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Influence of nano silica on impact resistance and durability of fly ash concrete in structural buildings

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ABSTRACT

The impact of integrating Nano Silica (NS) on mechanical characteristics, resistance towards impact, and chloride penetration on concrete having Fly Ash (FA) are investigated in this research. The NS particles are subsequently mixed into concrete at one, two, three, four, and five percent of the binder's mass, respectively. The performance of the specimens under an impact load is assessed by utilizing the drop weight impact technique, frequency on strikes, and impact force variation has been used to evaluate the specimen's impact resistance. The concrete's ability to withstand damage from chloride penetration was evaluated by determining the chloride diffusion coefficient of the samples. The test findings demonstrated that adding NS to concrete may significantly increase its mechanical characteristics as well as chloride penetration resistance. The optimum amount of NS substitution in concrete is two to three percent and it is discovered that if the proportion of NS is too large, the benefits of incorporating NS into the characteristics of the concrete are diminished, and might even have a detrimental effect on the resistance towards impact and durability of the concrete. Moreover, the experimental compressive strength and split tensile is compared with existing gene expression programming model.

Keywords: Nano Silica; Impact resistance; Durability; Chloride penetration.

1. INTRODUCTION

Normal concrete has been the most widely used and widely applied construction material because of its good load carrying capacity, additional ease with which the concrete can be worked, superior hydrothermal stability, and plentiful primary material wealth for quick binding. However, as the spectrum of concrete applications expands greater concrete property requirements are being recommended, such as for skyscrapers and buildings with a greater span, constructing assemblies in extremely cold places, and other particular reasons. As a result, researchers' use of different kinds of additives with cement-based composites is becoming a widespread way of improving the qualities of concrete. Nanomaterials are materials made up of particles with sizes ranging from 1 to 100 nm. Because of the nanoparticle's nanoscale sizes, the surface structures experience considerable modifications, leading to distinctive nano effects such as surface effects. As a result, nanoparticles have piqued the interest of several academics as a novel high-tech material with enormous application possible [1, 2]. Many features of concrete like flow ability, mechanical properties, and durability can be enhanced by incorporating nanoparticles due to their excellent properties. Several researchers have undertaken various studies based on adding low-dose nanomaterials to replace the binder in concrete mixes in order to improve the characteristics of concrete, with successful outcomes [3–6]. The inclusion of nano-silica (NS), nano $CaCO_3$, or nano TiO_2 particles demonstrated a great increase in the physical characteristics and durability of concrete due to its nucleation and micro-aggregate filling effects. In addition to nano-oxides, several nanocarbon materials have been developed and it has also been demonstrated to significantly improve the properties of concrete [7–9]. NS has such a greater effect and a peculiarly high surface area when compared to other nanoparticles; as a result, NS could show a large amount of pozzolanic reaction in concrete. Furthermore, NS can function as a stimulator for pozzolanic processes to enhance the breakdown on Ca_3SiO_5 and the creation of CSH (Calcium Silicate Hydrate). As a result, NS particles have drawn significant interest between these nanomaterials [10–12]. As a result, NS particles have drawn significant interest among these nanomaterial particles. According to findings compressive strength of concrete mixed by six percent of the cement mass of NS is thirty-six percent greater

