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SELECTION OF OPTIMIZED PROPORTION OF RECYCLED CONCRETE AGGREGATES AND BLAST FURNACE SLAG AS GRANULAR SUB BASE MATERIAL USED IN PAVEMENT

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Abstract: Due to rapid industrialization, the waste products are also being generated in huge quantity which occupies large quantity of precious land as well as creating environmental problems. Recycled Concrete Aggregates (RCA) which is generated as a part of Construction and Demolition material is a type of waste product. In the same way, Blast furnace slag is also a waste product of steel production. As the construction of pavements requires a massive amount of aggregates, the replacement of part of fresh aggregates with mixture of Recycled Concrete Aggregates (RCA) and Blast furnace slag will be very advantageous considering the dearth of fresh aggregates. Therefore, an attempt has been made in the present study to determine the optimum proportion of Recycled Concrete Aggregates (RCA) and Blast furnace slag as Base material in pavement.

The main objective of the study is to select the best possible percentage to increase the bearing capacity of sub base granular layer. The cost of construction of the pavement is considerably decreases if locally available low cost materials are used in the construction of sub base, sub grade etc. The design of pavement is based on the minimum specified structural quality of the soil that will be achieved for each layer of material. Each layer must resist shearing and avoid too many deflections that cause fatigue. It is also used to decrease the compressibility and permeability of the soil mass and to increase its shear strength. As the quality of the soil is increased, the ability to distribute the load is increased so that a drop in the thickness of the soil is also permitted.

Use of by- products is also a way to protect environment from the harmful effects of recycled aggregates and blast furnace slag as they are required to be dumped in open grounds or beneath the surface which affects the natural formation of the soil and degrades the surface. In this research various laboratory tests like atterberg limits, proctor test and CBR i.e California bearing ratio test is performed and the best possible combination of the required proportion is selected.

Index Terms **- Recycled Concrete Aggregates (RCA), Blast furnace slag, CBR, Granular Sub base (GSB), Atterberg limits.**

I. INTRODUCTION

Soil stabilization means improvement of strength or bearing capacity of the soil by the use of controlled compaction, proportioning and the addition of suitable admixture or stabilizers. It deals with the physical, physio chemical and chemical methods to make the stabilized soil its purpose as pavement component material.This recommended practice describes a method of stabilization of soils by utilizing Recycled coarse aggregate with blast furnace slag to prove a base/ sub base course in the design of road pavement. Slag is the by product of iron and steel Industries which can be generally characterized into blast furnace slag and steel making slag. Blast furnace slags were mainly classified into four types: i.e. granulated; air-cooled; expanded and palletised.

In engineering, soil Stabilization is used for a various types of works, the most common function is the construction of road and air field pavements.

The two main types of soil stabilization are classified below:-

a. Alteration or enhancement of soil properties of the existing soil lacking any admixture.

b. Amendment of the properties with the help of admixtures.

The examples of first type are Compaction and drainage, which develop the inherent shear strength of soil. Examples of second type of methods are mechanical stabilization, stabilization with cement, lime, bitumen and chemical etc.
In the present study an attempt has been made to improve the properties of soil subgrade by stabilization method using RCA and Blast furnace slag. In this investigation laboratory studies were carried to know the effect of RCA and Blast furnace slag when mixed separately and in combination with the soil by conducting various tests such as atterberg limits and CBR tests.

II. OBJECTIVES

1. To determine the optimal percentage of RCA and blast furnace slag by conducting various tests such as liquid limit, plastic limit and plasticity index by altering the percentage of same materials.
2. To study the behavior of soil using the above mentioned waste materials.
3. To determine the optimum moisture content (OMC) and maximum dry density (MDD) by conducting the standard proctor compaction test.
4. To determine the California bearing ratio (CBR) value of soil mixed with different percentages of recycled coarse aggregate and blast furnace slag.
5. To utilize the waste materials available in the industries.

