Metakaolin in Steel fibre Reinforced Portland Pozzolona Cement Concrete - An Experimental Investigation

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***Abstract* - Metakoline is a highly reactive pozzolana. It reacts with the excess calcium hydroxide resulting from hydration of cement and produces calcium – silicate – hydrate (C-S-H) and calcium alumina silicate hydrates. It is a very useful pozzolanic material for improving concrete quality by enhancing strength and reducing setting time. It may prove to be a promising supplementary cementing material. This paper presents the effect of metakaolin, when used as a partial replacement of Portland Pozzolona Cement on strength of Steel Fibre Reinforced Concrete. An Experimental study was carried out to determine the Compressive, Split Tensile and Flexural strength of Steel Fibre Reinforced Concrete made using Portland Pozzolona Cement (PPC) and 1% Steel Fibre. The partial PPC replacement (with metakaolin) level was varied between 10% to 16% by weight of cement, at an interval of 1%. M-25 referral mix at 0.46 water cement ratio was used. The Cube specimens, Cylinder specimens and Beam specimens were cast and tested for determination of Compressive strength of concrete at different replacement levels and Split Tensile and flexural strength at optimum replacement level (Determined on the basis of compressive strength). It was seen that at 12% replacement level, Compressive, Split Tensile, and Flexural strength increased substantially as compared to the referral concrete.**

Keywords- component; formatting; style; styling; insert (key words).

I. INTRODUCTION

Concrete is the widely used and versatile building material which is generally used to resist compressive forces as assumption is made in analysis and design. Addition of some pozzolanic materials can improve the various properties of concrete viz, workability, durability, strength, resistance to cracks and permeability. Many concrete mixes used to modified with addition of admixtures, which improve the microstructure as well as decrease the calcium hydroxide concentration by consuming it through a pozzolanic reaction. It is established fact that when fine pozzolana particles are dissipated in the matrix, a large number of nucleation sites are generated which precipitate the hydrated products. Therefore, this mechanism makes matrix more homogeneous. This is due to the reaction between the amorphous silica of the pozzolanic material and calcium hydroxide, produced during the hydration of cement.

Metakaolin is used as supplementary cementious material to enhance the mechanical properties of concrete and Steel Fibre is used to enhance the structural property of concrete, specially tensile and flexural strength. Steel fibre enhances various other properties of concrete such as fatigue resistance, abrasion resistance, permeability, impact resistance etc.

Metakoline which is a highly reactive pozzolana, reacts with the excess calcium hydroxide resulting from hydration of cement and produces calcium silicate hydrate and calcium alumina silicate hydrates [1]. It is quite useful material for improving concrete quality by enhancing strength and reducing setting time and may prove to be a promising material for manufacturing high performance concrete [2]. Metakaoline may be used as supplementary cementitious material in concrete to reduce the cement consumption and permeability; increase strength and rate of strength gain; and make more durable concrete [3-7]. It is reported that on inclusion of 10% high reactivity metakaolin (HRM), compressive strength increased by 9.10% at 28 days [8]. It is also reported that the compressive strength increases substantially with increase in metakaolin content [9]. It is concluded that the gain in compressive strength depend upon the replacement level of Ordinary Portland Cement (OPC) by metakaolin. The metakaolin inclusion generally improves tensile strength, flexural strength, bond strength and modulus of elasticity. The quantum of increase in the individual properties depends upon replacement level. As the compressive strength increases the tensile strength also increases with replacement level upto its optimum level [10]. It is reported that the tensile strength of concrete increases systematically with increasing metakaolin replacement level. The tensile strength increase reported as 7% (5% metakaolin), 16% (10% metakaolin) and 28% (15% metakaolin) at 28 days [9]. It is reported that the optimum replacement level of OPC by Metakaolin is 15%. The gain in compressive strength on Metakaolin inclusion is quite considerable and makes the concrete almost equal to M_{40} grade [11].

