A STUDY OF NALCO FLY ASH ON COMPRESSIVE STRENGTH FOR EFFECTIVE USE IN HIGH VOLUME MASS CONCRETE FOR A SUSTAINABLE DEVELOPMENT

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ABSTRACT

Fly ash is a rich cementitious industrial waste which has the great potential to substitute Portland cement, a major producer of CO_2 and there by decreasing green house gas emissions. The production of fly ash in India is likely to be more than 175 million tons by the year 2012.Though due to lot of efforts by State and Central Government the utilization of fly ash has gone beyond 50%, still a lot has to be done for full utilization of this precious wealth from the waste. The eastern state of Orissa in India has a large coal deposit thus facilitating thermal power plants and producing more and more fly ash day by day. But the effective utilization is restricted only to manufacture of Fly-ash Bricks, producing fly ash based Pozzolanic cement and use in pavements. The utilization in high volume mass concrete is very negligible due to absence of any major infrastructure projects or even a single RMC (Ready Mixed Concrete) plant in the state. In this context a study was made for utilization of fly ash generated by captive power plant of NALCO(National Aluminum Company), Angul, Orissa along with varying dosages of super plasticizer. The various Mix Design as per Bureaue of Indian Standards(BIS) methods were made by replacement of cement from 10% to 40% by fly ash. The super plasticizer helped for compensating the loss in early age strength by reducing the water cement ratio and increasing the workability of the mix. The 28 days target strength of the Mix was achieved with a replacement of 30% of fly ash with the cement. Hence, the efforts have to be made by the Entrepreneurs to establish the RMC plants in the state and State Government should come out with the infrastructure projects for use of high volume fly ash concrete to achieve a sustainable development.

Keywords
Flyash,Cementitious,Superplasticizer,High volume fly ash concrete,Compressive strength

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INTRODUCTION

Fly ash is a major producer of CO_2 and there by decreasing green house gas emissions. One ton of Portland cement production discharges 0.87 ton of Carbon dioxide to the environment. Utilization of fly ash minimizes the Carbon dioxide emission problem to the extent of its proportion in cement.

However the basic fundamental principle of sustainable development is to reduce, reuse and recycle. This can be achieved by recycling waste products (fly ash) by proper planning for collection and considering the many types of environmental impacts (e.g., global warming, resource depletion such as coal) at different life cycle stages of Portland cement (e.g., manufacturing, transportation, use, disposal).

Fly ash is a siliceous, or siliceous and aluminous, material which in itself possesses little or no cementitious value but available in finely divided form which in the presence of moisture, chemically react with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties. It is a valuable resource / raw material for a number of high volume and high value added applications primarily because of its pozzolanic characteristics.

Fly Ash utilization: WORLD Scenario Year 2001-02[1]

The European countries are leading in utilization of fly ash. Canada has done lot of research work in high volume fly ash concrete and also effectively using fly ash since last two decades. Japan is also front runner in utilization of fly ash in Asia. The utilization of fly ash by year ending 2001-2002 is given below:

Germany & Netherlands	:	100%
Belgium	:	90%
Japan	:	67%
India	:	13%

Fly Ash utilization: INDIAN Scenario

The Government of India launched the ‘Fly Ash Mission’, under the TIFAC Mode in 1994 towards promoting safe disposal and utilization of Fly Ash in the country. In addition, there are several other agencies (Government, Private, Public sector, NGOs) which have been working towards management of Fly Ash disposal & utilization. These include Ministry of Environment & Forests (MoEF), Ministry of Urban Development, Department of Science & Technology (DST), National Thermal Power Corporation (NTPC), CSIR Laboratories, Engineering Institutes, IITs, State Electricity Boards etc.

Ministry of Environment and Forests (MoEF) issued a notification on 14th September 1999 (amended in 2003), which made the use of Ash mandatory within a radius of 50 kilometers (amended to 100 km) of coal based TPS for all the Government, Semi-Government and private agencies involved in Cement, Cement based products, Bricks, Construction works, Roads etc. Also, this Notification directed all the TPS in INDIA to supply Ash free of cost to all the agencies and also prepare an action plan showing 100% utilization within 15 years i.e. by 2014[2].

