Effects of use of Metakaolin and Pond Ash in different types of Concrete

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Abstract - *The ever-expanding potential infrastructural and housing demand in India has made the country become the second largest cement producer in the World. Currently in India, cement production capacity is nearly 425 million tonnes, expected to reach a value as high as 550 million tonnes by 2025.With such enormous quantities of cements being produced every year, their lies an impending threat in terms of environmental concerns with rising levels of CO_2 emission in air. This emphasizes the need to employ the supplementary cementitious materials which improves the performance characteristics of concrete as well as enables the effective utilization of waste in concrete which otherwise is being sent to landfills. The present experimental work focuses on use of metakaolin and pond ash in different types of cements at 20% and 15% respectively as partial replacement percentages to cement and subsequently obtaining different types of concrete targeted at M25 grade. The results of compressive strengths of different types of concrete are compared and presented in conclusions.*

Key Words: Compressive strength, Metakaolin (MK), Ordinary Portland Cement (OPC), Pond Ash (PA), Portland Pozzolana Cement (PPC), Rapid Hardening Cement (RHC).

1. INTRODUCTION

Concrete is the most widely used building material for construction activities. The production of its constituent ingredient viz; cement attributes to environmental pollution as it involves the emission of CO_2 gas. Supplementary cementitious materials (SCM) are finely ground solid materials that are used to replace a portion of the cement in a concrete mixture. These supplementary materials may be naturally occurring, manufactured or man- made waste. Various types of pozzolanic materials that improves cement properties have been used in cement industry for a long time. Commonly used industrial waste materials which possess pozzolanic property are fly ash, ground granulated blast furnace slag and alternate cementitious materials such as metakaolin, silica fumes, steel fibers, quarry dust.

Metakaolin is manufactured additive which is produced for a specific purpose under carefully controlled conditions. This amorphous material is highly reactive, with pozzolanic and latent hydraulic reactivity, suitable for use in cementing applications. When used as a partial replacement for Portland cement, metakaolin may bound to improve both the mechanical properties and the durability of concrete.

The coal based thermal power plant are very popular, which generates large amount of fly ash, bottom ash and pond ash. The generated ash contains about 20 % Pond ash and 80 % fly ash of the total ash generated. Fly ash is being recycled as an alternative to cement while pond ash requires huge area, water and energy for its disposal.

The department related parliamentary standing committee on commerce submitted the 95th report on "performance of cement industry" [2011] to parliament of India strongly opines to conduct studies on non-limestone bearing raw material and binders, which can partially replace limestone and recommends to utilize fully the fly-ash generated by their captive power plants.

2. LITERATURE REVIEW

The literature studies listed below emphasizes on need for adoption of supplementary cementitious contents in cement in order to address these expanding issues.

Kianoosh Samimi, et.al [1], conducted experimental study on influences of metakaolin and cement types on compressive strength of self-consolidating concrete. The study involves use of three types of cement viz OPC, PSC, and PPC. This work concluded that though metakaolin affects the rheological properties of concrete, performance characteristics of metakaolin content beyond 15% shows decreasing.

Dr. K. Srinivasu, et.al [2], reviewed the use of metakaolin in cement concrete mortar and concrete, they inferred that cement replacements with metakaolin upto 20% in content gave maximum enhancement in pore refinement and compressive strength reduces when MK addition goes beyond 30% as a cement replacement.

Avancha Sri Sowmya1, et.al [3], opined that compressive strength of concrete increased when cement is replaced by metakaolin for M20 and M40 Grade of concrete. At 20% replacement of cement by metakaolin, the concrete attained maximum compressive strength for both M20 and M40 grade of concrete. The split tensile strength and the flexural strength are maximum at 20% of replacement. It is concluded that at 20% replacement of metakaolin, the resistance power of concrete is more.

Prashanth Kumar Sharma, et.al [4], recorded that from the experimental study that the pond ash when used as partial replacement to fine aggregate showed beneficiary effects over mechanical properties of concrete. The results indicate that the optimum pond ash replacement at 15% showed relative increment of compressive strength of concrete. It was seen that the bulk density and specific gravity of pond ash is lower to finer aggregate causes decrement in unit density of concrete.

Aditya Verma, et.al [5], conducted studies on utilization of pond ash partially replacement of cement concrete makes for variable replacements. The compressive strength for 7, 28, 56 and 90 days was increased up to 15 to 20% and after that the compressive strength were found to decrease with increase in replacement. A marginal decrease was observed in the flexural strength up to 15-20% replacement level. A decrease in strength of concrete with the increase in levels of fine aggregate replacement by coal bottom ash is due to the replacement of the stronger material with the weaker material. Splitting tensile strength of concrete improved on use pond ash as fine aggregate in partial replacement of sand. Workability of concrete was decrease found with the increase in percentage of Pond ash, as it is more porous, therefore absorb more water than sand hence some super plasticizer can be used in increasing dose as percentage of pond ash is increased. The densities of hardened concrete linearly decreased as the replacement ratio of ash was increased from 10% to 100% as compared to standard concrete.

