ASSESSMENT OF EFFECT OF NANO-SEALER ON THE CHARACTERISTIC STRENGTH (MECHANICAL) OF CONCRETE

Supported by tetfund

Blessing .O. Orogbade [1*], Grace M. Amusan [1], Adekunle O. David [1], Omobolaji T. Opafola[1], Adeyemi E. Adetoro[1], Olukunle O. Akisanya[1].

[1]Department of Civil Engineering, Olabisi Onabanjo University, Ogun State,Nigeria.

*Corresponding E - mail: orogbade.blessing@oouagoiwoye.edu.ng

Received: December 14, 2023 Accepted: March 28, 2024

Abstract: This study assessed the effect of nano-sealer (Zycoprime) on the characteristic strength (mechanical) of concrete. The effects in concrete were evaluated through a workability test, water absorption, SEM-EDX analysis and compressive strength test. A concrete mix design of grade M15 was employed in this study. The total samples were divided into four different concrete mixtures control specimen (0 kg), 0.5 kg, 1.0 kg and 1.5 kg of nano-sealer (Zycoprime). A total of 36 concrete cube specimens were cast for standard compressive test, three samples of each mix design were crushed/tested for 7 days, 14 days and 28 days. The result of the slump test showed that all the concrete produced with the addition of nano-sealer has a values ranges from 8 – 13 mm while that of control (0kg) has 10 mm. The water absorption test result showed that concrete produced with 0kg of nano-sealer has mean water absorption of 1.50%, while others range from 1.25% to 1.05% for 0.5, 1.0 and 1.5 kg incorporation of nano-sealer. The results of the compressive strength test performed on the concrete samples revealed that, on average, the concretes produced without the addition of nano-sealer had compressive strengths of 21.75N/mm^2 at 28 days and while others with the incorporation of nano-sealer at 0.5 kg, 1.0 kg and 1.5 kg have 16.50 N/mm^2, 15.52 N/mm^2 and 14.50 N/mm^2 at 28 days respectively. Also, the SEM analysis revealed the effect of the used nano-sealer on the produced concrete. The study concluded that the incorporation of the nano-sealer above 1.0 kg is not required where strength is the needed but can be increase in waterlog area for the durability of concrete.

Keywords: Nano-sealer, Zycoprime, Mechanical strength, Workability, Water absorption, SEM-EDX analysis

Introduction

Concrete is one of the most flexible building materials. Concrete may be shaped into practically any shape, just like water. Concrete has many advantages, including tremendous compressive strength, low maintenance requirements, excellent water and fire resistance, and a long service life (Raheem and Orogbade, 2018). Concrete may have been used in building and construction for less than a century. However, because concrete is used more frequently every 10 years, extensive and successful research has been conducted over the past century to increase the strength of concrete by using a number of additional cementing elements, such as nano-sealer, nanoparticles, pozzolans, and other materials (Orogbade and Raheem, 2018; Raheem and Ikotun, 2020; Japneet *et al*., 2022). Recent years have seen a significant increase in scientific interest in nanotechnology because of the unique applications of particles with a nanometer (10-9 µm) scale. This may be due to the fact that materials with consistent chemical composition and predictable grain sizes can perform noticeably better when their particle size is decreased to the nanoscale and incorporated in concrete to improve its durability (Nazari *et al*., 2010). Durability is one of the main problems that concrete faces and poses a danger to the structure's capacity to function during its life time which is majorly caused by water penetration (Japneet et al., 2022). However, Materials like nano-acrylic polymers, in particular Terrasil and Zycobond as well as other nano-sealers like Zycoprime and Zycosil, provided considerable control over shrinkage, segregation, water leakage and damping conditions of concrete which poses a danger to the concrete. Nano-sealers are the best at bonding with siliceous material and forming a better connection to seal even small fractures in concrete. Through the conversion of siliceous surface water-loving silanol groups to water-repelling alkyl siloxane groups, these organic sealers link with siliceous material contained in cement and become an important component of concrete (Ubaid and Harpreet, 2021). In an investigation by Ubaid and Harpreet, 2021, the use of Terrasil and Zycobond and various nano-sealers such as Zycoprime+ and Zycosil+ were studied to waterproof tunnels and according to the finding, various engineering properties such as permeability, compressive strength, durability, strength, and various other properties of concrete were enhanced. Also, Japneet et al., 2022, examined the effects of adding silane product (Zycosil+ and Zycoprime) to concrete integrally and utilizing the same substance for surface treatment to minimize water infiltration into concrete structures and to avoid degradation thereby enhancing their durability and service life of concrete. Zycoprime is an acrylic co-polymer emulsion that is ready to use as a bonding agent. It is also a versatile latex that can be used as a cement modifier for spalled concrete slabs, overhangs, beams, columns and floors (Ubaid and Harpreet, 2021).