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than the control concrete [13–15]. Researchers reached a similar conclusion, and even though they proposed that NS powders as a partial substitution of cement at little or no more than four percent might enhance the creation of CSH gel that modifies the porous structure of the concrete, and that when NS content exceeded four percent weight, the concrete strength might reduce due to differential dispersion of nanoparticles [16, 17]. This is due to the fact that employed dispersion NS in their research work and colloidal NS has the ability to attain greater dispersal inside a cementitious matrix over powdered NS. The investigators discovered that adding zero to 1.5 percent NS particles improved the physical properties of concrete. Furthermore, 2.5 percent NS particles are determined the optimum for tensile strength; but, when the amount exceeded 2 percent, the NS exhibited due to self and clustering together, resulting in small fractures and strength reductions in the composites [18, 19]. By most researchers, experimental results in concrete with the incorporation of NS, can be inferred as modest concentrations of NS can greatly improve the mechanical characteristics of concrete. The major steps adopted by governments across the globe to deal with environmental concerns are taking action to reduce and foster climate targets. Because cement manufacture is the primary source of CO_2, utilizing cementitious materials (SCMs) like copper slag and fly ash rather than just cement to build concrete is an efficient strategy to decrease CO_2 [20–22]. Coal FA is a form of nanoparticle created in power stations by the burning of coal carbon. FA has indeed been widely used for concrete as industrial waste in recent times, and its recycling has resulted in major financial and ecological advantages [23]. The reduction in the ignition is indeed a concern if fly ash is being utilized as SCM for producing concrete and the issue must be addressed [24, 25]. There is an issue that should be addressed. FA with a significant unreacted carbon content enhances concrete conductance, turning both mortar and concrete black. Furthermore, the corrosion behavior of the metal in concrete is increased by FA with a significant carbon concentration. Finally, it can cause unfavorable air entrainment and mixture isolation. The examinations on the durability of concrete integrating coal FA, discovered that using coal FA as a binding substitute may greatly increase the permeable resistance and concrete freeze and thaw resistance. Furthermore, FA and silica fume significantly increased the resilience of mortar and concrete by successfully blocking the alkali-silica reaction [26, 27]. The impact of silica fume on mechanical characteristics of fly ash concrete is studied. The strength improved as the silica fume volume increased, however, its capacity to withstand crack growth rapidly declined [28, 29]. A quantity of fly ash, on the other hand, is not always beneficial. During operational circumstances, an increasing number of concrete buildings are subjected to impact loads. Runways at airports are vulnerable to impacts from airplane landings, while coastal constructions are exposed to tidal effects. As a result, the structural safety of typical concrete with brittle failure properties offers a substantial problem under high impact loads [30]. Numerous studies have been undertaken by scientists' and results revealed that putting asphalt to the interface of aggregate significantly raised the toughness indexes of concrete and the resistance is best when the bitumen coating thickness is 120 μm. Furthermore, adding different fiber components to concrete is thought to be an efficient solution strategy for enhancing concrete's impact strength. Several fiber study outcomes show that the impact strength of concrete with fiber is much higher than that of regular concrete, owing to the fact that concrete with fiber may utilize more impact energy. As a result, the majority of existing approaches for improving the impact strength of concrete include the incorporation of energy-absorbing elements into concrete [31–34]. It's also commonly understood as durability is an important consideration when determining the lifetime of the concrete. Two critical components of its durability are resistance to chloride penetration as well as freeze and thaw effect. Chloride ions may reach the concrete by dispersion and capillarization in elevated concentrations of chloride ions, such as coastal regions and polar places in which deicing salts are utilized, leading to damage to internal reinforcements and degradation of the concrete. Freeze and thaw cycles also endanger the longevity of concrete buildings. Frequent rapid cooling cycles in concrete buildings may induce surface degradation including fracture progression, increase the corrosion and rust of steel bars, and considerably limit the lifecycle of buildings. As a result, the impacts of various NS quantities on the impact strength, chloride penetration resistance, and freeze and thaw resistance of concretes containing FA have been investigated. In this present study Nano silica is partially substituted from 0% to 5% by weight of cement to study the mechanical properties of concrete. Moreover impact test and chloride penetration test is also conducted to determine the optimum quantity of NS.

2. EXPERIMENTAL PROGRAM

2.1. Materials

The coarse aggregate is made up of consistently sorted with sizes ranging from 12.5 to 20 mm, while the fine aggregate are made up of river sand. To aid in the dispersion of the nanoparticles, a polycarboxylates superplasticizer is utilized. NS is added to the concrete mix by partially substituting the cement. The quality of NS is 99.88 percent and the key features of fly ash and NS are given in Tables 1, 2 and 3 respectively. Figure 1 depicts the look of powdered NS.

Table 1: Fly ash properties.

SPECIFICATIONS	PERCENTAGE
Fineness	9.31
Water content	0.6
Loss on Ignition	6.33
Sulfur trioxide	1.42
Calcium	0.20

Table 2: Nano silica properties.

SPECIFICATIONS	RANGE
Content (Percentage)	99.5
pH	6.0
Size of particle (nm)	29
Drying loss (Percentage)	1.1
Loss on Ignition (Percentage)	1.1

Table 3: Chemical properties of fly ash and nano silica.

SPECIFICATIONS	FLY ASH	NANO SILICA
SiO_2	51.50	99.88
Al_2O_3	32.58	0.004
Fe_2O_3	4.42	0.001
SO_3	5.19	–
CaO	0.50	–
MgO	0.21	–
Na_2O	1.35	–
K_2O	0.58	–
LOI(Loss Of Ignition)	1.50	–

Figure 1: Powdered NS.

The particle size analysis based on SEM images provides information about the average particle size and the range of particle sizes present in the sample. It enables the characterization of whether the nano silica particles are monodisperse (uniform in size) or polydisperse (varying in size). From Figure 2 and 3, SEM images can offer insights into the particle shape and morphology of nano silica and fly ash respectively. Depending on the synthesis method and conditions, nano silica particles may exhibit various shapes such as spherical, rod-like, or irregular.

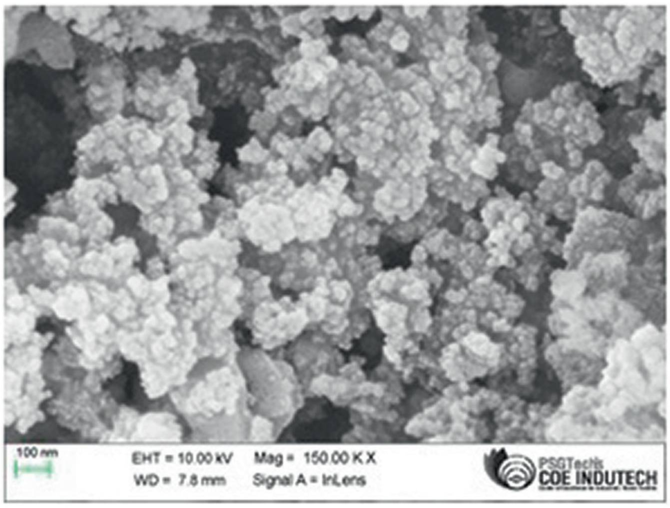

Figure 2: SEM image of nano silica.

