The Study of Strength Characteristics of Stabilized and Unstabilized Fly Ash with Special References to Cement and Crumbed Rubber Mixed Fly Ash

Er. Parveen Chahal, Er. Nitin Thakur

Abstract— **Fly ash is a waste by-product extracted by mechanical / electrostatic precipitator, obtained from coal fired power plants. In India most of the thermal power plants are utilizing bituminous or sub-bituminous coal for generation of electricity. Fly ash is the by-product of burning these types of coal. Utilization of low grade coal, having 35% to 55% of ash content results in bulk production of fly ash. It is estimated that in the year 2012 A.D. annual production of fly ash may reach 140 million tons. The quality and quantity of fly ash depends on Coal type and purity, Degree of pulverization of coal,Boiler type and operation, Air / fuel ratio and effectiveness of mixing the same and collection and stockpiling methods.**
In India Only 3% to 5% of the fly ash produced annually is utilized effectively. The unutilized large quantity requires special attention of researchers to identify the ways of bulk utilization of fly ash.
In the present study experiments were carried out to understand the strength characteristics of stabilized and unstabilized fly ash. Ordinary Portland cement and Crumbed Rubber were used as stabilizers. Different percentages of stabilizers were used for different tests. These percentages are – 6%, 8%, 10%, 12% and crumbed rubber was used 5%.

Index Terms— **Crumbed ruber, Stabilized, Unstabilized , Fly ash, Compaction**
Sub area : Construction Technology
Broad Area : Transportation Engineering.

I. INTRODUCTION

"Waste transformation" is the powerful term used in effective solid waste management technique. Under this purview the ultimate goal should be conversion of entire fly ash produced by thermal power plants due to burning of coal into useful engineering material. By doing this the growing concern of solid waste disposal problem can be avoided.

Currently in India only 5% of the fly ash produced annually is used for manufacture of pozzolana cement, bricks, fine aggregate in concrete and construction of fills. By using the fly ash in embankment construction, it could be utilized in bulk. Fly ash is a fine grained, cohesionless material hence highly erodible, which needs improvement in strength.

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Figure: Fly Ash

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- Coal type and purity,
- Degree of pulverization of coal,
- Boiler type and operation,
- Air / fuel ratio and effectiveness of mixing the same and collection and stockpiling methods.

In India Only 3% to 5% of the fly ash produced annually is utilized effectively. The unutilized large quantity requires special attention of researchers to identify the ways of bulk utilization of fly ash.

II. CLASSIFICATION OF FLY ASH

As per ASTM standard specification for mineral admixtures ASTM 1993, there are two classes of fly ash. Class F fly ash is pozzolanic in nature and is produced from burning anthracite or bituminous coal. Class C is a high calcium oxide content fly ash, produced from burning lignitic or sub- bituminous coal. In addition to having pozzolanic behavior, class C fly ash possesses self-hardening property in the presence of moisture.

Stabilization

Stabilization is the process involving treatment of soi1, so as to improve or modify the engineering behavior of soil. Physical, Chemical, mechanical, hydraulic and thermal methods or a combination of these methods can be employed to stabilize the soil. The objectives of soil stabilization are to improve strength and durability, decrease permeability, compressibility and erodibility and to provide volume stability of soil. Soil stabilization can be done to stabilize the soil at surface or shallow depth and deep depth also.

Commonly used additives like cement and crumbed rubber are mixed with soil and compacted in the presence of moisture to produce a strong material.

"Soil-cement" denotes the material, obtained by mixing soil and required quantity of cement to form a uniform mixture. According to Mitchell and Freitag, (1959) there are three categories of soil-cement.
Natural soil-cement in which 5%-14% of cement by volume is mixed and compacted. The moisture content is just sufficient to satisfy hydration requirement of cement.
Plastic soil-cement, in this type 5%-14% of cement by volume is mixed, but the quantity of water added is more to have a wet consistency of the mixture.
Cement - modified soil denotes less than 5% of cement by volume is added and compacted in the presence of moisture which produces a semi-hardened product of soil and cement.
Crumbed rubber and cement is used for stabilization. Presence of crumbed rubber decreases the strength of the sample but increases the ductility whereas cement increases the strength and stability of the sample.
The important factors in utilization of fly ash as engineering materials are its physical property, chemical reactivity and quantity of stabilizer requirement. As per recommendations of Portland Cement Association, fly ash is a suitable material for cement stabilization. The surface area of fly ash (4000-7000 cm2/gm) and cement 3000 cm2/gm enables more fly ash particles to stick on the surface of cement plates. The strength of cement stabilized fly ash is derived mainly from formation of cementitious bonds.

