STUDIES ON GEOTECHNICAL PROPERTIES OF BLACK COTTON SOIL STABILIZED WITH FURNACE DUST AND DOLOMITIC LIME

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Abstract - ***The recent development in the use of advanced composites in the improvement of soil is increasing on the basis of specific requirements and national needs. The need of efficient and strengthening techniques of existing soil has resulted in research and development of newer materials for improvement. Particularly for black cotton soil which have high swelling and shrinkage tendencies, demands great deal of attention for stabilization. Various techniques are available for stabilization of black cotton soil. Here as a further steps toward the innovative material to be used for stabilization, this study endeavor to use industrial waste material like Electric Arc Furnace Dust (EAFD) and dolime fine for the soil improvement.***

Steel industry plays an important role in the industrialization and development of a country, as it has the input within all manufacturing sectors. One of the most important problems encountered in steel foundries throughout the world is the management of the dusts produced from the electric arc furnaces. Extremely fine dust is formed in the electric arc furnace by metal vaporization, which is collected in the bag house. In a typical electric arc furnace operation, approximately 2% of the charge is converted to dust. Since metals such as zinc (Zn) and lead (Pb) are highly volatile at the temperature of molten steel, they are concentrated in the furnace dust. Electric arc furnace dust generated during steel production is regarded as a hazardous waste because of the presence of significant amounts of leachable compounds of heavy metals such as Zn and Pb. EAFD is listed as a hazardous waste by the regulations of most of the countries.

Dolomite stone is one type of lime stone and used in Electric Arc Furnace as additive for slag formation having size of 20 to 40 mm aggregate. During the crushing process of dolomite stone fine particle is generated known as dolime fine which is disposal as industrial waste.

In present work attempt has been made to evaluate the effect of waste addition in black cotton soil for improvement of geotechnical property by performing various laboratory test by varying the proportion of industrial waste to find the optimum mixture for use in geotechnical construction work.

Key Words: *soil, stabilization, Electric Arc Furnace Dust, Geotechnical properties*

1. INTRODUCTION

Soil is naturally available material. All the civil engineering structure is always supported on the naturally available soil. All the good land is used by engineer in past and nowadays world facing the problems of scarcity of good land for carryout the construction work. Civil engineers have to use that rejected site for carrying out construction activities. Some time geotechnical engineer have to alter the some engineering properties of soil through a numbers of in - situ ground improvement or replacement techniques, sometime those alternatives are very costly. Recycled material like fly ash, construction debris, plastic, cement kiln dust etc can be used to improve soil condition at site. Use of waste of recycled material in construction work will provide an attractive alternative to tradition engineering construction material such as cement grouting, chemical grouting, cement and natural aggregate and many others.

We are using steel in various industrial activities as well as construction activities. In steel making process specially when steel is recycle from steel scraps using electric arc furnace; at that time large amount of Electric Arc Furnace (EAF) Dust is produce as waste material and that waste material is creating problems for industry, because iron dust is falls under the catagory of hazardous waste and it will require special attention for waste disposal. It will require special site for disposal and then also as time passes it will leach out from that disposal and some time creating problems of soil and water contamination. If it is possible to use that iron dust as soil stabilizing material with other binding material then it can solve many problems. Sametime it will also provide an economic solution geotechnical construction work and problems of waste disposal is also solved.

The electric arc furnaces use dolomite chips of size 20-40 mm as fluxing additive which are obtained by crushing dolomite stones of larger sizes. During the crushing process, fine particles known as Dolime fines are produced which are disposed of as waste material. Dolime fine contain calcium oxides and when it will react with water it will work as cementenious material and bind the soil particle when it is used as additive material for soil stabilization.

2. LITRATUER REVIEW

Pavan kumar (2005) investigated the effect of lime addition on black cotton soil and concluded that addition of 6% of lime to a high expansive BC soil used in the investigation and in the prevailing conditions (temperature and humidity) in laboratory made the soil friable by enhancing the strength, penetration resistance and reducing the swelling and shrinkage behavior. Quick lime can be successfully used for treatment of BC Soil, which can be cost effective compared with other admixtures like cement and asphalt providing long life to the structures built on such soils with least maintenance. For non-plastic and low plasticity index soils in which lime alone is not satisfactory for stabilization, the addition of fly ash may be needed to produce the necessary changes. Rupal Katare et al. (2009) investigated the effectiveness of lime stabilization for expansive soil of Gwalior region and to determine the appropriate lime content. Quantity of lime is varied from 2% to 4% of soil content and corresponding changes in the properties of soil are observed. The value of MDD increases with the increased percentage of lime while OMC decreases and Swelling pressure is lowered by 29% at 4% lime and CBR increases eight folds. There is also reduction in compressibility of soil. S. Bhuvaneshwari, et el. (2005) carried out the some laboratory and field tests to study the geotechnical properties of black cotton soil stabilized with flyash (FA). Chanuhan Rajiv and et al (2009) has studies the strength improvement of soil treated with lime and flyash mix for durability criteria. In case of lime – fly ash and soil mixes maximum dry density decreased and optimum moisture content increase with increase the lime content. With an increase in lime content beyond 4% there is increase in an unconfined compressive of mixture. CBR test was also carried out on soaked sample for curing period of 7 days. In durability test the weight losses were 2 to 4% optimum moisture content and strength loss was also not significant. Sridevi G. et el. attempted to study california bearing ratio of soil and flyash when placed in layers, experiments were conducted by placing flyash and soil in layers. Study has also been made with lime stabilized flyash layer by varying lime content from 0 to 10%. The study reveals that providing lime stabilized flyash layer can improve CBR of black soil. Mirdamadi Alireza, et el. tested EAFD was for the possibility of producing CLSM with large proportion of this waste. The main properties measured in this study include chemical properties of EAFD and EAFD flowable fill geotechnical properties like UCS, CBR and flowability were measured. Alireza Mirdamadi et al (2009) studies the geotechnical properties of EAFD as CLSM. A laboratory test program was conducted to develop a flowable fill material which maximizing waste material utilization and satisfying the workability and performance requirement. The test program was design to investigate fresh and hardened properties of the material. It can be stated that EAFD material which is knows a waste by product can be applied in flowable fill as the economical fine aggregate. The UCS and CBR tests results showed that EAFD flowable gains sufficient adaptable strength for various purposes such as backfill, pavement base and sub-base. The strength mainly depends on water and cement content, lower the water cement content higher the strength. Rachana Malviya and Rubina Chaudhary (2006) investigate about the factors that will directly affect the Solidification / Stabilization (S/S) process. The S/S process is accepted as a well-established disposal technique for hazardous waste. As a result many different types of hazardous wastes are treated with different binders. The S/S products have different property from waste and binders individually. The effectiveness of S/S process is studied by physical, chemical and micro structural methods. Constantino F. Pereira, et al (2000) reported the stabilization of Electric Arc Furnace (EAF) dust containing hazardous metals such as Pb, Cd, Cr or Zn. The treatment involves a waste Solidification / Stabilization (S/S) process, using coal fly ash as the fundamental raw material and main binder. The efficiency of the process has been evaluated mainly through leaching tests on the solidified products and compliance with some imposed leachate limits. Guylaine Laforest, Josee Duchesne (2006) find out about the ionic composition of various waste material as well as cementitious material. Ionic competition in stabilization of major heavy metals from Electric Arc Furnace Dust (EAFD). Guray Salihoglu and Vedat Pinarli (2008) had investigated the effect of waste particle size on stabilization performance of hazardous electric arc furnace dusts (EAFD) from steel foundries through the measurement of the temperature rise during hydration and heavy metals leaching.

