Experimental Study on Compressive Strength of Concrete by Using Metakaolin

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Abstract - Now-a-days enormous development occurred in the field of concrete technology. Many engineers, scientists and researcher have been developed several techniques to improve strength parameter of the concrete. A number of studies have been carried out to investigate the possibility of utilizing a broad range of materials as partial replacement material for cement in the production of concrete. The use of supplementary cementitious material in production of concrete can result in major saving of energy and cost. It also helps to improve strength, durability, impermeability and chemical resistance of concrete.

The present study investigates the effects of Metakaolin & Super plasticizer on strength properties of M-35 grade concrete. The experimental program is designed to find the compressive strength of concrete by partially replacing the cement in concrete production. The replacement levels of cement by metakaolin are selected as 4%, 8%, 12%, 16% and 20% for constant water-cementitious material ratio of 0.43. For all mixes compressive strength is determined at 3, 7, 28 days for 150 X 150 X 150 mm size cubes. Current experimental study shows that 12% replacement of cement by metakaolin gives higher strength.

Key Words: Concrete, supplementary cementitious material, metakaolin, super plasticizer, compressive strength.

1. INTRODUCTION

The production of Portland cement is not only costly and energy intensive, but it also produces large amount of carbon emission. The production of one to of Portland cement produces approximately one ton of CO2 in the atmosphere. Limestone is a raw material available in nature; it is primary need for production of cement material. Earlier it was used directly to form silica flume mortar as a binding material in construction.

Supplementary cementitious materials are often used to reduce cement contents and improve the workability of fresh concrete, increase strength and enhance durability of hardened concrete. SCMs used in the manufactured concrete products industry as well as a review of blended cements. There are various types of supplementary cementitious material as fly ash, silica fume, slag cement, metakaolin, rice husk ash, coconut shell etc. Out of above Supplementary Cementitious Materials (SCMs) we use Metakaolin as partial replacement of cement and experimental investigation is carried out.

The advantages like high strength, durability and reduction in cement production are obtained due to the incorporation of metakaolin in concrete and the optimum percentage replacement of metakaolin ranging from 8 to 12% to obtain maximum 28-days compressive strength of concrete. Durability and the other mechanical properties of concrete are improved when pozzolanic materials are incorporated in concrete because of the reaction between metakaolin and the free calcium hydroxide during the hydration of cement and consequently forms extra calcium silicate hydrate (C-S-H). Consequently, the use of metakaolin concrete in civil structures is wide spreading. Incorporation of metakaolin in concrete has an adverse effect on workability. Therefore, super plasticizer is needed for higher percentage of cement replacement by metakaolin. In this paper our attempt has been made to study the effect of metakaolin on strength properties of concrete considering a constant water-cementitious material ratio of 0.43 for M-35 grade concrete mix.

2. EXPERIMENTAL PROGRAM AND RESULTS DISCUSSION

2.1 Experimental Program

A. Materials Used:
The following materials were used for experiment confirming to various standards.

1. *Cement:*
Ordinary portland cement of 53 grade (Coromandal King) available in the local market is used in the investigation. The cement used has been tested for various properties as per IS 4031-1988 and found to be conforming to various specifications of IS 12269-1987. The specific gravity is 3.09 and fineness is 2600 cm^2/gram.

2. *Fine aggregate:*
Locally available crushed sand was used as fine aggregate which confirms to zone II of IS 383-1983. Coarser sand were preferred, as finer sand increases the water demand of concrete and very fine sand may not be essential in metakaolin concrete as it usually has larger content of fine particles in the form of cement and mineral admixtures such as metakaolin etc. The specific gravity of fine aggregate is 2.69 and fineness modulus is 3.23

3. *Coarse aggregate:*
Crushed angular granite metal from a local source was used as coarse aggregate having size ranging from 10mm to 20mm. The specific gravity of coarse aggregate is 2.68, fineness modulus is 7.2 and water absorption is 0.7%.

4. *Metakaolin:*
Commercially available Metakaolin from Jeetmull Jaichandlall (Madras) Pvt. Ltd. Chennai, having the properties as shown in Table 1 is used.

