EFFECTS OF NANO-SILICA ON MECHANICAL & DURABILITY PROPERTIES OF CEMENT-SAND MORTAR

Abstract

Due to their distinct physical and chemical characteristics, nanoparticles are receiving more and more attention and are being used in numerous disciplines to produce new materials with novel functionality. In the current investigation, regular Portland cement was used to partially substitute nano silica (NS) (OPC). The replacement level was blended into cement mortar with a water binder ratio of 0.43 and a consistency of 28%, and it ranged from 0.5% to 2.0% in OPC. Studies on mechanical properties and durability tests, such as compressive strength and water absorption tests. The findings show that the plain cement-sand mortar with the same water cement ratio had a lower compressive strength than the cement mortars containing nanomaterials. With replacement, nano silica particles between 0.2 and 0.3 microns have been employed.

Keywords: Motor Specimens, Materials, Casting, Curing, Compressive Strength, Water Absorption, Mechanical Properties, Durability Properties.

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I. INTRODUCTION

Mortar is a useful glue made from calcium hydroxide and different fixings used to tie development hinders together and fill the holes between them. The blocks may be stone, block, ash blocks and so forth. Mortar turns out to be hard when it sets, coming about in an unbending total construction. Present day mortars are ordinarily produced using a combination of sand, a fastener like lime (and at times concrete) and water. Mortar can likewise be utilized to fix, or point, workmanship when the first mortar has washed away. Initially, lime mortars were utilized. Concrete mortar composite has wide application in workmanship work, putting, fixing harmed cement, fixing or filling, delivering, floor evening out, and the advancement of precast items. The composite is made out of cover, sand, water, and strands with a most extreme size of fine-grain material of 2 mm. The cover might be concrete, mineral admixtures of fly debris, ground granulated impact heater slag (GGBFS), rice husk debris, and so on, with polymeric or substance admixtures utilized relying upon the application. Normal and fake filaments are utilized to support the framework for further developed pliability, durability, flexural strength, exhaustion obstruction, and effect opposition. These filaments are likewise valuable to decrease the dying, shrinkage, and porousness of the lattice in its new stage. However, notwithstanding the advantages of involving supporting strands in the grid, it is hard to work in a new state, which at last influences the strength and solidness qualities of the concrete mortar composite. Consequently, to use the fiber support really, the new state properties of the composite materials should be examined, with the goal that it is not difficult to handle in the new state without influencing the strength and sturdiness.

1. **Nano-Silica Particles:** The addition of NS in concrete and mortar leads to more Efficient cement hydration. This also helps to reduce the Requirement for cement. NS improves the microstructure and Reduces the water permeability. Mortar with Strengths up to 50MPa can be produced with high Workability, properties and a short de-Molding time. A reaction between cement and water Produces calcium silicate hydrate, which gives mortar compressive strength and other mechanical and durability properties, as well as Certain including calcium hydroxide. The use of nano silica as one of the innovations in concrete technology has developed very rapidly. Some research mentioned that nanosilica obtained from the synthesis process silica sand is a type of material that is as pozzolana when added to the cement-sand mortar, so as to accelerate the hydration process in mortar.

Figure 1: Picture of Nano Silica

2. Chemical Composition

Table 1: Chemical Composition of Nano Silica

S.NO.	Contents	%
1.	Silicon dioxide, SiO_2	94.3
2.	Aluminum oxide, Al_2O_3	0.06
3.	Ferric oxide, Fe_2O_3	0.46
4.	Calcium oxide, CaO	0.51
5.	Titania	2.31
6.	Loss on Ignition	2.25

II. METHODOLOGY

1. To determine the compressive strength of cement mortar using Nano-silica (SiO2) by making cubes of size 70.7mm × 70.7mm × 70.7mm.
2. To determine the water absorption of cement sand mortar using Nano-silica(SiO2) by making cylinders of size 70.7mm × 70.7mm × 70.7mm.
3. To determine the sorptivity test of cement sand mortar using Nano-silica(SiO2) by making cylinders of size 50mm dia and 100mm height.

