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Stabilization of Black Cotton Soil using Quick Lime and Waste Glass Powder (WGP)

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A B S T R A C T

Expansive soils expand and lose their strength when wetted and shrink when dried, and this makes a considerable volume change. Construction on expansive soils has made problems around the world for different civil engineering projects such as highways (sub grade), railways, embankments, and foundations. Therefore, the improvement of expansive soils is very important, especially for road construction, sub structure. The strength improvement of these types of soils can be gain by adding another waste material which harms the environment and affects economy. So, quick lime and waste glass powder (WGP) was selected for this study which is generated from Glass manufacturing/recycling industries and municipal solid waste (MSW). The Lime (0% to 6%) and WGP mixed with the soil sample with various percentages: 0%, 10 %, 20%, and 30% by the dry weight of soil. Various laboratory tests were conducted for the treated and untreated expansive soil with the different percentages of the WGP and quick lime, including Sieve analysis, specific gravity, Atterberg limits, free swelling index.According to the test results, adding WGP to the expansive soils has a significant impact on the consistency limit and expansive behaviours of the soil.

Keywords: Waste Glass Powder (WGP), Black cotton soil (BCS), Quick Lime, Grain Size Distribution, Specific Gravity, Liquid Limit, Plasticity Index, DFS

1. INTRODUCTION

In India expansive soil are popularly known as black cotton soil due to its black in color and high productivity of cotton in it. In India the black cotton soil covers an area about 0.66 million Km^2, which is about 20% of the total land area. Expansive soils are those soils which have the tendency to increase in volume when water is added and to decrease in volume if water is removed. This volume change in swelling soils is the cause of many problems in structures that come into their contact or constructed out of them. Foundations constructed on these expansive soils are subjected to large uplift forces caused by swelling and inducing heaving, cracking and break up building foundations and slabs on grade members. Soils containing montmorillonite mineral swell considerably when it comes in contact which water.

Thus, the need of treating soil arises in order to utilize the locally available soil, Lime is well known additive for the stabilization of expansive soils. Lime is produced from industrial processes and is associated with the emission of greenhouse gases such as carbon dioxide (CO_2), sulfur dioxide (SO_2) and nitrous oxide (N_2O). Industrial by-product materials such as Waste glass, fly ash, blast furnace slag, cements kiln dust and lime stone dust etc. can also use as a stabilizer. By using this by-products environmental and economical problems can be solved. And Waste Glass Powder (WGP) has great potential to be used as a stabilizing agent because waste glass powder contains rich amount of Silica ($Si0_2$), Sodium oxide (Na_20) & Lime (CaO) etc.

The objective of this study is to investigate the effect of lime and Waste Glass Powder (WGP) in the stabilization of expansive soils. Use of industrial by-product&municipal solid waste (MSW), waste glass has been successfully tried for stabilization of various types of soils and also a partial replacement of

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cement, lime in concrete structures in recent past. Along with this major ingredient certain additives like sodium salts, gypsum, and lime in small quantity were used for stabilization of weaker and expansive soils.

A lot of research work has been done in the past to improve engineering properties of soil using additives like WGP with other materials has been investigated by several researchers for different types of soils.

Canakci Hanifiet.al. (2016), investigated that the addition of waste Soda Lime Glass Powder into clay has a significant effect on the strength and consistency properties of the clay. Their study reveals that the Specific gravity value increases with increase in percentage of WSLGP, while Liquid limit plastic limit, Shrinkage limit and cohesion value decreases with increase in the quantity of WSLGP in clayey soil.

Fauzi A. et al. (2016), studied the effects of crushed glass waste and plastic high-density polyethylene (HDPE) waste as additives in stabilized soil. They concluded that the values of Atterberg limit and optimum moisture content reduced, and A shrinkage limit and cohesion value of soil decreased when content of HDPE waste and glass waste increased.

Nuruzzaman D. and Hossain M.A. (2014), used soda lime glass dust that was passed through a sieve 300 micron to improve the clay soil. They concluded that the properties of the clay soil were improved by the addition of glass dust by comparing the behaviors of treated and untreated soil. The Atterberg limits values decrease with the addition of glass dust and swell index decrease with the addition of glass dust.

Blayi RizgarA.et.al. (2020), studies the effect of WGP with highly expansive soil and concluded that the WGP was used at various percentages, from 2.5%–25%. The LL, PL, PI, and LS decrease as the percentages of WGP increases.it can be seen that the majority percentages of WGP consist of silica, which is about 72 % so expansive soil replaced with non-plastic material; therefore, the LL was reduced (from 44.20% –22.28%), PL was slightly changed (from 24.81 % to 16.44 %), PI was significantly decreased from 19.39 % to 5.84 %, and the LS was reduced from 9.17 % to 2.63 % when the WGP added up to 25 % by dry weight of the soil.

