HIGH VOLUME FLY ASH CONCRETE TECHNOLOGY

AKSHAY NAGAR PROJECT
REAL ESTATE DEVELOPMENT PROJECT, HUBLI

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INTRODUCTION

Since 2002, ICON-MTL/CANMET (Department of Natural Resources Canada), in collaboration with the Confederation of Indian Industry (CII), has been implementing a CIDA-funded project on High-Volume Fly Ash Concrete (HVFAC) Technology in India. This technology, developed by CANMET in the mid 1980's, uses up to 55% fly ash, a by-product from the combustion of pulverized coal in Thermal Power Stations, as replacement of Portland cement in concrete. Various research studies have shown that concrete incorporating large volumes of fly ash, when properly designed, placed, finished and cured, will give excellent long-term durability and mechanical properties. The goal of the current project in India is to optimize the use of fly ash to reduce the GHG emissions signature of concrete in local construction, while assuring the long-term performance (durability) and the cost effectiveness of the concrete.

Suresh Enterprises PVT. Ltd., a real-estate developer located in Hubli, Karnataka, aims to promote sustainability and competitiveness through the use of fly ash in real-estate development projects in Akshaynagar, Hubli (Fig. 1A & 1B). Suresh Enterprises operates a ready-mixed concrete plant (daily capacity of 30m^3/hr, 6 trucks) to manufacture concrete products such as bricks, foundation and paving blocks, as well as the structural concrete for their townships development (Fig. 1C and 1D). Prior to this project (i.e. before 2004), the company was essentially using conventional opc concrete in their operations. Following the demonstration project at Suresh Enterprises PVT. Ltd., fly ash contents ranging from 30 to 65% are currently being used in a number of their concrete products.

This report presents the following information:

results of the investigations performed to develop fly ash concrete mix designs for structural applications (floor, beams, columns); and

characteristics and typical strength of fly ash concrete products (blocks, bricks and paving blocks).

STRUCTURAL CONCRETE TRIALS

In March and July 2004, CANMET engineers and Suresh Entreprises staff members (under the supervision of Mr. N. Revankar, consultant) performed a series of concrete trials to develop a M20 concrete mix design that could be used by the company for the structural elements (i.e. floors, beams and columns) in their housing developments under planning. The work involved preliminary work in a small laboratory-type mixer, followed by large-scale trials in the RMC plant.

MATERIALS

- *CEMENT AND FLY ASH*

The cementitious materials used consisted of a Super-43 Grade Portland cement from the Vasavadatta plant and a fly ash from the Raichur Thermal Power Station. The physical properties and chemical composition of the Raichur fly ash as reported by Sivasundaram (2004) are given in Table 1.

Table 1: Typical Physical Properties and Chemical Analysis of the Raichur Fly ash (Sivasundaram 2004)

	Raichur FA
Physical Tests	
Specific gravity	2.06
Fineness, < 45 µm, %	73
Specific surface, Blaine, m^2/kg	3020
Pozz. Activity index @ 7 days / 28 days, %	87.9 / 95.7
Water requirement, %	95
Chemical Analyses, %	
$SiO_2 + Al_2O_3 + Fe_2O_3$	93.0
Calcium oxide (CaO)	1.02
Total Alkalis as (Na_2O equivalent)	0.098
Sulphur trioxide (SO_3)	< 0.01
Loss on ignition (LOI)	1.62

- *AGGREGATES*

The coarse aggregate used consisted of a crushed stone available in the following two size fractions, i.e. 20-10 mm and 10-5 mm; the fine aggregate consisted of a natural river sand confirming to zone II of Indian Standards. Table 2 gives the physical properties of the coarse and fines aggregates.

Table 2 Physical Properties of Coarse and Fine Aggregates

Coarse aggregates		Fine aggregate	
Specific gravity	Absorption, %	Specific gravity	Absorption, %
2.66	0.50	2.57	0.50

- *ADMIXTURE*

A high-range water reducing admixture (Conplast SP 430 S) from Fosroc was used for the structural concrete. Table 3 gives basic information on the admixture.

Table 3 Results of Uniformity Tests on the Conplast SP430 S

Test Parameter	Test Method	Test value
Relative density	IS: 9103-99 E-3	1.200
pH	IS 9103-99 E-5	7.78
Water soluble chlorides	IS: 6925	Nil
Soild Content	IS: 9103-99 E-1.1	40.09%

TRIAL MIXES

The grade of concrete usually specified by the Indian Standard for this type of application is M20. The minimum cement content is 300 kg/m^3, the maximum water-to-cement ratio (W/C) is 0.55 and the slump should range from 50 to 100 mm.

