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AN EXPERIMENTAL INVESTIGATION ON THE CHARACTERISTIC PROPERTIES OF HYBRID FIBROUS FERROCEMENT

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ABSTRACT

Ferrocement is thin and light weight cement composite, with several unique properties. The addition of fibers to the concrete enhances the strength properties of the composite and transforms the brittle cement composite into more isotropic and ductile material called FRC. But these two materials viz- ferrocement and FRC have some drawbacks. These two materials cannot be employed where high vibration, high tensile forces and high impact are to be resisted. Hence the solution lies in the new composite called fibrous ferrocement, which is the combination of fiber reinforced concrete and ferrrocement. This new composite have some improved mechanical properties, such as toughness, impact resistance etc. Addition of more than one type of fibers to the composite improves the strength properties to even greater extent. Hence addition of more than one type of fiber to the ferrocement leads to hybrid fibrous ferrocement, which has cutting edge properties than the fibrous ferrocement.

The main objective of this experimental investigation is to study the characteristic properties of hybrid fibrous ferrocement. Different types of hybrid fibers and mono fibers planned in this study are (SF+GIF), (SF+HDPEF), (SF+PPF), (SF+WPF) and SF, GIF, HDPEF, PPF, WPF respectively. The fiber content used for SF, GIF, HDPEF, WPF and PPF is 1% and the fiber content used for (SF+GIF), (SF+HDPEF), (SF+PPF), (SF+WPF) is (0.5%+0.5%). Also these fiber combinations are compared with only mesh (i.e ferrocement).Mortar specimens were also cast in the work. Different strength parameters considered for the study are compressive strength, flexural strength, shear strength and impact strength. Along with these above tests, near surface characteristics such as water absorption and sorptivity are studied.

Key words: Ferrocement, Hybrid fibrous ferocement, fibrous ferrocement, Welded mesh, Chicken mesh.

INRODUCTION

Shelter is one of the basic needs of human being. But more than 80 developing countries in the world suffer from housing shortages resulting from population growth, internal migration etc. Most of the dwellings in rural areas are made of cheap local materials which are temporary and unsafe. Ferrocement is such a material that is slim and slender but at the same time strong and elegant which provides a potential solution to roofing problems [8]. The addition of fibers to the concrete enhances the strength properties of the composite and transforms the brittle cement composite into more isotropic and ductile material called FRC. But these two materials have some drawbacks. These two materials cannot be employed where high vibration, high tensile forces and high impact are to be resisted. Hence the solution lies in the new composite called fibrous ferrocement, which is the result of combining FRC and ferrocement. Fibrous ferrocement can overcome the limitations of both ferrocement and FRC to certain extent. Hence fibrous ferrocement can be employed where high impact, high vibration and high wear and tear are familiar [5]. In this unique material the advantages of both FRC and ferrocement are united. In fibrous ferrocement three types of reinforcement are used. The first type of reinforcement is welded mesh where smaller diameter bars are kept closely in both directions and are spot-welded. This mesh gives stability and shape to the structure. The second type of reinforcement is chicken mesh. This is mesh of smaller wires which are interwoven to different openings. The spacing between the wires of chicken mesh is small. This is a mesh mainly distributes the stresses evenly and the cracks will be minimized. The third type of reinforcement is fiber. The fibers may be of steel, polypropylene, GI, carbon, glass, etc [13].

Fibrous ferrocement is a new area of research and not many studies are available and hence there is a vast scope for testing of fibrous ferrocement composites [9].

OBJECTIVE

The main objective of this experimental investigation is to study the characteristic properties of hybrid fibrous ferrocement. Different types of hybrid fibers and mono fibers planned in this study are (SF+GIF), (SF+HDPEF), (SF+PPF), (SF+WPF) and SF, GIF, HDPEF, PPF, WPF respectively. The fiber content used for SF, GIF, HDPEF, WPF and PPF is 1% and the fiber content used for (SF+GIF), (SF+HDPEF), (SF+PPF), (SF+WPF) is (0.5%+0.5%). Also these fiber combinations are compared with only mesh (i.e ferrocement).Mortar specimens were also cast in the work. Different strength parameters considered for the study are compressive strength, flexural strength, shear strength and impact strength. Along with these above tests, near surface characteristics such as water absorption and sorptivity are studied.