TABLE 1:PHYSICAL AND CHEMICAL PROPERTIES OF METAKAOLIN

Sr. No.	Metakaolin Characteristics	Specification Requirement
1	Form / Appearance	Light brown colored fine powder
2	SiO_2	54.68%
3	Al2O3	44.15%
	Specific gravity	2.56
4	Particle size	< 2µm
5	Specific surface area (NAM)	25.80 m^2/g
6	Bulk Density	167 kg/m^3

5. *Water:*
The water used for the study was free of acids, organic matter, suspended solids, alkalis and impurities which when present may have adverse effect on the strength of concrete.

6. *Super plasticizer:*
Super plasticizers used in the experimental work conforming to IS 9103-1999, was supplied by a private agency and it is a Sodium Naphthalene Sulphonate based retarder type Super plasticizers EB-821/R with a dosage of 0.8 to 1.2% by volume to weight of total binder contentof concrete. Necessary properties, given by supplier are given in Table 2.

TABLE 2: PROPERTIES OF SUPER PLASTICIZERS

I. Sr. No.	Properties	Description
1.	Chemical admixture	Ura-plast SF
2.	Color	Dark brown
3.	Type	Sulphonated Naphthalene formaldehyde polymer
4.	Specific Gravity	1.12 at 20°C
5.	pH Value	6.7
6.	Chloride content	Nil
7.	Air Entrainment	Nil
8.	Nitrate content	Nil
9.	Viscosity	Medium Viscous

B. Mix Proportion:

Concrete mix design in this experiment was designed as per the guidelines specified in I.S. 10262-1982. Mix Proportioning by weight was used and the cement/ dried total aggregates ratio was 1:2.3:2.98. Metakaolin were used to replace OPC at dosage levels of 4%, 8%, 12%, 16% and 20% by weight of the binder. The mix proportions were calculated and presented in Table 3.

TABLE 3: QUANTITIES OF MATERIALS PER 1m^{3}OF CONCRETE

Composition of the concrete mixtures (Kg/m^3) per m^3 of concrete							
Mix	w/c	OPC (kg)	Metaka-olin (kg)	Fine Agg. (kg)	Coarse Agg. (kg)	Super plasticizer (kg)	Water (kg)
NC	0.43	380	0	881	1135	4.56	163
NC + 4% MK	0.43	364.8	15.2	881	1135	4.56	163
NC + 8% MK	0.43	349.6	30.4	881	1135	4.56	163
NC + 12% MK	0.43	334.4	45.6	881	1135	4.56	163
NC + 16% MK	0.43	319.2	60.8	881	1135	4.56	163
NC + 20% MK	0.43	304	76	881	1135	4.56	163

C. Preparation of Test Specimen:

In this study, a total number of 54 cubes for the control and cement replacement levels of 4%, 8%, 12%, 16% and 20% were produced respectively. All the mixes were cast using 1:2.3:2.98 mix proportion with constant w/c ratio of 0.43. For the compressive strength, 150mm x 150mm x 150mm cube moulds were used to cast the cubes. During moulding the cubes were mechanically vibrated. All freshly cast specimens were left in the moulds for 24 hours before being de-moulded and then submerged in water for curing until the time of testing 3 specimens were tested for each age in a particular mix (i.e. the cubes were tested at 3, 7 and 28 days respectively). The specimens were tested for compressive strength using a compression testing machine.

D. Testing Of Specimen:

Compressive strength test were carried out at specified ages on the cubes. For the compression test, the cubes are placed in machine in such a manner that the load is applied on the forces perpendicular to the direction of cast.

FIGURE 1: COMPRESSIVE STRENGTH TEST SETUP

In Compression Testing Machine, the top surface of machine is fixed and load is applied on the bottom surface of specimen. The rate of loading is gradual and failure (crushing) load is noted. Also the failure pattern is observed precisely. Figure 1 shows compressive strength test setup.

2.2 Results Discussion

A. Results of compressive strength of concrete:

The test was carried out conforming to IS 516:1959 to obtain compressive strength of M-35 grade of concrete. For compressive strength testing total 54 concrete cubes are casted. Six concrete mix samples are used. The compressive strength of high strength concrete with OPC, metakaolin and super plasticizer concrete at the age of 3, 7 and 28 days are presented in table 4. There is a significant improvement in the strength of concrete because of the high pozzolanic nature, fineness of the metakaolin and its void filling ability. The compressive strength of the mix M-35 at 3, 7 and 28 days age, with replacement of cement by metakaolin was increased gradually up to an optimum replacement level of 12% and beyond 12% to 20% there is decrease in compressive strength. The compressive strength of M-35 grade concrete with partial replacement of 12% cement by metakaolin shows 10% greater than the controlled concrete. The maximum compressive strength of concrete with metakaolin depends on three parameters, namely the replacement level, water cement ratio and chemical admixture. The maximum 3, 7 and 28 days cube compressive strength of M-35 grade with 12% of metakaolin was 16.83, 29.36 and 47.016 Mpa respectively.