Broad estimates of Ash production & utilization in different regions of India (Utility Thermal Power Stations) for the year 2001-2002 is given in Table 1.

Table 1: Fly Ash utilization: INDIAN Scenario Year 2001-02[1]

Sr. No.	Region	Fly Ash Generation (million tones)	Fly Ash Utilization (million tones)	Utilization (%)
1	Southern	13.5	0.8	6.0
2	Western	16.5	0.8	5.0
3	Central	18.0	2.84	15.8
4	Eastern	10.21	2.94	28.8
5	Northern	15.5	2.3	14.8
	TOTAL (All India)	73.71	9.68	13.1

During the year 2001-02, nearly 13% of total Fly Ash generation in the country was utilized mainly for manufacturing cement, bricks and construction of roads and embankments. The progress made over the years in Fly Ash utilization is presented in figure given below:

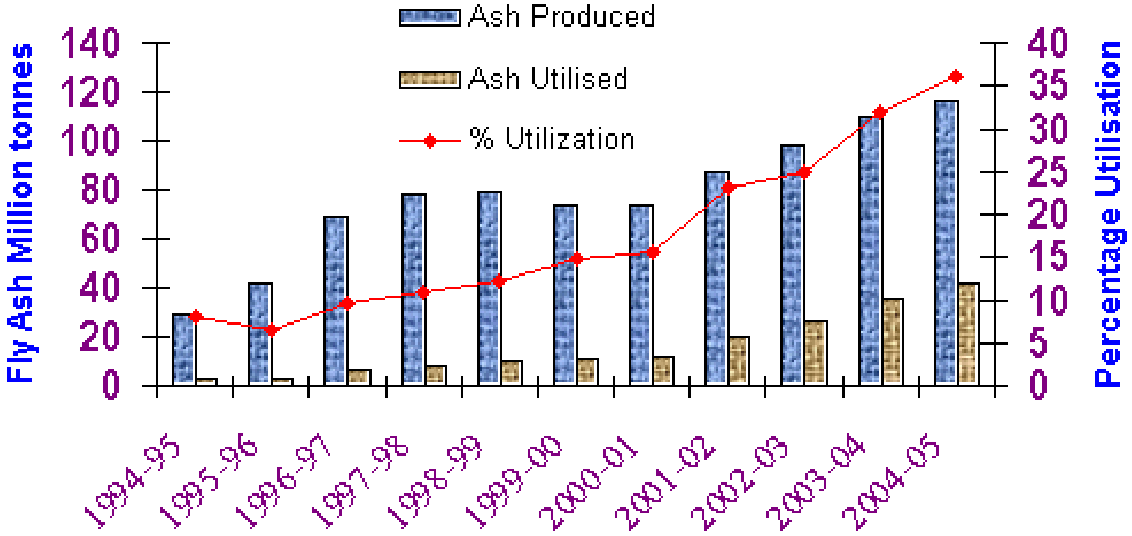

Figure 1: Fly Ash utilization in India[1]

Due to persistent efforts by the 'Fly Ash Mission, in India and some other agencies the utilization of fly ash has improved from a merge 3%(one million tone) in 1994 to 27%(22 million tones)in 2003-2004. This utilization increased further to 60 million tones per year (46% utilization)in 2006-2007 as against a generation of 130 million tones per year. The present utilization of fly ash has crossed 50% mark. While there has been a constant increase in the utilization of fly ash yet the unutilized fraction is also growing considerably increasing from 39 million tones in 1993-94 to 70 million tones in 2006-2007. This has grave environmental consequences. A lot still needs to be done. More than 55 demonstration projects have been completed or are under consideration at the fly ash mission. Some of these include use of fly ash in mine filling, construction of roads/ flyover embankments, hydraulic structures, raising of dykes, manufacture of several building components like bricks, blocks, tiles and use in agriculture. Table 2 shows some of the existing and proposed projects where fly ash to be used in NHAI's (National Highway Authority of India) road project work.

