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Mechanical Properties of Polymer Modified Ternary Blend Concrete

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Abstract: From many decades, the research work is in progress all over the world in concrete technology in finding the alternative or supplementary cementitious materials which can improve various properties of concrete viz, strength, workability, durability, resistance to cracks, shrinkage resistance etc. Few of the industrial by products like silica fume, fly ash, blast furnace slag, metakaolin, rice husk ash etc. have shown very good strength, durability and workability when used as partial cement replacement materials. This developed the concept of binary, ternary and tertiary blend concretes by incorporating different combinations of Supplementary Cementitious Materials (SCM). Use of appropriately proportioned ternary blend allows the effect of one SCM to compensate for the inherent shortcomings of the other. Silica fume and Metakaolin are such admixtures which in combination give greater compressive and shear strengths. Use of Polymer in Latex form improves adhesion or water tightness. By the addition of different percentage of polymer in ternary blend concrete, strength and durability of polymer modified ternary blend concrete may be substantially improved. In this experimentation, mechanical properties of ternary blend concrete(for M25 strength) having OPC 43 grade cement, silica fume, metakaolin, superplasticizer with varying percentage of polymer in it (from 0% to 5%)were investigated. Results of this experimental investigation reveal that 2% addition of Styrene Butadiene Rubber (SBR) latex in ternary blend concrete containing 20% metakaolin and 10% silica fume increased the compressive strength by 22% and shear strength by 33% with reference to control mix.

Keywords: *Ternary blend, Supplementary Cementitious Material (SCM), Silica Fume, Metakaolin, SBR Latex*

1. Introduction

Concrete has desirable engineering properties, which can be moulded into any shapes and also can be produced with cost effective materials. To make a better concrete now variety of innovative materials such as fibres, admixtures and construction chemicals, pozzolonas and different concrete making techniques are adopted in present day construction.

In developing countries, use of supplementary cementitious materials (SCM) is fundamental in developing low cost construction materials [2]. Concrete is generally used to resist compressive forces. But by addition of some pozzolanic materials, various properties of concrete viz, workability, strength, durability, crack resistance etc. can be improved. Modern concrete mixes mixed with admixtures, improve the microstructure as well as decrease the calcium hydroxide concentration by consuming it through a pozzolanic reaction. In addition, the physical effect of the fine grains allows dense packing within the cement hydration [2]. In general, the pozzolanic effect depends not only on the pozzolanic reaction, but also on the physical or filler effect of the smaller particles in the concrete mixture. Therefore, the addition of pozzolanas to ordinary portland cement (OPC) increases its mechanical strength and durability as compared to the unblended paste, because of the interface reinforcement.

1.1. Ternary Blend Concrete

Many alternative materials tried as partial cement replacement materials like fly ash, blast furnace slag, silica fume, metakaolin, rice husk ash, etc., which improves the strength, workability and durability performance now termed as Supplementary Cementitious Materials (SCM). These materials used to form binary, ternary and tertiary blend concrete based on their combinations. The use of appropriately proportioned ternary blend allows the effect of one SCM to compensate for the inherent shortcomings of another[3].

An attempt is made in this work to investigate the mechanical properties of polymer modified ternary blend concrete incorporating silica fume, metakaolin, and polymer. The properties investigated include workability, compressive strength and shear strength.

The total SCM replacement (SF + MK) is up to 30% to determine the workability, compressive strength and shear strength.

1.2. Ingredients

Following ingredients have been used in this experimental work to investigate mechanical properties of concrete.

1.2.1. Cement

In this experimentation, 43 grade OPC conforming to IS: 8112-1989 was used for all concrete mixes. The cement used was fresh and without any lumps. The specific gravity of cement is found to be 3.15

1.2.2. Fine Aggregates

Locally available natural sand conforming to IS: 383-1970 was used in this work. This sand complies with grading zone II (based on experiments). Specific gravity of sand was found to be 2.63.

1.2.3. Coarse Aggregates

Locally available crushed, angular and graded coarse aggregates having the maximum size of 20mm were used in the present work. The specific gravity of coarse aggregate was found to be 2.87

1.2.4. Water

Potable tap water with pH value of 7.0 conforming to IS: 456-2000 was used for making and curing of concrete specimens.

1.2.5. Silica fume (SF)

In cementitious compounds, silica fume works on two levels. When silica fume is added to concrete it chemically reacts with the CH to produce additional CSH. The benefits of this reaction are twofold: increased compressive strength and chemical resistance. Particle packing, refines the microstructures of concrete, creating a much denser pore structure impermeability is dramatically increased, because silica fume reduces number and size of capillaries that would normally enable the contaminants to infiltrate the concrete.