TABLE 4: COMPRESSIVE STRENGTH FOR VARIOUS MIX PROPORTIONS

Type of concrete	Compressive Strength (N/mm^2)		
	3 Days	7 Days	28 Days
Normal Concrete	15.34	28.49	43.17
Normal Concrete + 4 % Metakaolin	15.70	29.01	44.55
Normal Concrete + 8 % Metakaolin	16.36	29.34	45.19
Normal Concrete + 12 % Metakaolin	16.83	29.36	47.016
Normal Concrete + 16 % Metakaolin	15.05	24.72	45.47
Normal Concrete + 20 % Metakaolin	14.89	22.66	44.84

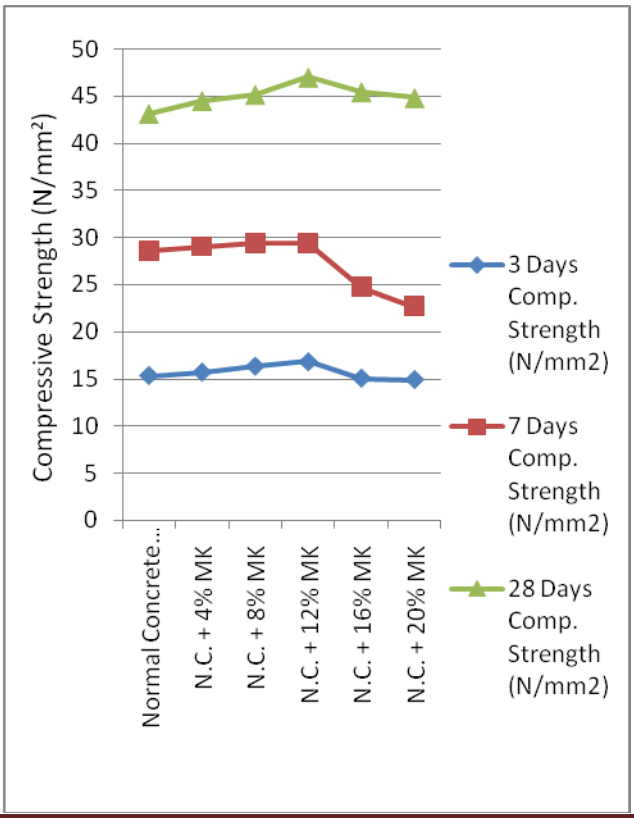

CHART NO.1: COMPRESSIVE STRENGTH OF CONCRETE CUBES FOR DIFFERENT TRIAL MIXES FOR 3, 7 & 28 DAYS CURING PERIOD

B. *Discussion:*

As expected the compressive strength increases with increase in content of metakaolin. As the total water/binder ratio is kept constant, the variation of strength with respect to constant water/cement ratio remains open to discussion. The compressive strength of metakaolin / metakaolin concrete increases with increase in metakaolin content upto 12% and further increment of metakaolin will result in strength reduction. The graph plotted denotes that the highest compressive strength of M-35 grade metakaolin concrete at optimum dose of 12 % is 47.016 MPa.

3. CONCLUSIONS

- Both the physical and chemical properties of metakaolin and cement are in compliance with the standard.
- Cement replacement up to 12% with metakaolin leads to increase in compressive strength for M-35 grade of concrete. From 16% there is decrease in compressive strength for 3, 7 and 28 days of curing period.
- The optimum dose of metakaolin for achieving higher compressive strength is 12%.
- Metakaolin increases the compressive strength of concrete more than 10%.
- In mixes blended with high percentage of metakaolin, the water demand will be more because of fineness of metakaolin. To maintain workability of concrete at construction site, use of super plasticizers becomes necessary.
- By effective usage of Metakaolin in optimum percentage in concrete may make concrete economic and environmental friendly.

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