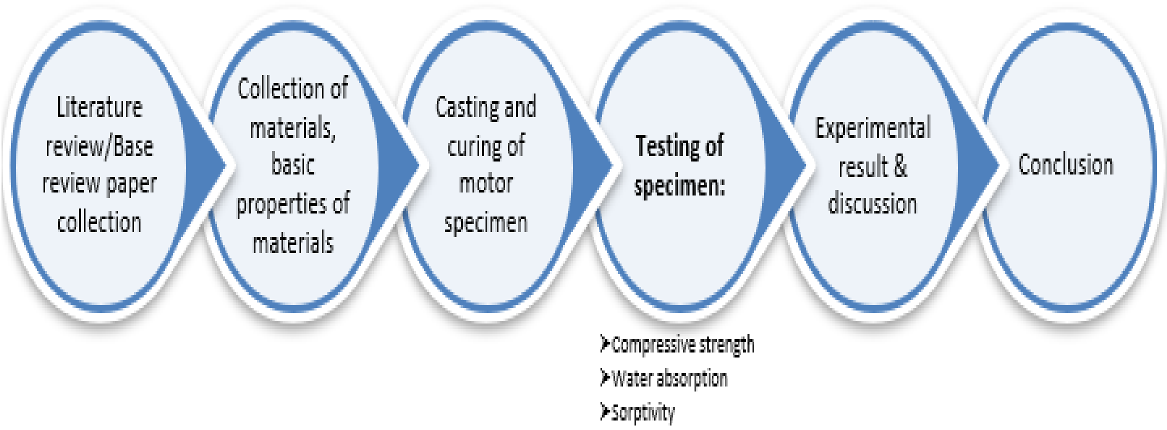

Figure 2: Methodology of the Research

Literature review, focusing on material collection and their basic properties for motor specimens. The study includes the meticulous casting and curing process of the specimens. Subsequently, tests for compressive strength, water absorption, and sorptivity are conducted. The experimental results are discussed, providing valuable insights into the mechanical behavior and durability of motor specimens. The conclusion highlights the significance of the study for advancing motor construction practices.

III. LITERATURE REVIEW

The effects of nano-silica on the mechanical and durability properties of cement-sand mortar have been a subject of growing interest in the construction industry. To understand the context of this research, it is essential to review previous works in this area. Several researchers have investigated performance measurement indicators and key performance indicators (KPIs) for construction industry projects. Yi et al. [1] conducted a critical review of performance measurement indicators for the construction industry, while Akhavan and Akhavan [2] focused on the identification and selection of KPIs for construction projects in Iran. Chan [3] and Abdelhamid [4] examined KPIs for measuring construction success and performance in construction projects, respectively. Moreover, Elbeltagi [5] explored risk assessment and allocation in the UAE construction industry, and Aziz [6] emphasized the importance of performance measurement in construction. Chen [7] and Shen [8] delved into key performance indicators for measuring construction project performance and proposed a construction performance excellence framework, respectively. Abdelhamid [9] identified KPIs for construction projects, while Asokan [10] measured the impact of information sharing on construction project performance. Alarcon [11] highlighted the significance of KPIs in construction project management, and Zou [12] examined the relationships among stakeholder collaboration, trust, and construction project performance. Furthermore, Zhang [13] focused on critical success factors for implementing green construction in China, and Yazici [14] investigated cost and schedule control systems criteria for success on international projects. Thomas [15] provided insights into measuring performance in construction, while Sohail [16] proposed a performance measurement framework for construction projects. Akintoye [17] surveyed construction project managers' perceptions of the benefits of building information modeling. Iqbal [18] reviewed KPIs for measuring construction project performance. Studies by Chan [19] and Guo [20] developed performance measurement frameworks for construction companies. Talib et al. [21] studied construction project performance measurement systems, and Chen [22] identified critical factors affecting schedule performance of highway construction projects. Flyvbjerg et al. [24] investigated the accuracy of demand forecasts in public works projects. Hwang [25] explored project management knowledge and skills for green construction. Koushki [26] identified factors affecting construction labor productivity, and Lee [27] performed a comparative analysis of quality management practices in construction projects among Korea, Japan, and Taiwan. Koskela [28] argued that the underlying theory of project management is obsolete. Among other relevant works, Zhang and Hu [29] examined critical success factors for implementing green construction in China, and Al-Bahar [30] investigated factors affecting construction labor productivity. Choudhry [31] explored the reasons behind unsafe work behavior on construction sites. Fong [32] studied the effects of lean construction on project performance, while Li [33] assessed the effect of risk management on construction project performance in China. Goh [34] discussed performance measurement in construction supply chains, and Ibrahim [35] proposed KPIs for measuring construction project success in Egypt. Ke [36] studied the performance measurement for construction firms and the impact of diversification strategy. Ling [37] researched KPIs for construction project success in Singapore, and Liu [38] identified and assessed KPIs for mega construction projects in China. Choudhry [39] delved into KPIs for construction processes, and Kamaruzzaman [40] discussed KPIs for sustainable building assessment. Additionally, Bharath [41] developed a framework for economically improving the quality of construction processes through Six Sigma. Other researchers, like Bharath [45], have focused on economically improving the quality of construction using Six Sigma and cost-benefit analysis. Lokeshwaran [43] and Srinivasan [44] addressed the causes and mitigation strategies of delay in construction projects and the development of a project performance measurement strategy for construction projects, respectively. In conclusion, previous research has provided valuable insights into performance measurement indicators, KPIs, risk assessment, green construction, labor productivity, quality management, and other relevant factors in construction projects. However, limited work has specifically examined the effects of nano-silica on the mechanical and durability properties of cement-sand mortar. Therefore, this present study aims to fill this gap and contribute to the understanding of the potential benefits of using nano-silica in construction materials, particularly cement-sand mortar, and its impact on mechanical and durability properties, thus providing valuable information to the construction industry and researchers in this field.

