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Effects of Nano Silica and Silica Fume on Compressive and Tensile Strength of Concrete

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ABSTRACT- The application of nanotechnology in concrete adds new content to efforts to improve its performance. Due to the very small size of nano materials, the properties of concrete can be influenced by changing the microstructure. The study involved the use of Silica fume (3%,6%,9%) and nano-silica (1%,2%,3%) b.w.c. As the percentage of Silica fume and nano silica increases, an increase in strength is observed.

Concrete is the material of present and future, It's widespread use in structures, from buildings to factories, bridges and airports, makes it one of the most searched material. Due to rapid population explosion and the rise of technology to meet these needs, there is an urgent need to improve the strength and durability concrete. Among the various materials used in concrete production, cement plays an important role due to its size and adhesive properties. Therefore, for the production of improved concrete, the cement humidification mechanism should be studied properly and better alternatives should be proposed. In this study, the cement is replaced by silica fume and nano silica materials. In addition, it is planned to determine the number of predictions of cubes in the program. These theses explore the standard optimization ratio for silica and fume to get the best compressive strength. Further this has to check for Indian standard uses for developing the demand of quality users in India.

All of the concrete mixtures were tested. These tests include performing Slump, compressive strength test. 24 cubes were molded for compressive strength, curing ages of 7,28 days for the concrete mixtures were applied in this work. The results proved the increase in compressive strength, durability, and various other properties of concrete by adding nano silica and silica fume in concrete.

KEYWORD- Concrete, M40, M30, Silica Fume, Nano Silica.

I. INTRODUCTION

Concrete is a versatile material for civil engineering construction. It was observed and noticed that since decade of years that the cost of building materials is currently so high that to do meaningful construction [11]. Industrial byproducts can be used as in concrete as admixtures in cement and raw material in cement clinker or as aggregates in concrete. Ordinary Portland cement is acknowledged as the major construction material throughout the world. Concrete has a good compressive strength, durability, specific gravity, but it has some negative properties. Perhaps concrete is best option rather than any other available material for civil engineering construction. These negative properties of concrete are minimized by adding some supplementary materials for increasing compressive strength and other properties of concrete. Different supplementary cementitious materials are added to concrete to improve its properties are as fly ash, blast furnace slag, rice husk, silica fume and Nano silica. Out of these Nano silica and silica fume are promising approach to improve its properties of concrete.

The development manufacturers are offering various innovative elements for the improvement of constructions [6]. Cement is one of the products employed in high volume for the constructions yet rising cement generation heads to pollution of the environment. The fundamental approach is to decrease the cement supply in a mixture, to substitute cement with additional substances possessing pozzolanic composition such as silica fume and Nano silica. Nanomaterials are extremely fine-sized substances which are very useful in improving the characteristics of the mixture. These nanomaterials are enhancing the concrete durability and permeability for microstructure by filling up the voids and pores. The application of Nano silica in the mixture will display effects of an enhancement in the concrete flexural, compressive, and tensile strength. A developing interest in current times to the application of SiO_2 Nanoparticles in a compound, they perform an important function in developing the engineering characterization of a mixture, they react with the released calcium hydroxide (CH) throughout the hydration, form more hydration products and supply the existing pores. Ultra-high strength concrete (UHSC) has numerous advantages, it proportioned with a low water-to-supplementary cementitious material ratio, these materials, which are used either as cement (replacement or as additives) to the concrete composite mixture. Many researcher studies and try to compose UHSC concrete, for its high compressive strength and improved durability made up of particles of the similar size which help to increase the concrete homogeneity and minimize the concrete tensile strain and leads to increase of final carrying load capacity. Improve all the tensile stress resistance and cracking, post-cracking strength, ductility, and capacity for absorbing energy by adding further material called steel fiber which improvement in the tensile behavior of the concrete by arresting crack growth and controlling on the macro cracks initiate and propagate.