Armugum K et al. [6] , conducted experiments on use of pond ash, fine aggregate with varying proportion of 0%, 20%, 40% and 60% of pond ash. They conclude that the density of concrete reduces with the increase in percentage of pond ash. The compressive strength of concrete with pond ash increased with increased curing period. The split tensile strength of concrete with pond ash increases up to the addition of 20% ash sand replacement. The flexural strength of concrete with pond ash increases up to the addition of 20% ash sand replacement. While the pond ash is used the workability is reduced. For obtaining the required workability, super plasticizers are added while preparing the concrete. The more pond ash to be added the more super plasticizers are required to be added for obtaining the required workability. With increasing replacement of fine aggregate with pond ash the average density of concrete shows linear reduction due to lower specific gravity.

The studies on several literatures have paved way for understanding that compressive strength is the most important parameter for assessing the engineering properties of concrete. It is inferred that use of metakaolin at 20 % and pond ash at 15% as partial replacements to cement have enhanced the performance and durability characteristics of concrete.

3. METHODOLOGY

The experimental setup envisaged the use of four different types of cements namely Ordinary Portland Cement (OPC) of 43 and 53 Grades, Portland Pozzolana Cement (PPC), Rapid Hardening Cement (RHC). Metakaolin and pond ash are used as partial replacements to cement in M25 Grade of concrete at 20 % and 15 % respectively. The same has been presented in the form of a flowchart in figure1.0.

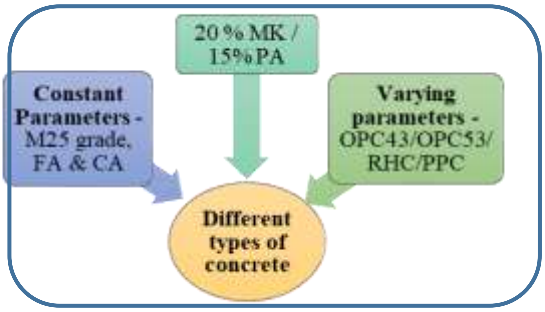

Figure 1.0 shows the flowchart of the present investigation

The physical properties of materials listed above were tested in laboratory and their values were found to be within the specified range. The results of physical tests carried out on four types of cements, coarse and fine aggregates, MK and PA are listed in the tables 1.0 and 1.1 below.

Table 1.0 Physical properties of types of cements

Sl. No	Physical properties	OPC 43	OPC 53	PPC	RHC
Source		*ACC*	*Birla shakthi*	*Ramco*	
1	Standard Consistency (%)	28.5	26.0	31.0	32.0
2	Initial Setting time (min)	120	110	100	95
3	Final Setting time (min)	400	390	370	365
4	Specific Gravity	2.31	2.65	2.32	2.35
5	Fineness by dry Sieving (%)	4.15	4.05	1.15	1.75
6	Fineness by Air Permeability Method, kg/cm^2	357	-	-	-
7	Compressive strength, MPa	25.3	29.83	20.50	30.0

Table 1.1 Physical properties of CA and FA				
Sl. No	Physical properties		CA	FA
1	Specific Gravity		2.67	2.52
2	Water Absorption (%)		0.34	1.30
3	Bulk Density	Loose(Kg/ltr)	1.46	1.62
		Compacted (kg/ltr)	1.56	1.77
4	Particle Finer than 75micron (%)		-	15.25
5	Shape Test (%)	Flakiness Index	10.21	-
		Elongation Index	12.12	-

In the present study, MK was procured from Specialty Minerals, Baroda, Gujarat and PA was obtained from Raichur thermal Power Plant (RTPS). Their specific gravity were found to be 2.65 and 1.85 respectively.

The design mix according to IS: 10262-2009[7] was carried out for M25 grade of concrete as it is the minimum compressive strength required at site. The arrived design mix values with MK and PA are presented below in tables 1.2 and 1.3.

Table 1.2 Design Mix : M25 with MK		
OPC 43/ OPC 53/ PPC/RHC		
Mix Calculations	Conventional	With 20% MK
Vol. of concrete	1m^3	1m^3
Mass of Cement	492.5 kg	394 kg
Mass of MK	-	98.5
Mass of FA	750 kg	750 kg
Mass of CA	980 kg	980 kg
Water content	197 litres	197 litres
W/C ratio	0.4	0.4

Table 1.3 Design Mix : M25 with PA		
OPC 43/ OPC 53/ PPC/RHC		
Mix Calculations	Conventional	With 15% PA
Vol. of concrete	1m^3	1m^3
Mass of Cement	374 kg	318kg
Mass of PA	-	56 kg
Mass of FA	974 kg	974 kg
Mass of CA	1025 kg	1025 kg
Water content	135 litres	135 litres
W/C ratio	0.37	0.4

4. RESULTS

In order to determine the compressive strength of concrete, cubes were casted in the laboratory and tested after curing them for 7days and 28 days as shown in the figures 1.1 and 1.2. The results are presented in table 1.4 (graph shown as figure 1.3) and 1.5 (graph shown as figure 1.4) for combinations with MK and combinations with PA respectively.

