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Synergistic Effect of Nano River Shell Powder and Zeolite on the Strength and Durability Characteristics of Concrete

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Abstract

Concrete is a composite material used in the construction sector because of its high-quality mechanical and physical qualities. Utilizing by-products from the aquaculture industry, such as snail shells, is a major problem. One of the most efficient ways to address this demand is to incorporate natural zeolites into the concrete-making process so as to increase the material's performance, structure, durability, and mechanical properties. Calcium-rich river shells are in demand as an additive to cement. One of the most demanding yet exciting research problems for many scholars in this industry to date has been enhancing the features of concrete to deal with such limits. This essay sets out to accomplish that very thing by outlining the steps required to create a nano-modified concrete with enhanced properties using nano-river shell particles and natural zeolite. The current study provides a novel way for integrating zeolite, a mineral additive, with spacers constructed of synopsis (nanosized river shell powder) to make a composite with greater strength and stability. The produced composites were used to experimentally evaluate the impact of natural zeolite and nanosized powders of snail shell on the structural and mechanical features of composites. Also evaluated were the effects of incorporating several percentages of zeolite into the cement mix (5 - 10%, 15 - 25%, and 20 - 30%). When combined with zeolite, the shell powders' filling and reinforcing characteristics led to positive results in mechanical strength testing. Natural zeolite's high-water crystallization made it an ideal internal cure and improved cement hydration in cement manufacturing.

Keywords

Composite, Concrete, Mechanical strength, Natural zeolite, Snail shell

Introduction

The accumulation of waste from agriculture and aquaculture is currently a significant environmental issue. The use of waste products from many industries, including agriculture, aquaculture, and manufacturing, as constituents for cement is the true objective of the exploration of building components and construction processes [1]. In addition, it is essential to retain the quality of the concrete at an acceptable level and frequently search for techniques to enhance the qualities of the concrete using recycled waste [2]. Using this strategy makes it possible to have complex monetary and environmental repercussions. To begin, it entails improving the technical qualities of concrete and concrete mixes. Two, the act of throwing waste away has an effect on the surrounding natural ecosystem. Thirdly, decreased prices have the potential to have a cost since they decrease the cost of producing new cement that is stronger [3]. Within the realm of scientific research, work is being done to look for viable replacements for cement that can be created from waste products. It is not an unrealistic assumption to make that if these wastes were used as alternatives in construction, it would help address both the ongoing rubbish problem and the urgent desire for more self-sustaining concrete mixtures [4]. The production of these waste products is expanding at alarming rates, and there is no conventional or efficient way to clean them up [5]. One of the waste components that is swiftly gathered is seashells, particularly in coastal regions and countries where there is a large consumption of seafood. The shell is considered to be a part of the animal's body. Shells that have been washed up on coasts are frequently discovered by beachcombers to be empty [6]. The soft parts of the organisms' shells have been consumed by the carnivores and predators who feed on the dead corpses of the creatures, leaving the shells empty [7]. It is noteworthy to notice that different kinds of shells, such as clam and mussel shells, may have similar chemical compositions [8]. As a result of the low value of shell trash, it is routinely abandoned on beaches, croplands, and roadside ditches, resulting in communities that are entirely covered with shells [9]. The residual meat that is still clinging to the shell gets broken down by microorganisms, which then release noxious odors that affect the area surrounding waste sites. Therefore, recycling shell waste is absolutely important in order to promote the sustainable growth of shellfish aquaculture [10]. Using any one of a number of different methods, one can determine how long concrete will last. A number of different types of water absorption tests, including those for electrical resistivity, penetration depth, surface water absorption, primary water absorption, and secondary water absorption, have gained popularity. Under the conditions of the ambient temperature, the sorptivity coefficient that zeolite possesses has increased [11, 12]. One of the most important aspects that determines how long concrete will last is the quantity of water that penetrates it. At room temperature, the amount of water that penetrates concrete can be lowered by increasing the amount of zeolite that is present in the concrete [13]. This inquiry makes use of 5%, 10%, 15%, 20%, 25%, and 30% zeolite as a replacement for cement at various percentages. The current work provides a novel way for producing a composite with better strength and stability by combining zeolite, a mineral admixture, and bio-carbonate fillers (nanosized snail shell powder).

