

EFFECT OF NANO SILICA ON RESISTANCE TO DRYING SHRINKAGE IN TETRANARY BLENDED CONCRETE

Abstract

The primary raw material used in the construction sector is cement. Cement is extensively manufactured and a significant contributor to carbon-dioxide (CO₂) emissions as a result of the worldwide constantly growing infrastructure demands [1,8,10]. Efforts are being made to utilize industrial pozzolanic by-products that may enhance concrete properties. For the purpose of the inquiry, high-strength and long-lasting concrete compositions are created using mineral additions such fly ash, alccofine, and nano-silica [11,12,14,21]. An investigation was carried out on the M30 and M60 concrete grades in order to find resistance to drying shrinkage when cement was replaced in part with a combination of 25% fly ash, 10% alccofine, and 0.5, 1, 2, and 3% nano silica. In comparison to conventional concrete, the combination of fly ash, alccofine, and nano-silica had the lowest value of drying shrinkage among all concrete mixes for both grades at all test ages.

Keywords: Fly ash, Alccofine, Nano Silica, Drying shrinkage, Tetranary Blended Concrete.

Author

Dr. Avuthu Narender Reddy
Assistant Professor
Department of Civil Engineering
School of Engineering, Guru Nanak
Institutions Technical Campus
Hyderabad, Telangana, India.
avuthunarender05@gmail.com

I. INTRODUCTION

In concrete manufacturing, Ordinary Portland Cement (OPC) is used widely throughout the world due to its easy operation and availability [1,8,10]. A large amount of lime is consumed and a large amount of greenhouse gases were released into the atmosphere, which becomes the critical ecological problem [6,7,9]. The global contribution of greenhouse gases released from the cement industries into the atmosphere is approximately 6-8% of the total emission [11,12]. Therefore, alternative materials should be identified to replace OPC, which will reduce the impact on the environment. The solid waste generated from various industries is creating an impairment to the environment due to air pollution, land filings and also pollutes the groundwater by leachate [13,14]. The solution to the problem is by proper utilization of the industrial by-products also called as supplementary cementations materials in concrete. Industrial by-products having pozzolanic properties, such as fly ash (FA), rice husk ash, red mud, ground granulated blast furnace slag (GGBS), alccofine (AL), and others, may be used in combination as a replacement material for cement without impacting the performance of the concrete [1,8,14,20,21]. Nanoparticles have recently become more popular in the building industry because they have a larger specific surface area. Nano-silica (CNS), which has a high pozzolanic nature among all nanomaterials, can significantly improve the mechanical and physical characteristics of concrete [11,14,20,21]. The greenhouse gas emissions produced during cement production will be reduced if the industrial by-products are used instead of OPC in concrete [20,21].

In the present investigation, Tetranary Blended Concrete (TTBC) is developed by replacing cement with a combination of fly ash, alccofine and nano silica. Since it is a relatively new type of concrete, there will be a need for wide range of experimental studies to evaluate this type of concrete. One of the important study is to asses the shrinkage behaviour, which is an important long term effect on the concrete. The present investigation was carried out to evaluate the drying shrinkage behaviour of TTBC by replacing cement in the combination of FA 25%, AL 10% and various percentages (0%, 0.5%, 1%, 2% and 3%) of CNS.

II. MATERIALS AND METHODOLOGY

1. Materials: 53 Grade Ordinary Portland cement (OPC) conforming to the IS specifications 12269-2013[16], having a finesses of 6.5%, specific gravity of 3.12, initial setting time of 50 min, final setting time of 420 min, soundness of 1.2 mm, the specific surface area of $290\text{m}^2/\text{kg}$ is used in concrete in the entire investigation. Low calcium fly ah (FA) (Class F type) with a specific gravity of 2.3 and fineness modulus 1.19% have been obtained from NTPPS - IBPM, confirming to IS 3812-2013 [18] was used in the entire study. Alccofine (AL) -1203 was obtained from Counto Microfine Products Pvt. Ltd., Goa with a specific gravity of 2.9 confirming ASTM C989-1999 [3] was used throughout the investigation. AL is a specially formulated material based on high glass content slag with high reactivity obtained by the controlled granulation process. Alccofine had a strength-gaining ability at early ages compared to conventional cement, as it is rich in alumina content and silica content. The major advantage of the usage of Alccofine with reduced water demand that enhances the workability of concrete during site operation and improvement of strength and durability properties. Nano-Silica (CNS) used in our study was acquired from Beechems Pvt limited, Kanpur. It is liquid-based silica with a

nanometric particle size of 10-20 nm, a purity of 99.8% and a specific gravity of 1.21. River sand passing through a 4.75mm sieve confirming to IS 383-2016 [17], which has a specific gravity of 2.6 and a fineness modulus of 2.71% was used as fine aggregates. Locally available crushed stone passing through a 20mm sieve and retained on 4.75 mm sieve confirming IS 383-2016 [17], which has a specific gravity of 2.7 and a fineness modulus of 7.2% was used as coarse aggregates. The tap water available in our campus was used for the preparation of the concrete mix in accordance with IS 456-2000 [19] recommendations. The high-performance polycarboxylic ether based superplasticizer confirming ASTM C 494 – 2017 [2], was used as for the entire investigation.

