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Study on Strength Durability and Bond Characteristics of Concrete Containing Nano Silica

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ABSTRACT: Concrete has come a long way since its birth during the Egyptian era. With the help of concrete technology, we have started making concrete that are durable and strong. Concrete, being a porous material, is susceptible to damage by infiltration of harmful substances through its external surface and their advancement through the pore system leading to various durability problems. The passage of water in the pore structure of concrete plays an important role in the deterioration of concrete structure. Durable reinforced concrete is the need of the hour. The financial losses due to the durability problem have made researchers work on ways to make superior and resilient concrete. Several techniques have been developed to assess the residual life time in existing constructions and to evaluate their corrosion resistance capability.

When Nano Silica (NS) is added with the concrete mix, it reacts with free calcium hydroxide, increasing the quantity of calcium silicate hydrate and resulting in a higher densification of the matrix, which increases the strength and durability. This research work is principally concerned with the strength and durability properties of the concrete containing NS and also intends to study the effect of corrosion on the pull-out and flexural bond strength of concrete containing NS.

KEY WORDS: Strength, Nano Technology, Nano-Silica Powder, Nano Silica Concrete, Compressive Strength, Split Tensile Strength.

I. LITERATURE REVIEW

•**J.Bernal, E Rayes, J.Massana, N leon, E sanchez (2018).** "Fresh and Mechanical Behaviour of a self compacting concrete with additions of nano silica, silica fume and ternary mixtures". This paper examines the behaviour of 10 mixtures of SSC prepared with binary and ternary dosages through use of Portland cement, mSi and nSi. A self compacting concrete was designed which used no mineral admixtures, with the rest of the dosages using different percentages.

•**Mojtaba Fathi, Abed Yousefipour, Ehsan Hematpoury Fakheri (2017).** "Mechanical and physical properties of expanded polystyrene structural concretes containing Micro silica and Nano-Silica" In the specimens without EPS beads, replacement of Micro Silica and Nano Silica upto 15 and 3 wt % of cement respectively led to compressive strength increase and water absorption decrease and after that these trends were carried vice versa.

•**Ehasan Ghafari et.al (2014)** "Effect of nano-silica addition on flowability, strength and transport properties of ultra-high performance concrete" Ehasan Ghafari et.al studied the effect of nano-silica addition on flowability, strength and transport properties of ultra-high performance concrete. They concluded that compressive strength of ultra high performance concrete increases with the rise in nano-silica content. The ultra-high performane concrete containing nano-silica is significantly denser and more homogeneous.

Peng-ku Hou et.al (2012) "Effect of colloidal nano-silica on rheological and mechanical properties of fly ash cement mortar" Peng-ku Hou et.al presented study on effect of colloidal nano-silica on rheological and mechanical properties of fly ash-cement mortar. They found that the addition of colloidal nano-silica enhances hardening process of fly ash cement paste. It also increases the viscosity of cement paste. The compressive strength of fly ash cement mortars can be greatly improved.

•**Anwar M. Mohamed et.al (2014)** "Influence of nano materials on flexural behaviour and compressive strength of concrete" Anwar M. Mohamed et.al presented study on Influence of nano materials o flexural behaviour and compressive strength of concrete. Nano-silica on wet condition and nano clay on dry condition have remarkable improvement on compressive strength of high performance concrete. There also appears improvement for flexural strength of concrete due to use of nano particles.

•**Min-Hong Zhang et.al (2011**) "Use of nano-silica to reduce setting time and increase early strength of concretes with high volume of fly as or slag"Min-Hong Zhang et.al presented study on Use of nano-silica to reduce setting time and increase early strength of concretes with high volume of fly as or slag. The results indicate that length of dormant period was shortened and rate of cement sand slag accelerated with 1 percent nano-silica. The nano-silica reduces the setting time and increases the early strength of high volume fly ash or slag.

•**Miguel Angel et.al (2015)** "Effect of silica fume fineness on the improvement of Portland cement strengthperformance" Miguel Angel et.al presented study on effect of silica fume fineness on the improvement of Portland cement strength performance. The partial replacement of Portland cement with 25 percent of silica fume produces high strength mortar and such fineness gives high strength and it can be used to produce high performance concrete.

•**S.T. Lee, Mr. H.Y. Moon and Mr. R.N. Swamys (2003)** "Sulphate attack and role of silica fume in resisting strength loss" This paper presented study on sulphate attack and role of silica fume in resisting strength loss. This study presents a detailed study on the process of deterioration and the formation of reactants by chemical reaction of mortars and pastes without or with SF in sodium and magnesium sulphate solutions.