The specific surface area ranges from 15-30 m^2/g. The silica fume used in the experimentation was obtained from Corniche India (P) Ltd, Navi Mumbai. Specific gravity of silica fume is 2.2. In the present investigation, 10% of cement is replaced by silica fume.

Table 1.1 *Chemical composition of silica fume (SF)**

Chemical composition	Percentages
Silica (SiO_2)	89
Alumina (Al_2O_3)	0.50
Iron Oxide (Fe_2O_3)	2.50
Alkalies ($Na_2O + K_2O$)	1.20
Calcium Oxide (CaO)	0.50
Magnesium Oxide (MgO)	0.60

** As given in manufacturer's lab reports.*

1.2.6. Metakaolin (MK)

The metakaolin used in the experimentation was obtained from Zigma International, Navi Mumbai. The specific gravity of metakaolin is 2.54. In the present investigation, 20% of cement is replaced by metakaolin.

Table 1.2 *Chemical composition of metakaolin (MK)**

Chemical composition	Percentages
SiO_2	58-65
Al_2O_3	30-34
Fe_2O_3	<0.9
TiO_2	<1.00
CaO	0.1-0.2
CaO + MgO	0.8-1.50
$Na_2O + K_2O$	0.8-1.50

** As given in manufacturer's lab reports.*

1.2.7. Chemical Admixture

To induce better workability, Conplast-SP 430 super plasticizer in the form of sulphonated Napthelene Polymers was used in this experimental study.Conplast-SP430 complies with IS:9103-1999 and ASTM 494 Type F. This super plasticizer has been specially formulated to give high water reductions up to 25% with reduced permeability.Conplast-SP430 was procured from FOSROC Chemicals Bangalore. Conplast SP430 is a chloride free, superplasticising admixture.

1.2.8. Polymer

Styrene Butadiene Rubber (SBR) latex polymer was used in this research work. SBR Latex Polymer manufactured by Fosroc Chemicals was used in this experimentation. Different percentages of polymer addition considered were 0%, 1%, 2%, 3%, 4% and 5%. Basic properties of SBR Latex polymer are presented in table 1.3.

Table 1.3 *Properties of SBR latex*

Property	Description
Type	Styrene Butadiene Polymer (SBR) liquid.
Color	White
Specific gravity	1.02 + 0.02
Solid content	34+2%

2. Research Methodology

To proceed with the experimental work, first specific gravity and water absorption of coarse and fine aggregates were determined experimentally. Then concrete mix design is calculated and trial mixes are made. Based on the workability, mix design proportions are fixed and casting of specimens carried out further for determining compressive and shear strengths of concrete specimens after 7days and 28 days of curing.

2.1. Concrete Mix Design

The mix design procedure adopted to obtain a M25 grade concrete is in accordance with IS 10262-2009.

2.1.1. Mix Proportion for Trial

From the mix design calculations, obtained mix proportion is 1:2.05:3.82 and following quantity of materials calculated for the concrete mix from the obtained proportion.

Table 2.2 *Quantities of materials after mix proportions in accordance with IS: 10262-2009*

Sl. No.	Materials	Specific Gravity	Quantity Kg/m^3
1	Cement (OPC 43 Grade)	3.150	240.0
2	Sand (Zone II)	2.630	703.5
3	Coarse Aggregates (20mm & down)	2.873	1308.6
4	Silica Fume (10%)	2.200	34.2
5	Metakaolin (20%)	2.540	68.4
6	Water	1.000	153.26
7	Super plasticizer (2%) (Conplast SP430)	1.140	0.048

2.1.2. Check for Workability

Workability of concrete was tested Slump Cone apparatus. The vertical distance by which the concrete of the mould subsides is record as the slump value of the mix in mm.

Slump test was conducted on mixes having three different water cement ratios, 0.40, 0.45 and 0.50. The desired slump of 60mm was obtained corresponding to 0.45 water cement ratio using 1% super plasticizer.

