A Study on Strength Characteristics of Sea Beach Sand Stabilized with Lime and Fly Ash

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Abstract: ***Construction and strengthening of highways and other roads is on the top of the agenda of the Government for the sustenance of the growing economy. Bitumen being the most commonly used pavement material; its demand is reaching about 5.5 million tons per year. As such the bitumen is becoming scarce and its availability is dependent upon the Indian/foreign oil refineries. The cost of bitumen is also on the rise due to its continuously increasing demand. Construction and strengthening of highways and other roads is on the top of the agenda of the Government for the sustenance of the growing economy. In this context, an investigation was taken up to examine the possibilities of the use of sea beach sand treated with lime and flyash; as a low cost alternative pavement material for the road construction. This paper presents the results of laboratory tests conducted on sea beach sand sampled from West coast beach of Karwar in Karnataka state. It was observed from the results that the lime-flyash treatment improves the strength characteristics of the sea beach sand. The UCS and CBR values of sand-lime-flyash mixture were found to increase with increase in the lime-flyash percentages. This trend was observed to be more pronounced with increased curing period of the mixture.***

Keywords: Beach sand, Karwar, lime, Fly ash, Strength characteristics

1. Introduction

Since the past decade, India has been witnessing a tremendous and rapid growth on the fronts of industrialization and urbanization; and the trend seems to continue in view of the growing Indian economy. The Government is all set to provide a matching infrastructure for the sustenance of this economical growth; and the roads form the basic component of such infrastructure. The pace of highway construction has reached at 20kms. per day and the Government aims to double this to a scorching pace at 40kms. per day. As a result there is a steep and continuous increase in the requirement of quality pavement construction materials having adequate strength and durability.

Bitumen is the most commonly used pavement material with its demand reaching about 5.5 million tones per year. The cost of bitumen is rising due to its ever increasing consumption. Its availability is dependent on the Indian/foreign oil refineries. Under these circumstances searching for the possibility of use of alternative material which is economical and locally available; becomes inevitable and relevant. The alternative material may be treated with suitable additives such as lime or fly ash to improve its performance as pavement material.

Stabilisation of soil and improving or modifying its properties has been a well addressed area of research over the past more than a decade. Additives such as lime, red earth, bitumen have been regarded as time tested stabilizing agents for bringing out the desirable changes in the soil that are useful particularly for the construction of sub-base and base course of the pavement. But however most of such investigations were focused on the stabilization of back cotton and other clayey soils which are considered problematic. Review of literature indicates that no considerable work has been carried out with respect to stabilization of sandy soils except a few researchers. Stabilisation of silt prominent alluvial soils using lime and fly ash was studied by Ghosh et.al.(1973). Raman and Ganesh (1989) studied the strength characteristics of lime stabilised clay-sand mixes. In the recent past, works on the use of sand for road construction have been carried out and investigations have been done on the sand stabilisation using admixtures such as lime, fly ash etc. Kim et.al.(2005) studied the geochemical properties of fly ash and sand mixtures for their use in the highway embankments. Gupta and Javed (2006) studied the seepage and strength characteristics of fly ash sand mixtures. Chauhan et.al.(2008) evaluated the performance of silty sand sub-grade stabilised with fly ash and fiber. Abdeltawab et.al.(2013) studied geoengineering properties of calcareous and quartzite sand from Mediterranean coastal line and quarry areas respectively and concluded that quartzitic sands perform better in CBR evaluation due to its chemical and mechanical stability. Dilipkumar et.al.(2014) investigated the geotechnical properties of fly ash and sand mixtures for their use in highways and embankments. They observed that the additives tend to improve the soil characteristics that are critical in road construction. Rajoor and Maisham (2016) studied the stability and fatigue life of bitumen mixes with partial replacement of dust by beach sand. Huwae et.al.(2017) conducted study on the use of natural sand as fine aggregate for mixed asphalt concrete road construction to reduce cost. In this context, an investigation was taken up to search for the possible use of treated beach sand as a low cost pavement material for the road construction. The study thus aims to utilize favorably such situations where sand is available in abundance, for example for the road construction in the adjoining areas of sea or in the nearby areas along the coastal line. This paper presents the results of tests conducted on sea beach sand mixed with lime and fly ash; with an objective of possibilities of bringing out desirable changes in the strength characteristics of beach sand for its use as pavement material in road construction.

