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A Study on Low Quality Fly Ash as an Opportunity for Sustainable and Economical Concrete

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ABSTRACT

As concrete usually has been produced by using high quality fly ash and without fly ash (standard concrete). By using high quality fly ash constituents, increase drastically the initial cost of concrete. The objectives of this research work were to intend to study the possibility of producing low cost concrete. To verify the impact of carbon content on fly ash on the strength and durability of concrete. For this purpose it was decided to enhance the 'as received' fly ash by eliminating particles coarser than 75µm, thus reducing the carbon content by 50%. It was also observed that the carbon content did have little impact on the strength and durability of concrete. Applications of fly ash, which is technically, sound, environmentally safe for sustainable development. Use of fly ash in various engineering applications can solve the problem of disposal of fly ash and other purposes. The major constituents of most of the fly ashes are Silica (SiO2), alumina (Al2O3), ferric oxide (Fe2O3) and calcium oxide (CaO). The other minor constituent of the fly ash are MgO, Na2O, K2O, SO3, MnO, TiO2 and unburnt carbon. This paper is study on low quality fly ash as an opportunity for sustainable and economical concrete for a new millennium.

INTRODUCTION

During 2005-06 about 112 million tonnes of ash has been generated in 125 such power stations. With the present growth in power sector, it is expected that ash generation will reach to 175 million tonnes per annum by 2012. To increase the use of fly ash, and to improve the properties of concrete, many investigations on high-volume fly-ash concrete have been made but for using low quality fly ash very less research is done. In general, some classified high-quality fly ash has been used in concrete. Many other kinds of fly ash, due to their low quality, are still unused. The total usage rate of fly ash in concrete is very low. It is, therefore, necessary to investigate and develop concrete incorporating large volumes of low quality fly ash (LVLQFA) to increase considerably the utilization of fly ash. In order to reduce the overall costs of production, it was decided to use high percentage of fly ash to replace OPC.

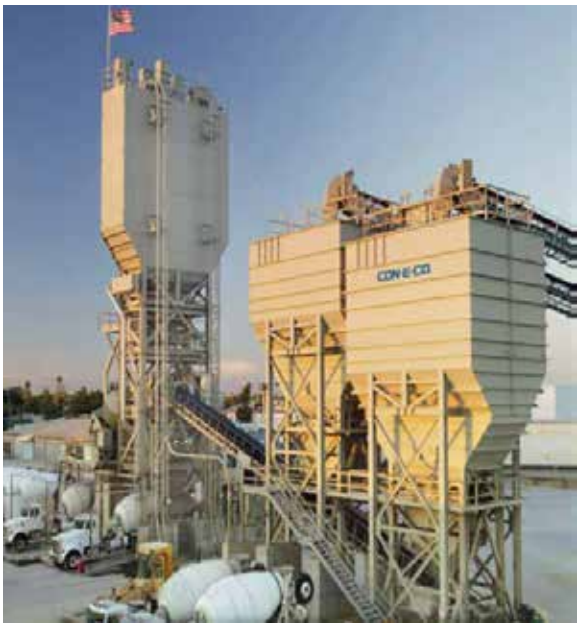

Figure 1 Fly ash plant
Source: Specifying Fly Ash for Use in Concrete by Karthik H. Obla, Ph.D., P.E.

TYPES OF FLY ASH

Three types of fly ash are Class N, C or F. It is true that Class F fly ash is more effective in increasing concrete's resistance to Alkali Silica Reaction (ASR) and sulfate attack. However, rather than disallowing Class C fly ash, durability can be ensured through a performance specification. In some regions, a good quality Class N pozzolana, such as calcined clay, is also used. Slag cement may be the preferred supplementary cementitious material in some markets.

PRODUCTION OF FLY ASH IN INDIA AND WORLD

The Indian Scenario

Fly ash is produced when coal is consumed by power plants. Fly ash can be used beneficially in numerous applications. The highest value application is replacing cement in production of concrete. Fly ash use improves concrete quality and creates significant environmental benefits. The analysis on fly ash production from coal based thermal power stations indicates that 82 power stations, as of today, produce about 155 million tonnes per year by 2012 A.D. with 20% annual rise in the thermal power generation slated for the decade. In India, it is estimated that 130-145 million tons of fly ash is generated by 70 major thermal power plants of which only 6-10 % is utilized by cement, construction and road industries.