- 2. Mix Design:** This research aims to examine the effect of the combination of FA, AL, and NS in concrete mixtures of M30 and M60 grade representing medium and high-performance concrete. M30 and M60 grade of mix designs were prepared as per the guidelines given in IS: 10262-2009 [15] and ACI 211.4R[4] respectively. The design mix proportion 1:2.06:3.63 with w/c ratio 0.43 was adopted for the casting of M30 grade of concrete and for M60 grade the design mix proportion 1:1.6:2.19 with w/c ratio 0.30 was adopted. The details of mix proportions of M30 and M60 grades are as shown in the table below.

Table 1: Mix Proportion Details

GC	MN	OPC (kg/m ³)	FA (kg/m ³)	AL (kg/m ³)	NS (kg/m ³)	Fine Aggregate (kg/m ³)	Coarse Aggregate (kg/m ³)	Water (kg/m ³)
M30	30CM	350.2	-	-	-	721.5	1273.8	150.5
	30N0	236.4	87.5	26.3	-	721.5	1273.8	150.5
	30N1	235.2	87.5	26.3	1.2	721.5	1273.8	150.5
	30N2	234.06	87.5	26.3	2.3	721.5	1273.8	150.5
	30N3	231.7	87.5	26.3	4.7	721.5	1273.8	150.5
	30N4	229.3	87.5	26.3	7.1	721.5	1273.8	150.5
M60	60CM	540.1	-	-	-	625.5	1180.8	162.03
	60N0	364.5	135.02	40.5	-	625.5	1180.8	162.03
	60N1	362.7	135.02	40.5	1.8	625.5	1180.8	162.03
	60N2	360.9	135.02	40.5	3.6	625.5	1180.8	162.03
	60N3	357.3	135.02	40.5	7.3	625.5	1180.8	162.03
	60N4	353.7	135.02	40.5	10.9	625.5	1180.8	162.03

- 3. Methodology:** Initially, admixtures such as fly Ash and alccofine are to be mixed well in order to mix it with cement evenly. The fine aggregate is to be added followed by the coarse aggregate dry mixed with the hand for about 3 minutes. Then the half volume of the water is to be mixed with nano-silica and was then added to the batch mixer. After a minute remaining half volume of the water mixed with superplasticizer is added to the batch mixer. It is thoroughly ground for about ten minutes in the mixer to obtain a uniform colour. The fresh concrete mix was poured into the moulds of 285 x 75 x 75 mm size and kept in room temperature of 28⁰C and relative humidity of 78%. It is then demoulded after 24 hours and kept for curing in freshwater for 7 days. Then they are removed from the water and kept in the open air for drying. The specimens were tested for drying shrinkage at 7, 28, 56, 90 and 180 days. The test was conducted as per ASTM

C 157M -2017[5]. Before spacing the specimen in the setup, the device has to be calibrated with the calibration rod. The test setup is shown in the figure below.



Figure1: Drying Shrinkage Experimental Setup

III. RESULTS AND DISCUSSION

Shrinkage occurs due to the loss of water retained in gel pores of the concrete [14]. The loss of free water in hardened concrete does not result in any major change in the dimension. The shrinkage is generally defined by a reduction in length expressed in micro strains ($\times 10^{-6}$). This section presents the results obtained for TTBC mixes in comparison with the control mix.

