Effects of Clinker on strength behavior of Fly ash- Mine Overburden Mixes

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Abstract:

India is sixth largest electricity generating and consuming country in the world. The rapidly increasing demand for energy in India leads to commissioning of new thermal power plants. Coal is the main fuel resource of these power plants. But Indian coal has about 30-40 % ash content. Disposal of ash, particularly fly ash is an environmental issue and is considered as waste material if it is not effectively reused. Surface mines displace huge overburden material as abandoned waste. Often the cost of production increases due to poor haul road. So an attempt has been made to use those mine spoils with fly ash as road construction materials. This paper presents characterization of fly ash and over burden materials. Composite materials have been developed with additive. Unconfined Compressive Strength, Brazilian Tensile Strength and Ultrasonic pulse velocity test results are reported. Tests were carried out with different percentages of Clinker (2%, 4% & 8%). The Scanning Electron Microscopy (SEM) is done in order to show surface image of cured composite materials stabilized with clinker.

Introduction:

There are about 170 opencast coal mines and many are near to thermal power stations. Haul road of these mines are of permanent and temporary in nature varying between 2 to 5 Km. Problems associated with vehicular breakdown and poor performance as well as low morale work force of manpower have been attributed to the poor condition of haul road. Haul road typically consists of four layers i.e. sub-grade, sub-base, base course and surface course. Poor construction material in sub-grade or sub-base reflects in adverse performance of surface course. Fly ash is available in abundance and its huge generation is a problem for safe disposal. Typically Truck haulage cost goes up to 50% of total cost incurred by an opencast mine (Thompson & Visser, 2003). Heavy large capacity dumpers are used to haul coal from the mine to the power plants. Gross vehicular weight of these heavy large capacity dumpers can go up to 4000KN. The tire pressures used to support the weight of the truck and the coal are typically in the range of 600 kPa to 690 kPa (Tannant & Kumar, 2000). Fly ash possesses good utilization potential for geo-technical applications. Its low specific gravity, ease of compaction, good frictional properties, freely draining nature and insensitiveness towards change in moisture content can be usefully utilized for construction of roads and embankments (Pandian, 2004). Pot holes, rutting and settlement are major symptoms observed at all most all mines (Tannant & Regensburg, 2001). Torrey (1978) reported use of Lime-Fly ash-Aggregate mix (LFA) for base and sub-base layers of roads. Fly ash exhibits some cohesion when moist that is influenced by the size and no. of void spaces and also by degree of saturation (Ramaswamy and Kanishka, 2001). Cost norm for 35t dumper for a fixed width decreases from Rs. 602/m to Rs. 442/m when CBR value increases from 3 to 7 (CMPDIL). In this investigation an attempt has been made to evaluate the potential of fly ash-overburden mixes in addressing the issue of a stable & durable haul road construction.

Materials & Methods:

The fly ash was collected in dry state by electrostatic precipitator from a thermal power unit of Rourkela Steel Plant. The F type fly ash was chosen for its low lime content and its availability in abundance. The overburden used for the investigation was collected from Basundhara opencast coal mine, MCL, Orissa. The additive as clinker selected for the study. The tests carried out to determine Atterberg limits, Specific Gravity, Particle Size Distribution, pH, Compaction Characteristics, Unconfined Compressive Strength, Brazilian Tensile Strength & Ultrasonic Test etc. were as per the prescribed Indian & ASTM Standards. Chemical compositions of overburden and fly ash were determined from Energy Dispersive X-ray technique. The Optimum Moisture Content (OMC) & Maximum Dry Density (MDD) of different composition of (Fly ash-Mine Overburden-Cement Clinker) were determined by modified proctor test. The samples were prepared at their respective optimum moisture content & maximum dry density obtained from the modified proctor compaction test. The following proportions of overburden-fly ash-clinker mixes were considered & shown in table 1.

Fly ash (%)	Overburden (%)	Clinker (%)
90	10	0
88	10	2
86	10	4
82	10	8
10	90	0
10	88	2
10	86	4
10	82	8

Table 1: Various proportions of fly ash- mine overburden-clinker mixes

Results & Discussion:

The physical properties of fly ash & mine overburden are shown in table 2. The specific gravity of fly ash is found to be less than that of mine overburden due to presence of cenospheres & less iron content. Materials with high content have relatively high specific gravity (Pandian & Krishna, 2002).