III. EXPERIMENTAL PROGRAM

The details of theexperimental work carried out to meet the objective of the study are presented in this chapter. Unconfined compression tests were performed to understand the strength behaviour of unsterilized and stabilized fly ash. The present study covers the influence of various parameters on strength of fly ash such as:-

- Density and moulding water content,
- Method of curing and testing,
- Types of stabilizers and their combinations
- Curing period.

The details of the parameters and their combinations are presented in Table 7.
The experimental program includes the sequence of preparation of samples, curing the samples, conducting unconfined compression tests in accordance with the method of testing, and determination of post-test moisture content of the samples. Daily record of environmental favors such as maximum and minimum temperature, humidity and rainfall was maintained throughout the period of curing under natural environment.

Materials Used

The details about fly ash and the stabilizers used are described in the following sections-

Fly Ash

The fly ash had been collected from an electrolytic precipitator of Dadri thermal power plant. It is grey in color and consists of predominantly silty material. This fly ash is anthracitic class F fly ash and has low lime content. The grain size distribution, chemical composition and geotechnical properties of Dadri fly ash are given in Tables 7, 8 and 9 respectively.

Stabilizers

The stabilizers used In the study are ordinary portland cement and crumbed rubber. The sources of the stabilizers are given In Table 10.

Testing program

Unconfined compression tests were conducted on statically compared fly ash samples in stabilized and unstabilized form. The parameters included in the study are presented in Table 8. Daily records of the temperature humidity and rainfall are maintained for the entire curing period.

IV. Unconfined Compression Tests

Sample preparation

The required quantities of fly ash and stabilizers, corresponding to dry unit weight requirement were calculated. An additional 2 grams of mixture was taken to compensate for losses during the preparation of samples. The total stabilizer content was kept constant as 4 percent of dry weight of fly ash. The fly ash and stabilizers were mixed together in a clean bowl in dry state, so as to have a uniform distribution of constituents in the mixture. Distilled water was added to the dry mixture as per the requirement of moulding water content and mixed well to form a homogeneous mixture.
The mixture was compacted in a cylindrical mould of 37.7 mm diameter and 73.5 mm long. Static compaction technique was adopted and compaction was done thrice alternatively from both ends of the mould to achieve uniform compaction. The sample was trimmed at both ends if required and extruded from the mould by using a hydraulic jack extruder.
The weight of the sample was measured in an electronic balance.

Methods of curing

Two methods of curing namely, laboratory curing and natural environment curing were adopted.

Laboratory curing

After preparation of the sample, it was kept in polythene bag and closed with a rubber band. Proper identification marks were made on the polythene bag using a permanent marker. The polythene bag was kept in a desiccator with water at the bottom and closed tightly with a lid. The desiccator was kept inside the temperature controlled room of the laboratory.

Testing procedure

Unconfined compression test were conducted on stabilized and unsterilized fly ash samples using strain controlled triaxial testing machine.
The deformation rate for laboratory cured and unsterilized fly ash was 0.4064 mm/min. In order to study the effect of immersion in water on strength, the laboratory cured samples were tested with and without immersion in water before the test.

V. Laboratory cured samples:

After the required period of curing, the samples were removed from the polythene bags and weighed. They were tested in a strain controlled triaxial testing machine at a deformation rate of 0.4064 mm/min. The entire sample after the test was kept inside an oven for determination of water content.To study the effect of immersion in water before testing, in a separate study, laboratory cured samples were immersed in water for 6-8 hours before testing. The weight of samples was taken before immersion in water. The water on the surface of the samples was wiped gently using a filter paper. The samples were then weighed and tested in a triaxial testing machine at a deformation rate of 0.4064 mm/min. The post test moisture content was determined.

Most samples were more or less dry when they were removed from open terrace after the curing period and in that state would have very high strength. In order to simulate the least favourable water content during testing, the samples were immersed in water for 6-8 hours before testing.

The weight of the samples was taken before immersion in water. The water on the surface of the samples was wiped gently using a filter paper.