•**Vimal jyothi (2017)** Volume 4 "An experimental Investigation on strength properties of concrete containing Micro silica and nano silica" This paper conducts the experiment by replacing the cement by mixture of nano silica and silica fume at different percentages. The compressive strength, flexural strength and tensile strength is increases when the percentage of nano silica at 1.5% and percentage of micro silica at 10%.

•**Sakshi Gupta,** concluded that Nanotechnology has the potential to be the key to a brand new world in the field of construction and building materials. The role and application of the nano and micro silica particles with cementitious materials have been reviewed and discussed in details. It is evident from the literatures reviewed that none of the researchers have carried out extensive or comprehensive study of the properties of paste and mortar, with nano silica, micro silica and their simultaneous use. There is a limited knowledge about the mechanisms by which nano silica & micro silica affects the flow properties of cementitious mixes. In India, the research work on use of nano silica is still in elementary stage. Thus, a need arises to study extensively the various properties of paste, mortar, and concrete containing various percentages of nano silica, micro silica alone as partial replacement of cement and then studying their combined percentage effects. As the properties of nanosilica and micro-silica reported in literatures relate with those manufactured or exported from abroad, there is urgent need to study the effect of these materials (manufactured in India) on various properties of cement paste, mortar and concrete. Major parties in the construction materials industry should divert more funds to research work on incorporating nanotechnology in construction materials. Thus, the main motive is to provide practical information, regarding the strength, sustainability & durability properties of nano silica, microsilica and their simultaneous use in paste, mortar and concrete. Also, the aim is to carry out the extensive studies to conceive the general purpose of testing new sustainable building processes and modern production systems, aimed at saving natural raw materials and reducing energy consumption. Taking advantage of nanostructure and microstructure characterization tools and materials, the simultaneous and also separate optimal use of microsilica and nano-silica will create a new concrete mixture that will result in long lasting concrete structures in the future. Thus, there is a gap or room available for further research towards the fruitful application of especially nano-silica for construction with different nano structure characterization tools, which will be enable to understand many mysteries of concrete.

III. MATERIALS AND METODOLOGY

3.1 MATERIALS:

In this experimental study cement, sand, coarse aggregate, water and nano-silica were used. Bulk of each items from their individual source was obtained in one batch is used to eliminate discrepancies and variation in material properties. Whose properties are given below.

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Physical Requirements and Results of OPC

Sr. No.	Characteristic	Test Values	Requirements
1)	Fineness, m^2/kg	268	>225
2)	Normal consistency, %	27	-
3)	Soundness By Le Chatelier method, mm	1.5	<10
4)	Setting Time		
	Initial Set(Minutes)	45	>30
	Final Set(Minutes)	530	<600
5)	Compressive strength(N/mm^2)		
	72 ± 1 h(3 Days)	32	≥27
	168 ± 2 h(7 Days)	43	≥37
	672 ± 4 h(28 Days)	53	≥53
6)	Specific Gravity	3.15	

Physical Characteristics of Coarse Aggregate

Sr. No.	Characteristic	Test Results
1)	Specific gravity	2.77
2)	Shape	Angular
3)	Size of aggregate	20mm
4)	Crushing Value	24
5)	Impact Value	9
6)	Fineness modulus	6.72

Physical Characteristics of Fine Aggregate

Sr. No.	Characteristic	Test Results
1)	Specific gravity	2.65
2)	Fineness modulus	2.81
3)	Type	Limestone

NANO – SILICA:

Nano-silica is typically a highly effective pozzolanic material. It normally consists of very fine vitreous particles approximately 1000 times smaller than the average cement particles. It has permeability. Nano-silica increases Compressive and Split tensile strength. It has proven to be an excellent admixture for cement to improve strength and durability and decrease permeability. Nano-silica increases Compressive and Split tensile strength of resulting cement in relation with other silica components that were tested. Nano-silica is obtained by synthesis of silica sol or by crystallization of Nano-sized crystals of quartz.

3.2 METHODOLOGY

The main aim of this project is to determine experimental investigation on behavior of Nano material with 0.5%, 1%, 1.5% and 2% by weight of cement ratio.

Sample	OPC (kg)	F.A. (kg)	C.A (kg)	NS (kg)	SP (kg)	Water (l)
C0	394.3	638.3	1191	0	0	197
C1	394.3	638.3	1191	1.97	1.77	197
C2	394.3	638.3	1191	3.94	1.97	197
C3	394.3	638.3	1191	5.91	2.37	197
C4	394.3	638.3	1191	7.89	2.96	197

3.3 CONCRETE MIX PROPORTION

The C0 sample mix was taken as the base and NS was added in proportions of 0.5%, 1%, 1.5% and 2% by weight of cement. In these mixtures, water addition was controlled to that of the control mix C0 and the samples with NS were added with superplasticizer (SP) to have a slump value similar to that of C0 sample. All the specimens were water-cured. The details of quantities of ingredients for various samples used in this study are given in Table.