Property	Fly ash	O/B
Specific Gravity	2.10	2.63
Atterberg Limits		
Liquid Limit (%)	31.57	32.90
Plastic Limit (%)	Non-plastic	22.10
Shrinkage Limit (%)	…	26.02
Plasticity Index (%)	…	10.80
Sieve Analysis (%)		
Gravel (>4.75mm)	…	9.12
Sand (4.75mm-0.075mm)	21.34	30.73
Silt (0.075mm-0.002mm)	76.68	47.04
Clay (<0.002mm)	1.98	13.11
pH Value	7.10	6.5
Modified Procter Test Results		
OMC (%)	22.3	10.30
MDD (Kg/m^3)	1296	1941
CBR (**Un soaked Condition**)	20.32	16.0
CBR (**Soaked Condition**)	1.14	2.53

Table 2: Physical Properties, Proctor Compaction and CBR Results of fly ash and mine overburden material

The chemical composition of mine overburden and fly ash are shown in table 3. The chemical composition of fly ash indicates that it has less CaO content.

Constituents	SiO_2	Al_2O_3	Fe_2O_3	CaO	K_2O	MgO	TiO_2	Na_2O	LOI
Mine Spoil	48.24	29.18	8.36	1.10	0.40	1.30	0.69		10.73
Fly Ash	53.11	33.64	6.44	0.55	1.45	0.83	2.05	0.13	1.8

Table 3: Chemical composition of mine overburden & fly ash

Compaction Characteristics:

Compaction is the process of increasing the density of soil by application of mechanical energy such as tamping, rolling & vibration. It is achieved by forcing the particles closer with a reduction in air voids. The maximum dry density of fly ash is lower than that of mine overburden as fly ash is non-cohesive in nature. Compaction characteristics showed that maximum dry density of fly ash-overburden mixes decreases with increase in fly ash content. The optimum moisture content is found to be more than 15% for most of the composites. The highest MDD observed is 1941 kg/m^3 for mine overburden only. OMC & MDD value of various composites are shown in table 4.

Sample	MDD (Kg/m^3)	OMC (%)
O/B only	1941	10.3
10%FA+88%O/B+2%CL	1927	11.5
10%FA+86%O/B+4%CL	1936	15.5
10%FA+82%O/B+8%CL	1949	15.9
20%FA+78%O/B+2%CL	1813	9.3
20%FA+76%O/B+4%CL	1821	9.0
20%FA+72%O/B+8%CL	1839	14.8
30%FA+68%O/B+2%CL	1779	6.5
30%FA+66%O/B+4%CL	1796	9.1
30%FA+62%O/B+8%CL	1807	15.4
88%FA+10%O/B+2%CL	1341	18.5
86%FA+10%O/B+4%CL	1369	14.9
82%FA+10%O/B+8%CL	1413	15.1
78%FA+20%O/B+2%CL	1441	15.7
76%FA+20%O/B+4%CL	1447	16.3
72%FA+20%O/B+8%CL	1449	16.1
68%FA+30%O/B+2%CL	1499	21.3
66%FA+30%O/B+4%CL	1508	20.8
62%FA+30%O/B+8%CL	1539	14.9
Fly Ash only	1296	22.3

Table 4: Compaction Characteristics of fly ash- mine overburden composites with Clinker as additive

Unconfined Compressive Strength:

Unconfined compressive strength is one of the most important design parameter & widely used laboratory test for pavement and soil stabilization application. Load and deformation readings were taken up to the failure of composite material. It is observed that UCS values those were insignificant without additives, increased dramatically as we go on increasing clinker percentage. But the increase rate varied differently for different combinations.

This test reports the unconfined compressive strength of fly ash-overburden mixes in various proportions like (10FA%+88%O/B, 10%FA+86%O/B, 10%FA+82%O/B etc.) stabilized with 2%, 4% & 8% clinker. The unconfined compressive strength of developed composite materials varies between 0.15MPa & 4.2MPa cured for 7 days shown in figure 1.

