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EVALUATION OF CROSS BREED FIBRE-REINFORCED CONCRETE WITH OPTIMAL UTILIZATION OF TWO MINERAL ADMIXTURES

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Abstract— The present investigation deals with the optimization of hybrid fibres in ternary blended concrete. Hybridization derives advantages from each of the fibre and reflects a synergetic response. Cement was replaced 30% by metakaolin and fly ash to produce a M40 grade of concrete based on I.S code method of mix design. Samples were prepared with and without metakaolin and fly ash by varying the fibres volume fraction from 0 to 1%. The present investigation focuses on to know the influence of steel and polypropylene fibre on the hardened properties of concrete, to do so the compressive, split tensile and flexural tests were conducted for 3,7,28 days of curing. The aim further extends to know the durability characteristics of this concrete. It was observed that with increase in steel fibre up to 0.75% and polypropylene fibre 0.25% showed greater results in terms of hardened properties. However the workability was reduced with the utilization of metakaolin and flyash as well as with the addition of steel and polypropylene fibres. Further, the concrete showed greater resistance against the acid which indicated the improved durability of the concrete.

Keywords— Hybridization, Steel fibres, Polypropylene fibres, Metakaolin, Fly ash.

I. INTRODUCTION

Concrete is one of the commonly utilized building constituents due to its various good qualities and available easily without much difficulty. However, concrete fails in providing tensile resistance due to forces developed in the concrete structure. To overcome this disadvantage concrete is generally reinforced with various fibres. The use of the fibres augments the crack resistance of concrete; additionally toughness of concrete and the impact resistance is improved. Arresting of cracks at the initial stage of concrete diminishes the concrete permeability, which improves the load taking ability of concrete. Their presence in concrete can boost the properties of binding materials in their hardened form especially the tensile strength and the crack propagation control. Fibres which have lower elasticity modulus are expected to improve the performance of strain whereas fibres having modulus of elasticity to some higher extent are found to boost the strength performance. Using an individual kind of fibre can also improve the characteristics of concrete to a certain level. But, the idea of adding two or more types of fibres into the concrete can provide better results than using individual fibre.

The present study makes use of SF & PP fibres to produce a HFRC. The Polypropylene fibres and steel fibres are being utilized widely to reduce the spalling of concrete, cracking of concrete and also to enrich the residual strength. The load carrying capacity and crack resistance is affected as SF & PP fibres gel together very well which will tend to produce a positive synergetic response [1].

The application of fly ash has some benefits like reduced bleeding and segregation, enriched consistency, improved impermeability, improved strength, improved resistance to acids etc. Due to the fineness and the pozzolanic reactivity, the utilization of fly ash considerably advances the cement quality gel as well as the microstructure of transition zone amongst binder matrix and aggregate, which ultimately increases the power of the concrete [2]. When researchers conducted study on 10%, 20%, 30% and 40% fly ash replaced concrete. Tests on Compression were executed for four different periods including early strength at 3 days and ultimate strength of 28 and 90 days. It was concluded that strength were improved for only 10% and 20% replacements [3].

Metakaolin is also a pozzolanic material and is dehydroxylated form of a clay mineral kaolinite. The calcination of this clay at temp of about 500°-800°C leads to production of metakaolin. The particles of metakaolin are extremely small having a usual particle size of 3µm. The welfares of using metakaolin as replacement of cement are, improved workability, reduced permeability, enhanced crushing value, augmented durability, increased ductile strength. The prominent elements of MK are Silicon di oxide and Aluminum oxide [2].

The utilization of Metakaolin in cement with lower water/binder ratio say about 0.3, concretes with high strength and performance can be developed. Their results revealed that Compressive-Strength, Split-Tensile Strength and the Flexural-Strength had higher values at 10% cement substitution by MK [4].

The results spectacles by the limited cement substitution with MK aids in attaining great strengths in concrete. It was found that at 15% substitution of cement with MK content expands concrete hardened properties. With rise in metakaolin content there is an upsurge in water requirement & concrete set time. The replaced cement demands considerably extra water content when compared to cement mix this occurrence is because of great refinement of metakaolin. However the cement substitution by MK by 10% showed the least water demand [5].

And the concrete slump comprising of 10% MK was declined from that of conventional concrete, the concrete produced by using 10% MK was needed 25-35% less HRWR than the other cementitious material of same dosage of replacement [6].