The concrete was mixed in a rotary mixer, because nano-particles are not easy to disperse uniformly due to their high surface area. Mixing was performed as described below: 1. The cement and NS were put in a container and mixed thoroughly at 28 rpm for 3 min. 2. Then sand was added to the mix and mixed at 28 rpm for another 2 min. 3. Coarse aggregate was added to the composite and mixed thoroughly. 4. Water was then added and stirred at 28 rpm for additional 2 min. 5. The super plasticizer was added last and stirred at 28 rpm for additional 60 sec.

3.4 TEST

3.4.1 Consistency

The cement and cement with NS were tested for consistency as per IS 4031 part 4. The test was carried out on six different sample proportions from cement with 0% NS to cement added with 2.5% NS to identify the increase in water demand due to NS.

3.4.2 Slump Test

The fresh concrete was tested for workability by slump test as per IS 1199 : 1959. This test was conducted on sample without NS and then on samples with NS. In samples with NS, the superplasticizer content was increased till the sample attained a slump value approximately equal to that of control concrete.

3.4.3 Compression Strength Test

Compression test was conducted on cubes of size 150 mm made from all the samples of concrete. The test was conducted after 7, 14, 28 and 60 days of curing as per IS 516 : 1959. Test was conducted on three specimens of each sample and the average was taken as the final value.

3.4.4 Split Tensile Strength Test

Split tensile strength test was conducted on cylinders of size 150 mm diameter and 300 mm height made from all the samples of concrete. The test was conducted after 28 days of curing as per IS 516 : 1959. Test was conducted on three specimens of each sample and the average was taken as the final value.

3.4.5 Flexural Strength Test

Flexural strength test was conducted on concrete prism of size 100 mm x 100 mm x 500mm. The test was conducted after 28 days of curing as per IS 516 : 1959. Test was conducted on three specimens of each sample and the average was taken as the final value.

3.5 CASTING AND CURING OF SPECIMENS

The required materials were weighed and machine mixed for casting the specimens. Testing was conducted on concrete cubes (150 mm x 150 mm x 150 mm), cylinders (150 mm diameter and 300 mm height), prisms (100 mm x 100 mm x 500 mm), cylindrical disks (100 mm diameter and thickness 50 mm), cylinders (50 mm diameter and 100 mm height) and flexural bond test beams (910 mm x 100 mm x 150 mm).

IV. RESULTS AND DISCUSSIONS

4.1 GENERAL

The effect on water demand was first confirmed by consistency tests on cement paste with NS and without NS. Then slump test was conducted on the designed mix proportion and a slump of 98 mm was achieved. In the designed mix proportion, NS was added at 0.5% by weight of cement and the slump was 79 mm. So, superplasticizer was added by trial and error method till the desired slump value (near 100 mm) was achieved. The process was repeated for 1%, 1.5% and 2% addition of NS. Using the proportions, concrete cubes, cylinders, prisms, cylindrical disks, cylinders for corrosion test and beams for flexural bond test were cast. After curing, compression test, flexure test, split tensile strength test. The durability properties were studied through acid attack test. Pull-out bond strength was tested between concrete and steel when NS was used.

4.2 CONSISTENCY TEST

The consistency test showed an increase in water demand with the addition of NS to cement. The test was carried out on six different sample 73 proportions from cement with 0% NS to cement added with 2.5% NS in steps of 0.5% NS. The addition of NS to OPC always increased the water demand and this increase was noticeable with an increase in NS content as seen in Figure 4.1. This confirms the study by Rajendiran et al. (2016) which showed that addition of NS to the cement mixture reduces the extent of flow due to the increase of cohesion in the mortar. it can be seen that cement without any NS had a W/C ratio of 0.36, and when 0.5% NS was added to the cement, the W/C ratio increased to 0.38 which is 4.1% increase in water demand. Similarly for 1% NS addition, W/C ratio was 0.39 and for 2% NS addition, W/C ratio was 0.42. There was a noticeable high water demand of 0.44 W/C ratio when 2.5% NS was added to the cement. The increases in water demand with 0.5% NS, 1% NS, 1.5% NS, 2% NS and 2.5% NS were 4.1%, 8.6%, 12.5%, 16.11% and 22.92% respectively. This shows that use of superplasticizer is essential to have desired workability without change in water to binder ratio. Also, it is obvious that the quantity of superplasticizer must be increased with increase in NS content in the mix.