In this study, the effect of nano-sealers (zycoprime) was investigated on both fresh and hardening properties of concrete through workability test (slump test), water absorption test, Compressive strength, SEM-EDX. The workability of concrete is defined as the ease and ability of freshly mixed concrete to be placed, compacted, and finished without segregation or excessive bleeding. It is a crucial property influencing the construction process and the ultimate quality of concrete structures. In this study, the slump test was used to assess the workability of the fresh concrete according to BS EN 12350–2. For hardening concrete, compressive strength is commonly used to evaluate the effectiveness of a particular concrete mixture. It determine how a hardening concrete can withstand a crushing loads. It gives precise information about whether a certain blend is appropriate to satisfy a particular grades of concrete. For this study, the compressive strength test used is in line with BS EN 12390-3 (2019) of grade M20.The water absorption test of concrete determines the water absorption capacity of a concrete sample. This test is important for determining the durability and resistance to water of the concrete, and helps to ensure that the concrete will perform as expected in its intended environment. This was carried out according to ASTM C642 (2013) in this study. Scanning electron microscopy (SEM) images are used to evaluate the microstructure of the concrete, porosity and degree of hydration estimation, concrete damage detection Srikanth (2022).

Materials and Methods

Materials

For this study, ordinary Portland cement, fine and coarse aggregate, nano-sealers (zycoprime), and water were employed. The following describes the characteristics of the materials used and the tests that were run:

Cement

The cement used for the study is in accordance with BS 12 (1996) requirements. It was ordinary Portland cement ASTM Type 1 (grade 42.5N) purchased commercially from Ibogun environment in Ogun-state, Nigeria.

Fine Aggregate

According to BS882 (1992), the fine aggregates used for the study was sharp sand, free from silt and impurities, fully air-dried before usage to avoid excess water during mixing and it was obtained from the Ibogun environment, Ogun state, Nigeria. Also, the aggregate size analysis was performed to grade the particle size before use.

Coarse Aggregate

For all of the specimens, crushed granite used as coarse aggregate have a maximum size of 19 mm that passed through a 4.75 mm sieve and was retained on a 2 mm sieve was utilized, as stated in BS882 (1992). The crushed granite was sourced from a quarry in Ibogun, Ogun State, Nigeria.

Nano-Sealer (Zycoprime)

The nano-sealer (Zycoprime) which was a milky-white, free flowing liquid with a specific gravity of 1.01 to 1.02 and having a viscosity of <500 cps at $25^{o}C$ with solid content of 35 ± 1%, with pH of 6 to 7 at $25^{o}C$ and non-flammable was obtained from a company in Lagos, Nigeria for the study. It was mixed with water as shown in Fig. 1 and added to the concrete mixture at different weight in the study.

Figure. 1: Nano-sealer mixed with water

Water

The water used for this study was natural and portable. It was ensured that the water was pure and free of any elements that could affect concrete, such as oils, acids, alkalis, salts, sugar, and natural materials.