II. OBJECTIVES

1. To find the optimal quantity of fibres required in the ternary blended concrete.
2. To evaluate concrete's compressive strength with varying proportions of hybrid fibres by fractional substitution of cement by fly ash & MK.
3. To evaluate the concrete's tensile strength and the flexural-strength having varying proportions of hybrid fibres by partial substitution of cement by fly ash & MK.
4. To investigate durability features of concrete mix accompanied by intrusion of two fibres by fractional replacement of cement by MK & fly ash**.**

III. LITERATURE REVIEW

1. Ramandeep Sharma et. al [7]

Cement was replaced with 15, 20 and 25% fly ash by weight. Two kinds of fibres, SF and PP fibres have been utilized by an amount of 0.5% and 1.0% by volume.

Effect of changing quantities of SF & PP fibres on hardened properties of fly ash concrete was studied. To attain the essential workability of concrete mix, water reducing admixture i.e. super plasticizer were used. 150 specimens were casted. Results reveal that as quantity of fly ash is amplified, concrete strength was decreased; however this decrease was reimbursed by the utilization of fibres.

The intrusion of steel fibres to fly ash concrete by volume (0.5 and 1 per cent) raises the Crushing-Strength of fly ash concrete at both 7 and 28 days. Parallel is the situation with flexural & split strength. Where, maximum enhancement is seen in case of 20% Fly ash replaced with cement and 1% SF is added to it. But in all the above mentioned cases, least improvement is seen is in 25%FA replacement along with addition of 0.5% SF.

2. Kavita S. Kene et. al [8]

The utilization of different fibres in an appropriate mishmash can possibly recover the complete features of mix. The conjoining of fibres, generally called hybridization, was studied for 3 M25 grade concrete. Control and the hybrid fusions were casted utilizing different fiber quantities of SF and PPF. Crushing-Strength test and Tensile-Strength tests were carried out & outcomes are comprehensively examined for the mentioned fibre mixtures. Slump test was conducted to decide fresh properties of concrete. The cubes were casted with 0% HFRC S0.5P0.5, HFRC S0.6P0.4, HFRC S0.7P0.3 and HFRC S0.8P0.2 fibres. SO.8PO.2 gave High Strength Equated to other Blend.

Slump Value- With the rise in percentage of SF in Hybrid Mixture reduced the slump value, to maintain the constant slump the quantity of super plasticizers was increased.

3. Ankur A Patel et. al [9]

The main target of study was to study the flyash and MK effect on the SF reinforced concrete. Cement was replaced by flyash and metakaolin by 30% in varying proportions. The SF was added by 1% of volume of concrete.It was established that insertion of SF raises the Compressive strength by 2.28% when paralleled to CC. Replacement of flyash by 15% and metakaolin by 15% showed better results than other mixes. These mixes gave 5.57% greater strength than the mix which consists of 30% flyash.

4. Ali Akbar Ramezanianpour et. al [10]

The aim of their study was to know the performance of metakaolin & pumice in HFRC. The results showed the optimal quantity of hybrid fibre was 0.75% SF and 0.25% PP fibre. The results also directed that there will be a negative effect with the rise in pumice content and the mechanical properties were improved with the intensification in metakaolin. The optimal quantity of metakaolin was 15%.

5. Rajendra T N et. al [11]

The aim of the investigation was to learn the variation in Compressive-Strength and Tensile-strength properties by substituting cement partially with Fly ash and MK and by utilizing M.Sand for river sand. The Investigational study consisting of the concrete specimen containing cement 15% with MK and Fly ash at 5% to 20% and using M.Sand as fine aggregates was carried out. Addition of MK and Fly ash had resulted in improved strength at initial ages and ultimate concrete strength. Fly ash 15% and MK by 20% replaced for cement, showed better results than the other mixes.

6. R M de Gutierrez et. al [12]

The intent was to study the impact of intrusion of different complementary materials on strength, chloride diffusion and permeability with and without the addition of fibres. The supplementary materials were fly ash, use of silica-fumes, GGBS & MK. The results publicized that with addition of silica fume, GGBS, and metakaolin, the compressive strength enlarged by 23%, 19% & 6% accordingly. The results conclude due to the presence of SF the compressive strength of concrete is increased.

IV. MATERIALS AND MIX PROPORTIONS

A. MATERIALS

1. Cement:

OPC 53 grade (Ultra-Tech) cement imitating to IS-12269 is procured for investigation. The cement characteristics are shown in Table below.

TABLE I

Represents the cement characteristics

Characteristics of cement	Normal Consistency	Specific gravity	Fineness	Initial Setting	Final Setting
Experimental results	34%	3.10	6%	50mins	230mins

2. Fine aggregate:

Local sand of zone-II as per IS 383:1970 is being used the experimental results of FA are as displayed in table below.

