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The long-term effects of nano-silica on concrete

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Abstract. The emergence on nanotechnology has driven the advancement of a lot of materials, one of which is nano-silica. Therefore, the research on the application of nano-silica in concrete has been conducted by researchers. The results showed that the strength and durability of concrete can be significantly increased by the application of nano-silica. However, the conducted research was limited to 28 days (short term). Furthermore, nano silica as a new material needs to be tested over a long period of time (more than 28 days) to determine its impact on concrete. Research on the long-term implications of using nano silica was carried out on f_c 45 MPa concrete. The percentage of nano silica used is fixed, at 5% of the weight of the binder. Furthermore, mechanical properties were tested including; compressive strength, tensile strength and slump test of normal concrete at 28, 56 and 91 days of the concrete'age. The results showed that the use of nano silica can increase compressive strength and tensile strength. The results showed that when compared to normal concrete, the use of nano silica can increase compressive and tensile strength and also produce better mechanical properties.

1. Introduction

Using nano-silica in a mixture of paste, mortar, and concrete greatly improves the mechanical properties and durability of concrete [1, 2]. The effect of using nano silica has received the attention of many researchers in recent years because nano silica has shown better performance compared to other additives [3]. Nano silica could fill the spaces between particles of gel C-S-H, acting as a nano-filler, and the pozzolanic activity of nano silica was very high, which increased the amount of C-S-H and resulted in higher densification of matrix, improving the strength and durability of concrete [4]. Nano silica is a relatively new material to be applied to high-performance concrete and the price is much higher compared to other pozzolanic materials, but it is very effective [5]. The researchers have sought to overcome the main disadvantage of fly Ash concrete with the addition of nano to cement and concrete paste to increase pozzolanic reactivity and early strength [6]. Percentage of nano silica used in concrete mixes will affect the mechanical properties in concrete, a low percentage of nano silica particles does not enhance the performance of mortar under long-term [7]. Percentage of nano silica 5-10% proved to be effective in increasing mechanical properties and durability of concrete [8, 9]. Nano silica is a highly reactive pozzolanic and could consume calcium hydroxide to form secondary Calcium silicate hydrate and improve cement composites properties through different mechanisms [10, 11]. There is a limited knowledge about the mechanism by which NS affects the settings times, workability, mechanical properties etc of concrete. Nano silica as a new material needs to be continuously researched both in the



laboratory scale and in the field. This is needed to better understand the behavior of nano silica in concrete. But unfortunately, research on the use of nano silica into a mixture of pasta, mortar, and concrete, is carried out at 28 days (short-term). For this reason, research on the long-term effects of using nano silica on concrete mechanical properties is important. In this study the effect of nano silica on mechanical properties in the form of compressive strength, tensile strength and slump for concrete f_c 45 MPa.

2. Materials and Method

The material used in this research was the type 1 ordinary portland cement, coarse aggregate, and fine aggregate from PT. Adhimix Precast Indonesia. The super-plasticizer used is the type of Polycarboxylate Ether Superplasticizer (PCE) from PT. John Idetama Teknik and nano silica type HDKN 20 from PT. Brataco with properties as shown in Table 1.

Table 1. Properties of nano silica HDKN 20

Properties	Unit	Value
Surface BET	m ² /g	197
pH-Value	No unit	4,0
Silicon dioxide	%	100
Sieve residue > 40 μ m	%	0,001
Loss on ignition	%	0,6
Content heavy metals	ppm	<25

While Table 2 shows the proportion of concrete mixture f_c 45 MPa in 1 m³, the specimen with BR code is normal concrete i.e. without nano-silica, BNS1 is concrete with the addition of 5% nano silica and 0.6% PCE, while the BNS2 concrete is made up of 5% nano silica and 3.5% PCE. Slump plan is 16 ± 2 cm. Concrete mixing in nano silica BSN1 is mixed with silica sand, while nano silica BSN2 is mixed with cement first.

Table 2. The proportion of f_c 45 MPa concrete mix in 1 m³

Material	BR	BNS 1	BNS 2
OPC (kg/m ³)	580	580	580
Nano silica (kg/m ³)	-	29	29
Coarse Aggregate (kg/m ³)	1014	1014	1014
Fine Aggregate (kg/m ³)	595	595	595
Water/ binder	0.31	0.31	0.31
PCE (litre/m ³)	3.5	3.5	20.3

Figure 1 shows the specimen and curing done. The number of specimens for the press and pull examination are 3 for each concrete age specimen.



