INTERNATIONAL JOURNAL OF INTEGRATED ENGINEERING
ISSN: 2229-838X e-ISSN: 2600-7916

IJIE

Vol. 16 No. 1 (2024) 350-360
https://publisher.uthm.edu.my/ojs/index.php/ijie

Combined Effect of Nano Ferrite and Nano Silica on Properties of Cement Mortar

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DOI: https://doi.org/10.30880/ijie.2024.16.01.030

Article Info

Received: 24 February 2023
Accepted: 24 February 2024
Available online: 1 June 2024

Keywords

Antibacterial, cement, mortar, nano-ferrite, nanotechnology

Abstract

This study investigates the effects of adding nano-ferrite (N.F.) and nano-silica (N.S.) on the mechanical and biological properties of mortar. By assessing four water-to-cement ratios (1-4%), the ideal nanoparticle doses were determined. Results indicated that both N.F. and N.S. significantly increased the mortar's strength at ratios between 1% and 4%, while combinations of N.F. and N.S. improved strength up to 3% and 4% substitution, respectively. The mechanisms of strength enhancement were attributed to nanoparticles acting as fillers and hydration accelerators, which densify the mortar microstructure and promote the production of calcium silicate hydrate (C-S-H) gels. In terms of biological properties, the study examined the antibacterial effects of nano-silica and nano-ferrite. Nano-silica demonstrated greater antibacterial potency against all bacterial strains assessed. Both materials exhibited a stronger antibacterial impact on Gram-positive bacteria (Staphylococcus aureus) compared to Gram-negative bacteria (Escherichia coli), due to differences in cell wall structures. The study emphasizes the importance of optimal nanoparticle dosages and identifies limitations that warrant further research, such as durability and potential downsides at higher concentrations. Despite these challenges, the findings underscore the potential of nanoparticles to enhance mortar performance and suggest promising applications in construction and the development of antibacterial materials. Future research should focus on overcoming these constraints and exploring the practical applications of nanoparticle-enhanced mortar in real-world scenarios.

1. Introduction

Globally, concrete is a highly common building material. The substance is a multiphase mixture that matures over time, having a nanostructured component. Amorphous phases with crystal sizes ranging from nano to micrometres make up mortar and concrete [1]. Concrete is made up of a variety of molecular structures, conglomerates, fibre surfaces, chemical bonds, molecular interactions, and nanoscale interphase diffusion. The placement of connections between sections and components, workloads, and the environment are determined by processes and qualities at the nanoscale. The majority of activities that impact bulk material performance and engineering attributes occur at the nanoscale. [2]. At the nanoscale (solid-solid or, more accurately, liquid-solid interfaces), engineering concrete can exist in three different states: solid, liquid, and interface [3]. It is always possible to nano-engineer concrete by combining small building particles to give it new properties or by adding cement, aggregate, and other particles to make the surface operate better. The production of nanoparticles indicates the possibility of creating novel cementitious materials, such as nano reinforcements and uncommon polymers. Its low compressive modulus has several detrimental effects on the production of concrete because of its exceptional compressive strength and modest tensile, which are frequently used. To improve mortar and cement for structural purposes, different materials are utilizing micro cementitious elements, micro clay, and micro silica into a new nano concrete mix. This increases the cement mortar's mechanical properties [4].

The creation of nanoparticles with specific properties marked the beginning of the science of nanotechnology. A nanoparticle's size can be expressed in nanometres (nm). Nanomaterials - particles with a single dimension less than 200 nm—were used to enhance product quality, and novel production processes were developed to produce one-of-a-kind goods using nanoscale SiO_2 and Fe_2O_3 oxide in mortar and concrete [5]. Concrete and mortar were mixed with ultrafine particles to produce a variety of materials with different qualities. Cement performance is strongly impacted by the size of its nanoparticles. Several distinguishing characteristics of nanoparticles, including strength, porosity, durability, and shrinking, are influenced by their size. SiO_2 nanoparticles fill in the spaces between C-S-H gel molecules by proceeding as a nanofiller. The pozzolanic response of calcium hydroxide facilitates growth in C-S-H, which increases medium compaction and material durability [6]. For shield applications in nuclear power plants, the inclusion of N.F. into mortar might be highly attractive due to its large specific weight and high fineness. The mechanical properties of N.F. in cement mortar were assessed at 7 and 28 days of age. After being exposed to high temperatures and radiation for two hours, the mortar specimens were inspected to compare the loss of strength [7]. After that, the samples were subjected to high temperatures for an additional 28 days. Because of the innovative possible application of particles in size, nanotechnology has received substantial scientific benefit (10-9) nm. The size of nanoparticles can significantly improve their properties when compared to ordinary grain-sized particles with the same chemical makeup. Because of this, companies might be able to re-engineer a range of existing materials and produce entirely new products that function at previously unheard-of scales [8]. The straightforward procedures and widely accessible materials utilized in the manufacture of nano ferrite serve as evidence of defiance. To enhance the concrete mix's strength and longevity, this study examined the effects of Ni-Zn-Mg nano ferrite antibacterial activity and nanoparticles as weight substitutes for Portland cement. the use of any chemical method to create nanoparticles in a lab setting.

