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# Effect of hybrid fibres on the properties of class C fly ash based concrete

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## Abstract

In this paper steel and palm fibres (natural fibres) was used as hybrid fibre volume fractions with class C fly ash as cement replacement material has been studied. This study aims the optimization of volume faction of steel and palm fibre content in class C fly ash concrete. In this study the percentage of total volume fraction of hybrid fibre is limited to 1.0 and the replacement level of class C fly ash in binder was maintained at 40%. In total five different concrete mixes was used. For each mix standard sizes of cubes, cylinders and prisms were cast as per Indian standards and tested for the mechanical properties such as compressive strength, split tensile strength, flexural strength , modulus of elasticity at age of 28 and 90 days. Compare the experimental results of different hybrid volume fractions of reinforced concrete with 1.0% volume fraction of steel fibre reinforced concrete mix. The test results showed that hybrid fibres (steel + palm) were most effective in improving the mechanical strength characteristics particularly comparable with concrete mix without fibres..

Key words : palm fibres-steel fibres-compressive strength-flexural strength-fly ash

## 1.0 Introduction

Concrete is an important and commonly used man made construction material, which can be constructed to have better strength and durability characteristics. Fibres in the concrete can be used to rectify the defects of porosity and micro cracks of concrete. Steel fibres alone will not satisfy the requirements of strength and durability of concrete, the concept of hybridization of fibres will come to the picture. Hybridisation is the process of adding two or more fibre types into concrete, can give better engineering properties as the presence of one fibres enables the more efficient utilization of the potential properties of the other fibre. The incorporation of fibres into concrete can effectively improve their toughness and ability of resisting crack has been proved.. In this paper experimental studies has been conducted to find the mechanical and durability properties of hybrid fibre reinforced concrete containing class C fly ash. Steel and palm fibres were used as hybrid combination. The total volume fraction of the fibres limited to 1.0%. The percentage of class C fly ash was fixed at 40% replacement level of cement. The mechanical properties include the compressive strength, split tensile strength and flexural strength and modulus of elasticity at the ages of 28 days.

## 2.0 Review of Literature

Mahyuddin Ramli and Eethar Thanoon Dawood[1] has studied the effects of Palm fiber on the mechanical properties of lightweight concrete using crushed brick. The density of the palm fiber lightweight concrete has increased slightly by the inclusion of palm fiber in the mix. The use of 0.8% of volume fraction of palm fibre can be considered an optimal percentage for this type of concrete from the view of highest compressive strength and flexural strength. Mustafa Sahmaran, I. Ozgur Yaman [2] observed that , incorporation of HVFA reduced the water requirement of a SCC mixture. The reduction in the compressive strength due to low pozzolanic activity of the Fly ash was partially set-off by the use of smaller sized SF2 type steel fibers. They concluded that the geometry of the fibres could affect the SCC properties in both fresh and hardened states. A. Sivakumar, Manu Santhanam[3] studied on Mechanical properties of high strength concrete reinforced with metallic and non-metallic fibres .A major significance of these findings is that steel fibres in concrete could be replaced to a small extent with non-metallic fibres (mainly polypropylene) to provide a similar toughness to steel fibre concrete.

Balaguru, P.N. and S.P. Shah[4] shown that the density of the palm fibre lightweight concrete has increased slightly by the inclusion of palm fibre in the mix. The use of 0.8% of volume fraction of palm fibre can be considered an optimal percentage for getting higher compressive and flexural strength. Neville, A.M[5] studied on Palm fibre with good physical properties has shown some encouraging results when used as an additive material in concrete and also From this study, it has been found out that the optimum length for fibre that yields the maximum strength is 5 cm for 0.25% fibre content and 3 cm fibre length for 0.50% fibre content. Eethar Thanon Dawood, Mahyuddin Ramli[6] studied on development of high strength flowable mortar with hybrid fibre the use of steel fibre increases the density while palm fibre decreases the density of high strength flowable mortar due to the specific gravity of these fibres. The compressive strength results show that the use of 0.5% palm fibre increases the compressive strength by about 12% while the use of 1.25% steel fibre increases the compressive strength by about 21% and this is due to the enhancement in mechanical bond between the cement paste and the steel fibres.