Methods

Design Mix

In accordance with IS: 456-2000 the mix design proportion for grade M15 (1:2:4) was adopted for this study. Nano-sealer was dissolved in the water at weights of 0.5 kg, 1.0 kg, and 1.5 kg. The mix ratio of the four doses of nano-sealer (0 kg, 0.5 kg, 1.0 kg, and 1.5 kg) is displayed in Table 1. The water-cement ratio was held constant at 0.60 for all samples.

Production of Concrete

Hand mixing was employed during the entire investigation. The materials—cement, fine aggregate, coarse aggregate, water, and nano-sealer were first weighed precisely according to the mix design proportion. After which all the materials were mixed together to make a homogeneous slurry. The fresh concrete's workability was assessed using the slump test after the mixing. The 150mm x 150mm x 150mm mold was used to cast fresh concrete cubes for each of the concrete mixture. After being withdrawn from the mold after 24 hours, the samples were water-cured for 7, 14, and 28 days before the compressive strength test. There were a total of 36 cast concrete cube samples.

Table 1: Design Mix proportion

Nano-sealer (Zycoprime) Incorporation	Cement (kg)	Fine Aggregate (kg)	Coarse Aggregate (kg)	Water (kg)
Control (0 kg)	9.55	20.43	42.77	0.6
0.5 kg	9.55	20.43	42.77	0.6
1.0 kg	9.55	20.43	42.77	0.6
1.5 kg	9.55	20.43	42.77	0.6

Workability Test

In this study, the slump test was used to assess the workability of the fresh concrete according to BS EN 12350–2. Slump test is carried out on all the sample of fresh concrete produced with the four distinct weights: 0 kg, 0.5 kg, 1.0 kg, and 1.5 kg of nano-sealer. The fresh concrete is poured into a steel cone mold that was placed on a smooth horizontal non- porous base plate in three (3) different equal layers. Each layers was tapped with 25 strokes tamping rod in a uniform manner over the cross section of the mold. Immediately after removal of the mould, the difference between the height of the mould and that of the highest point fresh concrete is calculated as the slump value BS EN 12350–2.

Compressive Strength Test

At the Olabisi Onabanjo University civil engineering laboratory, all samples were subjected to a compressive strength test in line with BS EN 12390-3 (2019). after 7, 14, and 28 days of curing. Utilizing the Universal Testing Machine (UTM) model no 36-3090/01 at a loading rate of 0.05 mm/s with a loading capacity of 3000 kN, each sample was weighed before being loaded until failure was reached.

For each sample, the failure loads were recorded. For each curing day test, three samples were used, and the average was calculated.

Water Absorption Test

The water absorption of all the concrete produced were determined at 28 days according to ASTM C642 (2013). After being removed from the curing tank, the concrete produced were dried in an oven at 105ºC until a set weight (Wdry) was achieved. Saturated surface dry weight (Wsat) of the produced concrete was obtained by immersing the concrete produced in water for another duration of 24 hours. The results of this test were averaged over the three results for each of the various weights of nano-sealer incorporation used.
Equation (1) was used to compute the water absorption (%).

Water absorption = $\frac{Wsat-Wdry}{Wdry} X\ 100$

Where: Wdry = the weight of the specimens before curing process.
Wsat = the weight of the specimens after curing process.

Scanning Electron Microscope Test
After testing the concrete cubes until failure using a Universal Testing Machine (UTM) with a loading capacity of 3000 kN, the particles were removed from the deepest part of the cubes and were taken to the central lab at Covenant University Ota Nigeria for SEM-EDX analysis using Personal SEM (PSEM) manufactured by ASPEX Cooperation with model number VP 3025. An acceleration voltage of 20 kV was used to observe the specimens at 1500 magnification.