Table 2 A: Existing projects / contracts of NHAI utilizing Fly Ash [3]

Sr. No.	Name of the project	Total quantity of Fly Ash proposed to be used(m^3)
(1)	Kms 8.200 to 29.30 of NH-1 in Delhi.	1.00 lakh
(2)	HALDIA Port Connectivity Project -4 laning of NH-41 from Kms 0 to 52.7	11.80 lakhs
(3)	Kms 470 to 483.33 & Kms 0 to 38 of NH-2 in Uttar Pradesh.	3.35 lakhs
(4)	4/6 - laning of NH-6 in the state of WB from Kms 17.60 to 72.00	32.35 lakhs
(5)	4/6-laning of NH-6 in the state of WB from Kms 72 to 132.45	3.21 lakhs
(6)	DURGAPUR Expressway	9.00 lakhs
	Total	59.71 approximately 60 lakhs m^3

Table 2 B: Proposed projects / contracts of NHAI utilizing Fly Ash [3]

Sr. No.	Name of the project	Total quantity of Fly Ash proposed to be used
(1)	ALLAHABAD bypass on NH-2	67.32 lakhs m^3

The use of fly ash in the Nizamuddin bridge road embankment at Delhi, India for 1.7 Kms. and a height of 8 meters in a flood zone had demonstrated the use of fly-ash in adverse conditions. This has not only saved the top soil and used fly ash which was otherwise a waste but also saved Rs.1.4 crores in a total project of Rs.10 crores[4].
Utilization of Fly Ash as a resource has been studied for decades in many areas such as in valuable element extraction, waste water treatment, ceramic products, paint and plastic industries, building products (brick, cement, aggregate, concrete), roads, agriculture etc. The use of fly ash in some other sectors is given below:

(1) AGRICULTURE & HORTICULTURE
(2) ROADS
(3) BRICKS
(4) PRE-CAST BUILDING PRODUCTS-TILES, PAVERS ETC
(5) LIGHTWEIGHT AGGREGATES
(6) CERAMICS, PLASTICS, PAINTS ETC
(7) DECOLOURIZATION OF DYESTUFF EFFLUENT
(8) FILLERS-CENOSPHERES
(9) CONSTRUCTION OF DYKE WITH FLY ASH
(10) BACKFILLING OF MINES
(11) ACID MINESOIL RECLAMATION
(12) CONSTRUCTION OF EMBANKMENTS & FILLS
(13) MANUFACTURE OF PORTLAND POZZUOLANA CEMENT
(14) AS A PARTIAL REPLACEMENT OF CEMENT IN MORTAR AND CONCRETE

Fly Ash utilization: Orissa Scenario

The eastern state of Orissa in India has a large coal deposit (26% of India's coal deposit) thus facilitating thermal and super thermal power plants. The bauxite and iron ore mineral rich state also facilitating in the process of setting Aluminum and Steel plant in the state. All these leads to producing more and more fly ash day by day. The major thermal, aluminum and steel industrial belt in the states are Kanhia-Talcher-Angul , Jharsuguda-Brarajnagar-IB valley, Kalinga Nagar-Jajpur Road, Damanjodi, Rourkela and Choudwar region for producing industrial waste slag as well as fly ash and making an environmental hazard in the near future to a complete catastrophe without any road map for effective utilization of these precious wealth form the waste for a more sustainable development. NALCO has 8 units of captive power plants with capacity of 210 MW each and generating 3.5 million tones of fly ash each year. Most of Nalco's fly ash ash was used to be pumped to its ash pond. A few years back a major disaster resulted from a breach in the dam holding the fly ash slurry in the pond. Since then NALCO has become more serious for utilization of its fly ash for which it has more proactive policies for utilization. But all these restricted to manufacturing of fly ash bricks, use in embankments without any use in high volume fly ash concrete. The major power generation stations at different locations with total capacity (MW) in the state of Orissa is given below[5]:

NTPC, Angul, Orissa (Coal based)	: 1,970
Smelter Plant, National Aluminum Corp. Ltd., Angul, Orissa (Coal based)	: 720
IB Valley, OPGC, AES Barhanpalli, Orissa(Coal based)	: 420
Steel Authority of India Ltd, Rourkela, Orissa (Coal based)	: 269
Indian Charge Chrome Ltd.(ICCL), Choudwar, Orissa (Coal based)	: 108

High Volume fly ash Concrete

The high volume fly ash concrete (HVFA) was developed by CANMET (The Canada Centre for Mineral and Energy Technology) in the year 1986. A minimum of 35% fly ash by weight of the cementitious material has to be replaced for a high volume fly ash concrete [6,7].The other characteristics for making a high volume fly ash concrete such as low water-to-cementious ratio generally less than 0.35 with a low dosage of super plasticizer. It produces a sustainable, higher ultimate strength, lower permeability and superior durability concrete [8,9,10].

