Influence of Nano Silica as Additive in Concrete

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Abstract*: Nanotechnology provides an impact on construction materials with new properties and produces materials with better performance. The use of nano-silica as one of the innovation in concrete technology has developed very rapidly. Some researches has proved that usage of nano-silica resulted in crack free concrete towards sustainable construction and also resulted in reduced permeability due to the nano-filler effect and pozzalanic effect reactions. This experimental study is to evaluate the effects of nano-silica on Mechanical properties of concrete. Nanoparticles namely nano-silica are incorporated at different proportions by weight of the binder and is tested. Flexural specimens with the optimized dosage of nano silica are tested under half-cyclic loading condition followed by monotonic loading condition. Mechanical properties are determined such as compressive strength and flexural strength through testing the concrete specimens at 28 days in order to derive the influence of nano-silica in concrete. Scanning electron microscopy is utilized to study about the smaller scale structure of the concrete.

Key words: Nano silica, flexure, cement hydration, SEM, EDS.

I. INTRODUCTION

Concrete is very solid mechanically, yet it experiences a few downsides, for example, low elasticity, penetrability to fluid and ensuing erosion of steel support, powerlessness to synthetic assault and low solidness. Since cement is a heterogeneous material, its properties fluctuate broadly from point to indicate due the arbitrary nearness of high quality totals, medium quality mortar and powerless total mortar interfaces even after legitimate blending technique is embraced. When particles are in macro size they obey gravitational law but when the particles are disintegrated at atomic level i.e., nano level, they undergo electrostatic force and quantum effect occurs. Due to this change in physical law, the structures properties changes at stages and promotes the element with high strength and resistance against foreign agents. Therefore, the utilization of nano technology in concrete has many kind of effect in its properties that is by changing the particles measure in its nano level. The properties and procedures at the nano scale characterize the cooperation's that happens among particles and stages at small scale and the impacts of working load and encompassing condition at large scale. The procedure happening at nano scale at last influences the building properties and execution of mass material. As of late, nano technology has pulled in extensive logical enthusiasm because of the new systems of use of particles at nano scale. It is the comprehension of particles and controlling it in dimensional dimension between around 1 and 100 nanometres.

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Because of the uncommon property, for example, high surface to volume proportions, the nano particles have increased more considerations in structural designing field. The nano adjustments of concrete put together materials increment the execution with respect to compressive, elasticity and sturdiness properties. Aside from these, the nano particles additionally change the toughness properties of solid subsequently empowering the solid to oppose substance assaults.

II. MATERIALS AND THEIR PROPERTIES

A. Cement

Ordinary Portland cement of 53 grade affirming to IS 12269, that involves high quality. The evaluation depends on the 28-day compressive quality of the bond mortar (tried according to IS 4031), which for this situation is not under 53 MPa.

Table 1 Properties of Cement

TEST	RESULT	AS PER IS STANDARDS
Consistency	32%	25%-30%
Initial setting time	40 minutes	≥ 30 minutes
Final setting time	275 minutes	≤ 600 minutes
Relative density	3.15	2.5 – 3.1

B. Fine Aggregate

The material which passes through IS sieve no.4.75 mm are considered as fine aggregate. Usually, natural river sand is used as fine aggregate. However, in this experiment we have used M-sand as fine aggregate whose relative density is 2.6.

Table 2 Properties of Fine Aggregate

TEST	VALUE	AS PER IS STANDARDS
Relative density	2.6	2.6-2.8
Fineness Modulus	2.90	2.2-3.2

C. Coarse aggregate:

In this experiment, the aggregate used is of 20mm size and are tested as per IS 2386-1963(I, II, III) specification. The Relative density of the aggregate of size 20mm was found out to be 2.75.

Table 3 Properties of Coarse Aggregate

TEST	VALUE	AS PER IS STANDARDS
Relative density	2.75	2.6-2.85
Fineness modulus	7.5	6.5-8

D. Nano silica:

Nano silica is an ingredient, which is incorporated in concrete. The physical and chemical properties of nano silica are listed in table. Due to its nano size, it changes the concrete properties. At a point when pozzalanic materials are mixed to concrete, the silica present in these materials undergoes chemical reaction with the calcium hydroxide discharged amid the hydration of cement and forms extra calcium silicate hydrate, which improves durability and the strength of cement.

Table 4 Physical Properties:

PARAMETERS	DESCRIPTION
Color	White
Appearance	Powder
Particle Size	17mm
Specific gravity	2.3
Specific surface area	202 m^2/g
pH	4.12

Table 5 Chemical Properties:

CONSITUENT	PERCENTAGE
SiO^2	99.5 (%)
$AL2O^3$	0.005 (%)
Fe^2O^3	0.001 (%)
TiO^2	0.004 (%)

E. Admixtures

Conplast SP430 (G) is used to maintain the workability of the concrete as Nano silica absorbs water content during hydration process which mixing.

