Behaviour Analysis of High Volume Fly Ash Concrete

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Abstract

Now a day's concrete pavements are gaining popularity for its own good paving properties, as such consumption of cement is increased drastically. As cement demand increases, production also increases. Every ton of production of cement releases approximately 7% carbon dioxide to environment. In many industries, including power plants, coal is used as fuel. This generates tonnes of coal ash, which is very difficult to dispose off, which in turn causes pollution. Thus the production of cement and electricity contributes huge amount of carbon dioxide emissions and coal ash causing environmental pollution. The present study aims at developing a concrete by replacement of Ordinary Portland Cement (OPC) Up to 50% Fly Ash by mass. The fresh and hardened properties of High Volume Fly Ash Concrete (HVFAC) with 50% replacement of cement and Ordinary Portland Cement Concrete (OPCC) are studied. The study discloses that high volume of Fly Ash in concrete reduces the water demand and improves the workability. Study also reveals that OPCC and HVFAC exhibit similar hardened properties. Comparison of flexural response of beams made with OPCC and HVFAC with different percentage of reinforcement are also studied. It is observed that HVFAC beams have shown notable improvement in the deflection, cracking behaviour and load carrying capacity.
Keywords: Concrete, Fly Ash, Behaviour Analysis, Improved Properties, Ordinary Portland Cement

I. INTRODUCTION

Fly ash is a waste product generated by coal burning power plants. It has been generally used for land filling. However in places where regulations preventing atmospheric pollution do not exist, it is billowed into the atmosphere. Fortunately the discovery made several years back that fly ash can be used as a partial replacement for cement in concrete as Millions of tons of cement is used every year that adversely affects environment. Cement is also an important building material for infrastructure development. Cement can be suitably replaced with low cost fly ash favoring environment and saving cement. It is very economical and favorable to replace cement in concrete with high volume of fly ash as large length of roads is required to be built in near future over the globe in general and in India in particular. The present technology of making flexible pavements is increasingly becoming unsustainable because of rising life cycle costs and could be suitably replaced with high volume fly ash based concrete roads.

Cement concrete is the most widely used construction material in any infrastructure development projects. The production of Portland cement, an essential constituent of concrete releases large amount of CO2 into the atmosphere. These gases are the major contributor to the greenhouse effect and the global warming of the planet, which is a major global environmental global issue currently the planet is encountering. The development and use of mineral admixture for cement replacement is growing in construction industry mainly due to the consideration of cost saving, energy saving, environmental production and conservation of resources. Mineral admixtures generally used are raw fly ash, rice husk ash, met kaolin, silica fume etc. Addition of such materials improves the concrete property. Fly ash is finely divided residue resulting from the combustion of powered coal and transported by the flue gases and collected by electrostatic precipitator. There are multiple benefits for the sustainable development of the construction industry by using fly ash to increase the strength characteristics of structural members. Fly ash reacts with calcium hydroxide, a byproduct of the hydration of Portland cement. Use of cement leads to large amount of CO2 emission which leads to environmental problem. Fly ash which is obtained from thermal power plant when added to cement reduces the cost and the problem of disposal of fly ash is solved.

II. HIGH VOLUME FLY ASH CONCRETE

High volume fly ash (HVFA) concrete uses high volumes of fly ash to replace the Portland cement content. Replacement levels as high as 60% has been reported to be successful (Hardjito and Rangan, 2005). HVFA concrete has been proven to be more durable and resource-efficient than the OPC concrete (Malhotra, 2002). The HVFA technology has been trialled in the field, for example the construction of roads in India, implemented 50% OPC replacement by the fly ash (Desai, 2004). The use of fly ash can improve workability, easier flow ability, pump ability, compact ability, reduce heat of hydration and increase resistance to sulfate attack, alkali-silica reactivity (ASR) and other types of deterioration as compared to normal mixes (Solis et al., 2010). HVFA concrete have very high durability to the reinforcement corrosion, alkali-silica expansion, sulfate attack, and have superior dimensional stability and resistance to cracking from thermal shrinkage, autogenously shrinkage, and drying shrinkage (Mehta, 2004). HVFA concrete has better surface finish and quicker finishing time when power finish is not required (Mehta, 2004). It has slower setting time and will have a corresponding effect on the joint cutting and lower power-finishing times for slabs. One major issue with HVFA is the slower strength gain where usually 90 days will be needed to gain the full strength potential (Mehta, 2004). With HVFA concrete mixtures, the strength enhancement between 7 and 90-day often exceeds 100%, therefore some researchers believe that it is unnecessary to overdesign them with respect to a given specified strength (Mehta, 2004). HVFA concrete has much higher electrical resistivity and resistance to chloride ion penetration after three to six months of curing according to ASTM Method C1202 (Mehta, 2004). HVFA concrete has better cost economy due to lower material cost and highly favorable lifecycle cost (Solis et al., 2010, Mehta, 2004). These concrete have superior environmental friendliness due to ecological disposal of large quantities of fly ash, reduced carbon-dioxide emissions, and enhancement of resource productivity of the concrete construction industry (Mehta, 2004).

