A Study on Strength Characteristics of Flyash, Lime and Sodium Silicate Mixtures at Their Free Pouring Conditions

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Abstract:
For the utilization of flyash in improving the strength of problematic soils a detail experimental study on the behavior of flyash stabilized with various percentages of lime and sodium silicate and the strength characteristics at their free pouring (30%, 35% & 40% of water by weight of flyash)consistencies have been studied. Different percentages of lime and sodium silicate (gel) were added to flyash and tested for UCS and split tensile strength for different curing periods like 3 days, 7 days and 28 days to obtain optimum dosage of lime and sodium silicate. From the test data it was found that 10 to 15 % of lime and 3 to 5 % of sodium silicate have been identified as optimum dosages. These mixes can be used for bricks and grouting techniques in civil engineering sector.

Keywords– flyash, sodium silicate (gel), unconfined compressive strength (UCS), split tensile strength.

Introduction:

To meet the demands of industrialization and urbanization high volume of road a network is required. Performance of road depends on the structural components such as subgrade, sub base, and base course etc. when roads are running on problematic subgrade such as expansive, soft, collapsible sub grades. Partial or complete failure of pavements takes place; repeated failures require lot of maintenance cost. This can be reduced by ground improvement techniques like full replacement, partial by stabilized material and grouting etc can be used.

Lot of researches has been conducted on flyashes with admixtures, some of these are Yudbhir and Honjo (1991) considered unconfined compressive strength of flyashes as a measure of self hardening property of flyashes. They explain free lime content of flyash contributes to pronounced self hardening. Sherwood and Ryley (1966); and Raymond(1961)v reported that the fraction of lime, present as free lime in the form of calcium hydroxide controls self hardening characteristics of flyashes. Syngh (1996a) studied the unconfined compressive strength of flyashes as a function of free lime present in them and found that flyashes having higher free lime content shows higher strength. In addition to these flyash columns and flyash admixture columns can also be used. In this study NTPC fly ash is stabilized with lime and sodium silicate and performed tests like Unconfined compressive strength, Split tensile strength to identify optimum dosage of lime and sodium silicate for bulk utilization of fly ash.

2.0 Material used

The materials used in this investigation are Flyash (NTPC), Lime and sodium silicate.
Flyash is collected from NTPC Paravada in Visakhapatnam and laboratory study was carried out for salient geotechnical characteristics of such as grading, Atterberg limits, compaction and strength. The physical properties of flyash shown in table 2 and chemical composition of flyash shown in table : 1.

Table: 1

Compound	Formula	Percentage (%)
Magnesium oxide	MgO	0.86
Aluminum trioxide	Al2O3	30.48
Silica dioxide	SiO2	59.83
Calcium oxide	CaO	1.74
Titanium oxide	TiO2	6.91
Zinc oxide	ZnO	0.09

Property	Values
Sand (%)	28
Fines (%)	72
a. Silt(%)	72
b. Clay(%)	0
Liquid Limit (%)	24
Plastic Limit (%)	NP
Specific gravity	2.1
OMC (IS heavy Compaction)	
Optimum moisture content (%)	21.0
Maximum dry density (g/cc)	1.28
California bearing ratio	3

Table : 2

3.0 Experimental programme:

In this study dry flyash has mixed with lime (5%, 10% and 15%) and Sodium silicate gel (1, 2, 3, 4 and 5%) by percentage weight of dry flyash and added water of 30%, 35% and 40% by their weight and thoroughly mixed to get the required consistency and poured these samples into given sizes(38mm X 76mm) of samplers and kept cured for 1 day , 3 days, 7 days and 28 days respectively by maintaining 100% humidity and without loss of moisture from the samples.

4.0 Results and Discussions:

4.1 Unconfined Compressive strength (kg/ cm^2):

The samples of sizes 38 mm diameter and height of 76 mm were prepared as said above by free pouring in the UCS moulds. All the prepared samples were cured for 1 day, 3 days, 7 days and 28 days by maintaining 100% humidity. Compressive strength test were conducted after completion of their curing period at a strain rate of 1.25 mm/min.