Ready mixed fly ash concrete

India consumes less than five per cent of total cement consumption. In ready mix concrete, various ingredients and quality parameters are strictly maintained/controlled which is not possible in the concrete produced at site and hence it can accommodate still higher quantity of fly ash. Ready mixed fly ash plant is located only in Metro and bigger cities. Smaller towns and cities in the country are yet to see the day of the light of Ready mixed concrete.

EXPERIMENTAL PROGRAMME

Materials:

Cement: Ordinary Portland Cement of 43 grade was used in this study. The cement has a specific gravity value of 3.15, Initial and final setting times of the cement were 90 minutes and 450 minutes, respectively. Fineness of cement was 7%.

Coarse aggregate: Crushed angular granite of maximum size 20 mm was used. The specific gravity and fineness modulus of coarse aggregate was 2.65 and 6.7.

Fine aggregate: Natural river sand passing through IS sieve 4.75 mm was used. The specific gravity and fineness modulus of fine aggregate was 2.55 and 2.6.

Fly ash: Fly ash (class F) was collected from National Aluminum Corporation(NALCO), Angul, Orissa. Specific gravity of fly ash was 2.73 and chemical oxide composition is shown in Table 3 [11].

Table: 3 Chemical Oxide composition

Sl.No.	Components	% by weights
1.	SiO_2	60.43
2.	Al_2O_3	30.63
3.	Fe_2O_3	4.79
4.	CaO	O.28
5.	Na_2O	0.10
6.	K_2O	0.25
7.	LOI(Loss on Ignition)	0.50

Super Plasticizer**:** To enhance the workability of concrete chemical admixture known as SNF (sulphonated naphthalene formaldehyde) based polymer was used. It improved the cohesiveness of the mix and reduced concrete segregation.

Mix Proportions

In this study, control mix was designed as per IS code 10262:1982 to achieve a target compressive strength of 36 MPa for M30 Mix Design and 48 MPa for M40 Mix

Design[12]. Fly ash was used to replace ordinary Portland cement at various levels of 0%, 10%, 20%, 30%and 40% by mass of binder content. The details of the Mix for M30 and M40 are given in Table 4 and Table 5 respectively.

Table 4: Mix Proportion of M30 Design Mix

Constituents	Control-1	Mix 1	Mix 2	Mix 3	Mix 4
Cement(Kg/m^3)	420	378	336	294	252
Fly ash(Kg/m^3)	-	42	84	126	168
Fly ash % Replacement of cement	0	10	20	30	40
Fine aggregate(Kg/m^3)	880	880	880	880	880
Coarse aggregate(Kg/m^3)	1100	1100	1100	1100	1100
Water(Kg/m^3)	170	125	135	145	160
Water/Binder Ratio	0.4	0.30	0.32	0.34	0.38
Admixture(% of Binder)	0.25 %	0.6 %	0.8 %	1.0 %	1.2 %

Table 5: Mix Proportion of M 40 Design Mix

Constituents	Control-2	Mix 5	Mix 6	Mix7	Mix 8
Cement(Kg/m^3)	440	396	352	308	264
Fly ash(Kg/m^3)	-	44	88	132	176
Fly ash % Replacement of cement	0	10	20	30	40
Fine aggregate(Kg/m^3)	680	680	680	680	680
Coarse aggregate(Kg/m^3)	1180	1180	1180	1180	1180
Water(Kg/m^3)	165	132	140	150	160
Water/Binder Ratio	0.38	0.30	0.32	0.34	0.36
Admixture(% of Binder)	0.4 %	0.6 %	0.8 %	1.0 %	1.2 %

Preparation and Details of Test Specimens

Concrete cubes 150 mm size for finding compressive strength, were cast. After casting, test specimens were demoulded after 24 hours and were kept in the curing tanks until the time of test. The cubes were air dried for 6 hours before the test. The each test result is the average test result of three cubes.

