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AN INVESTIGATION ON THE IMPACT BEHAVIOUR OF METAKAOLINE BASED HYBRID FIBER REINFORCED CONCRETE WHEN SUBJECTED TO ALTERNATE WETTING AND DRYING

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ABSTRACT

Combining fibres with different geometry and mechanical properties can improve the mechanical properties of fibre reinforced concrete. Often called hybrid fibre reinforced concrete (HFRC), these composites take advantage of different and synergistic effects on mechanical properties of each fibre type. Macrofibers of steel, due to their high modulus and improved bonding characteristics are known to improve toughness of concrete at relatively small crack openings; on the other hand, micro-fibres of polypropylene are expected to mitigate shrinkage cracking, improve the tensile strength of the matrix, improve the crack growth resistance and enhance strain capability.

In this experimental work an attempt is made to study the impact behavior of metakaoline based hybrid fiber reinforced concrete when subjected to alternate wetting and drying, in which 20 % of cement is replaced by metakaoline. Different fibers used in this experimentation are steel fibers (SF), galvanized iron fibers (GIF),waste coiled steel fibers (WCSF), high density polyethylene fibers (HDPEF), waste plastic fibers (WPF) and polypropylene fibers (PPF).Different combinations of hybrid fibers used in this experimentation are (SF+GIF), (SF+WCSF), (SF+HDPEF), (SF+WPF) and (SF+PPF). The impact behavior is studied by subjecting the concrete to 120 cycles of alternate wetting and drying, one cycle being 24 hours of wetting and 24 hours of drying.

Keywords: Hybrid fibres, mono fibres, steel fibers (SF), galvanized iron fibers (GIF), waste coiled steel fibers (WCSF), high density polyethylene fibers (HDPEF), waste plastic fibers (WPF), polypropylene fibers (PPF), impact strength, alternate wetting and drying.

I. INTRODUCTION

To overcome the deficiencies in fibre reinforced concrete(FRC), hybrid fibre reinforced concrete (HFRC) is gaining importance. In HFRC two or more different types of fibres are rationally combined in the matrix. Each individual fibre exhibit a synergestic response. The main purpose of use of HFRC is to arrest the cracks at different sizes and levels at different zones of concrete for different curing ages and loading stages. [1] Qian C.X. el al.[2] have observed that there is a synergy effect in the hybrid fibers system. Mobasher B et al.[3] have concluded that fracture toughness may be increased by the use of hybrid fibres. Hybrid composites are shown to have superior strength and toughness properties due to the interaction of reinforcing fibers.

Concrete shrinks when allowed to dry in air at a lower relative humidity and it swells when kept at 100% relative humidity or when placed in water. Just as drying shrinkage is an ever continuing process, swelling, when continuously placed in water is also an ever continuing process. If a concrete sample subjected to drying condition, at some stage, is subjected to wetting condition, it starts swelling. Just as the drying shrinkage is due to the loss of adsorbed water around gel particles, swelling is due to the adsorption of water by the cement gel. The water molecules act against the cohesive force and tend to force the gel particles further apart as a result of which swelling takes place. In addition, the ingress of water decreases the surface tension of the gel. The moisture movement in concrete induces alternatively compressive stress and tensile stress which may cause fatigue in concrete which reduces the durability of concrete owing to reversal of stresses [4] Dali J.S. et. al.[5] are of the opinion that the alternate wetting and drying cycles will affect the strength properties of concrete containing glass powder.

II. Materials used

Materials used in this study include ordinary portland cement (OPC 43), metakaoline, fine aggregate, coarse aggregate, steel fibre(SF), galvanised iron fibre(GIF), high density polyethylene fibre (HDPEF), waste plastic fibre (WPF), waste coiled steel fibre (WCSF), poly propylene fibre (PPF) .

