HINDUSTAN CONSTRUCTION CO. LTD.

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Potential use of High Volume Fly Ash Concrete in Indian Construction Industry

(HVFAC)

Introduction

- Cement produced in India – 100 million ton
- Fly Ash produced in India – 90 million ton
- Energy required to produce one tonne of cement – 1100 kCal/kg clinker / 140 kWh/t cement
- Utilization of Fly Ash – 4%
- One tonne of CO_2 is released during production of one tonne of cement

- Why we do not try to produce concrete which is durable, economical & eco-friendly?

Application of HVFAC in Infrastructure development

- Transportation
- Power (Hydro, Thermal, Nuclear)
- Dams, Barrages and Irrigation Projects
- Marine Projects – Underwater concreting
- Environmental engineering Projects

Transportation

- **HVFAC in Concrete Pavement.**
  - ✓ Many concrete road projects are under construction and many more are in pipeline
  - ✓ Design Requirement
    Compressive Strength – 40 MPa
    Flexural Strength – 4 Mpa
  - ✓ Slip-forming is used for construction
  - ✓ Encouraging results from Satara-Kolhapur Road Project

Transportation

Ingredients (Kg/m^3)	**Mixture**							
Project	Satara Kolhapur Road Project							
	SK0	SK1	SK2	SK3	SK4	SK5	SK6	Proposed
Portland cement	380	320	320	300	280	265	250	225
Fly Ash	NIL	80	80	100	120	145	160	225
% Fly Ash	0	20	20	25	30	35	40	50
Fine Aggregate	870	1025	1025	940	920	940	960	850
Coarse Aggregate	1060	1025	1025	1100	1100	1100	1110	990
Total Water	144	136	144	144	144	140	127	126
Water-cementitious material ratio	0.38	0.34	0.36	0.36	0.36	0.34	0.31	0.28
Admixture (% by wt. Of binder)	1.4	1	0.8	0.8	1	1.2	1.6	1.6
Slump (mm)	25	25	40	20	40	45	15	
Properties of hardened concrete								
Compressive Strength								
7 days	59.37	52.46	42.86	42.93	41.18	38.62	36.19	
28 days	70.64	71.78	65.9	62.84	60.9	58.02	57.31	
56 days	-	86.58	76.36	72.29	71.29	69	69.51	
Flexural Strength								
7 days	4.6	-	4.8	5	4.7	4.6	4.2	
28 days	7.3	7.2	6.6	7.2	6.6	7.2	7.2	
56 days	-	7.4	7.2	7.6	7.5	7.6	7.5	

Transportation

- **Advantages of HVFAC in Pavement.**
  - ✓ Better durability
  - ✓ Cohesive mix suitable for slip-forming (No edge collapse)
  - ✓ No Bleeding
  - ✓ No thermal cracks
  - ✓ Better texturing

Transportation

HVFA Roller Compacted Concrete Pavement and Dry Lean Concrete

Roller Compacted Concrete Pavement is

- Cost Saving
- Easy & fast to place

Suitable for –

- Service roads, Storage yards
- Parking yards, Container yards

Transportation

- **Fly Ash in RCCP, provide additional fine material needed to ensure adequate compaction.**

Example – For **M30**

- ✓ Cement – 180
- ✓ Fly Ash – 120
- ✓ Water – 120
- ✓ Coarse aggregate – 1210
- ✓ Fine aggregate – 810

Transportation

HVFA Roller compacted concrete pavement was tested in

- Lafarge Canada Cement Distribution yard
- The city of Edmonton Waste composing plant storage site