Figure 1.1 shows the concretes cubes of combinations kept in curing tank

Figure 1.2 shows the testing of concrete cube specimen in compression testing machine

Table 1.4 Compressive strength of M25 concrete with MK		
Combinations	Compressive strength, MPa	
	At 7 days	At 28 days
OPC 43	19.11	27.78
OPC 43+MK	21.48	31.31
OPC 53	19.58	29.26
OPC 53+MK	21.8	32.4
PPC	21.02	33.84
PPC+MK	23.74	37.07
RHC	22.36	36.78
RHC+MK	25.51	42.33

Table 1.5 Compressive strength of M25 concrete with PA		
Combinations	Compressive strength, MPa	
	At 7 days	At 28 days
OPC 43	26.00	38.88
OPC 43+PA	30.34	41.55
OPC 53	29.36	40.87
OPC 53+PA	32.57	43.95
PPC	29.97	42.80
PPC+PA	33.2	46.56
RHC	35.96	43.91
RHC+PA	39.82	47.71

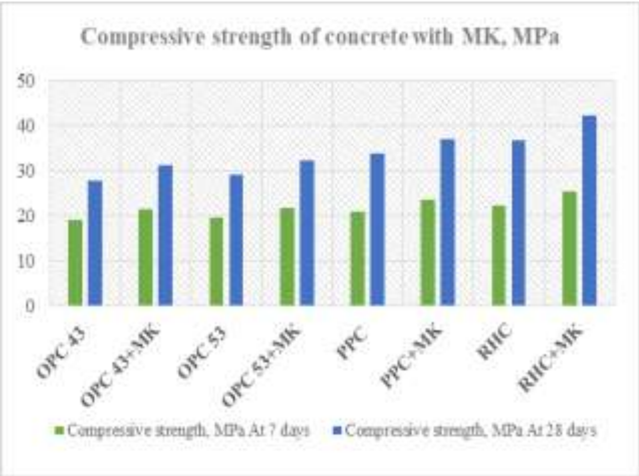

Figure 1.3 shows the graph of combinations of concrete with MK versus compressive strength, MPa

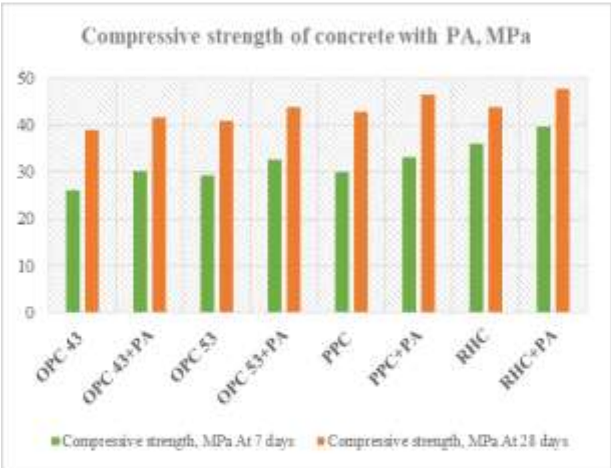

Figure 1.4 shows the graph of combinations of concrete with PA versus compressive strength, MPa

5. CONCULSIONS

- Concrete, the most extensively used construction material consumes materials leading to environmental concerns in terms of utilization of raw materials and also emissions of CO_2 while production of cement.
- Replacing them partially by pozzolana leads to modification in cement hydration and contributes to the cementitious products to matrix structure, treated as economical and it accelerates the pozzolanic activity by increasing the strength and durability properties of concrete.
- From figure 1.3, it can be seen that the combinations of RHC and RHC+MK are giving the highest results of compressive strength which is well established owing to its quick setting chemistry and properties. It is seen that PPC and PPC+MK are also showing higher values almost equivalent to RHC and its combination. This is due to the accelerated pozzolanic activity as compared to OPC 43 and 53 grades and their subsequent combinations. This implies that PPC along with blended pozzolana as additives can be an efficient and effective type of cement that could be utilized at various levels in construction industry and also accounts to be relatively environmental friendly building material.
- Comparing figure 1.3 with figure 1.4, it can be conclude that PA is a better pozzolanic material than MK as the compressive strengths of all combinations are showing higher values. Also, with the use of PA as an additive, the other three types namely, OPC 43, OPC 53 and PPC are behaving on par with RHC.

6. SCOPE FOR FUTURE RECOMMENDATIONS

- ➢ The present work can be extended to carry out design mixes for different grades of concrete with varying percentages of MK and PA.
- ➢ Other types of cements namely, high alumina cement, low heat cement, sulphate resisting cements could be used with MK and PA and other types of additives could also be used to assess the performance characteristics of concrete.
- ➢ The split tensile strength and flexural strength of the combinations of concretes defined above should be evaluated to present more precise and stringent conclusions.

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