

Stabilization of Red Soil Using Ground Granulated Blast Furnace Slag & Alccofine

¹Navdeep Mor, ²Lukesh Kumar & ³Neeraj Sharma

¹Research Scholar, Civil Engineering Department, NITTTR-Chandigarh (India)

²M.Tech Student, Civil Engineering Department, Sri Sai college of Engineering and Technology, Badhani, Pathankot (India)

³Assistant Professor, Civil Engineering Department, Sri Sai college of Engineering and Technology, Badhani, Pathankot (India)

ARTICLE DETAILS

Article History

Published Online: 10 October 2018

Keywords

Alccofine, Furnace slag, red soil

Corresponding Author

Email: navdeepmor12345[at]gmail.com

ABSTRACT

Structure foundations need to be on stable and strong soils. Soils range in strength. Some soils are able to support a skyscraper, while other soils are not able to support the weight of a human. If the soil under a building is not stable, the foundation of the building could crack, sink, or worse—the building could fall. The strength and stability of soil depend on its physical properties. Soil with good structure is more stable. Clay textures are often more stable than sand textures because they have better structure. However, a mix of particle sizes (and pore sizes) is best for engineering (just as it is best for growing crops). It is also important that soil is stable through wetting and drying cycles, so that expanding soil does not crack roads or foundations. Some clay minerals, from a family called smectite, are more likely to shrink and expand during wetting and drying cycles than minerals from other families, such as kaolinite.

1. Introduction

Economic development of any country is controlled to a great extent by the construction projects. This is becoming particularly apparent in the developing countries, where tremendous lengths of roads need to be constructed in order to facilitate the development of agriculture, commerce and industry. The cost of any construction project includes initial costs and subsequent maintenance costs. The initial costs include many items such as land, accommodation works, bridges and subways, drainage, foundation construction etc. The type and the thickness of the foundation construction determine a large percentage of the initial cost of any road project. Therefore, the development and use of methods to decrease the cost of foundation construction is very beneficial. It is essential to take into consideration the conditions of the sub grade soil before designing the type and the thickness of the foundation, as the sub grade carries the traffic loads as well as the foundation loads. Good qualities of sub grade soils are preferable for durable construction but not always available for general construction. The civil engineer designing a construction project may be faced by weak or unsuitable sub grade. In this case the following methods to overcome this problem can be considered. First improve in-situ materials by normal compaction methods and design for the modified properties. Second, import the suitable materials from the nearest convenient source and replace the site materials. Third, improve the properties of the existing materials by incorporating some other materials; this process is known as "soil stabilization". The most appropriate method will usually be determined by economic considerations, for example it may be cheaper to stabilize a soil using relatively expensive additives rather than excavate and dispose of unsuitable materials and place suitable fill, as well as the properties of the sub grade.

2. Ground Granulated Blast Furnace Slag (GGBS)

Ground Granulated Blast furnace slag is a by-product for manufacture of pig iron and obtained through rapid cooling by water or quenching molten slag. Here the molten slag is

produced which is instantaneously tapped and quenched by water.

This rapid quenching of molten slag facilitates formation of "Granulated slag". Ground Granulated Blast Furnace Slag (GGBS) is processed from Granulated slag. If slag is properly processed then it develops hydraulic property and it can effectively be used as a pozzolanic material. However, if slag is slowly air cooled then it is hydraulically inert and such crystallized slag cannot be used as pozzolanic material.

3. Alccofine

Alccofine is manufactured in the controlled conditions with special equipment to produce optimized particle size distribution which is its unique property. Alccofine 1203 and Alccofine 1101 are two types with low calcium silicate and high calcium silicate respectively. The computed blain value based on PSD is approximately 12000cm²/gm and is truly ultra-fine. Due to its ultra-fineness of Alccofine 1203, it provides reduced water demand for a given workability, even up to 70% replacement level as per requirement.

4. Literature Gap

In developing country like India due to the remarkable development in road infrastructure, Soil stabilization has become the major issue in construction activity. Stabilization is an unavoidable for the purpose of highway and runway construction, stabilization denotes improvement in both strength and durability which are related to performance. Soil stabilization means alteration of the soils properties to meet the specified engineering requirements. Methods for the stabilization are compaction and use of admixtures. Lime, Cement was commonly used as stabilizer for altering the properties of soils. Reuse of waste materials have been advocated for quite a while now and the utilization of industrial wastes in improving the properties of poor soils open up a new avenue for solid waste management. Expansive soils have been one of the most problematic soils encountered by a Civil

Engineer. A lot of techniques are available for stabilization of such poor soils including lime and cement stabilization. However, the utilization of solid wastes in soil stabilization is an area of potential and promise. It also provides the double advantage of waste management along with soil improvement. At present, year after year, most of the countries including India are producing millions of tons of blast furnace slag which is the by-product of steel industries. Alccofine is a granulated blast furnace slag based microfine material designed for soil stabilization. The National and International Scenario of the past studies can be concluded in a statement that so far, no evidence has been found where Blast Furnace Slag and Alccofine are used collectively for soil stabilization. Hence an attempt has been made to improve the strength and swell behavior of the soil using GGBS in this work.