State of art

According to the findings of the research [14], an innovative type of recycled aggregate concrete can be produced by crushing concrete using slag from electrical arc furnaces as the material. This process yields coarse recycled aggregate, which is then used in the production of recycled aggregate concrete. These counts are a waste product of the steel manufacturing process; nonetheless, their application in the technology behind concrete and asphalt is a cutting-edge invention that eliminates the requirement for the use of natural components. Traditional paver blocks were made with recycled asphalt concrete rather than natural coarse aggregate (CA) and river sand, as was done in the study [15]. The mechanical and durability parameters of the paver blocks, such as "density, compressive strength, water absorption, abrasion resistances, and ultrasonic pulse velocity," were evaluated. In earlier studies, different proportions of fly ash (15 and 30 percent by weight) and polypropylene fiber (0.06, 0.12, and 0.18% by volume) were employed in place of cement in increasing degrees [16]. Experiments on slump, density, ball penetration, and compacting factor using twelve various volumes of concrete mix were used to investigate the properties of new concrete. Also, the researchers investigated how the incorporation of fly ash changed the parameters of workability in coconut shell (CS) concrete [17]. In one mixture, CS was used, while in the other, traditional aggregate was combined with CS to create a mixture that also contained CS as CA. In each and every mixture, Class F fly ash was utilized in place of cement at varying percentages of weight replacement, including 0%, 10%, 20%, and 30%. According to the findings of the tests, the CS concrete mixture that contained 10% fly ash as a replacement level had the highest levels of both compressive and tensile strength. The purpose of the investigation [18] is to investigate the effects that would result from replacing cementitious materials in the production of concrete with high-volume sugar cane bagasse ash at a rate ranging from 10% to 50%. It was demonstrated that concrete mixtures could be formed that had breaking strengths of 28-day cubes that were larger than 25 MPa and that the strength increased with time, reaching greater than 30 MPa after three months. According to the findings of the research [19], the inclusion of snail shell powder served as a simple and cost-effective means of rendering graphite oxide concrete mixture composites more fluid. In addition, the efficacy of morphology, machinery, and durability in snail shell-based graphene oxide concrete compounds should be investigated. Experiments were carried out in the study [20] to determine the extent to which alccofine, zeolite, and polypropylene fibers contributed to the durability of concrete. In place of cement, zeolite (10%) and alccofine (15%) have been used. Experiments have been performed in order to determine what constitutes the optimal combination. As the fine aggregate (FA), we employed 55% natural river sand and 45% manufactured sand. The resilience of self-curing cements using calcination temperature and powdered zeolite as a cement substitute was the primary focus of the study [21]. Concrete that is normally treated in water is used as a comparison for testing the performance parameters of self-curing concretes that are cured in air [22].

Experimentation

Sample preparation

The term "shells" can apply to either seashells or other comparable materials, both of which are commonly gathered from the wild. The sand, mud, and other particles of their environment may have found their way into these shells [18]. It is necessary to wash the resulting shell powders to remove any remaining contaminants. The shells are washed and sanitized to remove any contaminants that could lower the quality of the end product. Following cleaning, the shells are heated to increase their brittleness. This is done so that grinding the shells into powder is less of a chore. The required degree of brittleness is achieved by subjecting the material to heat at a given temperature for a set amount of time [19]. In this example, the shells are heated at 200 degrees Celsius for one hour. This process decreases the structural integrity of the shells, making them more prone to breaking down into smaller fragments. The brittle shells are ground into a powder via a grinding process. Mechanical force is used to crush the shells into smaller pieces by grinding. In order to reduce the size of the generated shell particles to 40 microns [20], grinding is used. The increased surface area of the particles as a result of their size reduction is useful in many contexts, such as in the mixing of materials or the enhancement of reactivity. Lab synthesis reduces the powdered shells from micro- to nano-size. This is most likely achieved through nanoparticle synthesis, in which the micron-sized shell powders undergo additional processing to achieve nanoscale. When compared to bigger particles of the same substance, nanoparticles might display various behaviors and impacts due to their unusually small size (Figure 1). Table 1 presents oxide composition of raw materials.

Figure 1: Nano conversion of shells.

Table 1: Oxide composition of raw materials.

Oxides (%)	Cement	Zeolite	River sand	River shell
SiO_2	21.02	63.87	95.86	0.70
CaO	63.01	2.37	-	53.10
SO_3	2.92	-	-	0.21
Na_2O	0.51	6.81	-	1.23
P_2O_5	-	-	-	0.22
Fe_2O_3	4.08	0.215	0.65	0.60
ZrO_2	-	-	-	-
Al_2O_3	4.99	11.47	1.24	0.50
MgO	0.89	1.00	-	0.64
K_2O	0.23	0.94	0.35	0.10
TiO_2	-	-	-	0.02
Mn_2O_3	-	-	-	0.02
LOI	1.25	11.97	1.90	38.70

Mix details

For this study, we replaced some of the cement in the concrete with zeolites and nano-shell powders (nSP), varying the cement content from 5% to 30% by increasing it by 5% and from 0.2 to 1% by increasing it by 0.20%, respectively (Figure 2). The concrete control mix (CM) was used as a comparison to the concrete mixtures that were created using the cement replacements. Overall, there was a quantity of binder that equated to 500 kg/m^3 with a water-to-binder ratio of 0.4 [4, 5]. In the first step, the coarse and fine particles, together with the solid components, were mixed together for a period of three minutes. After the combined water had been absorbed, the components of the binder, including cement and nSP, were added very carefully, and the mixture was agitated for a total of five minutes before proceeding. After thoroughly combining the dry ingredients for the concrete for five minutes, the second half of the water and the superplasticizer (SP) were added (Table 2).

Figure 2: Specimen casted.

Table 2: Mix proportion details of developed samples.

