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Research paper

Study on effect of colloidal Nano silica blended concrete under compression

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Abstract

Ternary Blended Concrete (TBC) with Nano-Silica (NS) is receiving special attention because of its ability to improve the performance of concrete as compared with the control concrete. The present investigation deals about the behavior of TBC produced, using Fly Ash (FA) and Alccofine (ALC) as a partial replacement for cement along with four different types of colloidal NS (CemSynXLP, CemSynXTX, CemSynXFX, CemSynXTXla) as additives. The compressive strength of M30 grade of TBC was tested after 7, 14 and 28 days of curing. From the study, it has been found that the TBC mix with 25% replacement for cement (FA at 15% and ALC at 10%) and with addition of 1% CemSynXTXla type of NS as an additive has achieved higher strength than all other types of TBC mixes.

Keywords: *Nano Silica; Fly Ash; Alccofine; Cemsynxlp; Cemsynxtx; Cemsynxfx; Cemsynxtxla.*

1. Introduction

Cement is an essential raw material for the production of concrete. However, huge amounts of carbon-dioxide (CO_2) a greenhouse gas is emitted during the calcination of limestone for the production of one tonne of cement [1]. Since, the production of cement involves excessive emission of greenhouse gases that lead to depletion of the ozone layer and many other environmental problems, a substitute or alternative material for cement is needed for sustainable construction [2]. The pozzolanic materials like Silica Fume (SF), FA, Rice husk ash (RHA), Metakaolin, ALC, Ground Granulated Blast Furnace Slag (GGBS), etc are used as replacing material for cement reduces the CO_2 emission and also improve various physical properties of the concrete [3]. These materials are being used as a partial replacement of cement in the field of construction from the recent past to meet all the requirements and demands of construction industries. In the present investigation, the combination of FA and ALC materials are used in as a partial replacement of cement. Also, there are few investigations that deal with the usage of Nanotechnology in concrete. Recently nanotechnology received attention towards the usage of nanomaterials like nano silica (NS), nano metakoline (NMK), etc as additives in the concrete production. Among all the nanomaterials NS has been chosen as an additive because of its high capability in improving the microstructure of cement-based products like concrete [4]. However, there are only limited works which deal with the effects of NS on fresh state properties such as, setting time, consistency, workability and hardened properties such as mechanical and durability properties [8]. Reusing industrial by-products such as FA, ALC and NS are very important in order to achieve sustainability in civil engineering construction.

2. Literature review

S. Rajesh Kumar et al., [5] have done an investigation on the mechanical properties of ALC based M30 grade concrete. Form their investigation it is concluded that the replacement of cement by ALC increases the mechanical strength to a large extent at 10% replacement of cement.
K Gowdham et al., [6] have investigated about the mechanical behavior of high strength concrete containing ALC as admixture and micro steel fibers as reinforcement. The mix containing 10% ALC with 2% of micro steel fibers developed a marginal increase in strength when compared to the control concrete.
M. V. S. Reddy et al., [7] have done an investigation on partial replacement of cement by FA and ALC for M40 grade of concrete at varying percentages. They have concluded that addition of ALC increases the strength, passing ability, resistance to segregation and filling ability than that of FA mixes for several replacement percentages.
D. Sivakumar et al., [9] have conducted an experimental study on strength and durability properties by replacing the cement with ALC at 10 % by weight for M50 grade concrete. From the investigation, it has been found that addition of ALC has achieved more strength than the control mix. The durability of the alccofine mix was comparatively greater than the control mix at all the ages of curing.
Bharat Bhushan Jindal et al., [10] have conducted an investigation on FA based geopolymer concretes with various percentages of ALC. From their investigation, it has been concluded that the presence of ALC improved the properties of geopolymer concrete both in the fresh and hardened state of concrete.
S. W. M. Supit et al.,[11] have conducted an experimental investigation on durability properties of high volume FA based concrete

containing NS at 2% and 4%. They have concluded that the strength has improved by the addition of 2 % NS and it also significantly reduced the water absorption, sorptivity, porosity and chloride permeability of FA based concrete mix having 38% FA.
D. V. P. Rao et al.,[12] have studied about the influence of NS and FA on mechanical properties of concrete. In their study, the cement was replaced by FA at 20% and 30% and NS was added as 1.5%, 3% and 4.5% by weight of cement for M25 grade concrete. They concluded that NS had improved particle packing of concrete and the properties of concrete had improved with a combination of 20% FA with 3% NS for all the ages of curing when compared to all other mixes.

