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STUDY ON STRENGTH AND DURABILITY PROPERTIES OF TERNARY BLENDED HYBRID FRC

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ABSTRACT

Cement concrete is the most widely used material for various constructions. Properly designed and prepared concrete results in good strength and durable properties. The main ingredient in the conventional concrete is Portland cement. Availability of mineral admixtures marked opening of a new era for designing concrete mix of higher and higher strength. As a result, the use of new mineral admixtures has considerably increased within the concrete industry. For attaining a high strength and durable concrete for major applications in the constructions such as high-rise buildings, tall structures, nuclear power plants, etc., the essential need for additives both chemical and mineral is a must to improve the performance of concrete.

Unlike other pozzolans, Metakaolin is a primary product, not a secondary (or) by-product, this allows the manufacturing process to be structured to produce the optimum characteristics for the Metakaolin, ensuring the one production of a consistent product. Silica content of Metakaolin is 53% as against the minimum value of 35% stipulated in IS: 3812-1981. After calcination of kaolinite clay between 6500C and 8500C followed by grinding to a fineness of 15,000 m2/kg (B.E.T), Metakaolin is achieved as against the minimum value of 320 m2/kg stipulated by IS: 3812-1981.

The fibres act as crack arrestor in the continuum and would substantially improve its static and dynamic properties. Since then lot of investigations have been carried out to extract the best usage of fibre-reinforced concrete. The role of fibres is essentially to arrest any advancing cracks by applying pinching forces at the crack tips, thus delaying their propagation across the matrix and creating stage.

It is proposed to add crimped steel fibres to Ordinary Portland Cement concrete (OPCC) and Ternary blended concrete (Flyash & Metakaolin) for further enhancement of its strength and improvement with respect to its durability aspects.

Flat steel crimped fibres and polypropylene fibres will be used in this investigation. The variables proposed in this investigation are fibre content of 0, 0.5, 1 and 1.5% and various aspect ratio of fibres.

The present experimental investigation is an attempt to study the mechanical properties and durability aspects of ordinary Portland cement concrete, Hybrid fibre reinforced concrete, Ternary blended concrete and hybrid fibre reinforced ternary blended concrete.

The experimental investigation proposed to use IS-code (IS-10262-1982) and ERNTROY AND SHACKLOCK'S METHOD of mix design M2O, procedure for designing high strength concrete. Linear regression equations will be proposed to quantify the effect of fibre addition on the above mechanical properties of mixes in terms of fibre factor.

Key words: linear regression equations, Triple blending technique, Blended concretes, FRC properties.

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1. INTRODUCTION

Portland cement is a part and parcel of building material. It acts as binding material in concrete, mortar matrix and with other constituents [1].Concrete has become so popular and indispensable, as aforementioned, due to its inherent characteristics and advantages. Applications of mineral admixtures such as silica fume, Metakaoline in concrete are effective easy to future increase the strength and make durable for high strength concrete [2].

The use of reinforcement in concrete brought a revolution in the application of concrete. However generally, despite this, compared to other building materials such as metals and polymers, concrete is significantly more brittle and exhibits a poor tensile strength. Based on fracture toughness values, steel, in the form of reinforcement, is at least 100 times more resistant to crack growth than concrete [3&4]. Concrete in service thus cracks easily, and this cracking creates easy access routes for deleterious agents resulting in early saturation, freeze-thaw damage, scaling, discoloration and steel corrosion.

The concerns with the inferior fracture toughness of concrete are mitigated to a large extent by reinforcing it with fibres of various materials[5, 6 &7]. The resulting material with a random distribution of short, discontinuous fibres is termed fibre reinforced concrete (FRC) [8].As a rule, fibres are generally randomly distributed in the concrete so that after processing the concrete, the fibres become aligned in the direction of the applied stress and will thus result in greater tensile and flexural strength. Fibre reinforced concrete is slowly becoming a well-accepted mainstream construction material.

2. MATERIALS

2.1. Triple blended concretes

It belong to that strata of concretes where the strength and durability characteristics are maximized to the highest extent possible, in comparison to various other types of concretes, by subtle tailoring of its chemical composition, fineness and particle size distribution.

In simple words, triple blended cement is characterised by part replacement of cement with mineral admixtures/additives such as pozzolanic admixtures (fly ash, silica fume, granulated slag etc.) or inert fillers. The corresponding concrete is termed as triple blended concrete. These admixtures are found to enhance the physical, chemical and mechanical properties of the concrete i.e. in terms of its strength parameters (compressive and flexural) as well as durability parameters.