Mix ID	Cement	Zeolite	nSP	FA	CA	SP
	kg/m^3					l/m^3
CM	376	-	-	741	1228	2.7
nSPZ1	356.448	18.8	0.752	741	1228	3.1
nSPZ2	336.896	37.6	1.504	741	1228	3.9
nSPZ3	317.344	56.4	2.256	741	1228	5.2
nSPZ4	297.792	75.2	3.008	741	1228	5.9
nSPZ5	278.24	94	3.76	741	1228	6.8

Note: CM refers control mix, nSP refers nano-shell powders, FA refers fine aggregate, CA refers coarse aggregate, Z refers zeolite, SP refers superplasticizer.

Testing methods

The workability of concrete is a property in its fresh state. In this study, it is determined by slump cone test conforming to IS 1199-1959. The strength properties such as compressive, flexural, split tensile are performed as per the IS 516-2021 on 150 mm cubical samples, 100 x 500 mm prismatic samples, 150 x 300 mm cylindrical specimens, respectively. The impact test was conducted as per the procedure recommended by ACI committee 544 on concrete discs of 152 mm diameter and 62.5 mm thickness. The pull-out strength test of concrete measures the bond strength which develops between the concrete and steel. The bond strength of the concrete was determined as per the procedure stated in IS 2770-Part I. The concrete cubes were cast into 150 mm sizes with the steel rod embedded at the center of diameter 16 mm and length 500 mm is wound with insulated tapes on their outer surface. The bond strength can then be calculated using equation 1.

$$\sigma_{bu} = P_b/\theta dl \qquad (1)$$

Where, σ is ultimate bond stress, P_b is bond failure load, d is diameter of bar, l is length of the bar.

The water absorption and porosity of the samples are conducted on 100 mm concrete cubes as per ASTM C642 using equation 2 and equation 3, respectively.

$$\text{Water absorption} = \{(W_1 - W_2)/W_1\} \text{ x } 100 \qquad (2)$$

$$\text{Porosity } (\%) = \frac{W_2 - W_1}{W_2 - W_3} \text{ x } 100 \qquad (3)$$

Where W_1 is the weight of an oven dried specimen, W_2 is the weight of immersed specimen, W_3 is the weight of specimen in submerged condition.

The chloride penetration test was conducted using rapid chloride penetration test (RCPT) by measuring the electrical current that passed through the sample (measured in coulombs). The electrical conductance is calculated using equation 4, as follows.

$$Q = 900\,(I_0 + 2I_{30} + 2I_{60} + 2I_{90} + 2I_{300} + 2I_{330} + 2I_{360}) \qquad (4)$$

Where Q is charge passed in Coulombs; I_0 is current immediately after voltage is applied in amperes; It is current at t minutes after voltage is applied in amperes.

The RCPT procedure was performed on 100 mm diameter and 200 mm length cylindrical specimens in accordance with the procedure stated in ASTM C1202-19. To assess the durability of the concrete specimens the compressive strength was calculated after immersion in aggressive environments such as sulphate and acids. The 100 mm cubical concrete specimens were immersed in three different solutions containing 1% hydrochloric acid (HCl) and 5% sodium chloride (NaCl) for a period of 28 days and tested for compressive strength loss conforming to the procedure stated in IS 516-1999.

Results and Discussion

Fresh properties

Slump test results for prepared concrete mixes including various percentages of nSP and zeolite are presented in figure 3. The more cement was replaced by zeolite, the more SP was needed to sustain the slump of concrete, which can be linked to the huge number of pores in its frame structure and high surface area. Furthermore, adding more zeolite increased the viscosity of fresh concrete, making it appropriate for the production of pumping concrete. Other writers achieved similar results on the characteristics of fresh concretes including natural zeolite [23, 24]. However, it was discovered that naturally occurring zeolite had no discernible effect on the workability of fresh concrete [25]. The addition of nSP aids in maintaining the permissible slump limit, owing to the coupled impact caused by zeolite and nSP.

Strength characteristics

Figure 4 depicts the compressive, flexural, and split tensile strengths of concrete incorporating zeolite and nSP as cement substitutes. It is obvious that with 15% zeolite and 0.6% nSP replacement, the compressive strength value decreases slightly but does not go below that of the standard concrete mix (REF). The presence of zeolite reduced compressive strength, which became more evident at greater quantities, indicating an obvious constraint on compressive strength advancement, which is triggered by the aggregate emergence of filler particles, which leads to stress focus and thus reduces compressive strength. The increase in strength is mostly attributed to the filler's impact of nSP, which additionally aids in densifying the concrete combined with the zeolite content. Further to the zeolite impact in concrete, the shell powders occupied the spaces between the gaps in the concrete substrate. The strength decline above a certain level may be owing to highly fine shell powders that displayed interspecific enticement, creating aggregation of the powders and inadequate distribution in the matrix.

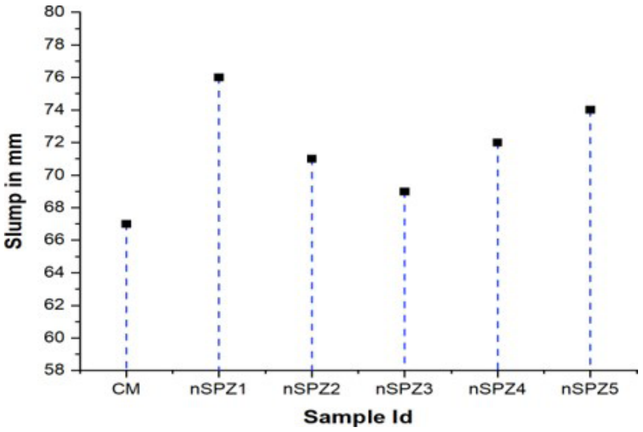

Figure 3: Slump results of developed concrete.