Flexural Strength results

	No Fly Ash	40% Fly Ash	55% Fly Ash
Flexural Strength (MPa)	3.7	3.5	3.5

Transportation

Roller Compacted Concrete Pavement

Transportation

Roller Compacted Concrete Pavement

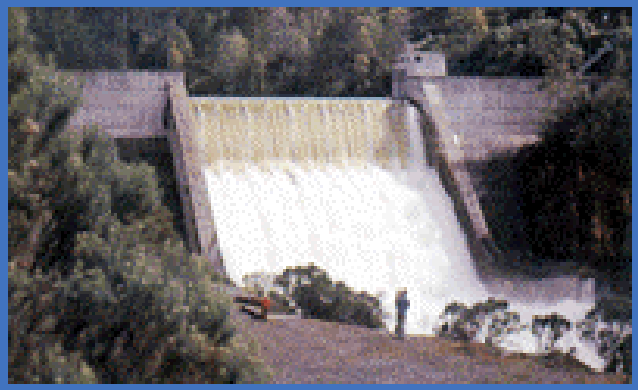
Transportation

- **HVFAC in Kerbs – M 25 Slip-forming**

Minimum cementitious material content required For Gujarat State Highway Project is 340 kg/m^3 for the slip forming,

- Cement – 170
- Fly Ash – 170
- Water Cement Ratio – 0.45
- Coarse aggregate – 1125
- Fine Aggregate - 755

Dams, Barrages and Irrigation Projects



Dams, Barrages and Irrigation Projects

- **HVFAC could be used in the following types of Dams,**
  - ✓ Concrete dams (Arch gravity)
  - ✓ Roller compacted concrete dams
  - ✓ Concrete core rock fill dams
  - ✓ Concrete face rock fill dams and
  - ✓ Massive sections of spillway –Piers, Abutments

Dams, Barrages and Irrigation Projects

Name of the Dam	Type	Cement (Kg/m^3)	Fly Ash (Kg/m^3)	Sand	Coarse Aggregate	Max. Size aggregate in (mm)	Water (Kg/m^3)	W/(C+P) or W/C	90 days strength	Density (Kg/m^3)
Hungry Horse (USA)	Arch gravity	111	53	499	1672	150	77	0.47	26.75	2415
Yellowtail	Arch gravity	117	50	526	1670	150	82	0.49	-	2449
Dworshak (USA)	Gravity	125	42	439	1770	150	97	0.59	26.25	2473
Libby (USA)	Gravity	88	29	536	1708	150	79	0.68	-	2439
Richard . Russell (USA)	Gravity	134	35	488	1755	150	103	0.57	-	2515
	Gravity	103	43	513	1741	150	105	0.67	-	2499
Itaipu (Brazil - Paraguay)	Hollow gravity butress	108	13	582	1837	150	85	0.70	22.50	2537
Peace Site I (Canada)	Gravity	94	63	575	1549	75	101	0.67	-	2379
Theo Roosevelt Modification (USA)	Arch gravity	128	32	566	1585	100	85	0.53	38.75	2397

Face Slab Concrete for Mohale Dam – M25A40

Cement	Fly Ash	Water	W/C_m	WRA	AEA	FA	CA
230	100	160	0.50	0.3	3.0	890	1120

Fly Ash % – 30%

Slump – 60 mm

Average 28 days Strength – 33 MPa

Average 90 days Strength – 45 Mpa

There is a further scope to increase % of Fly Ash

Dams, Barrages and Irrigation Projects

Mass Concrete for Mohale Dam – M15A40

Cement	Fly Ash	Water	W/Cm	WRA	AEA	FA	CA
165	110	146	0.55	0.4	2.5	1000	1130

Fly Ash % – 40%

Slump – 65 mm

Average 28 days Strength – 24 MPa

Average 90 days Strength – 31 Mpa

There is a further scope to increase % of Fly Ash

Dams, Barrages and Irrigation Projects

- **Advantage of HVFAC for Dams and Massive concrete structure**

✓ Lower Internal heat generation (No Thermal cracks)

✓ Improves workability and makes consolidation of concrete easier (No Honey-comb – No cold joints)

✓ Decreases the potential for damage from alkali aggregate reactivity and sulfate attack.

