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Economic Benefits of GGBS and Lime in Stabilizing Pavement Formation Level

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ABSTRACT: In India soil stabilization is inevitable as it has a vast expanse of Black Cotton Soil all over the country, thus construction of highways and runways gets adversely affected owing to the behaviour of such soils due to the changes brought about by moisture content during rains which causes heaving, fracture and breakdown of the pavements. The ultimate aim of stabilization is to upgrade the strength and durability thus improving the overall performance of the pavement design and construction. As India is a developing country the process of stabilization should be cost effective and should utilize the available resources without damaging the environment. The use of by-product from iron and steel industry namely GGBS (Ground Granulated Blast-furnace Slag) which is an industrial waste for stabilization of soil has both economic as well as environmental benefits. Over the years use of other things for stabilization of soil is well entrenched but utilization of an industrial waste instead is a good move. The investigation shows that GGBS-Lime stabilized soil has a pronounced effect on the quality of soil thus, the study shows that this could be suggested for preparation of pavement formation level so that the thickness of various layers could be reduced resulting in less cost for constructing a pavement.

KEYWORDS: Black Cotton Soil, Stabilization, Ground Granulated Blast-furnace Slag (GGBS), Lime, CBR, Direct Shear, Problem Statement: Design of flexible pavement.

I. INTRODUCTION

The highways, runways and road networks play an important role in facilitating the development of agriculture, industries and commerce facilities thus, the development of a country depends on such networks to a great extent. Good quality of formation level soil is a must for long-lasting pavement construction but such soil is not always available and depends from region to region. The black cotton soil has various issues such as less stability and shear strength also large shrinkage and expansion in volume is noticed with the change in moisture content in different seasons, thus it obstructs the construction.

In pavement design, the stress acting in each layer should be managed such that there is no deformation. The physical strength of each layer should resist shearing and prevent excess deflection which results in fatigue cracking. The initial cost of any road project is determined by the type of road and its thickness. The subgrade concerned should be highly resistant to deformation which will lead to thinner pavements and this will reduce the construction cost.

In general, sometimes stabilizing a soil mass using easily available additives is reasonable rather than excavating the desired soil from a different place.

II. LITERATURE REVIEW

The geotechnical properties of black cotton soil get upgraded when Lime and GGBS are used. It's a two-step reaction process. The first reaction is the hydration of GGBS activated by lime which produces C-A-S-H gel and hydrotalcite type phases containing magnesium [1]. This reaction consumes the lime in the process.

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The second is the clay-lime reaction which produces C-A-S-H and calcium aluminates and alumino-silicates. On comparing the pozzolonic reaction of lime with clay and that of slag hydration in the presence of lime, the later is much faster [2]. The lime added provides the necessary alkaline environment for activation of GGBS. Using GGBS and lime instead of lime only for stabilization of soil leads to a reduction in the total binder content [3].

Firstly, the tests regarding the strength and swelling characteristics should be conducted to fix an optimum % limit of Lime and GGBS content which could be used later for the purpose of stabilization.

III. EXPERIMENTAL INVESTIGATIONS

(A) Material Characterization

Black Cotton Soil

The soil sample was extracted from 7 feet deep excavation previously done for raft foundation from Visvesvaraya National Institute of Technology (VNIT) campus Nagpur, Maharashtra. According to the Indian Standard Classification System (ISCS) the soil comes under CH (Inorganic clays of high compressibility).

Ground Granulated Blast Furnace Slag

The GGBS was procured from the disposal site of Bokaro Steel Plant of Bokaro district, Jharkhand. The chemical composition and physical properties of GGBS are given in Table 1 and Table 2 respectively.

Lime

Commercially available pure hydrated lime $\text{Ca}(\text{OH})_2$ was used in the investigations.

(B) Tests Performed on Black Cotton Soil

1.Free Swell Test (IS 2720 Part 40: 1977)

50% swell increase was observed.

2.Liquid Limit and Plastic Limit Tests (IS 2720 Part 5: 1985)

Liquid Limit was found out to be 71.48%

Plastic limit was observed to be 32%

Plasticity index (PI) = Liquid Limit – Plastic Limit
= 71.48 - 32 %
= 39.48%

3.Standard Proctor Test (IS 2720 Part 7: 1980)

Optimum Moisture Content (OMC) = 25.28%

Maximum Dry Density (MDD) = 1.69

4.California Bearing Ratio (Soaked)

(IS 2720 Part 16: 1979)

The CBR reading came out to be 4.73%

5.Direct Shear Test (IS 2720 Part 13: 1986)

Cohesion = 0.4kg/cm^2

Angle of internal friction = 18°

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Table 1. Chemical Composition of GGBS*