III. LITERATURE REVIEW

1. K V Subrahmanyam et al studied A Comparative Study on Utilization of Waste Materials in GSB Layer A study was conducted to investigate the possibility of using Granulated Blast Furnace Slag (GBFS) and also with Waste Rubber Tyre (WRT) with various blended mixes of conventional aggregates in subbase layer with different percentages separately. This study also presents the result of experimental investigation on the influence of Rice husk ash (RHA) on the index properties of Red soil which is used as filler material in subbase layer. It is observed from the study that, with the addition of Rice Husk ash to the Red soil, the Liquid limit of the soil has been decreased and Plastic limit of the soil has been increased and the plasticity index decreased. By 20% replacement with GBFS the maximum CBR value for unsoaked is increased by 40.78% whereas, the CBR value for 4-day soaked is increased by 46.60%.

2. Isaac Akinwumi Soil Modification by the Application of Steel Slag This paper provides experimental insights on the modification of a soil using electric arc furnace (EAF) steel slag, which is limitedly used as a construction material because of its volumetric instability. Various percentages of pulverized steel slag were applied to a soil, having poor engineering properties, with the aim of improving the engineering properties of the soil. This study provides experimental insights that show that pulverized steel slag was beneficially used to improve the plasticity, uncured strength and drainage characteristics of the lateritic soil without any adverse swell behaviour observed. The improvement in the uncured strength of the soil was limited to the application of 8% steel slag to the soil. Addition of 8% of steel slag to the soil increased its unsoaked CBR by 40%.
3. Faisal I. Shalabi et al Effect of by-product steel slag on the engineering properties of clay In this work, by-product steel slag was used to improve the engineering properties of clay soils. Lab and field experimental programs were developed to investigate the effect of adding different percentages of steel slag on plasticity, swelling, compressibility, shear strength, compaction, and California bearing ratio (CBR) of the treated materials. The results of tests on the clay soil showed that as steel slag content increased, the soil dry density, plasticity, swelling potential, and cohesion intercept decreased and the angle of internal friction increased. For the CBR, the results of the tests showed an increase in the CBR value with the increase in slag content.

IV. METHODOLOGY

- **First Stage**: - Literature Survey of the work is done.
- **Second Stage**: - Percentages of gravel, sand, clay and silt in the soil is determined.
- **Third Stage**: - Materials to be used for the experimental work is selected.
- **Fourth Stage** :- The optimum RCA and blast furnace slag content is determined by mixing different percentage of RCA and blast durance slag such as 10, 20, 30 and 40 with soil and conducting plastic and liquid limit tests.
- **Fifth Stage**: - The proctor compaction test is conducted to determine the optimum moisture content and maximum dry density.
- **Sixth Stage**: - The CBR value is determined for soil mixed with varying percentage of RCA and blast furnace slag.
- **Seventh Stage**: - The results is finally concluded and Data analysis and presentation is done.
- **Eight Stage**: - After analysis and presentation we concluded the research work.

V. MATERIALS USED

5.1 Blast Furnace Slag: - Slag is the consequence of metallurgical processes. Steel- and iron production industries make various types of slags. Blast furnace slag which is a by-product of iron production process has a high SiO_2 content and hence, rapidly-cooled blast-furnace slag has an amorphous structure and pozzolanic properties.

5.2 Recycled Coarse Aggregate: - Recycled concrete aggregate (RCA) is a tattered waste produce during the destruction of concrete and reinforced cement concrete structures (RCC). The resulting aggregates are the area of research work to reduce the requirement of natural aggregates for various concrete applications.

5.3 Soil: - It is defined as natural aggregate of mineral grains with or without organic matter constitutes and that can be detached by general mechanical means such as disturbance in water. Soil consists of various particles of broken rock that have been transformed by chemical and mechanical processes that contain weathering and erosion. It is a combination of mineral and organic constituent's that are in solid.