Four trial mixes with fly ash content ranging from 20 to 50% were first investigated in order to achieve the specified requirement except for the specified minimum cement content. The total weight of cementitious materials ranged from 293 to 390 kg/m^3 and the w/cm ranged from 0.40 to 0.56. The concrete mixture proportions for the four fly ash concretes and the ordinary Portland cement (control) concrete usually used by the contractor in this type of application are presented in Table 4, together with fresh and hardened properties.

Table 4: Trial Mixes for Fly Ash Concrete

Concrete mixtures	Cementitious Materials, kg/m^3			Aggregates, kg/m^3			Water, kg/m^3	W/CM	Chemical Admixture, L/m^3	Initial slump, mm	Comp. Strength, MPa	
	Cement	Fly Ash	Total	20 mm	10 mm	Sand					7 days	28 days
Control	300	0 (0%)	300	885	379	657	162	0.54	1.0	75	14.8	35.6
FA Trial 1	312	78 (20%)	390	668	445	705	169	0.43	1.8	40	22.1	39.0
FA Trial 2	285	95 (25%)	380	684	455	722	154	0.40	2.8	80	15.3	35.6
FA trial 3	200	93 (30%)	293	836	358	620	164	0.56	1.0	60	17.6	23.2
FA Trial 4	195	195 (50%	390	653	436	690	168	0.43	2.5	…	12.9	22.9

The results of Table 4 shows that the fly ash concrete trial 2 (with 25% fly ash) performed similarl to the control concrete, the slump and the compressive strength at 7 and at 28 days were almost similar for both concrete mixtures. However, the reduction in cement content is not significant and, in terms of cost effectiveness, the fly ash concrete would have cost higher due to higher dosage in admixtures.

Considering the results obtained in this series of trial mixtures, additional mixes were planed, most likely using a modified version of the fly ash concrete trial 3, i.e. with a reduced W/CM. In fact, trial 3 met the slump and to some extent the strength requirements (for M20) but the W/CM was slightly higher than that required for this application (i.e. 0.55). Reducing the W/CM within the range 0.42 to 0.45 would obviously increase the dosage of admixture required, but would result in higher strength development.

CONCRETE MIXTURES SELECTED

The use of fly ash in the structural members is currently being considered for the future projects under planning. Further work is however required to finalize the optimum mix design for structural applications.

CONCRETE PRODUCTS: BRICKS, PAVING BLOCKS AND FOUNDATION CONCRETE BLOCKS

The use of fly ash for the manufacture of various concrete products [i.e. bricks (230 mm by 110 mm by 75 mm in size), paving blocks (150 mm by 200 mm by 80 mm in size), gutters and concrete foundation blocks (200 mm by 200 mm by 400 mm in size)] was also evaluated. Prior to this project, such concrete products were essentially made

using opc concrete only.

MATERIALS

- *CEMENT AND FLY ASH*

Similar to the structural concrete trials, the Super-43 Grade Vasavadatta Portland cement and the Raichur fly ash were used in the evaluation of the fly ash concrete products (Table 1).

- *AGGREGATES*

The aggregates used for the concrete products consisted of two fractions of crushed stone, i.e. 10 to 6 mm and 6 to 3 mm, a coarse sand and "stone dust".

- *ADMIXTURE*

No admixtures are used for the manufacture of the concrete products.

CONCRETE MIXTURE PROPORTIONING

Table 5 gives the concrete mixture proportioning for the concrete products. Fly ash was used in the mixtures by direct mass replacement of a certain proportion of cement ("original" vs "modified" mixtures in Table 5). All mixtures are typically made with a low unit water content and basically correspond to no-slump concrete mixes.

Table 5: Selected Concrete Mixtures for the Concrete Products

Material	Bricks, gutters		Paving blocks		Foundation blocks	
	Original	Modified	Original	Modified	Original	Modified
Cement , kg/m^3	200	100	157	57	175	125
Fly ash, kg/m^3	---	100 (50%)	---	100 (36%)	---	50 (29%)
6 mm aggregate, kg/m^3	385		385		550	
10 mm aggregate, kg/m^3	Nil		Nil		560	
Coarse Sand, kg/m^3	528		528		480	
Stone Dust, kg/m^3	571		571		140	
Admixtures, l/m^3	Not used		Not used		Not used	
Water, kg/m^3	45.4		37.6		60	
W/CM	0.23		0.24		0.34	
Volume of each unit, cm^3	1900		1680		16000	

MANUFACTURE OF CONCRETE PRODUCTS

Typically, the "dry" concrete is made in the RMC plant (pan mixer), placed into conventional dump trucks and transported on short distance to the manufacturing yard. The concrete is then manually fed into the various machines used to manufacture the large foundation blocks (Fig. 1E and F), concrete bricks and paving blocks (Fig. 2A and 2B).

