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Efficacy of Industrial waste admixture in Improving Engineering Performance of Clayey soil – A quantitative study

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ABSTRACT : *Infrastructure and industrialization serves as a back bone for a country's economy. However due to rapid industrialization there exist a problem in the form of waste accumulation and subsequent problems due to their disposal & effects of waste. In infrastructure development, roads play a major role. In general pavement construction needs bulk quantities of good soil keeping in view of the service and longevity aspects. Due to limitation in availability of good soil, often the cost of projects escalates. An ideal solution lies for reducing project cost, increasing longevity and reduce accumulation of waste shall be through utilization of industrial waste combined with weak soil for pavement construction. Few types of waste materials namely crusher dust, fly ash and Steel slag waste are popular as admixtures in improving weak soils. This paper discusses the performance of admixtures in improving weak soil through mechanical stabilization. Results of tests on index and engineering properties of mechanically stabilized clayey soil with industrial waste admixtures namely, crusher dust, fly ash and steel slag are presented for different admixture contents and test conditions. A comparison is made based on improved performance. It is observed that Steel slag is proven to be effective over other types. From the results optimum content of admixture for a given improvement is suggested.*

KEYWORDS: *Admixtures, Engineering performance, Mechanical stabilization, Subgrade soil*

I. INTRODUCTION

Strength of clayey soil improved with the help of various stabilization techniques like mechanical stabilization, action of reinforcement etc. mechanical stabilization is the process of improving engineering properties of clayey soil treating with industrial waste materials. Around million tons of waste material is produced annually in various industries. Effective utilization of these waste materials brings innovation in mechanical stabilization of soil. Previous studies highlighted two techniques for improving soft subgrade namely, mechanical and with reinforcement. Waste materials from industry and geosynthetics are identified as materials for improving soft subgrade characteristics. Fly ash is being identified as one of the potential admixture [1-4]. Lime clayey soil mixture exhibits higher strength compare to clayey soil fly ash mixture [5]. The influence of fly ash on organic and inorganic clayey soils is different; strength improvement with varying percentage of fly ash for inorganic soils is high compared to organic soils [6].

Recently quarry dust, Steel slag and artificial sand waste obtained from steel plants and quarries has also being identified as stabilizing material. Studies indicated improvement in engineering characteristics [7-15]. Geosynthetics (Geogrids) with high tensile strength used in combination with soil of high compressive strength have been found to be effective in the design of many civil engineering applications. The layer of reinforcement with geosynthetics provided in soil, carry loads thus reducing stresses in soil. Laboratory studies produced successful results in improvement for waste material mix composite systems like soil-fly ash-Geogrid, soil-lime-Geogrid, and soil-pond ash-Geogrid [16]. The field performance of marine clayey soil treated with lime, GBFS and geotextile - clay foundation soil bed has exhibited the justified load carrying capacity in wet season [17, 18]. The performance of clayey silt subgrade can be enhanced using artificial sand. The performance is comparable and similar in field. [19]. In Few complex situations with soft subgrade can be solved by providing stiffer aggregate layer over soft subgrade and the problem of mixing of subgrade with aggregate can be avoided with separator geotextile provision of stiffer aggregate layer over soft subgrade with geotextile separator improves CBR of composite subgrade [20].

The objective of present study is to use of Fly ash, Steel slag and Quarry dust in bulk quantity for reducing the total cost of construction in addition to providing a solution to an environmental problem. The following objectives are taken up for study.

[1] To study and evaluate few waste materials for their adequacy and bulk utilization through stabilizing a clayey subgrade soil.
[2] To study the effects of stabilization on index and engineering properties of soil using three types of waste materials as admixtures.
[3] To compare and suggest choice of admixture based on their relative influence and optimum content on properties of subgrade soil.
[4] To quantify degree of improvement vis-a vis admixture type and test conditions for utilization as subgrade.