IV. EXPERIMENTAL RESULTS

1. Material Properties

Specific Gravity of Fine Aggregate

Weight of the empty pycnometer (w1) = 601g
Weight of sample + pycnometer (w2) = 1163g
Weight of sample + water + pycnometer(w3) = 1883g
Weight of water + pycnometer (w4) = 1462g

2. Sieve Analysis on Fine Aggregate

Table 2: Sieve Analysis on Fine Aggregate

Diameter (mm)	Soil Retained (g)	Cumulative Weight Retained
4.75	0	0
2.36	15.0	1.5
1.18	230.0	24.5
0.60	410.0	65.5
0.30	193.0	85.0
0.15	130.0	98.2
0.075	20.0	100.2
Pan	2.0	100.4
Total	**1000**	**274.7**

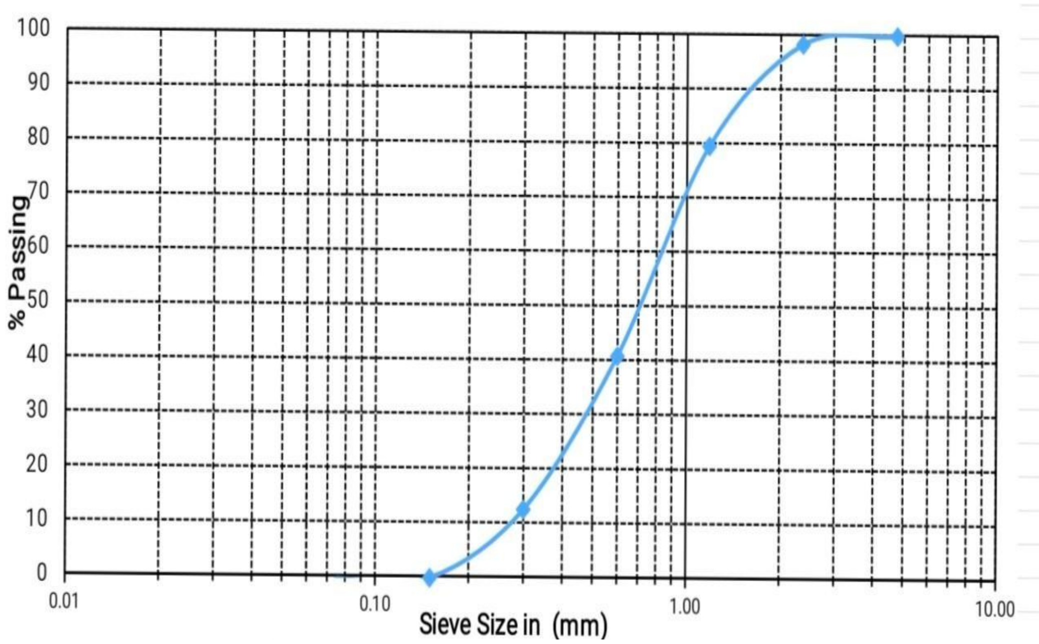

Figure 3: Seive Analysis of River Sand Conforming to Grading Zone II of Table 4 Of IS 383 Fineness Modulus=2.75

