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Predicting the Strength Properties of High Performance Concrete using Mineral and Chemical Admixtures

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ABSTRACT

This study shows that by using mixture-optimized, High Performance Concrete (HPC), significant reductions in CO_2 contributions can be realized for concrete construction-in conventional buildings, as well as in major projects. There is a growing awareness all over the world about the extensive damages being caused to the environment due to accumulation of waste material in the form of pulverized fuel ash from thermal power plants, silica fume, blast furnace slag etc. Worldwide efforts are being made to utilize these industrial wastes as an alternative material for both in building industry and for road construction. The paper presents experimental studies conducted on HPC mix of M_{70} grade using mineral and chemical admixtures in various proportions. The main purpose of this investigation is to develop confidence among user agencies in India to use mineral and chemical admixtures in a desirable proportion in most of the construction works. Overall, the paper highlights the usage of admixtures to achieve high strength concrete mixes and from the experimental investigation it is clear that mineral admixtures contribute effectively a lot not only for achieving durability, also high strength.

Keywords: *High Performance Concrete (HPC), Mineral Admixtures, Chemical Admixtures, Flyash (FA), Silica Fume (SF), Metakaoline.*

1. INTRODUCTION

One of the recent developments in concrete technology is High-Performance Concrete (HPC). It is designed to give optimized performance characteristics for the given set of materials, usage and exposure conditions, consistent with the requirement of cost, service life and durability. Like other pozzolans, Metakaolin reacts with the calcium hydroxide (lime) by-products produced during cement hydration. Metakaolin combines with the cacium hydroxide to produce additional cementing compounds; the material responsible for holding concrete together less calcium hydroxide provides more cementing compounds means stronger concrete.

The utilization of pozzolan was become establish especially in achieving a high strength and high performance of concrete. For the time being the pozzolans only used in binary blended system and the optimum replacement of the pozzolan to OPC was reported to be not more than 20%. This study focus on utilization of waste pozzolans products such as fly ash (FA) and rice husk ash (RHA) added together with OPC to produced ternary blended cement with an objective to increase up the optimum percentage replacement of pozzolan to OPC without effecting the concrete properties. Besides that, the utilization of pozzolanic materials used tends to put a commercial value to the waste product such as FA and RHA [1].

Kevin Smith Established a testing regime to optimize the strengths and dura-bility characteristics of a wide range of high-performance concrete mixes. The intent of the selected designs was to present multiple solutions for creating a highly durable and effective structural material that would be implemented on Pennsylvania bridge decks, with a life expectancy of 75 to 100 years. One of the prime methods of optimizing the mixtures was to implement supplemental cementitious materials, at their most advantageous levels. Fly ash, slag cement, and microsilica all proved to be highly effective in creating more durable concrete design mixtures [2].

A discussion on the application of the method of the simplex-lattice design for predicting the properties of cement-based composites. On the basis of the compressive Strength, its use was demonstrated on ternary paste systems composed of cement, silica fume and fly ash with constant water to binder ratio and a mass fraction of mineral admixtures not exceeding 30% [3].

Swamy, defines that ‘A high performance concrete element is that which is designed to give optimized performance characteristics for a given set of load, usage and exposure conditions, consistent with requirement of cost, service life and durability [4].

According to Aitcin, a high performance concrete is essentially a concrete having low water/binder (w /b) ratio. A value of 0.40 was suggested as the boundary between usual concrete and high performance concrete. The water binder ratio of 0.40 is arbitrary. But it is based on the fact that it is very difficult to produce concretes

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without super-plasticizers, with the most ordinary Portland cements, if the water/binder ratio is less than 0.40 [5].

2. MATERIALS USED IN THE PRESENT STUDY

2.1 Cement

Ordinary Portland cement Zuari-53 grade conforming to IS: 12269-1987 [6] were used in concrete.

The physical properties of the cement are listed in Table 1.

Table 1: Physical Properties of Zuari-53 Grade Cement

S/No.	**1**	**2**	**3**	**4**	**5**		
Properties	Specific gravity	Normal consistency	Initial setting time	Final setting time	Compressive strength (Mpa)		
Values	3.15	32%	60 min	320 min	3 days	7 days	28days
					29.4	44.8	56.5

2.2 Aggregates

A crushed granite rock with a maximum size of 20mm and 12mm with specific gravity of 2.60 was used as a coarse aggregate. Natural sand from Swarnamukhi River in Srikalahasthi with specific gravity of 2.60 was used as fine aggregate conforming to zone- II of IS 383-1970 [7]. The individual aggregates were blended to get the desired combined grading.

2.3 Water

Potable water was used for mixing and curing of concrete cubes.

3. SUPPLEMENTARY CEMENTING MATERIALS

3.1 Flyash

Fly ash was obtained directly from the M/s Ennore Thermal Power Station, Tamilnadu, India. The physicochemical analysis of sample was presented in Table 2.

Table 2: Physicochemical properties of Flyash sample.

Sample	**Specific Gravity**	**Specific Surface Area (m^2/g)**	**Moisture Content (%)**	**Wet density (gram/cc)**	**Turbidity (NTU)**	**pH**
Flyash	2.20	1.24	0.20	1.75	459	7.3

	Chemical Composition, Elements (weight %)							
	SiO_2	Al_2O_3	Fe_2O_3	CaO	K_2O	TiO_2	Na_2O_3	MgO
	56.77	31.83	2.82	0.78	1.96	2.77	0.68	2.39

3.2 Silica Fume

The silica fume used in the experimentation was obtained from Elkem Laboratory, Navi Mumbai. The chemical composition of Silica Fume is shown in Table 3.

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ARPN Journal of Science and Technology

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Table 3: Chemical composition of Silica Fume.