II. DETAILS OF MATERIALS, METHODOLOGY, RANGES OF ADMIXTURES AND TESTS CARRIED OUT

Locally available clayey soils, industrial waste admixtures namely, crusher dust, fly ash and steel slag are used in this present work. Steel slag is obtained from Concast ferro Inc, Dusipeta, Srikakulam district, Andhra Pradesh. The fly ash used in the study is of class-F type obtained from NTPC, Visakhapatnam. The quarry dust was collected from a local quarry. The ranges of admixtures are varied from 0 to 50% w.r.t weight of soil. The outline of work is presented in fig. I

Preparation of samples, details of tests and parameters determined:

Naturally available clayey soils are mixed with admixtures like Quarry dust, Steel slag and Fly ash at varying percentages to the dry weights of soils. Experiments are conducted on the samples blended with these admixtures to determine the index and engineering properties of the modified soils. The following tests are carried out on admixture soil and the parameters determined as

- Index properties (As per IS: 2720 part 5-1987)
- Compaction characteristics (As per IS: 2720 part 8-1987)
- Unconfined compression test (As per IS: 2720 part 10-1991)
- CBR test in Soaked and Unsoaked conditions. (As per IS: 2720 part 16-1987)

The experimental set up is presented in fig. 2 to fig. 4.

III. PRESENTATION OF RESULTS AND DISCUSSION

In the experimental study tests are carried out on admixture modified soil for their index and engineering properties. Based on the results obtained the performance of admixture in improving is computed as R_f given by the following formula. The performance of admixtures on index and engineering properties is quantified with improvement ratios R_f as detailed below. Results of .R_f for different admixture modified soil are presented in the subsequent sections and in tables 3 to 10, from fig. 5 to 12.

Performance improvement ratio (R_f) is calculated as

$$R_{fL} = \frac{MODIFIED \quad LIQUID \quad LIMIT \quad WITH \quad ADMIXTURE}{UNMODIFIED \quad LIQUID \quad LIMIT} \quad \ldots\ldots\ldots\ldots.... (1)$$

$$R_{Fo} = \frac{MODIFIED \quad OMC \quad WITH \quad ADMIXTURE}{UNMODIFIED \quad OMC} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

$$R_{fM} = \frac{MODIFIED \quad MDD \quad WITH \quad ADMIXTURE}{UNMODIFIED \quad MDD} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

$$R_{fV} = \frac{MODIFIED \quad VOID \quad RATIO \quad WITH \quad ADMIXTURE}{UNMODIFIED \quad VOID \quad RATIO} \quad \ldots\ldots\ldots\ldots\ldots.. \quad (4)$$

$$R_{fCS} = \frac{MODIFIED \quad SOAKED \quad CBR \quad WITH \quad ADMIXTURE}{UNMODIFIED \quad SOAKED \quad CBR} \quad \ldots\ldots\ldots\ldots\ldots \quad (5)$$

$$R_{fCU} = \frac{MODIFIED \quad UNSOAKED \quad CBR \quad WITH \quad ADMIXTURE}{UNMODIFIED \quad UNSOAKED \quad CBR} \quad \ldots\ldots\ldots\ldots...(6)$$

$$R_{Fsu} = \frac{MODIFIED \quad UNSOAKED \quad CBR \quad WITH \quad ADMIXTURE}{UNMODIFIED \quad SOAKED \quad CBR} \quad \ldots\ldots\ldots\ldots.. \quad (7)$$

$$R_{fU} = \frac{MODIFIED \quad UCS \quad VALUE \quad ADMIXTURE}{UNMODIFIED \quad UCS} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots... \quad (8)$$

Presentation of results for R_{fL}-Effect of admixture: The Variation of R_{fL} with various admixtures is presented in fig. 5 and table 3. It is observed that the admixtures are playing an important role in reducing liquid limit. Due to which R_{fL} is found to decrease with Admixture (%). Also is observed that liquid limit is reduced with higher Steel slag than other admixtures. This may be due to a non plastic nature of steel slag over other two types. The R_{fL} is found to decrease from 1 to 0.79, from 1 to 0.77 and from 1 to 0.83 for steel slag, quarry dust and fly ash respectively.

Presentation of results for R_{fO} and R_{fM}-Effect of admixture: The Variation of R_{fO} with various admixtures is presented in fig. 6 and table 4. It is observed that R_{fO} is decreases with Quarry dust and Steel slag due to inert property of Admixture and it is increases for the Fly ash due to the water absorption property. The R_{fO} is found to decrease from 1 to 0.61 from 1 to 0.63 for steel slag and quarry dust respectively and for Fly ash it is increase from 1 to 1.35. The Variation of R_{fM} with various admixtures is presented in fig. 7 and table 5. It is observed that R_{fM} is increases for both Quarry dust and Steel slag due to the remarkable reduction in void ratio as shown in fig. 10 and it is decreases for the Fly ash due to cohesive nature. The R_{fM} is found to increases from 1 to 1.09 from 1 to 1.06 for steel slag and quarry dust respectively and for Fly ash it is decreases from 1 to 0.87.

