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Analysis of Silica Fume and Nano Silica Microstructure in High Performance Concrete

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ABSTRACT- High performance concrete often has a water-to-cement ratio that is lower than traditional concrete in order to achieve the extended service life and appropriate mechanical strength that are required by the design. Because the presence of a large number of large pores or voids, particularly when they are concentrated in a particular region, can have an impact on the mechanical strength and durability of concrete, reducing the quantity of such pores or voids can help to increase the strength of the hydrated cement paste that is used in this type of concrete. Because a crystalline phase's strength increases with decreasing grain size, the grain size of the materials used in the production of concrete also has an effect on the characteristics of the finished product. Extensive experimental work was carried out to investigate the impact that different parameters had on the results of mechanical, and durability tests carried out on Nano Silicaand Silica Fume when they were subjected to compression and the silica fume ranged from 0% ,1% ,2% to 3% and combination of nano silica and silica fume was considered in which sililca fume values were considered cconstant at 2% and nano silica varied from 0% ,0.5%, 1%, to 1.5%. By this procedure an increase in the strength of the concrete was found.

KEYWORDS- Fine Aggregate, Water, Super Plasticizers, Silica Fume (SF), Nano Silica (NS)

I. INTRODUCTION

High performance concrete often has a water-to-cement ratio that is lower than traditional concrete in order to achieve the extended service life and appropriate mechanical strength that are required by the design. Because the presence of a large number of large pores or voids, particularly when they are concentrated in a particular region, can have an impact on the mechanical strength and durability of concrete, reducing the quantity of such pores or voids can help to increase the strength of the hydrated cement paste that is used in this type of concrete. Because a crystalline phase's strength increases with decreasing grain size, the grain size of the materials used in the production of concrete also has an effect on the characteristics of the finished product. The qualities of many various kinds of materials, such as plastics, metals, and carbon fibres, have the potential to be significantly improved by the use of nanotechnology. The utilisation of nanoparticles improves both contact and surface reactivity, which, in turn, leads to improvements in material properties. The utilisation of nano particles in the production process of concrete results in an improvement of the material's properties. Concrete's microstructure is what defines its mechanical strength and its service life. It is still conceivable to utilise nanoparticles to reduce the size and weight of concrete buildings, which might lead to large savings in the use of natural resources, primarily cement, as well as, in some circumstances, other components (steel, aggregates and water).

II. LITERATURE REVIEW

Hasan Nuri Turkmenoglu et al. (2022) in this study, the additive effects of micro-silica (MS) and Nano-silica (NS) on the characteristics of concrete with moderate and high strength were analysed. The W/Cm ratio was shown to have a significant impact on the effectiveness of micro and Nano refining, with results showing an increase in compressive strength of up to 37% being achieved.[1]

M. Mokhtar et al. (2022) it is common knowledge that nanoparticles have been used extensively around the globe as reinforcements in the manufacturing of high-strength and high mechanical performance concrete-based constructions. After then, high-performance concrete (HPC) was created by modifying it with three different kinds of additives: exfoliated Nano clay (NC), Nano-silica (NS), and hybrid particles [silica fume (SF) & limestone (LS)]. After 28 days of hydration, tests were conducted to determine the compressive, splitting tensile, and flexural strengths. The exfoliated NC was easily created by exfoliating the thermally activated ordinary clay with the assistance of organic ammonium chloride.[2]

Khan et al (2022) despite the fact that multiple review studies have already been conducted on Nano-silica-modified concrete, this study took a novel approach based on scientometric analysis to evaluate the keywords used in the field. Large amounts of bibliometric data can be processed by a scientometric study thanks to the availability of specialised tools for analysing the literature's many different aspects. Standard literature reviews sometimes fall short of providing an accurate and thorough overview of how various fields of study relate to one another. This study used a keyword analysis to identify and describe the most salient subtopics in the growing field of nanosilica-modified concrete research. There are several problems with employing Nano-silica, and now we know where to focus our investigations. In addition, literature data was used to create prediction models for calculating the strength of Nano-silica-modified concrete. High pozzolanic reactivity and a filler effect were cited as advantages of using nanosilica in cement-based composites up to an ideal dosage of 2-3%, while increased porosity and micro cracking owing to agglomeration of Nano-silica particles were cited as disadvantages. When NS is incorporated appropriately, the mechanical strength may increase by 20-25%. Improved accuracy in the prediction models for the strength of Nano-silica-modified concrete shows a high degree of agreement with experimental results. You can save time and money by using this sort of analysis to get a rough idea of a material's fundamental qualities rather than conducting costly experiments. It is suggested to look into low-priced approaches to dispersing Nano-silica in larger concentrations in cement mixes; additional thorough research is needed to produce more accurate prediction models to forecast Nano-silica-modified concrete qualities.[3]