MATERIALS USED

The materials used in this study include ordinary Portland cement, fine aggregates, steel fibers (SF), high density polyethylene fibers (HDPE), waste plastic fibers (WPF), polypropylene fibers (PPF), galvanized iron fibers (GI), welded mesh and chicken mesh.

Cement: Cement used in the work is OPC 43 grade confirming to IS 8112- 1989

Sand: Natural sand confirming to IS 3.83-1970 of zone II with specific gravity of 2.64 is used in the work.

Water: Potable water was used for the work.

Steel fiber: Crimped steel fibers of 1mm thickness and 35mm length giving an aspect ratio of 35 are used.

Polypropylene fiber: Fibers of 12mm length are used.

High density polyethylene fiber: HDPE fibers are produced from cutting HDPE oil cans. Fibers are cut to a length of 35mm, width of 3mm and thickness of 1mm giving an aspect ratio of 35mm.

Waste plastic fiber: Waste plastic fibers are obtained by cutting the waste plastic materials like buckets, tubs, and jugs etc. Fibers are cut to a length of 35mm, width of 3mm and thickness of 1mm giving an aspect ratio of 35mm.

Galvanized iron fiber: GI fibers are produced from cutting the GI wire. The size of the fibers used here is 35mm length and 1mm diameter, thus giving an aspect ratio of 35.

Welded Mesh: Square welded mesh of opening 12.5mm×12.5mm is used in the experimentation. The welded mesh have small diameter bars (16 gauges) kept closely in both directions and are spot welded.

Chicken Mesh: Chicken mesh having hexagonal opening with 15mm diameter is used.

METHODOLOGY

The cement mortar with a proportion of 1:2 was used with a water cement ratio of 0.45. To study the characteristic properties of hybrid fibrous ferrocement, the compressive strength specimens, flexural strength specimens, shear strength specimens and impact strength specimens were cast. For compressive strength test, specimens of dimensions 150×150×150 mm were cast. For flexural strength test, specimens of dimensions 100×100×500 mm were cast. For shear strength test, specimens of dimensions100mm×90mm×60mm (L-shaped specimens) were cast. The impact strength test specimens were of 150mm in diameter and 60mm thick. For impact strength test drop hammer was used (drop hammer weighs 4.5kg and falls from a height of 457mm). The number of blows required to cause the first crack and final failure were noted.

Depending upon the shape required for compression, flexural, shear and impact strength tests, the cage is prepared out of welded mesh and chicken mesh. The cage is prepared by tying the chicken mesh over the welded mesh at regular intervals by using binding wires (1WM +1 CM).

Calculated quantity of cement and sand is weighed and dry mixed thoroughly to get uniform mix. Calculated quantity of water is added to the dry mix to get uniform mix. Moulds are cleaned and lightly oil is applied to the inner surface of the moulds .The cages prepared by mesh are first placed in the mould and then the mortar is placed in the mould. Then the calculated quantity of fibers is uniformly dispersed throughout the mould. All moulds were kept on table vibrator and sufficient vibration was given to compact the fibrous mortar. The specimens were finished smooth after vibration. After 24 hours of casting, the specimens were demoulded and kept in water tank for curing; the period of curing was 28 days.

TEST RESULTS

NEAR SURFACE CHARACTERISTIC TEST RESULTS

Table 1 gives the water absorption and sorptivity test results for the different hybrid fibrous ferrocement and monofibrous ferrocement combinations. The variation in the water absorption and sorptivity are depicted in the form of graphs.