3. EXPERIMENTAL WORK

The purpose of the experimental work is to find out the effect of the addition of the EAF dust to black cotton soil (BC soil) on various geotechnical properties like specific gravity, grain size distribution, atterberg limits, unconfined compressive strength, california bearing ratio

(CBR), triaxial shear test etc. also check the suitability of the composite material for utilization in subgrade, sub base and embankment for the highway construction work. Other waste material used in experimental work is dolime fine. Dolime fine is one type of lime and it will work as binder material when it will react with water and stabilized the soil and EAFD.

3.1 Chemical Composition

EAF dust is a brownish material having a very fine particle, the typical chemical compositions of material are given below in Table 1

Table 1 Chemical Composition of EAF Dust used in Experimental Work

Composition	Value (%)
FeO	48.50
SiO_2	8.22
$AL_2 O_3$	2.87
CaO	9.75
MgO	5.84
MnO	0.52
ZnO	1.12

Dolime fine is a white material having fine to medium grain size particle. Chemical composition of material is given in Table 2.

Table 2 Chemical Composition of Dolime Fine

Composition	Value (%)
CaO	51.52
MgO	35.06
SiO_2	1.39
R_2O_3	1.43
L.O.I	9.28

3.2 Chemical Reaction

The use of lime soil mixture as a construction material has been known from ancient times in various parts of the world. Romans used in their roads nearly 2000 years ago. The first attempt to improve soil with lime was perhaps made in 1924 in Misouri, USA, as an experiment on the construction of roadway using hydrated lime. Inspite of initial success no serious attempt was made to extend the technique to large scale construction projects. In Europe significance is not imparted to the idea of stabilization till 1930 until there is a vast increase of motor vehicle traffic. During second world war most of the countries introduced earth stability by cement, tar or lime mainly for airfield constructions. After the war stabilization technique with admixtures extended to all the countries and is in progress.

The reactions which take place when lime is mixed with moist soil are complex; it is recognized that three types of reactions occurs. First, the addition of lime to a soil supplies an excess of multivalent cat ions which tend to replace monovalent cat ions such as sodium and potassium. Magnesium, also a multivalent cat ion, will react in somewhat similar manner. Clay soils with calcium ions on the surface are observed to reduce the plasticity of the soil. Flocculation of clay particles is a mechanism due to which particles aggregate with each other after Base Exchange and tend to agglomerate in to large sized particles; this basic change makes the soil lose its plasticity and makes it behave more like silt. These reactions are chiefly responsible for reduction in shrinkage and swell and improved workability.

Secondly, lime reacts with carbon dioxide from air to from weak cementing agents of calcium and magnesium carbonates depending on type of lime used. This is an undesirable reaction from an overall stand point and steps are usually taken to reduce the reaction as much as possible.

Thirdly, when adequate quantities of dolime and water are added, the pH of the soil quickly increases to above 10.5, which enables the clay particles to break down. Silica and Alumina will be released and they react with calcium from lime (Pozzolanic reaction) to form Calcium - Silicate - Hydrates (CSH) and Calcium Aluminate Hydrates (CAH). These compounds form the matrix that contributes to the strength of lime stabilized soil. Pozzolanic materials, such as fly-ash, are sometimes added to improve the strength.

Expansive clays containing montmorillonite react readily with lime, and soils with sodium montmorillonite cause greatest calcium depletion. The first reaction, discussed above, that of cat ion exchange is rapid and thus, the reduction of plasticity begins to take place immediately; in fact the change can be seen to take place as the soil and lime are mixed together. The third, or cementing reaction, requires many days or months for significant strength gain and this pozzolanic strength gain may continue for many years.

3.3 Mix Designation

For getting a good result all the material should be properly mixed in dry condition and required proportion should be maintain. Construction of pavement layer or embankments layer using EAF dust alone or dolime fine alone is not possible because EAF dust is very fine particle and very less cohesion between particles so it will not bind itself and fulfill the purpose. Addition of such material in cohesive soil will provide a better option of utilization of waste in field.

In the present study, EAF dust and dolime fine mixed with black cotton soil in different proportion. EAF dust proportion varying from 0 % to 30 % in the intervals of 10% for each case. Same way dolime fine proportions varying from 0% to 12 % in the intervals of 3% in each case. To make experimental work easy and avoid the misinterpretation; fix designation was given to each type of mixes. Here designation 30Fe6L mean 30% EAF dust mixed with 70% black cotton soil and 6% dolime fine of total weight is added. Various mixes and their designation are given in Table 3

Table 3 Mix Designations

Designation	Mix
30Fe0L	30 % Fe dust +70% Soil + 0 % Dolime fine
30Fe3L	30 % Fe dust +70% Soil + 3 % Dolime fine
30Fe6L	30 % Fe dust +70% Soil + 6 % Dolime fine
30Fe9L	30 % Fe dust +70% Soil + 9 % Dolime fine
30Fe12L	30 % Fe dust +70% Soil + 12 % Dolime fine
30Fe0L	30 % Fe dust +70% Soil + 0 % Dolime fine
30Fe3L	30 % Fe dust +70% Soil + 3 % Dolime fine

3.4 Index Properties

3.4.1 Determination of Specific Gravity

The specific gravity of the various materials was determined according to IS: 2720 (part-III, section-1) 1980. The specific gravity of EAF dust, black cotton soil and dolime fine were found out to be 3.55, 2.57 and 2.35 respectively.

3.4.2 Determination of Grain Size Distribution

Wet sieve analysis was carried out to determine the actual grain size distribution of black cotton soil as per the IS 2720 (part IV). Black cotton soil was washed through standard set of IS test sieves and percentage by weight retained on each sieves was found out after 24 hours of oven drying. To determine the actual grain size analysis for dolime fine and EAF dust material dry sieve analysis was carried because it is non cohesive material and dry sieve analysis will give correct results. The results of grain size analysis is given in Table 4.

Table 4 Grain Size Analysis for Materials

Sieve Analysis	EAF Dust (%)	Dolime Fine (%)	BC Soil (%)
Gravel	00	6	2
Sand	00	67	14
Silt	100	27	44
Clay			40
Classification	CL	SP	CH

3.4.3 Determination of Atterberg Limits

Liquid limit and plastic limit for various mixture were determined as per IS 2720 (part V) 1985. The samples failed in Compressive Strength test after 28 days curing, were pulverized and used for determination of Atterberg Limits. The results of test were tabulated in table 5 and 6.

TABLE 5 Results Of Atterberg Limits For Various Eaf Dust Content

EAF dust (%)	Atterberg Limits		
	W_l	W_p	PI
0	60.06	19.77	40.3
10	54.35	19.5	34.8
20	56.25	17.86	38.4
30	51.77	25	26.77

Table 6 Results of Atterberg Limits for Various EAF Dust and Dolime Content

Dolime Fine (%)	Atterberg Limits					
	0 % EAF DUST			30 % EAF Dust		
	W_l	W_p	PI	W_l	W_p	PI
0	60.06	19.77	40.3	51.77	25	26.77
3	50.51	22.2	28.3	48.72	19.35	29.4
6	48.31	26.35	21.8	45.3	26.1	19.2
9	45.15	28.95	16.2	41.5	17.86	23.6
12	30.44	34.2	NP	40.27	28.95	11.3

3.5 Determination of Free Swell Index

Free swell index were determined for various mixture as per IS: 2720 (part XL) 1977. The samples failed in Compressive Strength test after 28 days curing, were pulverized and used for determination of Atterberg Limits. The results of test were tabulated below. Here value of free swell index for only EAF DUST is observed negative. Result of test is given in table 7 and 8.