5. Problem Statement

With the increasing construction activities and in the light of scarce desirable sub-grade materials; efforts have been geared over the years towards finding economical alternative improvement techniques to soils of the locality. Just like in geotechnical engineering, where the underlying principle has always been “using better quality of sub-grade materials”, which decreases the foundation overload and thus reduces the cost of construction to cost effective road making and elongates the life span of the constructed roads. In India, soils used for construction of sub-grade are in short supply. Further, the soil for sub-grade collected from extensive area along length of roads show deficient engineering properties for their road making use due to depositional history. Numerous works have proved that these can be improved to ensure the satisfactory performance of the constructed road. Due to rapid industrialization throughout the world, the production of huge quantity of waste materials creates not only environmental problem but also depositional hazards. Safe disposal of the same is very vital issue and such situation can be addressed by the bulk utilization of these said materials mainly in the field of civil engineering applications. As road construction benefited from the stabilization process, a number of guidelines based on soil stabilization have been developed throughout the globe. Most of the guidelines are equipped with comprehensive guide and mechanism in analyzing potential natural soils to be used in the soil stabilization process. In view of this an experimental program was undertaken to determine the characteristic variations on mixing the GGBS and Alccofine in the locally available red soil, to attain significant gain in engineering and supporting characteristics for sub-grade construction. The samples were prepared in this study by replacing the red soil by 10% blast furnace slag, 20% blast furnace slag, 30% blast furnace slag and 40% blast furnace slag with an addition of 5% Alccofine and then by adding 10% of Alccofine in all these samples. The results were then compared with the standard sample of red soil without any stabilizing agent.

6. Specific objectives of the study

The study had the specific objectives of investigating the response of the Red soil soils through the application of the Ground granulated blast furnace slag and Alccofine combination at various contents and at different curing durations.

1. Determination of the engineering properties of red soil sample as well as blast furnace slag sample.
2. Determination of chemical composition of red soil as well as blast furnace slag sample.
3. Determination of optimum blast furnace slag content on strength characteristics of red soil and blast furnace slag mixture.
4. Effect of optimum blast furnace slag content on index properties, volume stability, durability, atterberg limit (i.e. liquid limit, plastic limit, plasticity index) of red soil and blast furnace slag mixture.
5. Effect of curing period of the strength of the soil.
6. Effect of curing period of red soil addition of the blast furnace slag of strength.

7. Methodology and Results

The soil sample selected is obtained from link road of Punjab and the following tests are conducted on the soil sample.

1. Grain size distribution
2. Liquid limit, Plastic limit, Modified Proctor Test, CBR test & Unconfined Compressive Strength

- I. Test sample 0 (TS0)- Red soil 100%
- II. Test sample 1 (TS1)- Red soil 85%+ Blast furnace slag 10%+5% Alccofine
- III. Test sample 2 (TS2)- Red soil 75%+ Blast furnace slag 20%+5% Alccofine
- IV. Test sample 3 (TS3)- Red soil 65%+ Blast furnace slag 30%+5% Alccofine
- V. Test sample 4 (TS4)- Red soil 55%+ Blast furnace slag 40%+5% Alccofine
- VI. Test sample 5 (TS5)- Red soil 80%+ Blast furnace slag 10%+10% Alccofine
- VII. Test sample 6 (TS6)- Red soil 70%+ Blast furnace slag 20%+10% Alccofine
- VIII. Test sample 7 (TS7)- Red soil 60%+ Blast furnace slag 30%+10% Alccofine
- IX. Test sample 8 (TS8)- Red soil 50%+ Blast furnace slag 40%+10% Alccofine

7.1. Grain Size Distribution

Table – 1.1: Grain Size Distribution

S. No.	Sieve (mm)	Percentage Finer
1	2.36	100
2	1.18	98.6
3	0.6	98.6
4	0.3	95.7
5	0.15	85.7
6	0.075	67.5
7	pan	0

7.2. Atterburg Limits: Liquid Limits, Plastic Limits and Plastic Index

Table -1.2: Atterburg Limit of different soil samples

S.No.	Designation of mix	LIQUID LIMIT (%)	PLASTIC LIMIT (%)	PLASTICITY INDEX (%)
1	TS0	33.6	24.47	9.13
2	TS1	33.5	24.5	9
3	TS2	32.4	24.7	7.7
4	TS3	31.5	25.5	6
5	TS4	30.8	26.1	4.7
6	TS5	30.4	26.2	4.2
7	TS6	28.8	26.4	2.4
8	TS7	28.1	26.9	1.2
9	TS8	26.4	25.4	1