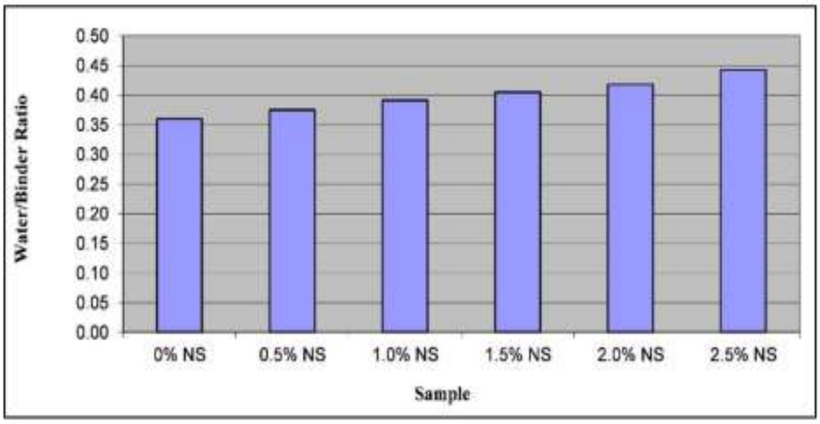

Figure 4.1 W/C ratio required in consistency test

4.3 SLUMP TEST

The slump value of control concrete C0 was 98 mm. So, to achieve a similar slump in concrete with NS, 1.77 kg/m3 of superplasticizer was added to concrete with 0.5% (C1) of NS. This was found by trial and error method. The superplasticizer requirement can be seen from Table 4.2 and Figure 4.2. As expected, the superplasticizer requirement increased with an increase in NS content. The percentage of increase in superplasticizer quantity was 11.11%, 33.33%, 66.67% for C2, C3 and C4 samples respectively, with respect to C1 sample.

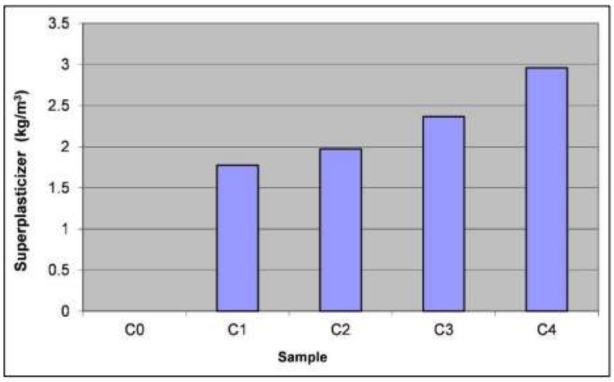

Figure 4.2 Superplasticizer requirement for various samples

4.4 COMPRESSIVE STRENGTH TEST

The compression test results are shown in Figure 4.3. The 7 days compressive strength of concrete with NS were found to be better than that of the concrete without NS. The samples C3 & C4 with 1.5% & 2% NS had the highest strength. This is due to the increase in the hydration of the concrete containing Singh et al. (2015) indicated that the hydration of C3S can be made quicker by adding of NS. During hydration, an early pozzolanic reaction on the silica surface takes place to form C–S–H and the hydration rate of C3S is increased significantly with increasing silica surface. The additional C–S–H which is the fundamental component for strength and density improves the strength of the matrix and at the same time portlandite (CaOH) is consumed. On comparing the compressive strength results, the samples containing NS were found to possess better strength at all ages compared to the control sample C0. Compressive

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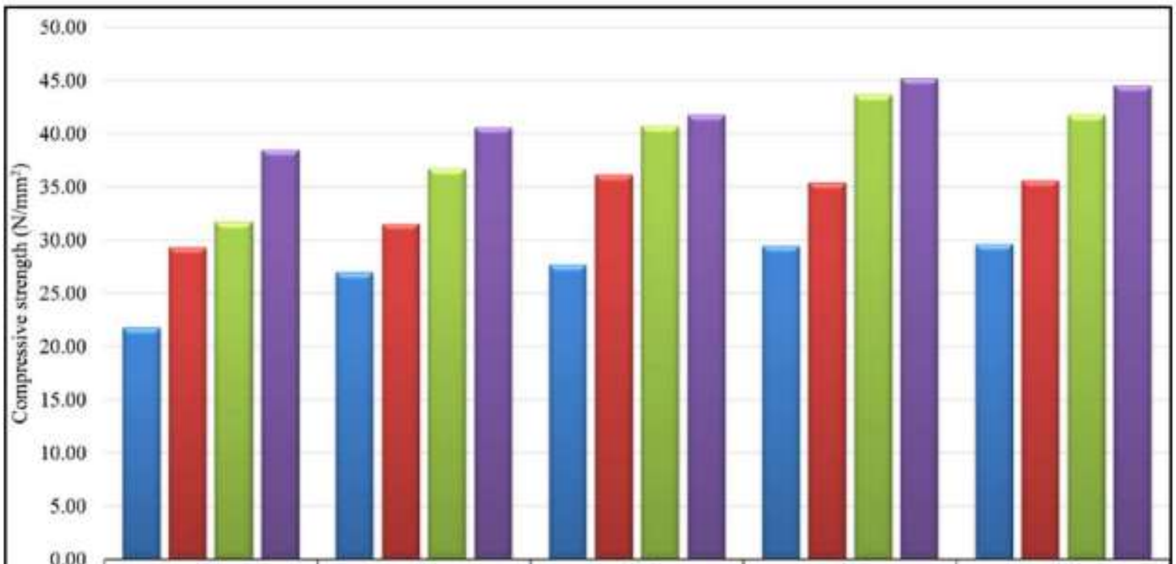
strength of concrete increases with increase in the NS content similar to the findings by Gesoglu et al. (2016).