According to the above literature reviews, WGP can be used for improving the geotechnical properties of different types of soils. However, the expansive soils need a more comprehensive study to determine the optimum percentage of WGP that it could be used in construction projects. For this study, waste glass Powder collected (from the Glass manufacturing industry, Bhopal, MP, India). The main objective of this study is to find the optimum percentage of WGP to be used for improving the property of expansive soil (BCs), especially for sub structure & road construction (sub-grade). Therefore, a series of laboratory tests were carried out for the BC soil and the soil sample by adding various percentages of WGP (0%, 10%, 20 % and 30%) with quick lime (0%, 4% and 6%) to the oven dry weight of soil sample.

2. MATERIALS

Black Cotton Soil-The black cotton soil used in this study was collected from village Piparia, near khamaria, Jabalpur Madhya Pradesh. The latitude and longitude of the site are 23.213939 and 80.036789. The black cotton soil collected from the site at 1.5-2.0m depth is brought to the laboratory for testing purpose. The properties of the BC soil collected from the site tabulated below –

Table 1 Properties of black cotton soil

S.No.	Particulars	Observation
1.	Specific gravity	2.276
2.	Liquid limit	58.73%
3.	Plastic limit	22.24%
4.	Plasticity index	36.49%
5.	Passing 75µ sieve	78.171%
6.	Differential Free soil	50.91%

Figure1. Waste Glass powder (WGP)

Figure2. Quick lime in powder form

Waste Glass Powder (WGP): The waste glass powder is brought form Glass Manufacturing industry, Bhopal, MP India.Million tons of waste glass is being generated annually all over the world. Once the glass becomes a waste it is disposed as landfills, which is unsustainable as this does not decompose in the environment. Glass is principally composed of silica. Use of milled (ground) waste glass in concrete as partial replacement of lime could be an important step toward development of sustainable (environmentally friendly, energy-efficient and economical) infrastructure systems. In this research waste glass powder used for improvements of engineering property of lime stabilized expansive soil and also solve the disposal problems.The properties of Waste Glass Powder are tabulated in table 2 and 3 given as –

Table 2 Physical properties of Waste glass Powder

S.NO.	PARTICULARS	PERCENTAGE
1.	Type	Powder
2.	Specific gravity	2.612
3.	Passing 75µpsieve	98%

Table 3 Chemical properties of waste glass powder

S.NO.	PARTICULARS	PERCENTAGE	
		(a)	(b)
1.	Silicon dioxide ($SiO_{2)}$	74%	71.21%
2.	Aluminium oxide ($Al_2O_{3)}$	1.3 %	1.91%
3.	Ferric oxide ($Fe_2O_{3)}$	0.57%	0.45%
4.	Calcium oxide (CaO)	10.5%	13.3%
5.	Magnesium oxide (MgO)		2.4%
6.	Sodium oxide (Na_2O)	13 %	10.1%
7.	Potassium oxide (K_2O)		
8.	Another accumulated component	0.63%	0.63%

Source: CanackiHanifi et al. 2016[(a)]
Rizgar A. Blayi et al. 2020[(b)]

Quick LIME: Quick Lime purchased from local market of Jabalpur, MP. The main benefits of using lime to stabilize clays are provide bond strength between waste glass and soil, also improved workability, increased strength, and volume stability. Lime increases the strength of clayey soil by reducing shrinkage and swell characteristics.

3. TESTING METHODOLOGY

The various tests can be conducted in the geotechnical laboratory to characterize the index properties of plain black cotton soil and lime stabilized soil with varying percentage of WGP. Some important tests were performed in the laboratory as per the relevant IS codes:

1. Specific gravity (IS: 2720 PART III/ Sec I) - 1980.

2. Liquid limit (IS: 2720 PART-V)-1985.

3. Plastic limit (IS: 2720 PART-V)-1985.

4. Differential free soil index (IS: 2720 PARTXL)-1977.

4. SAMPLE PREPARATION

The samples used in the study are prepared by blending black cotton soil (BCS) with different percentage of WGP and Lime is used as a stabilizer in this laboratory work. The samples are prepared as such

1. The black cotton soil, lime and WGP are oven dried separately.

2. The oven dried black cotton soil, lime (0%, 4%, and 6%) and WGP (0%, 10%, 20%, and 30%) are mixed in proportions by weight to form various mixes.

3. The formed dry mixes are being blended together with water in order to get a homogeneous blend as per the requirement of test.