They were trimmed from both ends to have plane surface and the final length of the samples was measured. The diameter of the samples was unaffected by the impact of rainfall. The samples were weighed including the trimmed mixture to determine the loss of material due to erosion. Then the sample was tested in a triaxial testing machine with reduced deformation rate based on final length of the sample. The moisture content of the sample was determined after the test.

After preparing the unstabilized samples of required density and moulding water content, they were weighed. The samples were tested in a triaxial testing machine, with the same deformation rate of 0.4064 mm/min.Post test water content determination of the samples was done as usual.

VI. Readings of Samples

4.1.1 After 7 days

	7 days sample		F.A+C+CR			Load in kg		
DDGR	C 12%	C 12% R 5%	C 10%	C 10% R 5%	C 8%	C 8% R 5%	C 6%	C 6% R 5%
0	0	0	0	0	0	0	0	0
10	11	6	5	1	10	7	9	4
20	25	12	14	4	22	14	15	6
30	42	21	25	8	43	26	28	9
40	63	31	43	13	69	40	48	16
50	91	40	66	19	101	54	66	26
60	127	49	94	26	136	63	84	35
70	163	66	123	33	177	79	98	45
80	208	85	152	40	205	88	109	52
90	250	103	171	48	232	94	121	58
100	282	122	195	61	251	96	129	62
110	315	137	221	74	266	98	134	64
120	342	150	254	89	275	99	139	66
130	371	160	244	103	214	99	108	68
140	394	164	193	113	197	98	97	69
150	408	159	128	125		95	89	69
160	95	155	90	137		90	87	68
170		152	58	147		83		64
180		146	41	154		74		55
190		132		159		68		38
200		73		158				
210		32		157				
220		26		153				
230				131				
240				109				
250				100				

Table: Readings after 7 days

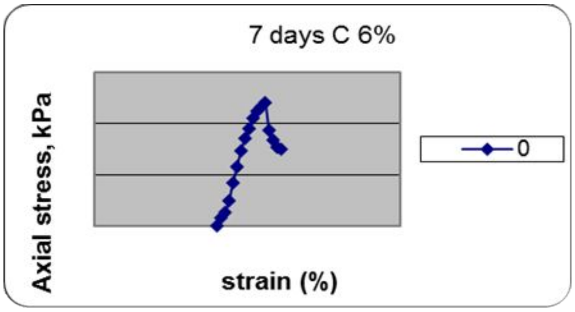
After 14 days

14 days	Proving ring							
	C 12%	C 12% R 5%	C 10%	C 10% R 5%	C 8%	C 8% R 5%	C 6%	C 6% R 5%
0	0	0.2	0	0	0	0	0	0
10	0.2	0.2	0.4	0.8	1.2	0.4	0.8	1
20	0.8	0.4	1	1	3	1	1.6	3.4
30	1.2	0.6	1.2	1.8	6	1.2	3.8	4.8
40	1.8	1	2.2	3.2	9.4	1.8	7	6.2
50	2.8	1.6	3.6	4.4	14.6	3.2	11	7.6
60	3.8	2	5.2	6.6	194	5.2	15.8	9
70	5	2.2	7.8	9.8	25	7.4	21.4	10.4
80	6	2.6	11	12.4	30.6	10.2	27.8	12
90	7	3.2	14.4	16.2	37	13.6	34	13.6
100	8.2	4	18	20.2	42.2	17.2	40.8	15.4
110	9.2	4.8	22.4	25	49	21.4	47	17.2
120	9.2	5.6	26.2	30.2	55.6	24.8	54.4	18
130	7.6	6.4	30	35.2	62.4	28.8	69.4	19.6
140		7.2	34	40.4	69.4	33.6	68.4	20.6
150		7.6	37.4	46.6	77	38.2	74.8	24.6
160		8	42.6	53.4	85	44.6	81	26.6
170		8.2	48.2	60.2	92	50	87	28.8
180		8.2	54	67.8	100.2	57	92	30.8
190		7	60.2	75.4	108	64	95.4	33
200			67	83.2	115	71		35
210			75	90.4	122	78		37.4
220			92.8	98.2	139	91		39.2
230			91	105.6	156	94		41.2
240			98.4	113	162	100		43
250			106.6	119.4	169.6	106.4		44.4
260			114.4	126.6	174	113		45.2
270			122	133.4	174.2	119		44.8
280			130	140	170.2	125		42.6
290			137.6	147		131		40
300			145.6	153.2		137		
310			153.6	159		140.6		
320			161	161		141.2		
330			168.6	140		130		
340			177.4					
350			185					
360			193.2					
370			200					
380			206					
390			210.4					
400			213.2					
410			208					