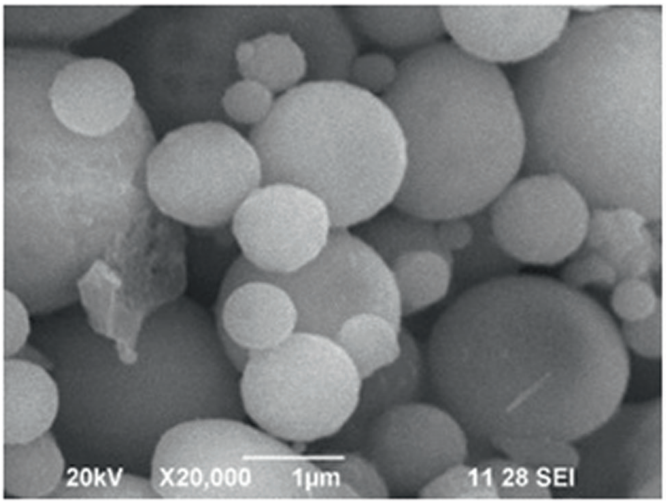

Figure 3: SEM image of flyash.

2.2. Preparation of specimen

The previous study on FA concrete, fifteen percent of the weight of the cementitious material is substituted with coal fly ash to assure the concrete's effectiveness. Six alternative mix quantities are developed, i.e one with a control mix and 5 mixes with varying NS dose combinations, whereas maintaining the water to binder ratio of 0.4 constant for all combinations. Of these, NS is utilized to cement replacement in percentages of one to five percentages respectively. The concrete mixture is depicted in Table 4. Various admixture doses are being utilized for each of the 5 sets of combinations to ensure a uniform slump level.

The regular distribution of NS is essential to assure the grade of concrete as well as produce great attributes in a specimen. The following processes are used to obtain greater scattering of SiO_2 nanoparticles as well as to create homogenous and constant concrete mixes.

1. Both NS, as well as admixture, are mixed together in water for ninety seconds.
2. The aggregates are combined for 90 seconds in the moisture concrete mixer.
3. Both cement and fly ash have been put in a blender and stirred for approximately 90 seconds.
4. Blender is filled with added water (including NS and admixture) and then stirred for approximately 90 seconds.
5. In control mixes, the excess moisture or even the full amount of water is added to the blender and stirred for nearly 90 seconds.

Table 4: Mix proportions.

PROPERTIES	IDENTITY OF MIXTURE					
	CC	NSF1	NSF2	NSF3	NSF4	NSF5
Cement (kg/m^3)	432	428	423	419	415	410
NS(kg/m^3)	0	4	9	13	17	22
Fly ash (kg/m^3)	76	76	76	76	76	76
Water (kg/m^3)	185	185	185	185	185	185
Fine aggregate (kg/m^3)	640	640	640	640	640	640
Coarse aggregate (kg/m^3)	980	980	980	980	980	980
Super plasticizer (Percentage)	0	0.2	0.4	0.6	0.8	1.0

Table 5: Fresh concrete properties.

S.NO	IDENTITY OF MIXTURE	SLUMP VALUE (mm)	COMPACTION FACTOR	DEGREE OF WORKABILITY
1	CC	90	0.90	Medium Workability
2	NSF1	92	0.90	
3	NSF2	92	0.90	
4	NSF3	93	0.91	
5	NSF4	94	0.91	
6	NSF5	94	0.92	

The freshly mixed slurry is instantly put into greased cube mould with a dimension of (150 × 150 × 150) mm and 150 mm diameter and 300 mm height is used to compute compressive strength and split tensile strength correspondingly. The specimens are removed from the mould after being put at 24 hours at room temperature and put in room temperature water for 28 days before being tested. Fresh concrete properties are arrayed in Table 5.

3. METHODOLOGY OF EXPERIMENTATION

3.1. Mechanical property examinations

Specimen dimensions (150 × 150 × 150) mm are used to test compressive strength of concrete and 150 mm diameter and 300 mm height are used to asses split tensile strength. The flexure strength test employed specimens with sizes of (100 × 100 × 500) mm and flexure testing equipment with a range of 1000 kN.

3.1.1. Test on impact resistance

The impact studies are conducted using a dropping hammer testing equipment and specimens measuring (150 × 150 × 150) mm. The dropping mass had an impact force band of 50–2000 Joules. After every phase, the impact mechanism is characterized as a phase, and the surface layer is carefully inspected. The frequency of hits at the moment the initial fracture developed in the specimen is recorded as "N1" for the earliest cracks in the concrete specimen. The following impact cycle is repeated till the width fracture on the specimen's surface extended to 1 mm, at which point the test is discontinued. The frequency of impacts is marked as "N2" at the time.