Sr No.	Particulars	Symbol	% by Weight
1.	Silica	SiO ₂	27-38
2.	Alumina	Al ₂ O ₃	7-15
3.	Ferric Oxide	Fe ₂ O ₃	0.2-1.6
4.	Manganese Oxide	MnO	0.15-0.76
5.	Calcium Oxide	CaO	34-43
6.	Sulphur Trioxide	SO ₃	up to 0.07
7.	Potassium Oxide	K ₂ O	0.08 to 1.83
8.	Sodium Oxide	Na ₂ O	0.20 to 0.48
9.	Loss on Ignition	-	0.20 to 0.85

*(National Slag Association data)

Table 2. Physical Properties of GGBS

Sr No.	Particulars	Observations
1.	Specific Gravity	2.705
2.	Passing 12.5mm sieve (Gradation)	98%
3.	Type	Granular

(C) Fixing The Optimum Percentage of Lime:

Various tests namely the Liquid Limit tests, Plastic Limit tests, Standard Proctor tests, CBR tests, Direct Shear tests and pH tests were performed on Black Cotton Soil for varying percentages of lime content and considering strength aspect and pH values, Optimum percentage of lime was fixed at 5%.

- It is observed that CBR value that is a strength parameter increases with dosage of lime and found to be optimum at 5%.
- OMC increases while there is a slight decrease in MDD with increase in dosage of lime.
- Liquid limit decreases with dosage of lime.
- Plastic limit increases with increase in lime content.

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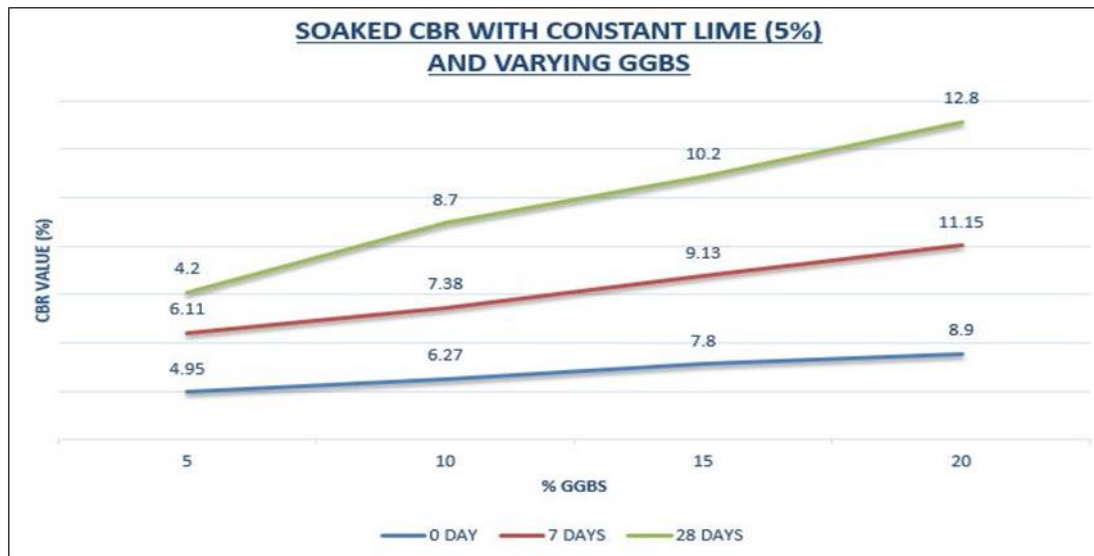
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(D) Tests Performed after fixing the Optimum dosage of Lime (i.e. 5%): -

1. California Bearing Ratio Test (Soaked)

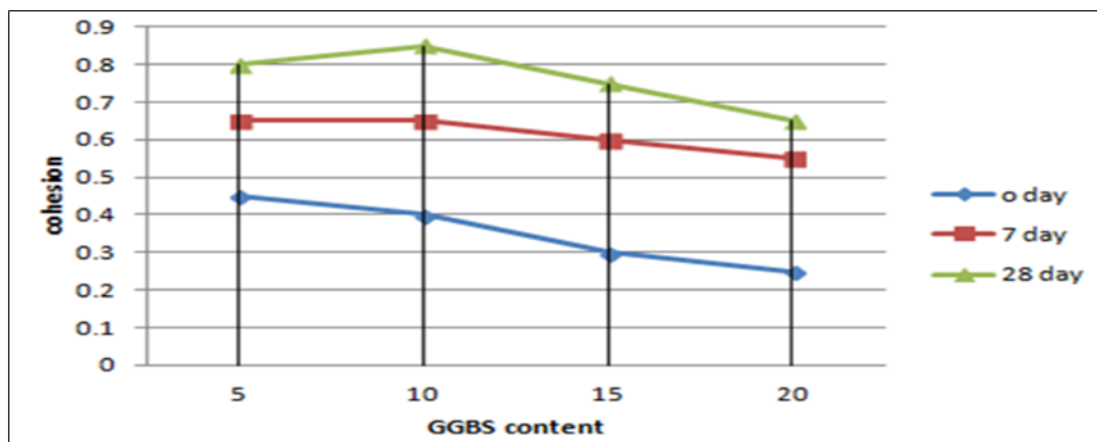
Black Cotton Soil + 5% Lime (optimum) + Varying Percentage of GGBS



