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Keywords

Durability; silica fume; nano silica

Abstract

The latest trend of concrete technology declared that concrete is not only needs strength but also durability. It is concurrently with the environmental issues that material durability is something that needs to be prioritized in its use. Various attempts have been made to produce concrete that has high durability. Many studies and experiments have been done partly by using admixtures of fly ash, and silica fume (FS). The latest development was the application of nano silica (NS) to improve the performance of concrete especially its durability. In this study, further experiments were done by using admixtures of nano silica with and without silica fume. The additives were applied to the concrete mix design of high performance concrete (HPC) with $f'c$ 100 MPa as a reference, then mixed with NS in a percentage of 3%, 5%, 10%, 15% with and without silica fume. Further compressive strength, and durability testing were done with a standard DIN 1045, and RCPT standard ASTM C 1202. The experimental results shown that the optimum admixtures proportion were the application of NS 5% and SF 5%, which given the best of concrete compressive strength and durability. Furthermore, the

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***Abstract*—The latest trend of concrete technology declared that concrete is not only needs strength but also durability. It is concurrently with the environmental issues that material durability is something that needs to be prioritized in its use. Various attempts have been made to produce concrete that has high durability. Many studies and experiments have been done partly by using admixtures of fly ash, and silica fume (FS). The latest development was the application of nano silica (NS) to improve the performance of concrete especially its durability. In this study, further experiments were done by using admixtures of nano silica with and without silica fume. The additives were applied to the concrete mix design of high performance concrete (HPC) with *f*'c 100 MPa as a reference, then mixed with NS in a percentage of 3%, 5%, 10%, 15% with and without silica fume. Further compressive strength, and durability testing were done with a standard DIN 1045, and RCPT standard ASTM C 1202. The experimental results shown that the optimum admixtures proportion were the application of NS 5% and SF 5%, which given the best of concrete compressive strength and durability. Furthermore, the combination of the used of nano silica with silica fume is more effective than nano silica without silica fume.**

Keywords-Durability; silica fume; nano silica

I. INTRODUCTION

This template, Durability is an important factor of concrete, which is the resistance of the material against external influences over the age of structure in the system of services. According to ACI 2008 concrete durability is defined as the ability to resist weathering, chemical attack, abrasion, or other damage [1]. Durable concrete will retain its original form, quality, and the ability of services though exposed to the environment [2]. However, due to interaction with the environment and the nature of the changes with respect to time, there is nothing inherently durable material.

Durability of concrete has decreased, due to mechanical or physical influences, such as chemical weathering by weather, abrasion, gas or polluting industries. As known, concrete is a building material that vulnerable to outside interference. Hence, it needs to be given special attention in the protection to bite. It is widely known that high performance concrete (HPC) with ratio of water and Binder ingredients between 0.3 and 0.4 is excellent in durability. Durability of concrete mostly depends on permeability and diffusion. Permeability is defined as property which regulates the rate of fluid flow to the porous material under pressure [3]. Concrete permeability can be measured by determining the flow rate of water through the concrete specimens. It is important that the concrete ingredients that have been detained are protected against the intrusion of outside material, for example from dirty water containing acids due to pollution. The higher ratio of water against concrete shows more pores that are interconnected and increase the possibility of high concrete permeability. On the other hand, the application of Silica fume and Nano Silica will decrease the permeability in concrete due to the reduction of porosity, as well as connected pores. In the case of diffusion, this is defined as the rate of migration of ions or elements in concrete due to the difference in concentration. The diffusion coefficient measurements conducted by reason of chloride shown that diffusion in concrete produced corrosion.

Some researchers [4,5] investigated the durability of concrete in relation with carbonation reactions, such as aggregate alkali, to the corrosion of reinforcement, and resistance to sulphate Meanwhile conducted a study on permeability based on microstructure observations of concrete, which said that concrete with Nano Silica had a good impermeability, and produced more solid concrete [6].