Figure 1. Specimen and curing

The specimen examination was carried out as shown in Figure 2. The examination was conducted by testing the slump with ASTM C 143-90 standard.



Figure 2. Testing of a slump (a), compressive strength (b) and tensile strength (c).

The compressive strength test refers to ASTM C39 and tensile strength refers to ASTM C496 / C496 M. The compressive strength examination was in form of a cylinder with 10 cm diameter and 20 cm height. The experiments conducted to test the compressive and tensile strength at 28, 56 and 91 days.

3. Results and Discussion

3.1. Slump Test

Slump test results as shown in Figure 3. BR 14 cm slump value. From the results of the slump examination, nano silica addition resulted in a decrease in the BNS1 slump value of 4cm. This slump value is in accordance with previous research, that addition 1,5 % NS significantly decreased the slump from 17,5 cm to 24 cm as reference slumps of concrete with $w/b = 0.65$ and 0.55 to 3 cm and 4 cm. [12]. The decrease in slump value is caused by the formation of the sort of structure that has high water retention after the addition of nano silica [13]. Furthermore, with the addition of 3.5% of PCE led to a slump value increased of 18 cm.

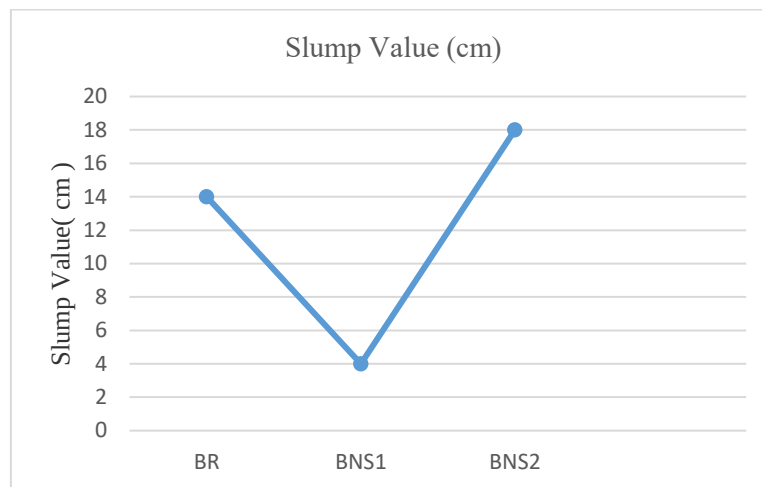


Figure 3. Slump value

From the conducted experiments, a conclusion can be drawn; to obtain a slump value of 16 ± 2 cm in nano-silica concrete requires 3.5% additional Polycarboxylate Ether Superplasticizer (PCE).

3.2. Compressive Strength

Figure 4 shows the results of compressive strength at 28, 56 and 91 days after mixing concrete at BR of 47 MPa, 49 MPa and 55 MPa. Whereas, BSN1 is 33 MPa, 36 MPa and 42 MPa. In BSN2, the compressive strength is 58 MPa, 65 MPa and 71 MPa. Based on the results of compressive strength with the addition of 5% of nano silica, fixed water/ binder 0.31 with 0.6% PCE, there was a decrease in compressive strength compared to concrete in reference. The decrease in compressive strength at 28, 56 and 91 days was 29.7%, 26.5%, and 23.4% respectively. This occurred because Agglomeration occurs [14]. However, agglomeration can be overcome by adding 3.5% of PCE with a percentage of by weight of cement. This can be seen from the value of the resulting slump and increased compressive strength compared to the concrete in reference. The percentage increase in compressive strength at BNS2 for 28 days of concrete age was 23.4%, 56 days at 32.7% and 91 days at 29%. There is a reduction in the amount of Ca(OH)_2 for nano modified concrete indicating the formation of the additional C-S-H gel. From mechanical characterization of compressive strength. The SiO_2 in nanoscale behave not only as a filler to improve the microstructure but also as an activator to promote pozzolanic reactions. The influences and importance of superplasticizer while mixing cement with nanoparticles for mortar or concrete preparation were addressed [15, 16].