3. Materials

3.1. Cement

The cement used in the present study is 53 grade Ordinary Portland Cement (OPC) and the properties of cement were tested as per IS 12269-1976.

Table 1: Properties of Cement

Characteristics	Experimental values	As per IS 12269 : 1987
Specific gravity	3.14	3.15
Fineness of cement	6.51%	< 10%
Normal Consistency	32%	30% - 35%
Initial Setting Time	55 min	> 30
Final Setting Time	425 min	< 600
Soundness	1.3 mm	< 10 mm

a) Fly Ash
FA used in this investigation is class F type FA which was acquired from Dr. Narla Tata Rao Thermal Power Station, Vijayawada, Andhra Pradesh.

Table 2: Properties of Fly Ash

2	Test results
Loss of ignition	0.4-0.9%
SO_3	0.1-2.1%
MgO	0.3-2.6%
CaO	0.7-3.6%
Fe_2O_3	4-10%
Silica	49-67%
Specific gravity	2.3

b) Alccofine
Alccofine is a processed pozzolanic material which was obtained by controlled granulation with high glass content and high reactivity. ALC contents of Alumina and Silica in higher percentages than other pozzolanic materials. ALC was acquired from Ambuja Cements Ltd, Goa.

Table 3: Properties of Alccofine

Characteristics	Test results
CaO	33.7%
SO_3	0.18%
SiO_2	32.5%
Al_2O_3	22.6%
Fe_2O_3	1.6%
MgO	7.4%
Specific Gravity	2.81
Fineness	~12000 cm^2/gm
Bulk Density	700-900 kg/m^3

c) Nano Silica
Four different types of NS are used in the investigation which is in the form of a water emulsion of colloidal silica. All the types of NS were acquired from Beechems, Chemical manufacturer in Kanpur, India.

Table 4: Properties of Nano Silica

Grade of NS	Nano Solids	Specific Gravity	Viscosity
CemSynXLP	15%	1.15	3-5 cp
CemSynXTX	29.5%	1.20	4-6 cp
CemSynXFX	39.4%	1.30	4-7 cp
CemSynXTXla	29.4%	1.20	4-7 cp

d) Fine Aggregate
Locally available river bed sand was used throughout our investigation.

Table 5: Properties of Fine Aggregate

Characteristics	Test results
Specific Gravity	2.612
Water Absorption	1.023%
Fineness Modulus	2.71
Grade Zone	II

e) Coarse Aggregate
Natural round uncrushed coarse aggregate with a nominal size of 20mm is used in our investigation.

Table 6: Properties of Coarse Aggregate

Characteristics	Test results
Specific Gravity	2.781
Water Absorption	0.56%

f) Water
Tap water available in our university is used in the entire investigation.
g) Super plasticizer
Conplast SP430 is used as a superplasticizer for the entire investigation at 1% by weight of the binder.

Table 7: Properties of Super Plasticizer

Characteristics	Results
Appearance	Brown liquid
Specific Gravity	1.23
Chloride content	Nil
Water reduction	24%

4. Mix design and mix notations

4.1. Mix design

M30 Grade of concrete mix design was done according to the code IS 10262 -2009.

Table 8: Mix Design

Materials	Binder kg/m^3	Fine Aggregate kg/m^3	Coarse Aggregate kg/m^3	Water kg/m^3
Quantity	350.221	770.162	1204.619	157.61

Mix Proportion =1: 2.1990: 3.4397 with water binder ratio (w/c) of 0.43.

a) Mix Notations
CM - Conventional Concrete mix.
CF1 - Mix with 5% FA as a replacement of cement.
CF2 - Mix with 10% FA as a replacement of cement.
CF3 - Mix with 15% FA as a replacement of cement.
CF4 - Mix with 20% FA as a replacement of cement.
CF5 - Mix with 25% FA as a replacement of cement.
CF6 - Mix with 30% FA as a replacement of cement.
CF7 - Mix with 35% FA as a replacement of cement.
CF8 - Mix with 40% FA as a replacement of cement.
CFA1 - Mix with combination of 15% FA and 6% ALC as a replacement of cement.
CFA2 - Mix with combination of 15% FA and 8% ALC as a replacement of cement.
CFA3 - Mix with combination of 15% FA and 10% ALC as a replacement of cement.
CFA4 - Mix with combination of 15% FA and 12% ALC as a replacement of cement.