4. In these blended soil samples geotechnical test performed as per the IS specifications.

5. RESULTS AND DISCUSSION

The laboratory tests are conducted in the geotechnical laboratory, Jabalpur engineering college, Jabalpur. Based on the extensive laboratory investigations on the various samples the following test results have been made, that's tabulated in the table given bellow.

Table 4 Effect of WGP and Quick Lime on index properties of expansive soil

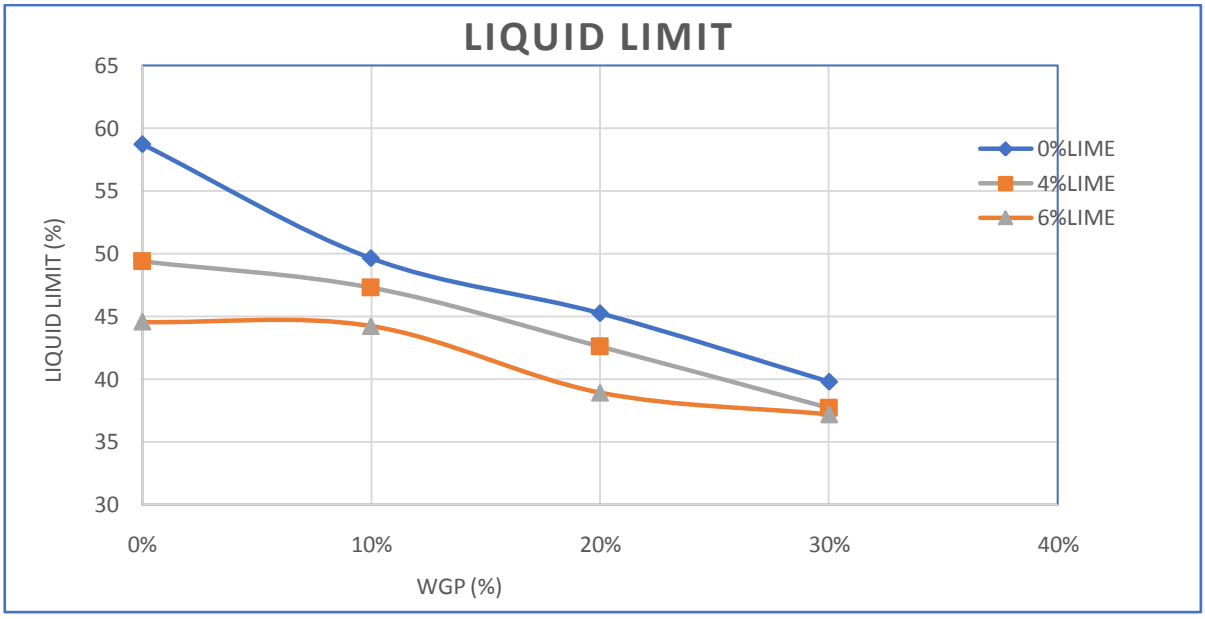
Details of mix (%)		Index properties			
Lime (%)	**WGP (%)**	**LL (%)**	**PI (%)**	**DFS (%)**	**Classification**
0	0	58.73	36.49	50.91	CH
0	10	49.654	22.387	36.50	CH
0	20	45.29	15.48	23.81	MI
0	30	39.818	8.788	15.69	MI
4	0	49.60	22.011	32.20	CH
4	10	47.31	15.99	25.56	MI
4	20	42.627	10.16	16.00	MI
4	30	37.72	4.257	10.66	MI
6	0	44.58	13.998	18.33	MI
6	10	44.27	10.54	16.36	MI
6	20	38.93	4.13	10.24	MI
6	30	37.185	2.108	4.76	MI

LL=Liquid limit, PI=Plasticity index, DFS=Differential free swell, WGP= Waste Glass Powder