Table 1: Water absorption and Sorptivity test results

Fiber description	Percentage water absorption	Sorptivity (mm/min$^{0.5}$)
(SF+GIF)	0.544	3.87
(SF+HDPEF)	0.670	4.00
(SF+WPF)	0.740	4.34
(SF+PPF)	0.897	4.64
SF	0.510	3.20
GIF	0.616	3.98
HDPEF	0.740	4.21
WPF	0.867	4.52
PPF	0.910	4.72
With mesh(ferrocement)	0.940	5.15
Only mortar	1.138	5.36

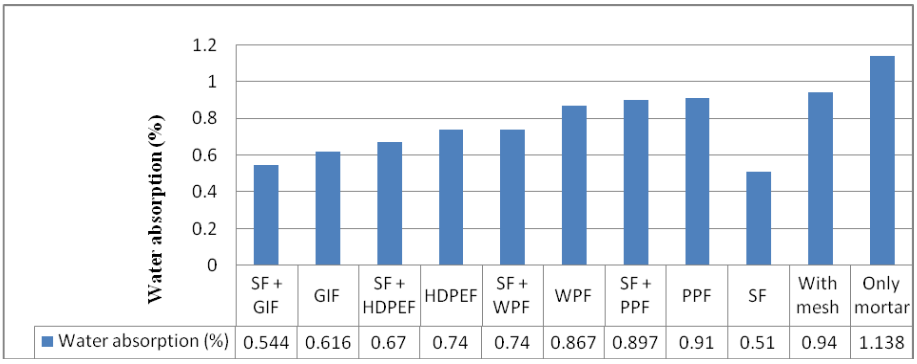

Fig 1: Variation of water absorption

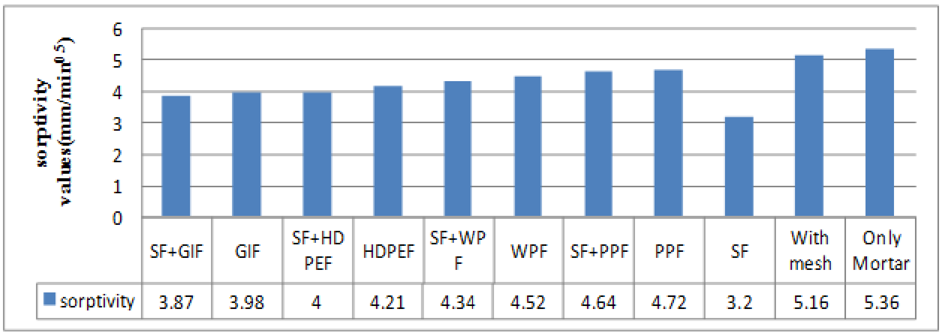

Fig 2: Variation of Sorptivity

STRENGTH TEST RESULTS

Tables 2, 3, 4, 5 and 6 give the results of compressive strength, flexural strength, shear strength, impact strength of hybrid fibrous ferrocement and monofibrous ferrocement. The tables also give the percentage increase of all the characteristic strength of hybrid fibrous ferrocement as compared to respective monofibrous ferrocement and percentage increase of all the characteristic strength of both monofibrous ferrocement and hybrid fibrous ferrocement as compared to ferrocement. The variation of strength is depicted in the form of graph as shown in the fig 3,4,5,6 and 7

Table 2: Results of compressive strength

Fiber description	Compressive strength (MPa)	% increase of compressive strength as compared to ferrocement	Percentage increase of compressive strength of hybrid fibrous ferrocement as compared to corresponding monofibrous ferrocement
(SF+GIF)	24.44	31.96	4.44
(SF+HDPEF)	23.40	26.34	5.31
(SF+WPF)	21.20	14.47	3.72
(SF+PPF)	20.14	8.74	3.82
SF	25.03	35.15	-
GIF	23.40	26.34	-
HDPEF	22.22	19.90	-
WPF	20.44	10.36	-
PPF	19.40	4.75	-
With mesh(ferrocement)	18.52	0	-
Only mortar	17.48	-	-

Table 3: Results of flexural strength

Fiber description	Flexural strength (MPa)	% increase of flexural strength as compared to ferrocement	Percentage increase of Flexural strength of hybrid fibrous ferrocement as compared to corresponding monofibrous ferrocement
(SF+GIF)	7.33	48.68	5.80
(SF+HDPEF)	6.73	36.51	10.87
(SF+WPF)	6.26	26.97	6.10
(SF+PPF)	5.30	7.50	6.00
SF	7.67	55.57	-
GIF	6.93	40.56	-
HDPEF	6.07	23.12	-
WPF	5.90	19.67	-
PPF	5.00	1.41	-
With mesh(ferrocement)	4.93	0	-
Only mortar	1.3	-	-