Results and Discussion
Workability Test

Prior to casting, the slump test is used to evaluate the workability of concrete. In this study, nano-sealer is included into concrete and tested for slump at four distinct weights: 0 kg, 0.5 kg, 1.0 kg, and 1.5 kg. The findings of a slump test on various weights of nano-sealer incorporation are shown in Figure 2. The control batch of the study (0 kg of nano-sealer) has a slump value of 15 mm but after the incorporation of the nano-sealer to the mixture at 0.5 kg, 1.0 kg and 1.5 kg the slump value decreases as the addition of the nano-sealer increases. This is in line with the result gotten by Qu and Yu (2018). This can be attributed to the reaction of nano-sealer with the concrete thereby minimizing water infiltration and causing rapid hardening of the mixtures. But at this, all the slump for the entire concrete batch mix may be classified as true slump according to BS EN 12350-2:2009 and ranges from 10 to 20mm.

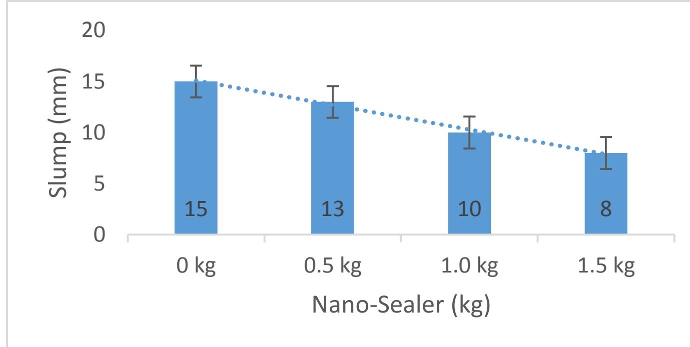

Figure 2: Slump test chart

Water Absorption Test
The result of water absorption properties of incorporating nano-sealer into concrete is shown below in Figure. 3. As depicted in the figure, concrete produced with 0kg of nano-sealer has a mean water absorption of 1.50%, from 0.5kg incorporation of nano-sealer, the mean water absorption reduced to 1.50% to 1.05% of 1.5 kg incorporation of nano-sealer which was similar to the result gotten by Ubaid and Harpreet,- (2021). From the results, it was deduced that-, the water absorption of the concrete decreases as the percentage of nano-sealer increases, this is due to the fact that nano-sealer (zycoprime) is an acrylic sealer which repels the absorption of water into the concrete thereby reducing the water absorption rate. The result of the water absorption test is in conformity with the result of the slump test discussed above.

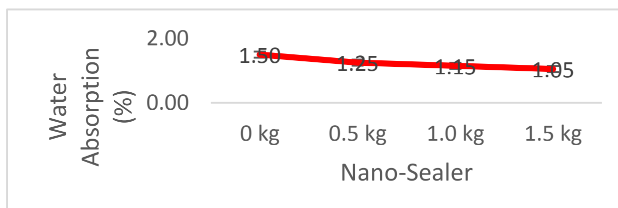

Figure 3: Average % of Water Absorption Test

Compressive Strength Test
The result of the compressive strength is shown in Figure 4. From the average compressive strength result of the three concrete cube samples for all the different weights of nano-sealer incorporation (0kg, 0.5kg, 1.0kg and 1.5kg) at 7, 14 and 28 curing days, it was observed that, the incorporation of nano-sealer (zycoprime) reduces the strength of the concrete samples; that is, as the percentage of the nano-sealer increases, the compressive strength of concrete decreases but increases as the curing days increases. This is due to the fact that nano-sealer (zycoprime) is an acrylic sealer which inhibits the hydration of the cement in the produced concrete samples which led to the reduction in compressive strength of the concrete samples and this is in line with Japneet et al., (2022), which recorded decrease in compressive strength of concrete with addition of Zycosil+ and Zycoprime and also in line with Domagała, (2015), which stated that higher water absorption rate increases the compressive strength of concrete and vice versa.