CFA5 - Mix with combination of 15% FA and 14% ALC as a replacement of cement.
CFA6 - Mix with combination of 15% FA and 16% ALC as a replacement of cement.
CN1 - Mix with combination of 15% FA and 10% ALC as a replacement of cement, 1% XFX NS as additive for concrete.
CN2 - Mix with combination of 15% FA and 10% ALC as a replacement of cement, 1% XTX NS as additive for concrete.
CN3 - Mix with combination of 15% FA and 10% ALC as a replacement of cement, 1% XLP NS as additive for concrete.
CN4 - Mix with combination of 15% FA and 10% ALC as a replacement of cement, 1% XTXla NS as additive for concrete.
CN42 - Mix with combination of 15% FA and 10% ALC as a replacement of cement, 2% XTXla NS as additive for concrete.
CN43 - Mix with combination of 15% FA and 10% ALC as a replacement of cement, 3% XTXla NS as additive for concrete.

5. Results

5.1. Compressive strength

Compressive strength test was carried out as per IS 516: 1959. The test was conducted after 7, 14, and 28 days of curing on the cube specimens of side 100mm. In this investigation compressive strength test was done in four phases.

5.1.1. Phase –i selection of optimum percentage of FA

Phase I describes the work carried out to evaluate the optimum percentage of FA as a partial replacement of cement with 5%, 10%, 15%, 20%, 25%, 30%, 35% and 40% replacement by weight. The result is graphically illustrated in Fig. 1.

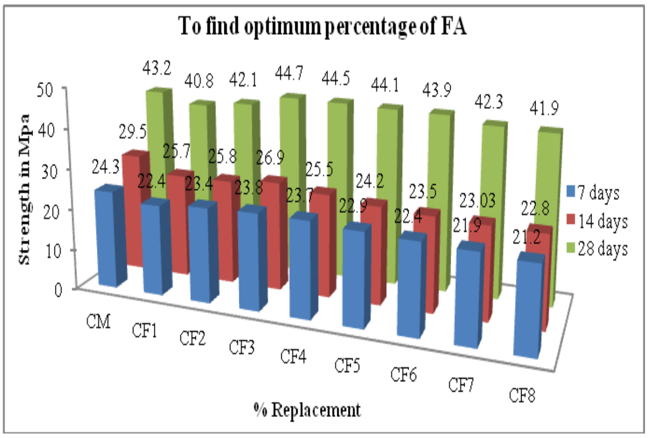

Fig. 1: Graphical Representation of Optimum Percentage of FA.

The mix with 15% replacement of cement by FA showed the maximum strength among all mixes. Hence, the optimum content of FA (CF3) is taken as 15%.

5.1.2. Phase –II Selection of optimum percentage for a combination of FA and ALC

Phase II describes the work carried out to evaluate the optimum percentage for a combination of FA and ALC as a replacement of cement. In this phase, the percentage replacement of FA is constant at 15% and the ALC as a partial replacement of cement at 6%, 8%, 10%, 12%, 14% and 16% replacement by weight of the binder. The result is graphically illustrated in Fig. 2.

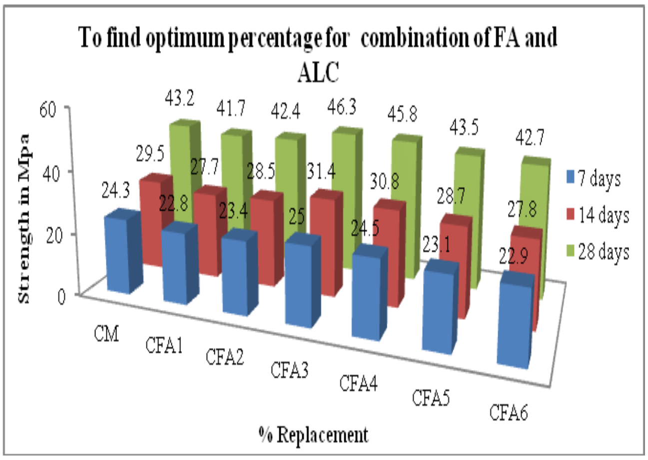

Fig. 2: Graphical Representation of Compressive Strength of TBC with FA and ALC Combinations.