Table 7 Value of Free Sweel Index for Various EAF Dust

Eaf Dust (%)	Free Sweel Index
0	54
10	52
20	50
30	47

Table 8 Value of Free Sweel Index For Various EAF Dust and Dolime Fine Content

Dolime Fine (%)	Free SWEEL INDEX	
	0 % EAF Dust	30 % EAF DUST
0	54	47
3	41	37
6	35	30
9	24	22
12	17	15

3.6 Determination of OMC and MDD

Optimum moisture content and maximum dry density were determined as per IS: 2720 (part VIII) 1983 by modified proctor test method. Nowadays availability of advanced machinery and compaction techniques justified the selection of modified proctor test for determination of OMC and MDD.

Table 9 Values OF OMC AND MDD FOR Different Mixes

Dolime (%)	10 % Fe Dust		20 % Fe Dust		30 % Fe DUST	
	OMC (%)	MDD (gm/cc)	OMC (%)	MDD (gm/cc)	OMC (%)	MDD (gm/cc)
0	18.6	1.785	18	1.805	17	1.83
3	19	1.77	18.37	1.787	17.34	1.81
6	19.4	1.75	18.74	1.77	17.7	1.79
9	19.76	1.73	19.12	1.752	18.04	1.77
12	20.15	1.71	19.5	1.735	18.4	1.76

3.7 Determination of Unconfined Compressive Strength

For determination of compressive strength, the all the materials EAF dust, DOLIME fines and black cotton soil passed from 4.75 mm sieve were mixed together in dry condition in required proportion. Then required amount of water (close to OMC) was added in the sample. This moist soil mass was kept in polythene bag at same moisture content for nearly 24 hours before moulding to give proper consistency to the soil mass for easy moulding. In the present study, sample was prepared using black cotton soil with various proportion of EAF dust (0,10,20 and 30%) and DOLIME fine varying from (0, 3, 6, 9, and 12 %).

Samples were moulded in standard mould of 38 mm diameter and 76mm height specified in IS: 2720 (part X) 1991 with applying static pressure by hand. The fresh samples were cured in airtight polythenec bag in humidity chamber at temperature of 30° and relative humidity of 85%. To find out the effect of curing period on the strength, samples were cured in humidity chamber for period of 1, 7, 14 and 28 days. The Compressive Strength of these cured samples were then determined using a Compression Testing Machine at strain rate of 0.6 mm/min. Data aquivisition processes were carried out using GEOSTAR software.

Table 10 Unconfined Compessive Strength for 0 Day Curing

Dolime %	UCS Strength (N/cm²)			
	0% EAFD	10% EAFD	20% EAFD	30% EAFD
0	44	44	45	46
3	50	50	49	48
6	56	54	53	52
9	63	60	57	54
12	71	66	61	58

Table 11 Unconfined Compressive Strength for 7 Days Curing

Dolime %	UCS Strength (N/cm²)			
	0% EAFD	10% EAFD	20% EAFD	30% EAFD
0	46	47	49	50
3	52	53	54	55
6	60	60	59	57
9	81	73	66	63
12	123	92	74	69

TABLE 12 Unconfined Compressive Strength for 14 Days Curing

Dolime %	UCS STRENGTH (N/cm²)			
	0% EAFD	10% EAFD	20% EAFD	30% EAFD
0	51	54	56	58
3	57	58	59	62
6	69	69	68	66
9	91	86	79	71
12	151	111	90	80

TABLE 13 Unconfined Compressive Strength for 28 Days Curing

Dolime %	UCS Strength (N/Cm2)			
	0% EAFD	10% EAFD	20% EAFD	30% EAFD
0	56	57	58	60
3	60	60	62	64
6	73	73	71	68
9	100	90	83	79
12	164	120	95	87

3.8 Determination of Shear Parameters

For determination of stress and strain value; UU test was carried out on black cotton soil, black cotton soil treated with 12% dolime fines and black cotton soil stabilized with 30% EAF dust and 12% dolime fine. All ingredients were mixed in dry condition with hand; then the mould of size 38 mm diameter and 76 mm height were prepared at OMC applying static load. Samples were cured in humidity chamber for 14 days at temperature of 30° and relative humidity of 85%.

After 14 days curing, test was carried out in triaxial test apparatus. The strain was applied at a rate of 0.6 mm/min. Three different cell pressure 4 N/cm2, 8 N/cm2 and 12 N/cm2 were applied for studies the shear parameter the stress strain curve and to find out inisial modulus of elasticity for all mixture.

3.9 Determination of CBR Value

California bearing ratio tests were conducted for black cotton soil, black cotton soil stabilized with 12% dolime fine and black cotton soil treated with 30% EAF dust and 12% dolime fine as per IS:2720 (part 16)1979. Standard CBR mould having 150 mm diameter and 175 mm height was prepared at moisture content equal to OMC and maximum dry density was achieveD by static compaction.
The prepared samples were cured in humidity chamber at 30° temperature and 85% relative humidity. Samples were soaked in water for 4 days prior to testing and test was carried out for curing period of 7 days, 14 days and 28 days cured samples.

Table 14 CBR Value for Various Curing Period

	Curing Period (DAYS)			
	0	7	14	28
Sample	0Fe0l	30Fe12l	30Fe12l	30Fe12l
CBR Value	2.8	32.7	43.9	60

4. RESULTS AND DISCUSSIONS

EAF dust a by-product of recycled steel formation process contain very fine particle. The safe and economical disposal of EAF dust is of great concern to industries producing EAF dust as it also comes under the category of hazardous waste materials. In the present studies an attempt has been made to studies the variation in geotechnical properties of black cotton soil treated with EAF dust and dolime fines. Here attempt has been made to find out optimum quantity of waste material to satisfy the geotechnical criteria like strength for used in various geotechnical works.

4.1 Index Properties

4.1.1 Specific Gravity

The specific gravity of EAF dust, Black Cotton soil and DOLIME fine used in experimental work is determine as per IS: 2720 (part-III, section1). The specific gravity of EAF dust, Black Cotton soil and Dolime fine were found to be 3.55, 2.57 and 2.35 respectively.
Specific gravity of EAF dust is higher than the black cotton soil because of presence of various heavy chemical compounds. Same way dolime fine have less specific gravity then black cotton soil because of presence of lighter particle.

4.1.2 Grain Size Distribution

Sieve analysis were carried out to determine the grain size distribution of black cotton soil as per the IS 2720 (part IV). Wet sieve analysis was carried out for Black Cotton soil and results show that 84% particle having is of clay and silt size so BC soil can be classif as CH soil. Dry sieve analyses were carried out for EAF dust and Do and it was classified as CL as shown in table 4.4. In case of EAF dust all particle comes under the silt and clay size. For Dolime fines 67% particle is of sand size so it is classify as poorly graded sand (SP).

4.1.3 Atterberg's Limits

Clay minerals are capable of attracting and holding water molecules and ions by electro-chemical forces, clay minerals carry an unbalanced negative charge and are therefore polar. Water molecules being dipolar get attracted to the negatively charged mineral surface electro statically with their positive poles directed towards the surface. The increasing order of addition of EAF dust to expansive clay enhances the content of EAF dust at one hand and reduced the amount of clay mineral at the other. In this way the activity of the mix reduced.
EAF dust particle adhere to the clay particles in the mixes. Decrease in the activity accompanied by the increasing EAF content; decrease the ion concentration near the clay surface. So the unbalanced negative charge will go on reducing in proportion of the increase of EAF dust content in the mix and this ultimately diminishes the affinity for water and liquid limit reduced gradually.
The liquid limit for Black Cotton soil and all mixes were determined as per IS: 2720 (part V) 1985. Effect of EAF dust and dolime fines addition in black cotton soil is given in Fig 5.1 and 5.2

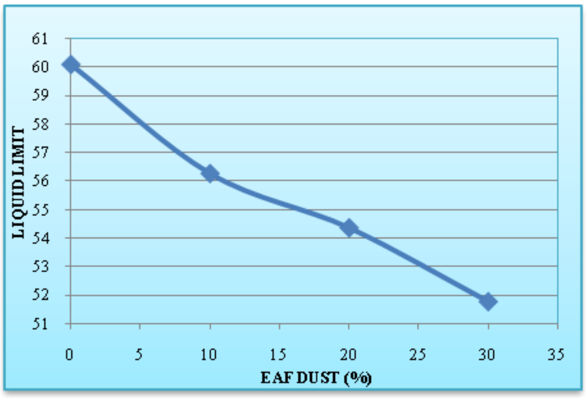

Fig. 1 Variation of liquid limit with EAF dust

From Fig. 5.1 and 5.2 it is clearly observed that as the EAF dust and dolime fines contents increase; the liquid limit of black cotton soil decrease.
Fig 3 and 4 show the effect of EAF dust and Dolime fines on plastic limit of Black Cotton soil. Fig 3shows that initially plastic limit decrease and then after increase as EAF dusts content increase where in case of Dolime fine plastic limit increase with increase in Dolime fine content.

