An Experimental Investigation on the Effect of Addition of Ternary Blend on the Mix Design Characteristics of High Strength Concrete using Steel Fibre.

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Abstract This paper presents the results of M60 grade of concrete. M60 grade of concrete is achieved by maximum density technique. Concrete is brittle and weak in tension and develops cracks during curing and due to thermal expansion / contraction over a period of time. Thus the effect of addition of 1% steel fibre is studied. For ages, concrete has been one of the widely used materials for construction. When cement is manufactured, every one ton of cement produces around one ton of carbon dioxide leading to global warming and also as natural resources are finishing, so use of supplementary cementitious material like alccofine and flyash is used as partial replacement of cement is considered. The effect of binary and ternary blend on the strength characteristics is studied. The results indicate that the concrete made with alccofine and flyash generally show excellent fresh and hardened properties. The ternary system that is Portland cement-fly ash-Alccofine concrete was found to increase the strength of concrete when compared to concrete made with Portland cement or even from Portland cement and fly ash.

Keywords: alccofine, fly ash, compressive strength, tensile strength, slump.

1. INTRODUCTION

Construction activities have accelerated the pace in India in the past 20 years and this pace of acceleration is likely to continue unabated for another 2-3 decades as priority is accorded to infrastructure developments. To meet the increasing requirement of built of space for residence, commerce and industrial and also to meet the dwelling units needs of the rising population in urban and semi urban areas, high rise buildings are the choice of planners, architects and
engineers. High strength concrete is typically used in the erection of high-rise structures, columns on lower floors, shear walls, foundation and reinforced or pre-stressed concrete girders for bridge purpose. In addition to this it can be used in parking garages and spaces where large spaces are required. High strength concrete helps in reduction of beams and columns dimension thus resulting in lower dead loads, least amount of reinforcements to be used and also proves to be more economical. Moreover high strength concrete has higher modulus of elasticity thus providing a stiffer structure which has less lateral deflection under wind loads (for tall structures) as well as under earthquake loads (for medium and low rise structures).

The necessity of high performance concrete is increasing because of demands in the construction industry. Efforts for improving the performance of concrete over the past few years suggest that cement replacement materials along with mineral and chemical admixture can improve the strength and durability characteristics of concrete. In order to obtain high performance concrete, it is of prime importance that the packing between cement and other binders used is as dense as possible. It therefore makes it essential to use ultrafine / microfine material in the range between 0.1 µm and 100 µm along with fine materials of size < 100 µm so that proper particle packing takes place between the cement particles and ultrafine materials. Alccofine and flyash are pozzolanic materials that can be utilized to produce highly durable concrete composites. Alccofine which is ultrafine, low calcium silicate product, is manufactured in India. Alccofine is derived in a molten form, quenched and then solidified into a coarse material, which resembles cement. It is then ground and granulated, controlling the particle size distribution, having particle range 0.1 - 17 microns average particle size is 4 micron.[4],[5]. Fly ash is another supplementary cementitious material which is pozzolonic in nature and reacts with calcium hydroxide and forms calcium silicate hydrate which is strength rendering minerology. Utilization of waste materials such as fly ash in construction industry reduces the technical and environmental problems of plants and decreases electric costs besides reducing the amount of solid waste, greenhouse gas emissions associated with Portland clinker production, and conserves existing natural resources. Low W/C ratios and the use of Alccofine make concrete mixes significantly less workable, which is particularly likely to be a problem in high-strength concrete applications where dense rebar cages are likely to be used. To compensate for the reduced workability, super plasticizers are commonly added to high-strength mixtures.

Concrete is characterized by brittle failure, the nearly complete loss of loading capacity, once failure is initiated. This characteristic, which limits the application of the material, can be overcome by the inclusion of a small amount of short randomly distributed fibers (steel, glass, synthetic and natural) and can be practiced among others that remedy weaknesses of concrete, such as low growth resistance, high shrinkage cracking, low durability, etc. Steel fiber reinforced concrete (SFRC) has the ability of excellent tensile strength, flexural strength, shock resistance, fatigue resistance, ductility and crack arrest. 50% of our country India being in the earthquake-prone zone, all structures have to be designed to withstand the effects of earthquake and must have ductile failure. When earthquake comes, the buildings may collapse immediately without giving any warning of its collapse. This is because the tensile strength of concrete is very low making the concrete brittle and causing immediate collapse on failure. Even concrete is not a crack free material. Many micro-cracks occur due to the very process of hydration. Many of these cracks are micro sized. There are also larger macro cracks which are stress induced or otherwise. When macro cracks expand and link with microcracks to form
continuous crack surface, problems emerge [3]. So by providing large number of short fibres can bridge the microcracks leading to increase in strength and ductility. So the so the effect on addition of 1% steel fibre is observed on the mix design characteristic of high strength concrete. To quote a few examples where alccofine is used in construction in high strength concrete are the metro rail line at kochi Kerala, a high rise structure namely Nathani heights at Mumbai, kishanganga hydroelectric power project, RCC pipes for drainage gravity line for micro tunneling at Vadodara, etc.