3.1.2. Resistance to chloride penetration test

Figure 4 exhibited the RCPT test setup and the silver nitrate solution (0.1) molality is promptly sprinkled upon a split surface after the specimens are separated into different pieces all along diameter. In about fifteen minutes, the color development is evaluated, and also infiltration level curves are created with a marker. The specimen is separated into 10 equal portions laterally, and the chloride penetration depth is determined. After the completion of the test, the dissemination coefficient of the chloride ions is calculated by Equation 1:

Figure 4: Chloride penetration test.

$$D_{RC} = \frac{0.023 \times (273 + T) L}{(U - 2) t} \left(X_d - 0.023 \sqrt{\frac{(273 + T) L X_d}{U - 2}} \right) \quad (1)$$

D_{RC} = Concrete non steady mitigation coefficient in m^2/s
U = Test load in voltage
T = Average anode solution temperature in °C
L = Thickness of specimen in mm
X_d = Average value of chloride ion penetration in mm
t = Electricity test time in seconds

4. RESULTS AND DISCUSSION

4.1. Influence of NS on the physical properties of concrete

Physical characteristics of FA concretes blended using NS are dramatically enhanced as compared with nominal concrete. Figure 5 demonstrates the impacts of varied NS levels here on the twenty-eight-day strength of the specimens and levels of NS, correspondingly, to make the analysis better expressive. The compressive strength of the concrete changed with the rising of NS percentage, initially increasing and afterward decreasing; the compressive strength achieved the highest value of 53.5 MPa when the quantity is three percent, a 17 percent increase over the Conventional mix. Similarly, the mix with three percentage NS components had the highest flexural strength, achieving 9.6 N/mm^2. NS is 28.3 percent more than the conventional mix. Significantly, the flexural and compressive strengths of the concrete having five percent NS contents are higher than among regular concrete without NS, despite not being the highest.

The addition of nano silica to concrete has been shown to have a positive impact on its compressive strength. Several studies have investigated the effects of nano silica on concrete properties, including its strength. The influence of nano silica on the compressive strength of concrete. They found that incorporating nano silica at a dosage of 3% by weight of cement significantly increased the compressive strength of concrete compared to the control mixture without nano silica. The researchers attributed this enhancement to the improved packing density and increased hydration of cementitious materials facilitated by the nano silica particles [35]. This reaction leads to the formation of additional calcium silicate hydrate (C-S-H) gel, which is the primary binding agent in concrete. The formation of more C-S-H gel contributes to the densification of the microstructure, resulting in increased compressive strength. The nano-sized particles of silica can fill in the gaps between cement particles and help to improve the packing density of the concrete matrix. This reduces the porosity and enhances the interparticle bonding, leading to a stronger and more durable concrete. Furthermore, nano silica particles can act as nucleation sites for the hydration products, promoting the early formation and growth of cementitious compounds. This accelerates the hydration process, resulting in the development of higher strength at earlier

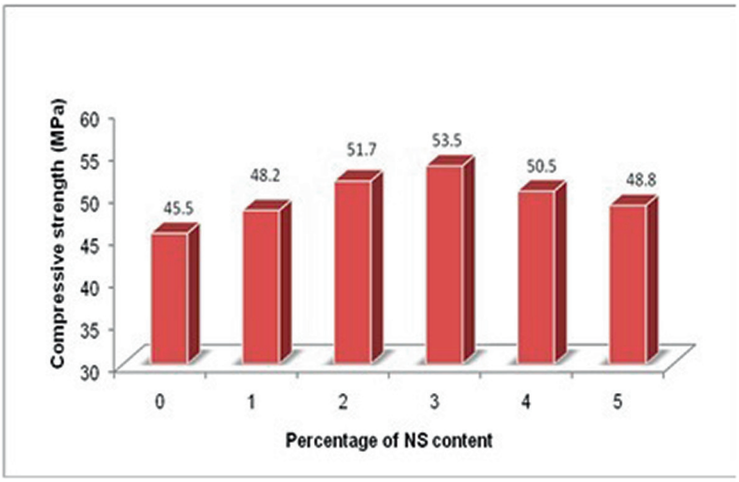

Figure 5: Fly ash concrete compressive strength with NS.