Unconfined Compressive strength of flyash with 5% lime and sodium silicate (free pouring consistency):

Curing period	Water content	sodium silicate %					
		1	2	3	4	5	6
1	30	0.569	0.823	0.84	0.9	1.12	
	35	0.52	0.8	0.84	0.88	1	1.19
	40	0.5	0.75	0.8	0.84	0.86	1.12
3	35	0.84	2.06	1.96	1.86	1.52	
	40	1.19	2.12	2.89	3.34	2.85	2.62
	30	3.88	5.52	8.89	7.46	7.02	6.84
7	40	2.32	4.26	3.28	2.89	2.65	
	30	3.02	3.68	5.74	5.12	4.06	
	35	5.08	9.06	14.4	13.2	12.5	12
28	30	3.42	5.24	8.78	8.24	7.58	
	35	5.72	8.62	10.32	9.24	8.84	.
	40	8.06	11.42	18.35	17.04	16.17	

Table: 3

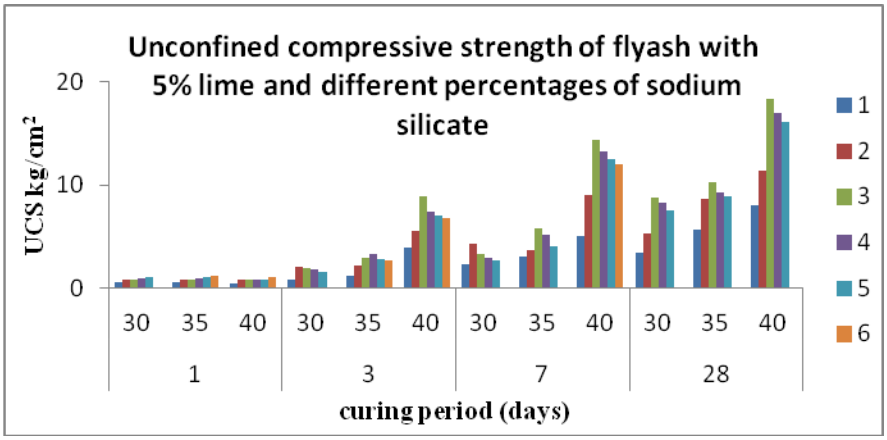

Fig: 1

For 5% lime, at different percentage of water content 3% sodium silicate gives good strength of flyash at all curing periods and the maximum strength observed at 40% water content and 28 days curing period is 18.35kg/cm^2.

Unconfined Compressive strength of flyash with 5% lime and sodium silicate (free pouring consistency):

Curing period	Water content	sodium silicate %					
		1	2	3	4	5	6
1	30	1.232	1.454	1.982	2.539	2.394	2.094
	35	1.14	1.69	2.07	2.842	2.53	2.21
	40	1.42	1.962	2.48	3.02	2.69	2.34
3	35	2.49	4.07	6.12	6.69	5.49	5.02
	40	4.18	6.39	8.12	10.68	9.12	8.24
	30	6.56	10.19	13.56	15.75	14.25	13.82
7	40	5.704	8.81	10.28	11.95	11.21	10.86
	30	8.78	12.45	14.8	15.32	14.24	13.63
	35	11.56	16.1	18.74	21.97	20.54	20.02
28	30	8.38	14.95	16.59	21.7	19.24	18.65
	35	10.82	14.95	17.62	21.71	19.23	18.12
	40	15.89	21.4	26.89	30.62	28.8	26.7