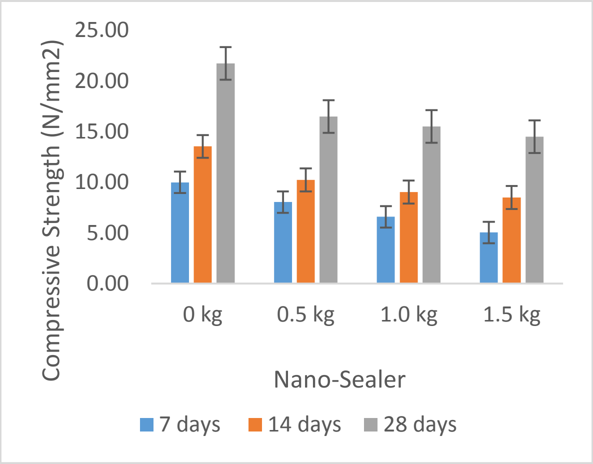

Figure 4: Variation of Average compressive strength of different Nano-Sealer incorporation

Scanning Electron Microscopy (SEM)

SEM analysis was performed to assess the nano-sealer (zycoprime) dispersion quality and the interaction of the nano-sealer within the concrete. The microstructural images of the different weight addition of nano-sealer in concrete cured for 28 days are shown in Figure 5 (A – D). With respect to the compressive, it was observed that the reaction of hydration in the control sample (0 kg) image was fully developed as the particles of the images were closely packed together due to the proper reaction of water within the concrete constituents when freshly mixed and in the hardening state. This evidence back up the rapid development of strength in the control sample. The evidences of decrease in the development of strength with incorporation of nano-sealer from 0.5 to 1.5 kg can be seen with the increase in the loosely void image in Figure 5B – 5D and this is similar to SEM analysis of Qu and Yu (2018). This is due to slow hydration between the pastes of the concrete constituents due to the nature of the nano-sealer.

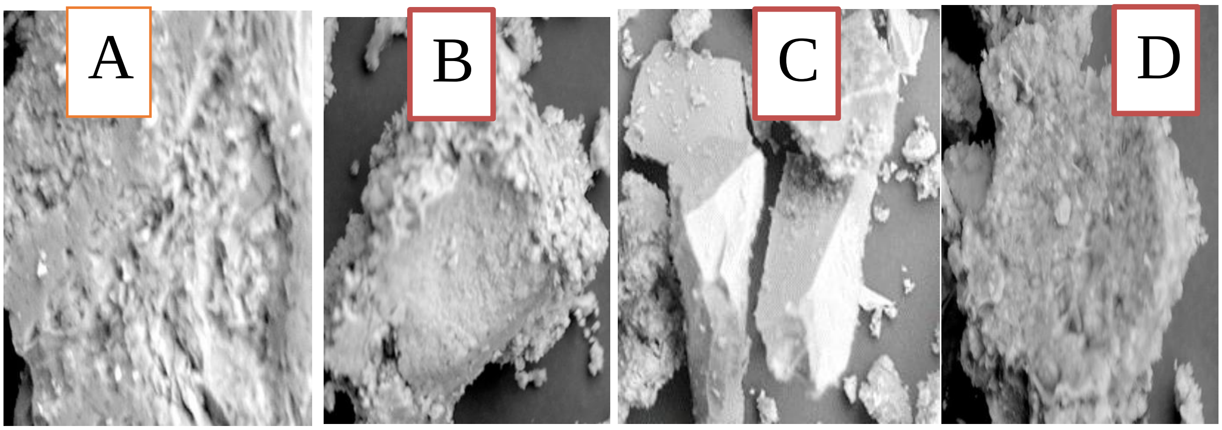

Figure. 5: SEM images (1500x magnification) of the concrete samples at 28 days: (A) 0 kg nano-sealer; (B) 0.5 kg nano-sealer incorporation; (C) 1.0 kg nano-sealer incorporation and (D) 1.5 kg nano-sealer incorporation.