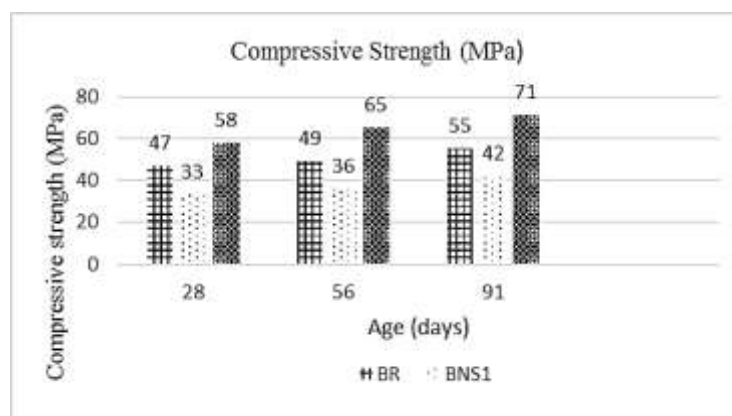


Figure 4. The Result of testing the Compressive strength

The results of compressive strength show that the long-term effect of nano silica has a similar performance to normal concrete, which increases with age of concrete.

3.3. Tensile Strength

The results of the concrete tensile strength at 28, 56 and 91 days is shown in Figure 5. The tensile strength of BR specimens at 28 days was 14.4 MPa and 56 days was 14.5 MPa. There was an increment of 0.7%. After 91 days, the tensile strength recorded was 16.9 MPa and this increased by 17.4%. The tensile strength for BNS1 at 28 days was 11.5 MPa and this decreased by 20.1%. At 56 days, the tensile strength was 12 MPa and this decreased by 17.2%. At 91 days, it was 14.9 MPa and this decreased by 11.8% from the concrete in reference. Meanwhile, in the BNS2 specimen, there was an increase in the tensile strength at 28 days by 47.9% to 21.3 MPa. At 56 days, it increased from 47.2% to 22.8% and at 91 days, a 40.8% increase from 16.9 MPa to 23.8 MPa. The results show that the addition of 5% of nano silica increased the concrete tensile strength in BSN2 and a decrease in BSN1 compared to BR.

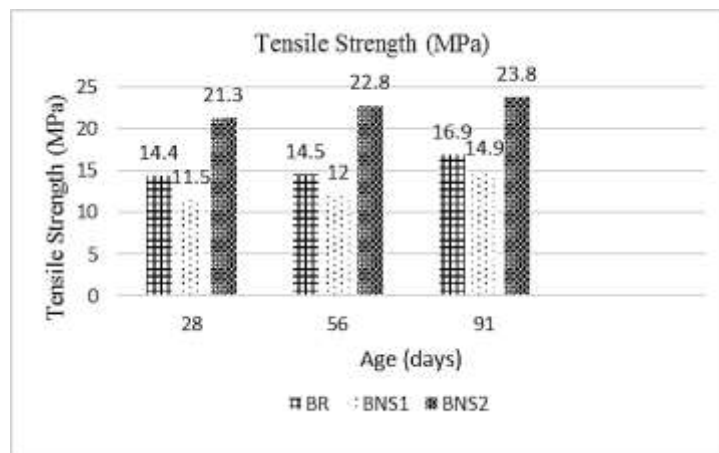


Figure 5. The Result of testing the Tensile strength

The increase in concrete compressive and tensile strength with the addition of 5% nano-silica, was influenced by the method of nano silica mixing. In BSN1, nano silica is stirred with fine aggregates, agglomeration occurs to inhibit chemical reactions. This results in a relative decrease in tensile strength. Whereas in BSN2, nano silica is mixed with cement first, enabling it to be dispersed well and this causes nano-silica to react perfectly. Therefore, this attribute can increase the compressive and tensile strength of the concrete.

4. Conclusion

1. The long-term effects of nano silica on concrete can improve its mechanical properties better than normal concrete.
2. The value of compressive strength can increase by 23.4% - 32.7% and tensile strength 40.8% - 47.2%.
3. The order to efficiently use nano silica, it must be mixed with cement first to produce a perfect reaction.

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