(Fig. 1). California Bearing Ratio Test (Soaked)

The figure shows the variation of CBR (soaked) with varying % of GGBS content in soil after soaking the samples for 4 days initially and then curing them for 0 day, 7 days and 28 days.

2. Direct Shear Test

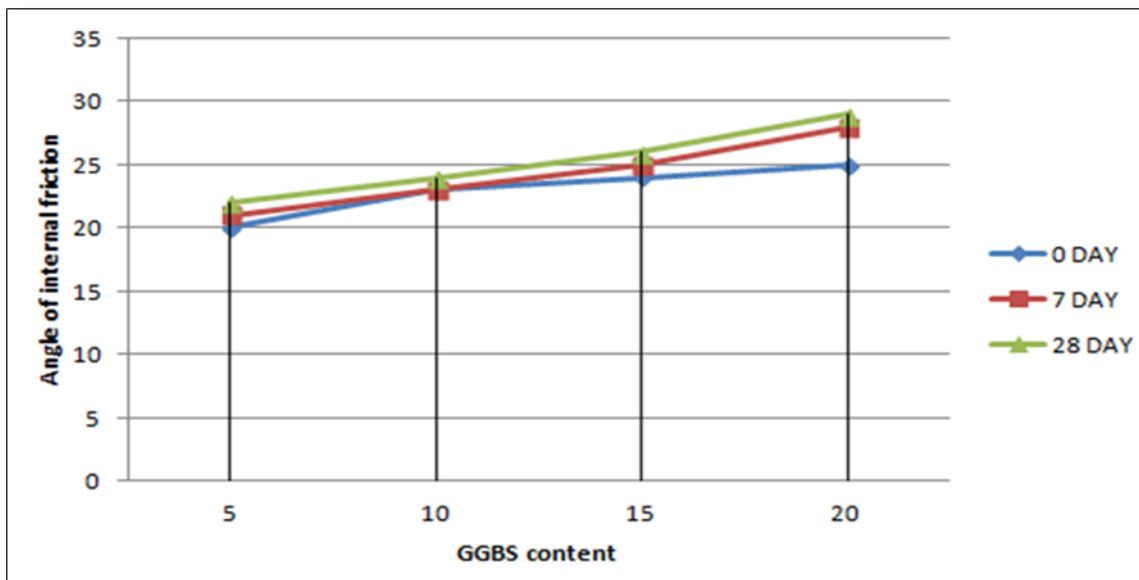


(Fig. 2). Variation of Cohesion in Soil with Lime (optimum) + Varying Percentage of GGBS

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(Fig. 3). Variation of Angle of friction in Soil for Lime (optimum) + Varying Percentage of GGBS

The above figures (Fig. 3&4) show the variation of Cohesion and Angle of Internal friction respectively with varying % of GGBS content in soil after curing the samples for 0 day, 7 days and 28 days.

Table 3. Direct Shear Test (0 day, 7 and 28 days readings for Cohesion and Angle of Internal friction)

Particulars	0 DAY		7 DAYS		28 DAYS	
	C	ϕ	C	ϕ	C	ϕ
SOIL + 5% LIME + 5% GGBS	0.45	20°	0.65	21°	0.80	22°
SOIL + 5% LIME + 10% GGBS	0.40	23°	0.65	23°	0.85	24°
SOIL + 5% LIME + 15% GGBS	0.30	24°	0.60	25°	0.75	26°
SOIL + 5% LIME + 20% GGBS	0.25	25°	0.55	28°	0.65	29°

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IV. RESULTS AND DISCUSSIONS

1. The increase in the soaked CBR results was more marked (increased to 4 times) when the GGBS content in the soil was between 15 to 20%. On further increasing the percentage of GGBS in soil the increase was found out to be very less.
2. The combination of 5% Lime (optimum) and 20% GGBS in soil proved to be a perfect combination for soil stabilization.
3. The shear strength of the soil (angle of internal friction) was found to increase thus signifying soils good shearing resistance and greater stability against failure.