E. Tobbala et al. (2022) at the moment, nanoparticles are utilised as admixtures with the purpose of slowing down the thermal degradation of concrete following its exposure to fire. However, not enough research has been done on how high temperatures affect high-strength concrete (HSC) that contains silica fume and nanoparticles. In the course of this research, a number of different HSC mixes that contained 1%, 2%, 3%, and 4% nanosilica (NS) or 1% and 2% Nano ferrite (NF) were manufactured in order to generate HSC that maintained a high level of durability despite being exposed to high temperatures of up to 800 degrees Celsius and actual fires. In order to evaluate the specimens, scanning electron microscopy, compression and splitting tensile tests, a test of the specimen's modulus of elasticity, and an examination of the material's water permeability coefficient were carried out. According to the findings, increasing the amount of NS and NF in HSC by up to 3% and 2%, respectively, led to an improvement in the material's mechanical characteristics as well as its water permeability coefficient when exposed to higher temperatures. At temperatures ranging from 200 to 800 degrees Celsius, the compressive strength of heated specimens containing 3% NS was superior to that of heated specimens containing 2% NF. In terms of the microstructure characteristic, the findings demonstrated that NS performed effectively as a suitable filler material, which resulted in the formation of a condensed microstructure that included additional compressed hydration outputs. This might be linked to a more intense pozzolanic reaction of NS, which resulted in a larger dispersion of the extra calcium silicate hydrate gel that was generated. The specimens that included 3% NS remained crack-free up until a temperature of 800 degrees Celsius, despite a modest increase in their porosity.[4]

Schiavon et al (2021) several kinds of nanoparticles have been shown to ensure higher physical–mechanical qualities and improvements in microstructure when used in cementitious compounds. In high-performance concrete, the interfacial transition zone (ITZ) between aggregate and paste is improved with the use of mineral admixtures such as silica fume (HPC). A super plasticizer additive containing colloidal nanosilica suspension and slurried silica fume with HPC was evaluated in this study, and its macro and microstructural characteristics were evaluated. X-ray micro tomography and scanning electron microscopy were used in this investigation to evaluate the mechanical and microstructural characteristics of concretes containing 1.5, 3, and 5 percent nanosilica and 5 and 10 percent silica fumes, respectively. Concrete's compressive strength and elastic modulus rose dramatically when mineral admixtures were used. At 28 days, the concrete with 10% silica fume and 3% nanosilica demonstrated an improvement in strength of more than 75%. For the same w/b = 0.35, the elastic modulus of the concrete rose by 36% over the reference material. Nanosilica and silica fume microstructural studies demonstrate that microstructure densification is responsible for the improvement in HPC performance.[5]

A. Serag Faried et al. (2021) This research presents a comparative study of various curing regimes, specifically standard curing (SC), internal curing (IC) with polyethylene glycol (PEG), and air curing (AC), which are used in ultrahigh-performance concrete (UHPC) premixed with a variety of nanomaterials. These curing regimes include standard curing (SC), internal curing (IC) with polyethylene glycol (PEG), and air curing (AC). In all, four distinct Nano waste materials—milled Nano-metakaolin (NMK), Nano waste glass (NWG), Nano rice husk ash (NRHA), and chemically prepared Nano silica—were produced (NS). Investigation was done on a few different UHPC mixtures including various percentages of nanomaterial (1%, 2%, and 3%) An examination of the sulphate attack, ultrasonic pulse velocity, microstructure, and compressive strength was carried out. The findings suggested that the performance of SC and IC in NS, NWG, and NMK was comparable to one another. In addition, the inclusion of PEG had a detrimental impact on NRHA's performance. Under the influence of IC, the compressive strength rose by 17% in NWG, 24% in NRH, 14% in NMK, and 13% in NS, respectively. Under the influence of IC, the sorptivity of NS, NMK, NWG, and NRHA fell by 84%, 60%, 48%, and 60% respectively.[6]

