EFFECT OF CURING TEMPERATURE ON THE STRENGTH OF LIME STABILIZED FLY ASH

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ABSTRACT

In India major source of power generation is coal based thermal power plants .where 57% of the total power generated is from coal-based thermal power plant. High ash content is found to be in range of 30% to 50% in Indian coal. The quantum of Fly Ash produced depends on the quality of coal used and the operating conditions of thermal power plants. Presently the annual production of Fly Ash in India is about 112 million tonnes with 65000 acre of land being occupied by ash ponds and is expected to cross 225 million tonnes by the year 2017. Such a huge quantity does cause challenging problems, in the form of land usage, health hazards and environmental dangers. Both in disposal as well as in utilization, utmost care has to be taken to safeguard the interest of human life, wild life and environment. Fly ash is generally classified into two types; Class C and Class F. Class C fly ash contains high calcium content which is highly reactive with water even in absence of lime. Class F ash contains lower percentage of lime. The main work carried out is to investigate the suitability of class F fly ash, containing CaO as low as 1.4%, modified with added lime as a construction material in different civil engineering fields. Slurry disposal lagoons/ settling tanks can become breeding grounds for mosquitoes and bacteria. It can also contaminate the under-ground water resources with traces of toxic metals present in it. Then comparison study has been done between sealed and unsealed samples. Then to study the effect of curing period on CBR value stabilized Fly ash samples were made with different percentage of lime (0%, 2%, 4%, 8%, and 12%) at a MDD and OMC corresponding to the compaction energy of 593 and 2483 kJ/m3 and these samples were cured for 7 days and 30 days with soaking period of 4 days for soaked samples. Comparison study has been done between soaked and unsoaked CBR with varying compactive energy and curing period simultaneously.

Keywords: *Lime Stabilization, Curving Temperature, CBR, Fly ash.*

INTRODUCTION

Fly Ash is a by-product material generated by thermal power plants from combustion of Pulverized coal. This is a fine residue produced from the burnt coal is carried in the flue gas, separated by electrostatic precipitators, and collected in a field of hoppers. This residue which is collected is called as fly ash and is considered to be an industrial waste which can be used in the construction industry. Fly ash is one of the major industrial wastes used as a construction material. The fly ash can either be disposed of in the dry form or the wet method in which it can also be mixed with water and is charged as slurry into locations called ash ponds. Disposal of residual waste is one of the greatest challenges faced by the manufacturing industries in India.

In many countries, including India, coal is used as a primary fuel in thermal power stations and in other industries. Four countries, namely, China, India, Poland, and the United States, together produce more than 270 million tonnes of fly ash every year and less than half of it is used. The coal reserve of India is approximately 200 billion tonnes and its annual production reaches 250 million tones approximately. Unlike the developed countries, in India, the ash content present in the coal which is used for power generation is about 30-40%. The generation of ash has increased to about 131 million ton during 2010-11 and is expected to grow further. In India major source of power generation is coal based thermal power plants .where about 57% of the total power obtained is from coal-based thermal power plant. High ash content is found to be in range of 30% to 50% in Indian coal. The quantum of Fly Ash produced depends on the quality of coal used and the operating conditions of thermal power plants. Presently the annual production of Fly Ash in India is about 112 million tones with 65000 acre of land being occupied by ash ponds and is expected to cross 225 million tons by the year 2017. Such a huge quantity does cause challenging problems, in the form of land usage, health hazards and environmental dangers.