2. Experiment Procedure

2.1 Properties of Cement

Type of cement for the duration of the trial, ordinary Portland cement from Iraq was utilized. Airtight plastic containers were used to keep it safe from the effects of moistness and high temperature as well. Tables 1 and 2 provide a statistical representation of the materials' physical attributes and chemical makeup. Based on test results, the selected cement satisfies Iraqi criteria (I.Q.S. No. 5/ 1984) [9].

***Table 1** Cement's physical characteristics*

Physical Property	Assess Results	Specification No. 5/1984
Setting time (Victa's method)		
- Initial (minutes)	2.04	ε1 hr
- Final (minutes)	3.90	δ10 hr
Specific surface area (m^2/kg)		
- Blaine method	369	ε230
Compressive strength (MPa); 70.7 mm cube		
- 3 days	20	ε15
- 7 days	25	ε23
Soundness (%)		
- Autoclave method	0.11	δ0.7%

***Table 2** Cement's chemical composition and primary constituents*

Arrangement of Oxide	Abbreviation	Percentage by mass (%)	Limits of (I.Q.S. NO.5 /1984)
Alumina	Al_2O_3	5	-
Magnesia	MgO	2.0	≤ 5 %
Insoluble Residue	I.R.	1.3	≤ 1.4 %
Loss on Ignition	L.O.I	2.4	≤ 3 %
Silica	SiO_2	21.9	-
Lime	CaO	66.1	-
Sulphate	SO_3	2.2	≤ 2.8 %
Iron oxide	Fe_2O_3	3.1	-
Lime Saturation Factor	L.S.F.	0.9	0.56 – 2
Central Mixtures			
Name of Compound	Formula	Abbreviation	Percentages (%)
Tetra-calcium Alumino-ferrite	$4CaO.Al_2O_3.Fe_2O_3$	C4AF	9.4
Tricalcium silicate	$3CaO.SiO_2$	C3S	58.1
Tricalcium aluminate	$3CaO.Al_2O_3$	C3A	8
Dicalcium silicate	$2CaO.SiO_2$	C2S	18.99

2.2 Fine Aggregate

Table 3 states that the sieve analysis was conducted in a laboratory. Based on the results of this test, the fine aggregate gradation met the conditions of Iraq (I.Q.S. No. 45/1984) in most cases [10]. However, Table 3 illustrates how the project complies with Iraq's standards by using 4.75 mm natural sand coupled with modest zone II grading as the fine aggregate.

***Table 3** Aggregate sieve analysis*

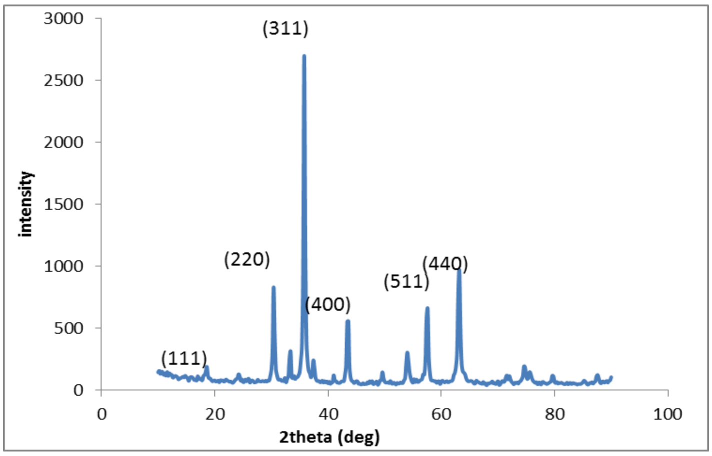
Sieve size (mm)	Cumulative passing %	Specification No.45/1988, zone II
0.15	7	0 -10
0.3	40	5 -20
0.6	74	15 -34
1.18	86	30 – 70
2.36	92	60 -90
4.75	97	90 -100
10	100	100