Workability of the Concrete Mix

Workability was measured by slump cone test. The slump values of all the mix were between 50-100 mm including the control mix. Slump values could be less than 50 mm for high volume fly ash concrete for highway pavements provided modern paving machines are being used [13].

Tests on Concrete Cubes

The compressive strength of the concrete is one of the most important properties. The compressive strength of concrete was tested at 7, 28 and 90 days in accordance with IS:516-1999.But for high volume fly ash concrete 56 days test could have been much better as against 28days target strength .The values of compressive strength of mixes at 7,28 and 90days are shown in the Table 6 and Table 7.

RESULTS AND DISCUSSIONS

The test result showed that early gain strength of both control mixes were higher up to 7-14 days thereafter the strength of mix with 10 and 20% replaced with fly ash were more than that of the control mixes (Figure 2 & 3). Early strength gain of fly ash replaced concrete decreased. Fly ash affects the early strength because it releases the free lime which still reacts during the curing process[14]. The strength of the mix with 30 % replacement was more than control mix after 21 days for M30 (Figure 2) and 90 days for M40(Figure3) Mixes. This was because of continued hydration of cementious-pozzolanic materials which increased the long-term strength. The strength of the Mix with 40% replacement with fly ash was all time lower than that of control mix(Figure 2 & 3). But the rate of gain of strength of all the mixes replaced with fly ash was higher than control mixes. This confirmed the general trend of later strength gain of fly ash replaced concrete. Figure 4 shows that 32% replacement with cement gave the same strength at 28days and 35% replacement with cement gave the same strength at 90 days with the control mixes. Hence for optimal use of fly ash the 28 days target strength of the Mix was achieved with a replacement of 30% of fly ash with the cement. Reduction of water binder helped in achieving the higher strength with a low dosage of superplasticizer.

Table 6: Compressive Strength of M30 Grade Concrete

Replacement of Cement with Fly ash	Compressive Strength (Mpa)		
	7 Days	28 Days	90 Days
Control	30.64	37.88	38.2
10%	28.33	51.03	52.48
20%	28.14	47.7	51.35
30%	22.96	41.34	43.56
40%	18.45	30.2	28.56

Table 7: Compressive Strength of M40 Grade Concrete

Replacement of Cement with Fly ash	Compressive Strength (Mpa)		
	7 Days	28 Days	90 Days
Control	38.4	47.53	48.12
10%	30.42	58.16	59.25
20%	32.21	51.91	53.45
30%	28.43	44.64	48.31
40%	25.26	35.1	38.26

