Influence of Steel Slag and Fly Ash on Strength Properties of Clayey Soil: A Comparative Study

Kiran B. Biradar[1], U. Arun kumar[2], Dr.PVV Satyanarayana[3]

[1]*Post graduate Student, Civil Engineering Department, GMRIT Rajam, AP, India*
[2]*Associate Professor, Civil Engineering Department, GMRIT Rajam, AP, India*
[3]*Professor, Civil Engineering Department, AUCOE Vizag, AP, India*

***Abstract*— Construction of structures over weak or soft soils possesses difficulties like differential settlements, poor strength and high compressibility. Clayey soils are poor in strength and they will result in poor pavement support and ultimately affects the pavement performance and its life period. Clayey soil also affects the design and construction of the pavement, resulting in higher cost of construction and early failure of pavement. Various techniques are available like soil stabilization, providing reinforcement etc. to improve load bearing capacity of soil. Soil stabilization is one of the modification technique used to improve the geotechnical properties of soil and has become the major practice in construction engineering which enables the effective utilization of industrial wastes as a stabilizer. This technique becomes more popular because of its easy availability and adaptability. Stabilization is a method of using the available waste materials for the production of low-cost roads construction.**

The present work describes a study carried out to check the improvements in the properties of Clayey soil with the addition of Fly ash and Steel slag. Fly ash and Steel slag are blended with unmodified soil in varying percentages to obtain the optimum percentage of admixture required for the soil stabilization. In this comparative study laboratory tests such as Atterberg's limit, Compaction test and CBR test were carried out for both modified and unmodified clayey soil.

***Keywords* - Clayey soil, Fly ash, Steel slag, Stabilization, CBR.**

I. INTRODUCTION

Construction methods should be carried in a manner so as to construct roads with minimum cost and maximum service life. Flexible pavement structure requires strong subgrade in order to minimize the pavement failure and to maximize the life of pavement. Strength of subgrade affects the thickness of flexible pavement structure. Subgrade stability is a function of soils strength and its behavior under repeated loading. Both properties significantly influence pavement construction and the performance of the pavement. Stabilization refers to a subgrade treatment, intended to provide structural stability to the soil by improving strength properties which helps to extend the life and performance of pavement. Soil Stabilization is the process by which the engineering properties of soil can be improved or treated by mixing the appropriate waste materials into the soil. Adequate blending percentage of admixture is necessary to achieve the maximum strength of soil. Million tons of waste materials are produced annually in India and their disposal has become a major environmental concern. Addition of these wastes in stabilization technique makes proper utilization of these wastes and solves the problem of disposal. Fly ash is produced as a by-product from municipal solid waste incinerators and coal fuelled power stations. Steel slag is a by-product produced during the conversion of iron ore or scrap iron to steel.

Prabakar et.al (2004) studied the behavioural aspect of soils mixed with fly ash to improve the load bearing capacity of the soil. Zalihe (2003) investigated that fly ash treatment results in reduction in swelling properties of expansive soil. Mehata and parate et.al (2013) observed that fly ash has good potential for use in geotechnical applications. An attempt is made by Satyanarayana et.al (2013) for the utilization of Fly ash in Bulk quantities by adding various percentages of Fly ash to the expansive soils and they verified its behavior. Poh et.al (2006) investigated that use of ground BOS slag fines in the area of soil stabilization. Manso et.al (2013) studied the properties of Ladle Furnace Slag (LFS) and the characteristics of several clayey soils susceptible to improvement with additions of this by-product. Lavanya et.al (2011) has studied the utilization of copper slag in geotechnical applications and its usage as an admixture to improve the properties of problematic soils.

II. MATERIALS

a. Soil

In this present work Clayey soils of required quantity are collected from a pit near Chaitanya Techno School, Rajam town, Srikakulam District, Andhra Pradesh.

Laboratory tests were carried out to find the index and engineering properties of unmodified soil. Based on the test results, from the IS classification the obtained soil sample is designated as clay of intermediate plasticity.

