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Comparison between Portland Pozzolana Cement & Processed Fly Ash blended Ordinary Portland Cement

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Abstract
This paper presents a comparison between two different procedures for the use of Fly ash (FA) in cement industry. The first which is very often used is by adding FA to clinker as in the manufacture of Portland Pozzolana Cement (PPC).The second which is recent trend is to process FA & by blending it with Ordinary Portland cement (OPC).Strength parameters are compared of both the types of cement. For the same target strength of the cubes OPC blended with Processed FA (PFA) proved to be more economical than PPC.
Keywords: Fly Ash ,Blending, Ordinary Portland Cement, Portland pozzolana Cement, Processed Fly Ash.

1.INTRODUCTION

To make economical use of the resources of our planet we should maintain a sustainable environment and preserve our future. There is strong need to explore the possibilities to reduce the use of material, to reuse the waste and to reduce the carbon dioxide (CO_2).
Our cement industry produces about 251.2 million tonnes cement per year. The type of fuel used in cement manufacture directly impact on CO_2 emission. Decarbonisation of raw material at high temperature being the major source of CO_2 emission. Therefore approximately 5% of manmade emission originate in the cement industry.[10]
To meet the power requirement of the nation, coal based thermal power plants have been a major source of power generation in India where 75% of the total power obtained is from coal based thermal plants. This result in generation of huge amount of bye product such as fly ash (FA) which is not being used in any significant manner. Most of the FA is dumped in lagoons, land fill sites and abandoned quarries.[3]
Test results indicated that the blended cement paste with classified FA produced paste with higher compressive strength than that with original FA.[4] Though the original FA is largely used by the cement industry in the manufacture of Portland pozzolana cement(PPC) but still there lies a large scope of use of FA by partially replacing cement in concrete and mortars. This is only possible when FA of higher fineness confirming to IS 3812 :2003 is made available in open market.

2.OBJECTIVE

The specific purpose of this paper is to compare the strength parameters of PPC & PFA blended OPC & to arrive at conclusion which type of cement is more beneficial for sustainability of environment & construction industry.

3.LITERATURE REVIEW

Numerous studies e.g., Bharat kumar *et al* (2000), Saraswati *et al* (2002), Chindaprasirt *et al* (2004, 2005), Manikandan *et al* (2007), Singh (2009), Chauhan (2011), Tiwari *et al* (2011), has quantify the effect of economical use of resources on environment. These studies clearly indicate that there is strong need to explore the possibilities to reduce the use of material ,to reuse the waste and to reduce the carbon dioxide (CO_2). This can be achieved by the use of processed FA
Bharat kumar *et al* (2000), studied mix proportioning of high performance concrete. The paper concluded that mix proportioning method uses FA as cement replacing material in obtaining economical HPC mix.
Saraswati *et al* (2002), studied Influence of activated fly ash on corrosion resistance and
strength of concrete. In this study Concrete specimens prepared with 10%, 20%, 30% and 40% of activated fly ash replacement levels were evaluated for their compressive strength at
at 7, 14, 28 and 90days and the results were compared with ordinary Portland cement concrete (without fly ash). All the studies confirmed that up to a critical level of 20–30%replacement; activated fly ash cement improved both the corrosion-resistance and strength of concrete. Chemical activation of fly ash yielded better results than the other methods of activation investigated in this study.
Alves *et al* (2003), compares mix proportioning methods for high-strength concrete by studying four proportioning methods. one being for conventional concrete and three specifically for high strength. The results

obtained indicate the advantage of using specific proportioning methods for HSC, as for the same compressive strength at 28 days, savings up to 50% in the consumption of cement were achieved.

Chindaprasirt *et al* (2004), experimentally investigate the effect of fly ash fineness on compressive strength, porosity, and pore size distribution of hardened cement pastes. Class F fly ash with two fineness, an original fly ash and a classified fly ash, were used to partially replace portland cement at 0%, 20%, and 40% by weight. Test results indicated that the blended cement paste with classified fly ash produced paste with higher compressive strength than that with original fly ash. The porosity and pore size of blended cement paste was significantly affected by the replacement of fly ash and its fineness. The replacement of portland cement by original fly ash increased the porosity but decreased the average pore size of the paste.

Manikandan *et al* (2007), studied the main issues associated with the variation in the fineness of fly ash produced within a plant and between thermal plants. The influence of fineness of fly ash is studied by collecting typical samples of fly ash from two thermal power plants with fineness of 414 m^2/kg and 257 m^2/kg, respectively. It was found that finer fly ash exhibits higher pelletization efficiency as compared to coarser fly ash. Addition of clay binders enhanced the pelletization efficiency of coarser fly ash.