2.3 Nanomaterials

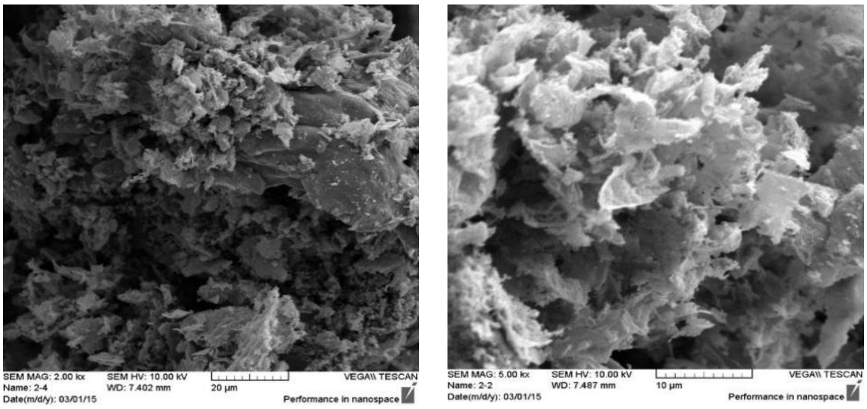
$Fe(NO_3)_39H_2O$ ferric nitrate is used as starting material with a citric acid molar ratio of 2:1 to prepare nano ferrites and zinc nitrate $Zn(NO_3)_2$ for the co-precipitation process. The solutions are precipitated using NaOH in a highly basic manner. Solutions of room temperature or above are used in this procedure. processed, pure Nano-ferrite (N.F.) precipitate produced in the laboratory with a particle size of 45.6 nm. The produced powder was photographed using an SEM instrument, as seen in (Fig. 1(a)). The (311) peak provided information on the stages of acquisition of the ferrite material. In scholarly talks, this peak is regarded as a great property of the material due to its wide and granular nano-scale size. The distinctive characteristics of the (311) peak emphasize the inherent superiority of the ferrite material's composition. where it was discovered that the powder's particle size was nanoscale and homogenous. An X-ray diffract analyzer is then used to examine the powder, as seen in (Fig. 1(b)). This showed that the powder had a very good description, and the Debye-Scherer Eq. (1). was used to calculate the crystalline size.

$$Dx = 0.9\,\lambda / (\beta \cos\theta) \quad (1)$$

where λ = wavelength; β = expansion of the deflection peak; and θ = deflection angle.



(a)



(b)

Fig. 1 *(a) spinel ferrite powder calcite at 500 C XRD diffraction; (b) SEM image of nano ferrite powder*

Under the MEYCO/MS610 brand, nanomaterials N.S. employs crystalline Micro silica, which has a 40 nm grain size and is manufactured from silica fume provided by the chemical company BASF. The pores in the cement paste need to be filled. The pozzolanic rate is linearly determined by the Blaine refinement value (60 m^2/g). The chemical composition of nano-silica is illustrated in Table 4. The strength activity value of micro silica was investigated following ASTM C1240-05 [11], which entails casting cubic pieces with and without silica while using regular sand in both combinations.

Table 4 *Chemical composition* of N.S. and N.F.*

Items	Chemical Composition	
	N.S.	N.F.
SiO_2	98.4	-
Fe_2O_3	-	98.9
Al_2O_3	1.11	-
CaO	-	-
SO_3	-	
MgO	0.4	
L.O.I	0.1	0.12
	Physical Properties	
Specific gravity	2.2	
Average particle size	40 nm	
SSA (m^2/g)	160	155
Density (g/cm^3)	1.7	0.11

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3. Method of Culture Bacterial

To prepare the Suspension of Culture Bacteria, full lopes of the cultured bacteria were activated on nutrient jelly sheets for 24 hours at 36° C. This resulted in a concentration of ~107-108 CFU/ml of E. Coli and Staph. aureus bacteria alone (per McFarland tube NO. 5). Subsequently, we added (10, 20, 40) mg/ml of $Ni_{0.5}Zn_{0.3}Mg_{0.2}Fe_2O_4$ nano ferrite and nano silica alone to one millilitre of each bacterial culture. We then maintained the mixture at 36° C for twenty-four hours in a shaking brooder (160 RPM), after which we repeated the serial dilution process three times. and for a whole day, 100 microliters of this solution were grown on Mueller Hinton Agar. The procedure used to calculate the bacteriostatic value was followed to account for the number of bacteria colonies at 37°C [12], [13]. The antibacterial activity of both nano-ferrite and nano-silica materials increased with concentration; thus, the optimal concentration was determined to be 40 mg/ml; nevertheless, the antibacterial activity of the nano-ferrite materials was superior to that of the nano-silica materials.

3.1 Mix Procedure

The impact of N ferrite, N.S. alone, and a combination of N ferrite/N.S. on the mortar's biological properties and compressive and flexural strengths were examined using some combinations in the study. In Table 5, the combined compound is displayed. The ratio of cement to sand in source mix N was 1:2. Mix N-ferrite, N.S. mortar, NF1, NF2, NF3, NF4, NS1, NS2, NS3, and NS4 in weight percent quantities of 1, 2, 3, and 4, respectively. In the mortar, mix NFS1, NFS2, NFS3, and NFS4 at weight percentages of 1%, 2%, 3%, and 4%, respectively. The mould measures 8 by 103 cm^3.