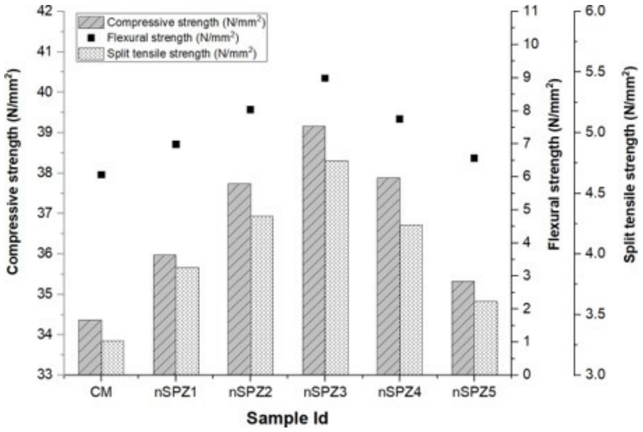

Figure 4: Strength behavior of nSP-Z substituted concrete mixes.

The flexural findings indicate that the nSP and zeolite substantially boosted the strength of the concrete mixes because of their surface properties, which enhanced cohesion among the concrete matrix and the filler material's surface, thereby boosting the flexural strength of concrete. The detected rise in split tensile strength could be attributed to the concrete's inherent strengthening potential as a result of the nSP + Z replacement. When comparing compressive, flexural, and split tensile strength to REF mix, the 28-day percentage strength gain has been identified to be 13.94%, 48.18%, and 45.43%, respectively.

Impact strength

Figure 5 depicts the impact strength of the nSP and zeolite-replaced concrete. It is obvious that as the nSP/Z substitute grew, the impact strength of the concrete rose, while exceeding 15% zeolite substitutes, the impact strength decreased. The concrete mix comprising 15% zeolite and 0.6% nSP had the strongest impact strength, with a recorded elevation in value of 14.9%, 34.3%, 47%, 23.2%, and 12.2% compared to the concrete CM for nSPZ1, nSPZ2, nSPZ3, nSPZ4, and nSPZ5. This demonstrates that combining zeolite

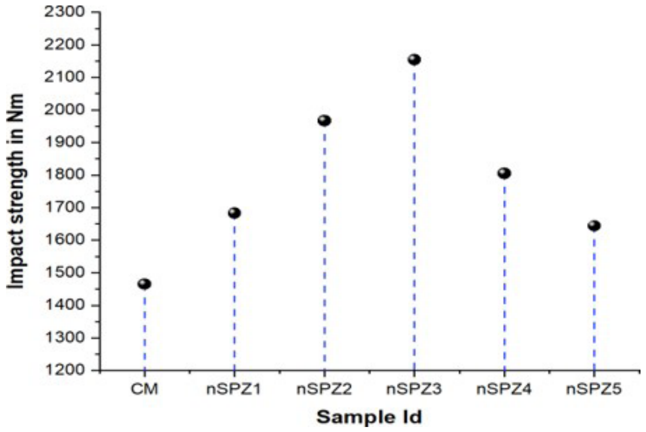

Figure 5: Impact strength of nSP-Z substituted concrete mixes.

and nSP provides a stronger effect on boosting concrete impact strength, thus raising the amount of energy necessary to induce cracks in the concrete.

Bond strength

The steel rod embedded within the concrete was enclosed by a well-stranded network of nSP and zeolite. The primary factor responsible for the rise in bond strength is the interfacial transition zone (ITZ). Consequently, the strength of the concrete's ITZ is informally indicated by the enhanced bond strength value. The cement matrix and FAs are reinforced by the extreme filler impact caused by nSP paired with zeolite. The reduction in the interlocking actions taken by FAs caused by an elevated substitute for cement percentage in concrete might be the reason for the observed drop in bond strength advancement beyond 15% zeolite (Figure 6).

Water absorption

The presence of zeolite improved the amount of water received by all concrete mixes. The pores created by the inclusion of zeolite generated a porous concrete matrix that functioned as spaces whereby water that was free could be confined, resulting in decreased water stability. Additionally, the zeolite's high hygroscopic tendency enabled water molecules to diffuse through the tiny spaces in the concrete matrix. However, the addition of nSP in the concrete compensates for this change, and the water absorption rate decreases as a result of up to a 15% zeolite substitute. Despite this, shell powders showed an exceptionally high degree of fineness and a significant number of tiny pores that enhanced their affinity for water, increasing the concrete's capacity for absorbing water. As a result, the nSP functioned as interconnecting routes to facilitate better conveyance of water rather than fillers. At 15% Z/0.6% nSP, there was a noticeable drop in water absorption, while the water absorption rate typically increases above 15%. The percentage drop for nSPZ1, nSPZ2, nSPZ3, nSPZ4, and nSPZ5 is approximately 10.76%, 26.22%, 35.62%, 25.44%, and 10.76%, respectively (Figure 7).