III. METHODOLOGY

A stand-type drum mixer with a 0.05 m3 capacity will be used to appropriately combine all of the ingredients once they have been accurately weighed using an electronic balance. Buttering will be done with sand, cement, and water in the same ratio as the original mix to prevent the real mix ingredients from sticking in the mixer. Measuring out and storing the right amount of super plasticizer for the batch is a standard procedure. Super plasticizer and all of the water will be combined beforehand. You can see that the Nano silica is spread out evenly because of the mixing, putting, and compacting processes. We will keep mixing until we get a concrete that is uniform and consistent. In order to ascertain whether or not freshly mixed concrete is suitable for use, a slump test will be conducted using equipment that has been calibrated in accordance with Indian Standard 1199 - 1959. The low water-to-cement ratio concrete samples will be protected from drying out by being covered with wet gunny bags as soon as possible (within an hour of casting). The specimens will be removed from the mould after 24 hours and cured in damp gunny bags for 7, 28 days.The specimen will be further treated with silica fume and nano silica in order to check the results.Firstly the specimen will be treated with 0%,1%,2%,3% silica fume for 7 and 28 days and the various tests will be conducted. The tests inculde compressive strength test, split tensile test, and flexural test. After getting the desired results the combination of silica fume and nano silica was considered, in which 2% constant value of silica fume and 0%,0.5%,1%,1.5% nano silica was used and the prior tests were repeated at the same time duration. The results were noted.

IV. RESULTS & DISCUSSION

In this section, result acquires several tests conducted out on mechanical characteristics of Nano silica and silica fume based High Performance Concrete (HPC) and structural performance under static circumstances are included in this part. The impact of adding Nano silica and silica fume to increase the mechanical and micro strengths was explored. The tests done are given below:

A. Compressive Strength Test

The specimen was treated with silica fume with 0,1,2,3% for 7 and 28 days. The results are given below. Fig 1 gives the results of 7 days and fig 2 shows the results of 28 days