The used of heavy cement Nano Silica 3.8%, could elevate the compressibility, tensile strength, and the durability of the concrete [7]. These were due to the onset of more homogeneous microstructures, more solid and gel size C-S-H. The average value of Coulomb Test RCPT to concrete mix ingredients and supplements such as silica fume, fly ash, and slag were low to very low [8]. The durability and mechanical properties of HPC depends on improvement of cement paste [9]. Further quality improvement in cement paste and aggregate interface were obtained through the use of admixtures. Thus, this research is a further experiment of the usage of Nano Silica and Silica Fume for durability improvement, and to investigate its impact on high performance concrete.

II. MATERIALS AND METHODOLOGY

The manufacturing of the specimens for this research was based on the reference concrete mix proportion of 100 MPa (100 f'_c R) composition: cement type I = 800 kg/m^3, Silica Fume ex Sika = 120 kg /m^3, water/binder: 0.23, fine aggregate = 637kg/m^3, coarse aggregate = 1091 kg / m^3, super plasticizer Viscocrete 10 = 5.21 liters. Size of Nano Silica ex Bratachem 20-40 nm.

Table 1. Shows the nomenclature on the specimen based on composition of mixture proportion.

TABLE I. NOMENCLATURE OF SPECIMENS

No	Specimen	Nano silica NS (%)				Silica fume (%)
		3	5	10	15	5
1	f'_c 100 R	-	-	-	-	-
2	f'_c 100 NS3	√	-	-	-	-
3	f'_c 100 NS5	-	√	-	-	-
4	f'_c 100 NS10	-	-	√	-	-
5	f'_c 100 NS15	-	-	-	√	-
6	f'_c 100 NS3 SF5	√	-	-	-	√
7	f'_c 100 NS5 SF5	-	√	-	-	√
8	f'_c 100 NS10 SF5	-	-	√	-	√
9	f'_c 100 NS15 SF5	-	-	-	√	√

Testing the permeability was conducted according to the concrete standard DIN 1045. Specimens in the form of concrete block size 200 mm x 120 mm x 200 mm, and aged of 28 days were used. The pressure to each specimen was 0.5 N/mm^2 for 3 times 24 hours. Rapid Chloride Penetration Test (RCPT) was carried out according to the standard ASTM C 1202 at the cylindrical specimens 50 mm x 100 mm.

III. Result and Discussion

A. *Impact on Compressive Strength*

Figure 1. Shows the impact of NS on different percentages against the compressive strength. The use of NS 5% without SF provide increased compressive strength of 43.8% (126.1 MPa), while the addition of NS 5% with SF 5% increase in the compressive strength of 57% (137.3 MPa). The results of combining the usage of NS and SF are more effective because the merger of filler and pozzolanic reactivity [10,11].

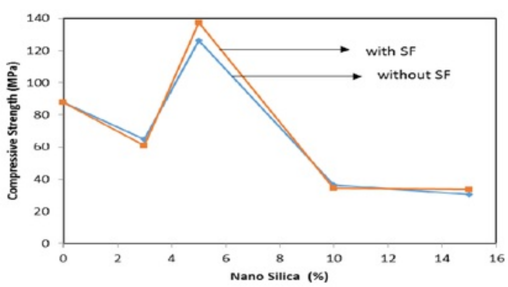

FIGURE I. COMPRESSIVE STRENGTH OF HPC CONTAINING NS WITH AND WITHOUT SF

B. *Impact on permeability*

Table 2 exposes the permeability test results, which shown that the composition of NS 5% and SF 5% produces a better waterproof.

TABLE II. PERMEABILITY TEST RESULTS OF f'_c100 WITH NS AND SF.