II. MATERIALS & METHOD

A. Methodological Details

The current survey is to design M30 and M40 grade of concrete is the rheology and curing properties of the developed mixture were investigated. In this study, cement was replaced by silicon powder and nano silica material [1]. The planned hybrid design is the American Concrete Institute approach because it is compared to other hybrid design methods. The percent substitution of the nano silica was chosen to be in the range of (1%, 2%, 3%) and for silica fume (3%, 6%, 9%).

B. Experimental Programmer

The experimental procedure involves the testing base material in the laboratory. Design combinations are used for basic material test results by using the American Concrete Research Institute method. For compressive strength of 24 samples were cast in the laboratory and tested for fresh and hardened properties. Detailed samples are shown in Table 1.

Table 1: Details of cubes with various percentages of Nano Silica and silica fume

Mixes	Silica Fume	Nano Silica as	Cubes	
	Replacement (%)	Additive (%)	7 days	28 days
Control mix	5	0	3	3
1	5	1	3	3
2	5	2	3	3
3	5	3	3	3
	Samples		12	12

C. Materials Use

- Cement: In this experimental work, conventional Portland cement (OPC) grade 43 according to IS: 8112-1989 was used. The cement used is a super high-tech cement obtained from a local agent.
- Fine aggregate: It is available in the river sand in zone 2 of IS 383-1970 and are used for project work.
- Coarse aggregate: Gravel granite and quarry are used as coarse aggregate. According to Indian standards, it has been found that the specific gravity and size of the 20 mm coarse pellet is reduced.
- Water: Water suitable for drinking is generally considered to be suitable for the production of concrete. Make sure the water is free of acids, alkalis, vegetables, and other organic impurities. In concrete mixtures, water has two functions. First, it chemically reacts with the cement to form a cement slurry until the cement slurry hardens. Second, it is used as a carrier or lubricant for fine aggregate and cement mixtures.
- Nano Silica: [3] Properties of the Nano silica are listed in Table 2.

Table 2: - Properties of Nano Silica

Properties	Standard Requirements	Results
Specific surface area (m_2/g)	200+20	
pH value (4% aqueous slurry)	3.7-4.5	4.12
SiO_2 (%)	>99.8	99.8
Chlorides (%)	<0.020	0.011
Al_2O_3	<0.030	0.005
TiO_2	<0.020	0.004
Fe_2O_3	<0.003	0.001

- Silica fume: Silica fume is very fine off white pozzolanic material processed from naturally occurring amorphous silica. Uniformity of product quality is ensured by careful blending of raw materials and the stringent process is control. The properties of the silica fume are used, and its chemical composition are shown in Tables 3 and 4 respectively [4].

Table 3: Properties of Silica Fume

Properties	Results
Specific gravity	2.61
Particle size	15µm
SiO_2 content	98.89%

Table 4: Chemical Composition of Silica Fume

Chemical composition	Values (%)
K_2O	0.7
CaO	0.30
MgO	0.8
Alkalies	800µ

III. RESULT AND DISCUSSION

A. Slump Cone Test

Slump cone test is the most well – known test that are used for determining the workability of concrete. The slump cone test cone is especially consisting of a metallic mould in the form of a frustum of a cone having interna dimensions as: bottom diameter 20 cm (8 inches), top diameter 10 cm (4 inches), height 30 cm (12 inches) and the thickness of the metallic sheet for the mould should not be thinner than 1.6 mm. The tamping end of rod is 16 mm diameter and 600 mm length. Concrete is filled in cone and removed and the shape of the concrete after the cone removal is then assessed to determine the workability. Reference to IS: 1199 – 1959 methods of sampling and analysis of concrete. The pattern of slump is shown as true slump, zero slump, collapse slump, and shear slump, but one test is measured that is only true slump.

The mixing design of concrete is done by mix proportion of M30 and M40 grade of concrete mixes by the weight of cement and adding Nano silica (1%,2%,3%) and silica fume (3%,6%,9%). The results of slump as shown in Table 5 & 6 for grade M30 and M40.