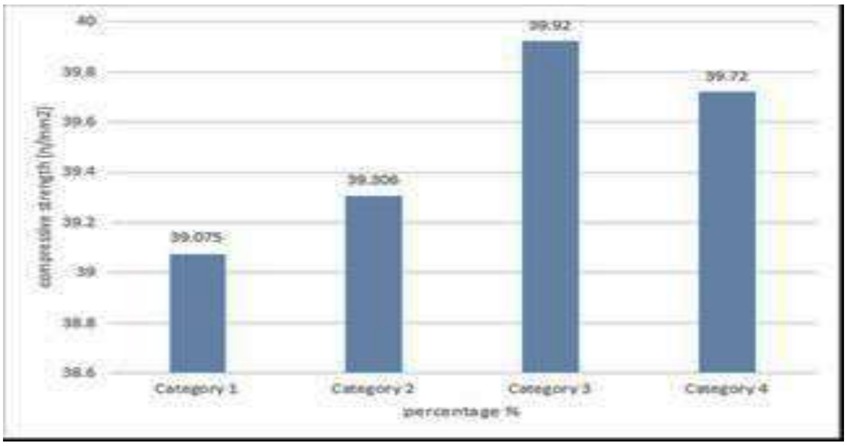

Figure 1: Compressive strength for 7 days in accordance with SF

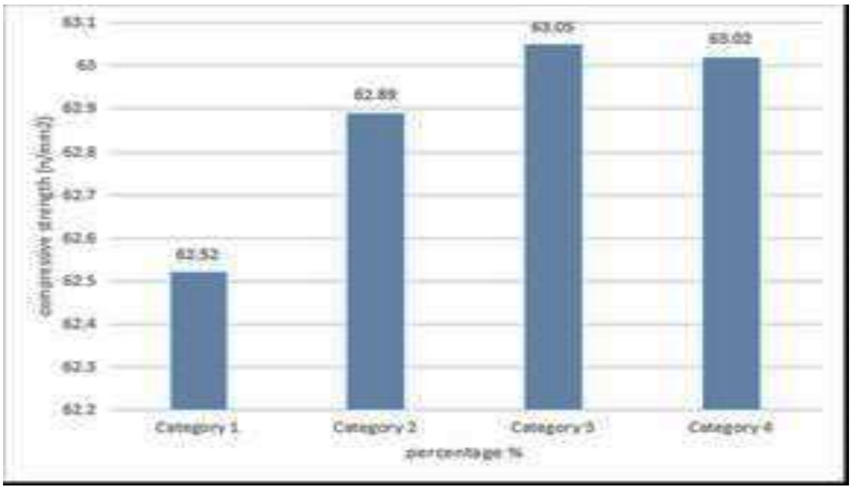

Figure 2: Compressive strength for 28 days in accordance with SF

B. Split Tensile Test

The control specimen underwent split tensile test . The tensile strength of the specimens was determined using the usual test protocol after 7 and 28 days with accordance of silica fume. The results are given below. Fig 3 shows the results for 7 days and fig 4 shows results for 28 days.

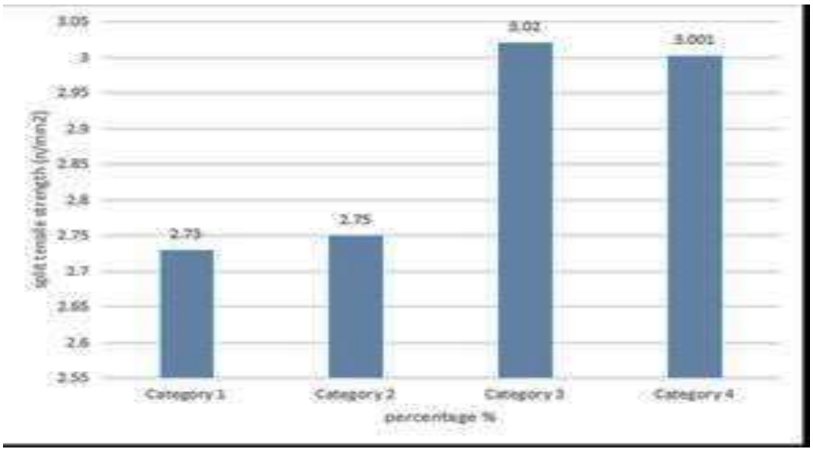

Figure 3: Split tensile strength for 7 days in accordance with SF

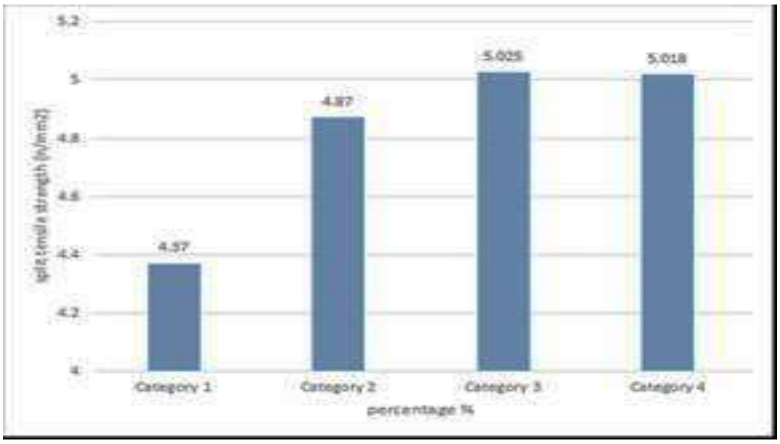

Figure 4: Split tensile strength for 28 days in accordance with SF

C. Flexural Test

Here, we talk about how the beam specimens respond to two point loading based on the relationship between load and mid span deflection. A flexural strength test was performed in accordance with ASTM-C78. The linear variable differential transformer was used to calculate the bending moment for each 1kN applied. The results of the aforementioned tests show that the flexural strength of the specimen improves with increasing amount of silica fume at 7 and 28 days of testing. Slight increment was observed in the flexural strength of the specimen when treated with 0%, 1%, 2%, and 3% silica fume for 7 days and 28 days. The results for the same are given below in the fig 5 for 7 days and fig 6 for 28 days.