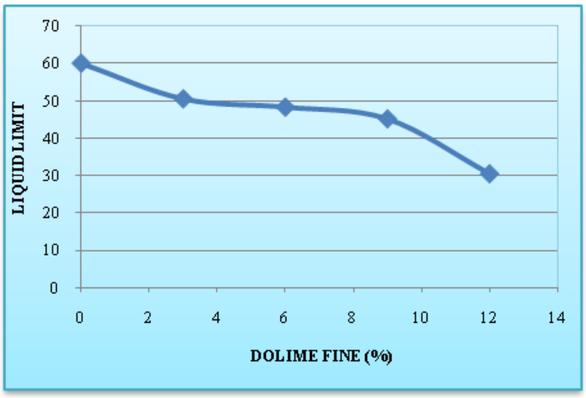

Fig. 2 Variation of liquid limit with dolime fines

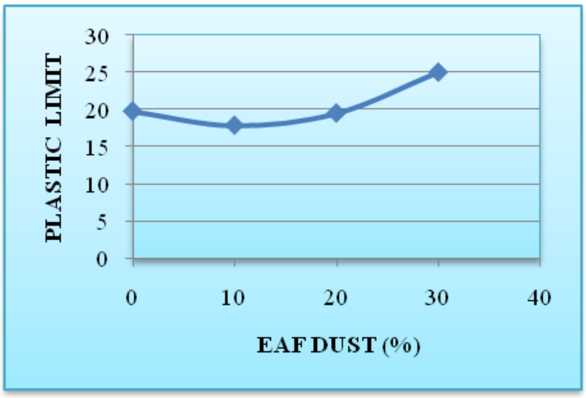

Fig.3 Variation of plastic limit with EAF dust

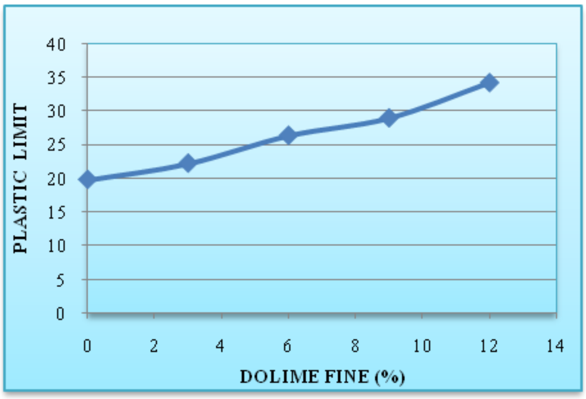

Fig. 4 Variation of plastic limit with dolime fine

From Fig 5 and gives the effect of EAF dust and Dolime fines addition on plasticity index of Black Cotton soil. From Fig 5 it is observed that plasticity index decrease as percentage of EAF dust increase and it may be due to decrease in total soil mass content. From Fig 6 it is clearly observed that as Dolime fine content increase there is raped decrease in plasticity index of Black Cotton soil. For 12% dolime fine content Black Cotton soil become non plastic and behaves like a silty soil.

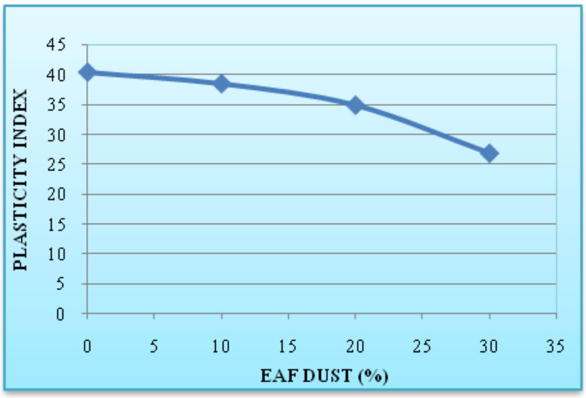

Fig. 5 Variation of plasticity index with EAF dust

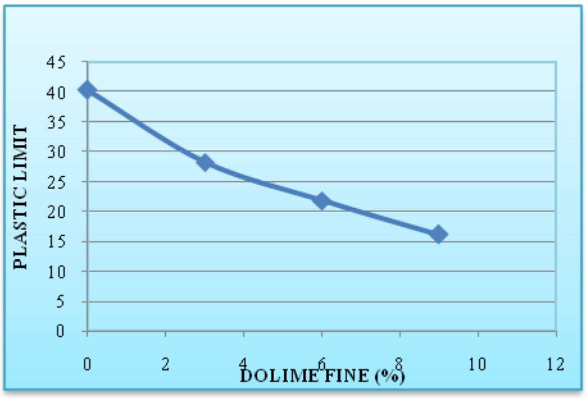

Fig.6 Variation of plasticity index with dolime fines

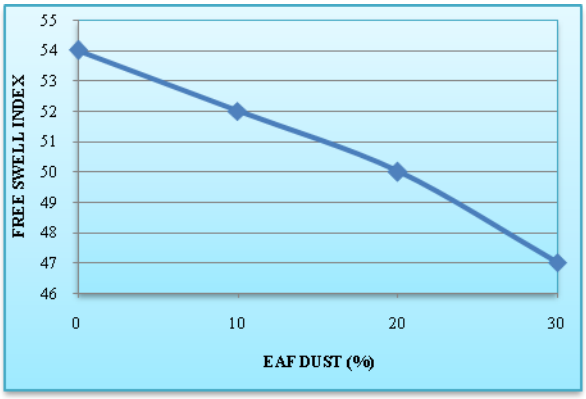

Fig. 7 Variation of Free Swell Index with EAF dust

4.2 Free Swell Index

Fig. 7 and 8 give the effect of EAF dust and Dolime fine addition on Free Sweel Index of black cotton soil. From Fig as percentage of EAF dust and Dolime fine increase Free Swell index decrease.

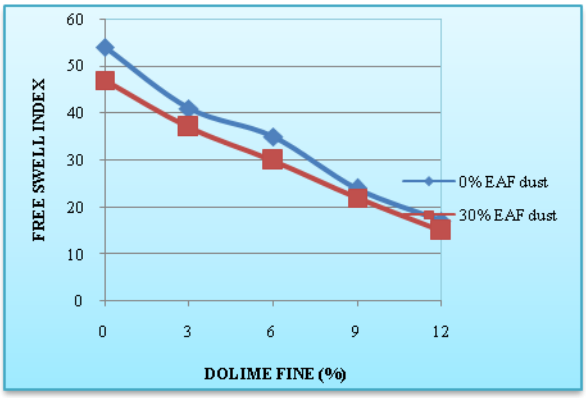

Fig. 8 Variation of Free Swell Index with dolime fine.

4.3 Dry Density – Moisture Content Relationship

A modified proctor test was selected to find out OMC and MDD. Due to availability of new technology and heavy equipment; it is possible to achieve higher value MDD in the field. Modified proctor tests were carried out as per IS: 2720 (part-8) 1983.