III. CONSTRUCTION AND PERFORMANCE OF INDIA'S FIRST HIGH VOLUME FLY ASH (HVFA) CONCRETE ROAD IN ROPAR, PUNJAB

A. *Duration: April 2005 to March 2006 (Gujarat Ambuja Cements Ltd., Ahmedabad)*

1) *Present Status and Progress*

Completed Findings/Conclusions India has very huge infrastructure needs. Concrete roads are having proven advantages over the traditional bituminous roads except that of high initial costs.

The use of fly ash upto 50% reduces the cost of concrete road substantially making it almost at par with bituminous roads. Further, use of fly ash in concrete roads increases durability and performance. For the first time in India, Gujarat Ambuja Cements Ltd. constructed a High – volume fly Ash (HVFA) concrete road at Ropar in the state of Punjab, India. The road has been constructed with the use of 50% fly ash, available from the Ropar Thermal Power Plant, replacing cement, and providing high performance and durable concrete. The road was designed by M/s Gujarat Ambuja Cements Ltd. for Indian conditions on the line of technology used in U.S.A. and Canada. Construction of this two-lane (7 metre wide), 300 mm thick and 0.75 km long road was completed within two and half months. No paver machine was used for the construction of this small section of HVFA concrete road. Conventional concrete mixture machine, vibrating tools, normal pond curing method were adopted.

The road is performing very well under heavy load vehicular traffic. (More than 500 trucks/commercial vehicles per day with an average weight of 15 to 45 MT.)

- High-volume Fly Ash (HVFA) concrete roads are one of the possible answers as an economical alternative for flexible pavements, and would be beneficial for developing countries.
- HVFA concrete in which, ordinary Portland cement is replaced by 50% fly ash, provides high strength, high performance durable concrete.
- For new roads, the cost of HVFA concrete is almost at par with bituminous roads.
- Like the conventional concrete roads, HVFA concrete road has high service life without major maintenance, needs less lighting, is not affected by rains, allows smooth traffic flow, causes low were and tear of vehicles, provides savings in fuel, and is environmental friendly.
- HVFA concrete is ideal for rural roads, district roads, state and national highways.

IV. FLY ASH AN INDUSTRIAL BY-PRODUCT

Fly ash is a by-product of the combustion of pulverized coal in thermal plants. The dust collection system removes the fly ash, as a fine particulate residue, from the combustion gases before they are discharged into the atmosphere. Fly ash types are typical spherical, ranging in diameter from <1μm upto150μm.

The type of dust collection equipment used largely determines the range of particle sizes in any given fly ash. The fly ash from boilers at some older plants using mechanical collectors alone is coarser than from plants using electrostatic precipitators. In Thermal Power Stations, two types of coal ashes are produced, the one which is light and flies up the chimney is known as fly ash and other slightly heavier and gets deposited at the bottom is called bottom ash Put together, it is known as pulverized fuel ash (PFA). It is worth noting here that in India, pulverized fuel ash is commonly known as fly ash. The properties exhibited by the ash are conditioned by their collection and disposal method. Several other parameters such as type and source of coal (bituminous, sub bituminous, or lignite), design of combustion system, combustion conditions (primarily temperature), and method of collection during generation of fly ash can influence its properties.

