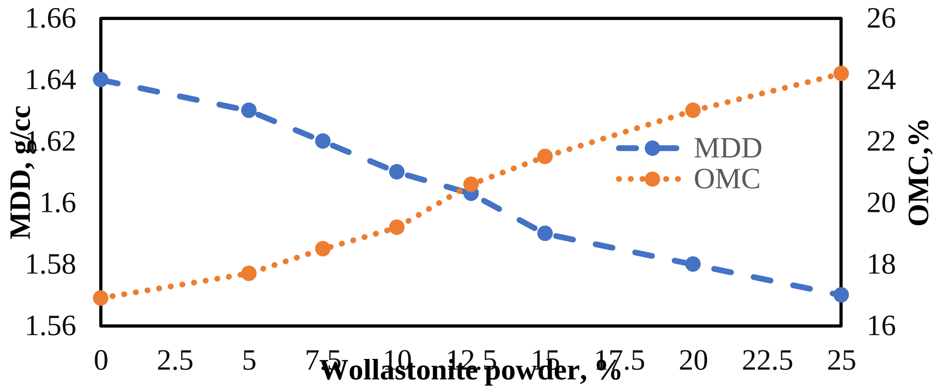


Figure 1. Variation of OMC and MDD with varying % of Wollastonite powder on soil S1

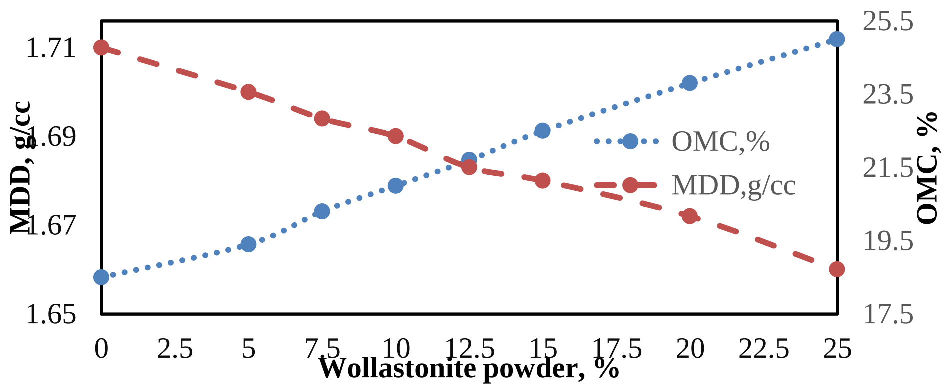


Figure 2. Variation of OMC and MDD with varying % of Wollastonite powder on soil S2

Free-Swell Index (FSI) which is defined as change in volume of soil without any peripheral restraint when submerged in water. The test was performed as per as per IS 2720 (Part 40)-1977. FSI test was directed on untreated soil and soil treated with 12.5 % wollastonite powder at different curing days to know Swelling potential of treated soil.

SEM Analysis was performed on untreated soils S1, S2, WP and soil treated with 12.5 % wollastonite powder at curing time of 28 days to distinguish the exterior morphological, molecule shape and condition of the elements utilized for this investigation alongside the microstructures of the hydrated adhesives of the soil treated with admixture and ideal paired blend in the wake of being uncovered for different restoring periods. Preceding SEM imaging testing, the examples were covered with a slim layer of palladium utilizing a sputter coater for expanded perceivability.

5 Result and Discussion

It was seen that wollastonite content decreases MDD and increases OMC. The decrement in MDD of soil-wollastonite mixture might be because of high specific gravity of wollastonite powder i.e. 2.89 compared with low specific gravity of soil tests S1 and S2 as 2.34 and 2.69 individually. The addition in water substance might be because of high water incorporation limit of wollastonite powder.

When wollastonite powder added to soil samples, mild increase in CBR value was observed in both Soils S1 and S2, when compared with untreated CBR values of 4.2% and 3.8% respectively. It is observed that at 12.5% dosage of wollastonite powder high load bearing capacity in soil sample S1 and S2 were showed, and at higher dosage of 15% there was decrement in CBR value was observed. Table 2 shows CBR values of both soil sample treated with varying percentages of wollastonite powder.