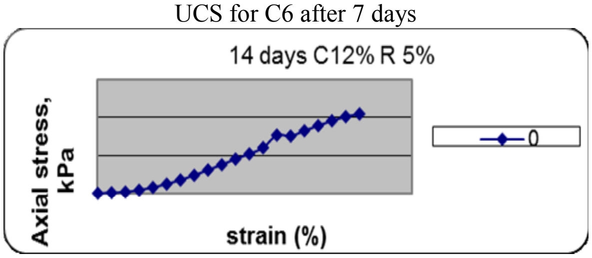
After 28 days

28 days								
	C 12%	C 12% R 5	C 10%	C 10% R 5%	C 8%	C 8% R 5%	C 6%	C 6% R 5%
0	0		0	0	0	0	0	0
10	7		4	6	3	8	6	4
20	14		16	12	15	12	14	7
30	22		27	19	31	24	20	10
40	35		44	31	50	39	30	16
50	50		69	56	80	59	39	24
60	67		104	88	119	86	53	34
70	87		141	130	154	105	66	47
80	112		180	168	195	120	78	59
90	148		224	207	234	130	86	70
100	199		262	239	272	137	89	78
110	256		302	268	303	142	97	85
120	321		338	285	320	143	110	89
130	397		368	293	323	142	126	93
140	473		371	266	175	138	138	94
150	546		278			115	133	94
160	614							93
170	673							87
180	705							80

Readings after 28 days



UCS for C6 after 7 days



UCS for C6 after 14 days

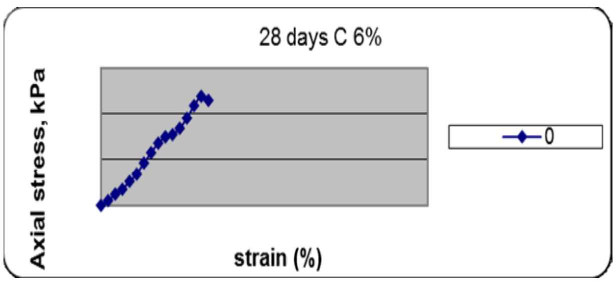


Chart 1: UCS for C6 after 28 days

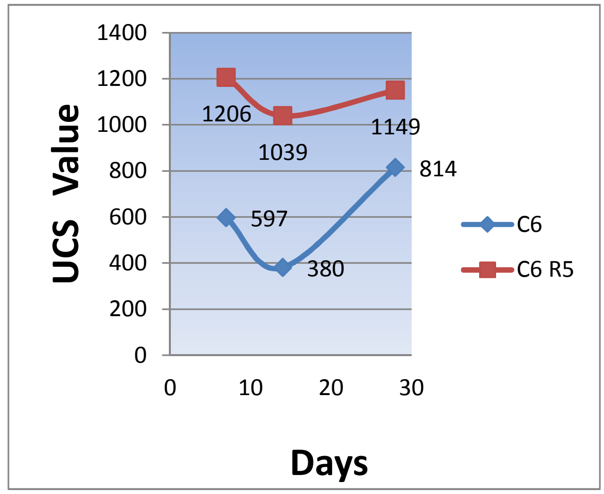
Consolidated Results

UCS Graphs

After 7 Days

Consolidated results UCS		
	7 days	7 days
	Failure strain (ε)	UCS
C 6	1.6	1206
C 6 R5	1.84	597
C 8	1.6	2386
C 8 R5	1.6	859
C 10	1.6	2203
C 10 R5	2.5	1366
C 12	2	3525
C 12 R5	1.84	1418
C 6	Days	UCS
	7	1206
	14	1039
	28	1149
C 6 R5	Days	UCS
	7	597
	14	380
	28	814

Table 1: Consolidated Results after 7 days



Consolidated Results after 7, 14, and 28 days for C6 and C6 R5.