Table 5: Results of slump test values grade M30

S No.	Grade	Nano silica %age	Silica fume %age	Slump (mm)
1	M30	0	0	114
2		1	3	126
3		2	6	137
4		3	9	145

Table 6: Results of slump value grade M40

S No.	Grade	Nano silica %age	Silica fume %age	Slump (mm)
1	**M40**	0	0	**125**
2		1	3	**136**
3		2	6	**143**
4		3	9	**148**

Table shows that the slump values decrease as the percentage of Nano silica and Silica fume increases.

B. Tests on Hardened Concrete

To establish the mechanical properties of concrete Nano silica and Silica fume added to the concrete with different percentage to the weight of the cement. Concrete mixes are detailed in the preceding section.[5]

Mixing of ingredients of concrete is done for grade M30 and M40 of concrete mixes by adding Nano silica (1% ,2%,3%) and Silica fume (3%,6%,9%).

C. Compressive Strength Test of Cube

It is one of the important properties of concrete is its strength in compression. The strength in compression has a relationship property of concrete that are improved with the improvement in compressive strength [2]. During the production of concrete of the compressive strength of concrete that depends upon water- cement ratio, quality of concrete material, quality control. The size of the mould is 150x150x150 mm and the concrete is poured and tempered properly so that not having any voids. After 24 hours these moulds are removed and put in water for curing. The top of the surface of the specimen should be made smooth. Concrete cubes that are tested for 7 days and 28 days of strength as per Indian Standard (IS): 516-1959 and are tested in a compression testing machine. Three specimens are tested for typical category and the mean compressive strength of three specimen is considered as the compressive strength of the specified category.

Table 7: Compressive Strength test of M30 grade of Concrete Cubes Without Nano Silica and Silica Fume for 7 days

Grade of concrete	Days	Load of crushing (KN)	Strength (N/mm2)	Average of compressive strength (N/mm2)
M30 for category 1	7	600	26.67	
M30 for category 2	7	560	24.89	26.22
M30 for category 3	7	610	27.11	

Table 8: Compressive Strength test of grade M30 Concrete Cubes with Silica fume and Nano silica for 7 days

Grade of concrete	Days	Load of crushing (KN)	Strength (N/mm2)	Average of compressive strength (N/mm2)
M30 for category 1	7	630	28	
M30 for category 2	7	590	26.22	27.55
M30 for category 3	7	640	28.44	

Bar chat (Figure 1) shows that the difference in strength for M30 grade concrete with or without nano silica and silica fume for 7 days.

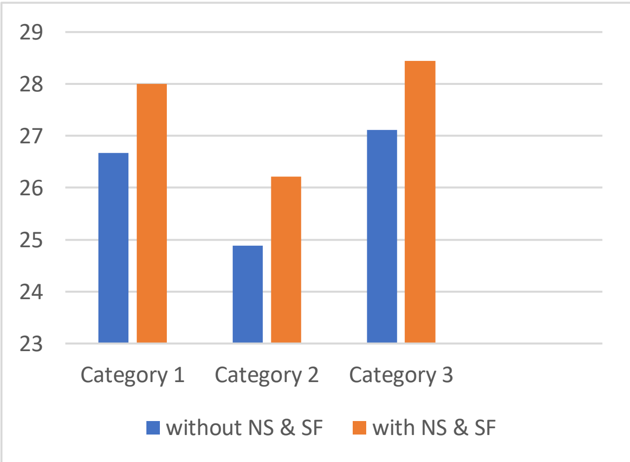


Figure 1: Difference in strength for M30 grade concrete with or without nano silica and silica fume for 7 days

Table 9: Compressive Strength test of grade M30 Concrete Cubes Without Silica fume and Nano silica for 28 days

Grade of concrete	Days	Load of crushing (KN)	Strength (N/mm2)	Average of compressive strength (N/mm2)
M30 for category 1	28	800	35.55	
M30 for category 2	28	810	36	36.15
M30 for category 3	28	830	36.89	

Table 10: compressive strength test of grade M30 concrete cubes with silica fume and nano silica for 28 days

Grade of concrete	Days	Load of crushing (KN)	Strength (N/mm2)	Average of compressive strength (N/mm2)
M30 for category 1	28	850	37.78	38.37
M30 for category 2	28	860	38.22	
M30 for category 3	28	880	39.11	

Bar chart (Figure 2) shows that the difference in strength of grade M30 with and without nano silica and silica fume for 28 days.