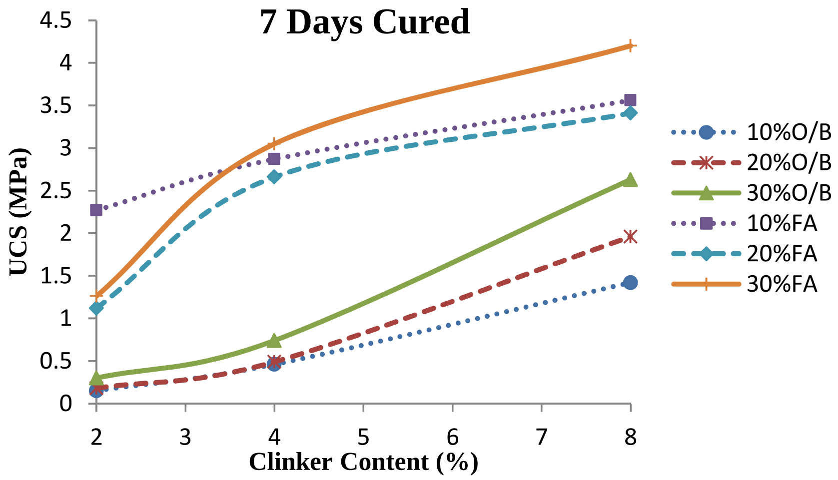

Figure 1: Effect of Clinker on UCS of fly ash-overburden composite materials Cured for 7 Days

Ultrasonic Pulse Velocity:

This test is valid for wave velocity measurement in both anisotropic and isotropic specimen although velocities obtained in anisotropic specimen may be influenced by factors like direction, travel distance and diameter of sensors. The test is carried out by applying two sensors to opposite surfaces of the specimen. Sufficient surface contact between sensors and specimen is maintained by a couplant as honey. This test reports the p wave velocity of fly ash-overburden mixes in various proportions like (10FA%+88%O/B, 10%FA+86%O/B, 10%FA+82%O/B etc.) stabilized with 2%, 4% & 8% clinker. The P Wave Velocity of developed composite materials varies between 661m/s & 1758m/s cured for 7 days shown in figure 2.

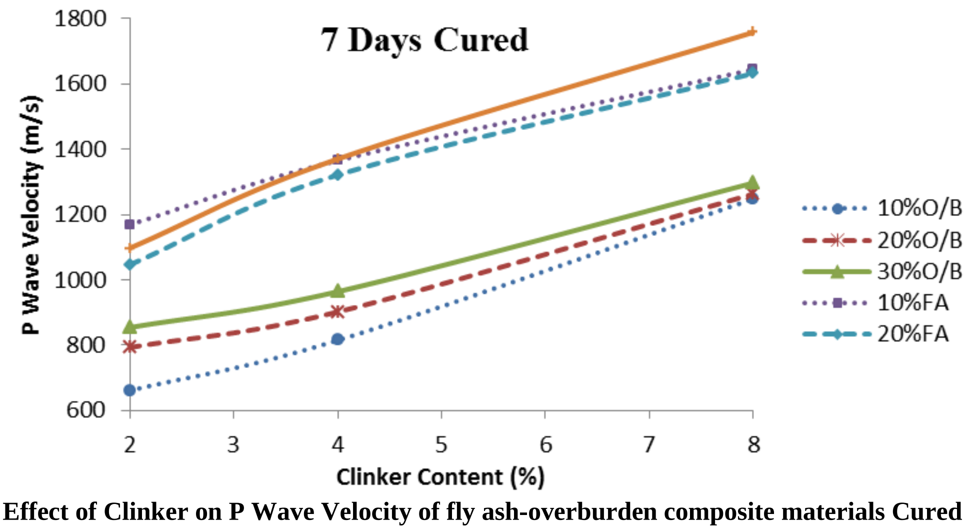

Figure 2: Effect of Clinker on P Wave Velocity of fly ash-overburden composite materials Cured for 7 Days

Brazilian Tensile Strength:

Tensile strength is an important parameter to evaluate the suitability of clinker stabilized fly ash-overburden composite material for the sub-base of haul road. This test reports the tensile strength of fly ash-overburden mixes in various proportions like (10FA%+88%O/B, 10%FA+86%O/B, 10%FA+82%O/B etc.) stabilized with 2%, 4% & 8% clinker. The Brazilian tensile strength of developed composite materials varies between 35KPa & 460KPa cured for 7 days shown in figure 3.

