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Study of Unconfined Compressive Strength of Cemented Flyash

Praveen Kumar[1], Ashish Arya[2]
[1,2]BRCM College, Haryana, India

Abstract: ***In India, coal is used as a fuel to generate electrical energy (76%) in thermal power plants and almost 170MT of fly ash is produced which content low lime. So we can define of flyash as a solid waste generated by thermal power plants. As the requirement of power is increasing very rapidly for human development purpose, then production of fly ash is also increasing rapidly while producing electrical energy by thermal power plant. Disposal of this wide amount of fly ash faces many problems of huge land requirement & transportation, and construction and maintenance of ash pound, which can be reduced by effective use of fly ash as a construction material for civil engineering purposes. To increasing the use of fly ash it is required to improve some properties by balance raw fly ash with suitable balance like lime or cement. It becomes an attractive construction material because of its hardening properties for which obtain free lime is stable. Its properties depends on the nature of coal, quality of pulverization, type of firmness and firing temperature. Large scale utilization of Fly ash in constructions will decrease the issues faced by thermal power plants for its removal mostly because its various property co- relate with the earth material as minerals, rocks etc. So judgement of the behaviour of fly ash at many conditions is required before its use as a construction material.***
Keyword: Fly-ash, UCS

I. INTRODUCTION

A. Fly Ash

Fly ash is a coal combustion product composed of fine particles that are driven out of the boiler with the flue gases. In modern coal-fired power plants, fly ash is generally captured by electrostatic precipitators or other particle filtration equipment before the flue gases reach the chimneys.

In About 43% is recycled, often used as a pozzolan to produce hydraulic cement or hydraulic plaster and a replacement or partial replacement for Portland cement in concrete production. Pozzolans ensure the setting of concrete and plaster and provide concrete with more protection from wet conditions and chemical attack.

Fly ash contains crystalline silica which is known to cause lung disease, in particular silicosis. Crystalline siilica is listed by the IARC and US National Toxicology Program as a known Human carcinogen.

Types of Fly-ash

1) Class F fly ash(>7%CaO) is pozzolanic in nature.
2) Class C fly ash(<20%CaO) self- cementing fly ash does not require an activator
3) Lime is calciumoxide which occurs as a product of coal seam fires and in altered limestone xenoliths volcanic ejecta and has the sense of *sticking or adhering*. Limestone is extracted from quarries or mines and selected according to its chemical composition is calcinated at about 1,000 °C in different types of lime kilns to produce quicklime as:

$$CaCO_3 \xrightarrow{heat} CaO + CO_2$$

Before use, quicklime is hydrated, that is combined with water, called slaking, so hydrated lime is also known as slaked lime, and is produced according to the reaction:

$$CaO + H_2O \longrightarrow Ca(OH)_2$$

II. LITERATURE REVIEW

The utility electricity sector in India has one National Grid with an installed capacity of 330.26 GW as on 31 May 2017. Renewable power plants constituted 30.8% of total installed capacity. As on 31 March 2015, India had estimated coal reserves of 306.6 billion metric tons (338.0 billion short tons), the fifth largest coal reserves in the world. India is the fourth largest producer of coal in the world, producing 536.5 million metric tons (591.4 million short tons) in 2014. The Indian coal has a low calorific value of 3,000–4,000 kcal/kg and a high ash content of 35–50%. Power plant ashes are generated as the finer pozollanic (capacity to react with lime in the presence of water at room temperatures to form a solid and water insoluble cement like substance) FLY ASH or the coarser non pozollanic bottom ash .Both these ashes are generally mixed and disposed in ash ponds requiring large areas of land.. More than 175 million tones of fly ash are expected to be generated in the country by the year 2012. This would require about 40000 hectares of land for the construction of ash ponds. As a result of the efforts of the 'Fly Ash Mission, in India and some other agencies the utilization of fly ash has improved from 3% in 1994 to 27%in 2003. From a little over one million tones in 1993-94 the utilization rose to 22 million tones in 2002. Fly ash utilization increased further to 60 million tones per year in 2006-2007 as against a generation of 130 million tones per year. While there has been a constant increase in the utilization of fly ash yet the unutilized fraction is also growing considerably increasing from 39 million tones in 1993-94 to 70 million tones in 2006-2007. This has grave environmental consequences. A lot still needs to be done. More than 55 demonstration projects have been completed or are under consideration at the fly ash mission. Some of these include use of fly ash in mine filling, construction of roads/ flyover embankments, hydraulic structures, raising of dykes, manufacture of several building components like bricks, blocks, tiles and use in agriculture.