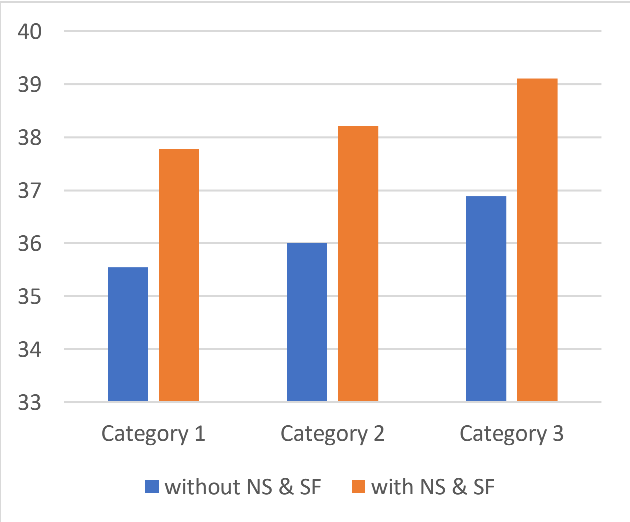


Figure 2: Difference in strength of grade M30 with and without nano silica and silica fume for 28 days

Table 11: Compressive Strength test of grade M40 Concrete Cubes Without Silica fume and nano Silica for 7 days

Grade of concrete	Days	Load of crushing (KN)	Strength (N/mm2)	Average of compressive strength (N/mm2)
M40 for category 1	7	850	37.78	37.33
M40 for category 2	7	810	36.88	
M40for category 3	7	840	37.33	

Table 12: Compressive Strength test of grade M40 Concrete Cubes with Silica fume and Nano silica for 7 days

Grade of concrete	Days	Load of crushing (KN)	Strength (N/mm2)	Average of compressive strength (N/mm2)
M40 for category 1	7	890	39.55	38.81
M40 for category 2	7	850	37.78	
M40for category 3	7	880	39.11	

Bar chart (Figure 3) shows that the difference of strength for grade M40 with and without nano silica and silica fume for 7 days.

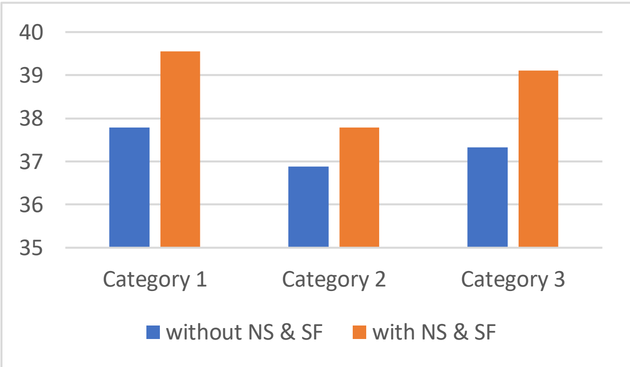


Figure 3: Difference of strength for grade M40 with and without nano silica and silica fume for 7 days

Table 13: Compressive Strength test of grade M40 Concrete Cubes Without Silica fume and Nano Silica for 28 days

Grade of concrete	Days	Load of crushing (KN)	Strength (N/mm2)	Average of compressive strength (N/mm2)
M40 for category 1	28	1050	46.67	45.78
M40 for category 2	28	10300	45.78	
M40for category 3	28	1010	44.89	

Table 14: Compressive Strength test of grade M40 Concrete Cubes with Silica Fume and Nano Silica for 28 days

Grade of concrete	Days	Load of crushing (KN)	Strength (N/mm2)	Average of compressive strength (N/mm2)
M40 for category 1	28	1130	50.22	
M40 for category 2	28	1110	49.33	49.33
M40for category 3	28	1090	48.44	

Bar chart (Figure 4) shows that the difference of strength for M40 grade of concrete with and without nano silica and silica fume for 28 days.