2. Materials and Methods

The details of the soil (beach sand) and the additives viz. lime, fly ash used in this investigation are presented below. The preparation of sand-fly ash-lime mixes and the experimental program conducted on various such mixes under different conditions are discussed in the following sections.

2.1 Soil

The soil used in this work is sea beach sand obtained from Karwar beach, Karwar (Latitude of 14˚49' 6.53" N and Longitude of 74˚8' 29.78" E) on the West coast of Karnataka state, India, which is at about 520 km. North-West of Bengaluru and at about 90 km. from Goa as shown in the Fig.1. The beach area is covered by deposits of varying thickness of clean uniformly graded sand. The sand was tested for salinity and it was found to have moderate salinity on the basis of sulphate, sodium chloride and chlorine contents as given at Table-1.

Table 1: Salinity test results of Karwar beach sand

Sl.No.	Test	Result
1	Sulphate content	4012.105 mg/l
2	Sodium chloride	E_c=0.651 and Tds=0.423
3	Chlorine	98.71 mg/l

The index and engineering properties of the sand are given at Table-2. The sand under study classifies as well graded sand (SW) based on the percentages of sand sub-fractions. Normal sand was used for the experimentation, as the purified sand showed the same properties except the reduction in salt content to the extent of 70-75%.

Table 2: Index and engineering properties of Karwar beach sand

Sl.N	Property	Value
1	Colour	Light yellow
2	Specific gravity	2.58
3	Particle size distribution:	
	Clay size (<0.002mm)	0%
	Silt size (0.002-0.075mm)	3.60%
	Sand size (0.075-4.75mm):	
	Fine sand fraction(0.075-0.425mm)	41.30%
	Medium sand fraction(.425-2mm)	31.60%
	Coarse sand fraction(2-4.75mm)	23.50%
	Gravel size (4.75-80mm)	0%
4	Plasticity characters	Non-plastic
5	Compaction parameters:	
	Optimum Moisture Content (OMC)	16.40%
	Maximum Dry Density(MDD)	1.51 gm/cm^3
6	Angle of internal friction	31˚
7	Cohesion	0.18 t/m^2
8	California Bearing Ration (CBR)	6.20%

2.2 Lime

The lime used in this work is a commercial variety, commonly known as hydrated lime having calcium hydroxide $Ca(OH)_2$ to the extent of about 75-85%. It has a specific gravity of 2.28 and density 0.62 gm/cm^3.

2.3 Fly ash

The fly ash used in the present study is procured from The West Coast Paper Mills, Dandeli, Karwar district, Karnataka which is located at about 100 km. from Karwar. Considering the proximity of source and availability aspects as well, the Dandeli fly ash was preferred and used for the study. The fly ash belongs to class-F category and its chemical composition and physical properties are given at Tables 3 and 4 respectively. Even though the fly ash is non-plastic it exhibits liquid limit value due to the fabric effects.

Table 3: Chemical composition of Dandeli fly ash

Constituents	Percentage (%)
Silica (Si O2)	57
Alumina (Al2 O3)	23
Ferric oxide (Fe2 O3)	8.32
Calcium oxide (CaO)	2.7
Magnesium oxide (MgO)	0.83
Titanium Oxide (Ti O2)	0.23
Loss on ignition	7.92

Table 4: Physical properties of Dandeli Fly ash

Property	Value
Specific gravity	2.07
Grain size distribution:	
Clay size	4.00%
Silt size	85.00%
Fine sand size	11.00%
Atterberg limits:	
Liquid limit	59.00%
Plastic limit	Non-plastic
Shrinkage limit	Varies with initial water content

2.4 Preparation of sand, lime and fly ash mixtures

Lime and fly ash were mixed with sand in various proportions (% by weight) in their fine state and such sand-lime-fly ash mixes were designated as given at Tables 5 and 6. The finely blended mixes were kept for oven drying for 24 hours and the tests were conducted after wet mixing with water in required quantity depending on the respective tests.