## 3.0 Experimental programme

3.1 Materials used

Cement**:** Ordinary Portland cement of 53 grade was used in the present investigation. The Cement used has been tested for various properties as per IS 4031-1988. The initial , final setting and specific gravity were 90 minutes,400 minutes and 3.15 respectively.

Fly ash**:** Fly ash was obtained from Neyveli Lignite Corporation Limited,(NLC) Tamilnadu, India. The fly ash belongs to Class C category as per ASTM C 618. The specific gravity of fly ash is 2.51. The chemical compositions of the fly ash are shown in following table: 1

**Table: 1** Chemical composition of Fly-ash (class C)

| Oxide | Si $O_2$ | $Al_2O_3$ | CaO | $Fe_2O_3$ | MgO | $SO_3$ | LOI |
|---|---|---|---|---|---|---|---|
| ( % ) | 55.0 | 20.0 | 15.0 | 3.0 | 3.0 | 2.0 | 2.0 |

Fine Aggregate: The sand was procured from local source and confirmed to zone III. Specific gravity and fineness modulus are 2.61 and 2.51respectively.

Coarse Aggregate: Crushed angular granite of 12.5 mm size was used as coarse aggregate . Specific gravity and fineness modulus are 2.68 and 7.66 respectively.

Steel fibres**:** Steel fibres of both ends hooked having length of 30mm, diameter of 6mm was used in this study. The aspect ratio and density of steel fibres were 50, 7850 $kg/mm^3$

Palm fibres**:** Plam fibres were procured from samalkot, Andhrapradesh**.** Palm fibres of length 30mm, average diameter 6mm was used in this study. The aspect ratio and density of palm fibres are 50, 1500 $kg/mm^3$

Super plasticizer**:** Ceraplast 300 is used as super plasticizer to make the concrete more workable. A volume fraction of 0.5% of binder content is added throughout this study.

3.2 Mix Proportions: In this study , concrete mix was designed as per ACI 311 guidelines. The grade of concrete M40 was used in this study. Class C fly ash category was used to replace ordinary Portland cement at 40% by mass of binder content. The mix proportion 1:1.20 :1.56 with 0.35 water/binder ratio was adopted for two mixes.

**Table 2:** Concrete mixes with hybrid volume fractions (%)

| Mix ID | CT | AN | AN1 | AN2 | AN3 | AN4 |
|---|---|---|---|---|---|---|
| Steel Fibres | 0.0 | 1.0 | 0.80 | 0.60 | 0.40 | 0.20 |
| Palm fibres | 0.0 | 0.0 | 0.20 | 0.40 | 0.60 | 0.80 |

### 3.3 Casting, vibrating and curing

Each batch of concrete was produced in a pan type concrete mixer. Cement, sand, aggregate and water were first added to the mix and mixed for 2 minutes. Super plasticizer was mixed in water and added into the pan mixer after completion of 2 minutes and steel and palm fibres were also added into the pan mixer and the mixture was further mixed for 2 minutes. All the specimens were cast in standard moulds conforming to IS: 10086-1982 and vibrated on a standard vibrating table. Test specimens were demoulded after 24 hours and placed into the curing tanks for further testing.

## 4.0 Tests conducted on the hardened concrete specimens:

4.1 *Compressive strength*: Compression test is conducted on hardened concrete . Three cube specimens at the age of 28 days were tested under digital compression testing machine of capacity 2000 KN available in the structures lab. The compressive strength can be evaluated and shown in the Fig .1

4.2 *Split Tensile Strength* : The split tensile test was done by placing a cylindrical specimen horizontally between the loading surfaces of a compression testing machine of capacity 2000kN. The load is applied until failure of cylinder, along the vertical diameter. The split tensile strength is determined on the ratio of failure load to the cross sectional area of the specimen. The split tensile strength of cylinders were tested at the age of 28 days . The results are given in the Fig 2.

4.3 *Flexural strength*: The aim of this test is to determine the maximum load carrying capacity of beam specimens. The prisms were tested under digital UTM of capacity 200 kN capacity. All the beams were loaded symmetrically under two point loading. The overall length of the test zone is 400mm and the load is applied through two rollers mounted at the third points of the supporting span. The flexural strength of prisms were calculated and shown in the Fig 3.

