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# Performance analysis of Fly ash lime Composites and mixtures in road pavements

Vipin Kumar[1], Anil Kumar[2]

[1](M. Tech. Scholar, Dept. of Civil Engg., BMU, Rohtak, Haryana)
[2](M. Tech. Scholar, Dept. of Civil Engg., GJU, Hisar, Haryana)

**Abstract: In this paper, the authors have estimated the suitability of fly ash lime composites in road pavements or construction. Fly ash is an industrial waste produced by the burning of coal in thermal power plants. From past years, fly ash is disposed in the form of landfills. Fly ash is an engineering material with unique properties. When compared with typical soils used for embankment construction, fly ash has large uniformity coefficient consisting of silt-sized particles mostly. Addition of Stone dust modifies the gradation of fly ash and also there will be an increase in unit weight of the composite material. This study has been carried out to know the possibility of using fly ash in combination with stone dust and lime or cement. The engineering properties of composite material (fly ash-stone dust-lime\cement) have been studied to bring out the possibility of using fly ash in the construction of embankments. Addition of stone dust to fly ash results in an increase in Maximum Dry Density (MDD), and at the same time observed a decrease in Optimum Moisture Content (OMC). Due to addition of stone dust, a significant increase in California Bearing Ratio (CBR) value is observed. The composite material consists of 60% fly ash +40% of stone dust and 40% of fly ash + 60% of stone dust were further tested by adding lime. With addition of lime, there is a decrease in MDD and increase in the CBR value. The composite consisting of 40% fly ash + 60% stone dust with 2% lime resulted in a soaked CBR value of 9.0 at Maximum Dry Density (MDD) of 1.55 g/cm3. This composite material may be used for the construction of subgrade for rural roads.**

**Keywords: Fly Ash, MDD, OMC, CBR, composites, mixtures.**

## INTRODUCTION

Fly ash is one of the industrial products obtained from combustion of coal. In the past decades, fly ash obtained from coal combustion was simply dumped into the atmosphere which caused many environmental and health hazards. More than 65% of fly ash produced is disposed of in landfills. India alone covers an area of 40,000acres (160 sq.km) with fly ash as landfills. Addition of fly ash stabilizes the soil, which in turn improves engineering performance of soil. On the other hand, Recycling fly ash includes environmental benefits such as reducing demand for virgin materials that would need quarrying and substituting materials which may be energy intensive to produce. This study has been undertaken to explore the possibility of use of fly ash with addition of stone dust and lime and also the engineering properties of the composite material (fly ash-stone dust-lime) have been studied.

The discussion of results includes the possibility of use of fly ash in the construction of rural roads sub-grades. Beeghly (2003) showed in his study that a combination of lime and fly ash is beneficial for high silt content soils. Jirathanathworn and Chantawarangul (2003) reported that by use of fly ash mixed with small amount of lime, improves some of the engineering properties of the clayey soils including hydraulic conductivity as well as strength. Chauhan et al (2008) observed that with increase in percentage of fly ash mixed with stone dust there will be an increase in optimum moisture content and decrease in maximum dry density. In present days, about 10% of fly ash is utilized in ash dyke construction and land filling and only 3% of ash is utilized in other construction industries. So far, the combination of fly ash, stone dust and lime has not been studied in detail.

Composite materials also called composites are materials made from two or more constituent materials with significantly different properties, that when combined, produce a material with characteristics different from the individual components. They can be used in buildings, bridges, pavements, or any other of areas of service. The composite used in any case must have the strength and ability to resist the external force from applied loads, from the weight of the concrete itself or from a combination of these. Therefore the composition of the composites is of utmost importance.

**Fly ash Composites**

Fly ash is the residue left from burning coal, which is collected on an electrostatic precipitator. It mixes with flue gases that result when powdered coal is used to produce electric power. Since the oil crisis of the 1970s, the use of coal has increased. In 1992, 460 million metric tons of coal-ash was produced worldwide. About 10 percent of this was produced as fly ash in the United States. In 1996, more than 7 million metric tons were used in concrete in the U.S.