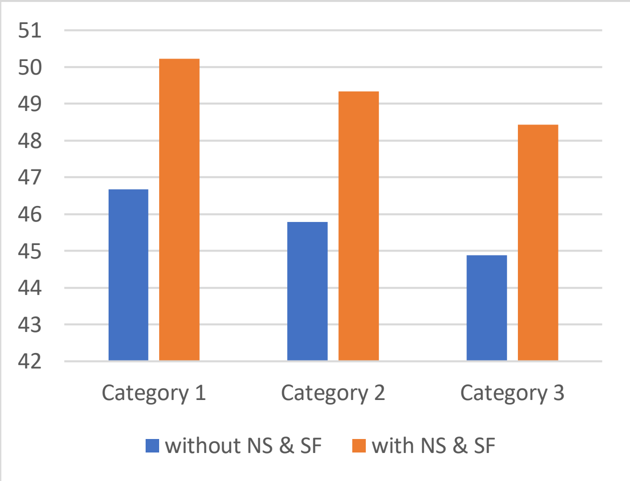


Figure 4: Difference of strength for M40 grade of concrete with and without nano silica and silica fume for 28 days

Mix Proportions, Mixing Casting and Curing

One concrete mix which is (ultra-high-strength concrete) was used with different variables that create (8 mixture) [5]. The first four mixes contain 3 percentage of Nano silica with a percentage of (0, 1, 2, 3% by weight of cement). The second four mixes contain 3 percentage of Nano silica with one portion of silica fume (9% by cement weight). Table 15 presented mix proportions used to cast all the molds.

Table 15: Details of normal concrete and UHPC mixes

Concrete Mix	Nano silica (%) by	Silica fume (%) by	Cement (kg/m3)	Sand (kg/m3)	Superplasticizer by weight	w/c
Mix (1) (Nano silica)	0	0	975	1100	6.25	0.2
Mix (2) (Nano silica)	0	0	975	1100	6.25	0.2
Mix (3) (Nano silica)	0	0	975	1100	6.25	0.2
Mix (4) (Nano silica)	0	0	975	1100	6.25	0.2
Mix (5) Nan0 silica+	0	0	975	1100	6.25	0.2
Mix (6) Nan0 silica+	0	0	975	1100	6.25	0.2
Mix (7) Nan0 silica+	0	0	975	1100	6.25	0.2
Mix (8) Nan0 silica+	0	0	975	1100	6.25	0.2

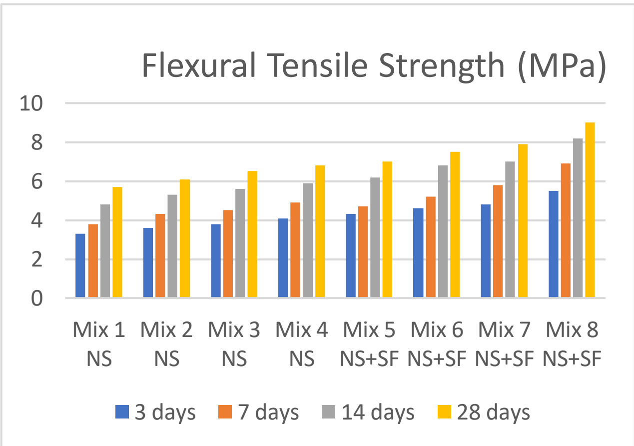
The usual significant step in the completion of each examination is the technique of mixing and ratios. After weighting and preparations of materials, molds are then connected and lubricated from inside to prevent adhesion on the inner surface. The fine materials were mixed at the beginning to ensure uniform mixing; later sand was added and mixed for a limited period. Superplasticizer was used here to compensate for the excess water. Superplasticizer and water were added to the concrete mixer gradually until they work. The casting was distributed within two sections, the first batch was added to the vibrator to ensure that the concrete was compacted and then the second layer was combined and subjected to the same process. Each specimen was coated with a nylon layer for 24 hours to limit the waste of moisture. In the second day of casting, the molds were opened and stored in water containers in the casting place to be preserved for 27 days, all units were removed of the water and deposited in the laboratory until the appointment of examination [10].