Table 4: Results of shear strength

Fiber description	Shear strength (MPa)	% increase of shear strength as compared to ferrocement	Percentage increase of shear strength of hybrid fibrous ferrocement as compared to corresponding monofibrous ferrocement
(SF+GIF)	15.40	38.61	2.7
(SF+HDPEF)	14.63	31.68	3.90
(SF+WPF)	13.89	25.00	10.15
(SF+PPF)	12.40	11.61	1.47
SF	15.92	43.30	-
GIF	15	35	-
HDPEF	14.08	26.73	-
WPF	12.6	13.41	-
PPF	12.22	9.99	-
With mesh(ferrocement)	11.11	0	-
Only mortar	2.02	-	-

Table 5: Results of impact strength to cause first crack

Fiber description	Impact strength to cause first crack (N-m)	% increase of impact strength to cause first crack as compared to ferrocement	Percentage increase of impact strength to cause first crack for hybrid fibrous ferrocement as compared to corresponding monofibrous ferrocement
(SF+GIF)	1131.35	242.00	4.11
(SF+HDPEF)	685.42	107.23	21.93
(SF+WPF)	589.52	78.24	19.44
(SF+PPF)	438.62	32.61	28
SF	1336.70	304.15	-
GIF	1086.60	228.53	-
HDPEF	562.11	69.95	-
WPF	493.50	49.20	-
PPF	342.75	3.63	-
With mesh(ferrocement)	330.74	0	-
Only mortar	171.38	-	-

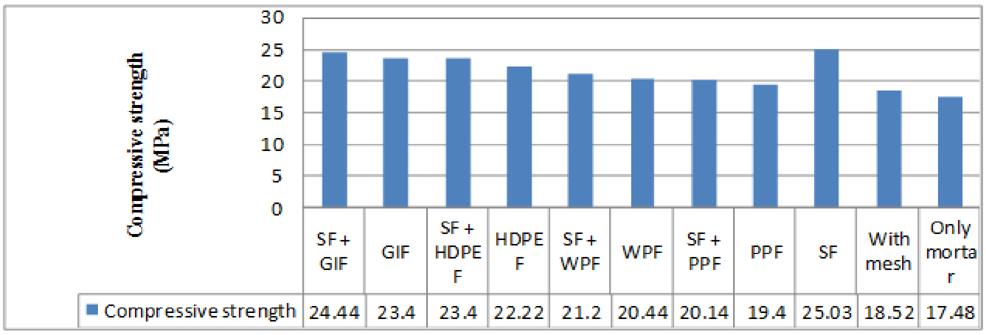

Fig 3: Variation of compressive strength

Table 6: Results of impact strength to cause final failure

Fiber description	Impact strength to cause final failure (N-m)	% increase of impact strength to cause final failure as compared to ferrocement	Percentage increase of impact strength to cause final failure for hybrid fibrous ferrocement as compared to corresponding mono fibrous ferrocement
(SF+GIF)	1474.28	252.56	13.2
(SF+HDPEF)	911.78	118.00	33
(SF+WPF)	706.03	68.84	17
(SF+PPF)	541.54	29.50	27.4
SF	1618.02	286.93	-
GIF	1302.46	211.47	-
HDPEF	685.53	63.93	-
WPF	603.24	44.26	-
PPF	425.01	1.64	-
With mesh(ferrocement)	418.16	0	-
Only mortar	249.93	-	-