Table: 4

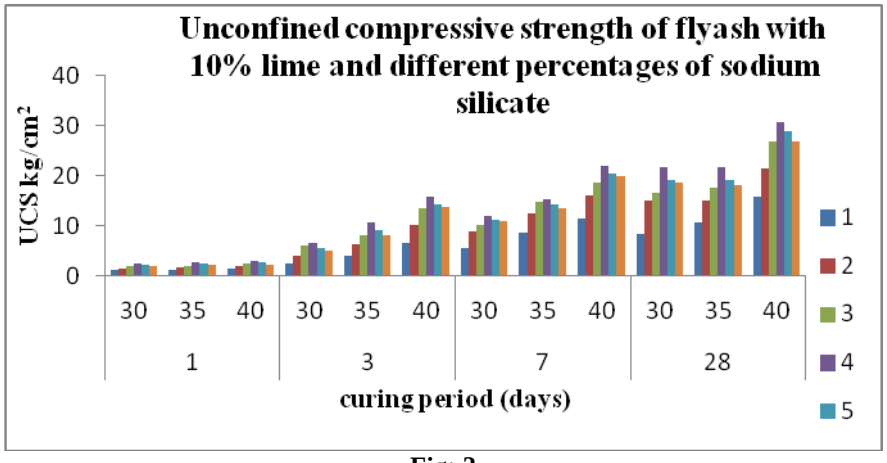

Fig: 2

For 10% lime, at different percentage of water content 4% sodium silicate gives good strength of flyash at all curing periods and the maximum strength observed at 40% water content and 28 days curing period is 30.62kg/cm^2.

Unconfined Compressive strength of flyash with 5% lime and sodium silicate (free pouring consistency):

Curing period	Water content	sodium silicate %					
		1	2	3	4	5	6
1	30	1.43	1.619	2.04	2.14	2.19	2.11
	35	1.85	2.12	2.36	2.58	2.91	2.46
	40	2	2.38	2.84	3.26	3.82	3.24
3	35	2.65	5.58	7.46	8.18	8.65	8.04
	40	4.95	7.68	9.65	11.72	12.86	11.24
	30	7.82	14.89	17.66	20.65	23.2	21.2
7	40	6.88	10.12	12.56	14.41	16.29	15.24
	30	9.66	13.89	16.2	17.54	18	17.12
	35	13.24	18.4	22.24	24.6	25.1	23.2
28	30	10.32	16.82	20.75	23.42	25.21	23.43
	35	11.64	18.35	22.89	24.85	26.39	25.21
	40	17.69	23.6	29.2	32.64	34.35	32.6

Table: 5

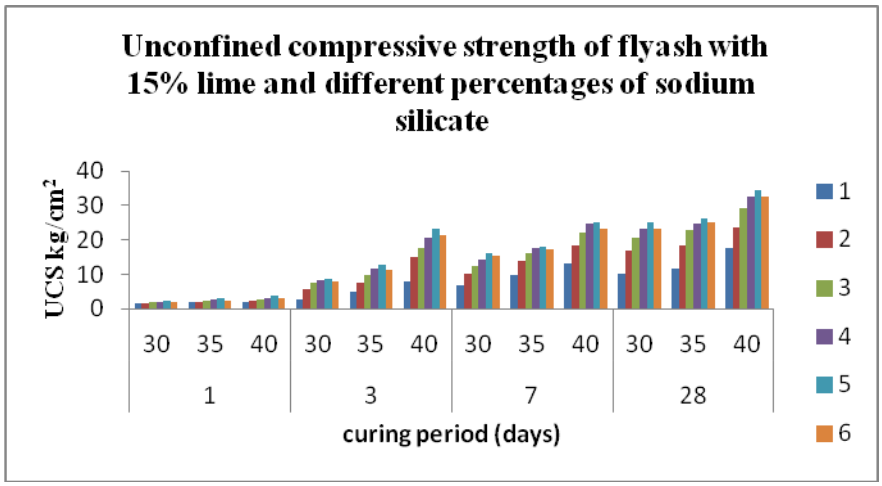

Fig: 3

For 15% lime, at different percentage of water content 5% sodium silicate gives good strength of flyash at all curing periods and the maximum strength observed at 40% water content and 28 days curing period is 34.35kg/cm^2.

4.4 Split Tensile Strength (kg/cm^2):

The samples of sizes 38 mm diameter and height of 76 mm were prepared by static compaction method to achieve maximum dry density at their optimum moisture contents OMC. All the prepared samples were cured for 1 day, 3days, 7 days and 28 days by maintaining 100% humidity. The sample is loaded until splitting / failure load takes after completion of their curing period at a strain rate of 1.25 mm/min.