The mix with a combination of 15% FA and 10% ALC replacement of cement showed the maximum strength when compared with other mixes. Hence, the optimum content FA and ALC combination are taken as 25% (combination of 15% FA and 10% ALC) making the concrete Ternary Blended Concrete.

5.1.3. Phase –III Selection of the grade of colloidal NS to be used as an additive

Phase III describes the work for the selection of the type of NS to be used as an additive to the TBC concrete. Four different types of NS with different grades were mixed in TBC at 1% by weight of the binder. The result is graphically illustrated in Fig. 3.

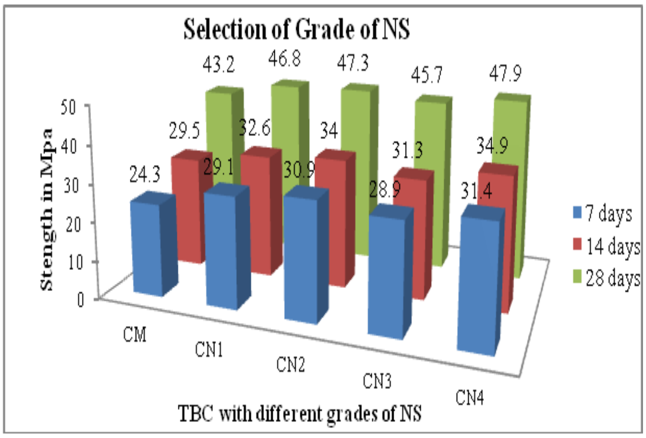

Fig. 3: Graphical Representation of Compressive Strength for Selection of Grade of NS.

The TBC mix with 1% XTXla grade NS had shown the maximum compressive strength when compared with 4 different grades of NS. Hence, the XTXla grade of NS is selected as the suitable additive for TBC.

5.1.4. Phase –IV Selection of optimum dosage of additive to be added in TBC

Phase IV describes the work carried out to find the optimum dosage of NS that can be added to TBC. The XTXla grade NS is added at 1%, 2% and 3% to the TBC and optimum percentage for the additive is evaluated. The result is graphically illustrated in Fig. 4.

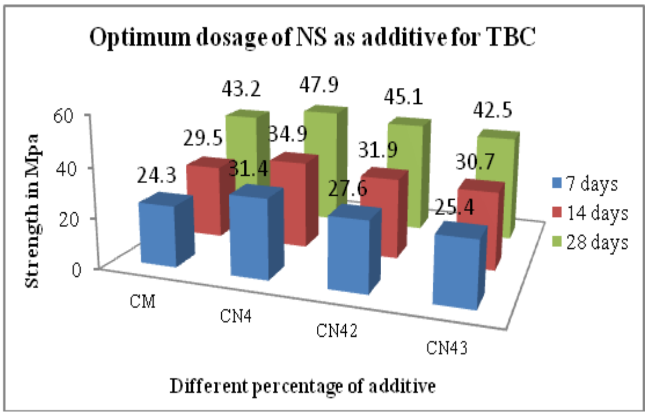

Fig. 4: Graphical Representation of Compressive Strength for Optimum Dosage of NS Additive.

1% XTXla grade NS as an additive for TBC gave the maximum compressive strength when compared with other two percentages of NS. Hence, the 1% XTXla grade NS is selected.

6. Conclusion

Experimental investigation has been done to understand the utilization of Fly ash and Alccofine contributes to the development of high strength TBC. It was observed that all TBC mixes with all four grades of NS sets quickly and also achieved high strength when compared with other blended mixes. The increase in compressive strength is about 20.699%, 18.3050% and 10.8796% for CN4 mix at 7, 14 and 28 days respectively when compared to CM. it was also found that when the XTXla NS percentage was increased to 2%, 3% as additive compressive strength reduced considerably. The total replacement of cement by 25% (FA 15% and ALC 10%) brings about reduction in cost resulting in economy. Furthermore the reduction in cement leads to sustainability, since there is reduction in CO_2 emission in cement manufacture.

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