TABLE II

Represents characteristics of FA

FA characteristics	Specific gravity	Water absorption	Bulk density in loose condition	Bulk density in compacted condition	Fineness modulus	Silt content
Experimental results	2.65	1.4%	1.36 g/cc	1.67 g/cc	2.63	2.29%

3. Coarse aggregate:

Locally available crushed angular basalt of down size 20mm and 12mm were utilized for investigational program. Table below describes the properties of CA

TABLE III

Represents properties of CA

Property of coarse aggregate	Specific gravity	Water absorption	Bulk density in loose condition	Bulk density in compacted condition
Experimental results	2.70	1.1%	1.10 g/cc	1.10 g/cc

4. Metakaolin:

For the present study metakaolin was procured from Royal Mineral, Madhapar, Gujarat. Figure 1 below shows Metakaolin sample used for the study. The composition of Metakaolin shown in Table IV.

Figure 1: Shows sample of Metakaolin

TABLE IV

Represents the composition of MK provided by royal mineral suppliers

Ingredient	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	Na_2O	K_2O
%age	52 -54	44 -46	0.6-1.2	0.65	0.09	0.03	0.10	0.03

5. Fly ash:

Class C flyash is used for the present examination which was procured locally from M/s Malu Industries, Gulbarga. Chemical composition of material used is displayed in Table below.

TABLE V

Represents the composition of fly ash provided by suppliers

Parameter	SiO_2	CaO	Al_2O_3	Fe_2O_3	MgO	Na_2O	K_2O
%age	23.1-50.5	11.6-29.0	13.3-21.3	3.7-22.5	1.5-7.5	0.5-7.3	0.4-1.9

6. Steel Fibres:

Hooked end fibres having L/D ratio of 50 were used. The steel fibres were procured from Maruthi steel suppliers, Bangalore. Figure 2 shows steel fibres sample used in the investigation and Table VI shows the property of SF used.

Figure 2: Shows sample of steel fibres

TABLE VI

Properties of steel fibres used

Property	Diameter	Length	Aspect Ratio	Density	Tensile-Strength
Prescribed value	1.0 mm	50.0 mm	50	7860 kg/m^3	1200 MPa

7. Polypropylene Fibres:

Fibrillated 12mm length polypropylene fibres are utilized for investigation and were procured from Dolphin Floats private limited, Pune. Figure 3 below shows the sample of PP fibre used in investigation.

Figure 3: Shows sample of PP fibres

8. Super plasticizer:

Fosroc Conplast (SP 430) is being used as a chemical admixture having specific gravity of 1.22.

9. Potable Water:

For the mixing and curing of concrete, potable water which is free from organic matter conforming to IS: 456 are used.

B. MIX DESIGN

Mix design for the casting of various mix of concrete was done accordingly IS: 10262-2009 with the help above preliminary test results. The mix design was done to create a concrete of M40 grade. A conventional trial mix was prepared by mix design having mix ratio of 1:2.15:3 and the w/c of 0.42

TABLE VII

Mix proportions of concrete

Material	**Quantity (kg/m^3)**	**Proportion**
Cement	379.5	1
FA	814.62	2.14
CA	1130.96	2.98
Water	138	0.42
Super plasticizer	5.7	1.5%

V. EXPERIMENTAL PROGRAM

A. GENERAL

The experimental investigation comprises casting of 36 cubes, 36 cylinders and 36 prisms and testing them after curing for 3, 7 & 28days to evaluate compressive, split-tensile & flexural-strength. There are four mix variations to study the trend of variation of strength and to conclude with optimal dose of the fibres. The table VIII shows the different mix details and their designations. For the durability of concrete, 3 conventional cubes and 3 cubes having an optimum dosage of MK, FA, SF and PP fibres are casted.

TABLE VIII
Shows mix variations involved in study

Mix ID	**Cement (%)**	**Metakaolin (%)**	**Fly ash (%)**	**SF (%)**	**PP (%)**
CC	100	-	-	-	-
Mix 1	70	15	15	0.25	0.75
Mix 2	70	15	15	0.50	0.50
Mix 3	70	15	15	0.75	0.25

The various stages involved in casting of concrete are,

1. Batching and Mixing: All the elements of concrete were batched by their weights. The quantity of constituents required as per the mix proportion was weighed to an accuracy of 0.5 grams. The mixing of ingredients of concrete was done on a platform which was water tight.

2. Workability test: Freshly mixed concrete is filled in slump cone in 3 layers, where each layer was tamped for about 25 times with the tamping rod to expel the entrapped air in the concrete mix. Test is performed confirming to IS: 1199 on conventional concrete as well as on the other mix variations which are displayed in Table 6.1.