2.2. Metakaoline (MK)

The raw material input inthe manufacture of Metakaolineis kaolin clay. Kaolin is a fine, white, clay mineral that has been traditionally used in the manufacture of porcelain. Metakaoline when used as a partial replacement substance for cement in concrete.

Figure 1 Metakaoline

2.3. Crimped Steel Fibers

Most of the cracks in concrete are formed due to the inherent weakness of the material to resist tensile forces. When concrete shrinks, and it is restrained, it will crack. Steel fiber reinforcement offers solution to the problem of cracking by making concrete tougher and more ductile.

Steel fibers are being produced by M/s. Ryan International, at their most modern factory situated at Pune, Maharashtra State, India. The fibers are factory – crimped to improve bonding characteristics with concrete and are available in diameters ranging from 0.45mm to 1.00m and length from 25mm to 60mm and aspect ratios are from 40 to 130.Results obtained from tension tests carried out on steel fibers are summarized below.

Table 1 Tension strength of steel fibers

Description	Range of ultimate tensile strength (MPa)	Minimum ultimate strength as per ASTM-A820 (MPa)
Steel fibers (0.45 to 1.00mm diameter)	840 to 1250	345

A steel fiber ensures good workability of concrete at all dosages.

Table 2 Improvement over non-fiber reinforced concrete

Property	Improvement over non-fiber reinforced concrete
Cracking and flexural tensile strength	100 to 200%
Shear strength	50 to 100%
Bearing strength and spalling	50 to 100%
Resistance to impact	100 to 500%
Fatigue resistance	Significant improvement

3. METHOLOGY

The present experiment includes casting and testing of specimens for compression. Specimens are prepared M20 grade of concrete with and without Metakaoline, Poly Propylene and Steel Fibers. Total of 25 cube specimens among which 16 were cubes and 9 were cylinderswith percentages of Metakaoline, PP and Fibers are casted. The details of casting and testing of specimens are described below. (Note: all of the following specifications are in adherence to IS: 516-1959). The materials were taken asper the proportion chosen (refer table 3) were weigh batched and mixed with M20 grade of concrete.

Table 3 Concrete mix proportion used.

Mix combinations: cement,fly-ash, micro silica,MK,PP,SF	
Cement (%)	85
Steel Fibers (%)	1.5
Metakaoline (%)	10
Poly Propelene (%)	3.5

3.1. Casting of specimen

For casting the specimens, standard C.I metal moulds have been used. The moulds have been cleaned of dust particles and applied with mineral oil on all sides, before concrete is poured into the mould. Thoroughly mixed concrete is filled in to mould.

3.2. Compaction by vibration

Each layer of concrete in the mould was vibrated using a vibrating table till the specified condition was achieved and till each corner and void within the mould was not completely and properly filled.

3.3. Curing

The test specimens after casting and leaving them in a dry place for 24 hours, were stored at a place free from vibration, in moist air having at least 90% relative humidity and at a temperature of 27°C + 2°C for 24 hours + ½ hour from the time of addition of water to the dry ingredients. After this period, the specimens were marked and removed from the moulds and then immediately submerged in clean, fresh water and kept there until taken out just prior to test. The water in which the specimens were submerged were renewed every seven days and maintained at a temperature of 27°C+ 2°C. The specimens were not allowed to become dry at any time until they have been tested.

3.4. Testing of Specimens

3.4.1. Compressive strength test

The compressive testing machine, which has been used in our project, is of a reliable type and of sufficient capacity for the tests. Its permissible error is not greater than + 2 percent of the maximum load. The testing machine is equipped with two steel bearing platens with hardened faces. One of the platens (the one that will bear on the upper surface of the specimen) is fitted with a ball seating in the form of a portion of a sphere, the centre of which coincides with the central point of the face of the platen. The other compression platen is a plain rigid bearing block. The bearing faces of both the platens larger than the nominal size of the specimen to which the load is applied. The bearing surfaces of the platens do not depart from a plane by more than 0.01mm at any point and they are maintained with a permissible variation limit of 0.02mm.

The movable portion of the spherically seated compression platen is held on the spherical seat but the design is such that the bearing face is rotated freely and can be tilted through small angles in any direction. The tests are made at the recognised ages of the test specimens, the most usual being 7 and 28 days. The ages shall be calculated from the time of the addition of water to the dry ingredients.