VI. EXPERIMENTAL INVESTIGATIONS:-

6.1 Determination of grain size distribution by wash sieve analysis.
6.2 Determination of specific gravity of soil by pycnometer.
6.3 Determination of Plastic and liquid Limit of Soil.
6.4 Determination of optimum moisture content and maximum dry density by proctor compaction test.
6.5 Determination of California bearing ratio (CBR) value.

Fig 6.1 Performing Liquid limit test

Fig 6.2 Performing Plastic limit test

Fig 6.3 Performing Proctor Compaction test

Fig 6.4 Performing CBR test

VII. RESULTS:-

Table 7.1 Determination of grain size distribution of the particle

Sl No	Sieve size	Weight of soil retained(gm)	Correctio (-ve) gms	Corrected weight gms	% retained	Cumulative % retained	Cumulative % finer
1	4.75mm	8	0.118	7.882	1.576	1.576	98.424
2	2.36mm	10	0.148	9.852	1.970	3.546	96.454
3	1mm	18	0.267	17.733	3.546	7.092	91.332
4	600□	8	0.118	7.882	1.576	8.668	90.148
5	425□	6	03088	5.912	1.184	9.852	88.964
6	300□	6	0.088	5.912	1.184	11.036	88.194
7	212□	4	0.059	3.941	0.788	11.874	88.176
8	150□	3	0.042	2.925	0.645	11.874	88.176
9	75□	2.36	0.038	2.592	0.518	12.342	87.658
10	Pan	0.3	0.004	0.296	0.0592	12.401	

Percentage of gravel = 1.576%
Percentage of sand = 10. 766%
Percentage of silt and clay = 87.6%.

Table 7.2 Specific gravity of Blast Furnace Slag

Sl. No	Particulars	Wt. in gm
01	Mass of pycnometer (M1)gm	642
02	Mass of pycnometer + BFS (M2)gm	1275
03	Mass of pycnometer + BFS+ Kerosene(M3)gm	1970
04	Mass of pycnometer + kerosene (M4)gm	1530
05	Specific gravity G	3.28

Table 7.3 Specific gravity of RCA

Sl. No	Particulars	Wt. in gm
01	Mass of pycnometer (M1)gm	642
02	Mass of pycnometer + RCA (M2)gm	1123
03	Mass of pycnometer + RCA+ water(M3)gm	2020
04	Mass of pycnometer + water(M4)gm	1730
05	Specific gravity G	2.52

Table 7.4 Results of plastic limit for varying percentage of RCA & Blast furnace Slag

Sl No	Soil + % of flyash	Particulars	Container No	Weight of container +wet soil(gm)	Weight of container +dry soil(gm)	Weight of empty container(gm)	Weight of water(gm)	Weight dry soil(gm)	Water content (%)
1	Plain Soil	I	P_{11}	20.782	17.242	8.588	3.54	8.654	40.905
2		II	P12	20.863	17.722	9.975	3.114	7.747	70.19
3		III	P_{13}	20.7	17.462	9.68	3.238	7.782	41.5
		Avg							40.86
1	Plain soil+ 5% BFS + 5%RCA	I	P21	21.892	17.93	9.419	3.962	8.511	46.55
2		II	P22	22.271	17.904	8.618	4.367	9.286	47.02
3		III	P23	20387	17.122	8.915	3.753	8.207	45.72
		Avg							46.43
1	Plain soil+ 10%BFS + 10%RCA	I	P31	22.961	18.131	9.137	3.83	8.994	53.7
2		II	P32	22.567	18.063	9.196	3.504	8.867	50.79
3		III	P33	22.114	18.301	9.283	3.813	9.018	42.28
		Avg							48.92
1	Soil+15% BFS + 15% RCA	I		_	_	_	_	_	_
2		II		_	_	_	_	_	_
3		III		_	_	_	_	_	_
		Avg		_	_	_	_	_	_
1	Soil+ 20%BFS + 20% RCA	I		_	_	_	_	_	_
2		II		_	_	_	_	_	_
3		III		_	_	_	_	_	_
		Avg		_	_	_	_	_	_