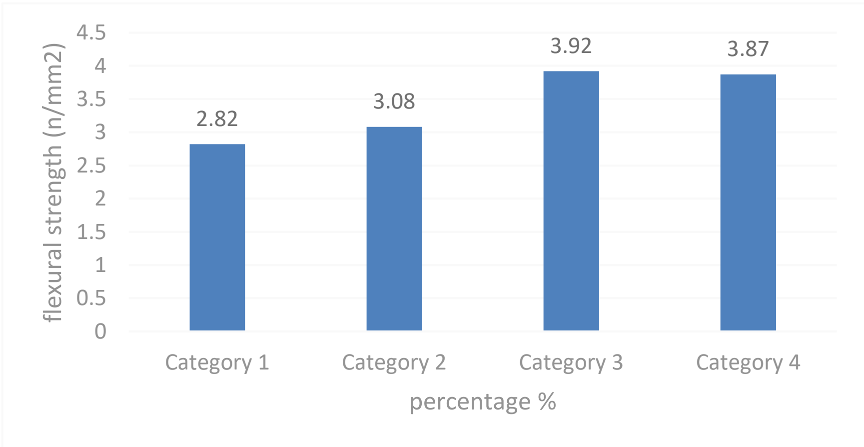

Figure 5: Flexural strength for 7 days with accordance with SF

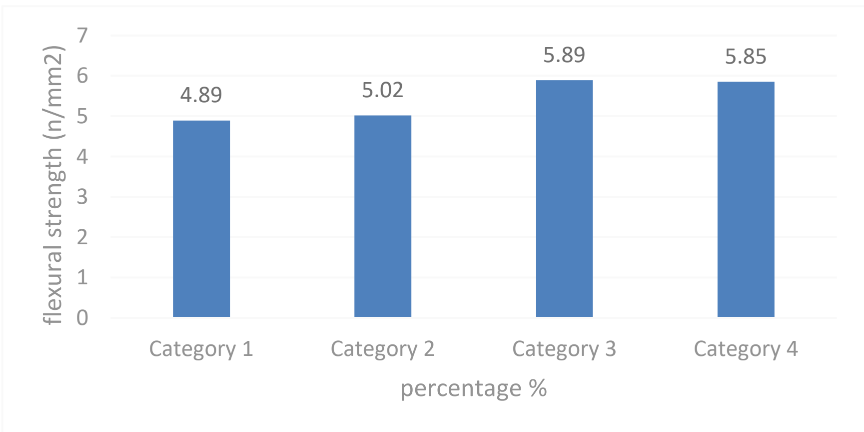

Figure 6: Flexural strength for 28 days in accordance with SF

The highest value of strength was acquired at 2% when treated with Silica fume. Combination of silica fume and nano silica was considered for the further investigation. In this procedure constant value of silica fume i.e; 2% was considered and the values of nano silica varied from 0%

,0.5%,1%,1.5%. The specimen performed better when treated in combination with silica fume and nano silica.

D. Compressive Strength Test

Rise in the compressive strength was seen in the combination of silica fume and nano silica upto a certain percentage. Moreover, minor decline in the compressive strength was seen with 2% silica fume and nano silica when examined after 7 and 28 days. Fig 7 shows results of 7 days and fig 8 shows results of 28 days.