Table 5: Designation and composition of 5% lime

Mix designation	Mix composition		
	Soil (%)	Lime (%)	Fly ash (%)
M1	90	5	5
M2	85	5	10
M3	80	5	15
M4	75	5	20
M5	70	5	25
M6	65	5	30
M7	60	5	35
M8	55	5	40

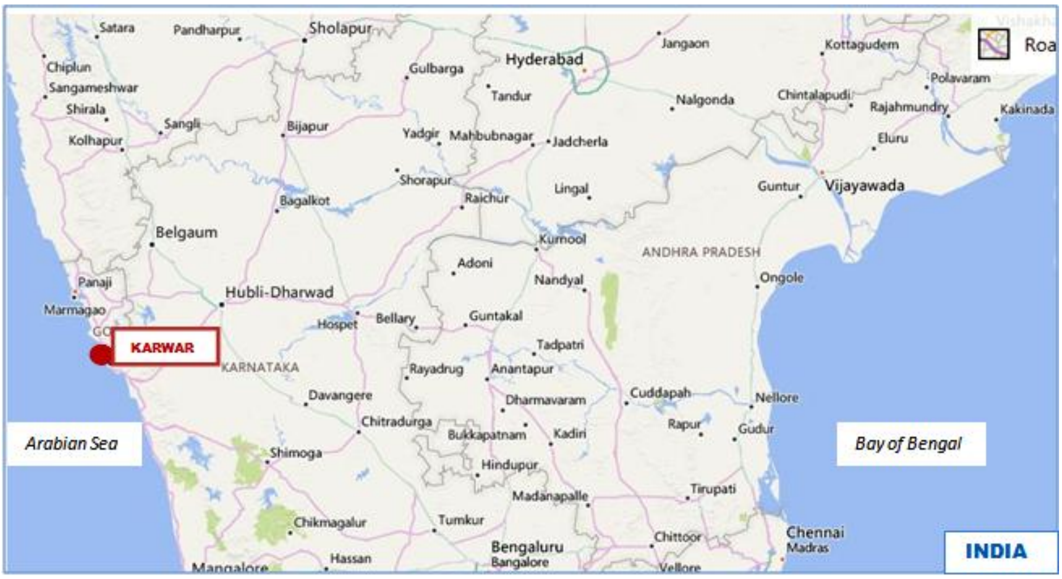

Figure 1: Location map of Karwar beach, Karwar

Table 6: Designation and composition of 10% lime mixes

Mix designation	Mix composition		
	Soil (%)	Lime (%)	Fly ash (%)
MX1	85	10	5
MX2	80	10	10
MX3	75	10	15
MX4	70	10	20
MX5	65	10	25
MX6	60	10	30
MX7	55	10	35
MX8	50	10	40

2.5 Experimental program

Standard Proctor test, unconfined compressive strength test and California bearing ratio tests were conducted on the sand-lime-fly ash mixes to determine the compaction and strength parameters and also to observe the effect of lime and fly ash in varying percentages.

2.5.1 Standard Proctor test

The OMC and MDD of the virgin sand and the designated mixes were determined by conducting standard Proctor test as per IS:2720 Part VII(1980/87). The values of OMC and MDD of the different mixes are given at Table-7 and the plots of the values are given at Fig.2(a) and (b).

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Table 7: Results of standard Proctor test

Mix	MDD (gm/cm^3)	OMC	Mix	MDD (gm/cm^3)	OMC (%)
M1	1.53	16.1	MX1	1.56	16.4
M2	1.55	15.9	MX2	1.59	16.2
M3	1.56	15.5	MX3	1.62	15.8
M4	1.58	15	MX4	1.65	15.6
M5	1.61	14.8	MX5	1.68	15.1
M6	1.65	14.5	MX6	1.68	14.7
M7	1.6	14.5	MX7	1.65	14.7
M8	1.54	14.4	MX8	1.63	14.6
5% Lime mixes			10% Lime mixes		