Presentation of results for R_{fV}-Effect of admixture: The Variation of R_{fV} with various admixtures is presented in fig. 8 and table 6. It is observed that R_{fV} is decreases for both Quarry dust and Steel slag due to similar physical properties and it is increases for fly ash .The R_{fV} is found to decreases from 1 to 0.86, from 1 to 0.71 for quarry dust and steel slag respectively and for Fly ash it is increases from 1 to 1.4.

Presentation of results for R_{fCS}, R_{fCU} and R_{fSU}-Effect of admixture: The Variation of R_{fCS} and R_{fCU} with various admixtures is presented in fig. 9, fig. 10 and table 7, table 8. It is observed that R_{fCS} and R_{fCU} are increases for Quarry dust, Steel slag and Fly ash. It is seen that (40%) Steel slag, (40%) Quarry dust and (30%) Fly ash is optimum percentage of admixture. The R_{fCS} and R_{fCU} are found to increases from 1 to 2.83, 1 to 2.31 and 1 to1.65 times and from 1 to 2.18, 1 to 1.79 and 1 to1.45 times for steel slag, quarry dust and Fly ash respectively. It is observed that improvement (%) of Soaked CBR over Unsoaked CBR with all the admixtures. Ii is observed that influence of admixture in CBR soaked condition is higher than that of Unsoaked condition. Performance improvement ratio (R_{fSU}) for soaked CBR 3.41, 4.23 and 2.76 times more than Unsoaked CBR with addition of (40%) Quarry dust, (50%) Steel slag and (30%) Fly ash respectively.

Presentation of results for R_{fU}-Effect of admixture: The Variation of R_{fU} with various admixtures is presented in fig. 12 and table 10. For UCS similar trend is observed as that of CBR. It is seen that (40%) Steel slag, (40%) Quarry dust and (30%) Fly ash is optimum percentage of admixture. The R_{fU} is found to increases from 1 to 1.27, 1 to 1.18 and 1 to 1.09 times for steel slag, quarry dust and Fly ash respectively.

IV. CONCLUSIONS

The following conclusions are drawn from the course of study:

1. The effect of all the admixtures on various properties is significant in general and of steel slag in particular. A decrease in consistency limits is observed with admixtures. A decrease of liquid limit to 0.78, 0.77 and 0.82 times and plasticity index decreased by 0.72, 0.34 and 0.74 times with quarry dust, steel slag and Fly ash respectively.
2. The composite soil has exhibited lower void ratios with the addition of Quarry dust and Steel slag. The variation of void ratio is same using steel slag and quarry dust admixture is same. However fly ash showed a different trend.. As fly ash content increases void ratios increases..
3. It is concluded that an in improvement in compaction characteristics namely. increase in maximum dry density and decrease in OMC with steel slag & quarry dust and an opposite trend with fly ash is possible. An increase to 1.06 and 1.09 times for (40%) Quarry dust and (40%) Steel slag respectively and decrease to 0.83 times for Fly ash. Optimum moisture content decreases to 0.73 and 0.63 times for Quarry dust and Steel slag respectively and increase to 1.35 times for Fly ash.
4. Both CBR (Soaked) and CBR (Unsoaked) has been improved with admixtures. However the improvement is more pronounced in Soaked performance over Unsoaked. An improvement ratio of 2.30, 2.81 & 1.65 times for Soaked and 1.79, 2.18 and 1.45 times for Unsoaked is observed for Quarry dust, Steel slag and Fly ash respectively.
5. Performance ratio improved for UCS with the addition of admixtures. 1.18, 1.27 and 1.09 times improvement is observed with addition of Quarry dust, Steel slag and fly ash respectively.