✓ Decreases permeability

✓ Reduce Portland cement factor for better economy

Dams, Barrages and Irrigation Projects

- **Canal Lining (Slip-forming – Shotcreting)**

✓ Cohesive mix suitable for slip-forming and shotcreting

✓ Better durability

✓ Decrease the risk of ASR and Sulphate attack from ground water

Example – Wet shotcrete Mix –

Cement	Fly Ash	%FA	Water	W/C_m	WRA	FA	CA
160	240	60	140	0.35	1.5	890	1120

Power Plants

- **Power plants (Thermal – Nuclear – Hydro)**
  - ✓ The common feature of all types of power plant is, massive foundations – large footings, massive rafts
- HVFAC could be utilized in –
  - ✓ Rock reconstruction
  - ✓ Backfill concrete

Power Plants

- Usually plain concrete of M15 – M20,
  HVFAC will be –
  - ✓ Economical
  - ✓ Durable
  - ✓ Easier to place

Backfill Concrete for Mohale Dam – M20A20

Cement	Fly Ash	Water	W/Cm	WRA	AEA	FA	CA
227	98	174	0.55	1.0	3.0	1130	880
Average 28 days Strength (MPa)						25.2	
Average 90 days Strength (MPa)						37.4	

Power Plants

Proposed HPC for raft of RAPP 5&6 (M45A20)

Project	Rajasthan Atomic Power Project
	RAPP1
Portland cement	360
Fly Ash	90
% Fly Ash	20
Fine Aggregate	710
Coarse Aggregate	1062
Total Water	150
Water-cementitious material ratio	0.333
Admixture (% by wt. Of binder)	0.7
Slump (mm)	Collapse
Properties of hardened concrete	
28 days Compressive Strength (MPa)	60.63
28 days Cylinder Strength (MPa)	54.77
28 days Split Tensile Strength (MPa)	3.9
28 days Flexural Strength (MPa)	5.42
28 days Modulus of Elasticity (MPa)	2.72×10^4
Permeability (mm)	Not permeable

Power Plants

- Construction of HVFAC Foundation designed for 1000 year service life

Cement	Fly Ash	Water	W/Cm	WRA	AEA	FA	CA
106	142	100	0.40	1.4	0.04	945	1120

Average 3 days Strength (MPa)	5.5
Average 7 days Strength (MPa)	9.6
Average 28 days Strength (MPa)	25.2
Average 90 days Strength (MPa)	37.4

Ref: V.M. Malhotra

Power Plants

- **Raft Foundation**
  - ✓ The mix developed by CANMET Lab. And utilized at the Lin Centre (University of British Columbia) is a very good example.
  - ✓ Economical , durable meet all the structural requirement and generate lower internal heat.

Power Plants

Mix used by CANMET Lab at the Lin Centre (University of British Columbia)

Cement	Fly Ash	Water	W/Cm	WRA	AEA	FA	CA
195	195	130	0.33	600 ml	30 ml	770	1080

Average 3 days Strength (MPa)	19.5
Average 7 days Strength (MPa)	24.4
Average 28 days Strength (MPa)	34.7
Average 90 days Strength (MPa)	39.8

Power Plants

Other mixes developed by CANMET Lab

	M1	M2	M3	M4	M5	M6
Cement	100	150	180	250	290	240
Fly Ash	125	100	220	352	0	0
FA	800	750	760	850	800	855
CA	1100	1100	1100	900	1020	1020
3 days	8.6	15.5	22.4	32.9	30.5	33.2
7 days	12.8	20.5	34.2	44.1	34.9	40.4
28 days	23.0	37.5	57.1	71.8	44.7	50.7
91 days	37.9	53.0	75.2	87.4	49.1	57.3
365 days	51.0	69.0	86.0	95.0	52.2	60.6

Other Structures

- Other Structural application
  - ✓ Marine Structures
  - ✓ Underwater concreting (Anti-wash properties)
  - ✓ Piles
  - ✓ Diaphragm walls
  - ✓ Tunnel lining