Table 5 *Mix compound*

Mix Type	Cement (g)	Sand (g)	C/S Ratio	W/C Ratio	SP (%)	N.F. (%)	N.S. (%)	N.F.S. (%)
N	500	1000	1:2	0.3	3	-	-	-
NF1	495	1000	1:2	0.3	3	1	-	-
NF2	490	1000	1:2	0.3	3	2	-	-
NF3	485	1000	1:2	0.3	3	3	-	-
NF4	485	1000	1:2	0.3	3	4	-	-
NS1	495	1000	1:2	0.3	3	-	1	-
NS2	490	1000	1:2	0.3	3	-	2	-
NS3	485	1000	1:2	0.3	3	-	3	-
NS4	480	1000	1:2	0.3	3	-	4	-
NFS1	490	1000	1:2	0.3	3	-	-	2
NFS2	480	1000	1:2	0.3	3	-	-	4
NFS3	470	1000	1:2	0.3	3	-	-	6
NFS4	460	1000	1:2	0.3	3	-	-	8

To prepare the moulds for the pouring of freshly mixed mortar, they were well-greased before the moulding process. There were three distinct mortar layers applied to each specimen during casting. After each specimen was squeezed with a pole, the moulids and surface were entirely covered with a polyester sheet to undergo wet curing. After one day, samples were extracted and submerged for 7, 28, and 90 days in tap water to aid in the curing process. The superplasticizer mixture's exceptional durability is accompanied by an appropriate viscosity at an insufficient water-to-binder (W/B) ratio. In the experimental procedure to mix and cure conventional self-curing mortar tap water is used.

4. Assessment of Hardened Mortar

4.1 Compressive Strength

The compression test for strength needs to be performed under Section 16, BS1881 [14]. 50 mm cubes, vibrating equipment, and an E.L.E. compression testing instrument with a force of 2000 kN are all employed in this test. The specimens were maintained in the mould at 25° ± 2 C and high humidity for the first twenty-four hours. After that, to cure, they had to remain in the cavity for 7, 28, and 90 days. The sample's compressive property was calculated by dividing its mean cross-sectional size by the maximum force it could sustain throughout the test. For every tensile strength measurement, an average of three samples was utilized. Flexural strength is a term used to describe an indirect way of measuring concrete's tensile strength. This test will determine whether or not an unreinforced concrete slab or beam can sustain bending failure. MPa or psi might be provided for the rupture index (MR), which is used to describe the outcomes of the flexural test conducted on concrete. If concrete is built according to ASTM C78 or ASTM C293 requirements, a flexural test can be done on it.

4.2 Flexural Strength

Prism samples are used in the flexural strength measurement process. The following are the prism parameters: The dimensions of length, breadth, and thickness are 160, 40, and 40 millimetres, respectively. The samples had to balance across every inch of the prism in the plane of the horizontal castings after the force was applied to the cylinder's centre. An E.L.E. International flexural/tensile testing apparatus with 10 kN capacity was employed during the test. The maximum flexural action force for this device is stated in kilonewtons, and the following formula was used to calculate the flexion strength by ASTM C293-02 [15]:

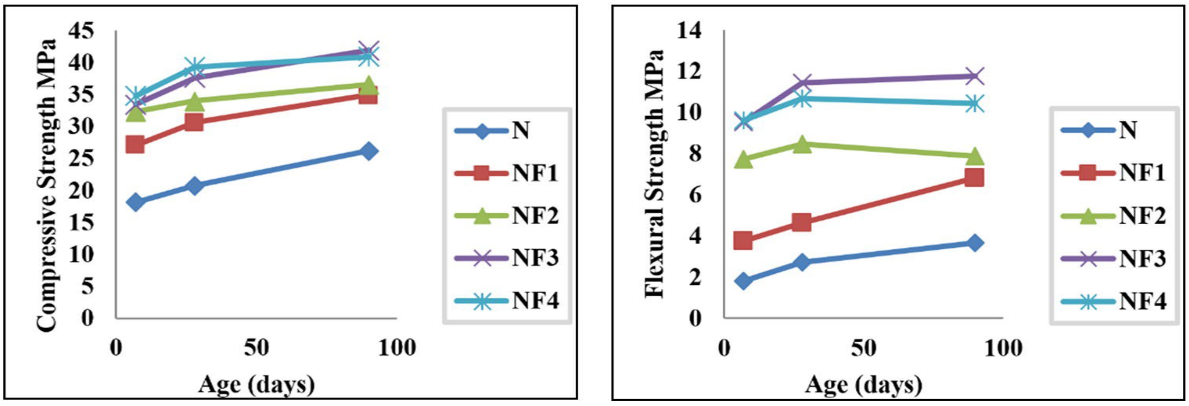
$$Fr = 3PL/2bd \tag{2}$$

where L is the specimen's length, measured in millimetres; b is the specimen's breadth, measured in millimetres; d is the specimen's thickness, measured in millimetres; and P is the maximum load, measured in newtons (N). Using an E.L.E. (10) K.N. power device, a centre point load test was performed following ASTM C293-02. The mean elasticity of breaking was determined for three cylinders at three different experimental intervals (7, 28, and 90 days).

