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# Harmonising Environment and Ecological Sustainability by Utilization of Fly Ash in Rigid Pavement

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**ABSTRACT**

*A huge quantity of fly ash is generated daily in 82 major thermal power stations of India. The safe disposal of this fly ash is the major environmental and socio-economic problem. Conventional method of Rigid Pavement construction requires various natural resources like metal stone, sand, murum, cement, etc. and hence causes ecological degradation and imbalance. The cement is a costly ingredient in such construction. The use of fly ash in rigid pavement construction as cement replacement by 10-30% will save such resources and hence reduces the resultant concrete without any loss in strength. So, use of fly ash in concrete solves the disposal problem and automatically reduces the construction cost. If fly ash is utilized on large scale for rigid pavement construction, harmonized environment and sustainable ecology and economic development of the road infrastructure, can be possible.*

**KEYWORDS: rigid pavement, fly ash, concrete, sustainable, economic development**

## INTRODUCTION

Thermal industry waste as fly ash is a fine glass powder recovered from gases emitted by burning coal during the production of electricity. Fly ash is a major waste of coal-based thermal power plants. Fly ash disposal is a significant environmental concern as it creates huge pressures on land and water and fugitive emissions.

Use of Fly Ash in construction of rigid pavement will improve transportation functionality and ecological sustainability and results in improved traffic safety and reduced life-cycle cost.

Use of Fly Ash in construction of rigid pavement will benefit transportation, the ecosystem, urban growth, public health and surrounding communities by encouraging smart growth by integrating and guiding future growth.

Roads are dominant mode of transportation in India today. They carry almost 90% of the country's passenger traffic and 65% of its freight. The density of India's highway network – at 0.66 km of highway per sq. km of land is similar to that of the United States (0.65) and much greater than China's (0.16) or Brazil (0.20). However, most highways in India are of poor surface quality and road maintenance remains under funded; and 40% of India's villages do not have access to all–weather roads and remains cut off during monsoon season.

Transport sector accounts for a share of 6.4% in India's Gross Domestic Product (GDP). Road transport has emerged as the dominant segment in India's transportation sector with a share of 5.4% in India's GDP. Road transport demand is expected to grow by around 10% per annum in the backdrop of a targeted annual GDP growth of 9% during the Eleventh Five Year Plan.

Major improvement in the transportation sector are required to support the country's continued economic and to reduce poverty.

**TABLE 1**
**INDIAN ROAD NETWORK**

| Indian Road Network | |
|---|---|
| Indian road network of 42 lakh Km. is second largest in the world and consists of : | |
| Road Category | Length(In Km) |
| Expressways | 200 |
| National Highways | 70,934 |
| State Highways | 1,50,342 |
| Other PWD Roads | 863241 |
| Rural Roads | 2577396 |
| Urban Roads | 574516 |
| Total Length | 4236429 Km |

Source: Indian road congress

## APPLICATION OF FLY ASH IN ROAD CONSTRUCTION




Figure 1 application of fly ash in road construction

Source: American coal ash association (2003), "fly ash facts for highway engineers", report no: FHWA-IF-03-019

## FLY ASH IN PORTLAND CEMENT CONCRETE

Fly ash is used in concrete admixtures to enhance the performance of concrete. Portland cement contains about 65 percent lime. Some of this lime becomes free and available during the hydration process. When fly ash is present with free lime, it reacts chemically to form additional cementitious materials, improving many of the properties of the concrete.

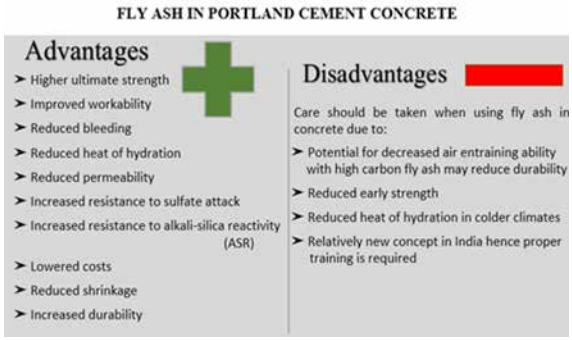



Figure 2 fly ash in portland cement concrete

Source: American coal ash association (2003), "fly ash facts for highway engineers", report no: FHWA-IF-03-019

## CLASSIFICATION OF FLY ASH

The chief difference between these classes is the amount of calcium, silica, alumina, and iron content in the ash. The chemical properties of the fly ash are largely influenced by the chemical content of the coal burned.

**1. Class N Fly ash:** Raw or calcined natural pozzolans such as some diatomaceous earths, opaline chert and shale, stuffs, volcanic ashes and pumice come in this category. Calcined kaolin clay and laterite shale also fall in this category of pozzolans.

**2. Class F Fly ash:** Fly ash normally produced from burning anthracite or bituminous coal falls in this category. This class of fly ash exhibits pozzolanic property but rarely if any self-hardening property.

**3. Class C Fly ash:** Fly ash normally produced from lignite or sub- bituminous coal is the only material included in this category. This class of fly ash has both pozzolanic and varying degree of self cementitious properties. (Most class C fly ashes contain more than 15 % CaO. But some class C fly ashes may contain as little as 10 % CaO.