- ***Cementicious material:*** In this experimental work, 43 grade ordinary Portland cement (OPC) with specific gravity 3.15, conforming to IS: 8112 – 1989 was used. [6] Metakaolin supplied by 20 Microns Company Vadodhara, was used in the present experimental investigation.
- ***Aggregate:*** Locally available river sand belonging to zone II of IS: 383–1970 and specific gravity 2.26, bulk density 1752 kg/m^3 and water absorption 1.0 % was used. Locally available crushed aggregates confirming to IS: 383–1970 and specific gravity 2.65, bulk density 1782 kg/m^3 and water absorption 0.6 % was used. [7]
- ***Fibres :*** Crimped steel fibres (SF) of 1mm thickness and 50mm length giving an aspect ratio of 50, with density 7850 kg/m^3 and ultimate tensile strength 395 MPa were used. Steel fibres were obtained from Stewools India (P) Ltd. Nagpur. Galvanized iron fibres (GIF) are made up of round galvanized iron wire of 1mm diameter,cut to the required length of 50 mm keeping an aspect ratio of 50.The ultimate strength and density of GI fibres was found to be 395 MPa and 7850 kg/m^3 respectively. Waste coiled steel fibres(WCSF) were obtained from lathe machine shops. The coiled steel wires were cut in lengths of 50mm. Average thickness was found to be 1mm so that the aspect ratio is 50. High density polyethylene fibres (HDPEF) were procured from cutting HDPE oil cans. Fibres were cut to a length of 50 mm and width of 2mm. Thickness was found to be 1 mm, so that the aspect ratio is 50. Density of HDPE fibre was found to be 900 kg/m^3. Waste plastic fibres (WPF) were procured from cutting waste plastic buckets. Fibres were cut to a length of 50 mm and width of 2mm.Thickness was found to be 1mm, so that aspect ratio is 50. Density of waste plastic fibre was found to be 230 kg/m^3. Polypropylene fibers (PPF) were obtained from Conmat India, Bangalore. Length of the polypropylene fibre is found to be 12mm. The specific gravity is found to be 0.92.

III. Methodology

In order to find out the resistance to alternate wetting and drying, after 28 days and 90 days of curing the specimens were kept in open air for 24 hours for drying and then immersed in water for 24 hours for wetting. This constituted one cycle of wetting and drying. A special water tank was prepared for this purpose. All specimens were subjected to 120 cycles of alternate wetting and drying. Then all the specimens were tested for their impact strength.

The mix proportion for M 30 grade concrete as per mix design was found to be 1:1.38:2.75 with w/c ratio 0.45. Required quantity of cement, fine aggregates, coarse aggregates were dry mixed. Before dry mixing, 20% of cement was replaced with metakolin. Monofibers were added 1% by volume fraction while hybrid fibers were added (0.5% + 0.5%) by volume fraction. To this dry mix, required quantity of water was added and thoroughly mixed. This green concrete was placed in three different layers in the moulds which were thoroughly oiled. The moulds were vibrated by keeping them on table vibrator. Hand compaction was also adopted simultaneously. After compaction the specimens were covered by wet gunny bags. After 15 hours, the specimens were demoulded and transferred to curing tank. They were allowed to cure in water for 28 days or 90 days as the case may be. For impact strength 150mm diameter and 60mm height cylinders were cast. Drop weight test or Schruder's impact test was adopted for testing impact specimen. The equipment was fabricated which can reduce the man power as shown in figure 1.0. The specimens were kept in the Schruder's impact testing machine and a hammer weighing 4.54 kg was dropped from a height of 457mm. Number of blows required to cause first crack and final failure were noted down. The final failure is defined as the opening of cracks in the specimen sufficiently so that pieces of concrete are touching at least three out of the four positioned lugs on the base plate. The impact energy is calculated as follows

Impact energy = m x g x h x n

= w/g x g x h x n

= w x h x n

Where, w = weight of the hammer = 4.54kg = 45.4N

h = height of the fall = 45.7cm = 0.457m

n = number of blows required to cause first crack or final failure as the case may be.