In our project we have taken the curing time to be that of 28 days. As the largest nominal size of aggregate does not exceed 20 mm, the size of test specimen used was 150 x 150 x 150 mm cubes, as proposed by the IS Code.

Figure 2: compression testing of specimen

Specimens stored in water were tested immediately upon removal from water and while they were still in wet condition. Surface water and grit were wiped off the specimens and any projecting fins were removed. Specimens when received dry were kept in water for 24 hours before being taken for testing.

The dried specimen were placed on the testing machine. The load was applied without shock and increased continuously at a rate of approximately 140kg/sq.cm/min until the resistance of the specimen to the increasing load broke down and no greater load could be sustained. The maximum load applied to the specimen was then recorded and the appearance of the concrete and any unusual features in the type of failure was noted.

3.4.2. Calculation of Compressive strength

The measured compressive strength of the specimen was calculated by dividing the maximum load applied to the specimen during the test by the cross-sectional area, calculated from the mean dimensions of the section and are expressed to the nearest kg per sq.cm. Average of the obtained values have been taken as the representative of the batch that is when the individual variation was not more than + 15 percent of the average. The cube specimens cured as explained above are tested as per standard procedure after removal from the curing tank and allowed to dry under shade. The cube specimens tested under digital compression testing machine of 2000 KN capacity. The results are tabulated in tables. All these stages are in strict compliance to IS: 516 – 1959 which comprises the specifications for all the above stages of casting as well as testing.

3.4.3. Split Tensile Strength of Concrete

As the largest nominal size of aggregate does not exceed 20 mm, the size of test specimen made is 150 mm diameter x 300 mm height cylinders as proposed by IS Code.

Figure 3: Split Tensile test on cylinder

The test results for plain concrete and ternary blended concrete were tabulated and discussed in results and discussions.

4. RESULTS AND DISCUSSION

The behavior of ternary blended concrete over plain concrete is compared with the tests values below.

Table 4: Compressive strength of plain cement concrete

S. No	Surface area(mm)	Compressive strength(N/mm2)	
		7 Days	28 Days
1	150x150	13.163	28.683
2	150x150	15.69	29.077
3	150x150	16.40	28.5
Average Compressive strength		14.91	28.75

Table 5 Compressive strength of ternary blended concrete with fibers

S. No	Surface area(mm)	Compressive strength(N/mm2)	
		7 Days	28 Days
1	150x150	16	35.12
2	150x150	17.07	36.01
3	150x150	17.8	37.34
Average Compressive strength		16.965	36.15

Percentage increase in compressive strength at 7 days by addition of fibers

= 16.95-14.91/14.91 x 100 = 13.68%

Percentage increase in compressive strength at 28 days by addition of fibers

= 36.15-28.75/28.75 x 100 = 25.73%

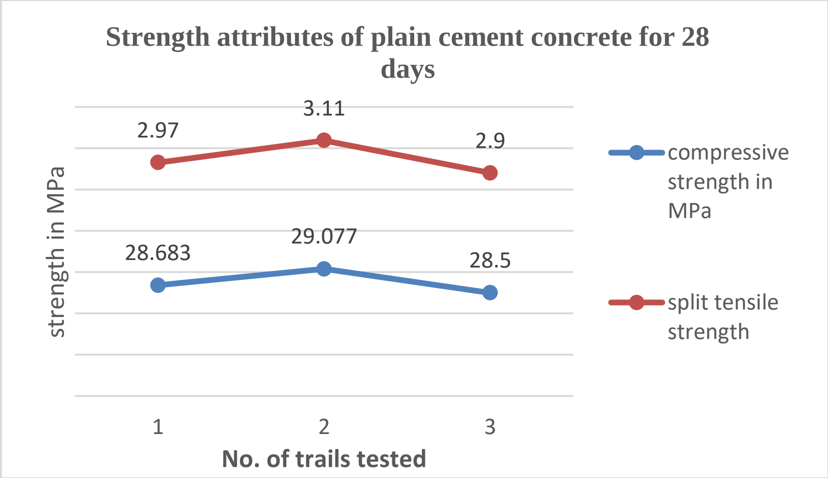


Figure 4: Strength attributes of plain cement concrete for 28 days

Table 6: split tensile strength (28days)of two different concrete types

S. No	Calculation parameters		Split tensile strength(N/mm2)	
	D	L	Plain concrete	ternary blended concrete
1	150	300	2.97	3.70
2	150	300	3.11	4.04
3	150	300	2.90	3.77
Average split tensile strength			2.99	3.83

The above Table 6, depicts the split tensile strength values for different load values. The notations D and L represents diameter of the cylinder and length or height of the cylinder respectively.