Table 7.5 Results of liquid limit for varying percentage of BFS and RCA

Sl No	Soil+%of flyash	Particulars	No of blows	Container	Weight of container	Weight of container +dry	Weight of empty container	Weight of water(gm)	Weight of dry	Water content
	Plain Soil	I	19	L_{11}	22.27	16.67	9.536	5.6	7.134	78.49
		II	23	L12	19.914	15.00	8.634	4.914	6.366	77.19
1		III	45	L_{13}	20.452	15.67	9.376	4.782	6.294	75.9
		Avg								**77.5**
	Plain soil+ 5% BFS + 5%RCA	I	17	L21	21.354	16.776	9.716	4.578	7.06	64.84
		II	21	L22	22.227	17.343	9.786	4.884	7.557	61.62
2		III	10	Y2	26.629	17.327	9.202	5.0302	8.125	65.25
		Avg								63.90
	Plain soil+ 10%BFS + 10%RCA	I	33	H17	23.455	17.817	8.695	5.638	9.122	61.81
		II	29	B9	21.222	16.462	8.956	4.76	7.506	59.4
3		III	35	D	19.183	15.301	8.969	3.882	6.332	61.30
		Avg								60.84
	Soil+15% BFS + 15%	_	_	_	_	_	_	_	_	_
4		_	_	_	_	_	_	_	_	_
		_	_	_	_	_	_	_	_	_
		_	_	_	_	_	_	_	_	_
	Soil+ 20%BFS + 20% Plain Soil	_	_	_	_	_	_	_	_	_
5		_	_	_	_	_	_	_	_	_
		_	_	_	_	_	_	_	_	_
		_	_	_	_	_	_	_	_	_

Table 7.6 Results of dry density for plain soil

Weight of mould=4.120 kg Volume of mould =1000CC
Diameter of mould =10 cm Height of mould =12.8 cm
Weight of rammer =4.5 kg Amount of compaction= light (25 blow)

DETERMINATION NO	1	2	3	4
Weight of Water Added, Ww (gm)	400 gm	550 gm	700 gm	850 gm
Weight Of Mould + Compacted Soil, (gm)	5.850	5.960	6.170	6.210
Weight of Compacted Soil, W (gm)	1.730	1.840	2.050	2.090
Bulk Density(gm/cc) = W/(Mould Volume)	1.73	1.84	2.05	2.09
Dry Density (gm/cc) = Bulk density/ (1+w).	1.56	1.61	1.75	1.74
Container No.	1	2	3	4
Wt. of container (gm) = W1	23.12	22.57	23.93	22.28
Wt. of container + wet soil (gm) = W2	24.32	24.82	26.18	25.80
Wt. of container + dry soil (gm) = W3	33.85	40.53	37.10	39.51
Moisture %	11.18	12.54	17.08	20.43

OMC=17.55% M.D.D= 1.76 gm/cc

Similarly , For Plain soil+ 5% BFS + 5%RCA :- OMC=20.05% M.D.D= 1.61 gm/cc.

For Plain soil+ 10% BFS + 10% RCA: - OMC=22.50% M.D.D= 1.64 gm/cc.
For Plain soil+ 15% BFS + 15% RCA: - OMC=26.70% M.D.D= 1.44 gm/cc.
For Plain soil+ 20% BFS + 20% RCA: - OMC=28.10% M.D.D= 1.42 gm/cc.