	C0	C1	C2	C3	C4
7 days	21.78	26.96	27.70	29.48	29.63
14 days	29.33	31.56	36.15	35.41	35.63
28 days	31.70	36.74	40.74	43.70	41.78
60 days	38.49	40.61	41.79	45.19	44.52

Figure 4.3 Compressive strength test results

The compressive strengths of C0 and C1 specimen were 21.78 N/mm2 and 26.96 N/mm2 respectively, marking an increased strength of 23.8% when 0.5% NS was added. Similarly C2, C3 and C4 were having a compressive strength gain of 27.2%, 35.37% and 36.05% respectively with respect to C0. Zhang et al. (2012) found that this early strength of concrete containing NS was due to the accelerated hydration of the increased nucleation sites provided by the fine NS. The compressive strength increases with increase in NS content up to 1.5%. When the addition of NS was 2% (C4), there is a small reduction in the strength compared to C3 at the age of 28 days and 60 days. This reduction may be due to the presence of excess NS particles than the quantity required to react with calcium hydroxide, thereby causing reduction in strength as it replaces cementitious material and does not add to strength as suggested by Chithra et al. (2016). Another factor that could affect the strength reduction may be the uneven distribution of NS as pointed out by Nazari Ali & Shadi Riahi (2011). The 60-day compressive strengths were also high for concrete with NS like 5.50% (C1), 8.58% (C2), 17.40% (C3) and 15.67% (C4) more than concrete without NS.

4.5 FLEXURAL STRENGTH TEST

The flexural strength at 28 days increased by 16.53% when 0.5% NS (C1) was added. There was 45% increase in flexural strength with the addition of 1.5% NS (C3). The sample C4 had a 42.98% increase in flexural strength compared to C0. There was a reduction in strength at 2% NS (C4) addition compared to C3 as shown in Table 4.6 and Figure 4.6. The flexural strength, in a similar fashion to the compressive strength, increased with an increase in NS content owing to the capacity of NS in improving the toughness of the concrete as stated by Li et al. (2004).

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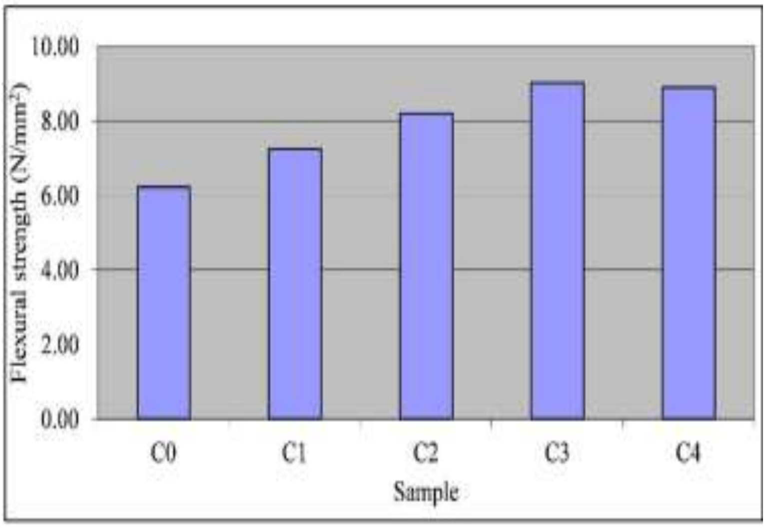

Figure 4.6 Flexural strength

4.6 SPLIT TENSILE STRENGTH

The split tensile strength at 28 days increased by 7.89% when 0.5% (C1) of NS was added. The split tensile test showed a steady increase in strength with increase in NS content up to 1.5% NS (C3). The split tensile strength of C3 was 3.26 N/mm2 and when 2% NS (C4) was added the strength came down to 3.05 N/mm2 . The test results were again similar to that of compressive strength results; there was a reduction in strength at 2% NS addition as shown in Table 4.7 and Figure 4.7.