The manufacturing practices used for opc concrete products were similarly reproduced when fly ash was included in the mixtures. The concrete products are dry-cast and left to "solidify" directly on the concrete floor of the casting yard or on racks for a 24-hour period. The concrete products are then subjected to curing by regular water hosing over a 14-days period in the case of the opc products; the curing period was extended to 21 days in the case of the fly ash concrete products (Fig. 2C).

USE OF CONCRETE PRODUCTS IN CONSTRUCTION

Figures 2D to 2F illustrate the use of concrete products in construction. The large concrete blocks are used for the foundation of the housing units; the wall structure is then built up with the concrete bricks. Concrete gutters are used to assure proper drainage of the housing park.

RESULTS

- *COMPRESSIVE STRENGTH*

Table 6 gives the range of compressive strength measured for the fly ash concrete products. According to the testing performed on site, the replacement of the Portland cement by 30 to 50% did not result in a significant reduction in the compressive strengths measured. This suggests that a

significant proportion of the cement in the original opc concrete products was not utilized in the process of strength development most likely due to the very low W/CM, and that the replacement by fly ash, with a potential contribution from additional pozzolanic reaction, did not result in a significant strength reduction.

Table 6: Basic Concrete Mix Proportions and Compressive Strengths for the Concrete Products

Material	Bricks, gutters		Paving blocks		Foundation blocks	
	Original	Modified	Original	Modified	Original	Modified
Cement , kg/m^3	200	100	157	57	175	125
Fly ash, kg/m^3	---	100 (50%)	---	100 (36%)	---	50 (29%)
W/CM	0.23		0.24		0.34	
28-day Compressive strength, MPa	**n.a.**	**14-15**	**n.a.**	**10-12**	**n.a.**	**11-13**

FINDINGS

- *PERFORMANCE*

Although no technical evaluations were carried out at this stage, the performance of the fly ash concrete products is reported to be equivalent to that of opc products used in previous applications.

- *COST EFFECTIVENESS*

Table 7 compares the actual unit cost savings for the various concrete products resulting from the use of fly ash as per mixes described in Table 5. The cost saving was 32% for the bricks, 35% for the paving blocks and 13% for the foundation blocks.

Table 7: Cost and Cost Savings of the Concrete Products Using Fly Ash

Material	Bricks	Paving blocks	Foundation blocks
Volume, cm^3	1900	1680	16000
No. per m^3 of concrete	458	518	49
Compressed Vol. per m^3 of wet concrete	0.87 m^3	0.87 m^3	0.79 m^3
Total cost (Rs.)	759.00	695.00	942.00
Cost saving per m^3 (Rs.)	240	240	120
Percentage Savings	32%	35%	13%

- *GHG REDUCTION*

Table 8 shows an estimate of the potential cement savings that could result from the full implementation of the selected fly ash concrete mixtures in the whole real-estate project. Considering that the production of one tonne of cement results in approximately one tonne of CO_2, a greenhouse gas, the full implementation of HVFAC in the structural concrete members and the concrete products in the various real-estate development projects of the company could result in CO_2 savings of 18,235 tonnes.

Table 8: Projected CO_2 Savings Resulting from the Use of Fly Ash Concrete

ITEM	AKSHAY NAGAR			AKSHAY COLONY IVTH PHASE			AKSHAY CENTRE		
	Vol. of Concrete (m^3)	(Rs.) Lakhs	Cement savings (Tonnes)	Vol. of Concrete (m^3)	(Rs.) Lakhs	Cement savings (Tonnes)	Vol. of Concrete (m^3)	(Rs.) Lakhs	Cement savings (Tonnes)
Structural Concrete	30000	64.32	3000	9000	19.3	900	45000	96.49	4500
Cement Bricks	42700	102.48	4270	12800	30.72	1280	15000	36	1500
Foundation Blocks	32700	39.24	1635	9812	11.77	490	2500	30	125
V-Shape Gutters	1600	3.44	160	500	1.06	50	300	0.64	30
Pavers	2100	5.04	210	650	1.56	65	200	0.48	20
Total	**109100**	**214.52**	**9275**	**32762**	**64.41**	**2785**	**63000**	**136.61**	**6175**
Corresponding CO2 savings			**9275**			**2785**			**6175** **----------** **18235**

CONCLUSION

This demonstration project has shown that it is possible to use fly ash to produce economical and environmentally-friendly concrete mixtures for structural elements as well as concrete products such as concrete blocks, pavers and bricks.

ACKNOWLEDMENT

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REFERENCE

Revankar, R.V. 2004. Fly Ahs Concrete – Demonstration in Real-Estate Development – A Case Study. Powerpoint Presentation given at HVFAC Seminar Series, Pune, 2004.