**TABLE 2**
**CHEMICAL REQUIREMENTS OF FLY ASH**

| CHEMICAL COMPOSITION OF FLY ASH | Class | | |
|---|---|---|---|
| | N | F | C |
| Silicon dioxide (SiO2) plus Aluminium oxide (Al2O3) plus Iron oxide (Fe2O3), Min, % | 70.0 | 70.0 | 50.0 |
| Sulphur trioxide (SO3), Max, % | 4.0 | 5.0 | 5.0 |
| Moisture content, Max, % | 3.0 | 3.0 | 3.0 |
| Loss on ignition, Max, % | 10.0 | 6.0 | 6.0 |

Source: ASTM C618 - 12a Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete)

**FLY ASH: ENVIRONMENTAL BENEFITS**




Figure 3 fly ash: environmental benefits

Source: American coal ash association (2003), "fly ash facts for highway engineers", report no: FHWA-IF-03-019

**ENERGY SAVINGS AND ENVIRONMENTAL BENEFITS**

Most of the developing countries face energy scarcity and huge housing and other infrastructure shortage. Ideally in these countries materials for habitat and other construction activities should be energy efficient (having low energy demand). The following table shows some examples of energy savings achieved through the use of Fly Ash in the manufacture of conventional building materials. It should be noted that use of Fly Ash also improves the properties of building material, as mentioned above:

**TABLE 3**
**ENERGY SAVINGS IN THE MANUFACTURE OF BUILDING MATERIALS THROUGH USE OF FLY ASH**

| BUILDING MATERIAL | COMPOSITION | MATERIAL COMPARED | ENERGY SAVINGS (%) |
|---|---|---|---|
| Portland pozzolana cement | 75% Ordinary Portland cement 25% Fly Ash | 100% Ordinary Portland Cement | 20 |
| Lime-pozzolana mixture | 25% Acetylene gas lime 75% Fly Ash | 25% Lime 75% Calcined brick | 75 |
| Calcium silicate brick | 90% Fly Ash tailings 10% lime (waste source) | Burnt Clay brick | 40 |
| Burnt brick | 75% Clay 25% Fly Ash | Burnt Clay brick | 15 |

Source: Building Materials in India: 50 Years – A Commemorative Volume, Building Materials & Technology Promotion Council, New Delhi, India, 1998.

**ESTIMATION OF RESOURCE SAVINGS ASSOCIATED WITH FLY ASH UTILISATION**

Fly ash utilisation will lead to savings in natural resources, mainly the land (and soil), water, coal and limestone. Large-scale utilisation of fly ash in the manufacture of bricks and the construction of road embankments will release considerable amounts of land. Water will be saved due to reduced fly ash disposal from power plants. PPC production will lead to reduced coal consumption as well as savings in limestone due to reduced clinker requirements.

**1. Land saved**

Fly ash utilisation would lead to reduced land/soil requirement for (1) ash ponds, (2) clay brick production and (3) the construction of road embankments.

**2. Water saved due to reduced ash disposal**

Ash is mixed with water to form slurry. The slurry is then pumped and disposed to the ash pond through pipelines.

**3. Coal saved due to PPC production**

The thermal and electrical energy required for production of PPC is less than that required for production of OPC. Generally coal is used as the source of thermal energy in cement plants.

**4. Limestone saved due to PPC production**

Limestone is required in the process of clinker production. The clinker requirements for the production of OPC and PPC are not equal and also vary with the process adopted for clinker production, i.e. dry, semi dry and wet processes. The clinker consumption for production of PPC is less than that consumed in the production of OPC in all processes of cement production.

TYPES OF RIGID PAVEMENT CONSTRUCTION BASED ON FLY ASH

The problem of fly ash utilization is not confined to India alone but is being experienced all over the world. However this problem is particularly acute in countries like India, where utilization of fly ash has not received much attention. The degree of its utilization varies among different countries. In India, the present rate of utilization is only about 10 percent, which is below the world average of about 16 percent.

1. Construction of Semi-Rigid/Rigid Pavements
2. Cement Fly ash Concrete Pavement
3. Dry Lean Fly ash Concrete

**CASE STUDY**

**Use of Fly Ash in Concrete Mixes for the Construction of Rigid Pavement from Dadri to Dehra Jhal, U.P., India**

The project was sponsored by National Thermal Power Corporation Limited, Dadri, U. P. the Scope of work involved evaluation of fly ash used in the concrete, development of suitable fly ash admixed concrete mixes, on-site demonstration and training of staff about construction methodology for fly ash based concrete road, random quality checking of materials, concrete mixes and laboratory testing of concrete samples prepared at site.

The work involved the construction of approximately 14 km long concrete pavement from Dadri to Dehra Jhal via NTPC Plant over existing bituminous pavement. The designed thickness of the roads is 28 cm to be provided over 10 cm thick dry lean concrete sub base. The designed 28 days flexural strength of the pavement quality concrete is 4.5 MPa. A concrete mix containing 371.25 kg/m3 of Ordinary Portland Cement and 98.84 kg/m3 of fly ash was suggested. On-site training, demonstration and instructions were given to the staff for carrying out the quality construction of concrete roads. The construction was carried out by adopting semi-mechanized methodology using needle and screed vibrators. Fig.4 shows the laying of Pavement Quality Concrete (PQC) with screed vibrators and Fig.5 shows a view of the constructed portion of the road.



Figure 4 PQC laying with Screed Vibrator



Figure 5 View of the constructed road

Source: Pavement Engineering and materials for Rigid Pavements, Central Road Research institute, Annual Report 2009-10

## CONCLUSION

Fly ash is a resource and not a waste product. Major initiatives are needed in India to use this large volumes in construction industry especially in rigid pavement construction and other infrastructure projects. India should aggressively identify projects that can use large amount of fly ash in road construction so that harmonising environment and ecological sustainability can be developed. Use of fly ash in road construction works will result in the less depletion of naturally available stone metal, gravel, sand and soil; and will save cement, which is the costliest ingredient will lead to reduction in construction cost. It will also help to solve the problem of safe disposal of the fly ash. However to achieve this objective, proper characterization of fly ash is necessary. With adequate knowledge on performance of fly ash based road pavements, a huge demand can be expected from the road sector to use fly ash for construction purposes.

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