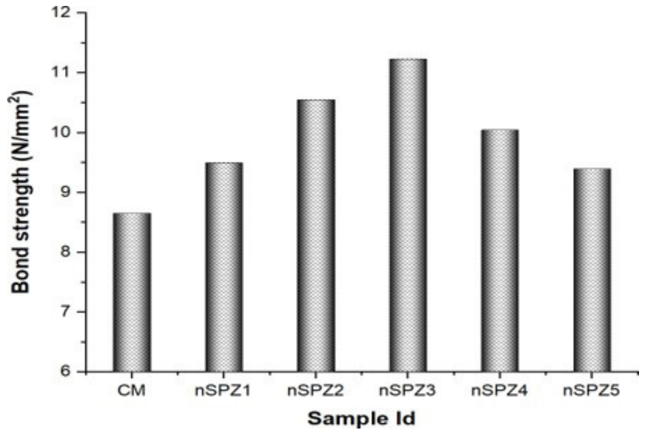

Figure 6: Bond strength of nSP-Z substituted concrete mixes.

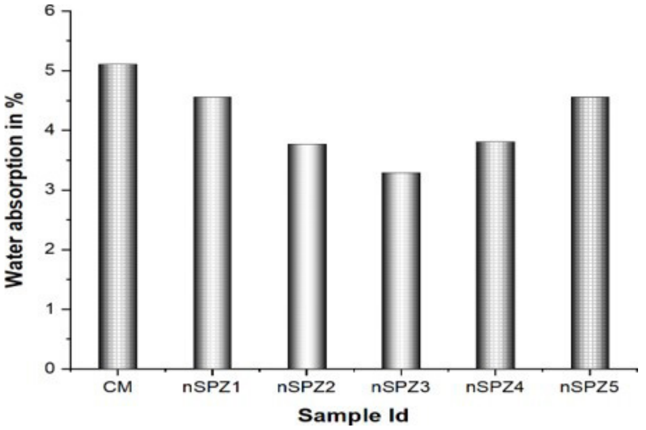

Figure 7: Water absorption of nSP-Z substituted concrete mixes.

Porosity

As zeolite and nSP concentrations increased up to 15% Z + 0.6% nSP, a declining trend in porosity values was noted. Subsequently, a discernible rise is apparent, which can be attributed to the abundance of micropores as well as the ineffective distribution of the shell powder, which creates spaces among the cement grains and raises the porosity proportionately. This type of porosity measured accounts only for the macro pores and generally micro-pores have a negligible role in this type of porosity measurement. It is clearly evident that at higher magnitude levels of substitution of nSP in the concrete created water channels leading to the excess amount of free water spaces that has led to the increment in the pores when evaporated. The 0.6% nSP showed the largest drop in porosity, indicating the hydrophobic nature of the used river shell powder. The higher porosity reduction of about 19.55% is attained at optimum replacement level. The substantial decrease in porosity could be ascribed to the zeolite and nSP's fine texture, which encompass the inter-crystalline as well as inter-laminate pores and alter the concrete matrix's permeable system. The porosity findings demonstrated a comparable pattern of rising or falling to those of the water absorption outcomes (Figure 8).

RCPT

The results presented in figure 9 clearly signify the beneficial role of nSP and zeolite in reducing the chloride penetration through the concrete. The total charge passed through the concrete reduced significantly with increase in the zeolite + nSP substitution but it increases slightly beyond 15% replacement level. Thus, the chloride penetration is greatly

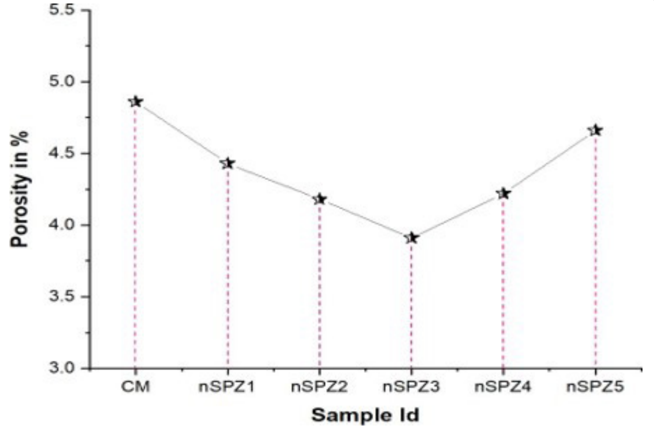

Figure 8: Porosity values of nSP-Z substituted concrete mixes.