7.3. Proctor Test

Table – 1.3: Observations of OMC (%) and MDD (g/cc)

S.No.	Designation of the mix	OMC (%)	MDD (g/cc)
1	TS0	12	1.93
2	TS1	10	1.92
3	TS2	12	1.9
4	TS3	14	1.88
5	TS4	12	1.87
6	TS5	10	1.84
7	TS6	12	1.92
8	TS7	16	1.89
9	TS8	12	1.77

OMC increased and MDD decreased with addition of GGBS & Alccofine. Decrease in MDD shows a decrease in strength, but the CBR value is increasing with the addition of GGBS at fixed percentage of Alccofine at 5% and 10%.

Although OMC and MDD are changing, the percentage change is small. The reason behind this is less time for the chemical action after adding the additives.

7.4. California Bearing Ratio (CBR) Test

Penetration (mm)	TS0	TS1	TS2	TS3	TS4	TS5	TS6	TS7	TS8
	Load (kg)								
0	0	0	0	0	0	0	0	0	0
0.5	113.05	146.3	166.25	199.5	212.8	226.1	252.7	232.75	146.3
1	192.85	259.35	272.65	279.3	305.9	332.5	359.1	345.8	266
1.5	272.65	365.75	385.7	418.95	418.95	445.55	472.15	452.2	372.4
2	352.45	452.2	472.15	492.1	505.4	532	558.6	545.3	465.5
2.5	412.3	558.6	591.85	605.15	631.75	651.7	678.3	645.05	571.9
3	452.2	631.75	638.4	651.7	678.3	698.25	744.8	678.3	611.8
3.5	485.45	691.6	731.5	704.9	744.8	764.75	791.35	738.15	678.3
4	518.7	744.8	758.1	718.2	784.7	804.65	844.55	778.05	724.85
4.5	551.95	791.35	804.65	791.35	844.55	864.5	891.1	844.55	784.7
5	578.55	831.25	857.85	831.25	891.1	891.1	917.7	857.85	824.6
5.5	605.15	871.15	911.05	931	950.95	970.9	957.6	924.35	891.1
6	625.1	904.4	944.3	964.25	984.2	1004.15	1004.15	970.9	931
6.5	645.05	937.65	957.6	977.55	997.5	1017.45	1044.05	977.55	944.3
7	658.35	964.25	984.2	1017.45	1024.1	1044.05	1070.65	1004.15	970.9
7.5	671.65	990.85	1030.75	1030.75	1044.05	1064	1090.6	1024.1	1010.8
8	684.95	1010.8	1037.4	1064	1077.3	1097.25	1123.85	1057.35	1024.1
8.5	698.25	1037.4	1083.95	1070.65	1110.55	1130.5	1157.1	1123.85	1064
9	704.9	1057.35	1110.55	1090.6	1150.45	1170.4	1197	1137.15	1090.6
9.5	711.55	1077.3	1123.85	1097.25	1163.75	1183.7	1210.3	1143.8	1110.55
10	711.55	1090.6	1123.85	1123.85	1170.4	1197	1223.6	1163.75	1117.2
10.5	718.2	1103.9	1143.8	1163.75	1190.35	1210.3	1236.9	1190.35	1137.15
11	724.85	1110.55	1143.8	1190.35	1203.65	1230.25	1256.85	1203.65	1137.15
11.5	731.5	1117.2	1150.45	1190.35	1210.3	1243.55	1270.15	1210.3	1150.45
12	731.5	1130.5	1157.1	1210.3	1223.6	1250.2	1276.8	1216.95	1157.1
12.5	738.15	1137.15	1170.4	1223.6	1236.9	1263.5	1290.1	1230.25	1163.75

The results reveal that CBR value of soil increases as the GGBS content increases with 5% Alccofine. The load v/s penetration graph indicates that the value of penetration increases with increase in GGBS %age at fixed value of Alccofine 5%. However, as the value of Alccofine increases from 5% to 10% with same percentage of GGBS the value of penetration decreases at the same load indicating that the more value of Alccofine restrain the penetration and hence the CBR value decreases.

7.5. Unconfined Compressive Strength Test

The unconfined compressive strength of red soil when tested initially was found to be 156.96kPa, which increase with the number of days and found to be 166.57kPa at 28 days indicating the increase in compressive strength with the ages. The compressive strength was found to increase a lot with addition of 10% GGBS and 5% Alccofine due to the filling of the

pores and reactive pozzolanic nature of Alccofine & GGBS in comparison of red soil only. The trend of increase in strength continues till the addition of 40% GGBS and 5% Alccofine.