Fly ash can substitute up to 66% of cement in the construction of dams. It is also used as a pozollanic substitute for cement in Roller Compacted Concrete dams-an innovative dam technology developed as a result of efforts to design more economical concrete dams that could be constructed rapidly with designed performance. Fly ash in R.C.C. is used not only for saving cement cost but also for enhancing strength and durability. Typically 15-30% of the Portland cement is replaced with fly ash. This results in net reduction in energy use and green house gas and other emissions.

III. EXPERIMENTAL WORK

A. *Material Used*

1) Fly ash sample was screened through 2mm sieve to separate out the foreign and vegetative matters. The collected samples were mixed thoroughly to get the homogeneity and oven dried at the tem of 105-110^0 then the samples were stored in airtight container.
2) Lime used in this study was first sieved through 150 micron sieve and stored in airtight container for subsequent use.

B. *Sample Preparation and Experimental Program*

UCS test is conducted in different lime contents, i.e.2%, 4% and 8%, were used for preparing stabilized fly ash samples with different curing time period of 3,7,28,90days.

Physical property of Fly ash

Physical parameters	Value	Physical Parameters	Value
Colour	Lightly grey	Shape	Sub rounded
Silt & Clay (%)	85	Coefficient of uniformity ,C_u	5.85
Fine Sand (%)	15	Coefficient of Curvature ,Cc	1.45
Medium Sand (%)	0	Specific Gravity, G	2.56
Coarse Sand (%)	0	Plasticity index	Non-plastic

Chemical composition of fly ash

Elements	MgO	Al_2O_3	SiO_2	K_2O	P_2O_5	CaO	Fe_2O_3	Na_2O	MnO	SO_3	LOI
Composition(%)	0.57	24.12	52.5	0.96	0.7	2.6	-	-	-	-	18.17

C. *Determination of Unconfined Compressive Strength*

To get Immediate UCS strength, UCS tests on fly ash and lime stabilized fly ash specimens compacted to their corresponding MDD at OMC with compactive effort varying as 118.6, 355.6, 593, 2483, kJ/m3 were performed according to IS: 2720 (Part X)-1991. For

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this test cylindrical specimens were prepared corresponding to their MDD at OMC in the metallic split mould with dimension 50mm (dia.) × 100mm (high). These specimens were tested in a compression testing machine with strain rate of 1.25% per minute till failure of the sample.

To determined the effect of curing period on strength property all samples were coated with wax and cured in a humidity camber at an average temperature of 33º C for a period of 3,7,28 and 90 days before testing.

Fig: Lime stabilized fly ash coated with Wax

Fig: UCS test on wax coated Lime treated fly ash

The unconfined compressive strengths of specimens were determined from stress versus strain curves plots and the unconfined strength and corresponding failure strain at different compactive energy after 0,7,28,90 Days of curing is given in below table:

Table: Immediate UCS of Fly ash and Lime-Fly ash mix at different compactive energy

Lime Content (%)	Compactive Energy								
	$355.8 kJ/m^3$			$593 kJ/m^3$			$2483 kJ/m^3$		
	Failure Strain (%)	UCS (kPa)	NUCS (kPa)	Failure Strain (%)	UCS (kPa)	NUCS (kPa)	Failure Strain (%)	UCS (kPa)	NUCS (kPa)
0	1.75	32.7	1	1.5	44.3	1	1.25	47.2	1
2	2	55	1.68	1.75	62.4	1.4	1.5	83	1.75
4	2	56.85	1.73	2	66.4	1.79	1.75	94.6	2.02
8	2	77.75	2.44	2	157.6	3.5	2	247.11	5.26

Table: UCS of Lime treated Fly ash at different compactive energy after 7 day of curing

Lime Content (%)	Compactive Energy								
	$355.8 kJ/m^3$			$593 kJ/m^3$			$2483 kJ/m^3$		
	Failure Strain (%)	UCS (kPa)	NUCS (kPa)	Failure Strain (%)	UCS (kPa)	NUCS (kPa)	Failure Strain (%)	UCS (kPa)	NUCS (kPa)
0	1.5	39.2	1	1.25	50.44	1	1.5	61.43	1
2	1.75	117.8	3.0	2	149.0	2.95	2	216.4	3.52
4	2	162.7	4.21	2	223.8	4.48	2.25	332.1	5.32
8	2	271.1	6.9	1.75	348.4	3.5	1.75	486.4	8.90

Table: UCS strength of Lime treated Fly ash at different compactive energy after 28 Days of curing