LITERATURE REVIEW

The coal reserve of India is estimated to be approximately around 200 billion metric tons. Due to this reason, around 90% of the thermal power stations in India are coal based. Total installed capacity of electricity generation is 100,000 MW in India. Out of this, about 73% is from thermal power generation. There are overall 85 coal based thermal and other power stations in our country. The quality of coal found here has a low calorific value of 3,000–4,000 kcal/kg and ash content of it is as high as 35–50%. In order to achieve the required amount of energy production, a high coal fired rate is necessarily required, generating greater ash residue. This method requires about 1 acre of land for every 1 MW of installed capacity, apart from a large capital investment which is mandated. Thus, the ash ponds occupy nearly about 26,300 ha of land in India. The utilization of this fly ash in various industries was just mere 3% in 1994, but after growth in the realization about the need for conservation of the environment in India it has gradually been increasing. In 1994, the Government of India had commissioned a Fly Ash Mission (FAM) with the major objective of building belief and confidence among the producers and the consumer agencies about the safe disposal and utilization of fly ash, through technology demonstrated projects. The Fly Ash Mission has so far chosen 10 major areas and has undertaken 55 technology demonstration projects at 21 locations across India. The fly ash utilization has increased from 3% in 1994 to almost 13% in 2002 which is still expected to grow even more. A notification which was issued by the Ministry of Environment and Forests of the Government of India (MOEF
1999) on September 14, 1999, established the basic framework for the advancement in utilization of fly ash and environment conservation efforts to be put in the country. This notification demanded the existing thermal power plants to achieve a total of 20% utilization of fly ash within a span of 3 years and 100% utilization within 15 years. Plants which were newly commissioned were required to achieve 30% utilization of fly ash within the next 3 years and 100% utilization within 9 years. One of the major applications in which fly ash are demanded in large quantities is for the construction purposes of compacted fills and embankments.

Reddy and Gourav(2011) examined the improvements in strength gaining characteristics of lime– fly ash by using an additives like gypsum and under goes through low temperature steam curing. They also discussed the influence of lime–fly ash ratio, steam curing and role of gypsum on gain in strength, and characteristics of compacted lime–fly ash–gypsum bricks. The test result showed that there is an increase in strength with increase in density irrespective of lime content, type of curing and water content in the fly ash. Apart from this the results revealed that in the normal curing conditions optimum lime–fly ash ratio yielding maximum strength is about 0.75 and at 800 C, 24 h of steam curing is sufficient to achieve nearly possible maximum strength. They even stated that under ambient temperature conditions the pozzolanic reactions of lime take place at a low pace and hence it requires very long curing durations to achieve meaningful strength values.

Singh and Sharan (2013) showed the effect of compaction energy and degree of saturation on strength characteristics of compacted pond ash. Here the pond ash sample was subjected to compactive energies varying from 357 kJ/m3 to 3488 kJ/m3 which were being collected from ash pond of Rourkela Steel Plant (RSP). By conventional compaction tests they found out The optimum moisture content and maximum dry densities corresponding to different compactive energies. The compaction characteristics of the specimen were assessed for different dry densities and moisture content. They reported that by controlling the compactive energy and moulding moisture content, the dry density and strength of the compacted pond ash can be suitably modified. In this study they ended up with a conclusion that pond ash can replace the natural earth materials in geotechnical constructions as the strength achieved by the pond ash in this test was as good as a similar graded conventional earth materials.

EXPERIMENTAL ARRANGEMENTS

Main concern of coal based thermal power plants is Safe and economic disposal of flyash. The problems faced by the thermal power plants for disposal of flyash can be reduced by utilizing

flyash significantly in geotechnical construction like highway and railway embankment, landfill, road bases and sub-bases etc. construction in civil engineering field is gaining momentum as it proves to be an effective and efficient means of bulk utilization of waste material like flyash .

However compacted ash suffers great loss of shear strength on saturation. So to transform the waste material into safe construction material Stabilization of flyash is required .for increasing use of flyash as a construction material, It is required to evaluate its behaviour at different conditions and enhance some properties before using as a construction material .The tests at laboratory scale provide a measure to control many of the variable encountered in practice as adequate substitute for full scale field tests are not available. In the laboratory tests the trends and

behaviour pattern observed to predict the behaviour of field structures. This is helpful for understanding the performance of the structures in the field and may be used in formulating mathematical relationship. In the current work the effect of curing temperature on the strength of lime stabilized flyash has been evaluated through a series of unconfined compression test, proctor compaction and CBR tests.