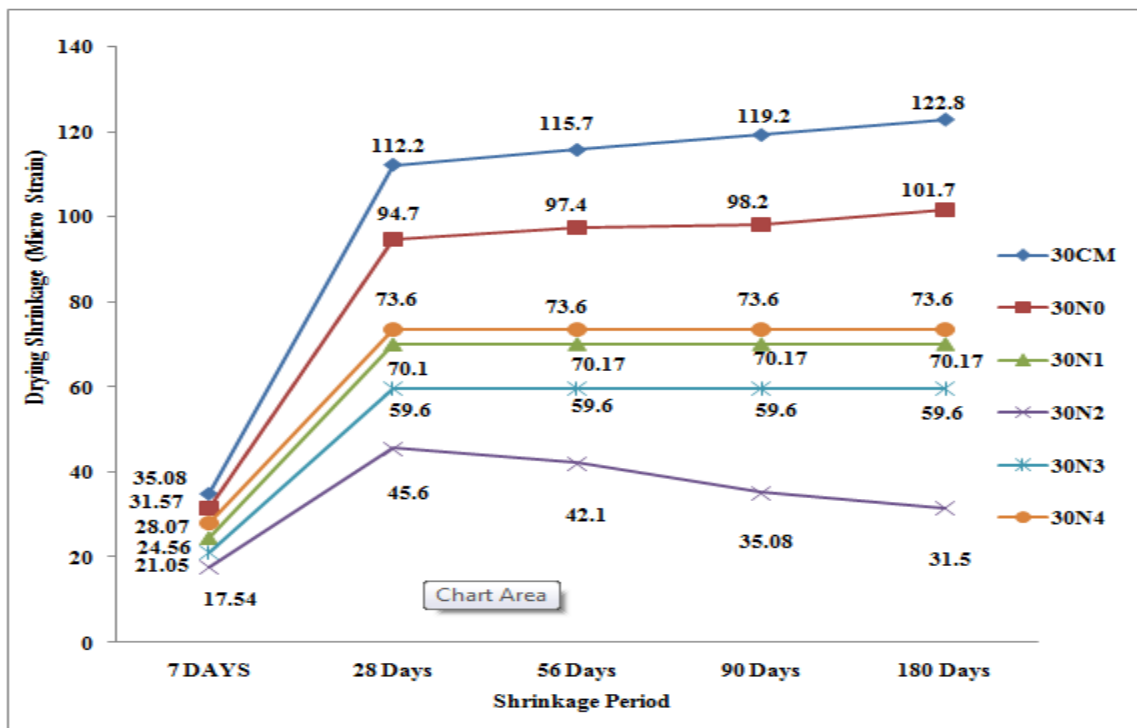


Figure 2: Graphical Representation of Resistance to Drying Shrinkage for M30 Grade of Concrete

From the figures 2 and 3, it can be seen the drying shrinkage increased with the age i.e., from 7 to 180 days. This may be due to the self-desiccation and water diffusion to the outside of the matrix. The drying shrinkage decreased about 10%, 29.9%, 49.9%, 40% and 19.9% for N0, N1, N2 and N3 mixes when compared with the control mix for M30 grade of concrete for 7 days period. Whereas for M60 grade of concrete, drying shrinkage decreased about 16.6%, 33.3%, 50%, 50% and 33.3% for N0, N1, N2 and N3 mixes when compared with the control mix for 7 days period.