This paper presents the effect of metakaolin (as a partial replacement of Portland Pozzolona Cement) on strength of Steel Fibre Reinforced Concrete. An Experimental investigation was carried out to evaluate the Compressive, Split Tensile and Flexural strength of Steel Fibre Reinforced Concrete made using Portland Pozzolona Cement (PPC) and 1% of Steel Fibre. The PPC replacement (with metakaolin) level was varied between 10% to 16% by weight of cement at an interval of 1%. M-25 referral mix at

0.46 water cement ratio was used. The Cube Specimens (100 mm x 100mm x 100 mm), Cylinder specimen (150 mm dia and 150 mm height) and Beam specimens (100 mm x 100 mm x 500 mm) were cast and tested for determination of Compressive strength of concrete at different replacement levels and Split Tensile and flexural strength at optimum replacement level(Determined on the basis of compressive strength) at 7 and 28 days.

II. MATERIAL AND METHODS

Materials used in present investigation were tested as per provision laid down in Indian Standards.

Cement: In present work, PPC obtained from a single batch was used throughout the investigation. The cement was satisfying the requirement of IS 1489 (part 1):1991. Properties of cement is given in table 1. However, similar material properties was reported by Shukla et al. [12].

TABLE I : PROPERTIES OF CEMENT

S. No.	Properties	Experimental value	Codal requirement (IS 1489(Part 1):1991
1	Normal Consistency %	31%	
2	Initial setting time	160 min.	Not less than 30 min.
3	Final setting time	215 min.	Not more than 600 min.
4	Soundness of cement (Le-Chatelier expansion)	0.75 mm	Not more than 10 min.
5	Fineness of cement (%age retain on 90 micron IS sieve)	4.15%	10%
6	Specific gravity of cement	2.67	3.15
7	7 days	33.0	22 N/mm
8	28 days	43	33 N/mm2

Fine Aggregate: Fine aggregate used in the investigation, was passed through 4.75mm sieve. The specific gravity was found to be 2.2 and fineness modulus to be 2.84. However, similar material properties were reported by Shukla et al. [12].

Coarse Aggregate: The coarse aggregate used was having two different sizes; one fraction was passed through 20 mm sieve and another fraction through 10 mm sieve. The specific gravity of coarse aggregate was found to be 2.66 for both the fractions. And fineness modulus for 10mm and 20 mm coarse aggregate fraction was calculated as 6.428 and 6.006 respectively. However, similar material properties was reported by Shukla et al. [12].

Metakaolin: Physical and chemical properties of metakaolin which was used is given in table 2. However, similar material properties was reported by Shukla et al. [12].

TABLE II : PROPERTIES OF METAKAOLIN

Physical Properties	
Appearance	Ivory to Buff
Density (Gm/cc)	0.38-0.42
Specific Gravity	2.54
Moisture on Board	max. 0.5 -1%
Loss on Ignition	< 1.4
BET Surface Area	15-18 sq.mtr/gm
Sieve residue on 45 micron	nil
d50 : Average Particle Size	3-4 MICRON
d90	12-14 MICORN
Chemical Properties	
SiO2	60-65 %
Al2O3	30-34%
Fe2O3	1.00%
TiO2	< 2.00%
CaO	0.2-0.8%
MgO	0.2-0.8%
Na2O+K2O	0.5-1.20%

Fig. 1 Metakaolin

Steel Fibre**:** The fibres used were of straight rectangular shape and of size 0.8 mm x 35 mm having aspect ratio of 43.75. The steel fibre used in the investigation is shown in fig. 2.

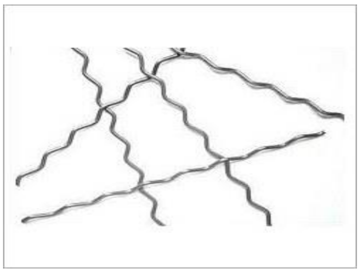

Fig. 2 Crimped Steel Fibre

Water: The water cement (w/c) ratio of 0.46 was used throughout the investigation.

Mix Design: Mix design was carried out as per procedure laid down in IS: 10262- (2009). M_{25} grade of concrete was designed with 1:2.08:3.86 mix proportion at 0.46 w/c ratio.

Nomenclature of specimen: Nomenclature of specimen is given in table 3 below.