Tensile strength, $S_t = 2P_u/ \pi Dt$

Where, P_u = ultimate load at which failure of sample.

D = diameter of specimen, mm. t = length of specimen, mm

Split tensile strength of flyash with 5% lime and sodium silicate (free pouring consistency):

Curing period	Water content	sodium silicate %				
		2	3	4	5	6
3	35	0.21	0.18	0.17	0.16	0.15
	40	0.26	0.36	0.41	0.38	0.34
	45	0.71	1.15	0.94	0.88	0.82
7	35	0.36	0.41	0.33	0.31	0.29
	40	0.48	0.73	0.68	0.59	0.53
	45	1.3	2.12	1.9	1.76	1.72
28	35	0.63	1.14	1.07	1.02	0.96
	40	1.22	1.49	1.33	1.29	1.27
	45	1.64	2.66	2.45	2.32	2.29

Table: 6

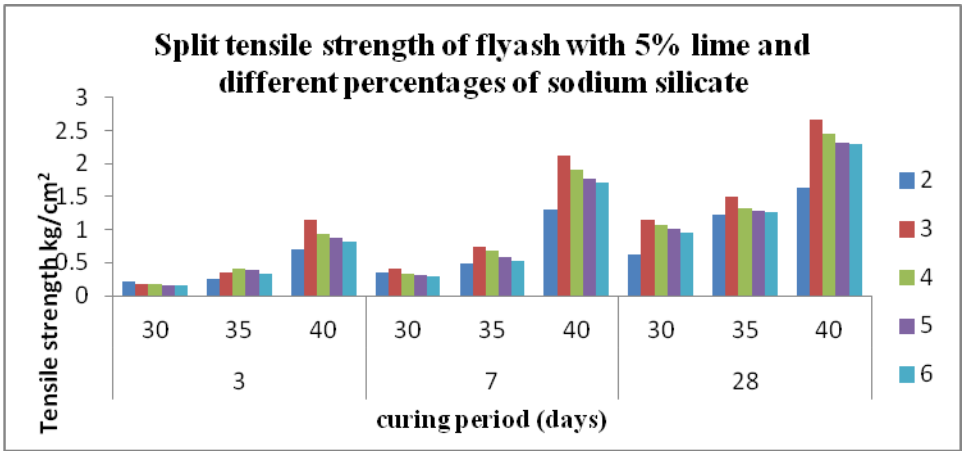

Fig: 4

For 5% lime, at different percentage of water content 3% sodium silicate gives good strength of flyash at all curing periods and the maximum strength observed at 40% water content and 28 days curing period is 2.66kg/cm^2.

Split tensile strength of flyash with 5% lime and sodium silicate (free pouring consistency):

Curing period	Water content	sodium silicate %				
		2	3	4	5	6
3	35	0.42	0.63	0.74	0.72	0.7
	40	0.81	1.04	1.35	1.31	1.29
	45	1.3	1.75	2.02	1.93	1.87
7	35	1.05	1.26	1.43	1.39	1.37
	40	1.68	1.75	1.86	1.82	1.78
	45	2.32	2.68	2.83	2.69	2.64
28	35	1.98	2.26	2.85	2.79	2.76
	40	2.12	2.62	3.09	2.95	2.89
	45	3.04	3.84	4.38	4.23	4.19