III. EXPERIMENTAL INVESTIGATION:

The experiment is done by modifying the concrete using Nano silica at various dosages (2.5%, 3.5%, and 4.5%) and the optimum dosage is derived out and for that Nano silica dosages, beam specimens are casted for flexural strength test. The water content was maintained at 0.4. The beam specimen is loading with monotonic loading condition and half-cyclic loading condition. The test results are contrasted with conventional specimen with same grade of concrete (M_{30})

Fig. 1 Compression Test Setup

Fig. 2 Flexure specimen Test setup

Fig. 3 Crack Pattern (Front)

The specimens of standard cubes of dimensions 150 mm x 150 mm x 150 mm and beams of dimension 150 mm x 150 mm x 1000 mm were cast with various dosage of Nano Silica. CTM was used to test 7^{th} and 14^{th} day compressive strength. The Flexural strength of the beam is tested on 28^{th} day from the date of casting and its deflections are noted and plotted in accordance with the load taken. The strain and deflections are noted for every 4kN load interval.

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Fig. 4 Crack Pattern (Back)

IV. RESULTS AND DISCUSSIONS:

A. Compressive strength test:

The optimum nano-silica dosage was found by testing the cubes. It was found that the compressive strength of the concrete containing Nano silica was greater at 2.5% in weight with cement, beyond which the concrete started to lose its strength. Hence, from the compression test the concrete of grade M_{30} with nano silica of 2.5% with compressive strength of 33.5 N/mm^2 at 7th day is optimum.

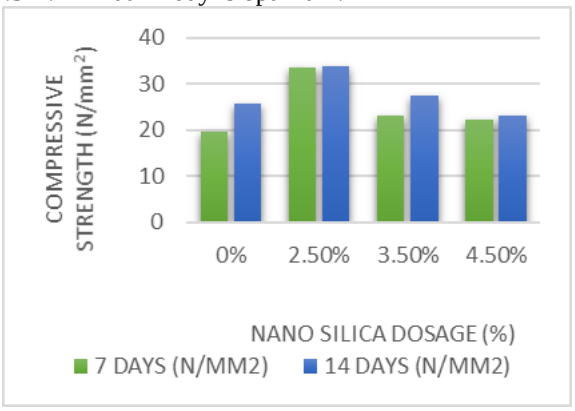

Fig. 5 Compressive Strength

B. Flexural strength test:

1000 x 150 x 150 mm under two point loading system with supports maintained as simply supported. The beam specimen is casted by incorporating nano silica of 2.5% with respect to binder content. The load is incremented by 4kN and corresponding deflection and strain is recorded. The beam specimen is loaded under half-cyclic loading condition followed by monotonic loading condition. The flexural test is executed on the specimen of dimension

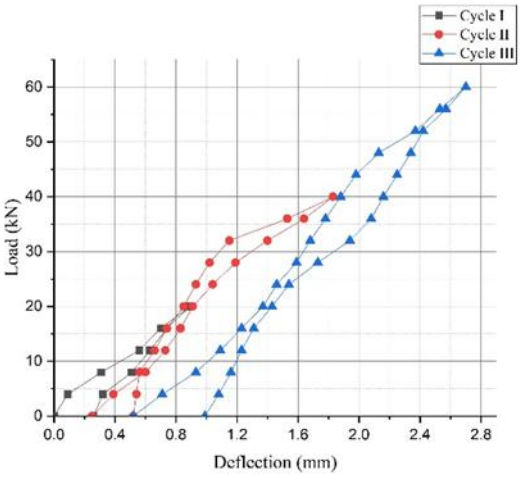

Fig. 6 Load vs Deflection (Half-Cyclic)

The figure 06 shows that the nano silica incorporated beam under gone 3 cycles under half-cyclic loading condition with maximum deflection of 2.7mm in cycle III at 60kN. The first crack formed in cycle III at 28kN proves the specimens mechanical strength due to the filling of pores at nano level by nano silica. Further undergoing half-cyclic loading, the specimen is loaded with uniform load at an interval of 4kN.

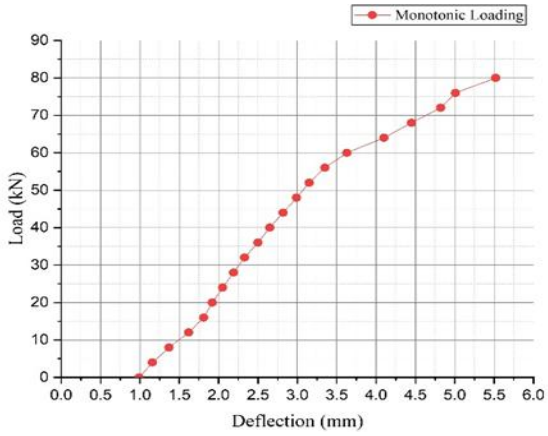

Fig. 7 Load vs Deflection

From the experiments, we know that concrete collapses under loading and unloading weight continuously. Figure 07 shows the load vs deflection, under monotonic loading in the specimen that undergone half cyclic loading which explains the ductility property of nano silica incorporated beam.