TABLE: 1
FLY ASH PRODUCTION IN INDIA

Year	Ash produced in Million Tones(MT)	Ash used in MT
2006-07	116	24.80
2007-08	123	27.15
2008-09	130	29.68
2009-10	138	32.21
2010-11	145	34.74
2011-12	154	38.00
2012-13	163	42.50
Projected values of fly ash utilization		
2013-14	173	48.00

Source : Prof. Jayesh R Pitroda, Thesis, "Techno-Economical Study of Fal-G Bricks in Central Gujarat Region of India" , S.P. University Vidhyanagar, Gujrat, June 2009

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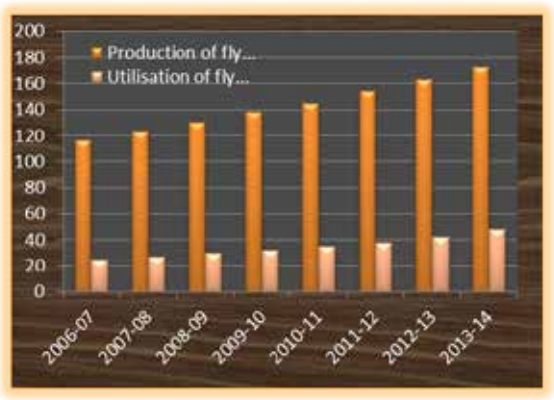

Figure 2 Fly ash production and utilization India
Source: Fly ash utilization in construction – presents status & future prospects.

TABLE: 2
COUNTRY V/S FLY ASH PRODUCTION: SCENARIO OF WORLD

Sr. No.	Country	Annual Ash Production (Million Tonnes)	Ash Utilization % of Ash Produced
1	USA	75	65%
2	CHINA	100	45%
3	INDIA	112	38%
4	GERMANY	40	85%
5	UK	15	50%

Source: Journal of engineering and technology, S.P.U., Vol-19, Dec.2006

FIGURE 3 Geographical locations of major thermal power plants in India
Source: http://flyashbricksinfo.com/construction/source-of-fly-ash-ash-content-in-indian-coal.html

DEFINATION OF LOW QUALITY FLY ASH
Most standards limit the carbon content of fly ash to 5% while few admit values as high as 7%. As the percentage of carbon content increases then it is known low quality fly ash.

PROPERTIES OF LOW QUALITY FLY ASH

TABLE: 3
CHARACTERISTICS OF LOW QULITY FLY ASH

Moisture (%)	0.09	Total: SiO2 + AL2O3 + Fe2O3 (%)	87.73
Loss on Ignition (%)	7.03	Na2O (%)	0.44
Fineness > 45 µm	27.53	K2O (%)	1.53
Fineness > 75 µm	14.30	MgO (%)	1.45
Free CaO (%)	0.00	SO3 (%)	0.25
Total CaO (%)	2.25	Chloride (%)	0.00
SiO2 (%)	58.46	P2O5 (%)	0.16
AL2O3 (%)	21.47	TiO2 (%)	0.93
Fe2O3 (%)	7.81	Specific Gravity	2.36

Source: "Low cost high performance concrete using low quality fly ash" by Aires Camões, Patrício Rocha, J.C. Pereira, J.B. de Aguiar, Said Jalali

TABLE: 4
LOSS ON IGNITION OF FLY ASH

Fly Ash	L.O.I. (%)
Total 'as received'	7
Particles > 75µm	26.5
Particles < 75µm (enhanced fly ash)	3.5

Source: "Low cost high performance concrete using low quality fly ash" by Aires Camões, Patrício Rocha, J.C. Pereira, J.B. de Aguiar, Said Jalali

HOW FLY ASH WORKS WITH CEMENT IN CONCRETE?
Ordinary Portland Cement (OPC) is a product of four principal mineralogical phases. These phases are Tricalcium Silicate-C3S (3CaO.SiO2), Dicalcium Silicate – C2S (2CaO.SiO2), Tricalcium Aluminate- C3A (3CaO.Al2O3) and Tetracalcium alumino-ferrite – C4AF(4CaO. Al2O3Fe2O3). The setting and hardening of the OPC takes place as a result of reaction between these principal compounds and water. The reaction between these compounds and water are shown as under

2C3S	+	6H		C3S2H3	+	3CH
tricalcium silicate		water		C-S-H gel		Calcium hydroxide
2C2S	+	4H		C3S2H3	+	3CH
dicalcium silicate		water		C-S-H gel		Calcium hydroxide

The hydration products from C3S and C2S are similar but quantity of calcium hydroxide (lime) released is higher in C3S as compared to C2S.