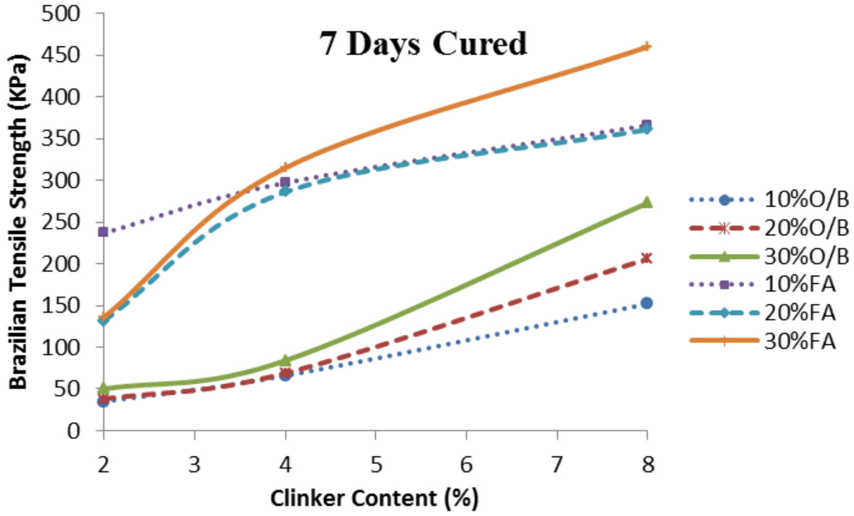

Figure 3: Effect of Clinker on tensile strength of fly ash-overburden composite materials Cured for 7 Days

Scanning Electron Microscopy:

The raw fly ash, mine overburden & Fly ash- mine Overburden-Clinker mix composites were examined by scanning electron microscope to observe the micro structural development within the composite. The JEOL JSM-6480LV scanning electron microscope coupled with an energy dispersive X-ray micro-analyzer was used for the purpose. The SEM images of untreated fly ash, mine overburden and cured developed composites are shown in figure. It is clearly visible in the micrographs that new cementitious compounds such as calcium silicate hydrate (C-S-H) and calcium aluminate hydrate (C-A H) were formed around fly ash and overburden particles as a result of the pozzolanic reaction after curing shown in figure 4a,b,c,d,e,f.