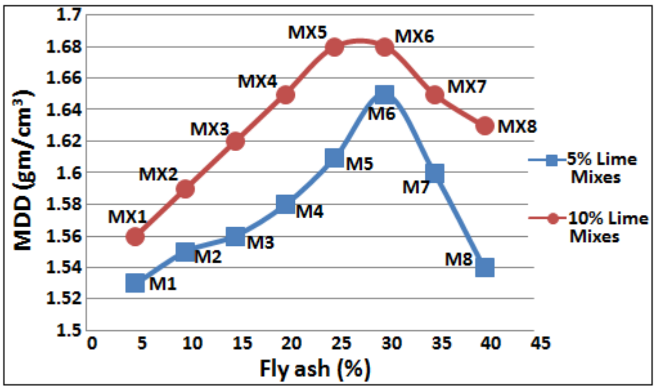

Figure 2(a): Variation of MDD with fly as ash %

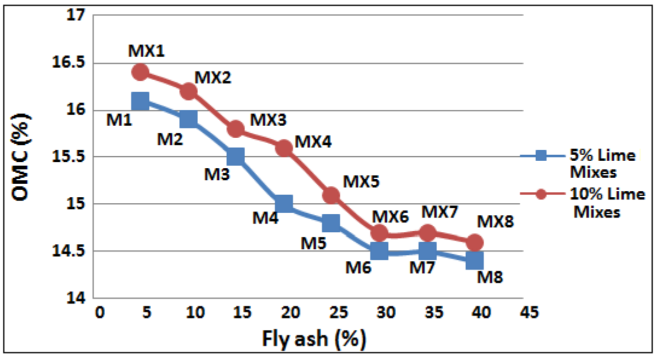

Figure 2(b): Variation of OMC with fly ash %

2.5.2 Unconfined compressive strength test

The unconfined compressive strength of the sand and the mixes was determined by conducting unconfined compressive strength test as per IS:2720 Part X (1991). The material quantities were determined based on the OMC of the mix and the volume of the mould used for preparing the UCS test samples. The sand mixture was then compacted in the cylindrical mould of 3.8cm diameter and 7.5cm height by static loading to get the required density. Preparation of specimen and its removal was to be done carefully at lower percentages of fly ash and lime. With the increased percentages of fly ash and lime along with sufficient curing period, the specimen preparation and its removal could be done with ease; which can be due to the chemical reactions of flocculation which take place during curing. The specimens were kept in polythene bags to preserve moulding water content during curing at room temperature for 7, 14, 21 and 28 days. After the desired curing period, the stabilised specimens were taken for testing.

Table 8: Results of Unconfined strength Test

Mix	UCS (Kg/cm^2) Curing period (days)					Mix	UCS (Kg/cm^2) Curing period (days)				
	0	7	14	21	28		0	7	14	21	28
M1	4.00	4.40	5.20	6.10	6.80	MX1	7.40	7.80	8.50	9.20	10.10
M2	4.40	5.10	5.90	6.90	8.10	MX2	8.20	8.40	9.20	10.10	10.90
M3	4.90	5.40	6.60	7.80	8.90	MX3	8.30	8.75	9.60	10.40	11.50
M4	4.90	5.50	6.70	7.80	9.10	MX4	8.50	9.30	10.10	11.15	12.20
M5	5.00	5.70	7.20	8.30	9.50	MX5	9.40	9.85	10.80	12.20	13.10
M6	5.30	6.20	7.60	8.80	10.10	MX6	10.00	10.30	11.60	12.80	14.20
M7	5.40	6.40	7.80	9.10	10.30	MX7	10.20	10.50	11.90	13.20	14.50
M8	5.40	6.60	7.90	8.75	10.70	MX8	10.30	10.80	12.10	13.40	14.90
	5% Lime mixes						**10% Lime mixes**				

The values of UCS for 5% and 10% lime mixes with curing periods of 7, 14, 21 and 28 days, are presented at Table-8. The test results are plotted as shown in Fig. 3 (a) and (b).