Other Structures

- Marine Structures – Massive blocks in aggressive environment

Advantages

- ✓ Protection against sulphate attacks
- ✓ No cold joints
- ✓ No thermal cracks

Other Structures

Ingredients (Kg/m^3) / Project	Bandra Worli Sea Link Project	
	BW1	BW3
	For pile cap M60	For piles M50
Portland cement	320	336
Silica Fume	43	20
Fly Ash	110	64
% Fly Ash	23	15
Fine Aggregate	870	950
Coarse Aggregate	940	970
Total Water	151	120
Water-cementitious material ratio	0.32	0.346
Admixture (% by wt. Of binder)	0.8 + 0.4	2.7
Slump (mm)	200	Collapse
Properties of hardened concrete		
Compressive Strength		
3 days	39.46	-
7 days	54.06	50.6
28 days	77.6	65.4
Permeability (mm)	1	1

Other Structures

Pile Cap – Bandra Worli Sea Link Project

Other Structures

Artist's impression on completed
Bandra-Worli Sea Link Project

Other Structures

- Mix for Diaphragm wall for Delhi-Metro Rail Project

Cement	Fly Ash	% Fly Ash	Water	W/Cm	WRA	FA	CA
330	110	25%	165	0.375	1.4	750	1030

Slump – Collapse

Average 7 days Strength – 41 MPa

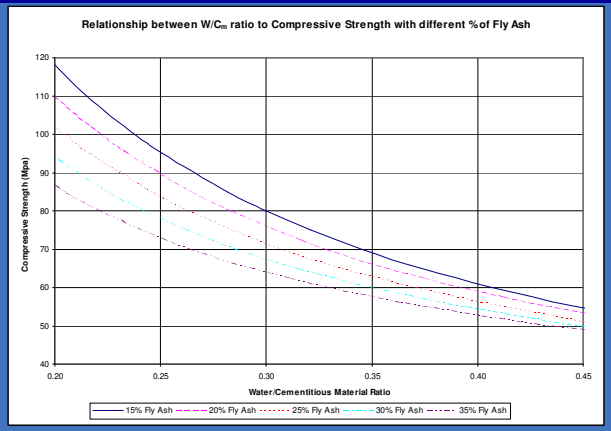
Average 28 days Strength – 60 Mpa

Mix Design with Fly Ash

HCC R&D is working on a project to develop such a guideline based on the following guides and substantial amount of data generated from lab trials.

- ACI 211.3R-97 – Guide for selecting proportions for No-Slump Concrete
- ACI 211.4R-93 – Guide for selecting proportions for High Strength Concrete with Portland Cement and Fly Ash
- ACI 363R-92 – State of the art report on High Strength Concrete

Mix Design with Fly Ash



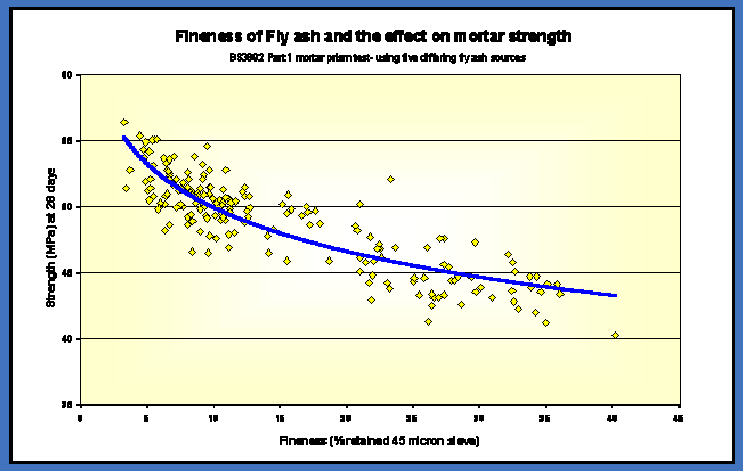
Note: 1. Cement considered has strength of 65-70 MPa.
2. Fly Ash considered is from Dahanu Thermal Plant conforming to ASTM 618.
3. The curves are for maximum size of aggregate 20 mm for concrete made with HRWRA