Fig. 1.0 Schruder's impact testing machine- A fabricated equipment

III. Experimental results

Table 1 and table 2 gives the results of impact strength of metakaoline based hybrid fiber reinforced concrete. Tables also gives the percentage increase of impact strength of hybrid fiber reinforced concrete with respect to respective mono fibre reinforced concrete. Tables also indicates the percentage increase of impact strength of hybrid fiber reinforced concrete and mono fibre reinforced concrete with respect to reference mix. The variation of impact strength is shown graphically in figure 2.0.and 3.0

Table 1.0 Results of impact strength for first crack when subjected to alternate wetting and drying

Description of concrete	Impact strength for first crack when subjected to alternate wetting and drying after 28 days of curing (N-m)	Percentage increase of 28 days impact strength (first crack) for HFRC with respect to corresponding mono fibre reinforced concrete	Percentage increase of 28 days impact strength (first crack) with respect to reference concrete	Impact strength for first crack when subjected to alternate wetting and drying after 90 days of curing	Percentage increase of 90 days impact strength (first crack) for HFRC with respect to corresponding mono fibre reinforced concrete	Percentage increase of 90 days impact strength(first crack) with respect to reference concrete
Without fibres (REF)	318.13	0	0	387.29	0	0

(SF+GIF)	13970.19	4	4291	16217.86	15	4088
(SF+WCSF)	13416.91	10	4117	15802.91	23	3980
(SF+HDPEF)	6500.98	21	1943	7157.99	15	1748
(SF+WPF)	6155.18	28	1835	6777.61	26	1650
(SF+PPF)	9267.35	13	2813	10097.26	13	2507
SF	13658.97	--------	4193	14315.98	--------	3596
GIF	13486.07	--------	4139	14108.50	--------	3543
WCSF	12172.04	--------	3726	12898.22	--------	3230
HDPEF	5394.43	--------	1596	6224.34	--------	1507
WPF	4806.57	--------	1411	5394.43	--------	1293
PPF	8195.38	--------	2476	8921.55	--------	2204