3. Casting: The cube, cylinder & prism moulds were filled with the freshly produced concrete in 3 layers; each deposit is given 25 strokes with the help of stuffing rod to ensure sufficient compaction. The moulds were demoulded upon the completion of 24-hours of casting & were submerged in water for different periods of curing. Figure 4 below shows the freshly casted cubes, cylinders and beams, which are kept in the moulds to attain shape for 24 hours.

Figure 4: Represents freshly casted specimens

4. Curing: After de-moulding of concrete specimens, they are completely immersed in potable water which is free from organic matter in water tank for 3 days, 7 & 28 days. Care should be taken so that concrete samplings are entirely immersed in water during the curing period. Figure 5 below depicts the concrete specimens submerged in water for the curing of concrete for the required period.

Figure 5: Represents Curing of casted specimens

B. RESULTS AND DISCUSSIONS

1. Slump cone test:

From the table below it is clear that with the intrusion of MK, Fly ash, SF and PP fibres the workability of the mix decreases.

Figure 6: Represents Slump cone test

TABLE IX

Represents slump test results

Sl.no	Mix ID	Obtained slump value in mm
1	CC	85
2	Mix 1	73
3	Mix 2	66
4	Mix 3	58

2. Compressive strength:

From the table and Chart below, it can be said that there is a substantial rise in cube strength of altered concrete than that of conventional concrete. The Mix 3 i.e., steel fibre 0.75% and polypropylene fibre 0.25% showed higher strength than any other mix.

TABLE X

Represents the compressive-strength results

Mix ID	Compressive Strength in N/mm^2		
	3 days	**7 days**	**28 days**
CC	18.30	31.20	49.60
Mix 1	18.90	31.48	52.61
Mix 2	19.33	31.67	53.20
Mix 3	19.55	32.05	55.62

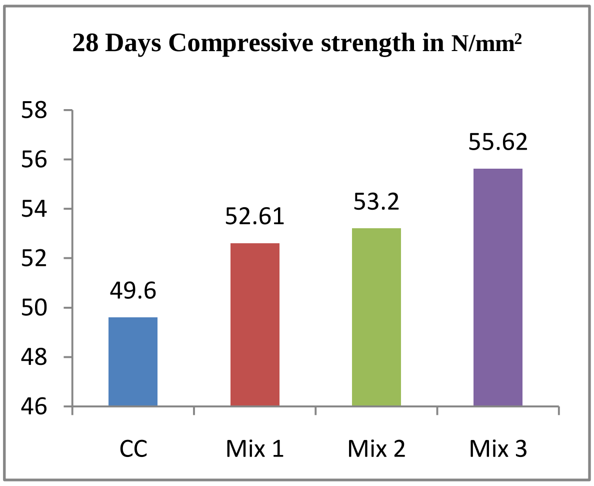

Figure 8: Represents the 28 days Compressive-Strength results

3. Split-tensile strength

From the table and Chart below it can be resolved that there is a great influence of presence of mineral admixtures and the fibres, as the Split-Tensile Strength is considerably improved.

TABLE XI

Represents the split-tensile strength results

Mix ID	Split-Tensile Strength in N/mm^2		
	3 days	**7 days**	**28 days**
CC	2.22	2.86	4.17
Mix 1	2.30	2.92	4.48
Mix 2	2.37	2.98	4.75
Mix 3	2.40	3.09	5.20

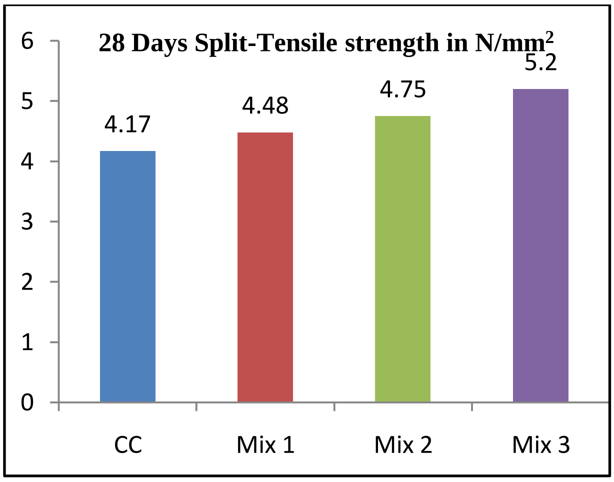

Figure 10: Represents the 28 days Split-Tensile Strength results

4. Flexural Strength

Beam specimens having depth and width 100 mm and length 500 mm were tested to achieve the flexural-strength. The results showed that, incorporation of fibres, especially SF showed better ductility to flexural load. The fibres resisted the load applied even after the initiation of cracks for a limited time as related to CC. The presence of SF by 0.75% and PP by 0.25% showed high strength than any other mix.