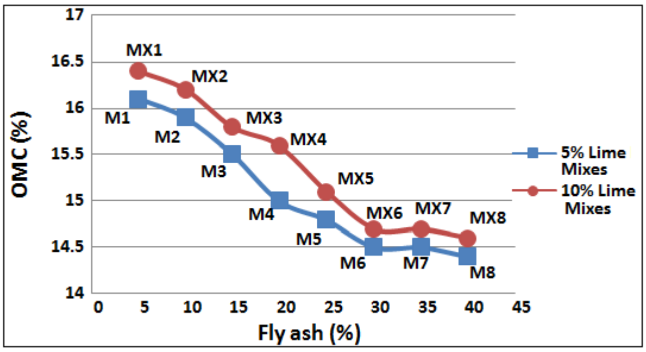

Figure 3(a): Variation of UCS with curing period for 5% lime mixes

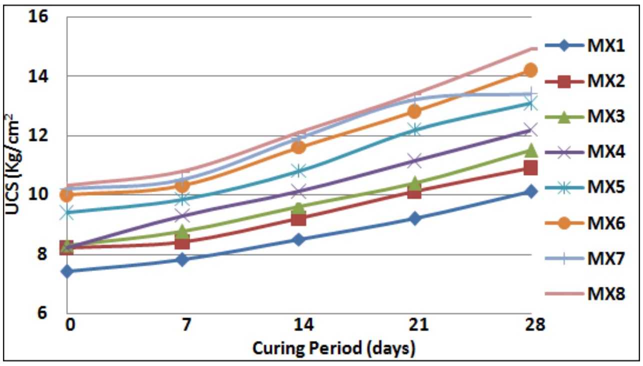

Figure 3(b): Variation of UCS with curing period for 10% lime mixes

2.5.3 California bearing ratio test

The California bearing ratio test was conducted on the sand and the designated mixes as per the specifications of IS:9669 and IS:2720 Part XVI(1980). The unsoaked and soaked CBR values were determined in two stages viz. before and after curing of the mixes for 28 days. The material quantities were determined based on the OMC of the mix and the volume of the CBR mould. The specimens were covered with polythene bag to preserve the moisture content during curing.

The CBR values for varying fly ash percentages under unsoaked and soaked conditions with no curing period are given at Table-9 and the corresponding plots of the values are given at Fig.4(a) and (b). Likewise the CBR values of the mixes after a curing period of 28 days are given at Table-10 and the values are plotted at Fig. 5 (a) and (b).

Table 9: Results of CBR Test with no curing

	CBR (%)			CBR (%)	
Mix	Unsoaked	Soaked	Mix	Unsoaked	Soaked
M1	6.8	5.9	MX1	8.4	7.1
M2	8	7	MX2	9	9.3
M3	11	9	MX3	12	12.9
M4	14	12	MX4	15	14.1
M5	17.6	13	MX5	18.3	16.8
M6	17.5	14.1	MX6	19.1	16.9
M7	17.3	13.8	MX7	18.7	15.7
M8	17.1	13.4	MX8	18.6	14.4
5% Lime mixes			**10% Lime mixes**		