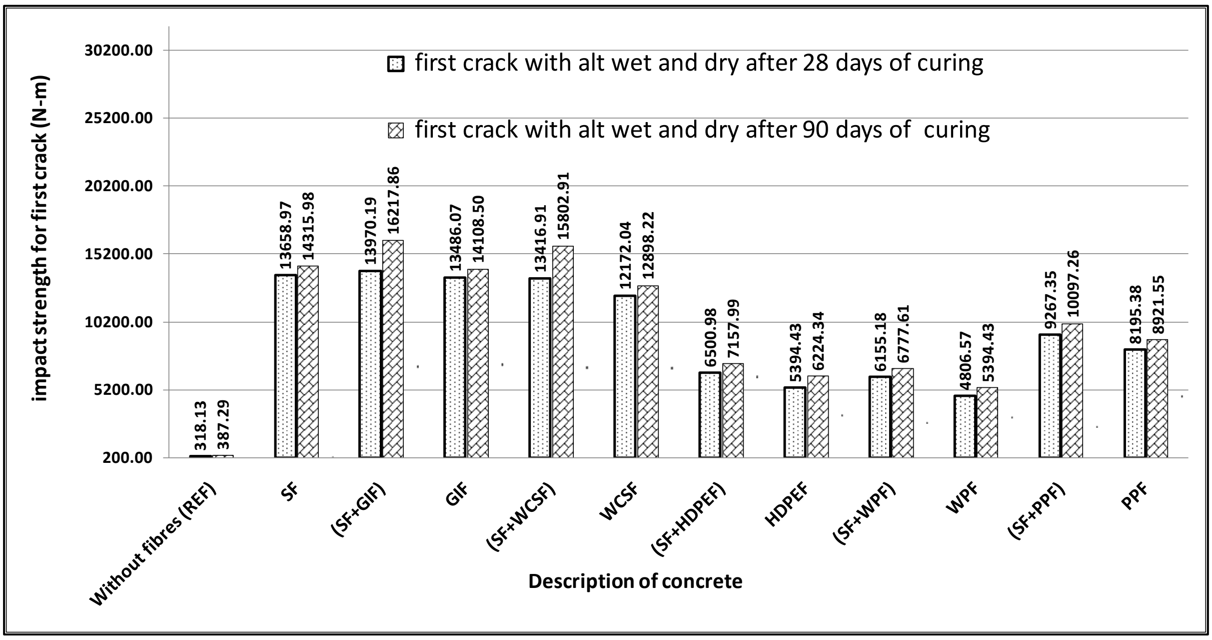

Fig 2.0 Variation of impact strength for first crack when subjected to alternate wetting and drying

Table 2.0 Results of impact strength for final failure when subjected to alternate wetting and drying

Description of concrete	Impact strength for final failure when subjected to alternate wetting and drying after 28 days of curing (N-m)	Percentage increase of 28 days impact strength (final failure) for HFRC with respect to corresponding mono fibre reinforced concrete	Percentage increase of 28 days impact strength (final failure) with respect to reference concrete	Impact strength for final failure when subjected to alternate wetting and drying after 90 days of curing (N-m)	Percentage increase of 90 days impact strength (final failure) for HFRC with respect to corresponding mono fibre reinforced concrete	Percentage increase of 90 days impact strength (final failure) with respect to reference concrete
Without fibres (REF)	421.87	0	0	484.12	0	0
(SF+GIF)	15145.89	7	3490	17220.67	16	3457

(SF+WCSF)	14488.88	12	3334	16563.66	21	3321
(SF+HDPEF)	7400.05	16	1654	7745.85	12	1500
(SF+WPF)	6950.51	30	1548	7469.21	21	1443
(SF+PPF)	9924.36	10	2252	10685.12	10	2107
SF	14488.88	--------	3334	15284.21	--------	3057
GIF	14177.66	--------	3261	14800.10	--------	2957
WCSF	12932.80	--------	2966	13728.13	--------	2736
HDPEF	6362.66	--------	1408	6915.93	--------	1329
WPF	5359.85	--------	1170		--------	1171
PPF	9059.87	--------	2048		--------	1914