For Plain Black cotton soil

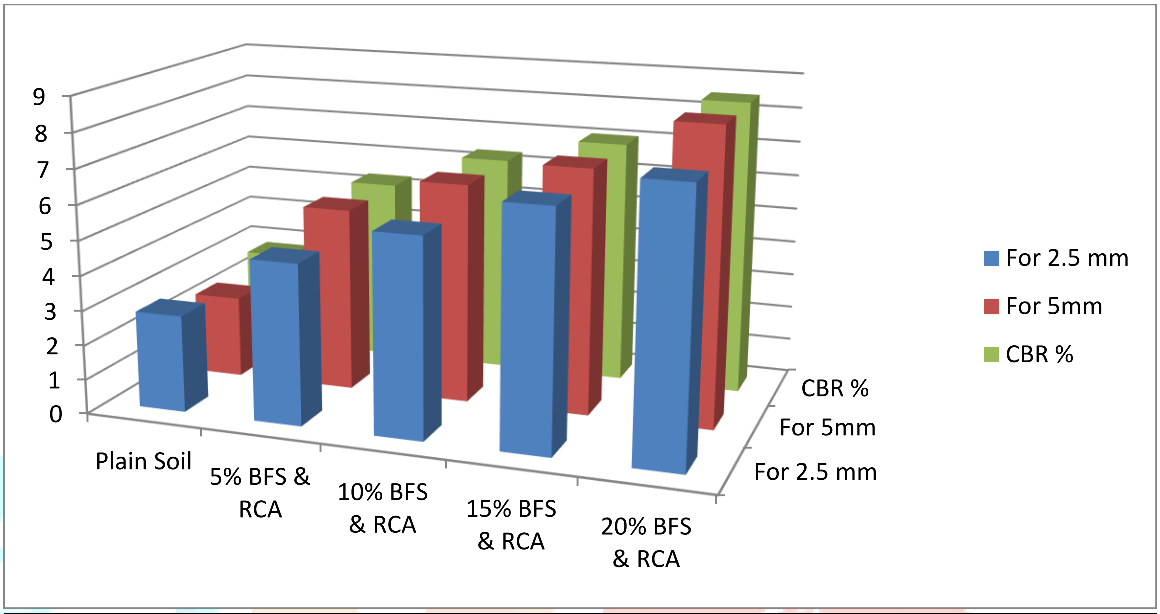
Table 7.7 LOAD PENETRATION DATA

Dial gauge reading in division	Penetration in mm	Proving ring reading	Load in kg
0	0	0	0
50	0.5	1.75	10.34
100	1.0	2.75	16.25
150	1.5	4	23.64
200	2.0	5	29.55
250	2.5	6.5	38.44
300.	3.0	7.25	42.85
400	4.0	8.0	47.28
500	5.0	8.75	48.75
750	7.5	9.0	53.19
1000	10.0	10.25	60.57
1250	12.5	11.25	66.48

Penetration (mm)	Pt (kg)	Ps (kg)	CBR (%)
2.5	38.44	1370	2.81
5	48.75	2055	2.37

CBR = 2.81%

For Plain soil+ 5% BFS + 5%RCA :- CBR = 5.32 %
For Plain soil+ 10% BFS + 10%RCA :- CBR = 6.33 %
For Plain soil+ 15% BFS + 15%RCA :- CBR = 7.05%
For Plain soil+ 20% BFS + 20%RCA :- CBR = 8.48%



Graph 7.1

VIII. CONCLUSION:-

The major conclusions from the study are as follows:-

- Soil stabilization method by using the waste products like RCA, blast furnace slag etc is productively improves the existing poor and expansive sub grade soil.
- RCA and slag is a waste product, cost effective and is easily available, hence it proved economical also.
- The various properties of RCA and blast furnace slag like specific gravity, impact value, abrasion value, water absorption were also calculated and found within the permissible limit.
- It is observed from the study that, with the addition of RCA and blast slag to the black cotton soil, the Liquid limit of the soil has been decreased and Plastic limit value of the soil after testing has been increased and the plasticity index of the soil decreased.
- The value of liquid and plastic limit are within the permissible limit upto 10 % proportion but after 10% increment it does not show any liquid and plastic limit values.
- It has been observed that the Max Dry Density has been gradually increased upto 10% after which it decreases and OMC increases upto 20% replacement.
- The accumulation of RCA and blast furnace slag in combination improved the properties & CBR value of the soil.
- As per this research all the results and observations, the best percentage for stabilization of Black Cotton Soil is recommended to be 20% if plasticity is not an issue and if plasticity is considered then we can use the proportion upto 10%

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