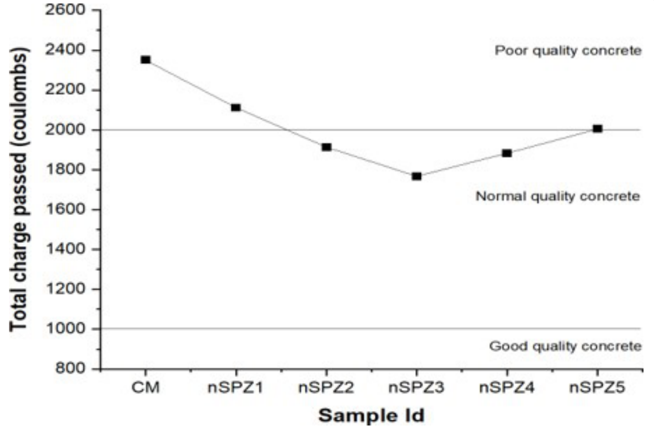

Figure 9: RCPT values of nSP-Z substituted concrete mixes.

hindered by the combined action of nSP and zeolite that reduces the charge that can be passed through the concrete. The finer nature of shell powder and zeolite makes the matrix highly resistant towards chemical attack and also reduced the minute opening through which ions can permit through. Comparing the charge passed of the CM, the percentage reduction of chloride penetration is recorded as 10.21%, 18.63%, 24.84%, 19.91%, 14.72% for nSPZ1 to nSPZ5 mixes, respectively. It is clearly evident that the obtained values range between 1500 to 2400 coulomb which results in negligible chance of chloride penetration.

Salt attack

The crystalline formation of salts upon the concrete surface causes significant degradation of the concrete's strength attributes. The use of concrete structures in salt-rich environments can cause significant harm to the surface characteristics of the concrete, making salt attack a must-study when considering the long-term reliability of concrete structures. Figure 10 depicts the mean compressive strength outcomes prior to and following immersion in salt solution. The original compressive strength of the nSP-Z replaced mix had been nearly entirely maintained after being exposed to NaCl, as shown in figure 11.

The loss in strength percentage is almost linearly decreasing for all the developed concrete mixes. As expected, the unmodified concrete exhibited higher strength loss than the other concrete mixes. The percentage strength loss is recorded as 3.58%, 3.06%, 2.70%, 2.22%, 2.67%, 3.09% for CM, nSPZ1, nSPZ2, nSPZ3, nSPZ4, nSPZ5 mixes, respectively. It can be clearly evident that the concrete with 15% Z-0.6% nSP exhibited least strength loss whereas beyond that the strength loss percentage increases linearly. Moreover, the presence of nSP in combination with zeolite effectively held the constituent particles of the concrete matrix from disintegrating and also prevents the micro crack formation and material separation.

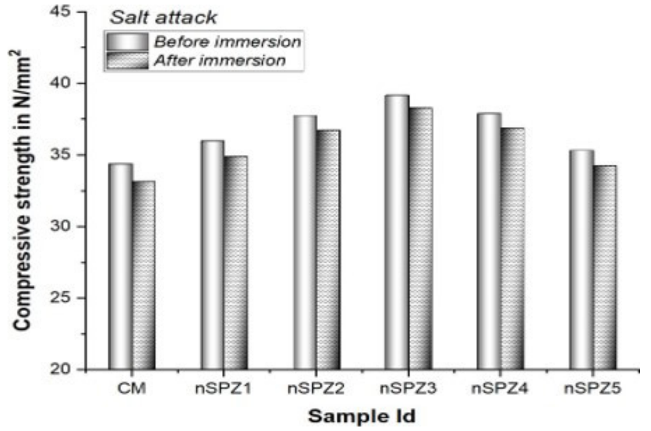

Figure 10: Compressive strength of nSP-Z concrete before and after NaCl exposure.

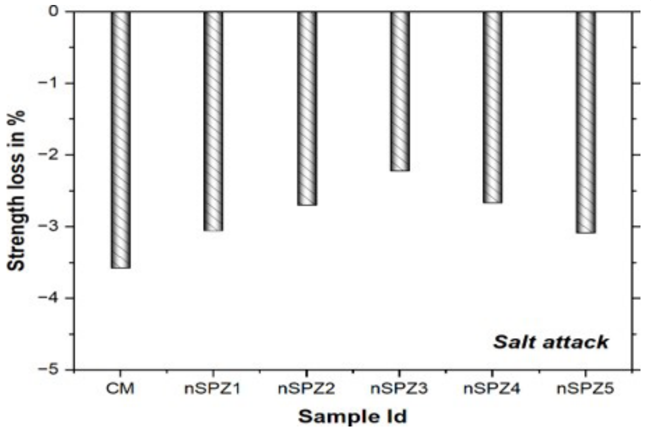

Figure 11: Strength loss percentage of nSP-Z concrete after NaCl exposure.

Acid attack

The physical and mechanical properties of concrete are high whereas subjected to the attack of acids the strength of concrete deteriorates quickly. Concretes are generally alkaline in nature and hence they are easily susceptible to the attack of acids. The alkaline phase reacts with acids to form calcium salts that get easily soluble and washed away. This formation of soluble salts weakens the concrete thereby affecting the durability of concrete. The chloride ions present in HCl acid react with the hydration product forming calcium chloride which gets easily transported from the outer layers of concrete to the interior regions. The strength recorded before and after exposure to acid exposure is presented in figure 12, whereas figure 13 represents the compressive strength loss.