Objective:
To study the effect of ternary blends on the workability and strength characteristics of steel fibre reinforced concrete on M60 grade of concrete. Cement is replaced by ternary blend combinations such as (OPC+FA) and (OPC+FA+ALCCOFINE) according to the proportions such as (OPC+0% FA), (OPC+10% FA), (OPC+20% FA), (OPC+10% FA+6.5% AL), (OPC+10% FA+9.75% AL), (OPC + 10% FA + 13% AL) and (OPC + 10% FA + 16.25% AL) Materials used

- **Cement:** 53 Grade Ordinary Portland Cement (OPC), with specific gravity 3.15, initial setting time 120 minutes and final setting time 220 minutes, and 7 day compressive strength of 29 N/mm$^2$ and 28 day compressive strength of 54 N/mm$^2$, complying with IS: 12269 – 1987 was used.
- **Fine aggregates:** Locally available sand with specific gravity of 2.62, falling under the zone-II, complying with IS: 383 – 1970 was used.
- **Coarse aggregates:** 20 mm and 10 mm size aggregate:
The crushed stone aggregates were collected from the local quarry Sevalia. The coarse aggregate (BLACK TRAP) used for the experiment were 20 mm and 10 mm down size and tested as per IS: 383-1970 and 2386-1963 (I, II and III) specifications. Specific gravity of coarse aggregates was found to be 2.82 and 2.78 respectively.
- **Steel fibres:** Crimped flat steel fibres of length 35 mm, width 2.2 mm and thickness of 0.7 mm and aspect ratio of 50 were used in the experimentation. Steel fibres were added by 1% of volume fraction. The density of steel fibre was found to be 78500 N/m$^3$. The steel fibres were obtained from Stewols India (P) Ltd., 5 Industrial estate, Kampteer Road, Uppalwadi, Nagpur. Flat Crimped steel fibres were used, since it helps in proper bonding.
- **Superplasticizer:** To improve the workability and to reduce the water content a Superplasticizer MasterGlenium sky 8860 was used at the rate of 1.5% by weight of cement. It is manufactured by Badiache Anilin-und Soda-Fabrik (BASF), Ahmadabad. MasterGlenium sky 8860 is based on polycarboxylate ether (PCE). It is brown liquid instantly dispersible in water. It has a specific gravity of 1.1 at 30°C. Its Chloride content is 0.023%. It is nontoxic and non-flammable. It has a minimum shelf life of 12 months when stored under normal temperature.
- **Fly ash:** Fly ash was obtained from Wanakbori thermal power plant. This was class F fly ash.
- **Alccofine:** Alccofine was procured from Ambuja Cements Ltd., plant at Goa.

Methodology:
Thus, M60 mix proportion was obtained with cement, sand and coarse aggregates (10mm and 20mm) with proportion of 1:1.79:1.11:2.08 using particle packing method [1],[2] [6]. After this, 1% steel fibres by volume was added to the mix and the different concrete mixes were
agitated thoroughly to get a homogeneous mix. The dosage of super plasticizer used was 1.5% (by weight of cement). To study the effect of ternary blends on the workability and strength characteristics of steel fibre reinforced concrete. Cement is replaced by ternary blend combinations such as (OPC+FA) and (OPC+FA+ALCCOFINE) according to the proportions such as (OPC+0% FA), (OPC+10% FA), (OPC+20% FA), (OPC+10% FA+6.5% AL), (OPC+10% FA+9.75% AL), (OPC+10% FA+13% AL) and (OPC+10% FA+16.25% AL). The required amount of water was added to this dry mix and intimately mixed. The calculated quantity of super plasticizer was now added and mixed thoroughly. Then the mix was placed layer by layer in the moulds to cast the specimens. The specimens were prepared both by hand compaction as well by imparting vibrations through vibrating table. The specimens were finished smooth and kept under wet gunny bags for 24 hours after which they were cured for 7 days and 28 days. After curing, they were tested for their respective strengths as per IS specifications. For assessing compressive strengths of Steel Fibre Reinforced Concrete (SFRC) with ternary blends, standard cube specimens of 150 x 150 x 150 mm were cast. For assessing the tensile strength, standard specimen of cylinder 150 mm diameter and 300 mm height were casted.