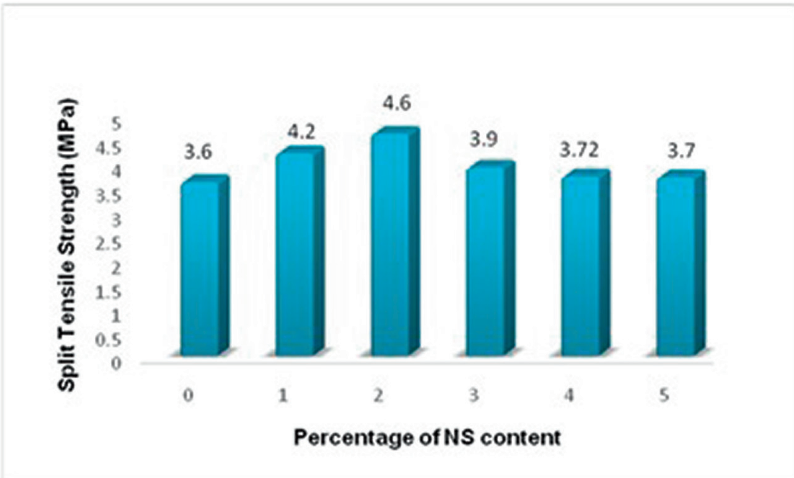

Figure 6: Fly ash concrete split tensile strength with NS.

ages. The specific dosage of nano silica in concrete mixtures can vary depending on factors such as the desired strength enhancement and the characteristics of the cement used. Generally, a small percentage of nano silica by weight of cement, typically in the range of 2% to 8%, is added to the concrete mix to achieve the desired improvement in compressive strength.It is important to note that while nano silica addition can enhance the compressive strength of concrete, other factors such as water-cement ratio, aggregate quality, curing conditions, and mix design should also be considered to optimize overall concrete performance.

Figure 6 depicts the impact of NS content modifications on the split tensile strength of concrete. When the NS content is two percentages, the splitting tensile strength of the concrete hit a high of 4.6 MPa, representing a twenty-percentage gain over the control concrete. The pozzolanic response and the nano-filling impact are the two significant explanations for the increased concrete strength. NS particles, in fact, create silanol groups due to their huge specific surface areas and ultrahigh responsiveness and combines with Ca2+ in the crystal of calcium hydroxide to generate a CSH gel. Furthermore, NS particles that show no reactions are scattered in smaller regions and fill the vacancy, enhancing the porous structure and enhancing concrete homogeneity. As said before, NS particles have exceptionally high exact surface areas, therefore coagulation events can develop in the mixture when the NS supplied exceeds the appropriate dose. Concurrently, the nanoparticles have high water retention as an outcome, abundant NS consumes the water initially necessary for the hydration process, leading to inadequate hydration process and a reduction in concrete strength. Incorporating nano silica at a dosage of 3% by weight of cement significantly enhanced the split tensile strength compared to the control mixture there by improving the bond strength between the cement matrix and aggregates due to the addition of nano silica.

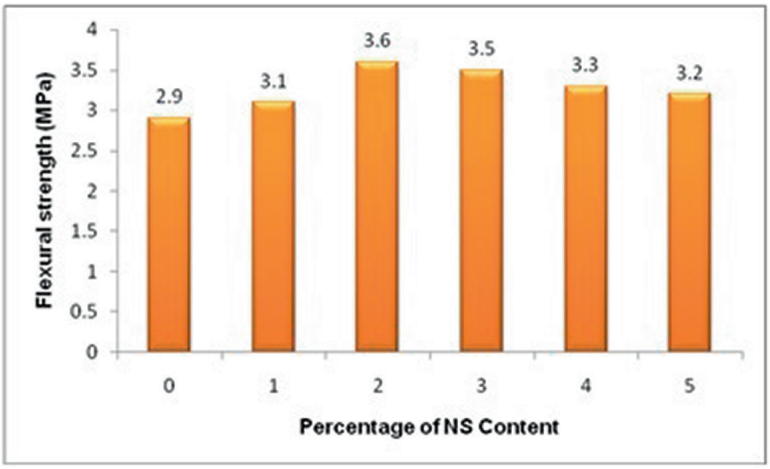

Figure 7: Fly ash flexural strength with NS.

Figure 7 shows the impact of NS content modifications on the flexural strength of concrete and the inclusion of NS had a comparable effect on flexural strength development. From the results obtained it is evident that concrete with two percentages of NS showed a 21.5% strength gain when compared to conventional concrete and beyond which strength started to decrease. The complexity in processing induced by the significant percentage of extremely fine particles is primarily responsible for the above phenomena. The influence of nano silica on the flexural strength of concrete. The researchers found that incorporating nano silica at a dosage of 2% by weight of cement significantly improved the flexural strength compared to the control mixture without nano silica. They attributed this enhancement to the improved bond strength between the cement matrix and aggregate particles, resulting in enhanced resistance to cracking and improved load-carrying capacity.