Economically, it makes sense to use as much of this low-cost ash as possible, especially if it can be used in concrete as a substitute for cement. Earlier in around 1914 it was recognized as pozzolanic ingredient for use in concrete which means it’s a siliceous or siliceous-and-aluminous material that reacts with calcium hydroxide to form cement. When portland cement reacts with water, it produces a hydrated calcium silicate (CSH) and lime. The hydrated silicate develops strength and the lime fills the voids. Properly selected fly ash reacts with the lime to form CSH–the same cementing product as in portland cement. This reaction of fly ash with lime in concrete improves strength.

Typically, fly ash is added to structural concrete at 15-35 percent by weight of the cement, but up to 70 percent is added for mass concrete used in dams, roller-compacted concrete pavements, and parking areas. Special care must be taken in selecting fly ash to ensure improved properties in concrete. The current production of fly ash is about 120 Million tonnes per year and is expected to reach around 170 Million tonnes by 2012 A.D (Kumar and Singh, 2006). This has posed a serious disposal and ecological problem in addition to occupying a large tract of scarce cultivable land. Although the beneficial use of fly ash in concrete, brick making, soil stabilization treatment and other applications have been recognized, only a small quantity of the total fly ash is being utilized in our country currently in such applications. There are two classes of fly ash: “F” is made from burning anthracite and/or bituminous coal, and “C” is produced from lignite or sub-bituminous coal. Till now most of the research works have been on the use of fly ash in cement and concrete.

## LITERATURE SURVEY

Mining provides us with essential resources. Historically, mining has evolved from small and simple operations to large and complex mining and processing systems that employ the latest in engineering technology. The total numbers of working mines at present are 2628 in 2010-11 out of which 574 mines deal in coal and lignite, 608 mines deal in metallic minerals and rest in non-metallic minerals. Presently, India produces around 90 minerals out of which 4 are fuel minerals, 10 are metallic minerals, 50 are non-metallic minerals, 3 are atomic minerals and 23 are minor minerals (Jha, 2011). Coal is the world’s most abundant and widely distributed fossil fuel. India is the third largest producer of coal in the world and has the fourth largest reserves of coal in the world (approx 197 billion tonnes) (Rai et al., 2011).

An estimated 55% of India’s installed capacity of 124,287 MW of power generation is through coal based thermal power plants. As per XI Plan, coal production would be raised to 680 million tonnes by the end of 2011-12 to meet the energy demand of the country (Ministry of Coal, 2007). Coal is mined by two main methods - surface or opencast mining and underground mining. Though underground mining is the oldest method of excavation, surface mining have been in force in recent years for its manifold advantages to meet the increasing demand of coal. In 1974-75 the share of total coal production from opencast mines was only 11%, whereas in 2009-10 and 2010-11 this has risen to 72.61% and 85% respectively

In most of surface coal mines, explosives are first used in order to break through the surface or overburden of the mining area. The overburden is then removed either by draglines or by shovel and truck. Once the coal seam is exposed, it is drilled, fractured and thoroughly mined in strips. The coal is then loaded on to large trucks or conveyors for transport to either the coal preparation plant or directly to where it will be used. The overburden originates from the consolidated and unconsolidated materials overlying the minerals and coal seams, and is required to be removed. The average stripping ratio (overburden to coal) during the last three decades in India was 1.97m3 /t (Chaulya et al., 2000).

Though there are attempts to reclaim the mined out area with filling by the waste dumps, the measures do not often accommodate all the displaced overburden. One of the major environmental challenges is to manage the huge volume of overburden generated in these opencast mines which is associated with the problems as aesthetics, visual impacts and landslides, loss of topsoil, soil erosion, water and air pollution, ecological disruption, social problems, safety, risk and health etc. The overburden is highly heterogeneous. These consists of alluvium, laterite, sandstone, carbonaceous shale, coal bands, clays, between coarse to medium grained highly ferruginous sandstone, thythmide, turbidite, etc. Gradation results suggest that fines and coarse grains are approximately equally represented in the soil (Ulusay et al., 1995).