5. Results and Discussion

5.1 Compressive and Flexural Strength of Nano Ferrite (N.F.)

The addition of N.F. particles, specifically up to a 3% substitution (NF3), increased compressive strength after the hardened samples were evaluated for 7, 28, and 90 days. The compressive strength of mortar samples at 7, 28, and 90 days with N.F. particles added is shown in Fig. 2(a). Compared to the normal mortar, the NF-modified mortar shows improved compressive strength and reduced brittleness. This might be attributed to the drying process, which reduces the number of voids with apertures, resulting in increased cohesiveness between the cement and particle mixture.



(a) (b)

Fig. 2 *(a) Compressive and flexural strength of nano ferrite (N.F.); (b) Flexural strength of the mortar specimen*

The incorporation of nano-ferric oxide (N.F.) in cement matrices is depicted in Fig. 2(b), presenting the flexural strength after 7, 28, and 90 days. The assessment reveals a notable enhancement in flexural strength from 28 days to 90 days when N.F. is introduced into the mortar. An optimal N.F. quantity, identified as 3 wt.% of the cement (NF3), exhibits the highest efficacy in improving flexural strength. This augmentation is credited to the existence of N.F. particles, supporting the feasibility of integrating ultra-pure (99.9%) nano-ferric oxide.

Table 6 *Nano ferrite (N.F.) modified mortar specimens' strength properties*

Mix type	Compressive strength (MPa)			Flexural strength (MPa)		
	7 days	28 days	90 days	7 days	28 days	90 days
N	18.11	20.82	26.19	1.82	2.71	3.65
NF1	27.03	30.65	34.94	3.75	4.65	6.83
NF2	32.32	34.01	36.58	7.74	8.46	7.87
NF3	33.47	37.63	41.92	9.53	11.44	11.76
NF4	34.78	39.33	40.86	9.61	10.67	10.44

Table 6 presents the comprehensive test results for flexural strength. Flexural strength shows a noticeable initial increase when N.F. content increases up to three weight percent, and then a subsequent fall. Despite this decrease, specimens with four weight percent N.F. show better flexural strength as compared to the reference mortar. The faster consumption of Ca(OH)2, a byproduct of cement hydration, which is more pronounced in the early phases of mortar formation because of the nanoparticles' increased reactivity, might explain this phenomenon.

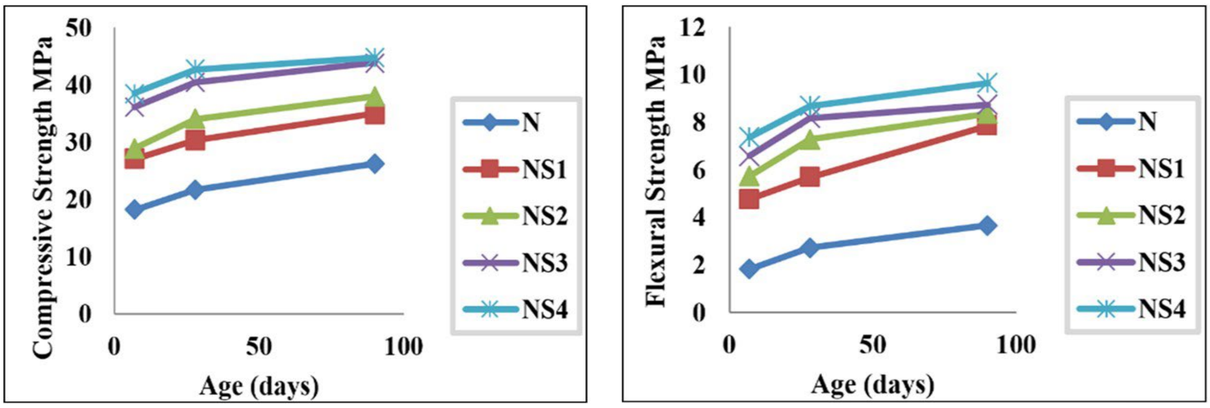
5.2 Compressive and Flexural Strength of Nano Silica (N.S.)

Compressive strength in Table 7 indicates that adding nano-silica (N.S.) to mortar specimens significantly increases their compressive strength. Interestingly, the variety of particle sizes is larger than that of the typical mortar for all age groups. The pozzolanic processes involving silica are responsible for the observed variances in mortar strength development. When it comes to pozzolanic reactions, nano-silica particles are more effective than nano-ferrite grains. Furthermore, the use of nano-silica particles aids in pore-filling, which increases mortar strength. Thus, it is assumed that adding N.S. will improve the mortar's strength properties concentrations of N.S. ranging from 1% to 4% by weight are examined, and the mortar's strength increases. The higher percentage of N.S. in the mixture allows for this improvement. It is crucial to remember that changes in the water content and material ratios in the mixture become required to prevent excessive fracturing and self-desiccation. This emphasizes how important it is to adjust the N.S. concentration with great care.