4.2. Impact resistance

Figure 8 depicts the effects of NS composition on the frequency of strikes at the initial fracture and at concrete failure. According to Figure 8 when the NS dose is even less than two percent, the frequency of hammerings rose as the NS replacement rate went up. Once substitution of NS is two percent the maximum number of hammerings at the initial fracture is found to be 38 and 41, correspondingly that are 24.1 and 30 percent greater than that of the conventional concrete. When the percentage substitution of NS is larger than two percent, blow count on concrete is made to drop as there is an initial and final crack; as the replacement rate of NS is five percent, the frequency of crack started to decrease and both first fracture and failure of concrete are loaded to 28, representing decreases of ten and thirteen percent, correspondingly, compared to the conventional mix. This shows that surplus NS can not decrease the improving effect of concrete's impact resistance; it can also decrease the impact strength. The impact energy gap of the concrete ranged from zero to 160 J as NS content fluctuated, with the greatest impact energy gap being just 160 J. This implies that NS might increase the concrete's first fracture impact resistance, however, the concrete maintains to retain energy beyond the initial crack. The volume isn't much enhanced, and the time from cracking to failure is quite short, with no change in concrete brittleness.

After being impacted, the concrete specimens having NS also shattered in partial impact path, suggesting that the inclusion of NS won't improve the impact damage structure of the concrete specimens as the specimens combined with NS even now display fragile failures pretty much identical to that of conventional concrete. Because of its strong pozzolanic activity, NS could create a CSH gel quickly by reacting with $Ca(OH)_2$ crystals placed within the Interfacial transition zone between cement and aggregate. Additionally, the NS particles infill the entire microstructure, creating it thicker and homogeneous, and so increasing the concrete strength. Furthermore, significant positive association between impact and compressive strength of NS concrete. The formation of excessive nanoparticles has a negative influence on the internal structure of the concrete, lowering its impact resistance even more. Concrete specimens mixed with NS still exhibit brittle failures similar to those of regular concrete, showing that the addition of NS did not improve the impact damage morphology of the concrete specimens. The concrete specimens containing NS also fractured in half along the impact direction after being impacted. The addition of the NS, which enhances the structure and strength of the concrete mixture, may be the cause of an increase in first crack and ultimate crack hammerings of the concrete specimens containing it. However, if excessive nanoparticles are added to the mixture, they will not be evenly distributed in the cement paste and will instead form agglomeration zones, which will then turn into weak zones.

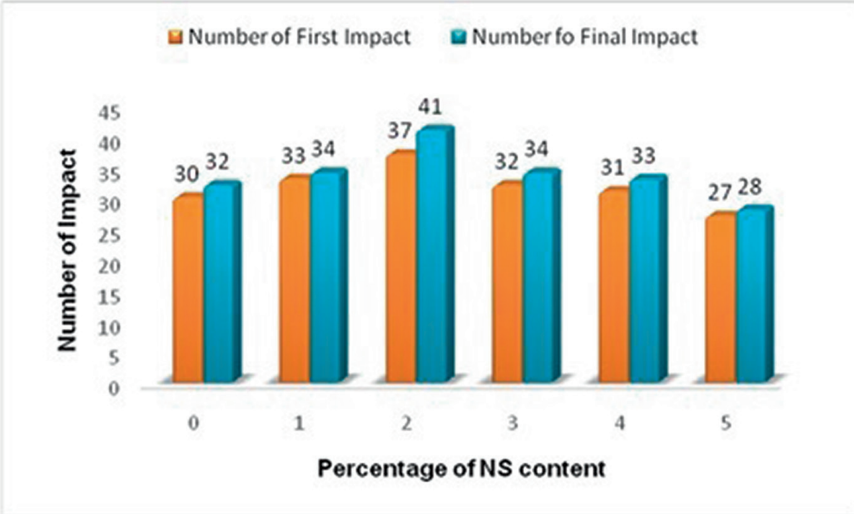

Figure 8: Influence of NS on concrete impact strength.

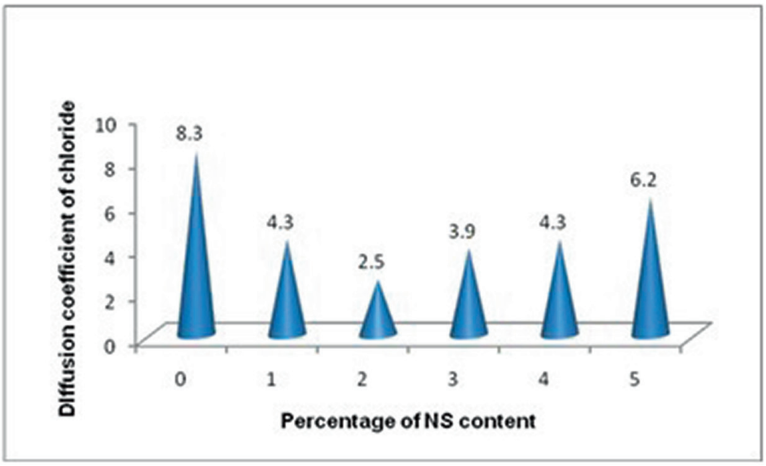

Figure 9: Influence of NS on concrete chloride diffusion coefficient.

4.3. Resistance to chloride penetration

Penetration resistance in concrete for chloride steadily improves as NS particles percentage increases. Figure 9 shows how the chloride diffusion rate (10–13 m^2/s) of concrete reduces initially and raises as the Proportion substitution of NS improves. As the NS substitution level is two percent, the chloride ion diffusion rate is at its lowest and is said to have an optimum anti-chloride ion penetrating ability.