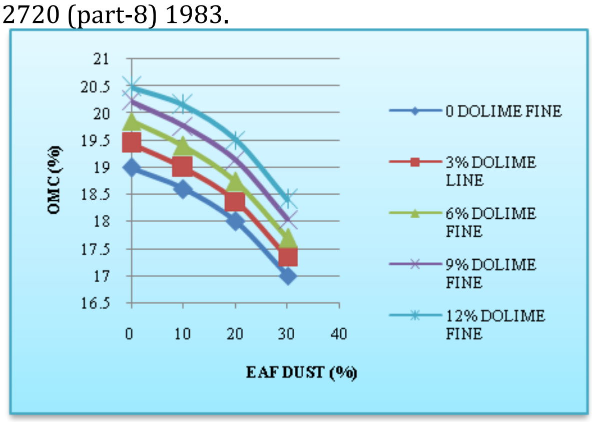

Fig.9 variation of OMC with EAF dust

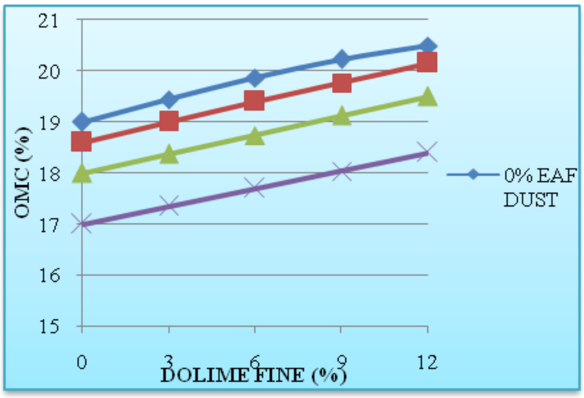

Fig. 10 Variation of OMC with Dolime fines

From Fig 9 and 10 it is observed that as percentage of EAF dust increase OMC value of Black Cotton soil decreases and as dolime fine content increases OMC value of soil increases. It is due to fact that Dolime fine react with clay mineral of soil and able to carry calcium and hydroxyl ions to clay surface which is necessary for binding property of Dolime fine as Dolime fine percentage increase the quantity of water is also increases.

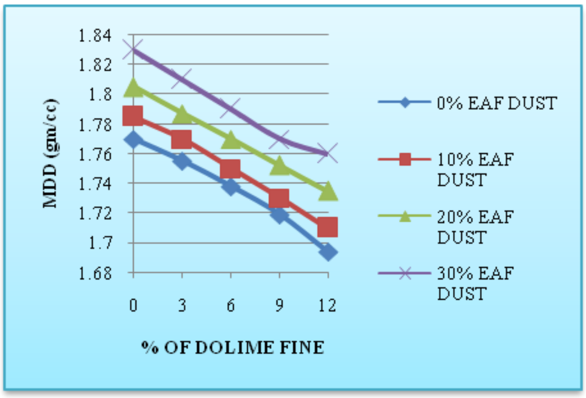

Fig. 11 Variation of MDD with dolime fines

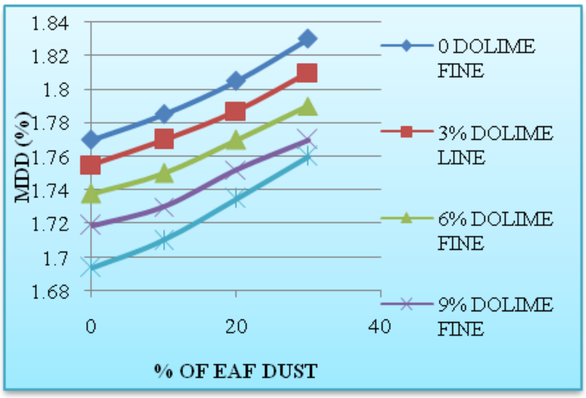

Fig. 12 Variation of MDD with EAF dust

From Fig.11 and 12 it is clearly observed that as percentage of Dolime fine content increase MDD of BC soil decrease and as EAF dust content increase MDD value of Black Cotton soil also increases. This is due to basic fact that the specific gravity of Dolime fine is low as compare to BC soil And same time EAF dust having higher specific gravity then the Black cotton soil.

4.4 Unconfined Compressive Strength Test Results

For determination of compressive strength of various mixes total 240 samples were tested to determine the effect of EAF dust content, Dolime fines content and studies the effect of curing period on all the sample. All samples were cured in humidity chamber at temperature of 30° and relative humidity of 85% for the curing period of 0, 7, 14 and 28 days.

4.4.1 Effect Of Dolime Content On Strength

The effect of Dolime fine and EAF dust content on strength of black cotton soil have been studies by varying the lime content from 0 to 12% at an interval of 3% and

EAf dust content from 0 to 30% at an interval of 10%. From the test results it is clearly observed that unconfined compressive strength of black cotton soil increase continuously with increase in dolime fines content up to 12% as studies in this experimental work.

The main reason of strength improvement is basically when adequate quantities of Dolime fines and water are added in BC soil, the pH of the soil quickly increases to above 10.5, which enables the clay particles to break down. Silica and Alumina will be released and they react with calcium from Dolime (Pozzolanic reaction) to form calcium - silicate - hydrates (CSH) and calcium - aluminate - hydrates (CAH). These compounds form the matrix that contributes to the strength of lime stabilized soil.

When mixture of Dolime fines, EAF dust and black cotton soil were prepared at moisture content equal to OMC, the pozzolanic reaction take place in mix which lead to CSH and CAH gel formation which is responsible for binding the small particle of EAF dust and black cotton soil and that will impart the strength to samples. Cementing reaction requires many days or months for significant strength gain and this pozzolanic strength gain may continue for many years.