View of specimens after immersion in 5%H2SO4 ACID ATTACK

View of specimens after immersion in 5% HCL

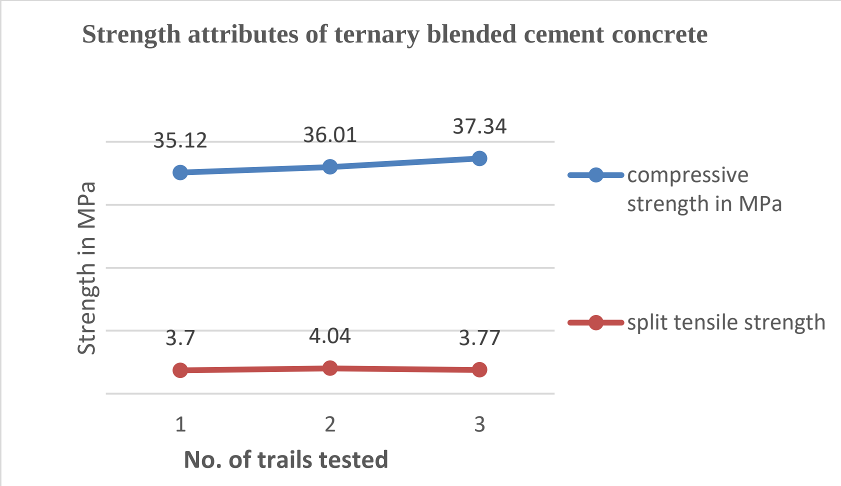


Figure 5 Strength attributes of ternary blended cement concrete for 28 days

From the above table results the Percentage increase in split tensile strength at 28 days by addition of fibers

= 3.83-2.99/2.99 x100 = 28.09%

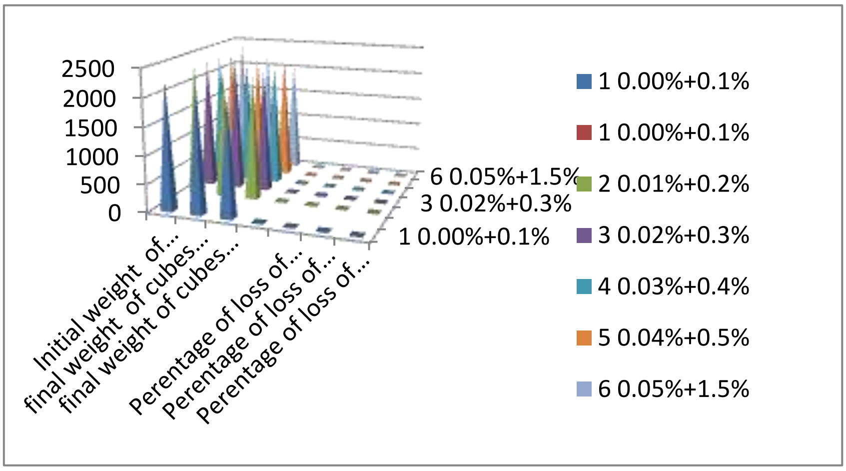
DURABILITY TESTS :

1.acid attack test

2. alkaline attack test

3. sulphate attack test

4. rapid chloride penetration test.



5. CONCLUSIONS

The following conclusions may be drawn based on the observation made in the present experimental study on performance evaluation of ternary blended hybrid fiber reinforced concrete.

- Addition of steel fibers @1.5% by weight to the blended concrete improves compressive strength at 7 days age by 13.68% higher than plain cement concrete.
- Addition of steel fibers @1.5% by weight to the blended concrete improves compressive strength at 28 days age by 25.73% higher than plain cement concrete.
- Addition of steel fibers @1.5% by weight to the blended concrete improves split tensile strength at 28days age by 28.09% higher than plain cement concrete.

- The slump value of blended concrete by addition of fibers is slightly reduced.
- durability tests are giving the less strength of 15% each when compared to steel fiber reinforced concrete .with metakaolin ,ggbs, fly ash. to normal concretes.

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