The chloride ion diffusion rate on concrete is forty percent NS substitution level is 69.4 percent lesser than of control concrete. When such NS substitution amount is raised to three, four, and five percent, the chloride ion diffusion rate of concrete steadily raised but dropped by 58.4, 52.3, and 21.8 percentage respectively, compare to control concrete, The chloride diffusion resistance is primarily analyzed by the pore sizes of the concrete and pores bigger than 100 nm would drastically affect the mechanical characteristics and permeable resilience on concrete. NS is mixed into the mix, a nano substance with a lower particle magnitude than other additives in concrete, and it may subsequently turn dangerous pores into innocuous ones as minimizing the permeability of the concrete. It can limit the formation of concrete pores, improve pore size, and make concrete microstructures thicker and much more homogeneous. Furthermore, the NS in the cementitious matrix can substantially choke or break down capillary in the concrete, resulting in deformability and increased disconnectedness of transportation pathways, substantially enhancing the concrete chloride permeability resistance. As previously stated, the NS particles will cluster and convert capable to scatter evenly as the mix at greater NS percentage is replaced, the chloride resistant penetration will be lesser than the concrete with optimal NS threshold.

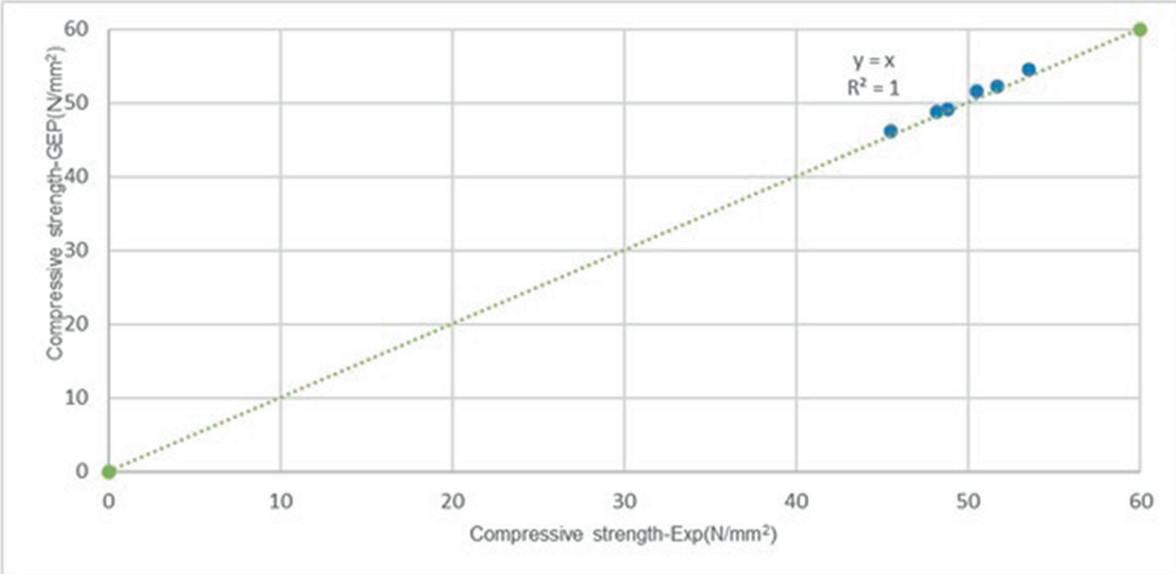

Figure 10: Predicted and actual values of compressive strength.

Table 6: Compressive strength experimental and GEP.

S.NO	NANO SILICA	E_{CS}	GEP_{CS}
1	0	45.52	46.2
2	1	48.2	48.8
3	2	51.7	52.3
3	3	53.5	54.6
4	4	50.5	51.6
5	5	48.8	49.2

Comparison of with Gene Expression Programming (GEP) model:

Gene Expression Programming (GEP) is an evolutionary computation and machine learning technique used to evolve computer programs or mathematical expressions for solving diverse problems. In GEP, computer programs are represented as gene strings, encoding mathematical expressions or sequences of operations. The process emulates natural selection and genetics, involving the evolution of populations of these programs through genetic operations like selection, crossover, and mutation. To assess the efficiency of GEP models for concrete made with nanomaterials, an experiment compared the predicted compressive strengths with the actual values using Equation 2 [35]. The results, illustrated in the Figure 10 and Table 6, demonstrate a strong correlation between the predicted and measured compressive strength values. The distribution of points closely aligns with the ideal fit, confirming the efficacy of the experimental outcomes for concrete with nanomaterials.

$$fc = \frac{\left(Ns + \left(\frac{CA}{C}\right)\right)}{0.34} + \frac{\left((10.53) + 17.03\right)}{\left(\frac{CA}{C}\right) - w/c} \tag{2}$$

Where fc = compressive strength, Ns = Nano silica, CA = coarse aggregate, C = cement, W/c = water cement ratio.