Lime Content (%)	Compactive Energy								
	355.8kJ/m^3			593 kJ/m³			2483 kJ/m³		
	Failure Strain (%)	UCS (kPa)	NUCS (kPa)	Failure Strain (%)	UCS (kPa)	NUCS (kPa)	Failure Strain (%)	UCS (kPa)	NUCS (kPa)
0	1.75	55.44	1	1.5	60.26	1	1.5	70.20	1
2	2	196.1	3.5	2.5	217.7	3.61	2.25	304.3	4.33
4	1	261.2	4.6	2.0	363.6	6.1	2.25	530.3	7.2
8	1.5	410.5	7.23	2.50	659.8	11.2	2.50	814.5	11.2

Table: UCS of Lime treated Fly ash at different compactive energy after 90 Days of curing

Lime Content (%)	Compactive Energy								
	355.8kJ/m^3			593 kJ/m³			2483 kJ/m³		
	Failure Strain (%)	UCS (kPa)	NUCS (kPa)	Failure Strain (%)	UCS (kPa)	NUCS (kPa)	Failure Strain (%)	UCS (kPa)	NUCS (kPa)
0	1.75	69.67	1	1.5	72.64	1	1.25	89.63	1
2	1.5	343.6	4.9	1.5	596.7	8.21	1.5	684.2	7.63
4	1.75	730.6	10.48	2.0	1372.5	18.6	1.75	1700	19.2
8	2	1476.2	21.10	2	2847.5	39.12	2	3547.7	38.2

D. Effect of Compaction Energy

Unconfined compressive strength tests were carried out on untreated fly ash specimens compacted to their corresponding MDD at OMC with compactive effort varying as 355.8, 593 and 2483kJ/m3. The stress-strain relationships of compacted fly ash were presented in Fig. Form these plots it is observed that the failure stress as well as initial stiffness of samples, compacted with greater compaction energy, are higher than the samples compacted with lower compaction energy. The immediate compressive strength of fly ash is 32.7 kPa at compaction energy of 355.8 kJ/m³ which increase to 47.2 kPa at compaction energy of 2483kJ/m³.However in general the failure strains are found to be lower for samples compacted with higher energies. The failure strains vary from a value of 1.5 to 1.75%, indicating brittle failures in the specimens. The increase in unconfined strength and initial stiffness of specimens with increased compactive effort is attributed to the closer packing of particles, resulting in the increased interlocking among particles. A closer packing is also responsible in increasing the cohesion component in the sample.