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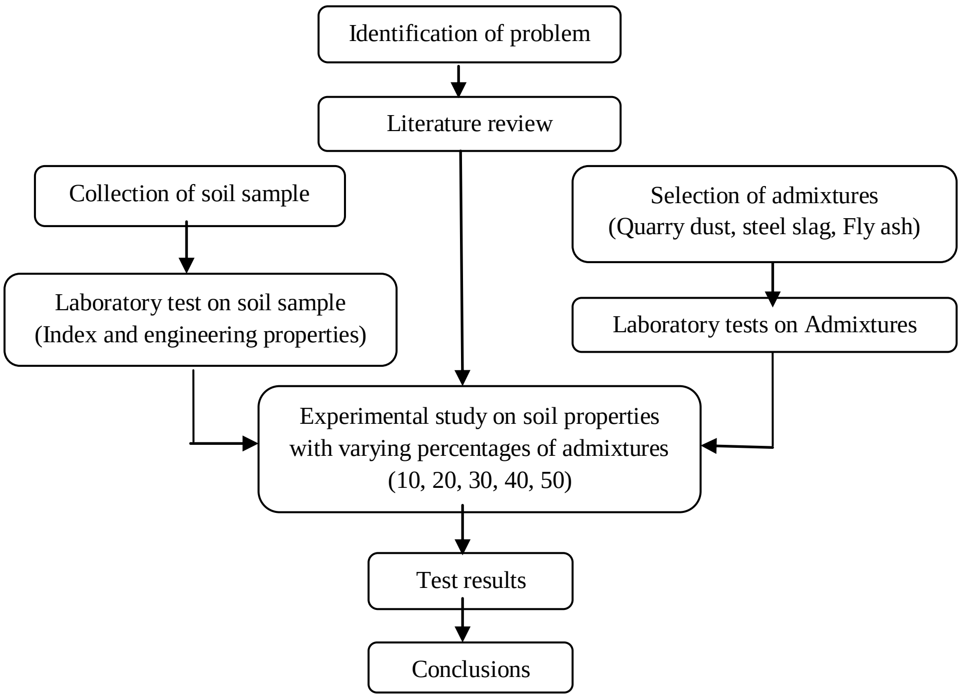
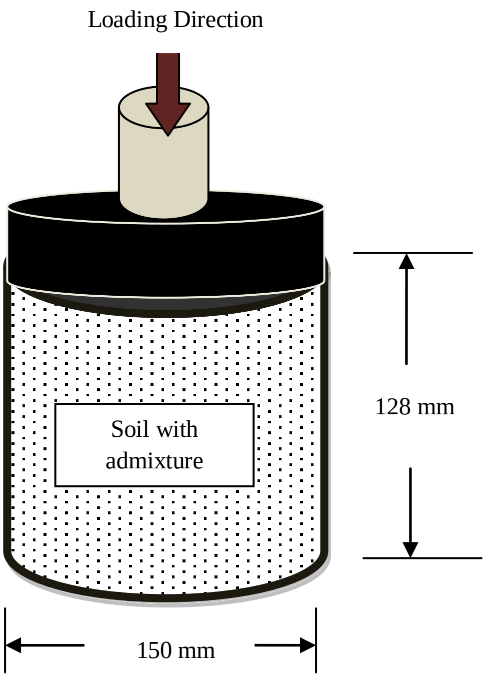


Figure 1 Methodology

Figure 2 Preparation of mixture by author for compaction test

(a) (b)

Figure 3 a) Sample for UCS test b) Author performing UCS test



(a)

(b)