After 14 Days

Consolidated results UCS			
	14 days	14 days	
	Failure strain (ε)	UCS	
C 6	2.5	1039	
C 6 R5	2.63	380	
C 8	2.63	1251	
C 8 R5	2.63	773	
C 10	2.63	729	
C 10 R5	2.63	820	
C 12	1.45	2453	
C 12 R5	2.37	2166	
	C 8	Days	UCS
		7	2386
		14	1251
		28	2798
	C8 R5	Days	UCS
		7	859
		14	773
		28	1240

Table 2: Consolidated Results after 14 days

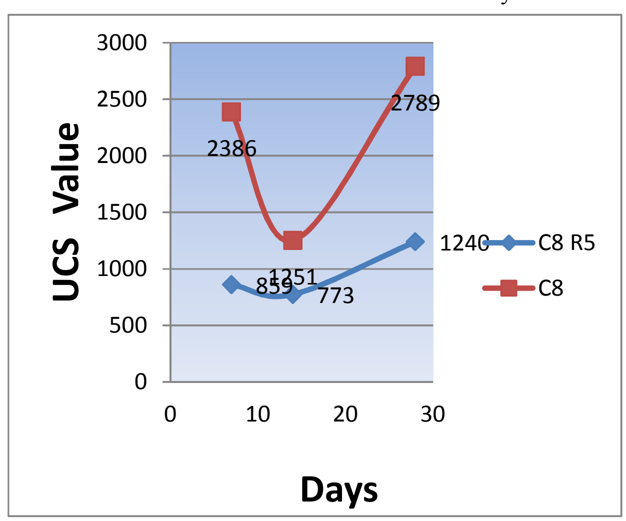


Chart 2: Consolidated Results after 7, 14, and 28 days for C8 and C8 R5.

Test results

The unconfined compressive strength (UCS) for a particular combination of variables was calculated as the average of the UCS of three samples tested for that combination of variables.

However, if the UCS of a sample was not within ± 10% of the average value, then it was discarded and the average UCS was recomputed with the remaining values. The results are presented in the following sequence.

- The effect of density and moulding water content on the UCS of unstabilized fly ash is shown in Table – 14,16,18,20,22,24,26,28,30,32,34,36.
- The influence of density and moulding water content on the UCS of laboratory cured, cement and crumbed rubber stabilized fly ash is shown in Chart 4,6,8,10,12,14,16,18,20,22,24,26.
- The effect of the method of curing on the UCS of cement stabilized fly ash is shown in Table – 15,17,19,21,23,25,27,29,31,33,35,37.
- The variation of UCS with time as affected by lime and cement for the laboratory cured fly ash samples is shown in Table 10,11,12,13.
- The influence of the other combination of stablizers on the UCS of laboratory cured samples is shown in Table 38,39,40.

DISCUSSION OF RESULTS

Effect of density and moisture content on the UCS of unstabilized fly ash

Table shows that at the MDD state the variation in water content causes only a small change in UCS. For 3% variation in OMC on the dry and wet side of OMC the UCS changes by +4.5% and -1.7% reflexively.However, the effect of change in density is more significant. At OMC if the density is decreased from MDD to 95% MDD, the Up decreases by 16.4%. The combination of increase in water content and decrease in density causes the maximum reduction in UCS.

Effect of density and moisture content on the UCS of stabilized fly ash

As in the case Of unsterilized Samples, in cement stabilization also, the higher density samples have a higher strength than the lower density samples at all stages of curing. However, the effect of water content is not significant. UCS of samples having 95% MDD but differing in water content by6% tend to be nearly the Same after 120 days of curing.

The higher UCS of sample at MDD state is due to the combination of factors like the availability of more fly ash particles for pozzolanic reaction with stabilizer, more quantity of stabilizer and the formation of dense structure with less void spaces.

Effect of method of testing on the UCS of laboratory cured stabilized fly ash

The UCS of stabilized samples tested without immersion is generally more than the Up of similar samples tested after 6 hours of Immersion in water. In the case of cement stabilization, immersion causes significant reduction in strength beyond one week curing period.

The moulding water content has greater influence on the UCS if the samples are immersed in water before testing. The reduction in the UCS of 56 days cured samples compacted at (95% MDD, OMC +3%) is 21.5%. But for samples compacted at (95% MDD, OMC -3%) the UCS is more or less same for immersed and un-immersed samples.

The moulding water content plays significant role on the UCS. For samples compacted at 95% MDD the UCS of the naturally cured samples is less than that of the laboratory cured samples prepared with moulding water content 3% more than OMC, the UCS of naturally cured samples is more than laboratory cured samples.

Till about 56 days of curing, the UCS of cement stabilized fly ash is more than that of lime stabilized fly ash (Table 10,11,12,13). This trend is same for different combinations of density and moulding water content.