Chemical Composition	Silica (SiO_2)	Alumina (Al_2O_3)	Iron Oxide (Fe_2O_3)	Alkalies as ($Na_2O + K_2O$)	Calcium Oxide (CaO)	Magnesium Oxide (MgO)
Percentage	89.00	0.50	2.50	1.20	0.50	0.60

3.3 Metakaoline

The Metakaoline was obtained from M/s. 20 Microns Limited, Baroda, India. The chemical composition of Metakaoline is shown in Table 4.

Table 4: Chemical composition of Metakaoline

Chemical Composition	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	SO_3	Na_2O	K_2O	LOI
Mass Percentage	52 to 54%	42 to 44%	< 1 to 1.4%	< 3.0%	0.1%	< 0.1%	< 0.1%	< 0.05%	< 0.4%	< 1.0%

4. SUPER PLASTICIZER(C

4.1 Varaplast

PC100: A high performance concrete superplasticizer based on modified polycarboxilic ether, supplied from M/s Akarsh specialities, Chennai.

5. RESULTS AND DISCUSSIONS

In the present work, proportions for high strength concrete mix design of M_{70} was carried out according to IS: 10262-2009 [8] recommendations. The mix proportions are presented in Table 5.

Table 5: Mix Proportion for M_{70} Concrete.

	Cement	Fine Aggregate	Coarse Aggregate (20mm 20% & 12.5mm 80%)	water	SCMs	Super-plasticizer
Composition in Kg/m^3	482	715	1012	153	120	9.6
Ratio in %	1	1.483	2.099	0.317	0.248	0.0199

The tests were carried out as per IS: 516-1959 [9] and IS: 5816-1999 [10]. The 150mm cubes and cylindrical specimens (15mm dia and 300mm height) of various concrete mixtures were cast to test compressive strength and split tensile strength. The cubes and cylindrical specimens after de-moulding were stored in curing tanks and on removal of cubes and cylinders from water the compressive strength and split tensile strength were conducted at 7days, 28days, 90 days and 180 days. The test results were compared with individual percentage replacements for M_{70} grade concrete. Results of compressive strength and split tensile strength for M_{70} were shown in Figure 1 and Figure 2.

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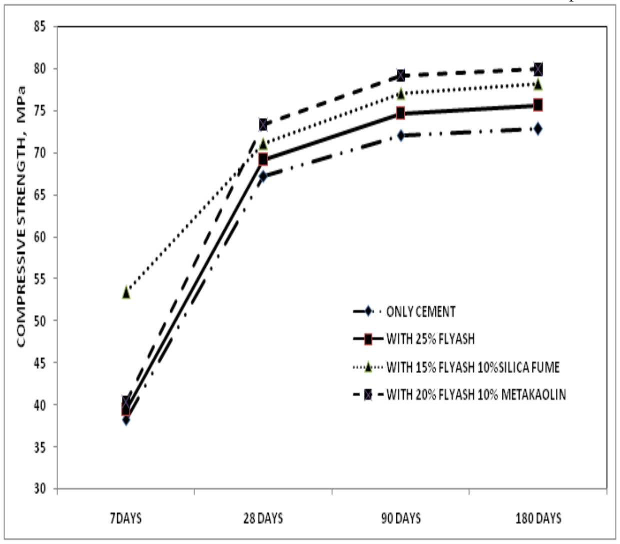

Fig 1: Shows the Compressive Strength results of M_{70} mix.

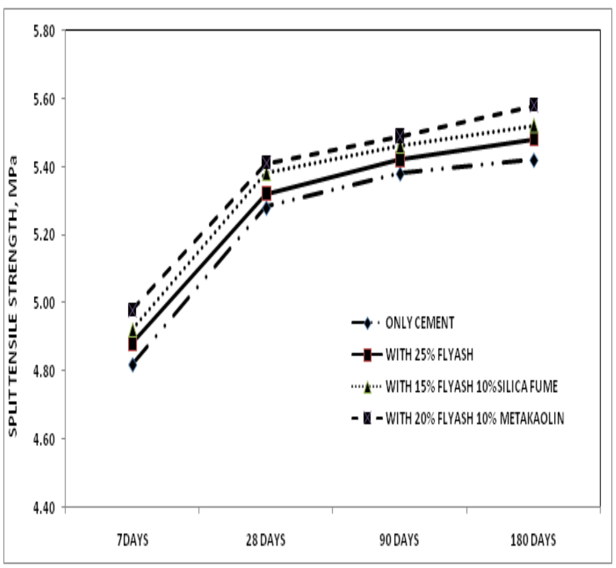

Fig 2: Shows the Split Tensile Strength results of M_{70} mix.

6. CONCLUSIONS

1. In high performance concrete mix design as water/cement ratio adopted is low, super plasticizers are necessary to maintain required workability. As the percentage of mineral admixtures is increased in the mix, the percentage of super plasticizer should also be increased, for thorough mixing and for obtaining the desired strength.

2. In M70 grade of concrete as the water-cement ratios of 0.317 is insufficient to provide the good workability, hence super plasticizer is necessary for making HPC.

3. Present study reveals that in case of combination percentage replacement of mineral admixtures the maximum compressive strength achieved in M70 grade concrete is 79.90 MPa with replacement of 20% Flyash and 10% Metakaoline for 180 days curing period.

4. Experimental study shows that in case of combination percentage replacement of mineral admixtures the maximum Split Tensile strength achieved in M70 grade concrete is 5.58 MPa with replacement of 20% Flyash and 10% Metakaoline for 180 days curing period.

5. The scope for using high strength concrete in our constructional activities are more such as precast, prestressed bridges, multi-storied buildings, bridges and structures on coastal areas. To affect this change, we will have to revive the designing of structures by encouraging use of high strength concrete mixes.

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