D. Flexural Strength Test

The flexural strength trial was conducted authorize to(ASTM C1609), on model units of(70 × 70 × 280 mm) with couples of concentrated loading employing a hydraulic hydraulic measurement device device(ELE). The addition of silica cloud and Nano silica to the admixture will produce exceptional factors and develop the strength which is presented in table 16 and colluded in Figure 5. This performance is due to refinement processes of severance size and grain size which meliorate the transformation zone and overcome the interfacemicro-cracking[8]. Results show that the adding chance in flexural tensile strength with the effect of Nano silica was important advanced at 3 days compared to(7, 14 and 28 days). When silica pall added together with the Nano silica to the mixes (and 8) an advance in flexural tensile strength up to (30.3 for mix 5) is achieved [9].

Table 16: Flexural tensile strength and increasing percentage (%) due to the effect of silica fume and Nano-silica

	Nano silica (%) by weight of cement	Silica fume (%) by weight of cement	Flexural tensile strength (MPa)				Increasing percentage (%)			
			3 days	7 days	14 days	28 days	3 days	7 days	14 days	28 days
Mix (1) NS	0	0	3.3	3.8	4.8	5.7	0	0	0	0
Mix (2) NS	1	0	3.6	4.3	5.3	6.1	0	0	0	0
Mix (3) NS	2	0	3.8	4.5	5.6	6.5	0	0	0	0
Mix (4) NS	3	0	4.1	4.9	5.9	6.8	0	0	0	0
Mix (5) NS+SF	0	9	4.3	4.7	6.2	7.0	30.30	23.68	29.17	2.81
Mix (6) NS+SF	1	9	4.6	5.2	6.8	7.5	27.78	20.93	28.30	22.95
Mix (7) NS+SF	2	9	4.8	5.8	7.0	7.9	26.32	28.89	25.00	21.54
Mix (8) NS+SF	3	9	5.5	6.9	8.2	9.0	27.91	25.45	28.13	23.29



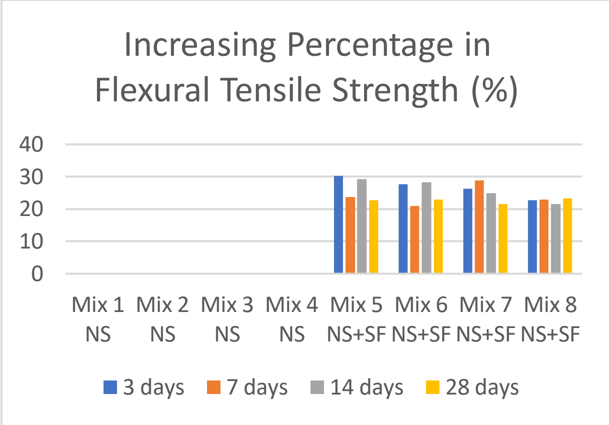


Figure 5: Flexural tensile strength and increasing percentage compared to 3 days due to the effect of silica fume and Nano-silica