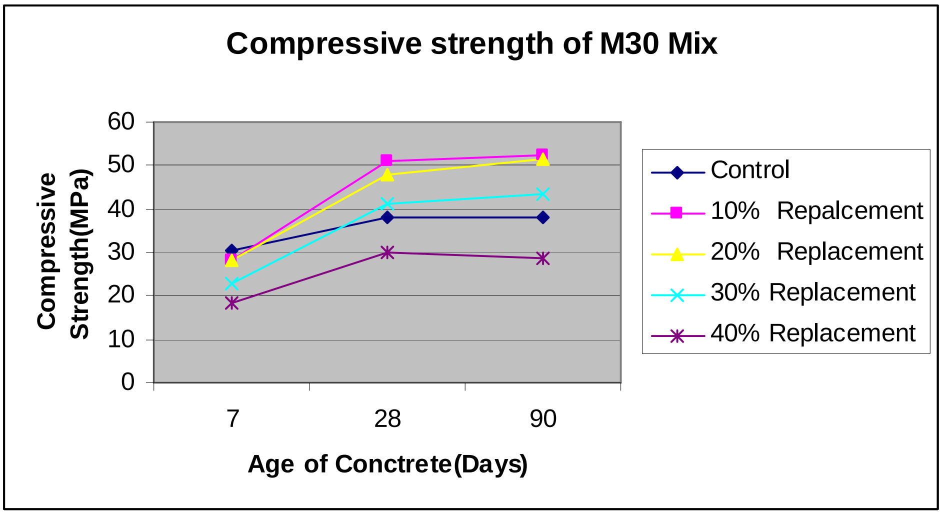

Figure 2: Compressive Strength of M30 Mix with fly ash replacement

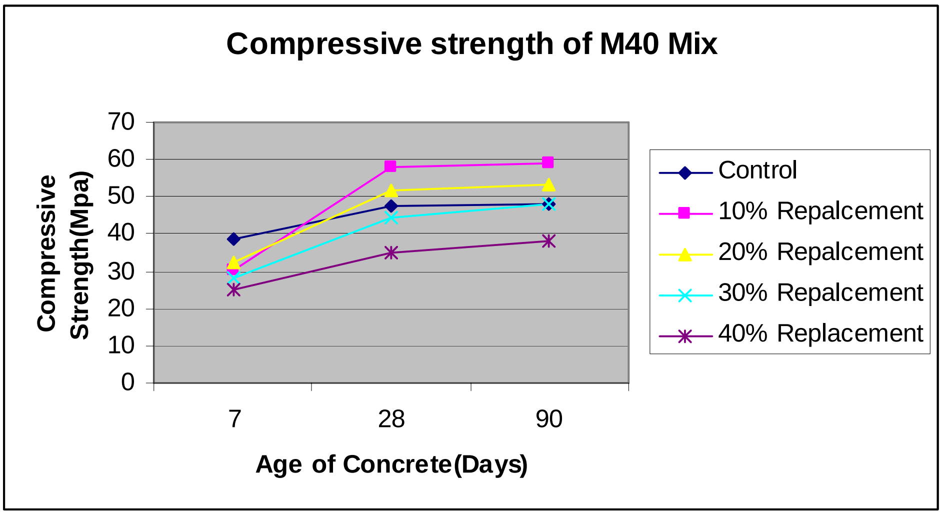

Figure 3: Compressive Strength of M40 Mix with fly ash replacement

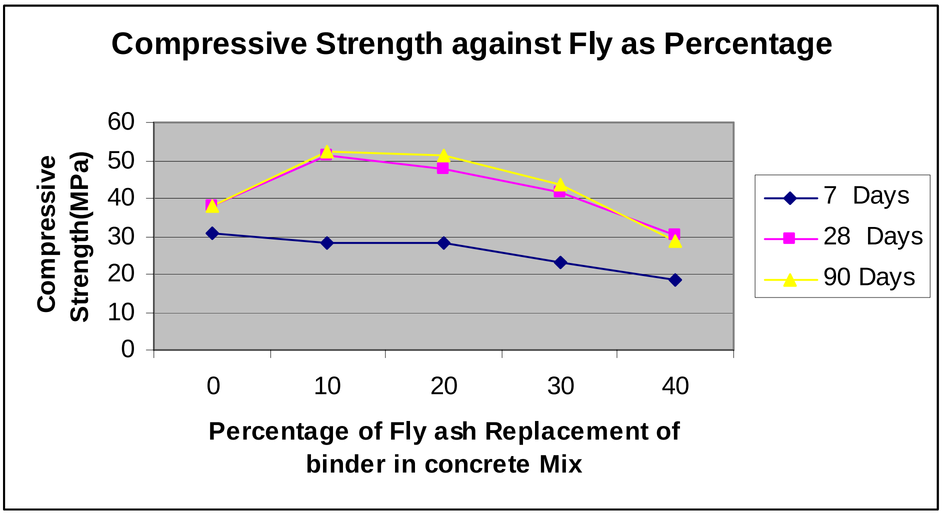

Figure 4: Compressive Strength against age of fly ash replaced concrete

CONCLUSION

Fly ash is a rich cementitious industrial waste which has the great potential to substitute Portland cement. The optimal use of NALCO fly ash is between 30-35% replacement of the cement for high volume fly ash concrete. The 28 days target strength of the Mix can be achieved with a replacement of 30% of fly ash with the cement. The super plasticizer helps for compensating the loss in early age strength by reducing the water binder ratio and increasing the workability of the mix. Hence, the efforts have to be made by the Entrepreneurs to establish the RMC plants in the state and State Government should come out with the infrastructure projects for use of high volume fly ash concrete to achieve a sustainable development.

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