However, the gain in UCS of lime stabilized samples increases rapidly after 56 days and at the end of 120 days the UCS of the cement and crumbed rubber stabilized samples are nearly equal. The reaction product is same (C-S-H jels) for both the stabilizers and probably the amount of reaction product due to the two stabilizers are nearly same after long period of curing.

Effect of curing period

. The UCS of all stabilized fly ash increased with curing time irrespective of factors like variation in density and moulding water content, method of curing and testing adopted and type of stabilizers. They however, affected the time rate of increases in UCS and the maximum UCS that might be attained after long period of curing.

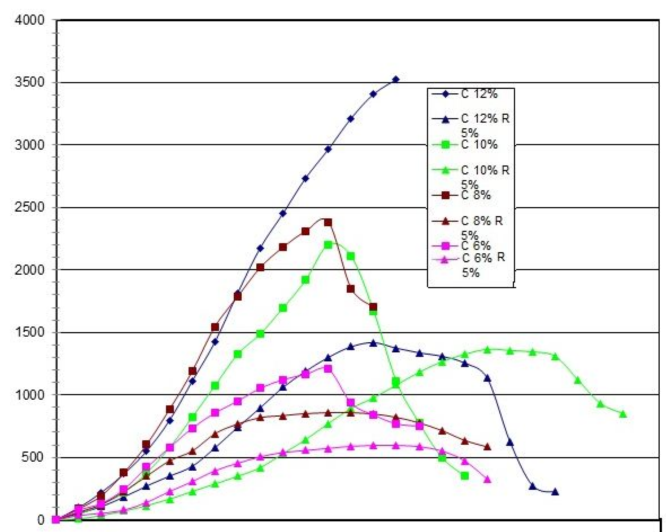
The strength gain is rapid for cement stabilized - laboratory cured - immersed and unimmersed samples. At 14 days the Up of cement stabilized fly ash was more than 50% of its 120 days UCS. The same trend holds good for naturally cured samples at MDD state. But the UCS of sample having 95% MDD decreased with curing time for the natural environment curing method. The samples having MDD were able to withstand the impact of environmental factors more than those having 95% MDD.

CONCLUSION

General

The conclusion of the experimental study is presented in this chapter. The scope for future is also identified at the end.

Conclusion



Conclusion of the Experiments

Unstabilized fly ash

The unconfined compressive strength (UCS) increase with increase in density but decrease with increase in water content.

The decrease in UCS with increase in water content is more pronounced for samples compacted at a lower density than MDD.

Stabilized fly ash

The UCS of lime or cement stabilized samples at MDD and OMC state is more than the UCS of lower density samples.

The effect of moulding water content on Up is not significant for laboratory cured fly ash but it influences the UC.,S of samples tested after immersion for laboratory and natural curing conditions.

The immersion of samples in water before the test reduces the UCS of laboratory cured, cement stabilized fly ash significantly.

The influence of immersion on UCS is more pronounced for samples compared at 95% MDD and OMC +3% and is insignificant for samples of 95% MDD and OMC -3%.

The UCS of samples at MDD is less affected than the UCS of samples at 95% MDD by environmental factors and immersion.

The combination of two stabilizers (cement & crumbed rubber) is less effective in increasing the UCS than that of cement.

The UCS of both stabilized fly ash samples increases with curing time.

CONCLUSION

The effect of density and moulding water content on the unconfined compressive strength (UCS) of stabilized sample. The strength gain is rapid for cement stabilized - laboratory cured - immersed and unimmersed samples. At 14 days the Up of cement stabilized fly ash was more than 50% of its 120 days UCS. The same trend holds good for naturally cured samples at MDD state. The following studies are suggested to be carried out to understand more about the strength behavior of stabilized fly ash.

1. Study about pozzolanicity of fly ash
2. Study of morphology and mineralogy of fly ash in stabilized and unstabilized forms.
3. The effect of various stabilizers in different proportions and combinations on the UCS.
4. The effect of stabilizers on the UCS of fly ash - soil mixtures.
5. The effect of inclusion of fibers on the strength behavior of stabilized fly ash - soil mixtures.
6. The effect of variation in water content and density on strength of stabilized fly ash – soil mixtures.
7. The effect of variation in deformation rate on the UCS of stabilized fly ash - soil mixtures.
8. 8 The effect of method of curing on the UCS of stabilized fly ash - soil mixtures.

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