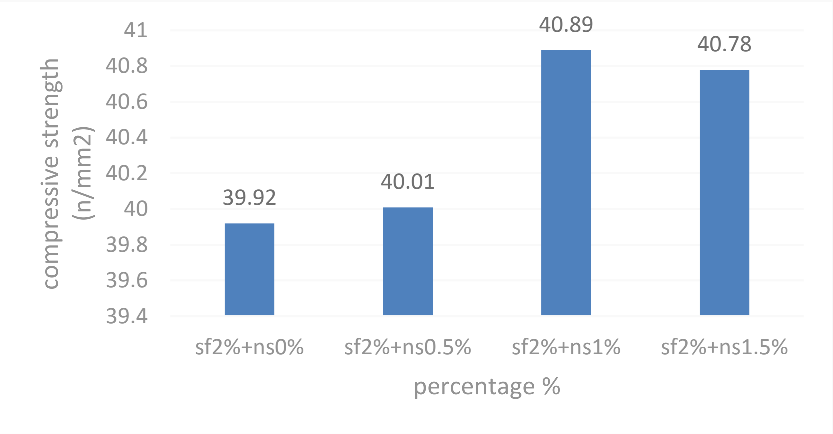

Figure 7: Compressive strength for 7 days in accordance with SF and NS

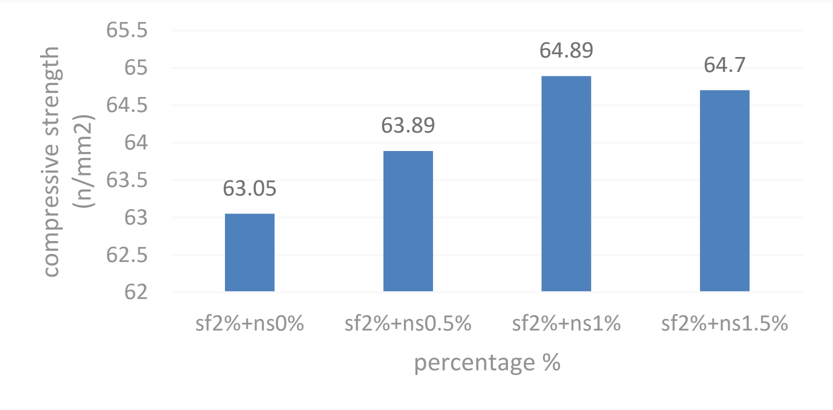

Figure 8: Compressive strength for 28 days in accordance with SF and NS

E. Split Tensile Test

According to the findings the strength of all concrete samples was enhanced when nano silica was in combination with silica fume. The chart below demonstrates that as the percentage of the nano silica grew, so did its strength. Effective bridging throughout the fracture width is the cause of this enhancement. Some researcher found that an improved binding between aggregates and hydrated cement contributed to the material's strength. The splitting tensile strength of concrete is claimed to rise with increase in nano silica, according to some resesrchers. The results found out after 7 and 28 days of testing are given below in fig 9 for 7 days and fig 10 for 28 days.

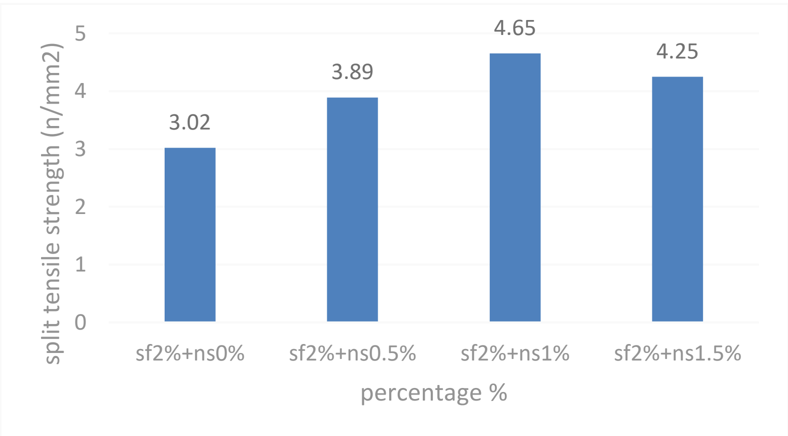

Figure 9: Split tensile strength for 7 days in accordance with SF and NS

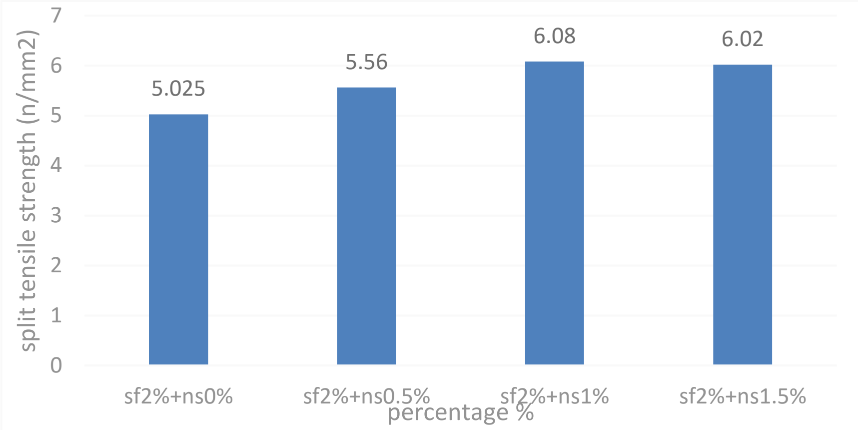

Figure 10: Split tensile strength for 28 days in accordance with SF and NS

F. Flexural Test

In this case the specimen was treated with nano silica along with silica fume. The percentage of the silica fume used was constant I.e; 2% and the percentage of the nano silica varied from 0%, 0.5%, 1%, 1.5%. Consistently, results demonstrated that Nano Silica enhanced the interfacial transition zone by decreasing the water-binder ratio. The procedure was tested after 7 and 28 days it was found out that their was an in increase in the flexural strength of the specimen. The results are given below in fig 11 for 7 days and fig 12 for 28 days.