V. CHEMICAL COMPOSITION OF FLY ASH

Table – 1
Chemical Composition of Fly ash

Al_2O_3	*31.23%*
SiO_2	*61.12%*
CaO	*.66%*
MgO	*.75%*
SO_3	*.53%*
Fe_2O_3	*1.5%*
Na_2O	*1.35%*
K_2O	*.84%*
TiO_2	*1.83%*

VI. ENGINEERING AND GEOTECHNICAL PROPERTIES OF FLY ASH USED

Table – 2
Engineering and geotechnical properties of fly ash used

Liquid limit	*23.9%*
Plastic limit	*13.14%*
Plastic index	*10.76%*
Specific gravity	*3.26*
Optimum Moisture Content	*31.2%*
Maximum Dry Density	*1.2 g/cc*
Cohesion	*Negligible*
Angle of Internal Friction	*35º*
Permeability	*1.3×10^{-4} cm/sec*
Optimum Moisture Content	*31%*
Maximum Dry Density	*1.22 cc*

VII. DETAILS OF MIX PROPORTION AS PER IS10262-1982

Table – 3
Details of Mix Proportion as per IS10262-1982

Mix	*M1*	*M2*
Fly ash % age	*0*	*50*
W/c ratio	*.37*	*.39*
Cement in Kg/m^3	*420*	*210*
Fly ash in Kg/m^3	*0*	*210*
Fine aggregate Kg/m^3	*750*	*568*
Coarse aggregate type 1 Kg/m^3	*720.25*	*785.50*
Coarse aggregate type 2 Kg/m^3	*354*	*386*
Water kg/m^3	*150*	*162*
slump	*12*	*.20*
Compaction factor	*.79*	*.82*

*M1 – controlled M40 mix without any flyash *M2-HVFAC with 50% flyash

VIII. RESULTS AND DISCUSSION

Temperature is one of the main factors that influence the strength. High temperature induces a loss of strength (both in compression and tension) and stiffness (Young's modulus). At high temperatures, chemical transformation of the gel weakened the matrix bonding, which brought about a loss of strength of fly ash concrete. 3.1 Compressive Strength In this research, the values of compressive strength for different fly ash contents (0%, 30%, 40% and 50%) incorporating different temperature (40ºC, 80ºC ,100ºC, and 120ºC) at the end of different curing periods (28 days, 56 days) are given. The results have also been plotted, which shows the variation of compressive strength with cement replacements at different curing ages respectively and variation of compressive strength for different fly ash percent incorporating different degree of temperature. The compressive strength was calculated as the average of three cylinder tests. It is evident that compressive strength of concrete mixtures with 30%, 40% and 50 % of fly ash as cement replacement was lower than the control mixture (M-0) at all ages and that the strength of all mixtures continued to increase with the age. With the increase in temperature, compressive strength of concrete mixes with

30%, 40% and 50 % of fly ash as cement replacement decreased. Compressive strength decreased with the increase in fly ash at different temperature. Compressive strength also decreased with the increase in temperature.

IX. COMPRESSIVE STRENGTH (MPA) OF FLY ASH CONCRETE

Table - 4
Compressive Strength (MPa) of Fly Ash Concrete

Sr. No.	*No. of curing days*	*M1 N/mm²*	*M2 N/mm²*
1	*3*	*22.2*	*18.1*
2	*7*	*34.88*	*25.2*
3	*28*	*51.3*	*34.1*
4	*56*	*-*	*49.5*
5	*90*	*-*	*50.1*

X. ENVIRONMENTAL BENEFITS

- High volume fly ash utilization has significant environmental benefits including:
- Increasing the life of concrete structures by improving concrete durability, besides exhibiting good workability and better strength.
- Net reduction in energy use and greenhouse gas emissions through cement industry.
- Reduction in amount of coal combustion by products that must be disposed in landfills.
- Conservation of natural resources and materials.
- More sustainable concrete industry.

XI. CONCLUSION

For reducing the adverse environmental impact of concrete industry, the first step can be cement conservation with the aim to check energy consumption and reduce greenhouse gas emission. It is worth mentioning here that though the technology has advanced in all fields including infrastructural one, concrete construction industry is not sustainable. For the benefit of our future generations, we need to make serious efforts to make it more sustainable. Certain recent investigations have be made with the aim to reduce environmental degradation by disposal of high volumes of fly ash in landfill. Use of high volume fly ash concrete in construction is one big step in natural resource conservation and it needs to be promoted all over the world. In fact, it will not be wrong if we call high volume fly ash concrete as a green concrete, since it can protect the environment from global warming to a large extent. There may be some negativity attached to the use of high volume fly ash concrete like slower construction rates as it gains strength slowly and gives lower early strengths. But, the same can be ignored as the later strengths (90 days or more) and durability of high volume fly ash concrete is much better than plain concrete. Moreover, we cannot forget our responsibility towards nature/ environment and shall sacrifice at least time in safeguarding it from global warming and help it be more sustainable

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