Table: CBR test result of Fly ash and lime treated Fly ash at 7days of curing with compactive energy of 2483 kJ/m3

Lime content in %	Soaked CBR value		Unsoaked CBR value	
	CBR Value at 2.5 mm Penetration(%)	CBR value at 5mm Penetration (%)	CBR Value at 2.5 mm Penetration(%)	CBR value at 5mm Penetration(%)
0	5.8	5.7	72.8	71.2
2	86.6	83.1	91.5	87.4
4	105.2	104.1	110.1	105.2
8	109.3	105.2	118.2	109.0
12	113.3	108.4	135.2	133.8

Cured permeability samples

Constant head permeability test

Constant head permeameter

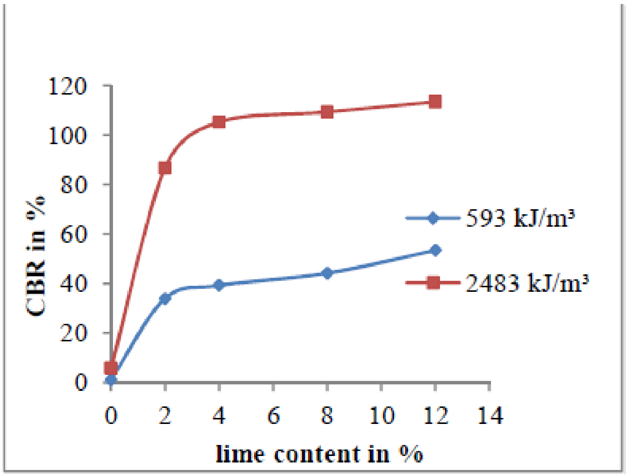
Table: Co-efficient of permeability of lime stabilized flyash with different curing period at compactive energy 593kJ/m3 and 2483kJ/m3

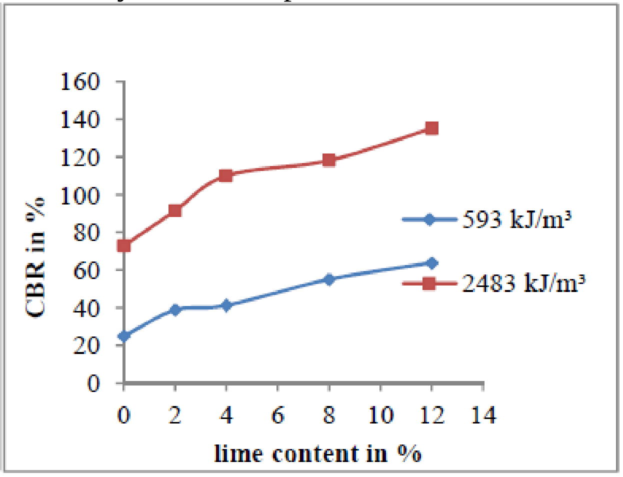
samples	Coefficient of permeability(k) at different compaction energy (cm/sec)					
	7 day		15 days		30 days	
	$593kJ/m^3$	$2483kJ/m^3$	$593kJ/m^3$	$2483kJ/m^3$	$593kJ/m^3$	$2483kJ/m^3$
FA+0%L	5.31×10^{-5}	3.91×10^{-5}	2.5×10^{-5}	1.605×10^{-5}	1.34×10^{-5}	1.31×10^{-5}
FA+2%L	4.65×10^{-5}	2.32×10^{-5}	2.105×10^{-5}	1.98×10^{-5}	1.20×10^{-5}	1.16×10^{-5}
FA+4%L	3.04×10^{-5}	1.44×10^{-5}	6.72×10^{-6}	3.97×10^{-6}	3.88×10^{-6}	3.67×10^{-6}
FA+8%L	2.26×10^{-5}	0.98×10^{-5}	2.91×10^{-6}	2.44×10^{-6}	2.42×10^{-6}	2.34×10^{-6}
FA+12%L	1.58×10^{-5}	0.474×10^{-5}	2.01×10^{-6}	1.23×10^{-6}	1.02×10^{-6}	1.00×10^{-6}