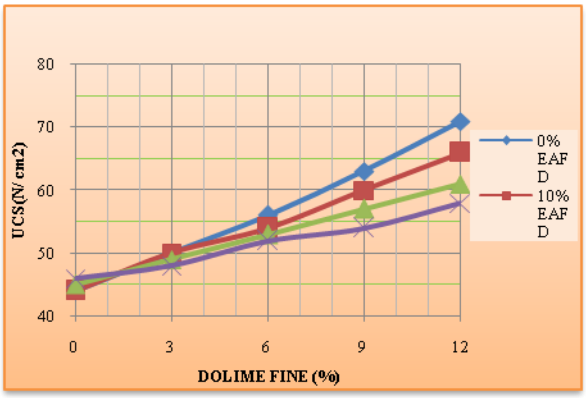

Fig. 13 Variation of UCS strength with dolime fines for 0 days curing period

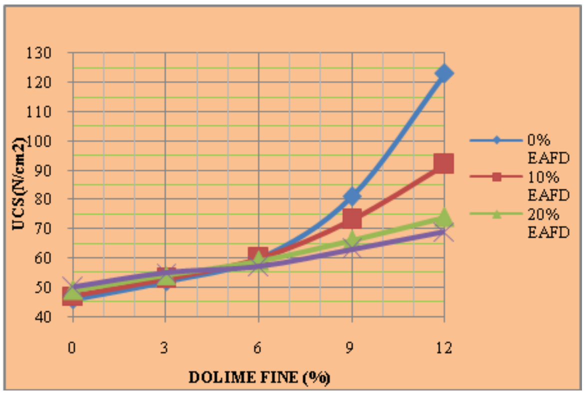

Fig. 14 Variation of UCS strength with dolime fines for 7 days curing period

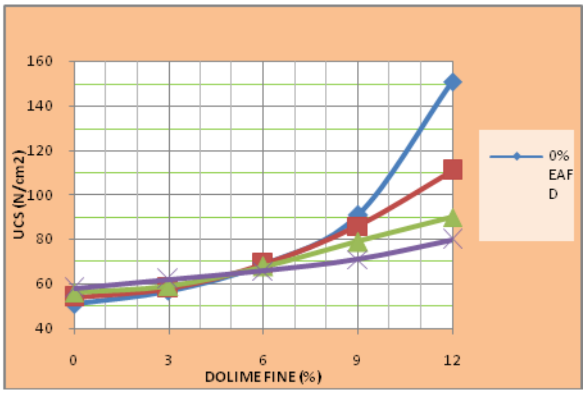

Fig. 15 Variation of UCS strength with dolime fines for 14 days curing period

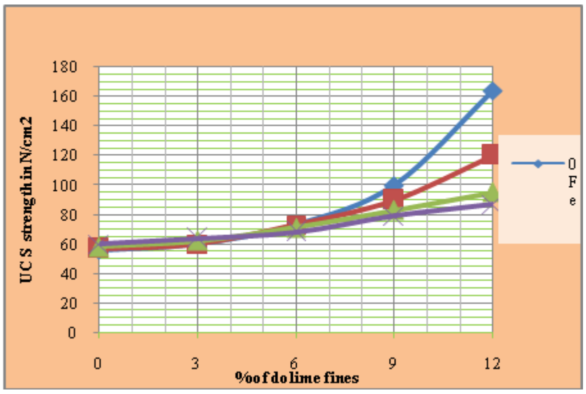

Fig. 16 Variation of UCS strength with dolime fines for 28 days curing period

Fig.13 to 16 shows the variation of UCS with dolime fine content for various percentage of EAF dust. From graph it is clearly observed that at less dolime fine content there is little change in UCS value of Black Cotton soil, as Dolime fine content increase there is noticeable increase in UCS value; because less dolime fine content will to produce enough gel to bind the soil particle as increase the dolime fine content beyond 6%; it will produce sufficient gel and react with soil particle lead to higher UCS value.

4.4.2 Effect Of EAF Dust Content on Strength

The effect of EAF dust content on strength of black cotton soil have been studies by varying the EAF content from 0% to 30% at an interval of 10%. From the Fig.17 to 20, it is clearly observed that unconfined compressive strength of black cotton soil decrease with increase in EAF dust content.

If Fig.17 to 20 carefully than we can able to notice that up to 6% dolime fine there is not considerable reduction in UCS value of Black Cotton soil as EAF dust content increase but at higher lime content (for 9 and 12%) as we increase the EAF dust content there is considerable decrease in UCS value because increase in EAF dust content reduce the total soil content.

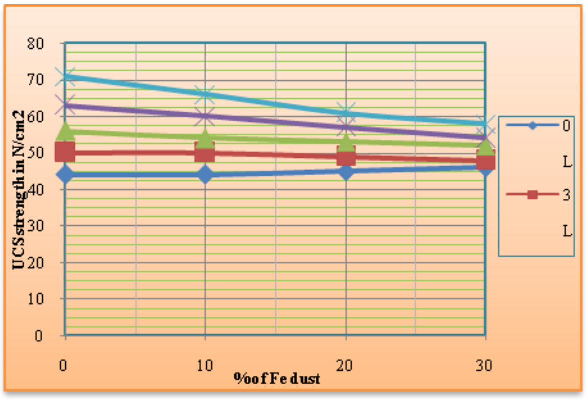

Fig. 17 Variation of UCS strength with EAF dust content for 0 days curing period

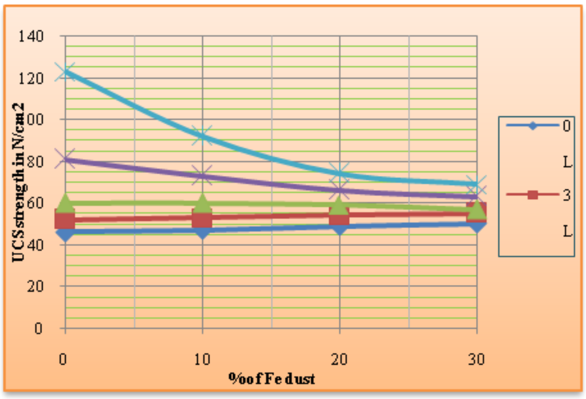

Fig. 18 Variation of UCS strength with EAF dust content for 7 days curing period

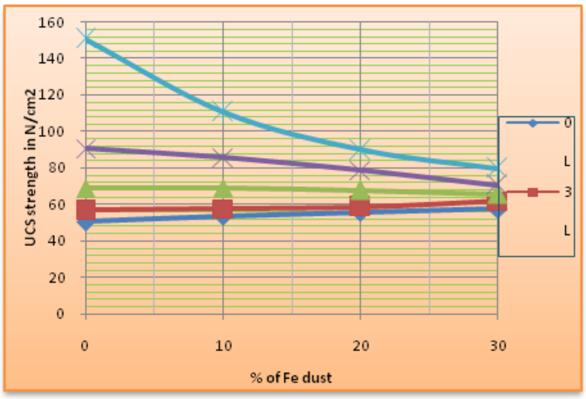

Fig. 19 Variation of UCS strength with EAF dust content for 14 days curing period

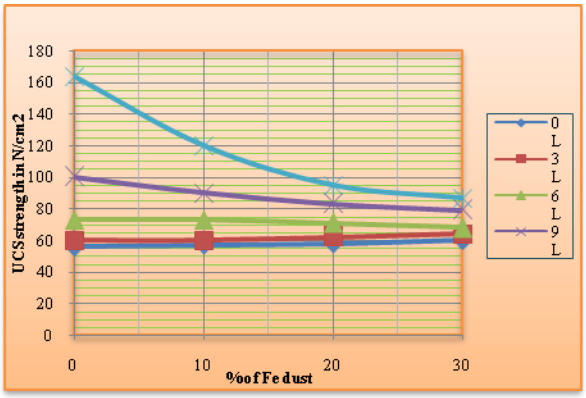

Fig. 20 Variation of UCS strength with EAF dust content for 28 days curing period

4.4.3 Effect Of Curing Period on Strength

The effect of curing period on strength of black cotton soil has been studies in this experimental work. Samples were cured in air tight plastic bags for 0, 7, 14, and 28 days in humidity chamber at temperature of 30° and relative humidity of 85%. From the graph it is observed that as curing period increase the UCS strength for all samples increase because when water is added in mixture cementing reaction take place which requires many days or months for significant strength gain and this pozzolanic strength gain may continue for many years.

From Fig 21 to 24, show the variation of UCS value with EAF dust content for different Dolime fine percentages. It is observed that up to 6% of Dolime fine content increase in UCS value is moderate but for higher percentage of dolime fine content UCS value increase rapidly.