Table 7 *Nano-silica (N.S.) modified mortar specimens' strength properties*

Mix type	Compressive strength (MPa)			Flexural strength (MPa)		
	7 days	28 days	90 days	7 days	28 days	90 days
N	18.11	21.63	26.19	1.82	2.71	3.65
NS1	27.03	30.35	34.94	4.75	5.67	7.84
NS2	28.92	34.01	37.98	5.73	7.27	8.35
NS3	36.07	40.43	43.82	6.57	8.17	8.73
NS4	38.48	42.63	44.78	7.37	8.68	9.64

N.S. has potent pozzolanic properties. Because N.S. contains small particles, it may fill in the spaces left by the cement paste, creating the filler effect - a higher packing density. As a result, the matrix becomes denser, and the calcium silicate becomes more hydrated. Accordingly, the mechanical assets and durability both saw significant increases. The application of N.S. Utilizing silica nanoparticles in conjunction with additional cementitious ingredients enhances the mortar's properties. Particles improve the structure of the capillary system's pores while also reducing their size. The N.S. improves the mechanical characterization of mortar. The C-S-H phases' nucleation is happening on the silica, which is why the ratio is increasing. When added to cement paste, nanoparticles show notable filler influence and chemical reactivity. This improves the quality of cementation materials and causes the interface transition zone to become compacted. On the other hand, N.S. Offering a larger quantity over the ideal ratio reduces the strength and durability of mortar and concrete [16].



(a) (b)

Fig. 3 *Nano silica (N.S.) modified mortar specimens (a) Compressive strength; b) Flexural strength*

5.3 Compressive and Flexural Strength of Nano Ferrite and Nano Silica (N.F.S.)

The results of N.F.S. mortar is shown in Table 8. According to the findings, N.F.S. mortar works better than N.F. and N.S. mortar alone at increasing mechanical strength. According to test results, a cement mortar's optimal

N.F.S. ratio should be between 1% and 4%. As a result, the N.F.S. particles improved the structural performance and changed the mortar's characteristics. The compressive strengths of the N.F.S. mortar for 7, 28, and 90 days, respectively, were 47.47, 49.63, and 49.82 MPa, as shown in Fig. 4. The addition of 3wt% additive in N.F.S. mortar resulted in a maximum strength of 23.2MPa at overall ages, with values of 25.9MPa at 28 days and 27.6MPa at 90 days. Similarly, in the mixes of N.F.S. mortar, the addition of 3wt% additive resulted in maximum flexural strength of 11.53, 12.64, and 14.25 MPa 7, 28, and 90 days. The impact of strength is contingent upon the characteristics and composition of nanoparticles. The substitution of a portion of cement with N.F.S. resulted in an augmentation of the mortar's strength. Nanoparticles undergo a reaction with calcium hydroxide that is delivered of the hydrate of calcium silicate (C-S-H).

Table 8 *Compressive and Flexural strength of Nano ferrite/Nano silica (N.F.S.) modified mortar specimens*

Mix type	Compressive strength (MPa)			Flexural strength (MPa)		
	7 days	28 days	90 days	7 days	28 days	90 days
N	18.11	20.82	26.19	1.82	2.71	3.65
NFS1	33.83	37.65	38.84	3.94	5.64	7.83
NFS2	38.32	39.81	40.58	8.57	8.78	9.84
NFS3	42.87	45.63	47.82	11.53	12.64	14.25
NFS4	41.34	43.23	44.45	10.87	11.72	11.74

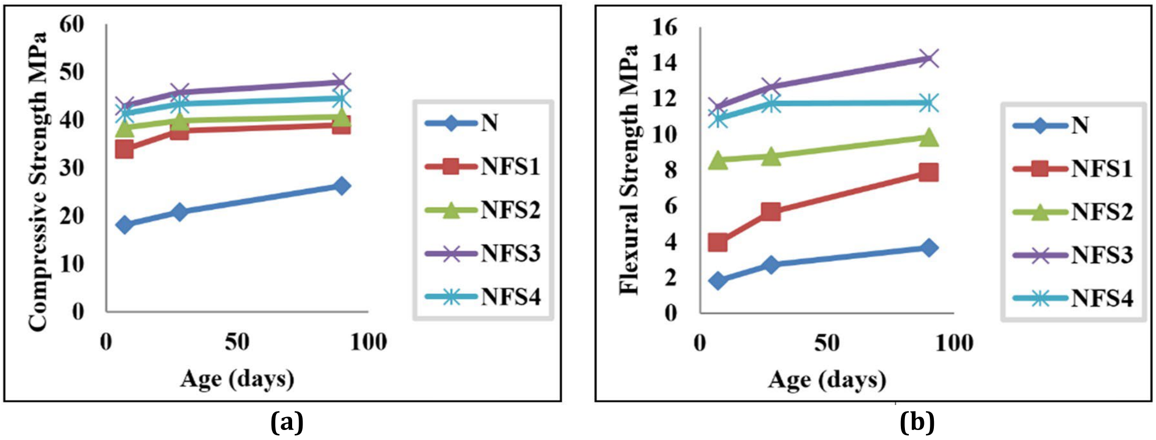


Fig. 4 *(a) Compressive and flexural strength results of nano ferrite (N.F.S.); (b) Modified mortar specimens*