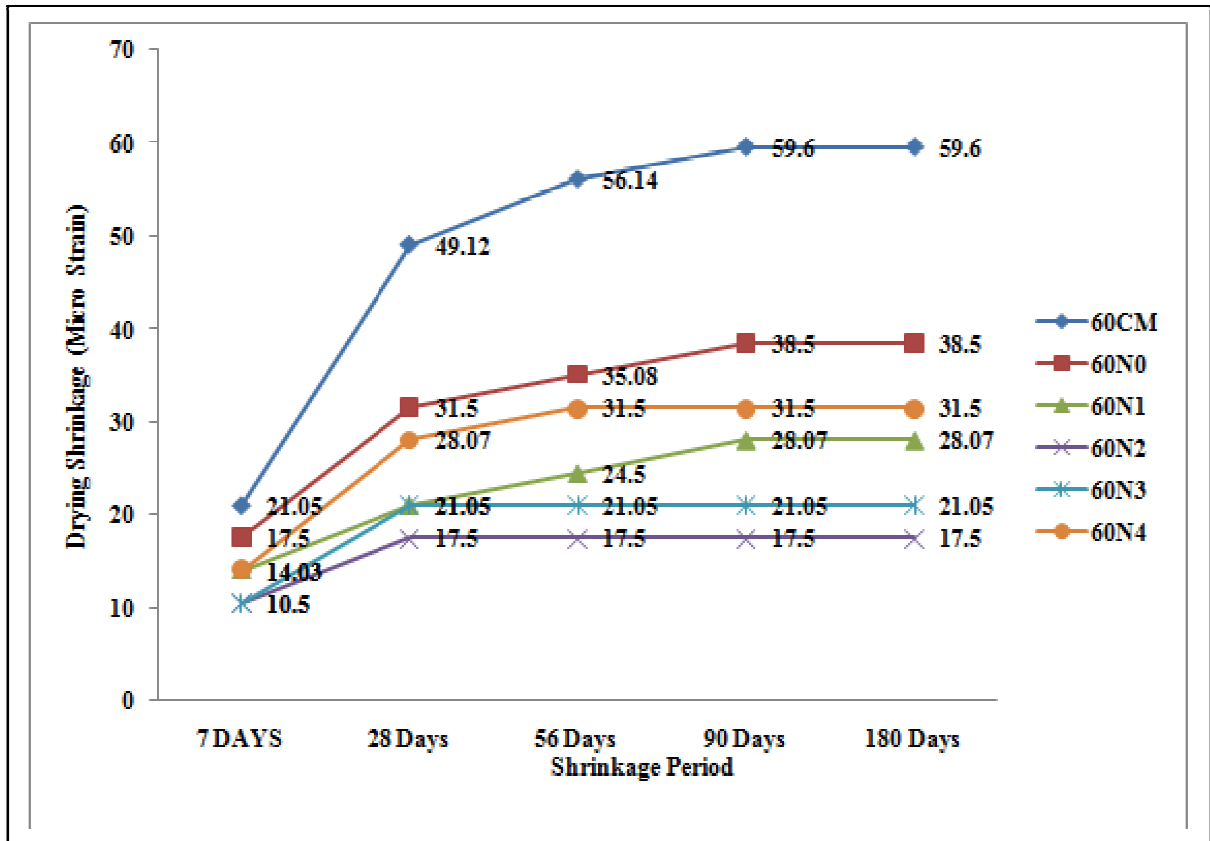


Figure 3: Graphical Representation of Resistance to Drying Shrinkage for M60 Grade of Concrete

The high resistance to drying shrinkage for the mixes may be due to the huge superficial area of nano-silica which acts as an activator to improve the hydration process, resulting in improvement of shrinkage resistance at early ages. For 28, 56, 90 and 180 days the drying shrinkage resistance For N0 mix is about 15.6%, 15.8%, 17.6%, 17.1% for M30 grade and 35.7%, 37.5%, 35.2%, 35.2% for M60 grade of concrete for 28, 56, 90 and 180 days. For N1 mix the drying shrinkage resistance is about 37.5%, 39.3%, 41.1% and 42.8% for 28, 56, 90 and 180 days for M30 grade of concrete and 57.1%, 56.2%, 52.9% and 52.9% for 28, 56, 90 and 180 days for M60 grade of concrete. For N2 mix the drying shrinkage resistance is about 59.3%, 63.6%, 70.5% and 74.2% for 28, 56, 90 and 180 days for M30 grade of concrete and for M60 grade it was 64.2%, 68.7%, 70.5% and 70.5% for 28, 56, 90 and 180 days. For N3 mix the resistance is about 46.8%, 48.4%, 49.9% and 51.4% for M30 grade of concrete at 28, 56, 90 and 180 days and 57.1%, 62.5%, 64.7% and 64.7% for M60

grade of concrete at 28, 56, 90 and 180 days. For N4 mix the resistance was 34.3%, 36.3%, 38.2% and 40% for 28, 56, 90 and 180 days for M30 grade of concrete and for M60 grade it was 42.8%, 43.7%, 47.05% and 47.05% for M60 grade of concrete at 28, 56, 90 and 180 days.

From the result it is seen that the addition of nano silica reduced the drying shrinkage. The shrinkage increases consistently from 7 days to 28 days for all the mixes and after 28 days the shrinkage value normalizes and shows very slight increase for all the mixes [14,20,21]. It was seen that all TTBC mixes showed higher resistance to shrinkage compared to control concrete for both M30 and M60 grades of concrete. Therefore, it can be concluded that the high resistance to shrinkage of TTBC at all the ages is exhibited due to the mineral admixtures (FA, AL and NS). They not only function as a filler for increasing the density of concrete, but also act as an activator for the hydration process.

IV. CONCLUSION

The results suggest the combination of mineral admixtures as a partial replacement for cement improves the concrete's shrinkage property. For both M30 and M60 grade concrete, the N2 mix containing 25% FA, 10% AL, and 1% NS had the lowest shrinkage value of all the mixtures. The decrease in resistance to shrinkage above 1% NS content is due to the fact that the quality of NS particles in the hydration process is greater than the quantity of lime produced, resulting in the leaching of excess silica, which leads to the formation of pores and a reduction in the effectiveness of pore bonding. However, the combination of FA, AL, and NS exhibited improved resistance to drying shrinkage in all employed cases for both M30 and M60 concrete grades. The use of this combination of admixtures (FA, AL, and NS) in concrete as a substitute for cement produces concrete that is environmentally friendly and sustainable.

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