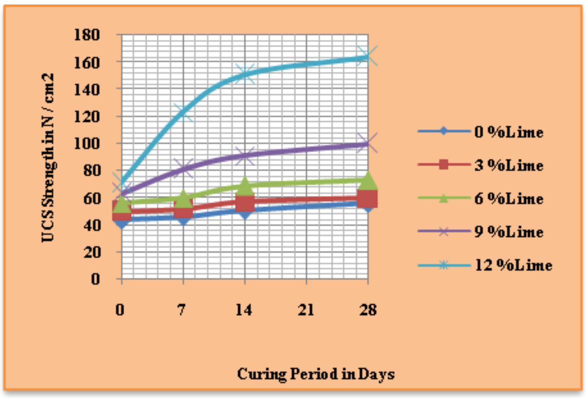

Fig. 21 Variation of UCS strength with curing period for 0% EAF dust

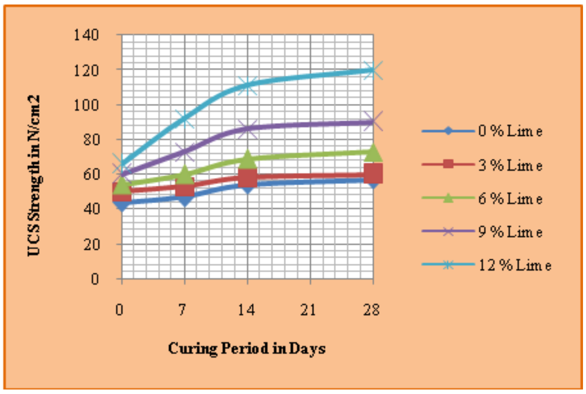

Fig. 22 Variation of UCS strength with curing period for 10% EAF dust

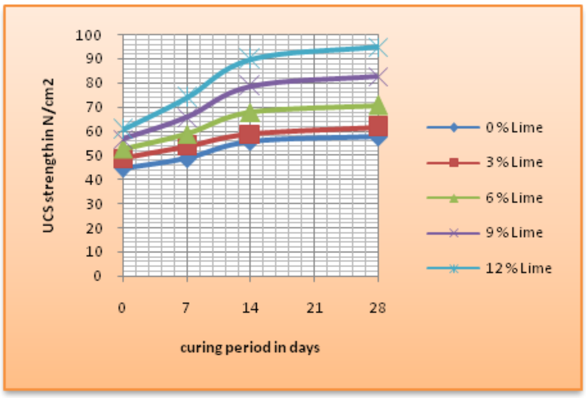

Fig. 23 Variation of UCS strength with curing period for 20% EAF dust

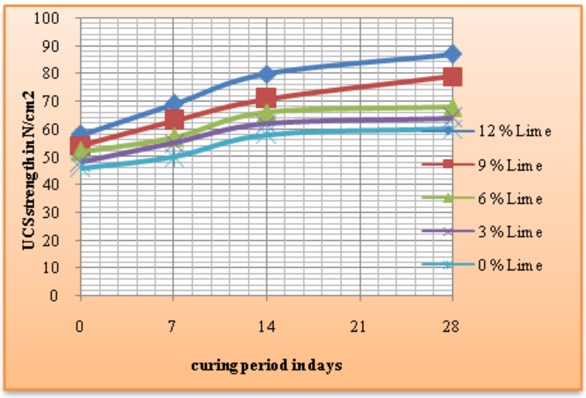

Fig. 24 Variation of UCS strength with curing period for 30% EAF dust

4.5 Unconsolidated Undrained Test Results

Unconsolidated undrained test was carried out to find out the stress - strain relation of Black Cotton soil, soil treated with 12% dolime fines and soil treated with 30% EAF dust and 12% dolime fines. Three different cell pressure 4 N/cm2, 8 N/cm^2 and 12 N/cm^2 was applied for studies the stress strain behavior and to find out the initial modulus of elasticity of samples.

Fig.25 to 27 shows the Stress Strain curve for Black Cotton soil, Black Cotton soil treated with 12% Dolime fine and BC soil TREATED with 30% EAF dust and 12% Dolime. From graph it is observed that as confinement pressure increase strength of sample increase.
Fig. 28 shows the stress strain curve for various samples at constant confinement pressure. From graph it is observed that BC soil treated with only Dolime fine gave the highest stiffness and strength and stiffness of soil treated with 30% EAF dust and 12% Dolime fine also gave higher result that stiffness of Black Cotton soil.

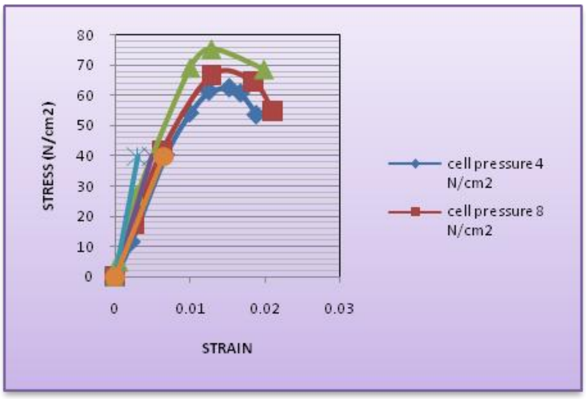

Fig. 25 Stress - Strain curve for Black Cotton soil

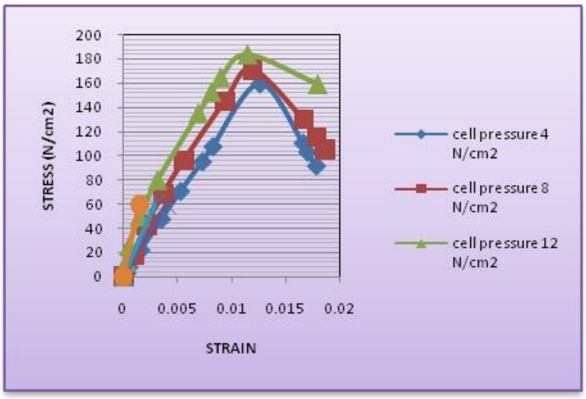

Fig. 26 Stress - Strain curve for black cotton soil with 12% dolime fine

4.6 California Bearing Ratio Test

Test was carried out to find out the effect of addition of EAF dust and dolime fine in black cotton soil. Samples were prepared with 30% EAF dust and 12% dolime fine mixed with black cotton soil in dry condition and moulded at OMC to achieve maximum dry density using static compaction by hand.

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California bearing ratio tests were conducted on standard samples. The prepared samples were soaked in water for 4 days before testing. Soaked CBR values were determined after 7, 14 and 28 days curing period; cured in humidity chamber at temperature at 30° and relative humidity of 85%.

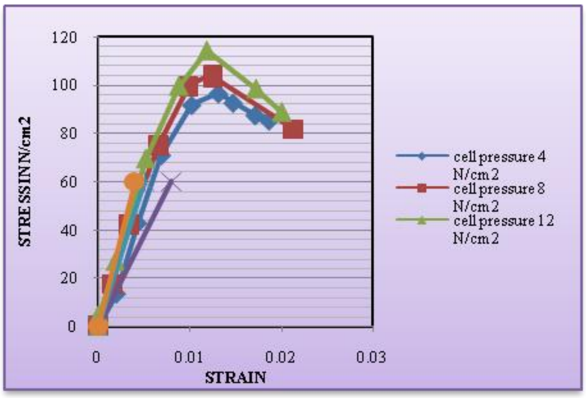

Fig. 27 Stress - Strain curve of black cotton soil with 30% EAF dust and 12% dolime fine

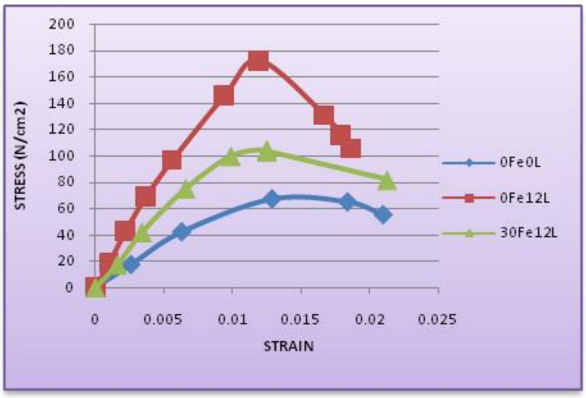

Fig. 28 Comparison of Stress – Strain for carious sample for 8 N/cm2 cell pressure

TABLE 15 Initial Modulus of Elasticity Of Various Samples

Sample	Initial Modulus OF Elasticity (X100000)		
	Cell Pressure		
	4 (N/cm²)	8 (N/cm²)	12 (N/cm²)
0Fe0L	0.6	0.8	1.34
0Fe12L	1.5	2	2.65
30Fe12L	0.75	1.2	1.5