The table 1 gives the Materials content for ternary blended concrete

| wate r | cemen t | Fly | Fly | Alcco | Alcco | Replac e | San d | 10 mm | 20 mm | vol. | vol. | vol. | vol. | vol. | vol. | vol. | vol. | Mix | Descripti on |
|-------|--------|-----|-----|-------|-------|----------|-------|-------|-------|------|------|------|------|------|------|------|-----|----------------|
| cont. | cont.  | as h | ash | %    | cont. | cont.    | cont. | cont. | cont. | of   | of   | of   | of   | of   | of   | of   | of   | Ref. Mix (only OPC) |
|       |        |      |     |      |       |          |       |       |       | S.P  | water | cement | FA | Alcco | Sand | 10 mm | 20 mm |              |
| 123   | 387    | 0    | 0   | 0    | 0     | 387      | 715   | 445   | 832   | 5.3  | 123   | 123    | 0    | 0    | 273  | 16   | 29   | 5             |
| 123   | 387    | 0    | 0   | 0    | 0     | 387      | 715   | 445   | 832   | 5.3  | 123   | 123    | 0    | 0    | 273  | 16   | 29   | 5             |
| 122   | 382    | 10   | 39  | 0    | 0     | 343      | 715   | 445   | 832   | 5.2  | 122   | 109    | 16   | 0    | 273  | 16   | 29   | 5             |
| 120   | 375    | 20   | 77  | 0    | 0     | 299      | 715   | 445   | 832   | 5.2  | 120   | 95     | 32   | 0    | 273  | 16   | 29   | 5             |
| 124   | 387    | 10   | 39  | 6.5  | 25    | 329      | 715   | 445   | 832   | 5.3  | 123   | 105    | 16   | 8.8  | 273  | 16   | 29   | 5             |
| 123   | 387    | 10   | 39  | 9.8  | 38    | 329      | 715   | 445   | 832   | 5.3  | 123   | 105    | 16   | 13   | 273  | 16   | 29   | 5             |
| 123   | 387    | 10   | 39  | 13   | 50    | 329      | 715   | 445   | 832   | 5.3  | 123   | 98     | 16   | 18   | 273  | 16   | 29   | 5             |
| 123   | 387    | 10   | 39  | 16   | 63    | 329      | 715   | 445   | 832   | 5.3  | 123   | 105    | 16   | 22   | 273  | 16   | 29   | 5             |
Test results: Different test results such as workability, compressive strength and tensile strength are tabulated as shown:

Table 2 gives the workability test results of ternary blended steel fibre reinforced concrete as measured from slump test.

Table 2. Workability test results of ternary blended fibre reinforced concrete.

| Different Percentage replacement of cement by ternary blend | Identification of mix | Ternary blend with (FA+AL) Slump (mm) |
|-------------------------------------------------------------|------------------------|--------------------------------------|
| (0+0) Ref. Mix                                             | M-1                    | collapse                             |
| OPC+1% Steel fibres                                        | M-2                    | collapse                             |
| (10+0) +1% Steel fibres                                   | M-3                    | collapse                             |
| (20+0) +1% Steel fibres                                   | M-4                    | collapse                             |
| (10+6.5) +1% Steel fibres                                 | M-5                    | 150                                  |
| (10+9.75) +1% Steel fibres                                | M-6                    | 155                                  |
| (10+13) +1% Steel fibres                                  | M-7                    | 132                                  |
| (10+16.25) +1% Steel fibres                               | M-8                    | 125                                  |