Table: 7

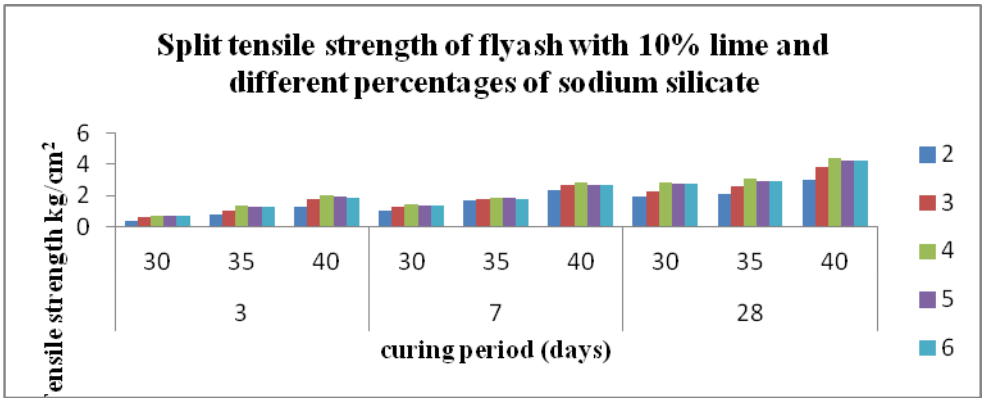

Fig: 5

For 10% lime, at different percentage of water content 4% sodium silicate gives good strength of flyash at all curing periods and the maximum strength observed at 40% water content and 28 days curing period is 4.38kg/cm^2.

Split tensile strength of flyash with 5% lime and sodium silicate (free pouring consistency):

Curing period	Water content	sodium silicate %				
		2	3	4	5	6
3	35	0.61	0.84	0.92	1.15	1.06
	40	1.02	1.26	1.52	1.89	1.76
	45	1.88	2.28	2.65	3	2.91
7	35	1.16	1.46	1.65	1.89	1.76
	40	1.68	1.98	2.1	2.51	2.43
	45	2.62	3.22	3.5	3.86	3.68
28	35	2.24	2.78	3.16	3.54	3.45
	40	2.68	3.32	3.58	4.01	3.89
	45	3.38	4.16	4.66	5.02	4.81

Table: 8

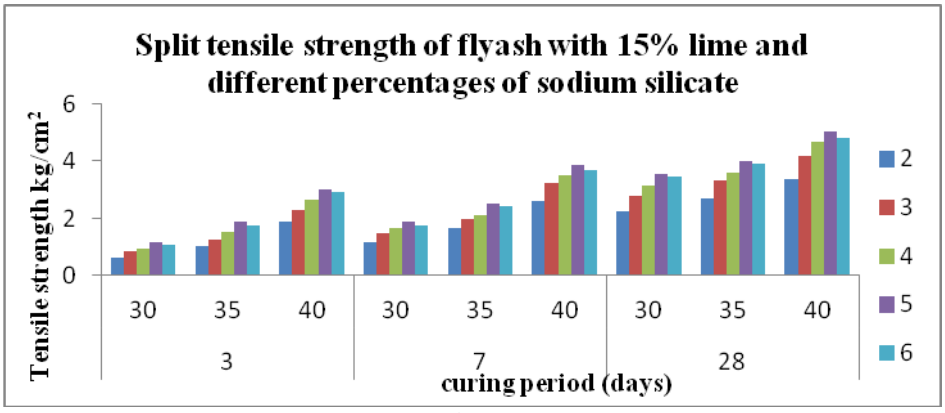

Fig: 6

For 15% lime, at different percentage of water content 5% sodium silicate gives good strength of flyash at all curing periods and the maximum strength observed at 40% water content and 28 days curing period is 5.02kg/cm^2.

Discussions:

For a given percentage of lime strengths increases with increase in sodium silicate content for all consistencies at higher dosages of lime for getting high strengths more dosages of sodium silicate is needed.

At lower consistency, at lower percentage of lime less dosage of sodium silicate was needed. To achieve high strengths at higher percentage of lime high dosage of sodium silicate was needed. At higher dosages a remarkable increase in strengths were observed at higher curing periods (7 days & 28 days).

The increases in strengths are due to interaction between lime and sodium silicate and flyash. This interaction leads to formation of calcium silicate and aluminate hydrated gels for getting high strengths. This gel formation combines particles together and make permanent because of the pozzolanic interaction between flyash, lime and silicate particles over a period of time i.e., at higher curing periods (7 days & 28 days).

Conclusions:

- With increase in percentage of lime and sodium silicate the mix has shown higher values. This is due to pozzolanic action between the particles of flyash and lime.
- For higher percentage of lime more amount of sodium silicate is required.
- As the percentage of lime increases the requirement of water is more for stabilization.
- It is observed that at 28 days curing periods, the strength values are maximum at all percentages of mixes.

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