RESULTS AND DISCUSSION

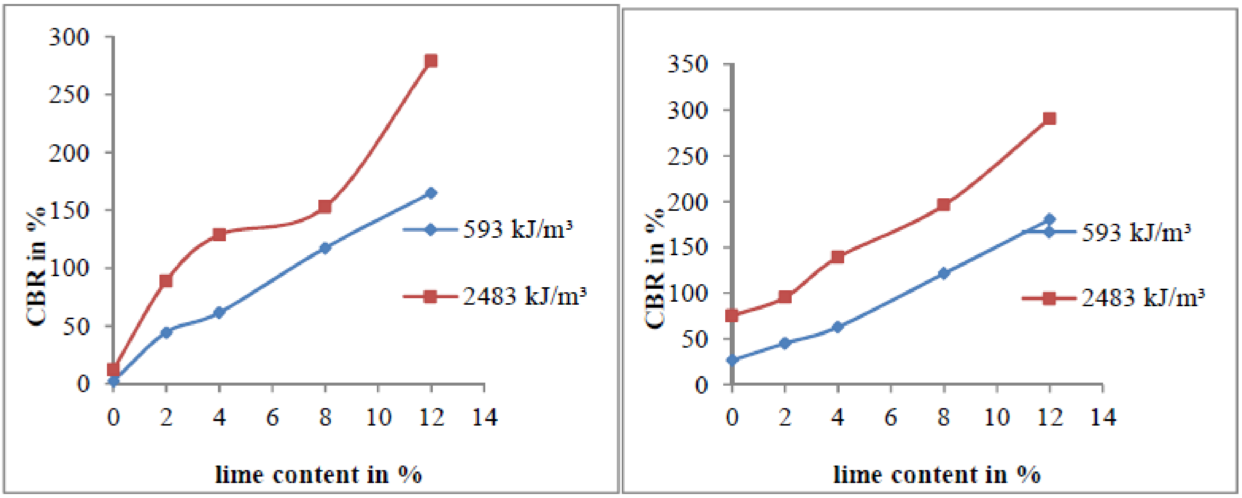
Fly ash is a fine residues generated due to combustion of coal, and comprises of very fine particles that rise with the flue gases. This material is solidified while suspended in exhausted and captured by electrostatic precipitators or other particle filtration equipment before the flue gases reach the chimneys of coal fired power plants. Fly ash generally contains spherical shape particles. Fly ash consists of inorganic matter present in the coal that has been fused during coal combustion. On compacted fly ash specimen a series of traditional laboratory tests are being carried out such as light and heavy compaction tests, unconfined compressive strength tests, CBR tests and permeability test.

CBR-test was conducted to characterize the strength and the bearing capacity of the fly ash. Toth et al. reported the CBR values of coal ashes to vary between 6.8 and 13.5% for soaked condition, and 10.8 and 15.4% for un soaked condition. The typical CBR value of Badarpur coal ashes tested under soaked and un soaked conditions reported by Pandian (2004). Basically the un soaked CBR value is more than soaked CBR value. CBR values under soaked conditions would always give a highly conservative value for design. CBR value increases with increase in compaction energy. The soaked CBR value of Fly ash is relatively low ranging from 1.3%to 5.8% as compaction energy increases from 595 to 2483 kJ/m3. However Lime treated fly ash has comparatively higher CBR value reaching a value of 44.2% at lime content of 10%.when the sample subjected to a curing period of 26 days and a soaking period of 4 days, CBR value considerably increases due to pozzolanic reaction of lime. This is mainly because fly ash, a fine grained material, when placed at 95% of Proctor maximum dry density and corresponding water content, exhibits capillary forces, in addition to friction resisting the penetration of the plunger and thus high values of CBR are obtained. On the contrary, when the same fly ash samples are soaked for 24 h maintaining the same placement conditions, they exhibited very low values of CBR. This can be attributed to the destruction of capillary forces under soaked conditions. The load Vs penetration curve of lime treated fly ash with 7days and 30 days cured samples are shown below.





variation of soaked and unsoaked CBR with different lime content for 7days curing period



variation of soaked and unsoaked CBR with different lime content for 30day curing period

This graph shows the variation of CBR value due to increase in lime content and curing period with 595 kJ/m3 to 2483kJ/m3 of compactive energy. And it is clearly visible that unsoaked and soaked CBR value of untreated flyash give lesser CBR value when cured for 7days and with curing period increase up to 30 days these values are slightly increased due to presence of some short of cementing material (free lime).And unsoaked and soaked CBR values are found to increase with lime beyond 4% which gives marginal strength. This trend is observed for specimens cured for 7days. However specimens cured for 30 days showed a continuous increase in CBR value. So for better strength igher doses of lime treatment also needed. Test result showed a great variation between unsoaked and soaked CBR values for untreated flyash or flyash treated with low percentage of lime but this difference is reduced when the samples are stabilized with higher percentage of lime.