**Mine haul roads and haul trucks**

In open cast coal mines, haul roads are basically required for the transportation of coal from the various coal faces to the coal receiving pits, overburden materials to the dump yard and also for the movement of vehicles to the workshops or parking places (Figure 1). Construction of haul road is a very important part in controlling sediment-laden runoff from a mine site.

**Figure 1: A typical permanent haul road**

## METHODOLOGY

The aim of the investigation is to improve upon the condition of surface coal mine haul road as well as evaluate the potential of fly ash to achieve this. This chapter reflects methodology adopted and materials used to achieve the objectives. The main inputs are overburden material, fly ash and lime. Fly ash collected from local power plant used in this investigation. Sample preparation and testing techniques used for characterisation of materials as well as development of composite materials are also reported.

**Collection method**

The fly ash used in the present study was collected in dry state from electrostatic precipitators of CPP-II of RSP. During the combustion of pulverized coal in suspension-fired furnaces of thermal power unit, the volatile matter is vaporized and the majority of the carbon is burned off. The mineral matter associated with the coal, such as clay, quartz and feldspar disintegrate or slag to varying degree. The finer particles that escape with flue gases are collected as fly ash using electrostatic precipitators in hoppers and stored. The hoppers have small outlets. Gunny bags made of strong poly-coated cotton with 50kg capacity each were used to collect the dry fly ash. The chute of hoppers was slowly opened and the bags were filled. The mouth of each bag was sealed immediately after collection and the same was again inserted in another polypack to prevent atmospheric influences. The bags were transported with utmost care from the plant to laboratory and kept in a secure and controlled environment. Samples of fly ash were taken out as per requirement of test.

**Overburden Materials**

Overburden from a surface coal mine is an important material for the investigation. It was sourced from an active mine Bharatpur opencast coal mine, Talcher, Odisha. It is situated at about 300 km from Rourkela . The coal belongs to Gondwana sequence. Major part of the area is covered by Barakar / Karharbari / Talcher exposure with east west strike of beds. The typical overburden material consists of alluvium, laterite, fine to medium grained sandstone, carbonaceous shale, pink clays, etc. The mine produces coal of about 9 MT annually. The layout of the mine permanent haul roads and branch haul roads which are connected with the coal transportation roads is shown (Figure.2). The length of main haul road is 5.760km and branch haul roads are 930m, 1.150km, and 1.335km at different locations of the mine. Haul roads are basically flexible pavement type which are designed by California Bearing Ratio (CBR) method. The mine follows drilling, blasting, loading and dumping operations. Shovel and dumper combinations are used to handle over burden materials. 50ton and 85ton dumpers (make: BEML and Hindustan) are used to haul overburden material.

**Collection method of overburden material**

The overburden dump area is about 2 to 2.5 kms from the active benches. The over burden area spreads about 300m long and 400m wide. Dozers/spreaders are used to spread the material once dumpers dump those. Samples for testing were selected and collected that those represent the average materials found in the mine. Sample collections were carried out from all parts of the dump area. Gunny bags were used to collect the loose soils sample leaving the gravels, boulders etc aside. The process followed for fly ash collection was also repeated to collect overburden material. The material was explored in the laboratory sieved to discard gravels, pebbles etc. The materials were thoroughly mixed, covered for 2 hours for homogenization and then stored in poly pack for experimentations.