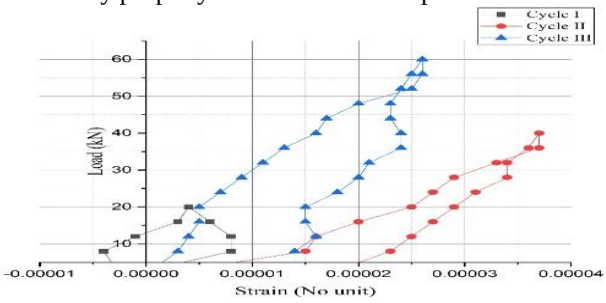

Fig. 8 Load vs Compression zone strain

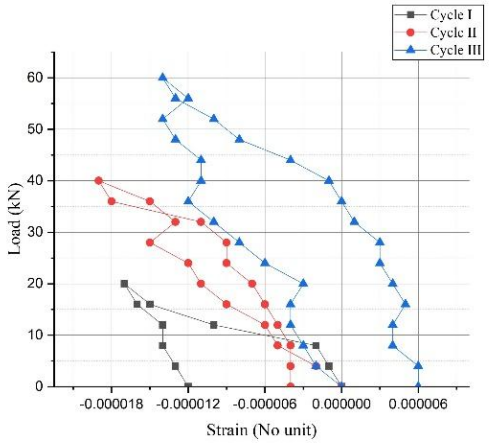

Fig. 9 Load vs Tension zone strain

C. Scanning Electron Microscope Results:

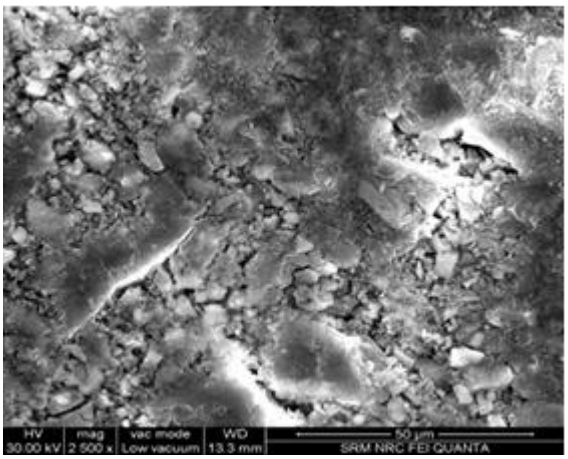

Fig. 10 Nano silica (SEM)

A scanning electron microscope (SEM) instrument is a kind of electron magnifying instrument that produce images of a sample by examining it with an engaged light emission. The electrons cooperate with particles in the sample, delivering different signs that contain data about the sample's surface geology and structure. SEM can accomplish goals superior to 1 nano meter. The samples can be seen in high vacuum, in low vacuum, in wet conditions and at a wide scope of cryogenic or raised temperatures. The composition from SEM shows the formation of C-S-H that helps in increasing the tightness of concrete resulting in stable structural element. The SEM analysis proves that nano silica blocked the pores and reduced the formation of $CaOH_2$ compound among the hydrates. This mechanism explains the high class mechanical strength performance of the cement mortars with the nano silica.

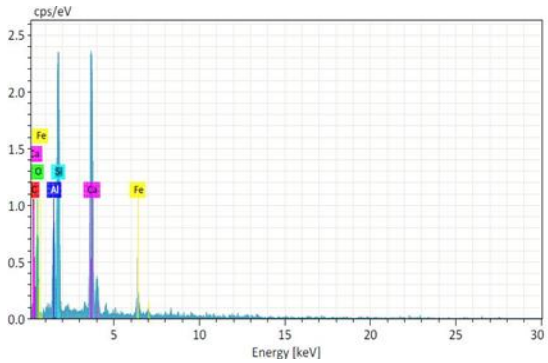

Fig. 11 NS Concrete Composition (EDS)

V. CONCLUSION

From the experimental investigations the following results were concluded,

1. The above result data's portrays that the impact of nano silica alongside cement and concrete bring significant development in the properties of penetrability, pore-filling impacts, and small-scale structure investigation. Overall, the whole survey demonstrated the final proposal in utilizing the Nano innovation as in general and Nano silica specifically.
2. The 7^{th} day and 14^{th} day compressive strength of nano silica incorporated cubes proves the early gaining of strength using nano silica at 2.5% in weight with respect to cement weight. Beyond which the concrete started to lose its compressive strength.
3. The cracks originated from the support edges and propagated towards centre in a definite pattern, which proves shear failure.
4. Even after three consecutive half cyclic loading, the beam underwent monotonic loading with an ultimate load of 80Kn and deflection of 5.5mm, which explains the influence of nano silica in concrete.

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