TABLE XII

Represents flexural-strength test results

Mix ID	Flexural-Strength in N/mm^2		
	3 days	**7 days**	**28 days**
CC	2.68	3.04	4.85
Mix 1	2.79	3.07	5.00
Mix 2	2.96	3.17	5.25
Mix3	2.94	3.22	5.63

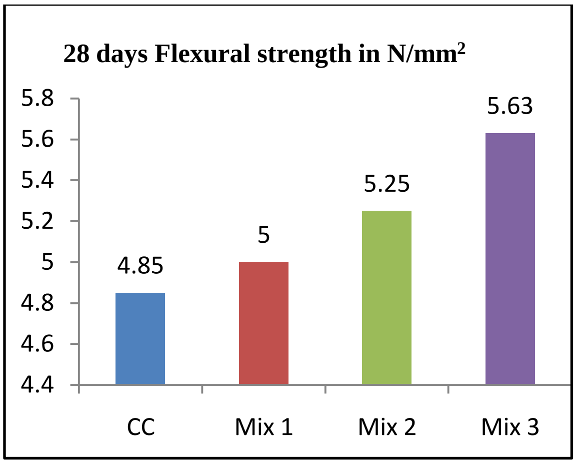

Figure 12: Represents the 28 days Flexural-Strength results

From the above representations it is clear that, the Flexural-Strength is effectively enhanced by the intrusion of steel fibres.

5. Acid test

- The cubes were submerged in 5% sulphuric acid solution for 7 days to determine the loss in weight which represents resistance of concrete against the acidic environment.
- The resistance to acid for the Fly ash and MK incorporated concrete was greater than the CC. The water from the solution gets into the concrete by absorption phenomenon leaving the formation of white film on the surface of the cube.
- The Table 5.10 below shows the results for the %age loss in weight. The presence of Fly ash in concrete raises the resistance against the sulphate attack.
- The average percentage loss in weight was 4.20% whereas that of Fly ash and MK based concrete was 3%

TABLE XIII

Represents test results of acid attack with the weight loss in percentage

S.No	Mix	Initial weight of cube	Weight of cube after 7 days	Weight Loss %
1	CC	8.890	8.500	4.38
		9.108	8.730	4.16
		8.973	8.607	4.07
2	Optimum Mix (Mix 3)	9.276	9.020	2.76
		9.398	9.094	3.23
		9.146	8.873	2.98

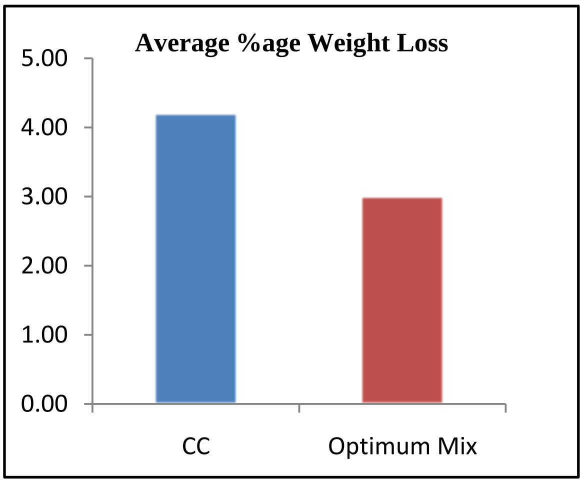

Figure 13: Represents average %age weight loss

VI. CONCLUSIONS

- The workability of concrete of M40 grade decreases with addition of MK and Fly ash and also with addition of SF and PP fibres.
- The addition of SF & PP fibres makes the concrete denser than the CC.
- The optimum dosage of SF and PP fibre was 0.75% and 0.25% respectively in the concrete containing 15% metakaolin and 15% fly ash.
- The cube strength i.e., the Compressive Strength rises with the use of SF and PP fibres. The maximum increase was for concrete having 0.75% SF and 0.25% PP fibre i.e., Mix 3. There was an increase in 12.13% of strength when compared with conventional strength.
- The addition of both the fibres also enhanced split tensile strength of concrete considerably. Maximum value was seen for a mix having 0.75% SF and 0.25% PP fibre, the magnitude of increase was 24.7% when compared with normal concrete.
- The Flexural-Strength remarkably enriched with the presence of SF and PP fibres, the amount of rise in strength was 16% when compared against the conventional concrete.
- The resistance of concrete containing Fly ash and MK against the acid was comparatively more than the CC. The average percentage weight loss for conventional concrete was 4.20% whereas for that of concrete possessing MK and Fly ash was 3%.

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