Singh (2009), presented the innovative type of self help techniques to tackle the problem of integrating different aspects of project decisions, management & implementation that attend to concerns with indoor air quality, pollution, climate change, energy & water conservation, affordability & sustainability in general. He suggested that use of materials like cement, steel & bricks, which consumes considerable amount of energy, should be completely eliminated or reduced to the maximum possible extent.

Chauhan (2011), presented a comprehensive study on the availability of pozzolanic materials & their suitability for cement industry in India. He remarked that the role of cement industry is significant in the economic development of the country. He deduced that the total installed capacity of the cement manufacturing reached around 175 MT p.a. The availability of FA & blast furnace slag is around 125 MT p.a.is sufficient for blending with 342 MT p.a. of cement clinkers as per the BIS norms.

Tiwari *et al* (2011), studied the CO_2 emission from cement industry. They presented the measures which should be taken to reduce the CO_2 emission. They proposes "Amine Scrubbing" & "Ammonia based absorbent" as the CO_2 capture technology for cement industry. Need to reduce the use of raw material in manufacturing process was also highlighted as a measure to reduce CO_2 emission from cement industry.

4.EXPERIMENTAL SETUP

4.1 For PPC Concrete:

S.No.	Particular
1	Cement fineness test
2	Consistency, Initial and Final setting time
3	Cement mortar compressive strength
4	Compressive Strength Results for M-20 Concrete

4.1.1 Cement Fineness Test

Cement manufacture :- ULTRATECH
Type of cement :- PPC
Grade of cement :- 43

Trial No	Weight of Cement in (gms) (A)	Weight of Cement retained on 90 µ. Sieve (B)	% of Fineness (B/A) X100	Average
1	200	12.0	6.0	
2	200	11.5	5.3	5.6
3	200	11.3	5.7	

TABLE 1 CEMENT FINENESS

4.1.2 Consistency, Initial and Final setting time test

Standard Consistency	30.5	Limit
Initial setting Time	55 min	Minimum 30 min
Final setting Time	190 min	Maximum 600 min

TABLE 2 CONSISTANCY & SETTING TIME

4.1.3 Compressive Strength of M-20 PCC Concrete Cubes (as per IS:516-1991)

7 Days Compressive Strength Results

CUBE NO	WEIGHT (Kg)	VOLUME (Cum)	DENSITY (Kg/m3)	TEST AREA (mm2)	MAX. LOAD (KN)	COMP. STRENGTH (N/mm2)	AVERAGE STRENGTH (N/mm2)
1	8.72	0.003375	2583.7	22500	380	16.9	
2	8.74	0.003375	2589.6	22500	390	17.3	
3	8.72	0.003375	2583.7	22500	385	17.1	**17.1**

TABLE 3

28 Days Compressive Strength Results

CUBE NO	WEIGHT (Kg)	VOLUME (Cum)	DENSITY (Kg/m3)	TEST AREA (mm2)	MAX. LOAD (KN)	COMP. STRENGTH (N/mm2)	AVERAGE STRENGTH (N/mm2)
4	8.68	0.003375	2314.6	22500	585	26.0	
5	8.65	0.003375	2306.6	22500	593	26.3	
6	8.68	0.003375	2314.6	22500	588	26.1	**26.1**
7 & 28 Days Compressive Strength Ratio =				0.66			

TABLE 4

4.2 FOR PFA BLENDED OPC CONCRETE:

For deciding the percentage of PFA to partially replace OPC in concrete, DOE Method of Concrete-mix Design was used. The DOE method was first published in 1975 and then revised in 1988. While Road Note No 4 or Grading Curve Method was specifically developed for concrete pavements, the DOE method is applicable to concrete for most purposes, including roads. The method can be used for concrete containing fly ash.DOE method is standard British method of concrete-mix design.

4.2.1 MIX DESIGN

	Water Kg/m^3	OPC Kg/m^3	PFA. Kg/m^3	Coarse Aggregate Kg/m^3	Fine Aggregate Kg/m^3
20% PFA	183	266	66.5	1244.5	670
25% PFA	185	253	84	1230	663
30% PFA	190	259	111	1127	690

TABLE 5

4.2.2 Compressive Strength of 20% PFA Blended OPC Concrete Cubes (as per IS:516-1991)

7 Days Compressive Strength Results

CUBE NO	WEIGHT (Kg)	VOLUME (Cum)	DENSITY (Kg/m3)	TEST AREA (mm2)	MAX. LOAD (KN)	COMP. STRENGTH (N/mm2)	AVERAGE STRENGTH (N/mm2)
7	8.23	0.003375	2440	22500	380	16.9	
8	8.24	0.003375	2441.5	22500	376	16.7	
9	8.22	0.003375	2435.5	22500	385	17.1	**16.9**