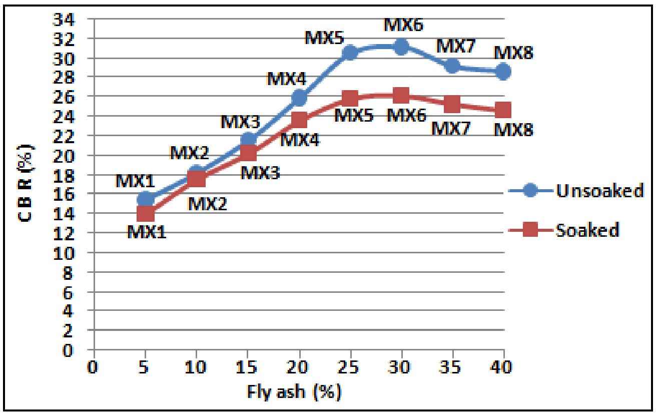

Figure 4 (a): Variation of CBR with fly ash % for 5% lime mixes with no curing

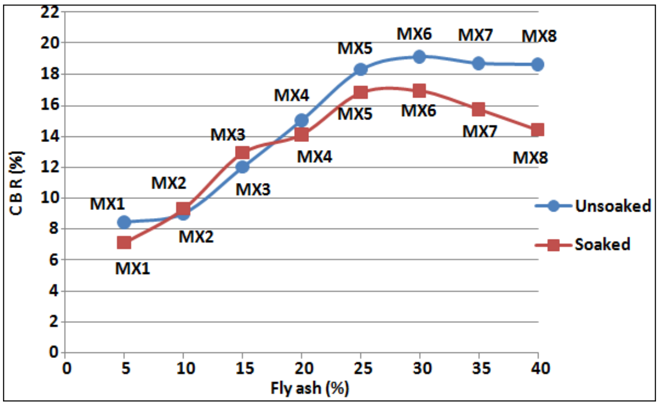

Figure 4(b): Variation of CBR with fly ash % for 10% lime mixes with no curing

Table 10: Results of CBR test with 28 days curing

Mix	CBR (%)		Mix	CBR (%)	
	Unsoaked	Soaked		Unsoaked	Soaked
M1	11.60	9.70	MX1	15.40	13.90
M2	13.10	11.20	MX2	18.10	17.50
M3	17.30	15.60	MX3	21.60	20.20
M4	21.40	19.10	MX4	25.90	23.60
M5	24.20	23.80	MX5	30.50	25.80
M6	26.10	23.80	MX6	31.10	26.10
M7	25.90	22.60	MX7	29.20	25.20
M8	25.30	21.70	MX8	28.60	24.60
5% Lime mixes			10% Lime mixes		

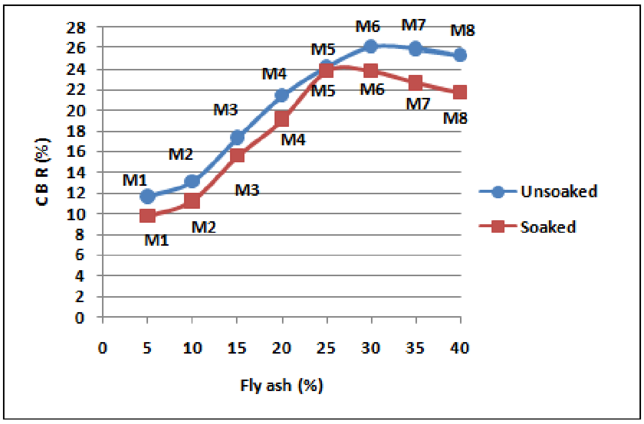

Figure 5(b): Variation of CBR with fly ash % for 10% lime mixes with 28 days curing

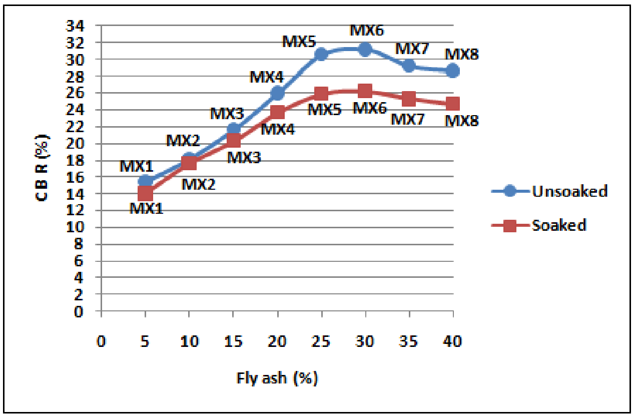

Figure 5(b): Variation of CBR with fly ash % for 10% lime mixes with 28 days curing

3. Test Results and Analysis

3.1 Compaction Parameters (MDD and OMC)

The results of standard Proctor test are presented at Table-7. The plot at Fig.2(a) shows the variation of MDD for 5% and 10% lime mixes. It may be observed that for 5% lime mixes, MDD increases gradually from 1.53 gm/cm^3 for M1 mix to a peak value of 1.65 gm/cm^3 for M3 mix having 30% of fly ash. Similar trend is seen for 10% lime mixes as well, wherein the MDD increases from 1.56 gm/cm^3 for MX1 mix to 1.68 gm/cm^3 for MX5 mix having 25% of fly ash. Further, an observation of the graph at Fig.2(b) indicates the decreasing tendency of OMC with increase in the fly ash %. There is a gradual reduction in OMC from 16.10% for M1 mix to a lowest value of 14.5% for M6 mix, after which increase in the fly ash % shows no conspicuous effect on OMC values. In case of 10% lime mixes, a reduction of OMC from 16.4% for MX1 mix to 14.7% for MX6 mix is observed; beyond which the effect of increase in fly ash% is negligible.

With increase in the fly ash %, the sand-lime mixture becomes relatively well graded thereby yielding higher densities. The effect of flocculation also adds to the density of the mix. Increasing fly ash beyond certain % i.e. 25-30% in the present case; tends to render the gradation of the mix poorer which in turn starts yielding lower densities.