ADVANTAGES OF FLY ASH
- In road Embankments
- In Road way construction
- As Soil reinforcement
- In cement concrete
- In cement construction

OTHER ENGINEERING APPLICATION:
- Manufacture of Portland Pozzolana Cement & Performance improver in Ordinary Portland Cement (OPC).
- Part replacement of OPC in cement concrete.
- High volume fly ash concrete.
- Roller Compacted Concrete used for dam & pavement construction.
- Manufacture of ash bricks and other building products.
- Construction of road embankments, structural fills, low lying area development.
- As a soil amender in agriculture and wasteland development.

LIMITATION

- Fly ash is black, yellow and red in color. In some concretes, this may cause the finished concrete to have a grayish/black tint, which may not be desirable.
- A replacement with fly ash produces a minimal color change.
- Also, the fly ash must be able to meet the quantity requirements of the precast manufacturer.
- Fly ash increases workability of concrete.
- It is possible to replace up to 40% of cement by low quality fly ash with carbon content up to and slightly higher than 7%.

CASE STUDY

In the present study, effects of low quality fly ash as cement replacement on the compressive strength of concrete having mix proportions as per table:5 was investigated. Compressive strength of concretes replacing 0%, 20%, 40%, and 60% of Portland cement by 'as received' fly ash. Tests were performed for compressive strength for all replacement levels of low quality fly ash at different curing periods (3, 7, 28 & 56-days).

TABLE: 5
PROPORTION OF CONCRETE

Mix	Cement	Fly Ash	Gravel	Sand 2	Sand 1
FA 0	500	0	863	306	516
FA 20	400	100	857	327	469
FA 40	300	200	851	349	423
FA 60	200	300	850	370	374

Source: "Low cost high performance concrete using low quality fly ash" by Aires Camões, Patrício Rocha, J.C. Pereira, J.B. de Aguiar, Said Jalali

TABLE: 6
CONCRETE: SLUMP TEST AND COMPRESSIVE STRENGTH

Mix	Slump (cm)	Compressive Strength (MPa)			
		3 days	7 days	28 days	56 days
FA 0	0	53.3	57.3	64.5	67.5
FA 20	3.5	44.7	47.3	59.0	64.8
FA 40	6.0	33.4	35.6	55.8	60.4
FA 60	3.5	13.5	20.1	35.1	43.0

Source: "Low cost high performance concrete using low quality fly ash" by Aires Camões, Patrício Rocha, J.C. Pereira, J.B. de Aguiar, Said Jalali

It is noted that the strength gain of concretes with fly ash replacing Portland cement is slower for early ages, i.e. up to 7 days, due to the induction period for the pozzlanic reactions. It is noted that at 56 days the strength is around 90% of the reference batch, with no fly ash, but with a tendency to increase further. This confirms the well - known fact that the strength gain of fly ash concretes is slower than the comparable reference concretes with no fly ash. No significant difference is noted when comparing results from concretes using 'as received' fly ash, i.e. FA 20 and FA 40.

CONCLUSIONS

It is possible to produce low cost HPC, with 90 day strength in the range of 70 MPa, using low quality fly ash. It is possible to replace up to 40% of cement by low quality fly ash with carbon content up to and slightly higher than 7%. Separation of fly ash and eliminating the coarser size particles, thus, lowering the carbon content by 50% did have significant effect on the strength gain of the concrete. This may well indicate that the limit of carbon content for acceptance of fly ash could be increased from the present 5 or 7%. So, we can say that low quality fly ash utilized for economical and sustainable development of concrete. Uses of low quality fly ash in concrete can save the thermal waste disposal costs and produce a greener concrete for construction. This study concludes that fly ash can be innovative supplementary cementitious Construction Material but judicious decisions are to be taken by engineers.

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