Table 2. CBR values of Sample S1 and S2 treated with Wollastonite Powder

Curing Days	**California Bearing Ratio(CBR) Values, %**									
	Sample S1 + WP (%)					**Sample S2 + WP (%)**				
	5	7.5	10	12.5	15	5	7.5	10	12.5	15
4	5.50	6.17	6.69	8.48	5.66	4.46	5.06	5.58	6.69	6.02
7	6.11	7.59	8.18	9.00	6.57	5.80	6.25	6.62	7.66	7.14

Figure 3 - Figure 4, shows the load vs penetration plots of untreated and treated soil samples with wollastonite powder at 7 days curing period. Figure 5 - Figure 6 shows effect of increasing percentages of wollastonite powder on soil samples S1 and S2.

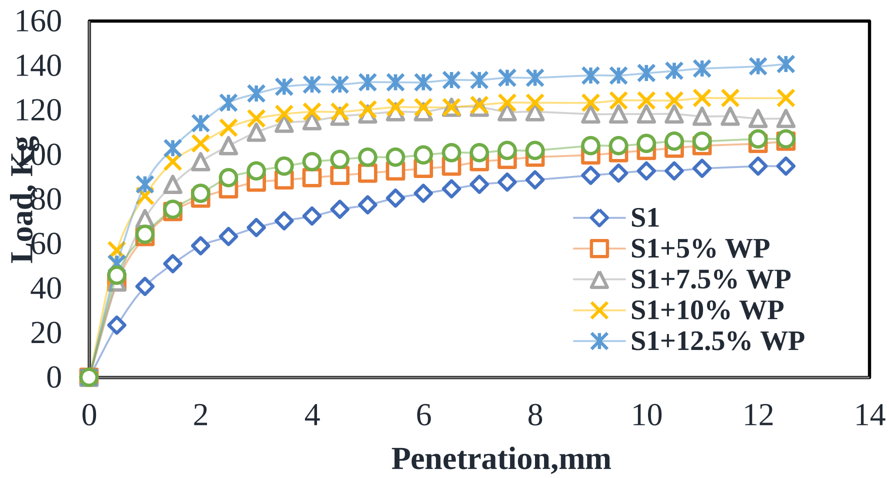


Figure 3. Load vs Penetration plot for treated Soil Sample S1 for 7 Days of Curing

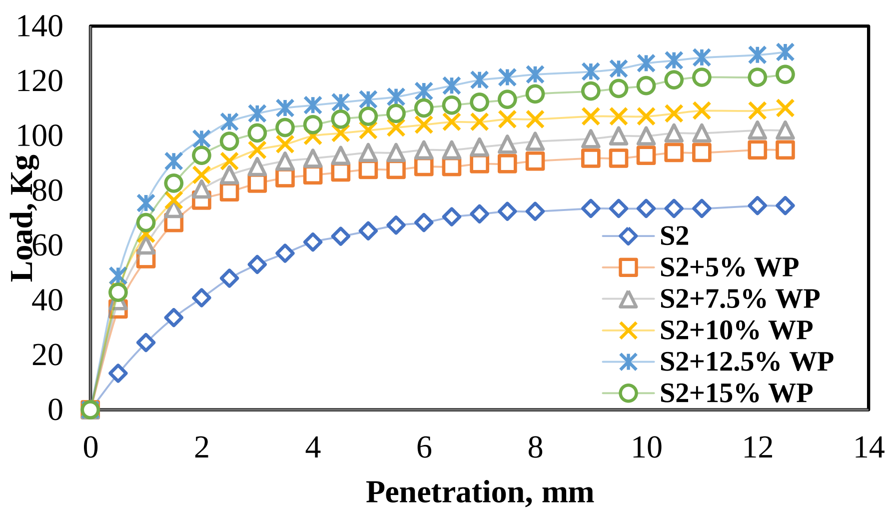


Figure 4. Load vs Penetration plot for treated Soil Sample S2 for 7 Days of Curing

Along with load vs penetration plot, the increasing trend in quality was considered by presenting Admixture Impact Ratio (AIR), which reveals the rough ascent in sub grade quality with different dosage of wollastonite powder content, whose relation is referenced as an underneath

AIR = (CBR of treated soil / CBR of untreated soil) * 100 (1)

The rate increment in AIR is shown in Table 3, by this it can be very well seen that at low percentages of wollastonite powder, the expanding pattern of CBR esteem was very little viable. 4 and 7 days preserving, the rate of augmentation is very articulated as it reaches to 212.7 % and 219 %

for S1 and S2 individually concerning a higher dose of 12.5% WP. As of now it tends to be legitimized that the high accessibility of Ca content, just as the high actuation vitality of binder WP, lead to the beginning of cementitious responses which are given in Table 3.