The obtained results clearly evident that the increasing

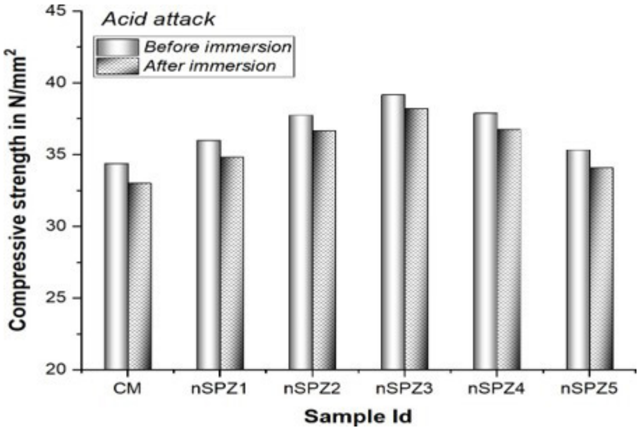

Figure 12: Compressive strength of nSP-Z concrete before and after HCl exposure.

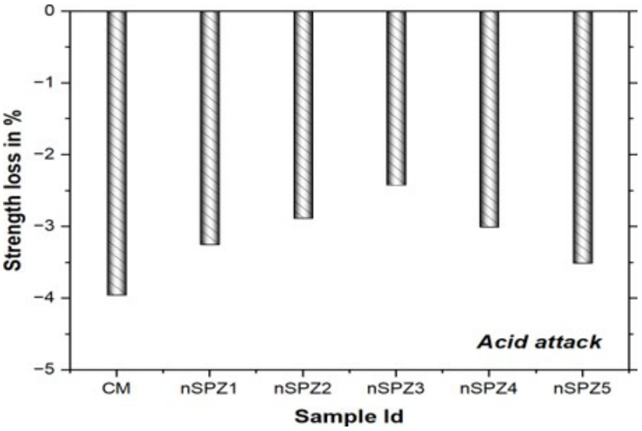

Figure 13: Strength loss percentage of nSP-Z concrete after HCl exposure.

substitution of both nSP and zeolite in concrete matrix decreased the strength loss percentage till 0.6% and 15% substitution, respectively. After that a slight increase in strength loss is observed but not greater than the concrete CM. The higher strength loss after exposure to HCl is visible in CM whereas the lower strength loss is recorded as 2.43% for nSPZ3 mix. At 20% and 25% zeolite in combination with respective percentage substitution of nSP (0.8% and 1%), the strength loss percentage is slightly increased to 3.01% and 3.51%, respectively, while 3.96% is recorded for CM.

Microstructural analysis of concrete

Scanning electron microscope (SEM) analysis

By examining the microstructure of the concrete, one may clearly identify the mechanical behavior and physical properties of the ingredients. The specimens that were evaluated under compressive strength and then coated for precise SEM imaging served as the samples for the SEM study. The SEM analysis of concrete zeolite mixed with nanosized snail shell powder was performed. Figure 14 depicts the SEM images of zeolite and snail shell powders.

It was found that the density morphology in the specimens of nanosized snail shell powder points to the existence of compact hydration production, the CSH layer, and needle-like crystalline structure. By inducing the synthesis of CSH and C3S, zeolite hastens the hydration process in concrete. The hydration process refers to the chemical interaction between water and cement. The first reaction phase, the quiescent period, the accelerating period, the declaration time frame, and the final sluggish reaction period are the five stages of the absorbed water. Zeolite mix reduces setting time, concrete porosity, and deterioration in concrete, increasing cement hydration rate. The hydration process that takes place at the surface is mostly to blame for this. By preventing water from mixing with the concrete well during hydration process, the detonation creates a crystal-like layer on the top next to the cement grains. The water content under the shell is accelerated by the incorporation of nanoparticles at the nucleation location, leading to a thinner structure and increased CSH gelation. Additionally, it aids in the uniformly distributed of cement substitute on the surface by promoting denser morphology.

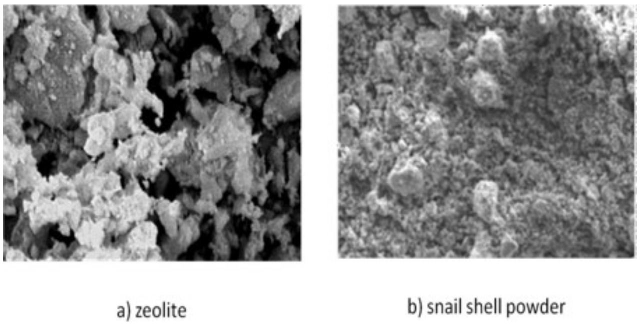
a) zeolite b) snail shell powder

Figure 14: SEM images of zeolite and snail shell powder.

Energy dispersive X-ray spectroscopy (EDX) analysis

EDX analysis was performed on the zeolite and nanosized snail powder samples. EDX analysis revealed significant components including Si, C, Ca, O, and Al, validating the synthesis of CSH, CH, and ferrite in the concrete aggregate. A graph showing cross count vs energy level is the EDX diversity. Each peak represents a unique, separate element. An entity's presence in the sample under study was larger in proportion to its number in the EDX spectrum. Altered protein ions could also be appropriately resolved in the cross peaks at the same time. The percentage of the cement's primary elements (Ca, Si, Fe, and Al) was discovered by microanalysis using EDX, and this information may be utilized to ascertain the cement's characterization. Figure 15 illustrates the elemental makeup of the nanosized snail shell powder specimen.