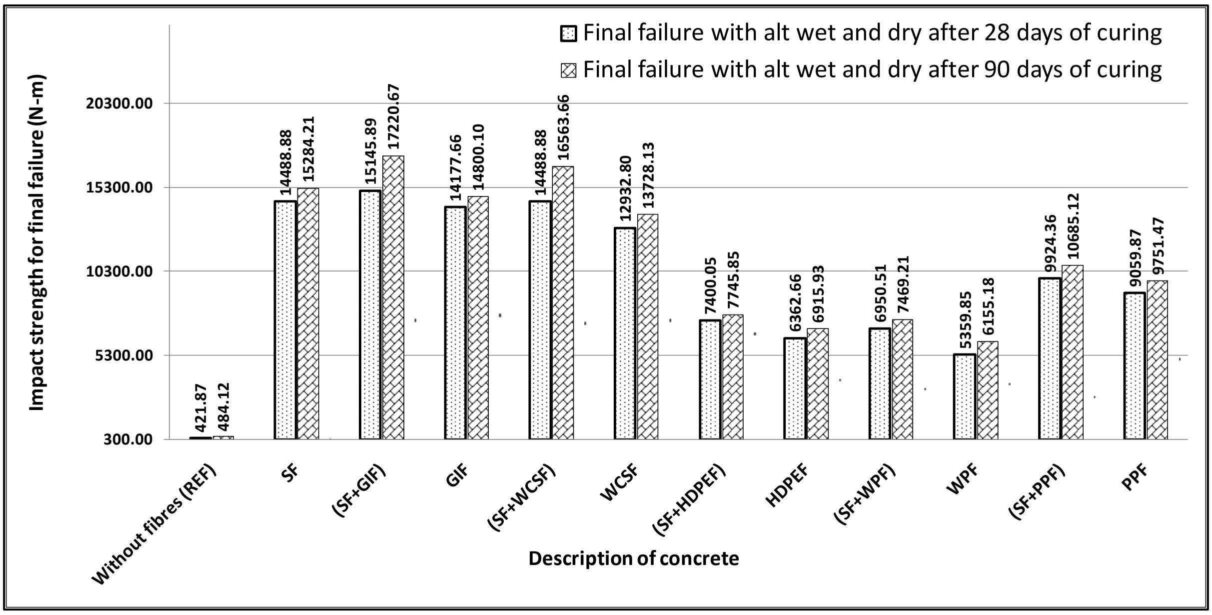

Fig 3.0 Variation of impact strength for final failure when subjected to alternate wetting and drying

V. Observations and discussions

Following observations are made based on the experimentations conducted on the impact behavior of metakaoline based hybrid fibre reinforced concrete when subjected to alternate wetting and drying.

The impact strength test results for metakaoline based hybrid fibre reinforced concrete when subjected to alternate wetting and drying are presented in table 1.0 and table 2.0. It is seen that the performance of metakaoline based hybrid fibre reinforced concrete is much superior as compared to corresponding mono fibre reinforced concrete. Metakaoline based hybrid fibre reinforced concrete with combination of fibres (SF+GIF), (SF+WCSF), (SF+HDPEF), (SF+WPF) and (SF+PPF) show 4%, 10%, 21%, 28% and 13% increase in the impact strength for first crack with respect to corresponding mono fibre reinforced concrete when subjected to 120 cycles of alternate wetting and drying after 28 days of curing. Similarly the above mentioned hybrid fibre reinforced concretes show 4291%, 4117%, 1943%, 1835% and 2813% increase in impact strength for first crack as compared to the reference concrete without fibres when subjected to 120 cycles of alternate wetting and drying after 28 days of curing. Metakaoline based hybrid fibre reinforced concrete with combination of fibres (SF+GIF), (SF+WCSF), (SF+HDPEF), (SF+WPF) and (SF+PPF) show 15%, 23%, 15%, 26% and 13% increase in the impact strength for first crack with respect to corresponding mono fibre reinforced concrete when subjected to 120 cycles of alternate wetting and drying after 90 days of curing. Similarly the above mentioned hybrid fibre reinforced concretes show 4088%, 3980%, 1748%, 1650% and 2507% increase in impact strength for first crack as compared to the reference concrete without fibres when subjected to 120 cycles of alternate wetting and drying after 90 days of curing. Metakaoline based hybrid fibre reinforced concrete with combination of fibres (SF+GIF), (SF+WCSF), (SF+HDPEF), (SF+WPF) and (SF+PPF) show 7%, 12%, 16%, 30% and 10% increase in the impact strength for final failure with respect to corresponding mono fibre reinforced concrete when subjected to 120 cycles of alternate wetting and drying after 28 days of curing. Similarly the above mentioned hybrid fibre reinforced concretes show 3490%, 3334%, 1654%, 1548% and 2252% increase in impact strength for final failure as compared to the reference concrete without fibres when subjected to 120 cycles of alternate wetting and drying after 28 days of curing. Metakaoline based hybrid fibre reinforced concrete with combination of fibres (SF+GIF), (SF+WCSF), (SF+HDPEF), (SF+WPF) and (SF+PPF) show 16%, 21%, 12%, 21% and 10% increase in the impact strength for final failure with respect to corresponding mono fibre reinforced concrete when subjected to 120 cycles of alternate wetting and drying after 90 days of curing. Similarly the above mentioned hybrid fibre reinforced concretes show 3457%, 3321%, 1500%, 1443% and 2107% increase in impact strength for final failure as compared to the reference concrete without fibres when subjected to 120 cycles of alternate wetting and drying after 90 days of curing.