3. Test on Cement

- Using vicat apparatus: Consistency = 28%
- Initial setting time = 35 mins

4. Mix Proportion

- The binder content was taken as the sum of cement and nanoparticles. Fresh mortars were prepared with cement/sand weight ratio (C/S) of 1:3 and W/B is 0.43
- All mortars were prepared with the same W/B ratio and produced with 0%, 0.5%,1%,1.5% and 2% Nano-SiO2 in weight, replacing cement.
- The amount of water incorporated with Nano-SiO2 was taken into account by reducing the nominal content of water added to the preparation of the mortar.
- These compositions are shown in Table 4

Table 3: Mix Proportion

Nano-SiO_2 (wt%)	W/B Ratio	MIXTURE COMPONENTS			
		Water(ml)	Cement(g)	Sand(g)	Nano-SiO_2(g)
0	0.43	1260	3150	9450	0
0.5	0.43	1260	3134.25	9450	15.75
1	0.43	1260	3118.5	9450	31.5
1.5	0.43	1260	3102.75	9450	47.25
2	0.43	1260	3087	9450	63

V. RESULTS & DISCUSSION

1. **Compressive Strength Test:**The compressive strength test was conducted in a compressive testing machine (CTM) of 200KN capacity. The test was done using cubes of 70.7mm × 70.7mm × 70.7mmsize.. The compressive strength values were nominally increased when increases of nano-silica partial replacement level of weight in cement.

Compressive strength of conventional mortar increases with the addition of Nano silica. The results that are obtained for the compressive strength of Nano silica Cement- Sand mortar at 3days, 7days and 28 days are as shown below**:**

Table 4: Average Compressive Strength of Cement Mortar

S.NO.	Nana Silica%	NO. OF DAYS OF CURING	AVG.COMPRESSIVE STRENGTH OF MORTAR(Mpa)
1.	0%	3days	13.33
		7days	28.01
		28days	43.23
2.	0.5%	3days	18.67
		7days	30.67
		28days	48.33
3.	1%	3days	20.5
		7days	35.01
		28days	48.33
4.	1.5%	3days	25.01
		7days	40.33
		28days	50.85
5.	2%	3days	25.58
		7days	37.88
		28 days	45.58

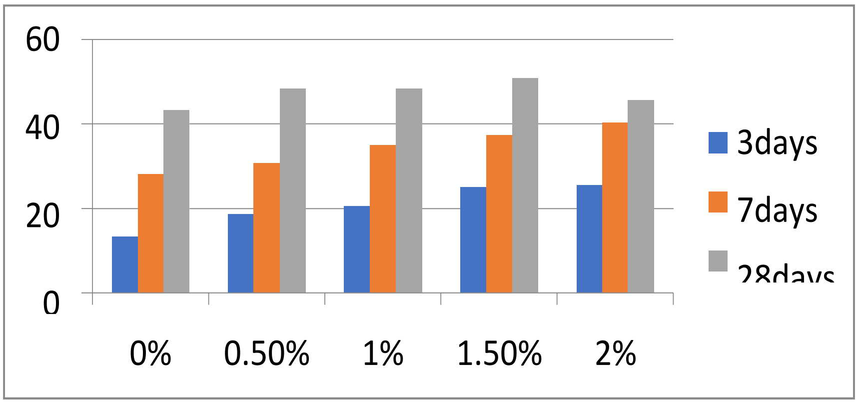

Figure 4: Avg. Compressive Strength of Cement Mortar Having NS.0%,0.5%,1%,1.5%,2%.

- The compressive strength of cement mortar without nano-silica at age of 3days as 13.33Mpa , at the age of 28days the compressive strength as 43.23Mpa.
- In addition of 0.5% of nano-silica at the early age (3days) 40.06% is improved when compared to conventional mortar, At the age 28 days 11.79% is improved when compared to conventional mortar.
- In addition of 1% of nano-silica at the early age (3days) 53.78% is improved when compared to conventional mortar, At the age 28 days 11.79% is improved when compared to conventional mortar.
- In addition of 1.5% of nano-silica at the early age (3days) 87.62% is improved when compared to conventional mortar, At the age 28 days 17.62% is improved when compared to conventional mortar.
- In addition of 2% of nano-silica at the early age (3days) 91.89% is improved when compared to conventional mortar, At the age 28 days 5.43% is improved when compared to conventional mortar.