It was discovered that the calcium content was higher than the atomic amount of silica. According to the spectra, trace elements such (Al, Fe, K, Mg, and S) were only in small amounts. Additionally, EDX's quantitative study of composite material often yields unreliable results. Figure 16 depicts the range of zeolite admixture. In this range, the strength of the silica and calcium peaks stands out.

Due to contraction and creep growth, there will be weak pore architecture if the number of nanoparticles is more than the optical quality. Pore size reduction increases cement density, which may enhance the relationship only between cementitious matrix and aggregates formation. As a result, improved cement strength may be associated with

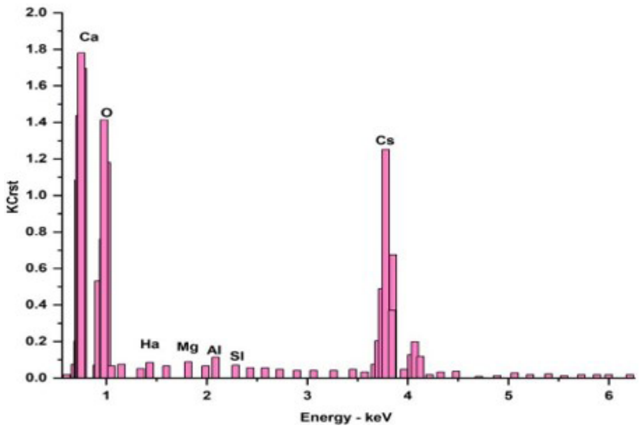

Figure 15: EDX spectrum for nanosized snail shell powder.

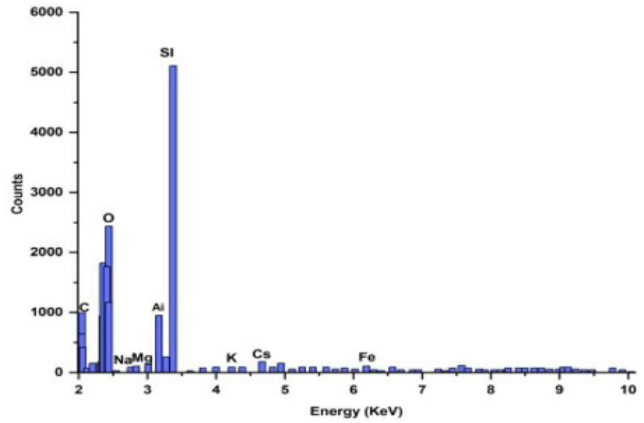

Figure 16: EDX spectrum for concrete zeolite-admixture.

increased density. In this study's microstructural analysis, it was discovered that 10 - 20% zeolite substitution in cement produces the best results.

Conclusions

The strength and endurance properties of zeolite and nano-river shell powder as cement substitutes are explored. The zeolite/nSP concrete underwent evaluation with multiple replacement percentages (0 to 25% zeolite and 0.2 to 1% nSP). Each evaluation took place across three samples corresponding to each mix, and the mean of all three results was employed to figure out the research outcome. Both specific and broad implications that might be drawn from the results of the research are as follows.

- The inclusion of nSP helps to counteract the effect caused by the substitution of zeolite and maintained the slump within the acceptable criteria.
- With regard to mechanical strength, the nSP substituted concrete matrix exhibited improved compressive, flexural and split tensile strengths until 15% zeolite and 0.6% nSP substitution. The least strength percentage increment of about 2.76% (compressive), 8.25% (flexural), 10.06% (split tensile) is attained for nSPZ5 mix, whereas the greater percentage attained for nSPZ3 is observed to be 13.94% (compressive), 48.18% (flexural), 45.43% (split tensile) respectively. The strength increment is chiefly due to the filler effect of nSP which further helps in densifying the concrete along with the zeolite content.
- The efficient binding of nSP with zeolite in the concrete matrix increased the energy required for inducing cracks in the concrete. The extreme filler effect of nSP along with zeolite around the FAs and cement matrix thereby strengthening the ITZ.
- Water particles diffused through the concrete matrix's pores owing to the water-soluble behavior of zeolite, although the impact was mitigated by the concrete's incorporation of nSPs. Rather than serving as additives, the nSPs acted as interconnecting channels that facilitated better movement of water.
- Because zeolite and nSP occupied the inter-crystalline and inter-laminate pore spaces, modifying the permeable structure of the concrete matrix, there may have been a substantial decrease in porosity.
- The salt attack and acid attack result also indicated that the concrete with zeolite and nSP showed reduced strength reduction percentage until 15% Z and 0.6% nSP whereas beyond that the strength loss slightly increases. This improved resistance to both salt and acid attack is due to the enhanced properties of nSP and zeolite in concrete. Thus, the developed nSP-Z concrete can be used as an efficient material to be used in structural applications prone to sea water attack such as coastal regions.

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None.

Conflict of Interest

None.

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