Fly Ash Utilisation for Value Added Products
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Use of fly ash admixed concrete for pavement construction*

U.K. GURU VITTAL and SATANDER KUMAR
Scientists, Central Road Research Institute, New Delhi-110 020

1.0 INTRODUCTION

Fly ash is the inorganic portion of the source-coal obtained as waste material from thermal power stations. It is usually found in the form of spherical, often hollow spheres of silicon, aluminium and iron oxides and unoxidised carbon. Coal fired power plants produce millions of tonnes of fly ash annually, but only a fraction is productively employed. The balance must be disposed in ash ponds at great expense. On the other hand R&D work carried out in India and abroad has established that fly ash can be converted to meaningful wealth as a construction material, especially as an additive to cement concrete.

Fly ash improves the properties of both fresh and hardened concrete. In green state, fly ash added to cement concrete results in reduction of heat of hydration and increases the workability. It improve the strength of hardened concrete at later stages. Fly ash makes efficient use of products of hydration of portland cement. Besides, the economy achieved by addition of fly ash, most important gain, would be increased in durability of concrete.

2.0 DURABILITY OF FLY ASH ADMIXED CONCRETE

Concrete in service is exposed to a range of external and internal stresses, environmental and material related, which can lead to a reduction in service life or premature failure of the concrete. Some of the environmental stresses include aggressive chemicals in groundwater or soils, cycles of freezing and thawing and exposure to de-icing chemicals. Material related stresses can be a result of alkali-silica or alkali-carbonate reactions, excessive shrinkage and related micro-cracking, thermal stresses from excessive heat of hydration, high permeability, etc..

The traditional method of improving concrete durability by raising the portland cement content is not sufficient to protect concrete in service from many of these destructive forces. Present day cements are typically more finely ground and contain higher C_3S content to achieve higher early strength. Because of these characteristics, more heat is generated rapidly during cement hydration, and more water soluble calcium hydroxide is created. Increased cement content contributes to increased drying shrinkage and thermal stress, and provides additional alkalies to support alkali aggregate reactions. Proper use of mineral admixtures such as fly ash will improve concrete properties related to durability.

*Full text of paper

2.1 Permeability Reduction

To achieve high durability, concrete requires a high degree of impermeability. Highly impermeable concrete will resist the intrusion of external chemical attack (sulphates and chlorides) as well as water penetration. Moisture is also required to activate alkali-aggregate reactions, and to initiate corrosion of reinforcing steel. A decrease in concrete permeability improves durability.

Use of fly ash creates a discontinuous pore structure and clogs channels with the additional hydration products. The result of these reactions will be slower transport rates for both water and chlorides through the cementitious paste. The consumption of water-soluble calcium hydroxide (produced as a by-product of hydration of portland cement) by the pozzolanic reaction creates additional calcium silicate gel, which is much denser than the gel without the pozzolana. The modification of pore structure and permeability reducing effect is more pronounced in case of Class F fly ash (produced by burning Anthracitic coal) than with Class F fly ash (produced by burning Lignite coal).

2.2 Sulphate Resistance

Use of an effective pozzolana will reduce the potential for expansion due to sulphates. The mechanism is three fold: the pozzolanic reaction reduces the calcium hydroxide content of the concrete, the use of Class F fly ash reduces the absolute amount of calcium aluminate available to support ettringite formation by reducing the cement content, and permeability of concrete is reduced, thus diminishing the sulphate penetration.

Research has shown that Class F fly ash is more effective in reducing sulphate attack. Class F fly ash used at a relatively high percentage of the total cementitious content will provide a high degree of protection, when combined with the appropriate type of cement. The effect is even more pronounced in lean concretes, where additional fly ash produces dramatic permeability reductions.

2.3 Alkali-Silica Reaction

Fly ashes when compared with low alkali cements, typically contain high levels of silica. This silica, present as highly reactive silicates, is responsible for the pozzolanic properties of fly ash. Alkalies (sodium and potassium hydroxide) form during the hydration of portland cement, and co-exist with calcium hydroxide in the gel/pore water structure. The fly ash pozzolanic reaction also combines some of the alkali metals into the calcium silicate matrix, rendering them unavailable to support alkali-silica reaction. Studies have shown that alkali-silica reaction is substantially reduced in concretes containing very high percentages of fly ash. Where alkali-silica reaction is a concern, cement contents (the major source of alkalies) should be kept as low as possible. In general, a higher fly ash content means a lower potential for alkali silica reaction.