CH= Highly plastic inorganic clay, MI= Intermediate plastic silt

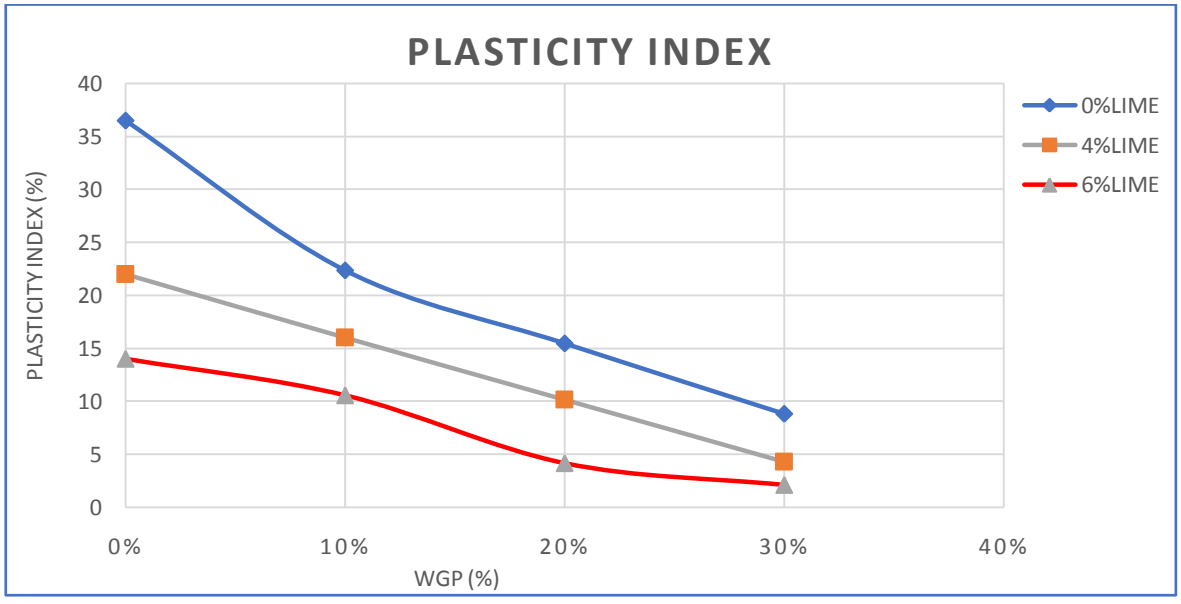
The following graphs were observed-

Liquid limit of the lime stabilized soil and blended samples



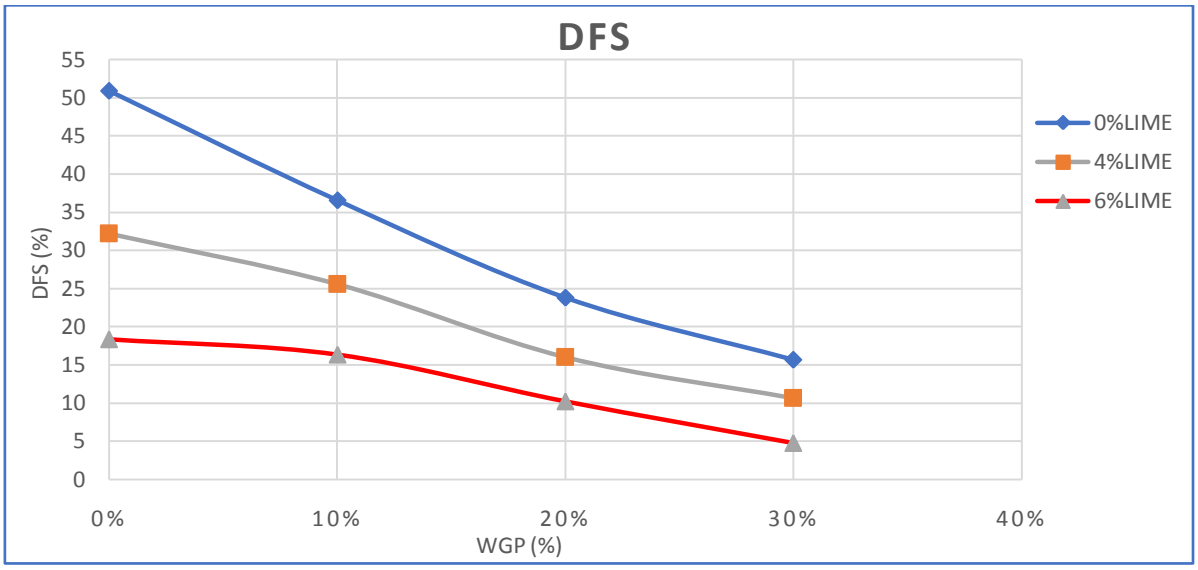
Graph 1 Variation of liquid limit of soil in different percent of WGP

Plasticity index of lime stabilized soil and blended samples



Graph 2 Variation of plasticity index of soil in different percent of WGP

Differential free-soil index of lime stabilized soil and blended samples



Graph 3 Variation of differential free swell index of soil in different percent of WGP

6. CONCLUSION

The initial value of plasticity index of the plain BC soil is very high 36.49%, it decreases gradually on addition of lime and WGP. The value decreases to 8.788%, 4.257% and 2.108% with the addition of 30% WGP and 0%, 4% and 6% lime respectively. The expansive behaviour of soil has been reducing significantly as it reduces from 50.91% to 4.76% on addition of 30% WGP and 6% lime. Based on the above study it can be concluded that waste glass powder has good potential to utilize it for the stabilization of weak soil and to utilize it in many geotechnical applications like road sub- grades, foundation soils and embankments etc.

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