Splitting tensile strength is a crucial mechanical property of concrete with significance in structural design. In a similar manner to compressive strength, experimental data for split tensile strength is utilized to assess the accuracy of the GEP model's predictions using Equation 3. The GEP model use to predict the splitting

Table 7: Split tensile strength experimental and GEP.

S.NO	NANO SILICA	E_{STS}	GEP_{STS}
1	0	3.6	3.8
2	1	4.2	4.3
3	2	4.6	4.7
3	3	3.9	4.2
4	4	3.72	3.82
5	5	3.7	3.9

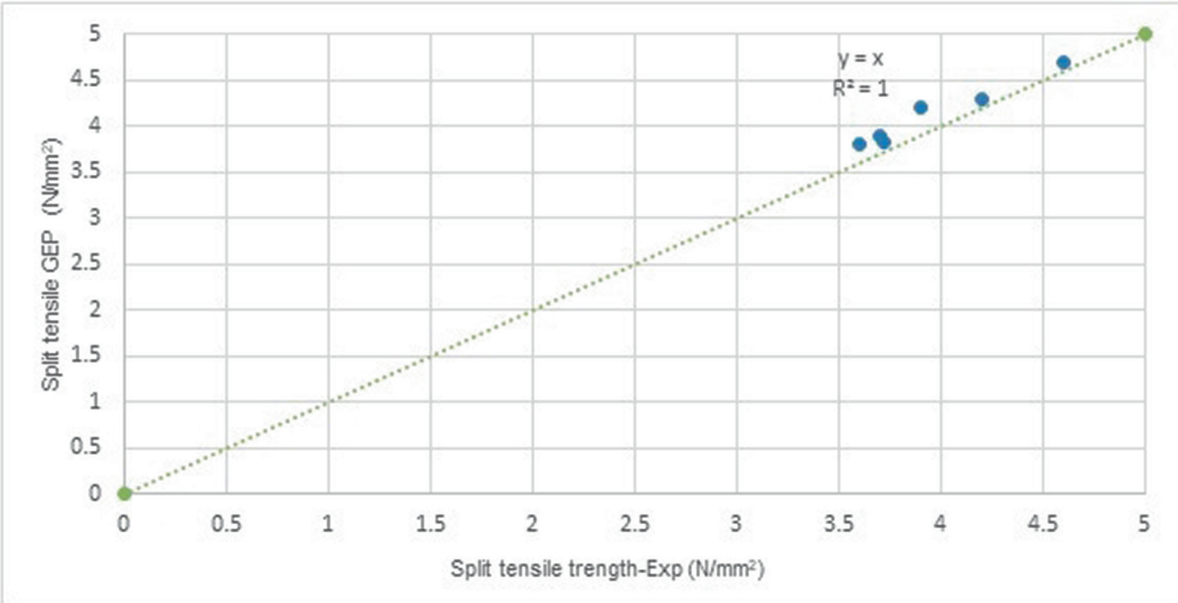

Figure 11: Predicted and actual values of split tensile strength.

tensile strength of concrete based on the water-binder ratio, age of the specimen, and the compressive strength of the 150-mm cube. To validate the GEP model, additional experimental data, separate from the data used during the training and testing of the model, is employed. The GEP model's predictions are then compared with the actual experimental results as shown in Table 7 and Figure 11. The study's findings indicate that the GEP formulations outperform in predicting the splitting tensile strength of concrete, showcasing their superior performance compared to the experimental results.

$$fs = \sqrt{fc + 2WB - 5.58 * \sqrt{\frac{0.4AS - 1}{AS}}} \tag{3}$$

Where fc = compressive strength = Water binder ratio, AS = Independent variable.

5. CONCLUSION

Based on experimental findings of physical properties, resistance test which includes impact and chloride penetration, the following findings have been reached:

1. The interaction of NS particles that have $Ca(OH)_2$ at the ITZ produced greater CSH gel and densified the microstructure, resulting in considerably better mechanical characteristics of the specimens compared to a conventional mix. The ideal quantity for every mechanical attribute, meanwhile, is dissimilar; the split tensile strength achieved the highest strength, NS substitution level is two percent, while the compressive and flexural strength reaches peak value when NS substitution level is three and two percent respectively.

2. Adding NS particles improves impact resistance at the initial breaking of the concrete; nevertheless, time from beginning cracking to failure is quicker, and the fragility of the concrete remains the same. Following an impact, the concrete specimens having NS are split into two parts mostly on the impact axis, and the specimens displayed brittle failures, much like regular concrete.
3. In comparison to the control concrete, a little quantity of NS could significantly improve the concrete's chloride diffusion resistance. A homogeneous scattering of NS particles is easily done at the two percentage replacement levels. The decrease in the chloride diffusion coefficient is caused by the enhancement of the porous architectures in the concrete as well as the packing action of the NS.
4. The experimental compressive strength and split tensile strength are in agreement with existing GEP model.

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