3.0 PAVEMENT CONSTRUCTION USING FLY ASH ADMIXED CONCRETE

Use of cement concrete for road pavement construction is increasing due to its several benefits like improved serviceability, reduced maintenance cost, ability to withstand traffic loading, etc. Fly ash admixed concrete can be used for constructing rigid pavements in many ways. They include Dry lean fly ash concrete, Roller compacted cement concrete, Fly ash cement concrete pavements, Fly ash admixed concrete paving blocks, etc.

3.1 Dry Lean Fly ash Concrete (Lean Cement Fly ash Concrete)

The beneficial effects of addition of fly ash like reduced bleeding, segregation and improved plasticity, cohesiveness in wet concrete are more pronounced in the case of lean cement concrete, permitting its easier placement and finishing. Cement content is low in Dry lean Fly ash concrete, and hence replacement of sand upto 50 percent is usually adopted. R&D work at CRRI has shown that 100-175 percent increase in the compressive strength of lean cement fly ash concrete (in which 50 percent of sand has been replaced by Fly ash) over plain mixes of equivalent proportions. Typical mix proportions of lean cement fly ash concrete that have been found to be satisfactory are 1 cement : 3.5 sand : 3.5 Fly ash: 14 Coarse aggregate (by weight).

3.2 Cement Fly ash Concrete Pavement

In concrete roads and runways, a part of cement and sand can be replaced by good quality fly ash to the extent of 10-30 percent and 5-15 percent respectively. This would result in lowering cost of resultant concrete and saving in cement without any loss of strength. The design and construction techniques of cement-fly ash concrete pavement are identical with that of conventional cement concrete pavement.

3.3 Roller Compacted Concrete

In roller compacted concrete paving technology, 30-50 percent of cement can be replaced using fly ash. Since this type of paving requires zero slump concrete, better workability can be achieved by using fly ash keeping the same water/ cement ratio. Ordinary static road rollers can be used for compaction of roller compacted concrete.

4.0 CONSTRUCTION OF DEMONSTRATION ROAD STRETCHES

To demonstrate construction of road stretches using fly ash admixed Dry lean concrete and roller compacted concrete, 200 m stretch was selected in BC soil area near a thermal power station. The road stretch was in MDR and traffic density was low. Dry lean fly ash concrete was used for base course and roller compacted concrete for wearing course. The cross section of the pavement adopted is shown in fig. 1.

Dry lean fly ash concrete (1:3.5:3.5:14) was used for base course. During laboratory investigations, the 28 days compressive strength of dry lean concrete was found to be 75 kg/sq.cm. The 28 days compressive strength of roller compacted concrete (1:1.5:3) with 40 percent replacement of cement by fly ash was found to be 270 kg/sq. cm. However taking into consideration , quality control limitations during field construction, the percentage of fly ash admixture was limited to 30 percent. The stretch has been constructed successfully and its performance has been found to be very good after one year. Further monitoring of its performance is proposed.

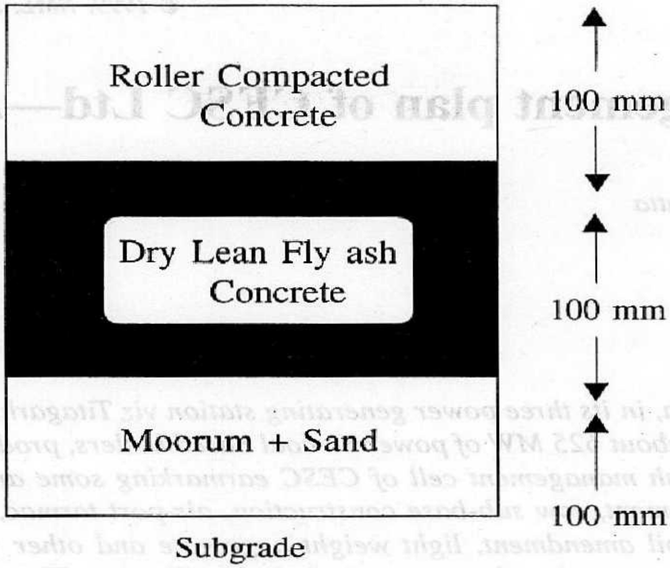

Fig. 1 : Pavement Cross Section

5.0 CONCLUSIONS

The technical benefits of Fly ash use and the mechanism of Fly ash cement reaction are well known. Adequate amount of pozzolana like fly ash impart properties to concrete that can not be achieved by increasing cement content alone. The goal of producing a durable concrete for longer design life and expected level of service invariably needs fly ash. At a time, when many cement concrete road works are being planned, judicious use of Fly ash as an admixture will go a long way in helping us construct better roads.

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