Figure 4 a) Cross section for CBR sample b) Author performing CBR test

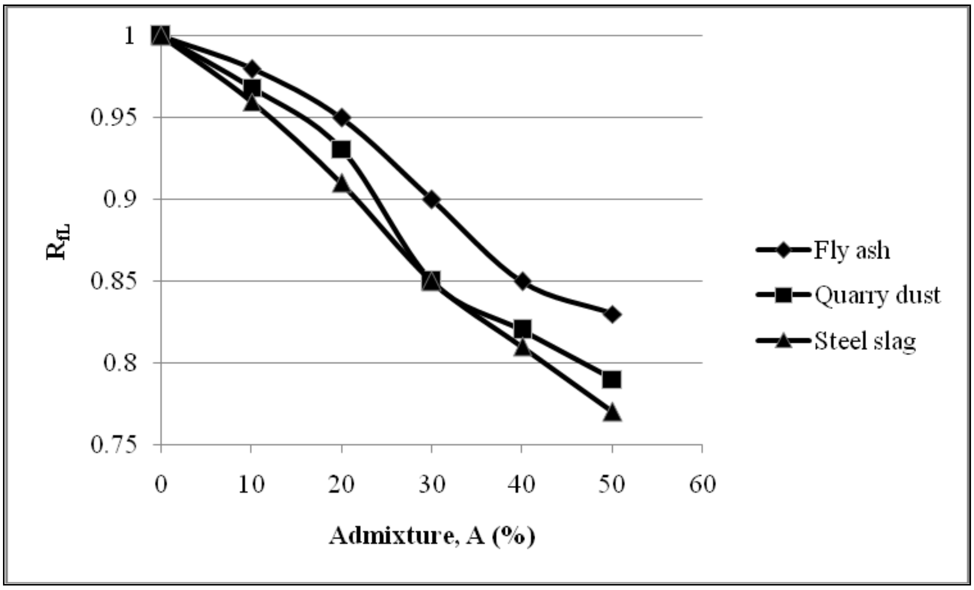


Figure 5 Variation of R_{fL} with Admixtures

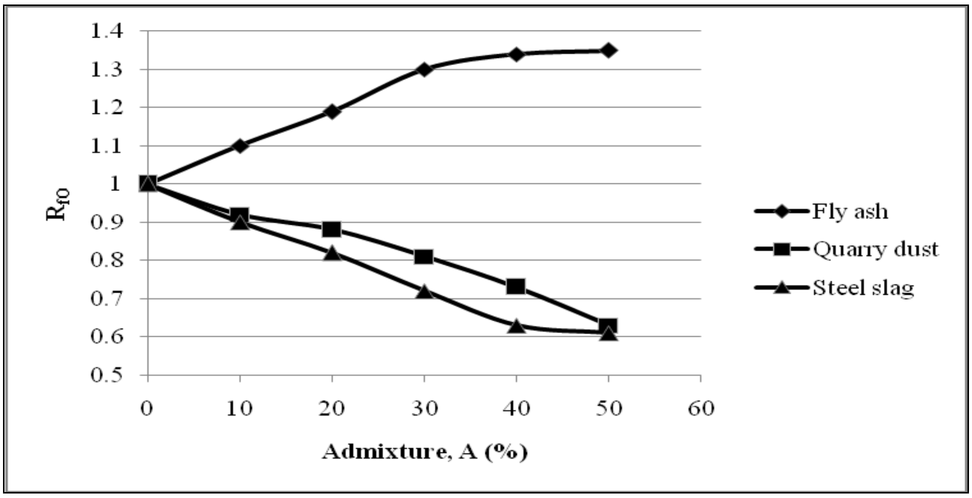


Figure 6 Variation of R_{fO} with Admixtures

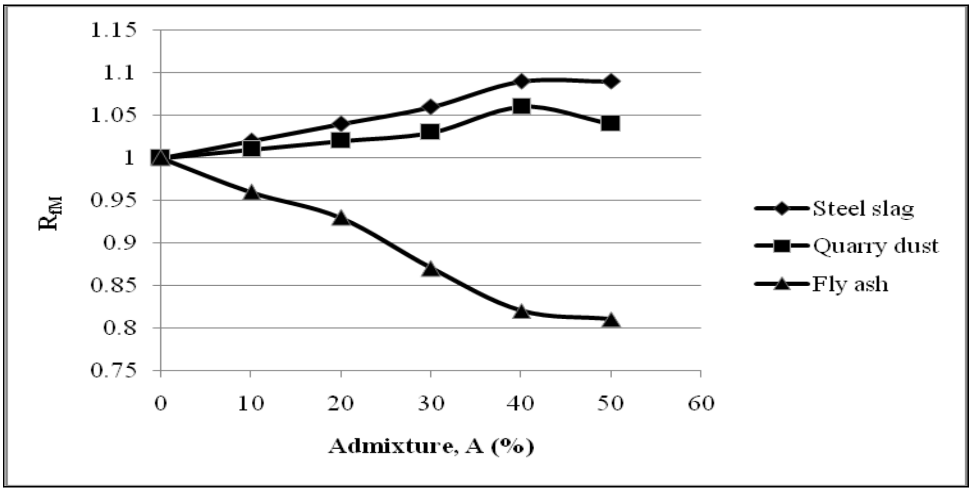


Figure 7 Variation of R_{fM} with Admixtures

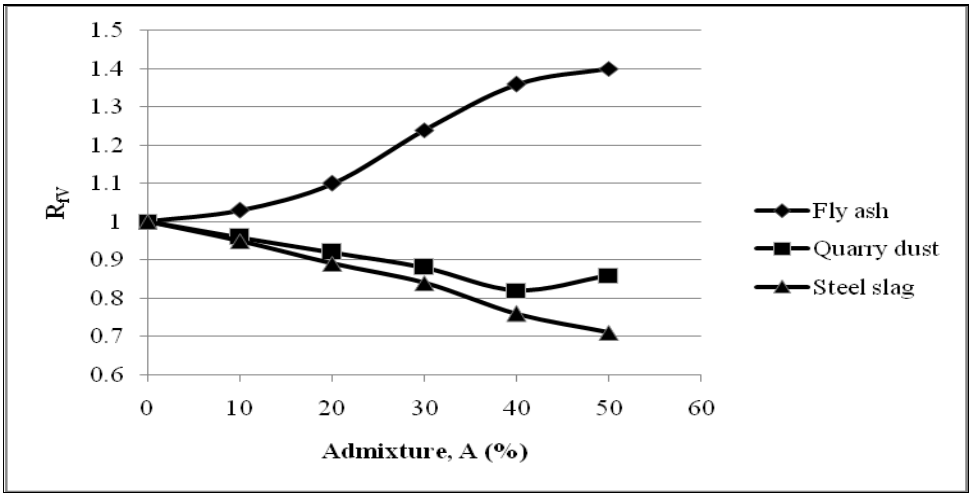


Figure 8 Variation of R_{fV} with Admixtures