Conclusion

The effect of the incorporation of nano-sealer (Zycoprime) on the compressive strength of concrete has been investigated in this study. Based on the findings of the investigation, it was concluded that:

- a decrease in the compressive strength of concrete is observed as the percentage of incorporation of the nano-sealer increased from 0.5 – 1.5 kg either from 16.50 N/mm^2 to 14.50 N/mm^2
- incorporation of nano-sealer up to 1.0 kg is recommended for use because the strength still meets the minimum strength requirement for M15 grade of concrete and also improves the durability of concrete. While addition of nano-sealer to the concrete mix beyond 1.0 kg improves the durability of the concrete but lowers the strength of the concrete.
- incorporation of nano-sealer in concrete has little significant effect on the compressive strength of the concrete but increases the durability of concrete in water log area because of its nature of acrylic sealer which forms a resistant barrier around the concrete and prevents improper absorption of water by the concrete.
- the use of nano-sealer in areas like swimming pools and dams embankment will help the concrete to withstand the infiltration of water and stop water linkage thereby prolonging the service life of the concrete.

References

ASTM C642-13 (2013). Standard test method for density, water absorption and voids in hardened concrete, ASTM International, West Conshohocken, PA, USA,

BS 12 (1996). *Specification for Portland cements*. London. British Standard Institution.

IS: 456-2000. Plain and Reinforced Concrete. Code of Practice. Bureau of Indian Standards, New Delhi

BS EN 12390-3 (2019). Testing hardened concrete. Compressive strength of test specimens. London. British Standards Institution.

BS EN 12350-2 (2009). Testing fresh concrete. Slump test of test specimens. London. British Standards Institution.

BS 882 (1992). Specification for Aggregates from Natural Sources for Concrete. London. British Standard Instituition.

Domagała, L. (2015). The effect of lightweight aggregate water absorption on the reduction of water-cement ratio in fresh concrete. *Procedia Engineering*, *108*, 206-213.

Japneet Sidhu; Pardeep Kumar; Robin Bharadwaj; vinay Kumar (2022). "Experimental Investigation on Hydrophobic Treatment of Cement Concrete with Organosilane Based Compound". *Journal of Civil Engineering and Materials Application*, 6, 3, 149-158. doi: 10.22034/jcema.2022.353918.1091

Nazari, A., Riahi, S., Riahi, S., Shamekhi, S. F., & Khademno, A. (2010). The effects of incorporation Fe2O3 nanoparticles on tensile and flexural strength of concrete. *Journal of American Science*, *6*(4), 90-93.

Orogbade BO, Raheem AA. (2018). Chemical and Physical Characteristics of Blended Cements Produced from Softwood Ash. *LAUTECH Journal of Civil and Environmental Studies (LAUJOCES)*, Vol 1 (1), pp 1-7. DOI: 10.36108/laujoces/8102/10 (0110)

Raheem A.A, Orogbade B.O. (2018). Characteristics of blended cement produced from selected hardwood ashes. *FUOYE Journal of Engineering and Technology*. 3 (1) 61-66.

Raheem A.A., Ikotun B.D., (2020). Incorporation of agricultural residues as partial substitution for cement in concrete and mortar – A review, *Journal of Building Engineering* doi: https://doi.org/10.1016/j.jobe.2020.101428.

Srikanth Sagar Bangaru, Chao Wang, Xu Zhou, Marwa Hassan (2022).Scanning electron microscopy (SEM) image segmentation for microstructure analysis of concrete using U-net convolutional neural network. *Automation in Construction*. 144, 104602, ISSN 0926-5805. https://doi.org/10.1016/j.autcon.2022.104602.

Ubaid Ali Parray and Harpreet Singh (2021). Waterproofing of primary lining in tunnel using nano chemicals and soil modifiers in Concrete. *IOP Conf. Series: Earth and Environmental Science* 889 012032, 1-10. doi:10.1088/1755-1315/889/1/012032

Z.Y. Qu, Q.L. Yu, (2018).Synthesizing super-hydrophobic ground granulated blast furnace slag to enhance the transport property of lightweight aggregate concrete, Construction and Building Materials,Volume 191, Pages 176-186, ISSN 0950-0618, https://doi.org/10.1016/j.conbuildmat.2018.10.018.