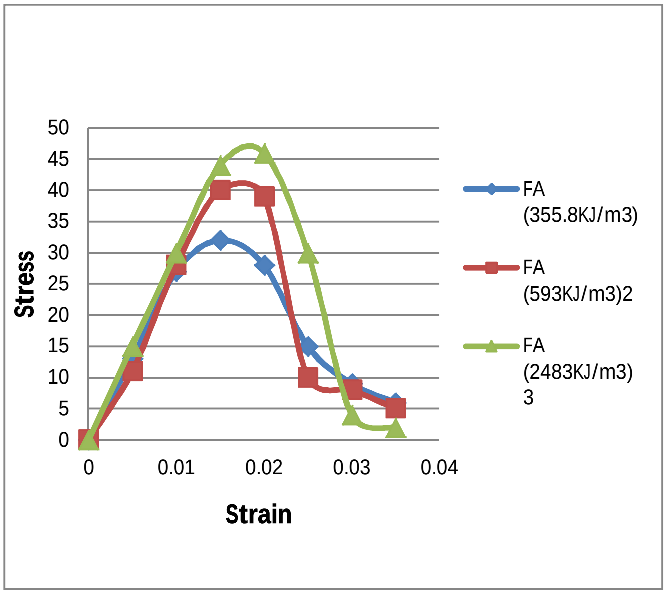

Fig: Stress-strain relationship of Fly ash at different compaction energy

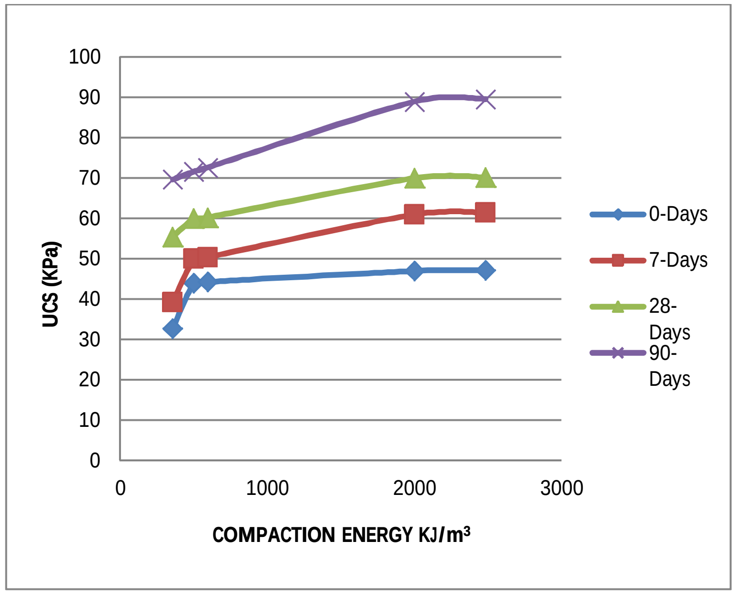

Fig: Variation of UCS strength with Compactive energy at different curing period

E. Effect of Curing Period

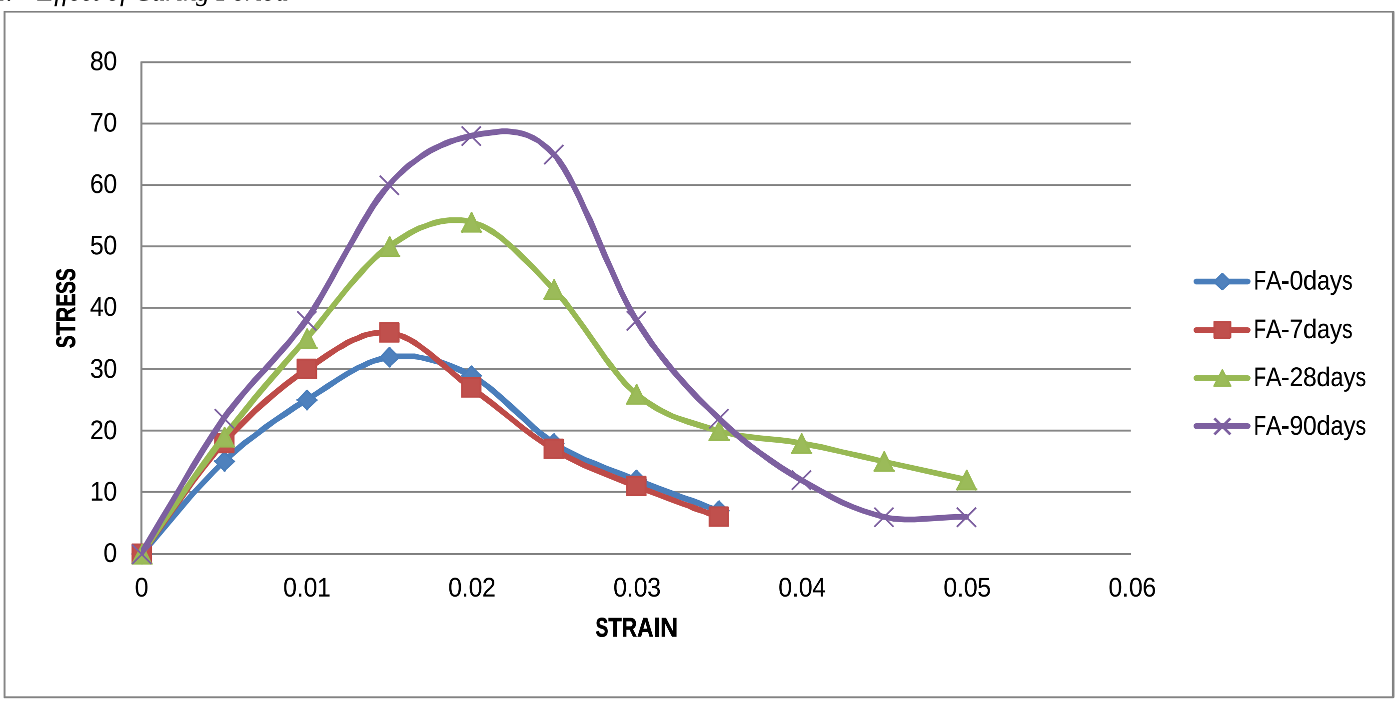

Fig: Stress-strain curve of Fly ash at compaction energy of 355.8 kJ/m³ at different curing period

IV. CONCLUSION

A. A linear relationship is found to exist between the compaction energy and unconfined compressive strength.

B. The UCS value is found to change from 32.764 to 47.271 kPa with change in compaction energy from 355.8 kJ/m^3 to 2483kJ/m^3 indicating that the gain in strength is not so remarkable. It revealed from the test results that a linear relationship exists between the initial tangent modulus with unconfined compressive strength and deformation modulus.

C. Increase in curing period of lime treated fly ash specimen show improvement in the UCS value. However the gain in strength with curing period is more in initial days of curing which tends to decreases with increase in curing period.

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