2.2. Casting of Specimen

Cement sand and aggregate were taken in a mix proportion 1:2.05:3.82 which correspond to M25 grade concrete. IS 10262:2009 mix proportioning method was adopted for mix design. 10% of cement was replaced by silica fume and 20% of cement was replaced by metakaolin in all mixes. Also as a reference mix, specimen were cast without SF and MK. Three specimens were prepared for finding 7 days strength and three specimens were prepared for finding 28 days Strength for both compressive and shear strength tests for each 0%,1%.2%,3%,4%,5% by volume fraction of polymer. For preparation of specimen, batching of constituent material is done by weight. All the ingredients dry mixed homogeneously. Then required quantity of water is added (w/c=0.45%) and entire mix was again homogeneously mixed. Now super plasticizer was added at dosage of 1% (by weight of binder). The fresh concrete was compacted in the moulds by means of table vibrator. After the compaction the specimen were given smooth finish and all the specimens were cured under polythene sheets for 24 hours in the laboratory environment. After 24 hours, the specimens were demoulded and transferred to curing tank and were allowed to cure for 7 and 28 days.

After 7th and 28th days the specimen were removed from curing tank and were kept out in open atmosphere for drying. Then specimens were tested for evaluating compressive strength and shear strength.

2.3. Testing Procedure

Casted specimens are then tested to obtain Compression Strength and Shear Strength. Specimen tested on 2000KN capacity compression testing machine as per IS 516:1959.

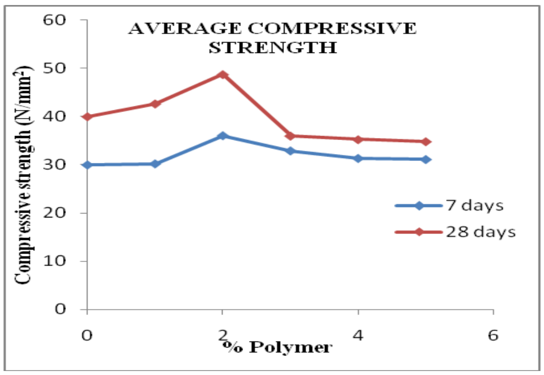

Figure 2.1 *Variation in average values of compressive strength for 7 days and 28 days*

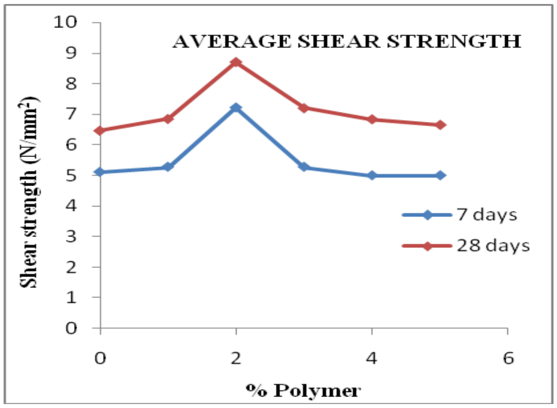

Figure 2.2. *Variation in average values of shear strength for 7 days and 28 days*

Figure 2.3 *Compressive Strength Test set up*

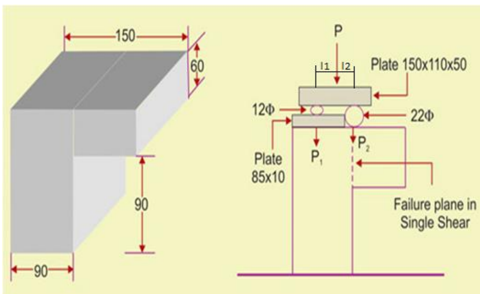

Figure 2.4 *Shear Strength Test set-up as suggested by Bairagi and Modhera*

2.4. Test Results

The details of test conducted on compressive and shear strength of 60 specimens and the average values and graphs are tabulated.

Table 2.1 *Average compressive strength (MPa) after 7 days and 28 days of curing*

% Polymer	After 7 days curing	After 28 days curing
0	30.00	40.00
1	30.23	42.66
2	36.00	48.74
3	32.89	35.99
4	31.34	35.23
5	31.12	34.81

Table 2.2 *Average shear strength (MPa) after 7 days and 28 days of curing*

% Polymer	After 7 days curing	After 28 days curing
0	5.11	6.47
1	5.28	6.85
2	7.22	8.70
3	5.28	7.20
4	5.00	6.84
5	5.00	6.66

2.5. Conclusions

Following conclusions are drawn based on the experimental investigation on polymer modified ternary blended (PMTB) concrete. This concrete containing 10% silica fume and 20%metakaolin with varying percentages of SBR latex polymer.

- Addition of 2% SBR Latex polymer in ternary blended concrete containing 10% silica fume and 20% metakaolin increases the Compressive strength by 22%.
- Addition of 2% SBR Latex polymer in ternary blended concrete containing 10% silica fume and 20% metakaolin increases the Shear strength by 37%.
- Thus polymer modified ternary blend concrete can be recommended for applications where higher shear strength and compressive strength are required.

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