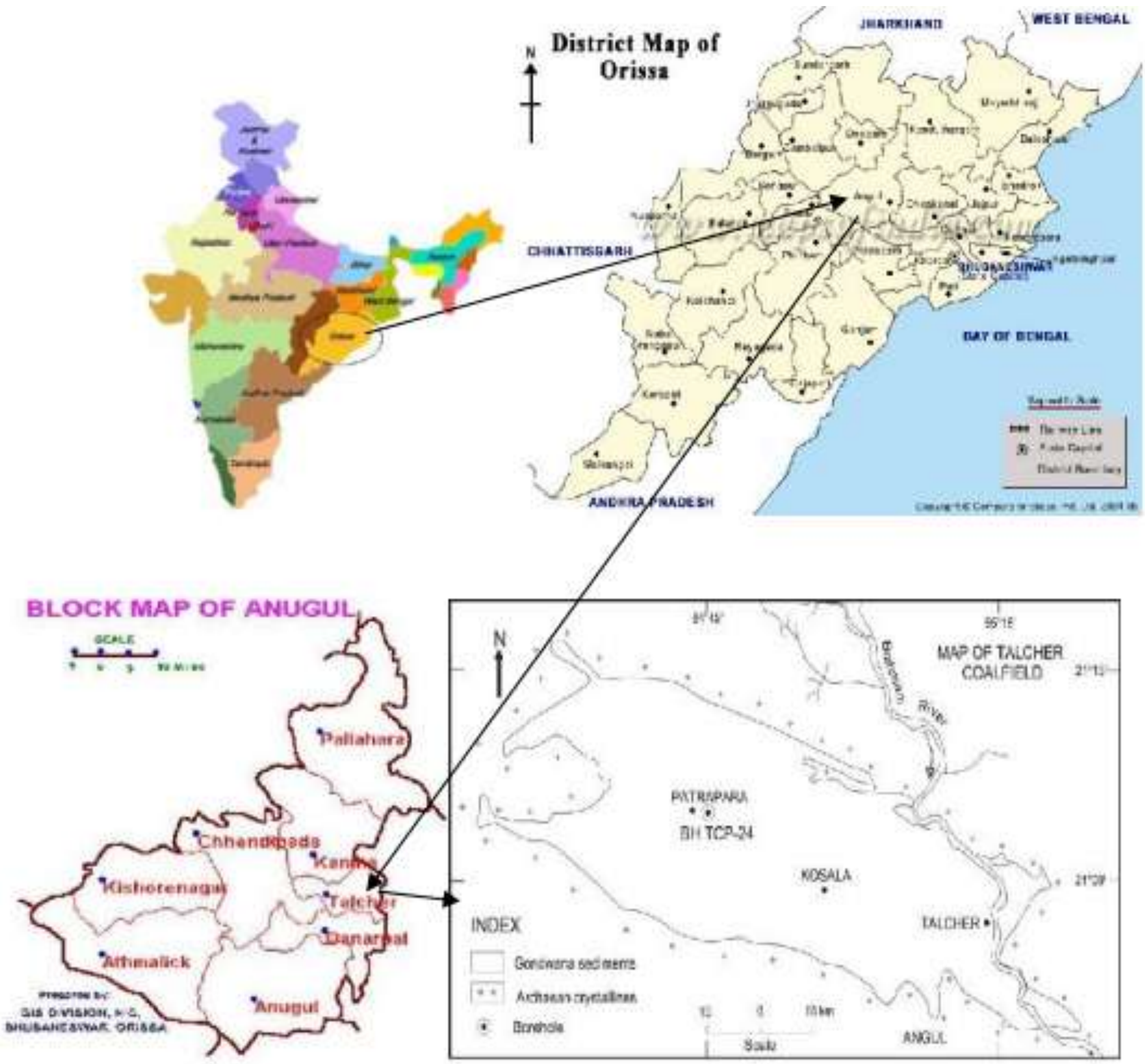


**Figure 2: Map of Talcher Coalfield, Odisha**

**Figure 3 : Collection of mine overburden**

**Observation from mine visit**

Frequent mine visits were made to Bharatpur opencast mine, Talcher not only to collect overburden samples but also to obtain mine operation data, to inspect the haul road condition and study the haul road construction process, to hold discussion with mine officials as well as with dumper operators, to critically observe the various problems associated with haul road, etc. A sample photograph (Figure.4) depicts the observation.