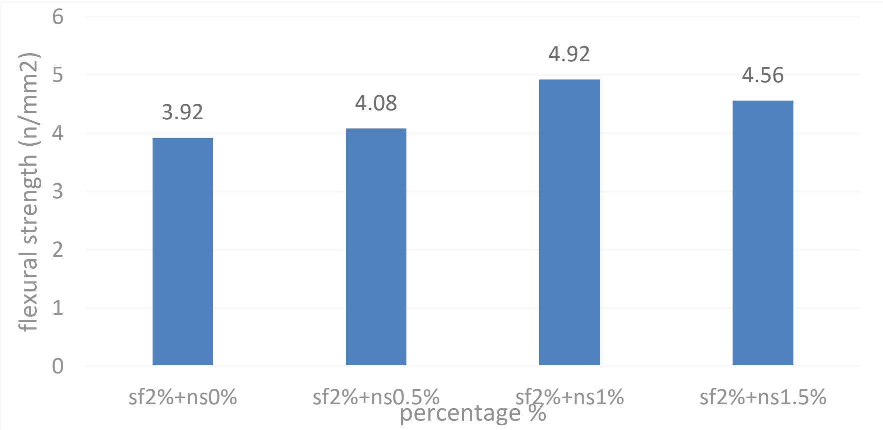

Figure 11: Flexural strength for 7 days in accordance with SF and NS

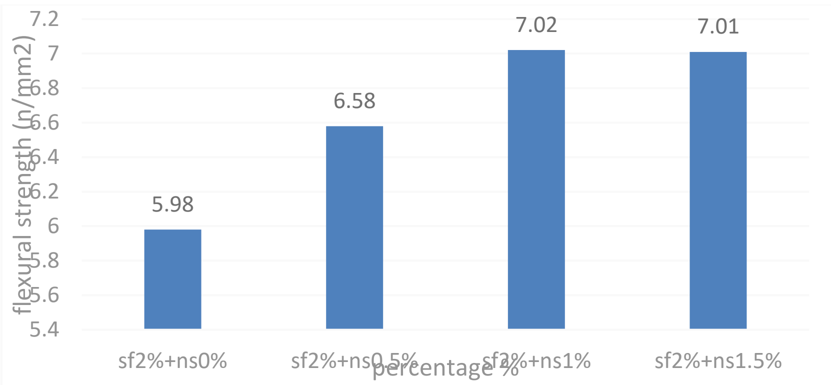

Figure 12: Flexural strength for 28 days in accordance with SF and NS

V. CONCLUSION

The compressive strength of high-performance concrete was intended to be 62.52N/mm2 when it was designed. A mixture with 0 percent, 1 percent, 2 percent, 3 percent, of the weight of friction replaced by silica fume (SF) was conducted ist and then and then combination of 2% Silica fume and varying 0 percent, 0.5 percent, 1 percent, 1.5 percent of nano silica was conducted. At 7 and 28, respectively, the effects of silica fume and combination of Nano silica and silica fume on various mechanical properties of concrete such as compressive strength, flexural strength, splitting strength, were investigated. These properties include compressive strength, flexural strength, splitting strength. This work demonstrates that the addition of Nano silica and silica fume to high performance concrete results in an improvement to the concrete's mechanical strength, which is preferable

At every age, the inclusion of Nano silica (NS) and silica fume (SF) to concrete resulted in an increase in the material's compressive strength compared to the control conditions. On the other hand, Nano silica in combinaton with silica fume demonstrated significantly superior performance than silica fume alone. In comparison to silica fume (SF) concrete, the inclusion of Nano silica and silica fume combination raised the compressive strength of concrete by 35 percentage points after 7 days, 39.0 percentage points after 28 days of curing accordingly.

The load carrying capacity, first crack strength, and ultimate fracture strength all increased in proportion to the weight fraction of Nano silica that was present in the material. The initial fracture load in high performance concrete increased by 35.60% and the ultimate load increased by 37.9% for every 3% of weight fraction that contained Nano silica.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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