4.4 *Modulus of elasticity*: The extensometers was attached at the ends, or on opposite sides of the specimen and parallel to its axis. The extensometer was fixed with the recording points at the same end. The specimen was immediately placed in the testing machine and accurately centered. The load was applied continuously and without shock at a rate of 140 kg/sq cm/min until an average stress of ( C + 5 ) $kg/cm^2$ is reached, where C is one-third of the average compressive strength of the cubes calculated to the nearest 5 $kg/cm^2$ and the readings were taken at a constant interval. The modulus of elasticity values are shown in the Fig 4.

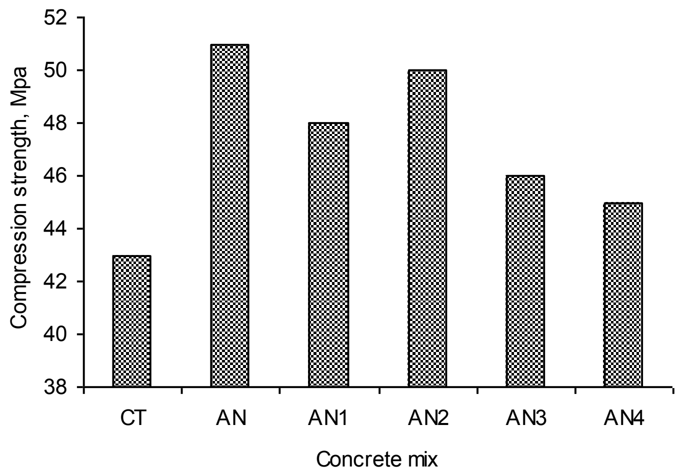


Fig. 1 Compressive strength for concrete mixes at 28 days

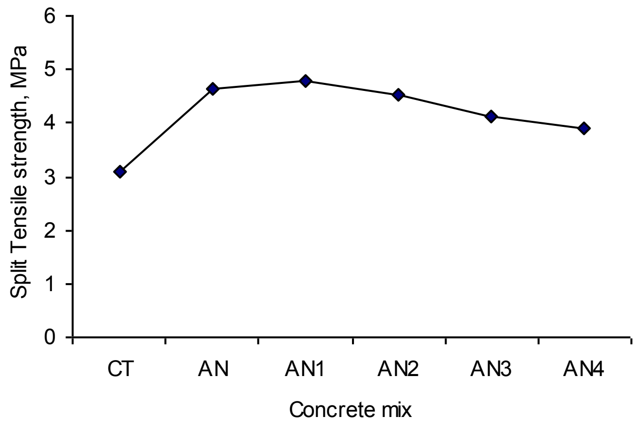


Fig. 2 Split tensile strength for concrete mixes at 28 days

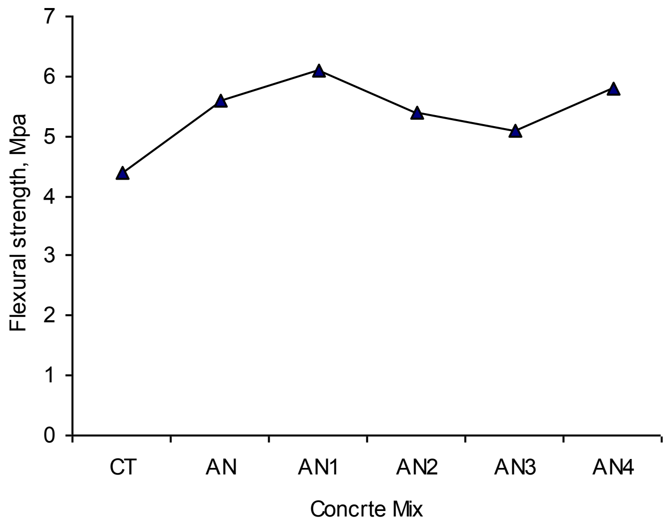


Fig. 3 Flexural strength for concrete mixes at 28 days

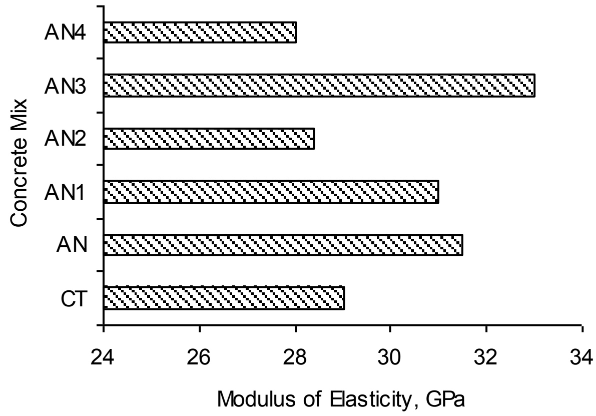


Fig. 4 Modulus of elasticity for concrete mixes at 28 days

## 5.0 Results and Discussion

5.1 Compressive strength: From Fig 1, when a steel fibre alone was used, the compressive strength of the concrete mix AN with steel fibre was improved to 18.5% compared with that of the concrete mix without fibres. The compressive strength of hybrid fibre mixes like AN3 and AN4 was reduced by 9% to 10% compared with steel fibre concrete mix AN. This can be attributed to the air voids and disintegration when the excessive fibre content was used in these hybrid concrete mixes. From fig.1 the compressive strength at 28 days of concrete mixes SP0, SP1, SP2, SP3 and SP4 increases 18.5%, 11.6%, 16.2% , 7% and 4.5% compared with concrete mix without fibres. The hybrid concrete mixes AN3 and AN4 shows marginal improvement in the compressive strength compared with reference mix.

5.2Split Tensile strength: The split tensile strength of the concrete mixes as shown in the Fig 2. The split tensile strength of the concrete mix AN with steel fibres alone increased up to 50% compared with concrete mix CT. The split tensile strength of hybrid fibre mix AN1 (Steel: Palm = 0.8:0.2) increased by 1.73% compared with AN concrete mix having steel fibre