**Figure 4: Undulations and potholes are marked in the haul roads**

## RESULTS AND DISCUSSION

A typical surface coal mine in India has about 5km of permanent haul road with a life span of 25 to 30 years. The carrying capacity of transportation trucks as well as other heavy machineries undergoes many upward revisions in the life of an operating coal mine as the demand for fuel continues to increase. However the design of haul road and its construction do not undergo corresponding improvement. It is often observed that mine operators simply cut or fill haul roads with the materials existing at the location to save capital cost. In case of acute adverse condition, only the surface course of the haul road is repaired without, any change to other courses, specifically to subbase course. So, it is most important to design and build the haul road sub-base with material of sufficient bearing capacity. The engineering properties of a material are dependent on the composition of material to a great extent. There exists wide variation in the composition of fly ash depending on coal type, type of furnace, temperature, collection mechanism, etc (Mishra, 2003). The overburden material over coal strata in the Gondwana basin also exhibit similar heterogeneous attributes. The pertinent geotechnical properties of the develop materials were determined as per established mechanism. All the results of the above investigation and their corresponding analyses have been presented in different section as mentioned below:

**Tensile strength characteristics**

The tensile strength is a vital parameter to evaluate the suitability of the stabilized soil or fly ash as road base material. Tensile strength is an important property to predict the cracking behavior of pavement, structures using stabilized soils (Baghdadi et al., 1995). In the present study split tensile test was conducted on specimen to characterize the tensile strength and the cracking behavior of lime treated fly ash–overburden material as described in section 2.3. The tensile strength of untreated fly ash, untreated overburden as well as untreated fly ash–overburden composite materials was very low and hence not reported here. However the behavior of composites changed dramatically and values could be recorded as lime was added. The treated fly ash–overburden composite materials at 7 and 14 days exhibited marginal values due to low strength and hence not reported here.

All the specimens failed more or less at the middle through an induced force which is tensile in nature . The failure occurred within 60 to 100 seconds. At 28 days curing all composites showed more than 50kPa strength values with maximum values at 9% lime with 30% fly ash and 70% overburden. The sample exhibited 291kPa at 28 days curing (Figure 5.). Brazilian tensile strength of all the composites was between 73 to 357 kPa at 56 days of curing . The mine overburden mixed with 30% fly ash and 9% lime exhibited maximum tensile strength as compared to that of other composites at 28 and 56 days of curing respectively. The strength achieved in all the composites in this investigation is above these values after a period of curing and hence useful for mine haul road construction.

**Figure 5 : Post failure profiles of a few tensile test specimens**

## CONCLUSIONS

In this investigation, potential of lime stabilized fly ash and mine overburden was evaluated for haul road construction and improved the road condition by reducing strain in the road pavement through experimental and numerical study. Lime stabilization is widely used to improve the strength of road building materials. The characterization of fly ash and its interaction behaviour with mine overburden and lime is likely to provide viable solutions for its large scale disposal and utilisation in geotechnical applications as mine haul road construction. Strength characteristics of any construction material are vital parameters to judge its suitability. Strength characteristics of the fly ash composites are studied through different conventional test methods such as CBR, unconfined compressive strength, Brazilian tensile strength and ultrasonic velocity which cover a broad area of design parameters, useful for mine haul road application and to understand the engineering behaviour of composite materials. Microstructural analyses carried out to gain better understanding of the mechanism of lime, fly ash and overburden interaction. The change in surface morphology and variation in chemical composition due to formation of hydration products were analyzed through scanning electron micrographs and energy dispersive X-ray results. X-ray diffraction analyses were carried out to identify the hydration production phases. Leaching studies were carried out to analyze heavy metal concentration in the composites. The numerical studies (2- dimenstional finite element modeling) were carried out to study the effectiveness of the developed composite materials on the stress-strain behaviour of haul road pavement.

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