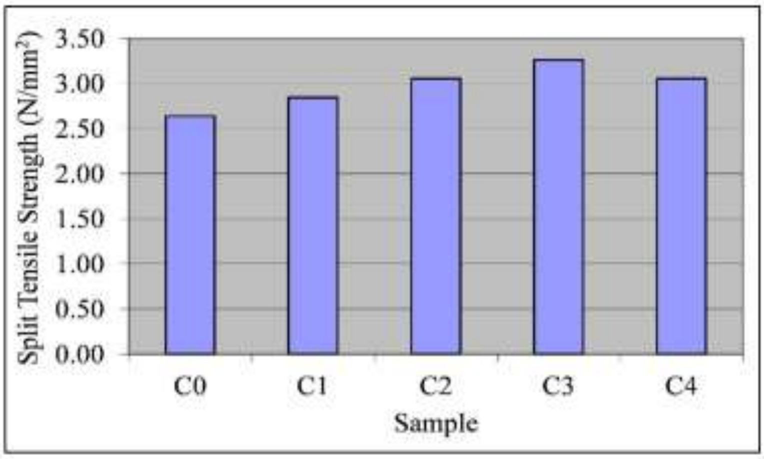

Figure 4.7 Split tensile strength

ACID RESISTANCE TEST

All the concrete cubes immersed in acid for 28 days showed reduction in the compressive strength and weight loss compared to the cubes that underwent 28 days of water curing. The weight loss of concrete in H2SO4 was greater compared to the weight loss due to HCl as seen in Table 4.13. The Figure 4.44 and Figure 4.45 show the weight loss in H2SO4 and HCl respectively. The weight loss due to H2SO4 was 0.36% (C1), 7.81% (C2), 27.53% (C3) and 25.48% (C4) which was less when compared to the noted C0 sample. The weight loss due to HCl was 15.30% (C1), 22.50% (C2), 32.34% (C3) and 29.63% (C4) which was less when compared to the C0 sample. Here, it can be seen that the concrete with higher NS content had lower weight loss compared to the concrete without NS. The weight loss decreased with an increase in NS content.

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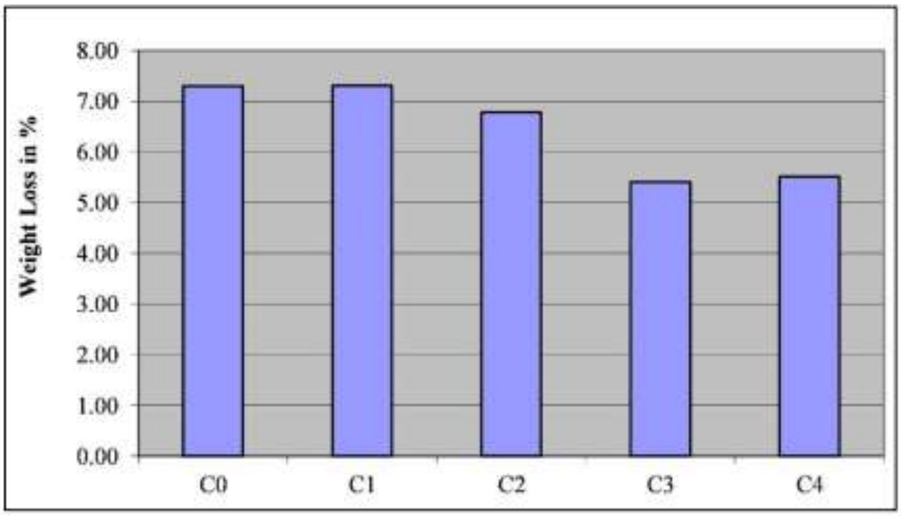