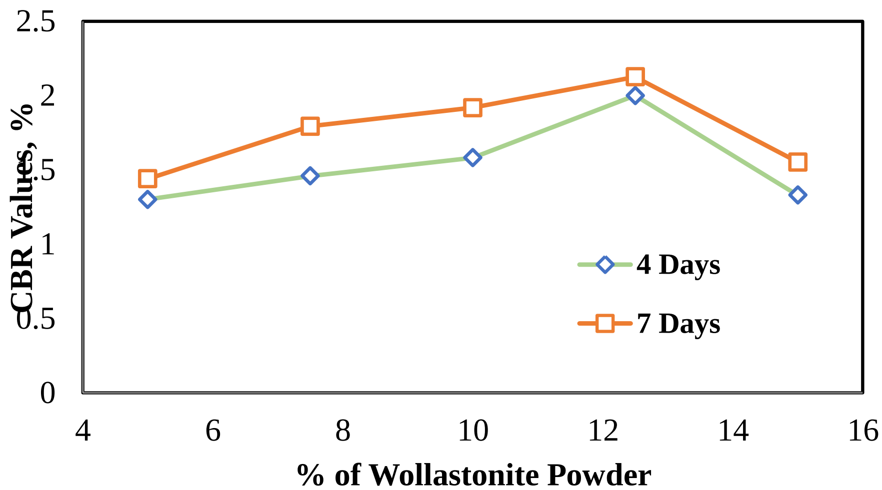


Figure 5. Variation of CBR results of S1 with increase in % of wollastonite powder

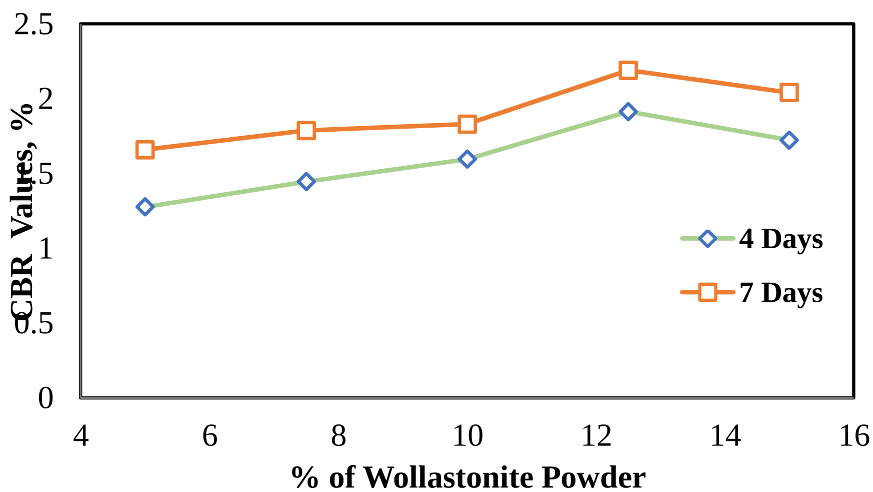


Figure 6. Variation of CBR results of S2 with increase in % of wollastonite powder

Table 3. AIR of treated soil S1 & S2 with varying % of WP for different curing periods

Curing Days	Admixture Impact Ratio(AIR), %									
	Sample S1 + WP, %					Sample S2 + WP, %				
	5	7.5	10	12.5	15	5	7.5	10	12.5	15
4	129	145	158	200	133	116	132	146	175	157
7	144.	179	193	212	155	151	163	173	200	186

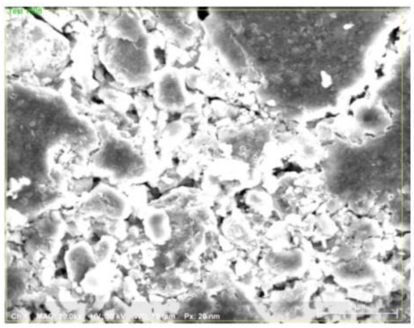
By obtained CBR and AIR results, the soil treated with 12.5% of wollastonite powder delivers high strength and durability, at this point it can be justified as the optimum dosage of admixture. The same was observed in compaction characteristics also, where maximum dry density and optimum moisture content got intersect at range of 12.5 %.