The use of 4% N.F. components has been demonstrated to diminish the strength of compression due to the existence of N.F. The abundance of nanoparticles in the combination exceeds the required quantity for reacting against the natural lime throughout the process of hydrating. This leads to enhanced filtration of silica, which in turn causes inadequate strength owing to the substitution of a small amount of the cementing substance. The lack of effectiveness may be ascribed to flaws in the distribution of nanoparticles, resulting in the formation of vulnerable regions [17]. Nanoparticles (N.S. particles) have a minuscule impact on the filling process, which is crucial for achieving a thick mortar with exceptional strength. This is attributed to their tiny size. Particles infiltrate the spaces between particles inside the solidified cement structure of the matrix, so enhancing its density and strength. Cracks can rapidly spread via interface zones, particularly in the aggregate/cement matrix. N.S. undergoes a reaction with calcium hydrates that are created during hydration processes, resulting in the production of calcium silicate hydrate. This reaction contributes to the enhancement of mortar strength [18].

5.4 Biological Properties

The findings explain why nano ferrite has a greater effect on Staph. aureus bacteria than E.coli bacteria or nano silica. The percentage of bacteriostatic was 87%, 94% and 99% when nano ferrite nano ferrite in concentration 10, 20 and 40 mg/ml against Staph. aureus comparison with used nano ferrite nano ferrite against E.coli the bacteriostatic was 85%, 90% and 96% (Fig. 5). When using silica, the percentage of bacteriostatic was 80%, 85% and 90 % against Staph. aureus comparison with used nano silica against E.coli the percentage of bacteriostatic was 78%, 83% and 88% (Fig. 6).

The result of this composite using a mixture of a lot of nano minerals (Ni, Zn and Mg) in different percentages to form nano ferrite materials from nano Ferrite posed the ability to affect gram-positive and harmful bacteria in different percentages and on gram-positive more than negative according to the cell wall of each bacteria and different in thickness of peptidoglycan layer of cell wall between two types because the nano ferrite adherence with bacterial wall and small particles penetrated it and made on destroyed it so bacteria will dead (Fig. 7 and Fig. 8) [19]. all the minerals used posed this ability, so antibacterial activity appeared clearly when using this mixture. The findings corroborated the findings of [20], which elucidated the differential impact of Zinc ferrite on gram-positive and gram-negative bacteria because of variations in the peptidoglycan layers. Additionally, [21] demonstrated the antibacterial properties of magnesium ferrite and its mode of action involving the penetration of bacterial cell walls and subsequent disruption. Furthermore, [22] highlighted the capability of nickel ferrites to convince gaps and holes, resulting in the fragmentation of bacterial cell membranes. This study proved the significance of nano ferrite nano ferrite as an antimicrobial, and it is essential in a lot of drug delivery and biotechnology applications.