Table 2.1: Properties of Unmodified Soil

Specific gravity	2.60
Percent finer (%)	65.92
IS Classification	CI
Liquid limit (%)	47.70
Plastic limit (%)	25.65
Plasticity index (%)	22.05
OMC (%)	15.80
MDD (kN/m³)	18.04
CBR Soaked (%)	1.82
CBR Unsoaked (%)	3.46

b. Steel slag and Fly ash

In this study Steel slag is obtained from Concast Ferro Inc, Dusipeta, Srikakulam district, Andhra Pradesh. It consists mainly of sand size particles (95%).

Table 2.2: Properties of Steel Slag and Fly Ash

PROPERTIES	STEEL SLAG	FLY ASH
Specific gravity	2.74	2.10
MDD (kN/m³)	19.77	1.40
OMC (%)	7.81	19
Gravel Size particles (%)	1	0
Sand Size particles (%)	95	27
Fines Size particles (%)	4	73

The fly ash used in the study is obtained from the Sri Vishnu Sai Saravana Enterprises, Visakhapatnam, Andhra Pradesh. The grade of fly ash used in the experimental work is "F" grade. Fly ash consists of Sand size particles (27%) and Fine size particles of (73%).

III. RESULTS AND DISCUSSION

The proportions of Steel slag and Fly ash used along with the unmodified soil in the study are 0%, 10%, 20%, 30%, 40% and 50%. The following tests were conducted on the soil samples which are mixed with different proportions of Steel slag and Fly ash. The liquid limit and plastic limit tests were conducted as per IS: 2720 (Part 5) - 1995. Standard compaction test was carried out according to IS: 2720(Part 7)-1997. The California Bearing Ratio (CBR) tests were conducted at OMC and MDD as per IS: 2720 (Part 16) – 1997.

Atterberg's limit test:

Table 3.1: Effects of Steel Slag and Fly Ash on L.L and P.I

(SOIL+ ADMIXTURES) IN (%)	STEEL SLAG		FLY ASH	
	L.L	P.I	L.L	P.I
100+0	47.70	47.70	22.05	22.05
90+10	45.80	46.90	18.96	21.16
80+20	43.30	45.50	16.10	20.36
70+30	40.70	42.80	12.77	18.43
60+40	38.90	40.70	10.51	16.75
50+50	36.75	39.5	7.55	16.39

From the Fig.3.1 & Fig.3.2, it is observed that as the percentage of Steel slag and fly ash increases, there is a marked reduction in liquid limit and plasticity index of clay that was tested.

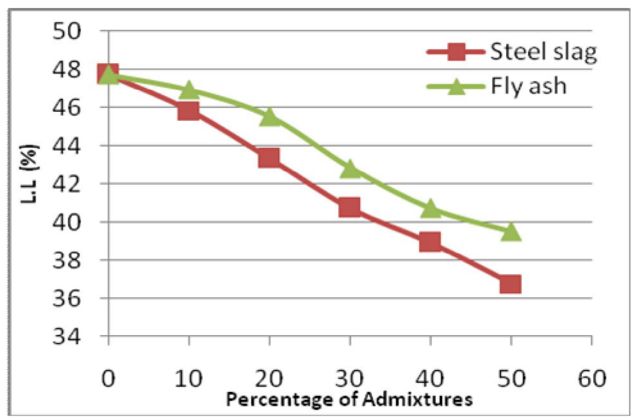

Fig.3.1: Influence of Steel Slag and Fly Ash on Liquid Limit

The addition of the Steel slag to the unmodified soil reduces the clay content and thus increases the percentage of coarser particles, in turn reducing the Liquid limit and Plasticity index of soil. The liquid limit of the modified soil at 50% addition of fly ash and Steel slag is reduced to 36.75% and 39.5% respectively.

Plasticity characteristics of the soil sample are gradually decreasing with increase in the percentage of Steel slag and fly ash. The plasticity index of modified soil is reduced to 16.39% and 7.55% respectively with addition of (50%) of Fly ash and (50%) steel slag.