Table 5: Water Absorption, Wet Density, Dry Density of Cement Mortar Having NS.0%, 0.5%, 1%, 1.5%, 2%.

S.NO.	Nana Silica %	NO. OF DAYS OF CURING	AVG.WATER ABSORPTION (%)	AVG.WT DENSITY (kg/m^3)	AVG.DRYDEN SITY (kg/m^3)
1.	0%	3days	1.775	2211.887	2208.35
		7days	1.650	2219.43	2215.06
		28days	1.70	2211.65	2207.0
2.	0.5%	3days	1.17	2256.21	2255.08
		7days	1.25	2251.5	2248.1
		28days	1.41	2238.46	2234.33
3.	1%	3days	0.755	2266.6	2178.1
		7days	1.05	2259.56	2234
		28days	1.14	2258	2255.06
4.	1.5%	3days	0.89	2262.8	2186.4
		7days	1.1	2255	2239.2
		28days	1.05	2252	2250.21
5.	2%	3days	1.21	2240.45	2238
		7days	1.33	2238.89	2236.65
		28 days	1.45	2235.55	2231.74

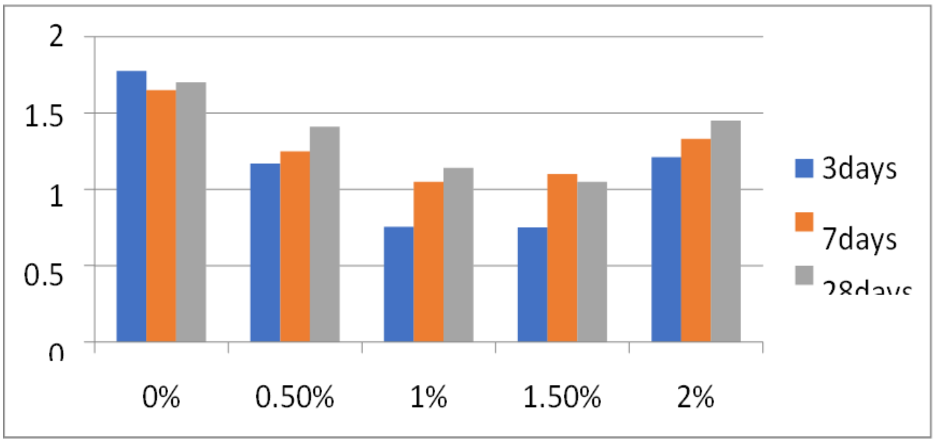

Figure 5: Avg Water Absorption of Cement Mortar Having NS.0%, 0.5% ,1%, 1.5%, 2%.

2. **Sorptivity Test:** The water sorptivity test is a unidirectional absorption test. Capillary water sorptivity defines the tendency of the concrete to absorb water through capillary suction by which ingress of aggressive substances can occur. Sorptivity testing was performed in accordance with ASTM C1585-11. The sorptivity was determined by the measurement of the capillary rise absorption rate on reasonably homogeneous material. Water was used of the test fluid. The specimen size 50mm dia and 100mm height after drying in oven at temperature of100 + 10 °C was drowned with water level not more than 5 mm above the base of specimen. Sorptivity is the property by which water has been absorbed and transmitted by capillary action.

   Sorptivity (S) is calculated by
   S= (Wc-Wd)/(Axδxt0.5) Wd = dry weight of the cylinder in grams
   Wc = weight of the cylinder after capillary suction in grams
   A = surface area of the cylinder exposed to water penetration by capillary action in mm2
   δ = density of water t = time in minutes

Table 6: Sorptivity of Cement Mortar Having NS.0% ,0.5% ,1% ,1.5% ,2%

Composition Of NS%	**No. Of days ofCuring**	**Sorptivity test**		
		Dry weight (gms)	**Wet weight (gms)**	**Sorptivity ×(10)$^{-2}$ (mm/min$^{0.5}$)**
0%	3days	590.4	597.5	3.3009
	7days	601.5	605.9	2.0456
	28days	608.3	612.2	1.8131
0.5%	3days	600.6	605.4	2.2316
	7days	614.5	618.7	1.9526
	28days	621.7	626.6	1.7139
1%	3days	610.9	615.3	1.9456
	7days	619.7	623.3	1.6737