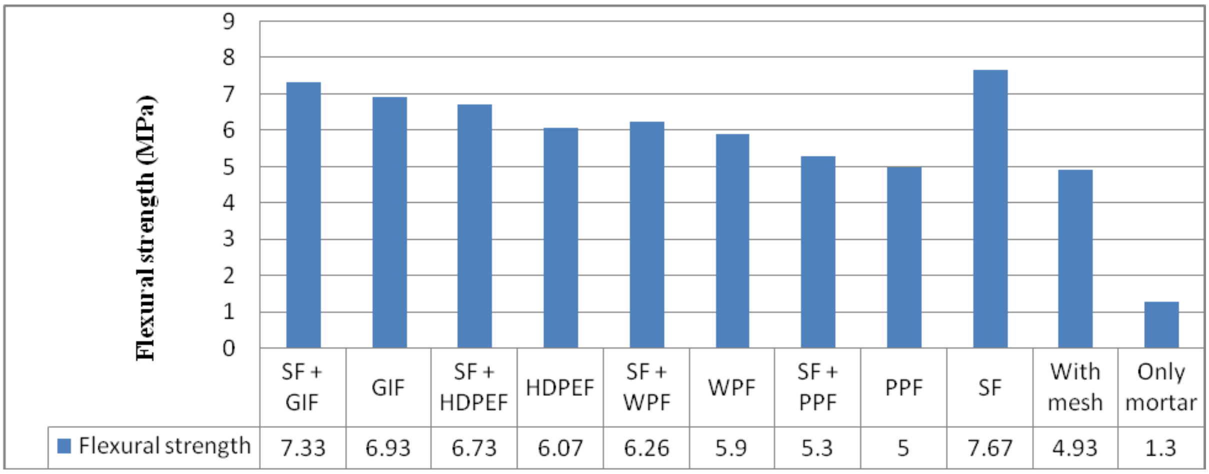

Fig 4: Variation of flexural strength

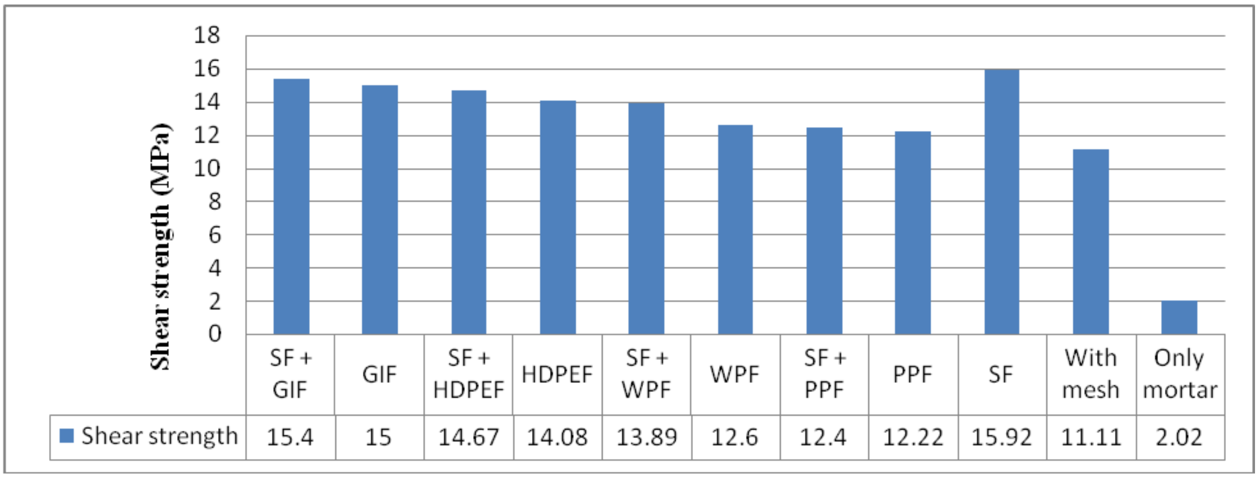

Fig 5: Variation of shear strength

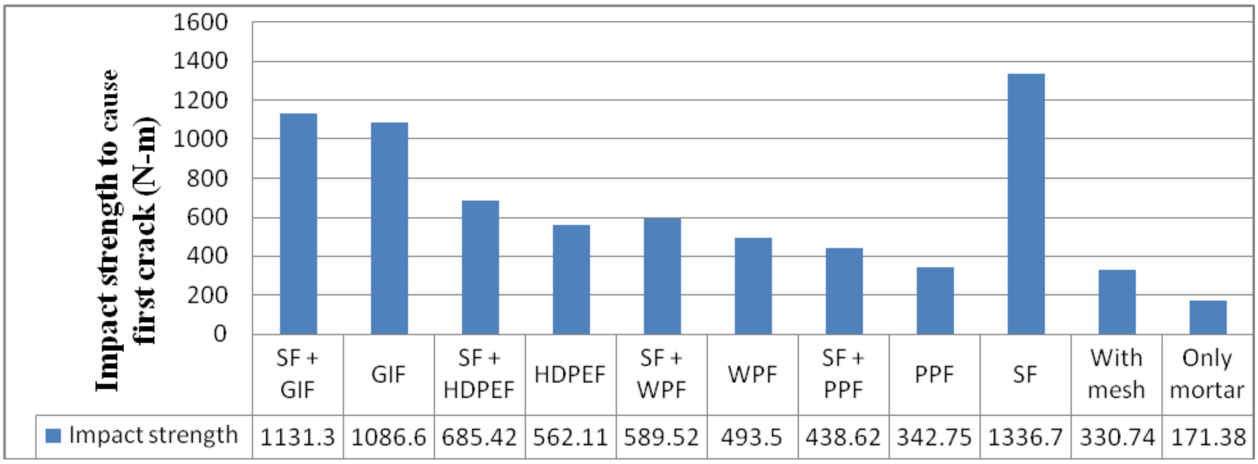

Fig 6: Variation of impact strength for first crack

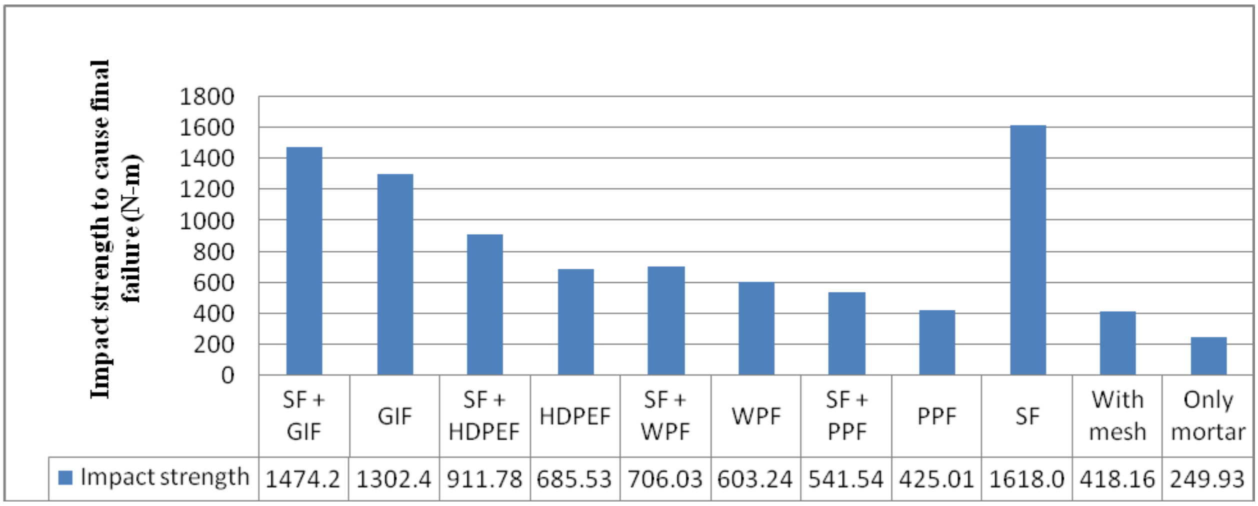

Fig 7: Variation of impact strength for final failure

OBSERVATIONS AND DISCUSSIONS

Following observations are made based on the experimentation conducted on the characteristic properties of hybrid fibrous ferrocement.

- It is observed that the water absorption and sorptivity values of monofibrous ferrocement are lower as compared to ferrocement. This is true for monofibrous ferrocement produced with SF, GIF, HDPEF, WPF and PPF. This may be due to the fact that the addition of monofibers to the ferrocement will act as barriers for the infiltration of the water, thereby decreasing the water absorption and sorptivity values.
- It is observed that the water absorption and sorptivity values of hybrid fibrous ferrocement are lower as compared to ferrocement and as compared to monofibrous ferrocement. The water absorption and sorptivity values for hybrid fibrous ferrocement produced with (SF+GIF), (SF+HDPEF), (SF+WPF) and (SF+PPF) are lower as compared to monofibrous ferrocement produced with their corresponding fibers such as GIF, HDPEF, WPF and PPF. This may be due to the fact that the addition of monofibers to the ferrocement will act as barriers for the infiltration of the water, thereby decreasing the water absorption and sorptivity values.
- It is observed that compressive strength of monofibrous ferrocement is higher as compared to ferrocement. The percentage increase in the compressive strength is found to be 35.15%, 26.34%, 19.9%, 10.36% and 4.75% for SF, GIF, HDPEF, WPF and PPF monofibrous ferrocement respectively as compared to ferrocement. A similar trend