3.2 Unconfined compressive strength (UCS)

It is observed that the curing period has considerable influence on the UCS of sand-lime-fly ash mixes, as can be seen from Fig.3. Increase in the UCS of the mixes with increasing % of lime and fly ash is noted to be common for any curing period. From the Fig.3 it can be seen that, for both 5% and 10% lime mixes the increase in UCS becomes negligible and gradually starts decreasing after certain maximum % of fly ash i.e. 25-30%. The strength gain of the sand-lime-fly ash mixes is mainly derived from the following reactions owing to the lime and free lime (CaO) available from fly ash:

i) Dehydration of san– a short term reaction
ii) Ion exchange and flocculation – a short term reaction
iii) Pozzolonic reactions – a relatively long term reaction

The pozzolonic reactions add significant contribution to the strength, in which the cementitious content (calcium silicates, aluminates) is formed by the reactions of silica and alumina of sand with the calcium made available from the additives viz. lime and fly ash. With increase in the fly ash content beyond 25%, the UCS decreases due to the slow down and ultimately ceasing of the pozzolonic reactions. This subsequently results in excess of unutilized free fly ash content in the mix; resulting in the decrease of strength thereon. As can be seen from the test results given at Table-8, the UCS of both 5% and 10% mixes have shown an increase to the extent of nearly 40% for short curing period of 7 days. With the increased curing period of 28 days, the

UCS is observed to show further improvement and increase in its value by 55-60%.

3.3 California bearing ratio (CBR)

The effect of lime and fly ash on the CBR values of the sand-lime-fly ash mixes before curing and after 28 days curing is shown in Fig.5 and Fig.6 respectively. In general the CBR shows an increase with the fly ash %; for both 5% as well as 10% lime mixes. It is observed that the effect appears to be more pronounced for the mixes that are tested after allowing for curing. In case of 5% lime mixes the unsoaked CBR values increase from 6.8% to 17.6% with the increasing fly ash %. Further addition of fly ash then after tends to exhibit no effect on the CBR value. Addition of fly ash beyond 35% is observed to result in the decrease of CBR value. The percentage of increase in CBR value is observed to improve slightly with increase in the lime %. As mentioned earlier, the curing has considerably favourable effect on the sand-lime-fly ash mixes. The soaked CBR value is critical and normally adopted for design of pavements. After 28 days of curing of 10% lime mixes, the soaked CBR value is observed to increase from 13.9% to a peak value of 26% with the corresponding increase in fly ash from 5% to 30% respectively. Then after the CBR value shows no further increase but a decline with any increase in the fly ash %.

As per the guidelines for the design of flexible pavements prescribed in IRC:37-2012 (Third revision), the soil selected for sub-grade formation should have minimum CBR of 8% for the roads having traffic of 450 commercial vehicles or more for which the indicative VDF (Vehicle Damage Factor) = 3.5. A properly proportioned and stabilized sand-lime-fly ash mix may hence be suitably used for sub-base or base course in the construction of low cost roads.

4. Conclusions

Following conclusions have been drawn based on the test results and analysis presented from this study:

1) Strength characteristics of beach sand improve with lime-fly ash treatment.
2) Maximum dry density of the beach sand increases moderately with the addition of lime and fly ash. Beyond 25% of fly ash in the sand-lime-fly ash mix, it remains constant and decreases thereafter with further increase in the fly ash %. The corresponding optimum moisture content slightly decreases initially with addition of fly ash up to 30% and subsequently shows no considerable change.
3) Unconfined compressive strength and California bearing ratio of sand-lime-fly ash mixes normally increase with lime and fly ash treatment and the period of curing has considerable influence on these parameters. A longer curing period further facilitates in building up the strength with an average increase of unconfined compressive strength value by about 35-40% over a curing period of 28 days. The effect of curing period is more pronounced in case of California bearing ratio value; which showed an average increase of over 80-90% on allowing the mix for curing for 28 days.
4) Beach sand blended and cured with 10% lime and a fly ash % varying between 25-30%, yields optimum results for the strength parameters viz. maximum dry density, unconfined compressive strength and California bearing ratio; studied in the present work. As such a well proportioned sand-lime-fly ash mix can be used for sub-base or base course in road construction as well as fill materials for embankments.

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