alone. This shows the hybrid fibre concrete mix improved in split tensile strength compared with concrete mix consists of steel fibres alone. The hybrid fibre mix AN4, the split tensile strength was reduced compared with all other hybrid fibre concrete mixes. The split tensile strength at 28 days of concrete mixes AN, AN1, AN2, AN3 and AN4 increases 50%, 51.6%, 46.13% , 33.55% and 25.80% compared with concrete mix C.

5.3 Flexural strength: The flexural strength of the concrete mixes as shown in the Fig. 3. The flexural strength of the concrete mix AN with steel fibres of 1.0 $V_f$ alone increased up to 27.2% compared with that of the concrete mix CT. The flexural strength of hybrid fibre mix AN1 and AN4 increased by 9.0% and 3.6% compared with AN concrete mix having steel fibre alone. This shows the hybrid fibre concrete mix of AN1 (Steel: Palm = 0.8:0.2) improved in flexural strength compared with steel fibre concrete mix. The hybrid fibre mixes AN2 and AN3 shows decreased values of flexural strength compared with SP0.The flexural strength at 28 days of concrete mixes AN, AN1, AN2, AN3 and AN4 increases 27.0%, 38.64%, 15.90%, 13.6% and 31.80% compared with concrete mix CT.

5.4 Modulus of Elasticity: The modulus of elasticity as shown in the Fig 4. The elastic modulus of hybrid fibre mix AN3 alone improved 13% compared with concrete mix CT. The other concrete mixes including steel fibres show marginally improvement in the elasticity values.

## 6.0 Conclusions

1. The compressive strength of hybrid fibre concrete mix AN2 is comparable with AN mix with steel fibre alone.
2. The split tensile strength of hybrid fibre mixes increases from 25% to 50% compared with concrete mix without fibres.
3. The split tensile strength and flexural strength of hybrid fibre mix AN1 increases marginally compared with AN concrete mix.
4. There is an improvement of modulus of elasticity of hybrid fibre mixes compared with concrete mix without fibres.

5. The hybrid fibre concrete mix consists of steel and palm fibres (0.8:0.2) $\%V_f$ shows better strength characteristics compared with other combination of steel and palm fibre concrete mixes.

## 7.0 References

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