PROBLEM STATEMENT: - Design of Flexible Pavement

Consider a two lane road having lane distribution factor as 0.50. Average % growth in traffic is taken to be 7.5%. Project life is taken to be 15 years. Million standard axle as 10 MSA. Using IRC (Indian Road Congress) 37 2012, following table showing thickness reduction due to stabilization of soil is as follows:

Thickness Variation

Type	CBR	overall thickness	GSB	BC	WC	% reduction
BC Soil	3.31%	760	380	250	130	---
BC Soil + 5% LIME	6.09%	615	260	250	105	17%
BC Soil + 5% LIME + 5% GGBS (0 DAY)	4.95%	660	300	250	110	13.00%
BC Soil + 5% LIME + 10% GGBS (0 DAY)	6.27%	580	230	250	100	23%
BC Soil + 5% LIME + 15% GGBS (0 DAY)	7.80%	550	200	250	100	27%
BC Soil + 5% LIME + 20% GGBS (0 DAY)	8.90%	540	200	250	90	28%
BC Soil + 5% LIME + 5% GGBS (7 DAYS)	6.11%	615	260	250	105	19%
BC Soil + 5% LIME + 10% GGBS (7 DAYS)	7.38%	570	220	250	100	25%
BC Soil + 5% LIME + 15% GGBS (7 DAYS)	9.13%	540	190	250	90	28%
BC Soil + 5% LIME + 20% GGBS (7 DAYS)	11.15%	530	200	250	90	30%
BC Soil + 5% LIME + 5% GGBS (28 DAYS)	4.20%	700	330	250	120	9%
BC Soil + 5% LIME + 10% GGBS (28 DAYS)	8.27%	550	200	250	100	27%
BC Soil + 5% LIME + 15% GGBS (28 DAYS)	10.20%	540	200	250	90	28%
BC Soil + 5% LIME + 20% GGBS (28 DAYS)	12.80%	520	180	250	90	32%

By adding 5% Lime and 20% GGBS to the Black Cotton Soil and curing it for a period of 28 days, it was found that there is a 32% decrease in the overall thickness of the pavement.

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(A) BILL OF QUANTITIES FOR PURE BLACK COTTON SOIL*

Sr.No	Description	Number	Quantity	Rate ₹	Amount ₹
1	Cutting trees, Cutting trunks	2.1	10	112	1120
2	Clearing and grubbing road land	2.2	7000 m	1.9944	13960.8
3	Granular subbase (mix in place)	4.10 b (2)	2660 m ²	470	1250200
4	Water Bound Macadam	4.80 b(2a)	1750 m ²	691	1209250
5	Prime Coat	5.1	7000 m ²	19	133000
6	Dense graded Bituminous Macadam	5.6 a (1)	630 m ²	5243	3303090
7	Tack Coat	5.2 (1)	7000 m ²	8	56000
8	Bituminous Concrete	5.8 a (1)	280 m	5962	1669360
	Total				₹ 7635930

*(Done using CSR for Nagpur region, Maharashtra)

If Pavement Formation Level is prepared using Unstabilized i.e. Pure Black Cotton Soil, the generalized BOQ is as presented above.

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(B) BILL OF QUANTITIES FOR BLACK COTTON SOIL + 5% LIME + 20% GGBS*

Sr.No	Description	Number	Quantity	Rate ₹	Amount ₹
1	Cutting trees, Cutting trunks	2.1	10	112	1120
2	Clearing and grubbing road land	2.2	7000 m	1.9944	13960.8
3	Granular subbase (mix in place)	4.10 b (2)	126 m ²	470	592200
4	Water Bound Macadam	4.80 b(2a)	1750 m ²	691	1209250
5	Prime Coat	5.1	7000 m ²	19	133000
6	Dense graded Bituminous Macadam	5.6 a (1)	350 m ²	5243	1835050
7	Tack Coat	5.2 (1)	7000 m ²	8	56000
8	Bituminous Concrete	5.8 a (1)	280 m	5962	1669360
9	Lime		280000 kg	4	980000
	Total				₹ 6489940

*(Done using CSR for Nagpur region, Maharashtra)

Thus using Soil stabilized with 5% Lime and 20% GGBS instead of Pure Black Cotton Soil in the design of flexible pavement has resulted in the savings of ₹ 1145990.

V. CONCLUSIONS

1. From the above study it is observed that the strength of soil increases with increase in percentage of lime and GGBS.
2. It is also observed that when Lime is added to Black Cotton Soil, the CBR increases by four times for 5% lime and 20% GGBS as compared to Pure Black Cotton soil. Therefore, this increase can be suggested for preparation of formation level so that thickness of various layers of the pavement can be reduced which reduces the overall cost of constructing a pavement.
3. As seen from the economical point of view, the cost of waste material i.e. GGBS is negligible as it's a waste material and a classified irritant and it solves problem of disposal of GGBS which otherwise acquires large area of land.
4. By comparing the Direct Shear Test value, it was found that strength increases as we increase the content of GGBS with optimum percentage of lime.

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BIOGRAPHY



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