CONCLUSIONS AND FURTHER WORK

Experiments are carried out to investigate strength properties of lime treated flyash. The effects of lime content, curing period and curing temperature on the strength properties are investigated.

Based on the experimental investigations the following main conclusions are arrived at:

- The fly ash shows uniform gradation of particles having most of the grains is of fine sand to silt size. The percentage of flyash passing through 75µ sieve was found to be 88%. Coefficient of uniformity (Cu) and coefficient of curvature (Cc) for flyash was found to be 5.67 & 1.25 respectively, indicating that it is a uniformly graded material..
- Dry density of compacted specimens is found to change from 1.12 to 1.236 g/ccwith change in compaction energy from 595 kJ/m3to 2483 kJ/m3, whereas the OMC is found to decrease from 40.5 to 33 %. This shows that fly ash sample responds very poorly to the compaction energy. An addition of lime flocculates the particles which results in decrease of dry density and increase in moisture content at a given compactive effort at lower doses of lime. However higher lime content tends to increase the MDD value as the specific gravity of lime is higher than that of the flyash particles.
- The failure stresses of lime stabilized samples, compacted with greater compaction energies, are higher than the samples compacted with lower compaction

energy. However the failure strains are found to be lower for samples compacted with higher energies with lower lime content. The failure strains vary from a value of 2 to 3.5 %, indicating brittle failures in the specimen. A linear relationship is found to exist between the lime content and unconfined compressive strength.

- The UCS value is found to change from 290.60 to 320.5 kPa with change in lime content from 0 to 2% indicating that the gain in strength is not so remarkable with smaller amount of lime that is 0 -2% the strength improvement is practically insignificant, even if cured for long time.But a higher dose of lime that is beyond 2% enhances the unconfined strength by many folds. This shows that about 2% of lime is used for colloidal type of reaction and lime in excess to this amount is utilized for pozzolanic reaction and increase in strength.
- Increase in curing period of lime treated fly ash specimen shows improvement in the UCS and CBR value. But with smaller amount of lime that is 1%-2% the strength improvement is practically negligible, even if cured for long time. This is similar to the colloidal reaction with lime, which is mainly responsible in modifying the physical properties not the mechanical strength. With increased lime content the pozzolanic reaction peaks up producing adequate amount of cementitious ompounds leading to visible increase in strength. As the lime percentage increases this facilitates the pozzolanic reaction that form cementitious gel that binds the particles. The process of pozzolanic reaction is improved with curing period which results higher strength.
- Curing temperature is found to influence the unconfined strength of both sealed and unsealed samples .The UCS values of flyash added with higher percentage of lime show a remarkable increase in strength with increase curing temperature .however flyash added with lower percentage of lime does not show this trend. This indicates that a higher temperature favours a better pozzolanic reaction than a lower temperature .specially when the lime content is high.
- Both unsealed and sealed samples shows almost comparable strength values when the lime content is when the lime content is low and low curing period .Unsealed samples with higher lime content shows an improved strength over the sealed sample at comparable conditions. The increase in strength is remarkably high with higher curing temperature and longer curing periods. This shows that the water added during moulding of samples is insufficient to complete the pozzolanic reaction especially when the lime content is more. Hence it is recommended that ash samples stabilized with higher amount of lime should either be compacted wet of OMC or sufficient be added subsequently for proper curing.
- The stress strain curves of lime treated flyash specimens show an increase in both the stiffness value and failure stress with increase in lime content. However the failure strain is found to decrease with increase in lime content. This indicates wit addition of lime the samples became more stiff and strong where as it behaves more like a brittle material.

FUTURE WORK

For effective utilization of lime treated fly ash, some more aspects have to be investigated

- Effect of mineral and chemical admixtures like silica fume, glass powder etc
- Durability test to study the durability aspect
- Behaviors of stabilized flyash of perform study of under repeated loading
- Compressibility and Consolidation characteristics of compacted fly ash.

 Studies on microstructure and morphology and correlate this to the developed strength.
 Effectiveness of lime in controlling the leachate quality coming out of flyash.
 Liquefaction susceptibility of fly ash.

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