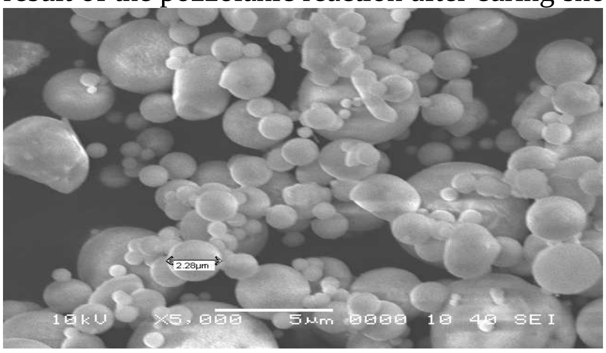

Figure 4(a): Fly ash

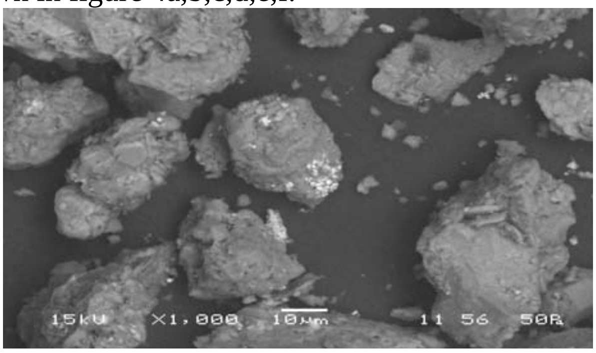

Figure 4(b): Mine Overburden

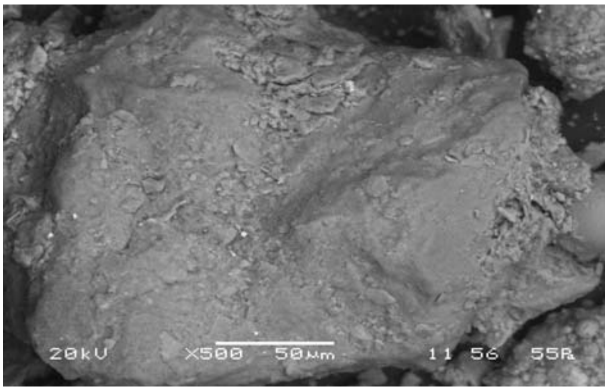

Figure 4(c): 30%FA+62%O/B+8%CL

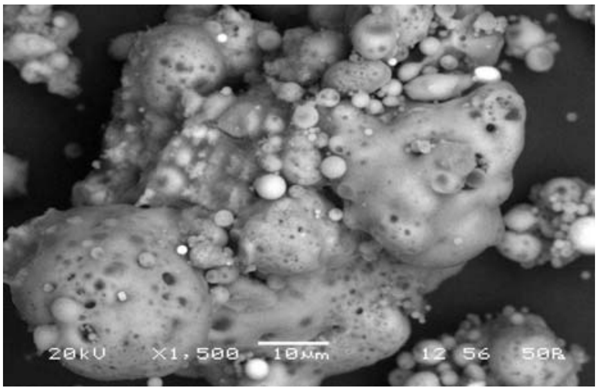

Figure 4(d): 20%FA+72%O/B+8%CL

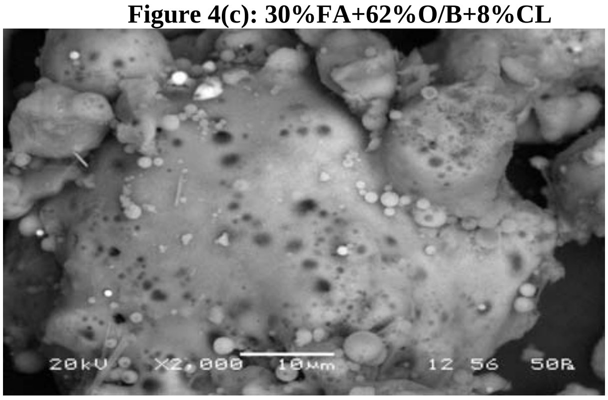

Figure 4(e): 10%FA+82%O/B+8%CL

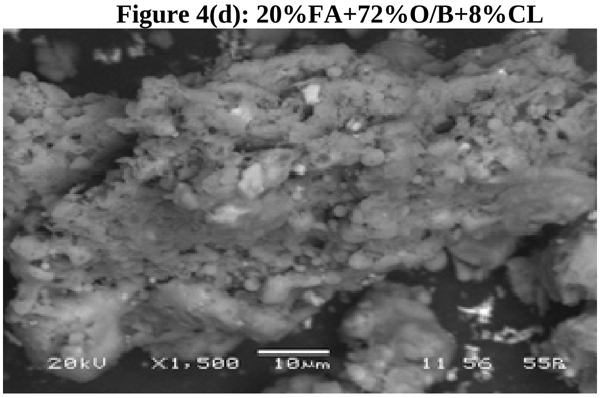

Figure 4(f): 62%FA+30%O/B+8%CL

Conclusion:

Clinker content showed a significant effort on strength behavior of fly ash- mine overburden mixes. The strength value showed an increasing trend with increase in clinker percentage. Almost a linear relationship is found between unconfined compressive strength, Brazilian tensile strength, P wave velocity and clinker content. An increase in overburden quantity in fly ash at a given percentage of clinker improved the unconfined compressive strength, Brazilian tensile strength, p wave velocity of the developed composite material. The investigation showed that fly ash can be used in bulk as sub-base material in haul roads.

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