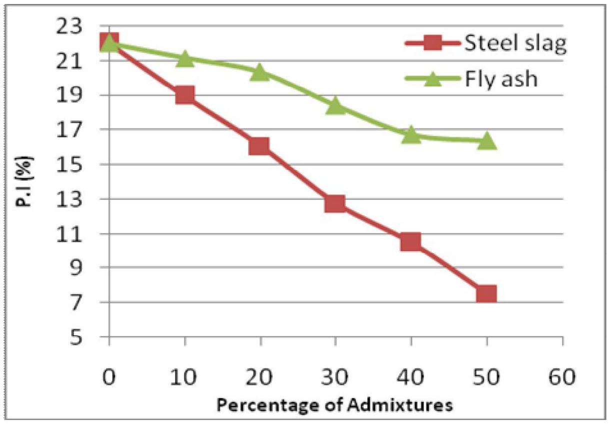

Fig.3.2: Influence of Steel Slag and Fly Ash on Plasticity Index

Compaction test:

Table 3.2: Effects of Steel Slag and Fly Ash on OMC and MDD

(Soil+ Admixtures) in (%)	Steel slag		Fly ash	
	OMC (%)	MDD (kN/m³)	OMC (%)	MDD (kN/m³)
100+0	15.80	18.04	15.80	18.04
90+10	14.2	18.38	17.5	16.85
80+20	12.9	18.68	18.8	16.02
70+30	11.4	19.10	20.6	15.2
60+40	10.05	19.70	21.2	14.8
50+50	9.6	19.75	21.4	14.50

The variations of compaction characteristics such as OMC and MDD for the clay treated with fly ash and Steel slag are presented in Fig.3.3 & Fig.3.4.

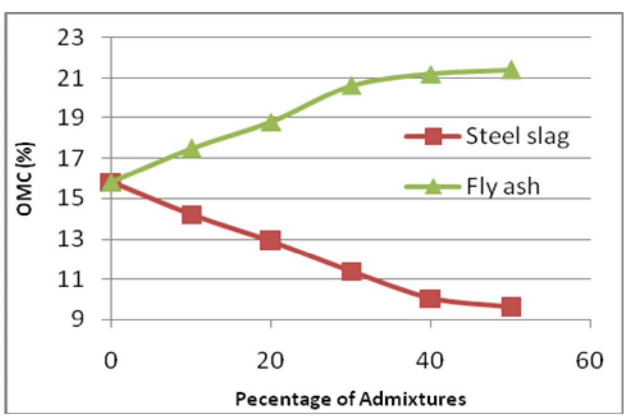

Fig.3.3: Influence of Steel Slag and Fly Ash on OMC

It can be seen that there is a decrease in OMC and increase in MDD value with increase in percentage of Steel slag. High percentages of reduction in voids affect the density of soil+ Steel slag mixes.

It is observed that the clay sample when replaced with 50% of Steel slag yielded maximum dry density of 19.75kN/m³ at optimum moisture content of 14.50%.

In case of Fly ash it is observed that there is a decrease in MDD of modified soil with increase in percentage of Fly ash, due to the lower specific gravity of Fly ash as compared to the unmodified soil and OMC of modified soil is increase as the percentages of Fly ash increases, due to the increase in cohesive property of soil.

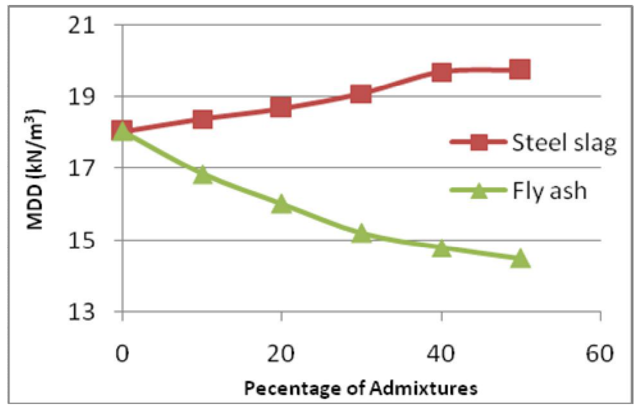

Fig.3.4: Influence of Steel Slag and Fly Ash on MDD

CBR test:

Soaked CBR test results of Steel slag and Fly ash treated soil are presented in Fig.3.5.

From this plot, it is observed that as the percentage admixture such as Steel slag increases, the CBR value also increasing in a reasonable trend. The optimum value of CBR is found at 30% of fly ash and 50% of Steel slag. The CBR value of modified soil increases from 1.82% to 5.20% with 50% addition of Steel slag and for 30% fly ash CBR is increased to 3.01%.