Mix Design with Fly Ash

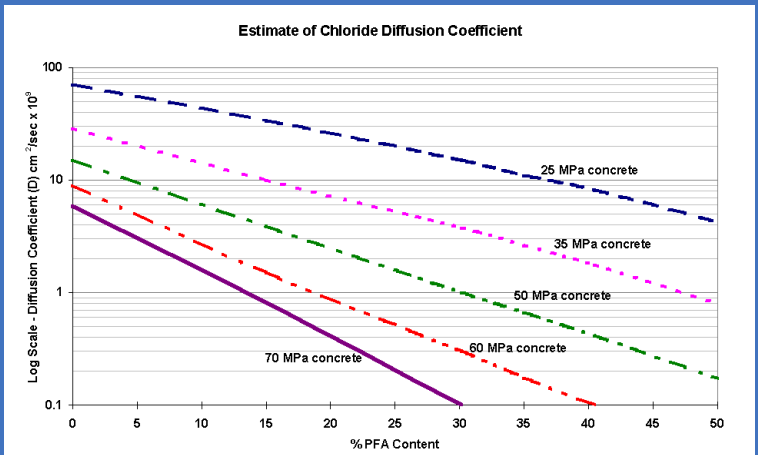
Properties of Fly Ash used for experiments

Description	Results
Chemical Properties	
Sillicon Dioxide , Sio_2 (%)	59.98
Ferric Oxide, Fe_2O_3 (%)	4.63
Alumina Al2O3(%)	29.51
Sumof SiO_2 + $Fe2O_3$ + Al_2O_3 (%)	94.11
Calcium Oxide (%)	1.28
Magnesium Oxide (%)	0.48
Sulfur trioxide (%)	0.04
Loss of Ignition (%)	0.82
Pottasium Oxide (%)	0.80
Sodium Oxide (%)	0.37
Total alkali , Na2o Eqv.(%)	0.89
Moisture (%)	0.08
Physical Properties	
Retained on 45 u Sieve(%)	3.64
Strength Activity Index with portland Cement	
07 days , (%of Control)	88.00
28days , (%of Control)	91.80
Autuclave Expansion ,(%)	0.05

Mix Design with Fly Ash



Mix Design with Fly Ash



- **Precautions -**
  - ✓ Selection of proper Fly Ash as per requirements.
  - ✓ Selection of good quality cement
  - ✓ Compatibility of admixture with Fly Ash + Cement
  - ✓ Correct proportioning of mix
  - ✓ Use of Batching plant
  - ✓ Protection of fresh concrete against plastic shrinkage
  - ✓ Curing

Conclusion

Advantages in fresh concrete stage

- Enhances the rheology of the mix, workability
- Deficiency in sand is corrected by providing sufficient fines, which makes the concrete ideal for pumping
- No bleeding
- No cold joints

Conclusion

Advantages in hardened concrete stage

- Increases the durability as lower permeability is achieved
- Improves the quality of cover to the reinforcement
- Protection against sulphate attack and chloride penetration
- Safeguard against Alkali-Silica reaction
- Decreased thermal cracks due to lower heat of hydration

Conclusion

Advantages to the nation

- Substantial saving in power
- Decrease in emission of CO_2 – pollution free environment
- If all the fly ash generated each year were used in producing concrete, the reduction of carbon dioxide released from cement production would be equivalent to eliminating 25% of the world's vehicles

Conclusion

Advantages to the nation

- By reducing consumption of OPC, the rate of depletion of mineral resources (National Resources) required for production of cement can be reduced
- At present, nearly 90 million tones of fly ash is being generated annually in India and ash ponds presently occupy 65,000 acres of land. If this fly ash is used the problem of disposal will be reduced, thus reducing the environmental hazards

Thank You