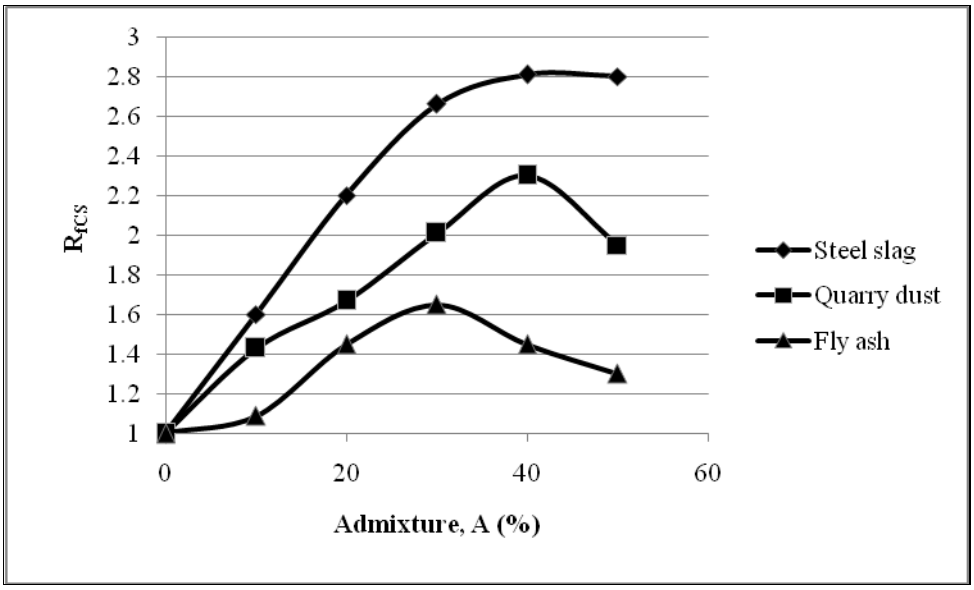


Figure 9 Variation of R_{fCS} with Admixtures

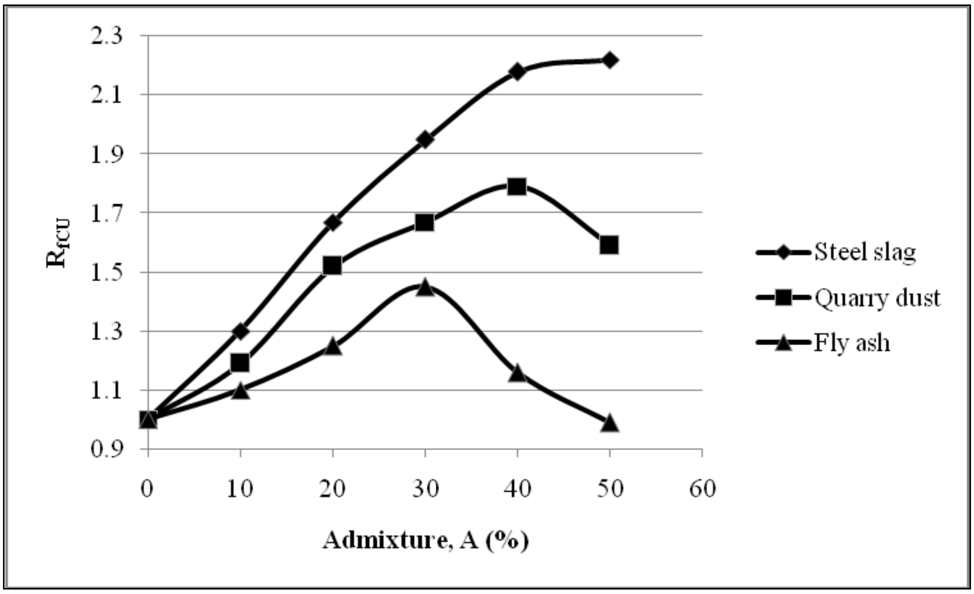


Figure 10 Variation of R_{fCU} with Admixtures

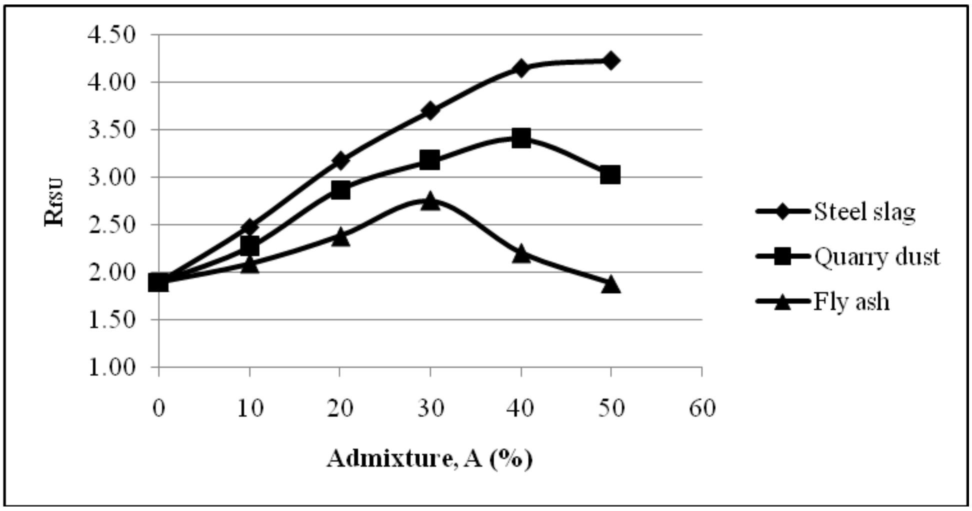


Figure 11 Variation of improvement (%) ratio for Unsoaked CBR over Soaked CBR

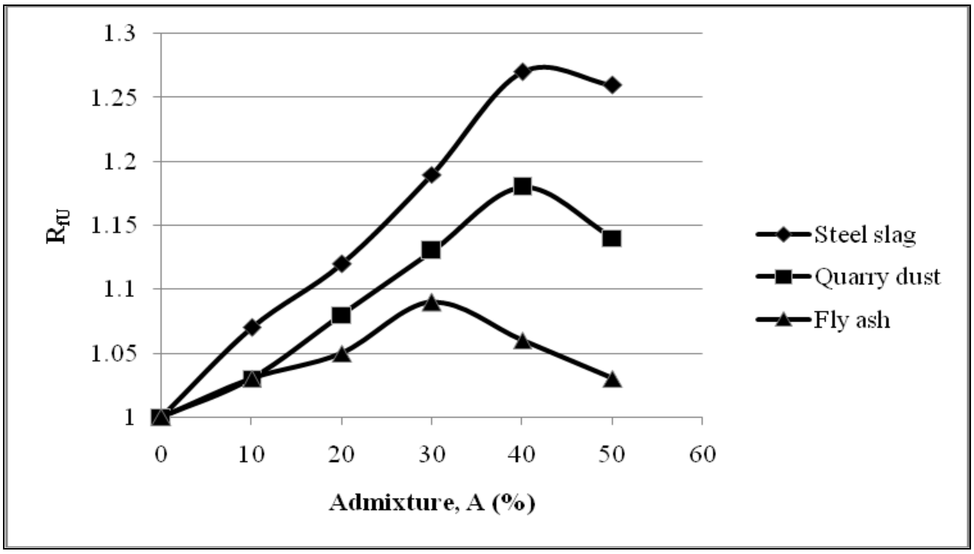


Figure 12 Variation of R_{fU} with Admixtures

Table 1 Index and engineering Properties of soil and Admixtures

Properties	Soil	Quarry dust	Steel slag	Fly ash
Specific gravity	2.60	2.63	2.74	2.10
Liquid limit (%)	47.70	NP	NP	NP
Plastic limit (%)	25.65	NP	NP	NP
Plasticity index (%)	22.05	NP	NP	NP
Gravel size particles (%)	2	1	1	0
Sand size particles (%)	33	97	95	27
Fines size particles (%)	65	2	4	73
Classification as per USCS	CH	SP	SP	NP