Table 3.3: Effects of Steel Slag and Fly Ash on Soaked CBR

(Soil+ Admixtures) in (%)	Steel slag	Fly ash
100+0	1.82	1.82
90+10	2.91	2
80+20	4.02	2.64
70+30	4.83	3.01
60+40	5.10	2.64
50+50	5.20	2.3

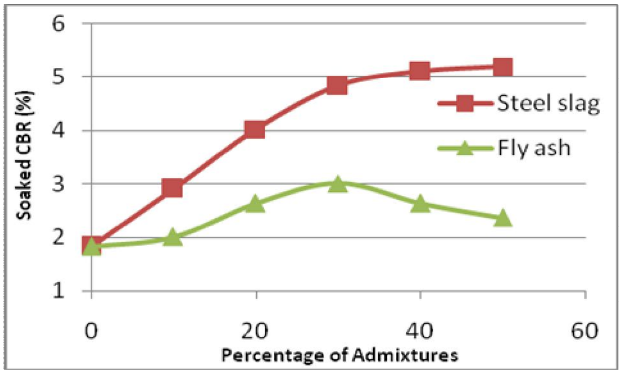

Fig.3.5: Influence of Steel Slag and Fly Ash on Soaked CBR

Table 3.4: Effects of Steel Slag and Fly Ash on Unsoaked CBR

(Soil+ Admixtures) in (%)	Steel slag	Fly ash
100+0	3.46	3.46
90+10	4.52	3.82
80+20	5.78	4.34
70+30	6.74	5.02
60+40	7.55	4.02
50+50	7.7	3.44

The optimum value of CBR is found at 30% of fly ash and 50% of Steel slag. The CBR value of modified soil increases from 3.46% to 7.70% with 50% addition of Steel slag and for 30% fly ash CBR increased to 5.02%.

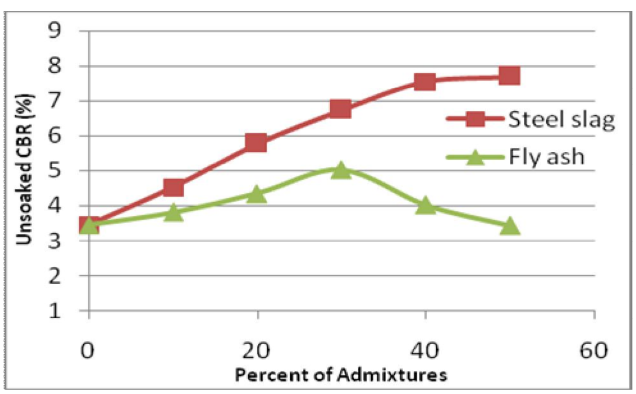

Fig.3.6: Influence of Steel Slag And Fly Ash on Unsoaked CBR

Unsoaked CBR test results of Steel slag and Fly ash treated soil are presented in Figure 3.6.
The optimum value of CBR is found at 30% of fly ash and 50% of Steel slag. The CBR value of modified soil increases from 3.46% to 7.70% with 50% addition of Steel slag and for 30% fly ash CBR increased to 5.02%.

IV. CONCLUSIONS

The following conclusions are derived from the test results of the experimental studies:
1. Liquid limit of the modified soil is reduced by 22.96% for Steel slag and 17.19% for Fly ash, when blended with the unmodified soil.
2. Plasticity index of the modified soil is decreased by 65.76% for Steel slag and 25.67% for Fly ash.
3. Maximum dry density of the modified soil is increased by 9.20% for (40%) Steel slag and it is decreased by 19.62% for (50%) of Fly ash.
4. Optimum moisture content of the modified soil is reduced by 39.24% for Steel slag and it is increased by 35.44% for Fly ash.
5. CBR (Soaked) for the modified Soil is increased by 180% for (40%) Steel slag and 65% for (30%) Fly ash.
6. CBR (Unsoaked) for the modified Soil is increased by 122% for (40%) Steel slag and 45% for (30%) Fly ash.
7. It is observed that addition of Steel slag to clayey soil results in attainment of higher CBR value than the Fly ash.

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