No	Type	Permeability test with DIN 1045 standard	
		28 day (cm)	Result
1	f'_c 100 R	1.0	waterproof
2	f'_c 100 NS3	2.3	waterproof
3	f'_c 100 NS5	1.2	waterproof
4	f'_c 100 NS10	3,2	waterproof
5	f'_c 100 NS15	3.2	waterproof
6	f'_c 100 NS3 SF5	2.8	waterproof
7	f'_c 100 NS5 SF5	1.1	waterproof
8	f'_c 100 NS10 SF5	3.2	waterproof
9	f'_c 100 NS15 SF5	3.5	waterproof

The impact of using NS alone as admixture against concrete permeability is shown in Figure 2. The use NS 3% increase in permeability to 2.3 cm (130%), NS 5% increase in value to 1.2 cm (20%), NS 10% increased to 3.2 cm (220%) and NS 15% increase in permeability to 3.3 cm (230%). This shows that the use NS not affect the permeability of concrete and even tended to increased permeability values, however, the resulting concrete are still providing watertight concrete because it limits the penetration to less than 5 cm.

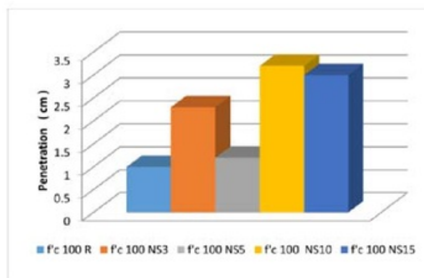

FIGURE II. THE USAGE OF NS WITH WATER PENETRATION

The used of NS in conjunction with SF, as shown in Figure 3, increase in the permeability value to 180%, 220%, and 250%. However, f'_c 100 NS 5% SF 5% gave an increase of 10% against reference. These results indicate that the used of NS 5% and SF 5% is the optimum mixture. The cement paste was added with nano silica, it increased the chain length of CSH gel and significantly improves the CSH. That an increase CSH would increase the leaching resilience of calcium, and increase the durability [12].

The improvement of concrete compressive strength and a decrease in permeability occurred because NS and SF will be dispersed and reacted with crystalline $Ca(OH)_2$ as pozzolanic material. It creates a matrix of cement, which is more homogenous and compact, and reducing the capillary pores. Hence, making the concrete more impermeable and increased compressive strength [13,14].

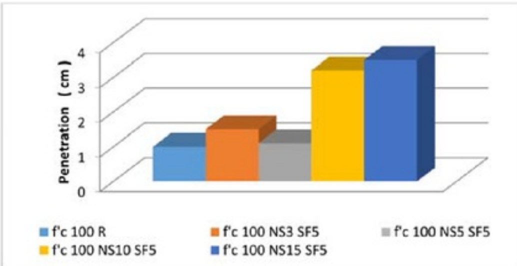

FIGURE III. THE USAGE OF NS AND SF AGAINST WATER PENETRATION

C. *Impact on Reinforcement Corrosion*

The impact on reinforcement corrosion by Rapid Chloride Penetration Test is presented in Table 3. The usages of NS alone and with SF were measured through the charge that passed each specimen. With the charge that passed the high performance concrete (f'_c 100 R) at 28 days is considered as Very Low (107,1 Coulomb), the other specimens are considered as Low, moderate and very low. It is found that the admixtures of NS 5% and SF 5% had passed charge of 339 Coulomb, which is considered as Very low

TABLE III. TEST RESULTS OF RCPT FOR F'$_C$ 100 RWITH NS AND SF.

No	Type	RCPT Test standard ASTM C 1202	
		28day (Coulombs)	Result
1	f'c 100 R	107,1	Very low
2	f'c 100 NS3	2661	Moderate
3	f'c 100 NS5	351	Very low
4	f'c 100 NS10	1602	Low
5	f'c 100 NS15	1512	Low
6	f'c 100 NS3 SF5	264	Very Low
7	f'c 100 NS5 SF5	339	Very Low
8	f'c 100 NS10 SF5	1608	Low
9	f'c 100 NS15 SF5	1377	Low

IV. CONCLUSION

In this research experiment the durability improvement of high performance concrete was conducted by improving its permeability and the resistance of concrete reinforcement against corrosion. It was found that:

- The optimum proportion of admixtures of NS 5 % and SF 5% has given the best compressive strength and concrete durability;
- The combination admixtures of NS with SF are more effective than NS without SF; and
- Percentage nano silica usage that exceeds 10%, lowering the mechanical properties and durability of concrete

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