The strength was found to be 175.60kPa at initial stage for sample TS3. However, the strength found to be decreased with addition of more Alccofine i.e. 10% at 10% GGBS indicating that excess Alccofine does not increase the strength at initial stage. The unconfined compressive strength was found to increase with ages for all the samples. The compressive strength with addition of 10% Alccofine was found to increase than 5% Alccofine for same percentages of GGBS indicating that the Alccofine start reacting not immediately but after certain time and the strength increases due to the small size & pozzolanic behavior of Alccofine.

Table – 1.5: Unconfined compressive strength for samples

Sample	Unconfined compressive strength (kPa)				
	0	3	7	14	28
TS0	156.96	158.92	159.9	161.87	166.57
TS1	158.92	198.16	207.97	223.67	531.7
TS2	165.79	205.03	215.82	236.42	644.52
TS3	175.6	221.71	230.54	323.73	657.27
TS4	158.92	231.52	246.23	343.35	718.09
TS5	160.88	242.31	248.19	348.26	778.91
TS6	161.87	249.17	263.89	446.36	933.91
TS7	164.81	248.19	258	567.02	1149.73
TS8	167.75	285.47	367.88	444.39	1007.49

8. Conclusion

Following important conclusions can be drawn from the study:

1. Liquid limit decreased and plastic limit increased for soil as can be seen from Tables. Increase in liquid limit and decrease in plastic limit indicates increase in strength. Decrease in plasticity index shows that the volume change during wetting and drying is less with increase in addition of GGBS and Alccofine.
2. The shrinkage insignificantly decreased with the addition of Alccofine and GGBS and were more effective at arresting shrinkage. On the top of that it was observed that addition of Alccofine & GGBS significantly reduced shrinkage property of the red soil
3. OMC increased and MDD decreased with addition of GGBS & Alccofine. Decrease in MDD shows a decrease in strength, but the CBR value is increasing with the addition of GGBS at fixed percentage of Alccofine at 5% and 10%. Although OMC and MDD are changing, the percentage change is small. The reason behind this is less time for the chemical action after adding the additives.
4. The results reveal that CBR value of soil increases as the GGBS content increases with 5% Alccofine.
5. As the value of Alccofine increases from 5% to 10% with same percentage of GGBS the value of penetration decreases at the same load indicating that the more value of Alccofine restrain the penetration and hence the CBR value decreases.

6. The compressive strength was found to increase a lot with addition of 10% GGBS and 5% Alccofine due to the filling of the pores and reactive pozzolanic nature of Alccofine & GGBS in comparison of red soil only. The trend of increase in strength continues till the addition of 40% GGBS and 5% Alccofine.
7. The strength found to be decreased with addition of more Alccofine i.e. 10% at 10% GGBS indicating that excess Alccofine does not increase the strength at initial stage.
8. The unconfined compressive strength was found to increase with ages for all the samples.
9. The compressive strength with addition of 10% Alccofine was found to increase than 5% Alccofine for same percentages of GGBS indicating that the Alccofine start reacting not immediately but after certain time and the strength increases due to the small size & pozzolanic behavior of Alccofine.

9. Scope for future work

1. In the present study only up to 10 percent Alccofine was used which may be increased to get the optimized results.
2. Other types of material like stone quarry, plastics, recycled aggregates, polythene bags etc. also need be tried to know the effect of various type of additives.
3. Durability of Alccofine needs to be checked, by conducting the tests for different curing period.

References

1. Erdal Cocas, Veysel Yazici, Vehbi Ozaydin (2009) "Stabilization of Expansive clays using ground granulated blast furnace slag & cement", *Geotechnical & Geological Engineering Journal*, Vol.27, pp 489-499.
2. Jiang L, Chirdchanin M, Katsutada O (2005) " Stabilization effects on surplus soft clay with cement & ground blast furnace slag", *Journal of Environmental Sciences*, Vol.16, No.3, pp 397-403
3. Brook-Bradley HE (1952) "Soil-cement roads in Worcestershire", *Surveyor* 3, pp 571-573.
4. Paul Hughes & Stephen Glendinning (2004), " Deep dry mix ground improvement of a soft peaty clay using blast furnace slag & red gypsum" *Quarterly Journal of Engg. Geology & Hydrogeology*, Vol.37, Issue 3, pp. 205-216.
5. Higgins D.D., Kinuthia J.M. & Wild S.(1998) " Soil stabilization using lime-activated ground granulated blast furnace slag", *Proceedings of 6th CANMET, ACI publication SP*, pp 1057-1074
6. Higgins D (2005), "Soil stabilization with ground granulated blast furnace slag", *UK CSMA publication*, pp 1-15.