was observed in flexural strength, shear strength and impact strength. The percentage increase in the flexural strength is found to be 55.57%, 40.56%, 23.12%, 19.67% and 1.41% for SF, GIF, HDPEF, WPF and PPF monofibrous ferrocement respectively as compared to ferrocement . The percentage increase in the shear strength is found to be 43.30%, 35%, 26.73%, 13.41% and 9.99% for SF, GIF, HDPEF, WPF and PPF monofibrous ferrocement respectively as compared to ferrocement. The percentage increase in the impact strength to cause final failure is found to be 286.93%, 211.47%, 63.93%, 44.26% and 1.64% for SF, GIF, HDPEF, WPF and PPF monofibrous ferrocement respectively as compared to ferrocement. This may be due to the fact that the addition of monofibers to ferrocement will increase the stiffness and resist the cracks in a more efficient way, thereby increasing the strength characteristics of monofibrous ferrocement.

- It is observed that the compressive strength of hybrid fibrous ferrocement is higher as compared to ferrocement. Also it is observed that the compressive strength of hybrid fibrous ferrocement is higher as compared to its corresponding monofibrous ferrocement. The percentage increase in the compressive strength is found to be 4.44%, 5.31%, 3.72% and 3.82% for hybrid fibrous ferrocement produced with (SF+GIF), (SF+HDPEF), (SF+WPF) and (SF+PPF) respectively as compared to its corresponding monofibrous ferrocement. A similar trend was observed in flexural strength, shear strength and impact strength. The percentage increase in the flexural strength is found to be 5.90%, 10.87%, 6.10% and 6% for hybrid fibrous ferrocement produced with (SF+GIF), (SF+HDPEF), (SF+WPF) and (SF+PPF) respectively as compared to its corresponding monofibrous ferrocement. The percentage increase in the shear strength is found to be 2.70%, 3.90%, 10.15% and 1.47% for hybrid fibrous ferrocement produced with (SF+GIF), (SF+HDPEF), (SF+WPF) and (SF+PPF) respectively as compared to its corresponding monofibrous ferrocement. The percentage increase in the impact strength to cause final failure is found to be 13,2%, 33%, 17% and 27.4% for hybrid fibrous ferrocement produced with (SF+GIF), (SF+HDPEF), (SF+WPF) and (SF+PPF) respectively as compared to its corresponding monofibrous ferrocement. This may be due to the fact that the addition of hybrid fibers to ferrocement will act synergistically and increase the stiffness and resist the cracks effectively, thereby increasing the strength characteristics of hybrid fibrous ferrocement

CONCLUSIONS

The following conclusions were drawn based on the experimentation conducted on the characteristic properties of hybrid fibrous ferrocement.

1. The water absorption and sorptivity values of monofibrous ferrocement produced by using fibers such as SF, GIF, HDPEF, WPF and PPF are lower as compared to ferrocement.
2. The water absorption and sorptivity values of hybrid fibrous ferrocement produced by using the combination of fibers such as (SF+GIF), (SF+HDPEF), (SF+WPF), (SF+PPF) are lower as compared to their corresponding monofibrous ferrocement.
3. The strength characteristics such as compressive strength, flexure strength, shear strength and impact strength of monofibrous ferrocement produced by using fibers such as SF, GIF, HDPEF, WPF and PPF are higher as compared to ferrocement.
4. The strength characteristics such as compressive strength, flexural strength, shear strength and impact strength of hybrid fibrous ferrocement produced by using hybrid fibers such as (SF+GIF), (SF+HDPEF), (SF+WPF) and (SF+PPF) are higher as compared to monofibrous ferrocement.

5. The hybrid fibrous ferrocement may be used as structural material because of the increase in the strength characteristics and increase in the durability characteristics.

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