TABLE 7.12

28 Days Compressive Strength Result

CUBE NO	WEIGHT (Kg)	VOLUME (Cum)	DENSITY (Kg/m3)	TEST AREA (mm2)	MAX. LOAD (KN)	COMP. STRENGTH (N/mm2)	AVERAGE STRENGTH (N/mm2)
10	8.30	0.003375	2459.2	22500	542	24.1	
11	8.27	0.003375	2450.4	22500	545	24.2	
12	8.34	0.003375	2471.1	22500	540	24	**24.1**

TABLE 7.13

4.2.3 Compressive Strength of 25% PFA Blended OPC Concrete Cubes (as per IS:516-1991)

7 Days Compressive Strength Results

CUBE NO	WEIGHT (Kg)	VOLUME (Cum)	DENSITY (Kg/m3)	TEST AREA (mm2)	MAX. LOAD (KN)	COMP. STRENGTH (N/mm2)	AVERAGE STRENGTH (N/mm2)
13	8.18	0.003375	2423.7	22500	370	16.4	
14	8.16	0.003375	2417.7	22500	363	16.1	
15	8.20	0.003375	2429.6	22500	378	16.8	**16.4**

TABLE 7.14

28 Days Compressive Strength Results

CUBE NO	WEIGHT (Kg)	VOLUME (Cum)	DENSITY (Kg/m3)	TEST AREA (mm2)	MAX. LOAD (KN)	COMP. STRENGTH (N/mm2)	AVERAGE STRENGTH (N/mm2)
16	8.19	0.003375	2426.6	22500	532	23.6	
17	8.21	0.003375	2432.6	22500	530	23.5	
18	8.17	0.003375	2420.7	22500	528	23.5	**23.5**

TABLE 7.15

4.2.4 Compressive Strength of 30% PFA Blended OPC Concrete Cubes (as per IS:516-1991)

7 Days Compressive Strength Results

CUBE NO	WEIGHT (Kg)	VOLUME (Cum)	DENSITY (Kg/m3)	TEST AREA (mm2)	MAX. LOAD (KN)	COMP. STRENGTH (N/mm2)	AVERAGE STRENGTH (N/mm2)
19	8.12	0.003375	2405.9	22500	315	14	
20	8.14	0.003375	2411.8	22500	310	13.8	
21	8.13	0.003375	2408.9	22500	308	13.7	**13.8**

TABLE 7.16

28 Days Compressive Strength Results

CUBE NO	WEIGHT (Kg)	VOLUME (Cum)	DENSITY (Kg/m3)	TEST AREA (mm2)	MAX. LOAD (KN)	COMP. STRENGTH (N/mm2)	AVERAGE STRENGTH (N/mm2)
22	8.10	0.003375	2400	22500	442	19.6	
23	8.14	0.003375	2411.8	22500	445	19.8	
24	8.12	0.003375	2405.9	22500	439	19.5	**19.6**

TABLE 7.17

5 RESULTS & DISCUSSIONS

MIX TYPE	Quantity of Cement Kg/m^3	Quantity of PFA Kg/m^3	7 Day Compressive Strength N/mm^2	28 Day Compressive Strength N/mm^2	Ratio of 7Day to 28 Day Strength
PPC	350	0	17.1	26.1	0.66
OPC+20% PFA	266	66.5	16.9	24.1	0.70
OPC+25% PFA	**253**	**84**	**16.4**	**23.5**	**0.70**
OPC+30% PFA	259	111	13.8	19.6	0.70

Above table represent the comparison of strength of different type of mixes. It was found :

- Ratio of 7 Day to 28 Day Strength is higher in PFA blended OPC concrete-mix than PPC concrete-mix.
- Target Mean Strength is highest in OPC+20% PFA Mix.
- The most economical concrete-mix design was obtained is with OPC+ 25% PFA Therefore it is recommended a **25% replacement of OPC by PFA**

Present study shows that there lies a large scope of reducing consumption of cement in construction industry. If all FA generated is processed & is used as partial replacement of cement in place of grinding it with clinker 126 million tonnes of CO_2 can be prevented to emit in the atmosphere in addition to save a large amount of energy.

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LIST OF INDIAN STANDARD CODES

S.N.	CODE NO.	NAME OF CODE
1	IS:456:2000	Code of Practice for Plain and Reinforced concrete
2	IS 8112 : 1989	Specification for 43 grade ordinary Portland cement
3	IS 383 : 1970	Specification for coarse and fine aggregates from natural sources for
4	IS 9103 : 1999	Concrete Admixtures - Specification
5	IS 7861 : Part 1 : 1975	Code of practice for extreme weather concreting: Part I Recommended practice for hot weather concreting
6	IS 4926 : 2003	Ready-Mixed Concrete - Code of Practice
7	IS 10262 : 2009	Recommended guidelines for concrete-mix design
8	IS 516 : 1959	Method of test for Strength of concrete
9	SP 23 : 1982	Handbook on Concrete-mixes
10	IS 3812:1981	Specification for Fly Ash for use as pozzolana and Admixture