Table 3 Overall result of compressive strength for 7 & 28 days

| MIX  | 7 days strength | 28 days strength | Percentage increase or decrease of compressive strength w.r.t. ref. mix |
|------|-----------------|------------------|-------------------------------------------------|
| M-1  | 60.14           | 68.3             | -                                               |
| M-2  | 64.88           | 73.04            | 6.939970717                                     |
| M-3  | 50.96           | 68.59            | 0.424597365                                     |
| M-4  | 47.11           | 66.96            | -1.96193265                                     |
| M-5  | 63.7            | 71.11            | 4.11420205                                     |
| M-6  | 66.22           | 77.04            | 12.781845                                       |
| M-7  | 63.25           | 73.33            | 7.364568082                                     |
| M-8  | 62.22           | 72.89            | 6.720351391                                     |

Table 4 Overall result of tensile strength for 7 & 28 days

| Type of Mix | 7 days strength Average tensile strength (MPa) | 28 days strength Average tensile strength (MPa) | Percentage increase or decrease of tensile strength w.r.t. ref. mix |
|            |                                             |                                               |                                                             |
| M-1        | 3.52                                        | 4.33                                          | -                                                           |
| M-2        | 4.36                                        | 18.465                                       | 11.1422                                                     |
| M-3        | 4.33                                        | 17.568                                       | 10.4884                                                     |
| M-4        | 4.28                                        | 16.414                                       | 9.72565                                                     |
| M-5        | 4.36                                        | 18.593                                       | 11.3601                                                     |
| M-6        | 4.49                                        | 21.927                                       | 20.092                                                      |
| M-7        | 4.41                                        | 19.876                                       | 13.625                                                      |
| M-8        | 4.37                                        | 18.85                                        | 11.2511                                                     |
Observations and discussions: - Following observations were made based on the results obtained.

1. By providing 1% steel fibre the compressive strength has increased by 7% and the tensile strength has increased by 11.18%. When steel fibre is put the workability decreases.

2. The workability of ternary blended fibre reinforced concrete with (FA+AL) combination as measured from slump, show better results as compared with reference concrete and steel fibre reinforced concrete with no blends. Mixes containing fly ash and Allocone improve the workability. This is due to the reason that allocone have better particle size distribution, which provides dense matrix pore structure resulting in to reduced water content and better workability. Allocone particles are smaller than the cement particles. So it fills even the minute space between different materials and the combined action of Allocone and chemical admixture results in more cohesive mixture and workability increases. This may be due to the fact that the fly ash particles which are spherical in shape induce ball bearing effect in concrete, thereby increasing the workability. The glossy spheroid and smooth surface of fly ash particles naturally induce flow properties to concrete without any segregation effects. Thus it can be concluded that as allocone content increases in ternary blended fibre reinforced concrete with (FA+AL) combination, the workability decreases and better value of workability is obtained at (10+9.75) combination.

3. It is observed that the compressive and tensile strength of ternary blended steel fibre reinforced concrete shows higher values at (10+9.75) replacement with (FA+AL) combination. There after the compressive strength and tensile strength shows a decreasing trend. This observation is true for 7 days and 28 days strength, where percentage increase in compressive strength is found to be 10.10% and 12.8% respectively and percentage increase in tensile strength is found to be 21.93% and 20.09% respectively with respect to reference mix which is without steel fibre. Allocone due to its pozzolanic nature give an improved paste characteristics and good transition zone. The increase in strength is due to the presence of allocone, which results in to the formation of dense pore structure and increased secondary hydrated product due to the inbuilt CaO content. But the maximum enhancement is obtained at 8-10% alcocone replacement. Beyond that there is no significant change in the compressive strength. Spitting tensile strength is greater in allocone concrete when comparing to control mix or reference mix.

Conclusions:
Following conclusions can be drawn based on the experimental results.

1. The study was carried out using M 60 grade concrete.

2. By providing 1% steel fibre the compressive strength has increased by 7% and the tensile strength has increased by 11.18%. When steel fibre is put the workability increases.

3. It is apparent that ternary cementitious blends of Portland cement, allocone, and fly ash offer significant advantages over binary blends and even greater enhancements over plain Portland cement.

4. The combination of allocone and class F fly ash is complementary: the allocone improves the early age performance of concrete with the fly ash continuously refining the properties of the hardened concrete as it matures. Thus it can be concluded that the compressive and tensile strength of ternary blended steel fibre reinforced concrete shows higher tensile strength at a replacement level of (10+9.75) with (FA+AL) combination. This may be attributed to the
fact that at a replacement level of (10+9.75) with (FA+AL) combination, most of the pores in the concrete matrix gets filled up there by rendering a dense microstructure.

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