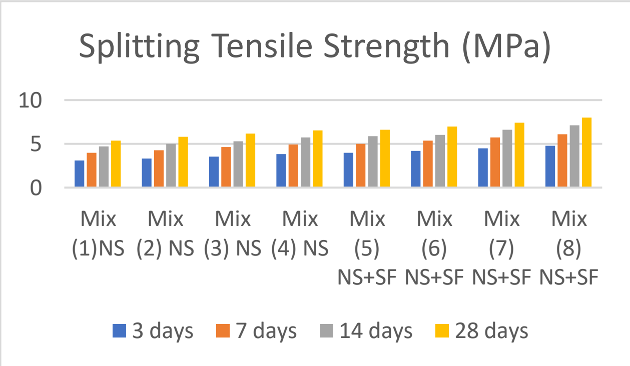
E. Splitting Tensile Strength Test

Tensile strength in splitting was handled on (100×200mm) cylinders. Fibers are improved to the properties of cement-based matrices throughout the setting. They are capable of bridging the cracks, to transfer stresses across a crack and to prevent crack extension in the compacted state. According to the restraining of the micro-cracks, the incorporation of Nano-silica and silica fume results in improving the split and flexure strength. The microcracks are arrested by fiber, led to an improv ed bond, consequently, an improved mechanical property which is presented in Table 17 and plotted in Figure 6. The improvement according to the application of Nanoparticles came from the filler influence, pozzolanic impact and the wide surface area intensify the bond connecting fiber/matrix interface in an attachment to the extension restraining for jointly macro and microcracks. Result shows that the increasing percentage in splitting tensile strength with the effect of Nano silica was much higher at 3 days compared to (7, 14 and 28 days). When silica cloud is added together with the Nano silica to the composites(, and 8), the enhancement in blistering tensile strength up to(30 for blend 8) is achieved[7].

Table 17: Splitting tensile strength and increasing percentage (%) due to the effect of silica fume and Nano-silica

Concrete Mix	Nano silica (%) by weight of	Silica fume (%) by weight of	Splitting tensile strength (MPa)				Increasing percentage (%)			
			3 days	7 days	14 days	28 days	3 days	7 days	14 days	28 days
Mix (1) NS	0	0	3.1	4	4.7	5.4	0	0	0	0
Mix (2) NS	1	0	3.3	4.3	5	5.8	0	0	0	0
Mix (3) NS	2	0	3.5	4.6	5.3	6.3	0	0	0	0

Mix (4) NS	3	0	3.8	4.9	5.7	6.5	0	0	0	0
Mix (5) NS+SF	0	9	4	5	5.9	6.6	29.03	25	25.53	22.22
Mix (6)	1	9	4.2	5.4	6	7	27.27	25.58	20	20.69
Mix (7)	2	9	4.5	5.7	6.6	7.4	28.57	23.91	24.53	19.35
Mix (8)	3	9	4.8	6.1	7.1	8	30	23.08	25	23.19



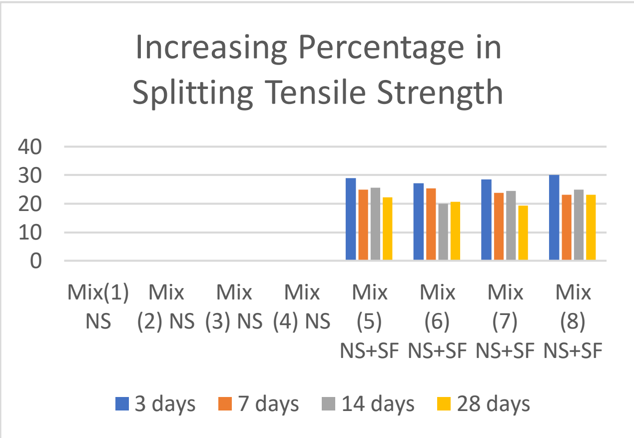


Figure 6. Splitting tensile strength and increasing percentage compared to 3 days due to the effect of steel fiber, silica fume and Nano-silica

IV. CONCLUSION

Related to the laboratory work outcomes in this research, results indicated that the impact of Nano silica and silica fume were responsible for the enhancement in the strength by creating particles from C-S-H gel, results in the extra upgraded microstructure. Nano silica improves the strength by filling the micropores and making a dense concrete. Fibers are enhanced of cement-based matrices throughout the setting. They are capable of bridging cracks, to transfer stresses across the crack and to prevent crack extension in the hardened status. The incorporation of Nano-silica and silica fume that results in improving of the split and flexure strength according to the restraining of the micro-cracks, the microcracks arrested by fiber, led to an improved bond, consequently, improved mechanical properties. Adding of Nano SiO2 there is a considerable improvement in the initial-age (3 days) the intensity of mixture correlated to the (7, 14 and 28 days) increase in strength. The compressive strength improved with SiO2 Nano particles incorporation at (7, 14 and 28days), following the mixed effect of silica fume and SiO2 Nano particles. All tensile and flexural strength are improved with time under the combined influence for both Nano SiO2 and silica fume. SEM microFigures show that the mix that containing Nano SiO2 particles appear more homogeneous, denser, less pore volume and less roughness fracture surface than the concrete with silica fume only.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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