	28days	628.3	631.1	1.3017
1.5%	3days	621.3	624.7	1.9526
	7days	626.5	629.2	1.2552
	28days	632.8	635.3	1.1623
2%	3days	621.3	624.7	1.5342
	7days	625.4	628.7	1.5342
	28days	630.1	634.3	1.7526

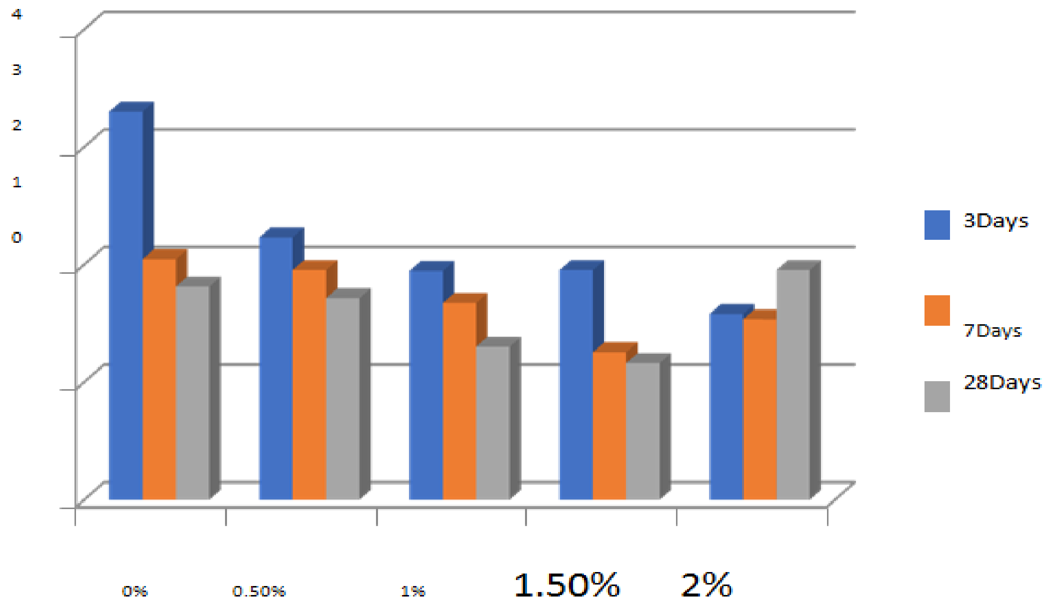

Figure 6: Sorptivity of Cement Mortar Having NS.0% ,0.5% ,1%,1.5% ,2%.

- The sorptivity of cement mortar without nano-silica at age of 3days as 3.3009× 10-2mm/min, at the age of 28days sorptivity value as 1.8131×10-2mm/min.
- In addition of 0.5% of nano-silica at the early age (3days) 47.91% is reduced when compared to conventional mortar, At the age 28 days 5.78% is reduced when compared to conventional mortar.
- In addition of 1% of nano-silica at the early age (3days) 69.66% is reduced when compared to conventional mortar, At the age 28 days 39.28% is reduced when compared to conventional mortar.
- In addition of 1.5% of nano-silica at the early age (3days) 69.05% is reduced when compared to conventional mortar, At the age 28 days 55.99% is reduced when compared to conventional mortar.
- In addition of 2% of nano-silica at the early age (3days) 91.89% is reduced when compared to conventional mortar, At the age 28 days 3.45% is reduced when compared to conventional mortar.

VI. CONCLUSIONS

The following broad conclusions were drawn from the above investigation.

1. Compressive strength of the mortar increases with partially replacement of Nano silica in weight of cement especially at early ages.
2. 1.5% Nano Silica mixgives higher compressive strength compared to the conventional cement mortar mixes. These results indicate that the pozzolanic activity is greaterthan that of other mixes studied.
3. The water absorption tests indicate that the Nano Silicamortar have better permeability resistance than the control mix.
4. The Sorptivity values are low in 1.5% Nano Silica mix.
5. From the above investigation, it is concluded that 1.5% of Nano silica in mortar was found tobe more beneficial and better performance in strength and durability among all other mixes was studied.

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