Free-swell index test was performed utilizing powdered soil sample of treated sample following to leading the test. The prepared samples remained uninterrupted for 24 hour. Free-swell index of treated soil is provided in Table 4.

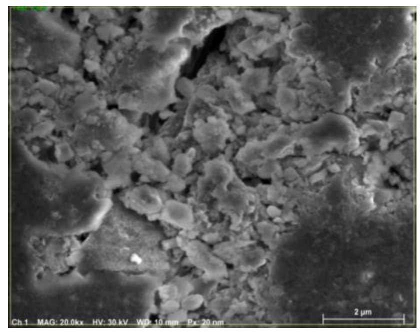
Table 4. Free-Swell Index for untreated and soil treated with 12.5% WP for different curing Days

Curing Periods (Days)	Soil Sample S1 (%)	Soil Sample S2 (%)
0	70	95
3	62.5	85
7	50	69
14	47	56
28	40	38

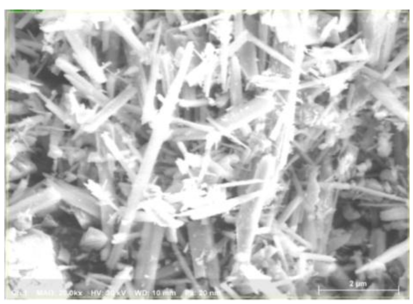
Subsequently a falling instance of the free swell index observed with the development of wollastonite powder. The improvement of pozzolanic blends made soil elements to organize into flocculated structure, which finally realized a lessening of a swelling potential. The high analyst swells breaking point of soil got diminished and thusly it might be foreseen that the ability to profoundly change volume was exceedingly decreased with the extension of wollastonite powder.



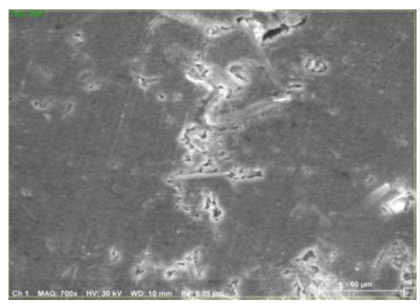
(a) Soil sample S1



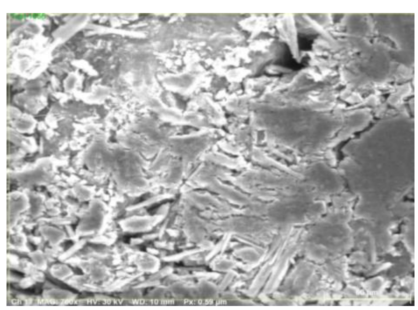
(b) Soil sample S2



(c) Wollastonite powder (WP)



(d) Soil S1 treated with 12.5 % WP at 28 days of curing



(e) Soil S2 treated with 12.5 % WP at 28 days of curing

Figure 7. SEM micrographs of soil samples S1, S2, WP and treated soil samples

As per Figure 7, The SEM micrographs of untreated soil shows type of microstructure, with stratified shape elements present in a random order. These friable atoms were identified as quartz and illite minerals. In Soil treated with wollastonite powder, it was observed that the structure of treated soil is brilliantly changed when compared with untreated soil. The treated soil micrographs shows that elements of wollastonite has made virtuous bonding with soil particles. It also represents soil interaction with wollastonite powder which leads to increment the strength of treated soil.

6 Conclusion

Two soil sample S1 and S2 were used for this investigation which were treated with varying percentages of wollastonite powder, the following conclusions were drawn:

The results obtained by compaction test shows rising optimum moisture content and falling maximum dry density, by which it was found that 12.5% is optimum dosage of wollastonite powder.

The results of CBR test, it was observed that at 12.5% of wollastonite powder maximum CBR value was obtained, which were showing 212.66 % and 200.52% increase compared to untreated soil S1 and S2 respectively.

Free-swell index of soil treated with 12.5% wollastonite powder showed a dropping instance with increase in growth of bonding between soil particles and admixture.

SEM micrographs of soil treated with 12.5% wollastonite powder showed magnificent change in microstructure of treated soil, which represents the formation of new compounds that helps increasing the strength of soil.

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Biographies

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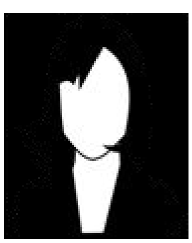

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