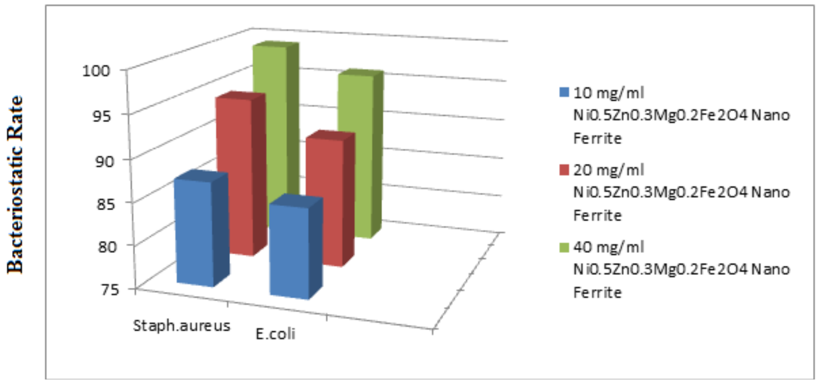


Fig. 5 *Comparison of Bacteriostatic of nano ferrite*

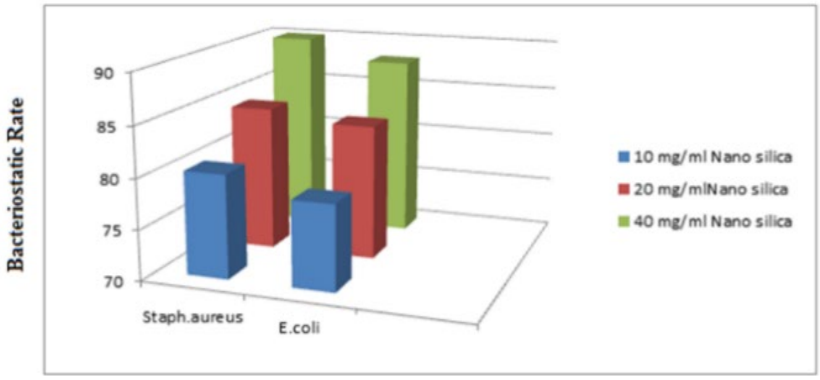


Fig. 6 *Comparison of Bacteriostatic nano*

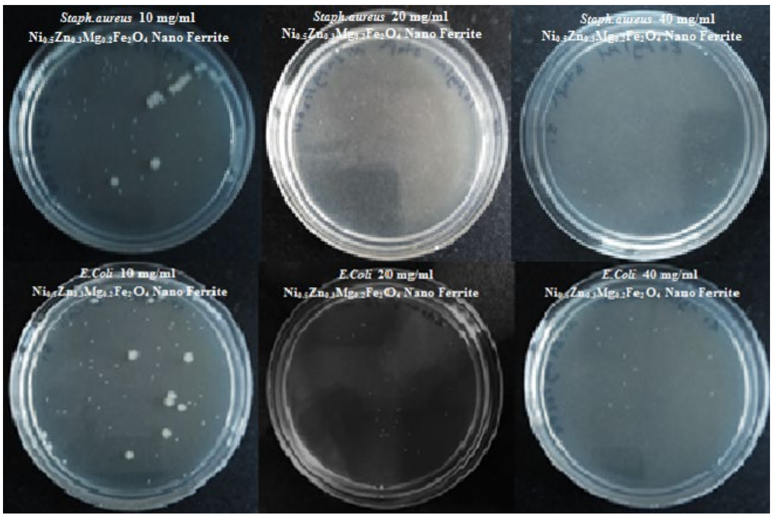


Fig. 7 *Antibacterial activity of nano ferrite in different concentrations (10, 20 and 40 mg/ml)*

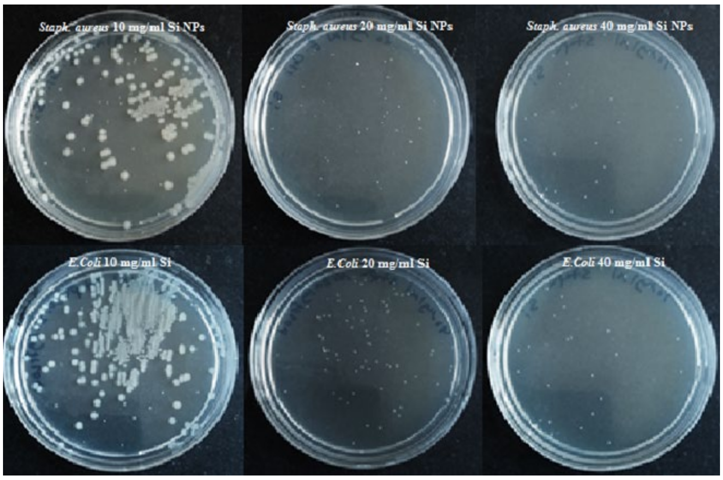


Fig. 8 *Antibacterial activity of nano silica in different concentrations (10, 20, 40) mg/ml against E. coli and Staph. Aureus bacteria*

6. Conclusions

Based on the outcomes of thorough experimental analyses, the cement mixture's compressive and flexural strengths have significantly improved. But it's important to recognize that higher concentrations of nanoparticles (N.F., N.S. and N.F.S.) negatively impact mechanical properties, especially flexural strength. The test findings highlight how crucial it is to keep mortar samples' nanoparticle concentrations at optimal levels. Particularly preferred is the ideal range, which was shown to be between 2 and 4 weight percent.

The comparison studies indicate the superiority of N.S. mortar specimens over N.F. equivalents. The incorporation of nanoparticles into mortar specimens results in noticeable changes in biological, mechanical, and microstructural characteristics, which may be ascribed to the significant ratio of surface area to volume. Nanoparticles serve as both a filler and an accelerator, playing a crucial function in enhancing hydration processes in mortar samples.

Recent tests reveal a promising possibility: N.F. particles, with an average size of 15 nm, could replace up to 4% of the cement favourably. This discovery enhances the sustainability aspect of using nanoparticles in cement-based structures.

Acknowledgement

We would like to express our sincere gratitude to the University of Technology - Baghdad for generously providing access to their laboratory facilities, which were instrumental in conducting the research presented in this paper. Their support and resources have contributed to the success of this study.

Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of the paper.

Author Contribution

The authors confirm their contribution to the paper as follows: ***study conception and design:*** *Salman, Rawdhan, Bohan, and Al-Jubouri;* ***data collection:*** *Salman, Rawdhan, and Bohan;* ***analysis and interpretation of results:*** *Salman, Rawdhan, Bohan, and Al-Jubouri;* ***draft manuscript preparation:*** *Salman, Rawdhan, Bohan, and Al-Jubouri. All authors reviewed the results and approved the last version of the manuscript.*

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