Figure 4.44 Percentage of weight loss in H2SO4

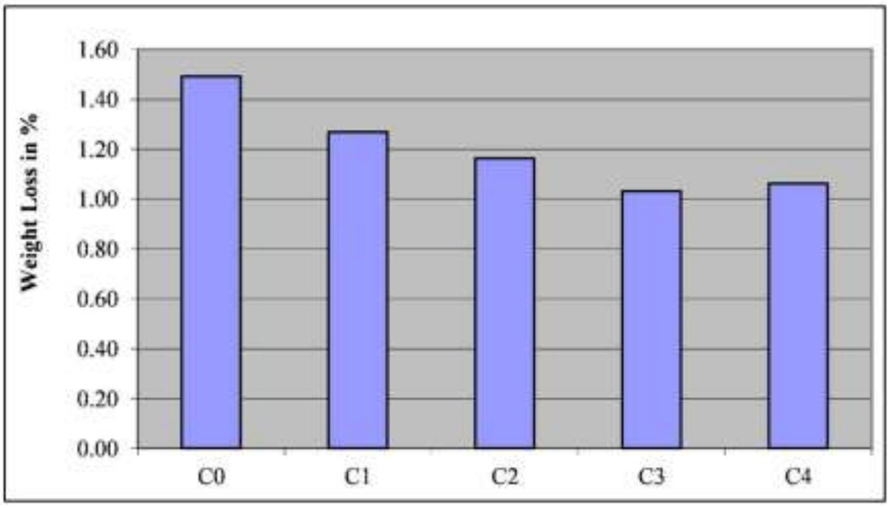

Figure 4.45 Percentage of weight loss in HCl

The reduction in weight was due to the deterioration of the concrete in acid environment, and this leads to loss of strength. The strength was compared to the 28-day strength of concrete after water curing. Similar to weight loss, the strength loss was greater in H2SO4. Figure 4.46 shows the concrete cube after H2SO4 exposure; the aggregates are clearly visible. It can be seen from Table 4.14 that concrete with NS had lower strength loss compared to the concrete without NS and strength loss decreased with an increase in NS content. As it was pointed out by Zivica & Bajza (2002) and Mahdikhani et al. (2018), a better pore structure gives a better resistance to acid attack, and NS helps by reducing the pores. So it can be concluded that NS can improve the concrete's resistance to acid attack.

Table 4.14 Strength loss due to acid attack

Sl.No	Sample	Strength loss in %	
		H_2SO_4	HCl
1	C0	73.18	24.40
2	C1	72.65	23.43
3	C2	71.40	22.15
4	C3	71.02	21.59
5	C4	70.76	21.93

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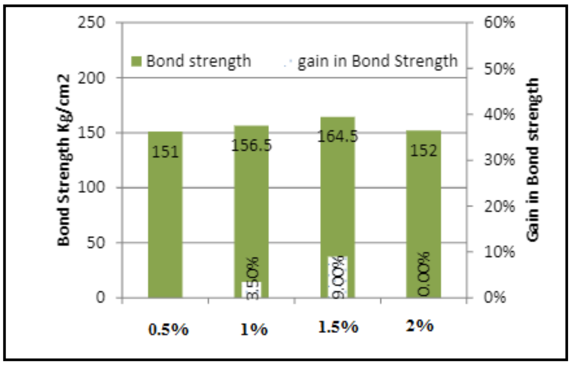
Figure 4.46 Concrete cubes after H2SO4 exposure

Bond strength

The results reveal that splitting occurred for allspecimens either those containing nano silica or thecontrol mix. Figure-9From Figures (10 and 11) the following can beobserved:The bond strength was slightly improved by theaddition of nano silica 3%, and then the gain in bondstrength began to decrease by using 4.5% nano silica.The results are in a good agreement with thetensile strength behavior since the failure occured with therebars was splitting due to the weak confinement providedby the covering concrete around the rebars (less than 4.5bar diameter).The bond strength value reached 164.5 Kg/cm2by the addition of 3 % nano silica instead of 151 Kg/cm2for the control mix (containing 0% nano Silica).The gain in bond strength reached (3.5, 9, and0%) by the addition of (1.5, 3, and 4.5%) nano silicarespectively.The optimum percentage of nano silica toimprove bond strength is 3% (gain 9% as compared to control mix 0%W) due to the improvement in the tensilestrength of 3% nano silica mixes.

Figure-. 16 mm rebars splitting behavior.



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V. CONCLUSIONS

5.2.1 Effect of NS on Fresh Cement and Concrete

- The consistency test showed that there is an increase in water demand with addition of NS to cement. This shows that use of superplasticizer is essential to have desired workability without the change in water-tocement ratio and the quantity of superplasticizer must be increased with increase in NS content in the mix. The percentage increase in water demand for 0.5% NS, 1% NS, 1.5% NS, 2% NS and 2.5% NS was 4.1%, 4.4%, 3.9%, 3.6% and 6.8%, respectively.
- The workability of fresh concrete reduces with an increase in the addition of NS. This is due to an instant reaction between the NS and the content in the concrete mix. The use of a suitable quantity of superplasticizer can help overcome this difficulty and improve the workability to the desired level to aid in the easy placing of fresh concrete. The percentage of increase in superplasticizer quantity was 11.11%, 33.33%, 66.67% for C2, C3 and C4 samples respectively, with respect to C1 sample.
- The superplasticizer should be added after the addition of water to the dry mix and it should be thoroughly mixed. The addition of plasticizer after the addition of water will help in better dispersion of mix ingredients. A good distribution of all the ingredients must be ensured before adding superplasticizer for improvement in properties else expected enhancement of concrete cannot be attained. The mixing procedure adopted plays an important role in the making of good concrete.