MDD (kN/m³)	18.04	17.02	19.77	14.0
OMC (%)	15.80	8.30	7.81	19
CBR (Un-soaked) (%)	3.46	-	-	-
CBR (Soaked) (%)	1.82	-	-	-
UCS (kN/m²)	117.64	-	-	-

Table 2 Notations adopted for each parameter and improvement factor

Parameter considered	**Notation for R_f**
Liquid limit	R_{fL}
OMC	R_{fO}
MDD	R_{fM}
Void ratio	R_{fV}
CBR Soaked	R_{fCS}
CBR Unsoaked	R_{fCU}
CBR ratio for Unsoaked over soaked	R_{fSU}
UCS	R_{fU}

Table 3 Performance ratio, R_{fL} for modified soil with admixtures

Soil+ Admixture	**% of Admixtures**					
	0	**10**	**20**	**30**	**40**	**50**
Soil+ Quarry dust	1	0.97	0.93	0.85	0.82	0.79
Soil+ Steel slag	1	0.96	0.91	0.85	0.81	0.77
Soil+ Fly ash	1	0.98	0.95	0.90	0.85	0.83

Table 4 Performance ratio, R_{fO} for modified soil with admixtures

Soil+ Admixture	**% of Admixtures**					
	0	**10**	**20**	**30**	**40**	**50**
Soil+ Quarry dust	1	0.92	0.88	0.81	0.73	0.63
Soil+ Steel slag	1	0.9	0.82	0.72	0.63	0.61
Soil+ Fly ash	1	1.1	1.19	1.3	1.34	1.35

Table 5 Performance ratio, R_{fM} for modified soil with admixtures

Soil+ Admixture	% of Admixtures					
	0	**10**	**20**	**30**	**40**	**50**
Soil+ Quarry dust	1	1.01	1.02	1.03	1.06	1.04
Soil+ Steel slag	1	1.02	1.04	1.06	1.09	1.09
Soil+ Fly ash	1	0.96	0.93	0.87	0.82	0.81

Table 6 Performance ratio, R_{fV} for modified soil with admixtures

Soil+ Admixture	% of Admixtures					
	0	**10**	**20**	**30**	**40**	**50**
Soil+ Quarry dust	1	0.96	0.92	0.88	0.82	0.86
Soil+ Steel slag	1	0.95	0.89	0.84	0.76	0.71
Soil+ Fly ash	1	1.03	1.1	1.24	1.36	1.4

Table 7 Performance ratio, R_{fCS} for modified soil with admixtures

Soil+ Admixture	% of Admixtures					
	0	**10**	**20**	**30**	**40**	**50**
Soil+ Quarry dust	1	1.43	1.67	2.01	2.3	1.95
Soil+ Steel slag	1	1.6	2.2	2.66	2.81	2.8
Soil+ Fly ash	1	1.09	1.45	1.65	1.45	1.3

Table 8 Performance ratio, R_{fCU} for modified soil with admixtures

Soil+ Admixture	% of Admixtures					
	0	**10**	**20**	**30**	**40**	**50**
Soil+ Quarry dust	1	1.19	1.52	1.67	1.79	1.59
Soil+ Steel slag	1	1.3	1.67	1.95	2.18	2.22
Soil+ Fly ash	1	1.1	1.25	1.45	1.16	0.99

Table 9 Performance ratio for Unsoaked CBR over Soaked CBR

Soil+ Admixture	**% of Admixtures**					
	0	**10**	**20**	**30**	**40**	**50**
Soil+ Quarry dust	1.90	2.27	2.87	3.18	3.41	3.04
Soil+ Steel slag	1.90	2.48	3.18	3.70	4.15	4.23
Soil+ Fly ash	1.90	2.10	2.38	2.76	2.21	1.89

Table 10 Performance ratio, R_{fU} for modified soil with admixtures

Soil+ Admixture	**% of Admixtures**					
	0	**10**	**20**	**30**	**40**	**50**
Soil+ Quarry dust	1	1.03	1.08	1.13	1.18	1.14
Soil+ Steel slag	1	1.07	1.12	1.19	1.27	1.26
Soil+ Fly ash	1	1.03	1.05	1.09	1.06	1.03

BIOGRAPHIES

Kiran B. Biradar, presently pursuing M.Tech in Transportation Engineering in Department of Civil Engineering, GMR Institute of Technology, Rajam, AP, INDIA. He had one year of experience in Industrial projects.

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