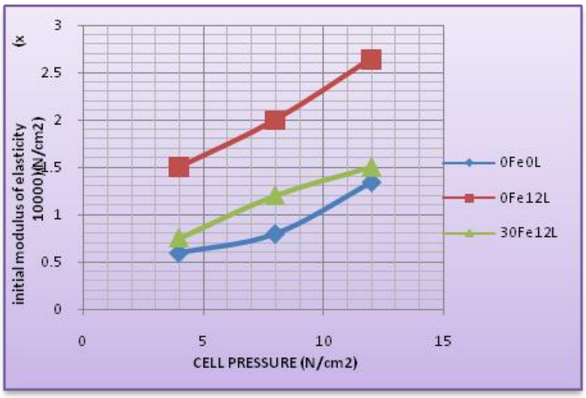

Fig. 29 variation of modulus of elasticity with cell pressure for all samples

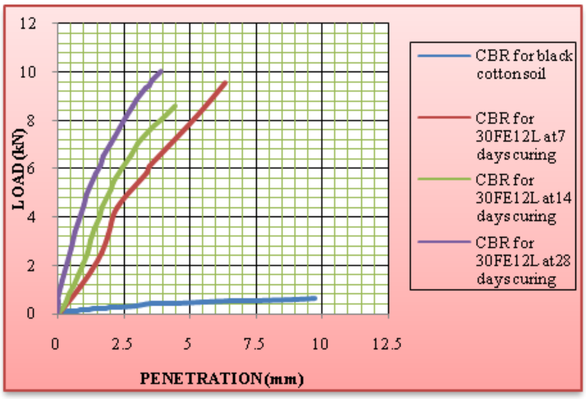

Fig. 30 Load penetration curve for CBR test

4.6.1 Variation Of CBR Value With Curing Period

From Fig.31, it is clearly observed that soaked CBR value of black cotton soil is very low. Soaked CBR value of a sample treated with 30 EAF dust and 12% dolime is very high compare to black cotton soil. As curing period increase CBR value of sample increase up to28 days as studies in current work. CBR values of treated sample increase because both additive material content calcium oxide and that will work as binder material which react with water and formed a calcium gel which bind the soil particle and impart strength to the soil. Here process of gel formation is slow and take time so as curing period increase CBR value of sample increase.

4.6.2 Determination of Total Pavement Thickness From CBR Value

Total thickness of flexible pavement can be determined from various methods. Here we are going to find out the total thickness of pavement from CBR method. This method is based on strength parameter of the material and is, therefore more rational then the other method. The basic assumption in the method is that a layer of pavement is of superior quality then the layer below. Here total thickness of pavement for three traffic condition is determined considering 70 % of lab CBR value as design value as per IRC: 51 – 1992 and given in Fig.32.

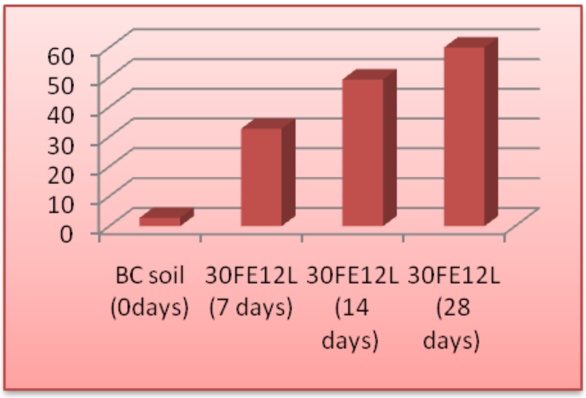

Fig. 31 variation of CBR value with curing period

From Fig. 33, reduction in total pavement thickness comes out 83.33% that is from 690 to 115mm for heavy traffic condition when black cotton soil treated with 30% EAF dust and 12% dolime fine. The higher CBR value leads to lower total pavement thickness of the flexible pavement so this lead to economy in the overall project as the material of construction is reduced.

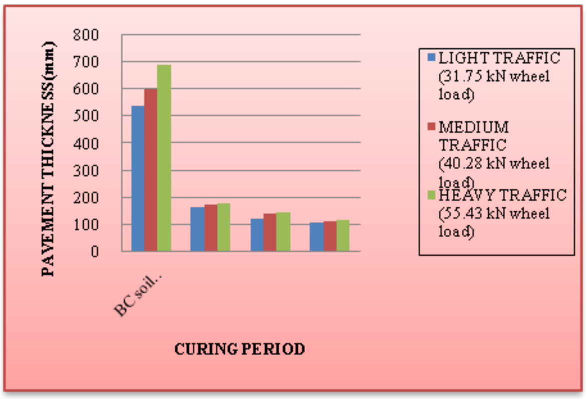

Fig. 32 Total pavement thickness for various traffic conditions

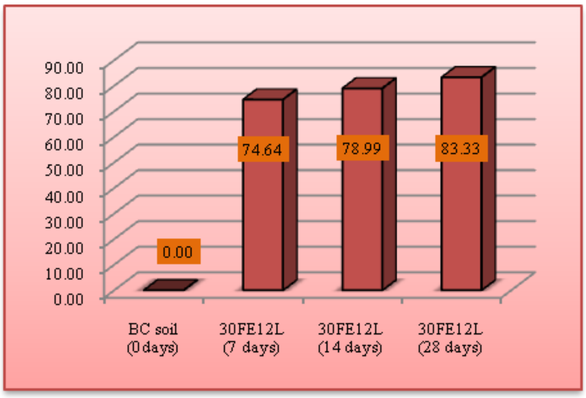

Fig. 33 reduction in total pavement thickness for heavy traffic condition

5. CONCLUSION

The use of recycled material in the stabilization of soil gives better option to disposal of waste material. Use of such materials in highway construction must provide a clear advantage in the terms of improvement of the geotechnical properties of foundation, subgrade, subbase, and embankment materials. EAF dust having a specific gravity (3.55); more than that of conventional earth material and Dolime fine having a specific gravity (2.35) slightly less than that of conventional earth material and conventional earth material having a specific gravity of 2.55. The Liquid Limit of black cotton Soil continuously decreases with increase in lime content and EAF dust content (up to 12% and 30% as investigated in the present study) and 49.32 % and 13.80% of reduction is observed in liquid limit due to addition of 12% and 30% dolime fine and EAF dust addition respectively. Plasticity index of black cotton soil decrease with increase in EAF dust content and dolime fine content. Free swell index of black cotton soil decreases with increase in dolime fine content.68.09% reduction is found due to stabilization of black cotton soil with 30% EAF dust and 12% dolime. Optimum moisture content increases as increase the dolime fine content and maximum dry density decrease with increase in dolime fine content. Optimum moisture content decrease as EAF dust content increase and maximum dry density increase with increase in EAF dust content. The unconfined compressive strength value of black cotton soil increases with increase in dolime fine content. The unconfined compressive strength value of black cotton soil increases with increase in EAF dust content up to 6% dolime fine and then decrease with increase in EAF dust content. The unconfined compressive strength value of black cotton soil increases with increase in curing period. The modulus of elasticity value is highest for sample stabilized with 12% dolime fine and intermediate for black cotton soil stabilized with 30% EAF dust and 12% dolime. Cohesion value (C) decrease as dolime fine and EAF dust percentage increase and angle of internal friction (Ø) increase with increase in EAF dust and dolime fine contents. The soaked CBR value of BC soil is tremendously increase with addition of 30% EAF dust and 12 % lime for 28 days of curing period. Black cotton soil stabilized with 30% EAF dust and 12% dolime fine give good result and 83.33% reduction observed in total thickness of flexible pavement. The higher CBR value leads to lower total pavement thickness of the flexible pavement and this lead to economy in the overall project as the material of construction is reduced. From the present studies it is recommended that EAF dust and dolime fine can be use in sub grade construction work, hence environmental related criteria should be studies as EAF dust comes under the hazardous waste category.

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