5.2.2 Effect of NS on Strength of Hardened Concrete

- The improvement in the physical properties is due to the formation of more C-S-H by reaction of NS with Ca(OH)2 which in turn provides better strength and density to the concrete. Therefore when the NS content increases strength improves. The 28-day compressive strengths were high for concrete with NS like 15.88% (C1), 28.50% (C2), 37.85% (C3) and 31.77% (C4) more than concrete without NS. As the days increased, the differences between C0 sample and NS sample decreased.
- The 28-day flexural strengths were high for concrete with NS like 16.53% (C1), 31.82% (C2), 45.13% (C3) and 42.99% (C4) more than the concrete without NS.
- The 28-day split tensile strengths were high for concrete with NS like 7.90% (C1), 15.77% (C2), 23.68% (C3) and 15.79% (C4) more than the concrete without NS. Even adding 1% and 0.5% NS to that of cement by weight proves to give better results than concrete without NS, and the addition of 1.5% NS proves to be the optimum proportion since it increases the compressive, flexural and split tensile strengths of concrete to the maximum. When the addition of NS was 2%, there was a small reduction in the strength compared to 1.5% NS. This reduction may be due to the presence of excess NS particles than the quantity required to react with calcium hydroxide, thereby causing reduction in strength as it replaces cementitious material and does not add to strength. Another factor that could affect the strength reduction is the uneven distribution of NS. The weight loss due to H2SO4 was 0.36% (C1), 7.81% (C2), 27.53% (C3) and 25.48% (C4) less when compared to C0 sample. The weight loss due to HCl was 15.30% (C1), 22.50% (C2), 32.34% (C3) and 29.63% (C4) less when compared to C0 sample. Here, it can be seen that the concrete with higher NS content had lower weight loss compared to the concrete without NS. The compressive strengths of C1, C2, C3 and C4 samples immersed in• H2SO4 were 18.19%, 37.01%, 48.96% and 43.67% higher than C0 sample. The compressive strengths of C1, C2, C3 and C4 samples immersed in HCl were 17.39%, 32.34%, 42.98% and 36.09% higher than C0 sample. Strength of the concrete with NS was higher than the concrete without NS.
- Bond strength of 16 mm rebars has the same trend ofthe splitting tensile strength; the dominant behaviorwas splitting for all mixes. The optimum percentage of Nano silica to improvebond strength of using 16mm rebars is 1.5% (gain 9%as compared to control mix 0%W) due toimprovement in the tensile strength of 1.5% Nano silicamixes

REFERENCES

[1]. R. Sakthivel and Dr.N.Balasundaram (2016) "Experimental Investigation on Behavior of Nano Concrete" International Journal of Civil Engineering and Technology, Volume 7, Issue 2, March April 2016, pp. 315-320.

[2]. Rutuja Mininath Sarade, Suraj Ramesh Shinde, Rohan Kantilal Wayase, Namdev Bapu Rajguru, Dr. P. D. Nemade (2017) "Effect of Nano Silica on Compressive Strength of Concrete" International Journal for Scientific Research & Development, Volume 5, Issue 04, 2017, ISSN: 2321-0613

[3]. .Mani.M, Dr. G. Nandini Devi (2017) " Study on Behavior of Nano Concrete " International Journal of Emerging Trends & Technology in Computer Science, Volume 6, Issue 5, September October 2017, ISSN: 2278-6856.

[4]. Jitendra Patil, Dr. Umesh Pendharkar (2016) "Study of Effect of Nanomaterials as Cement Replacement on Physical Properties of Concrete" International Research Journal of Engineering and Technology, Volume: 03, Issue: 01, Jan 2016, e-ISSN: 2395-0056, p-ISSN: 2395- 0072.

[5]. Yuvaraj, Shanmugasundaram, Dinesh Nagarajan, Karthic Ramachandran, Dr. Suji Mohankumar (2012) “Experimental Study on the Influence of Nano silica in the Strength and Durability of Concrete.”, pp. 4246.

[6]. IS: 456-2000, Indian Standard "Plain and Reinforced Concrete" Code of Practice (Fourth Revision), Bureau of Indian Standards, New Delhi 110002

[7]. IS: 2386-1963 (Part-III). Indian Standard " Methods of Test for aggregates for concrete Part III specific gravity, density, voids, absorption and bulking", Bureau of Indian Standards, New Delhi 110002.