Sivasundaram, V. 2004. Evaluation of Indian Fly Ashes for the HVFA Concrete, Part II: behaviour in Concrete. The Indian Concrete Journal, Vol. 78, No. 11 (November 2004), pp. 41-50.

Fig 1. A&B: Akshay colony. C: Ready-mixed concrete plant of Suresh Enterprises in Hubli. D: Ready-mixed concrete trucks. E & F. Dry concrete and machinery used in the manufacture of large foundation blocks.

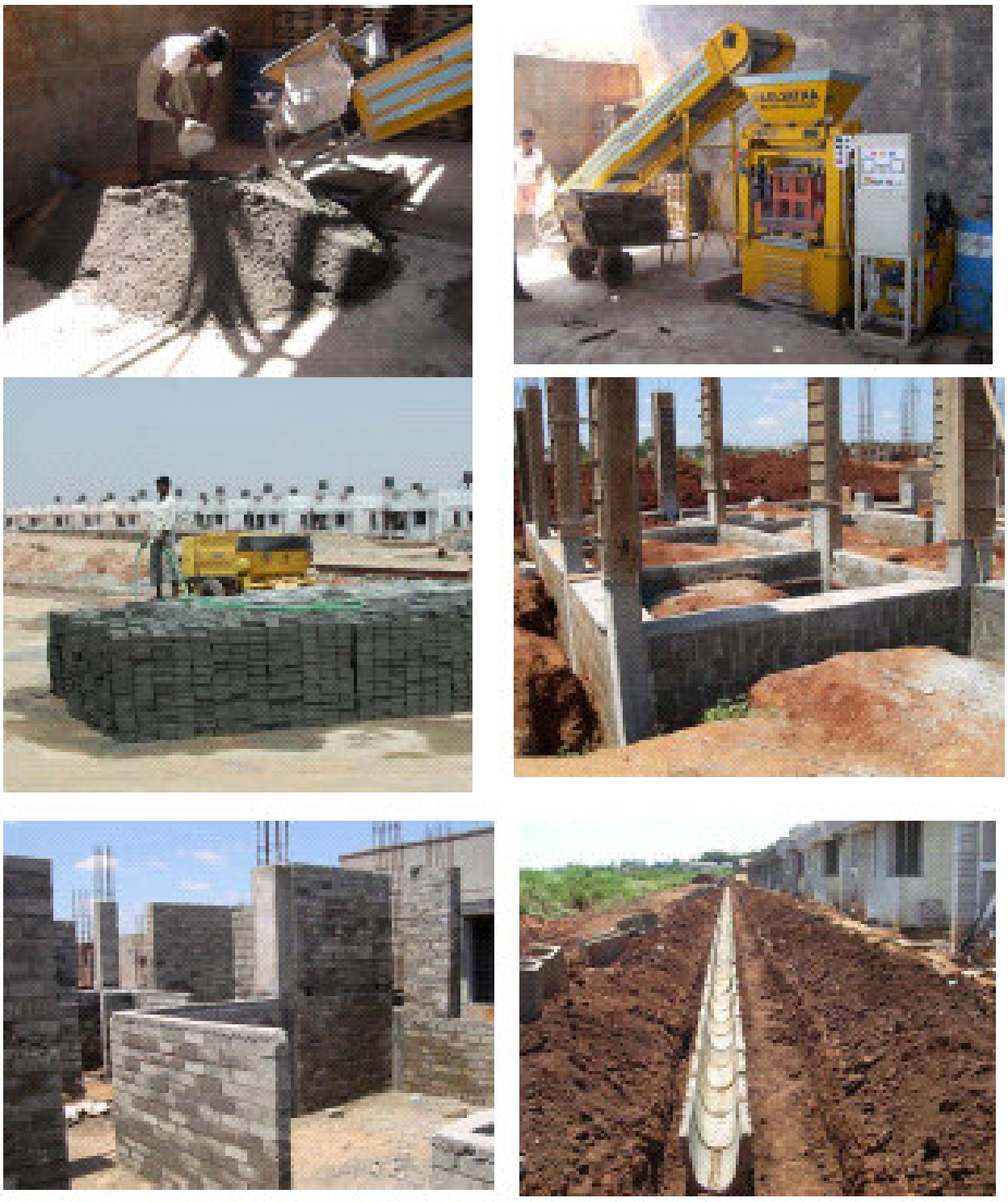

Fig 2. A&B: Dry concrete and machinery used in the manufacture of bricks and paving blocks. C: Curing of the concrete paving blocks. D. Large concrete blocks for housing foundation. E&F. Concrete bricks (E) and gutters (F).