TABLE III : NOMENCLATURE OF CUBE SPECIMENS

S.No	Cube Designation	Metakaolin (%, by weight of cement)	Steel Fibre (%, By volume)
1	C1	0	0
2	C2	0	1
3	C3	10	1
4	C4	11	1
5	C5	12	1
6	C6	13	1
7	C7	14	1
8	C8	15	1
9.	C9	16	1

TABLE IV : NOMENCLATURE OF CYLINDER AND BEAM SPECIMENS

S.No	Cylinder Designation	Beam Designati on	Metakaolin (%, by weight of cement)	Steel Fibre (%, By volume)
1	Cy1	B1	0	0
2	Cy2	B2	0	1
3	Cy3	B3	12	1

III. RESULTS AND DISCUSSION

It is seen that metakaolin as partial replacement of PPC increases the compressive and split tensile strength of concrete at all replacement level, both at 7 & 28 days .

Compressive Strength of Steel Fibre Reinforced (SFRC) Metakaolin Concrete (SFRMC): The compressive strength is maximum at 1% steel fibre and 12% metakaolin (as partial replacement of cement) and it is about 18% and 20 % more than that of referral SFRC at 7 & 28 days respectively when compared to the referral SFRC and PPC concrete.

Compressive strength of referral concrete as well as SFRMC at 7 & 28 days are given in table 4 and the variation of compressive strength of specimens at different replacement level of metakaolin is shown in fig 3.

TABLE IV COMPRESSIVE STRENGTH OF SPECIMENS AT DIFFERENT REPLACEMENT LEVEL

S.No	Cube	Compressive Strength(N/mm^2)	
		Strength (7 days)	Strength (28 days)
1	Co	23.4	31.6
2	C1	23.8	33.4
3	C2	25.6	36.0
4	C3	26.0	37.1
5	C4	28.2	38.2
6	C5	27.0	37.0
7	C6	26.8	36.3
8	C7	26.2	35.7
9	C8	25.2	34.6

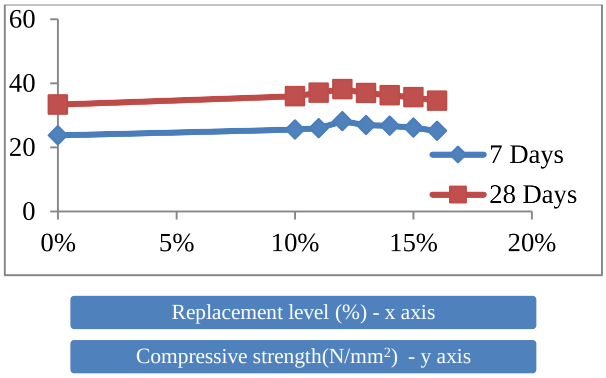

Fig.3 : Variation of compressive strength at different replacement level in SFRMC

Split tensile strength of referral concrete as well as SFRMC at 7 & 28 days are given in table no. 5.

TABLE V : SPLIT TENSILE STRENGTH OF SPECIMENS AT DIFFERENT REPLACEMENT LEVEL

S.No	Cylinder	Split Tensile Strength (N/mm^2)	
		7 days	28 days
1	Cy1	2.97	5.23
2	Cy2	3.28	5.55
3	Cy3	4.5	7.19

Split Tensile Strength of SFRMC: The split tensile strength is maximum at 1% steel fibre and 12% metakaolin and it is about 30% and 25 % more than that of referral SFRC at 7 & 28 days respectively when compared to the referral SFRC and PPC concrete,.

Flexural Strength of SFRMC: As compared to the referral SFRC, the Flexural strength is maximum at 1% steel fibre and 12% metakaolin and it is nearly 30% and 25 % more than that of referral SFRC at 7 & 28 days respectively.

Flexural strength of referral concrete as well as SFRMC at 7 & 28 days are given in table no. 6.

TABLE VI : FLEXURAL STRENGTH OF SPECIMENS AT DIFFERENT REPLACEMENT LEVEL

S.No	Beam	Flexural Strength (N/mm^2)	
		7 days	28 days
1	B0	3.24	5.76
2	B1	4.80	6.45
3	B3	6.00	7.35

IV. CONCLUSION

From the above study following conclusion may be drawn,

1) Compressive strength of SFRC made using metakaolin is increased both at 7 and 28 days at all the replacement levels.
2) Tensile Strength of SFRC made using metakaolin is substantially increased at 12% replacement level.
3) Flexural Strength of SFRC made using metakaolin is substantially increased at 12% replacement level.
4) Optimum replacement level of PPC by metakaolin is 12%.

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