The phenomenon of alternate wetting and drying occurs in many structures and is considered as one of the durability test for concrete. The metakaoline based hybrid fibre reinforced concretes show better resistance to alternate wetting and drying as compared to their corresponding mono fibre reinforced concretes. This is attributed to the fact that the hybrid fibres can resist the reversal of stresses developed due to alternate wetting and dying due to their synergestic effect. Also the pozzolonic reaction of metakaoline which results in more C-S-H gel will naturally add the strength to concrete to bear the reversal of stresses.

Thus it can be concluded that the metakaoline based hybrid fibre reinforced concretes show good performance in impact when subjected to alternate wetting and drying as compared to their corresponding mono fibre reinforced concretes by imparting higher strength characteristics.

It is observed that metakaoline based hybrid fibre reinforced concrete with the combination (SF+GIF) has exhibited better performance in impact when subjected to alternate wetting and drying as compared to metakaoline based hybrid fibre reinforced concrete with (SF+WCSF), (SF+HDPEF), (SF+WPF) and (SF+PPF). This is attributed to the fact of similar modulii of both SF and GI fibres and their synergestic interaction.

Thus it can be concluded that the metakaoline based hybrid fibre reinforced concrete with (SF+GIF) has greater resistance to impact when subjected to alternate wetting and drying as compared to metakaoline based hybrid fibre reinforced concrete with (SF+WCSF), (SF+HDPEF), (SF+WPF) and (SF+PPF).

IV. Conclusions

Following conclusions may be drawn based on experimentations conducted on the impact behavior of metakaoline based hybrid fibre reinforced concrete when subjected to alternate wetting and drying:

1. Metakaoline based hybrid fibre reinforced fibre concretes show good performance in impact when subjected to alternate wetting and drying as compared to their corresponding mono fibre reinforced concretes by imparting higher strength characteristics.

2. Metakaoline based hybrid fibre reinforced concrete with (SF+GIF) has greater resistance to impact when subjected to alternate wetting and drying as compared to metakaoline based hybrid fibre reinforced concrete with (SF+WCSF), (SF+HDPEF), (SF+WPF) and (SF+PPF).

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References

1) Ravi Kottur, *An experimental investigation on the characteristic properties of hybrid fibre reinforced concrete,* A Ph.D. thesis submitted to Visvesvaraya Technological University, Belgaum, August 2009

2) Qian C.X, Stroeven P, *"Development of hybrid polypropylene–steel fiber– reinforced Concrete",* Cement and Concrete Research, Vol. 30, 2000,pp. 63-69.

3) Mobasher. B, Li and Cheng Yu, *Mechanical properties of hybrid cement – based composites,* ACI Materials Journal, Vol. 93, No. 3, May-Jun, 1996, pp. 284-292.

4) Shetty M.S, *Concrete technology theory and practice*, S. Chand & Company ltd. Publications, New Delhi, Edition-2012.

5) Dali J.S, Tande S.N, *"Performance of concrete containing mineral admixtures subjected to high temperature",* 37th Conference on Our World In Concrete & Structures**:** 29 - 31 August 2012, Singapore, Article Online Id: 100037018

6) IS: 8112 – 1989, *43 Grade ordinary Portland cement—Specifications*, (First revision), Bureau of Indian Standards, Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi, May 1990.

7) IS: 383 – 1970, *Specifications for coarse and fine Aggregate from natural sources for concrete* (Second revision), Bureau of Indian Standards, Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi, April 1971.

8) Deepak Namadev Mudgal, *An experimental investigation on the characteristic properties and structural behavior of silica fume concrete produced with hybrid fiber*, A Ph.D. thesis submitted to Shivaji University, Kolhapur, May 2012.