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The Effect of Water-Cement Ratio in Compressive and Abrasion Strength of the Nano Silica Concretes

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Abstract: Development and construction of hydraulic structures like dams, the concrete durability in these kinds of structures has gained special attention. One of the crucial factor in concrete technology is it durability in hydraulic structures. Concrete has to resist against abrasion due to the crash of particles carried by water. To enhance the abrasion resistance of concrete different methods have been offered. In the present stud, the role of water-cement ratio in compressive and abrasion strength of nano silica concrete was investigated. The constructed concrete samples with 3% nano silica and water-cement ratios of 0.33, 0.36, 0.40, 0.44 and 0.50 were experimented. Other design features remained fixed in all concrete samples. The compressive strength of block samples of 15×15×15cm^3 were evaluated in duration of 7, 28 and 91 days. The abrasion strength of the same block samples were tested after 28 days. The results of compressive strength experiment showed that due to reduction of water-cement ratio from 0.33 to 0.50, the compressive strength improved by 34.4 and 35.2 %, respectively. The results for abrasion experiments showed that due to reduction of water-cement ratio from 0.50 to 0.33, the abrasion strength improved by 36.13%.

Key words: Compressive strength · Abrasion strength · Water-cement ratio · Nano silica concrete · Hydraulic structure

INTRODUCTION

One of the factors endangering the durability of concrete hydraulic structures is the nature of erosion occurred in these types of structures [1, 2]. Failures due to erosion may occurs on the concrete surface; mainly because of the existence of gravel, sand, stone, ice particles or any kind of sediments carried out by fluid flow [3-5]. The process of erosion depends upon factors such as shape, stiffness, the amount of particles carried out by flow of water, water speed, the existence of turbulent flow and also the quality of concrete [6, 7]. There are different methods improve the abrasion strength in concrete; here experiments have been conducted on effect of water-cement ratio [6, 8-10]. The strength of concrete samples within a wide range of water-cement ratio were evaluated. Water-cement ratio is usually depends on properties of mixture of sands, gravels, silica powder and cements [11, 12]. In traditional cements in order to obtain the required strength and durability, the water-cement ratio kept constant [13-15]. However the water cement ratio has to chosen by variation of amount of water or cement in the mixture of fixed size of aggregates, sands and silica composition [16-18].

In the present study, the ratios of water -cement were varied from 0.33-0.50 to examine the compressive strength in the concrete samples. It was found that a suitable ratio may resulted in highly stable and strengthen concrete.

Experiments Conducted on Concrete Samples: The prepared concrete samples have 3% nano silica and the water-cement ratios in the mixture were 0.33, 0.36, 0.40, 0.44 and 0.50. Other design features were fixed in all concrete samples. The following experiments were conducted on concrete samples.

- The compressive strength of block samples of 15×15×15 cm^3 after duration of 7, 28 and 91 days were determined.
- The abrasion strength of block samples of 15×15×15 cm^3 after aging 28 days in Water Sand Blast way were defined.

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Table 1: Compressive strength experiment for samples with water-cement ratio of 0.33

Average Compressive Strength (Mpa)	Aging, days	Water-Cement ratio, W/C
42.71	7	0.33
58.03	28	
62.92	91	

Table 2: Compressive strength experiment for samples with water-cement ratio of 0.36

Average Compressive Strength (Mpa)	Aging, days	Water-Cement ratio, W/C
40.43	7	0.36
54.81	28	
59.56	91	

Table 3: Compressive strength experiment for samples with water-cement ratio of 0.40

Average Compressive Strength (Mpa)	Aging, days	Water-Cement ratio, W/C
37.73	7	0.40
50.83	28	
55.27	91	

Table 4: Compressive strength experiment for samples with water-cement ratio of 0.44

Average Compressive Strength (Mpa)	Aging, days	Water-Cement ratio, W/C
35.66	7	0.44
47.13	28	
51.76	91	

Table 5: Compressive strength experiment for samples with water-cement ratio of 0.50

Average Compressive Strength(Mpa)	Aging, days	Water-Cement ratio, W/C
31.78	7	0.50
42.07	28	
46.55	91	

Mixture Prepared for Nano Silica Concrete: In prepared mixture of samples, the following issues were focused:

- Slump of samples ranged in 60-100 mm.
- Rock materials were non-ballast kind.
- The most diagonal of aggregates were 20 mm.
- The consuming cement was in regular Portland kind (First-Type).
- The nano silica amount was fixed for all samples and the amount of 3% cements were added.
- Particular compressive strength of sample after age of 28 past days were 35 Mpa.
- The water-cement ratio was varied and the ratio ranged and experimented between 0.33 to 0.50.
- To reach the desired fluidity and performance, the super-plasticizer, the MELCRET is used.

Compressive Strength Experiments: After conducting the compressive strength experiment some results were extracted and summarized in Tables 1-6 as stated as follows:

Compressive Strength Experiments:

- The most or highest compressive strength after aging 7, 28 and 91 days related to samples with water-cement ratio of 0.33.
- The least or minimum compressive strength after aging 7, 28 and 91 days related to samples with water-cement ratio of 0.50.
- About 68% of compressive strength of samples with the age of 91 days resulted in the first 7 days.
- About 75% of compressive strength of samples with the age of 28 days resulted in the first 7 days.
- By increasing the water-cement ratio, the compressive strength of concrete samples was daily decreased.
- The least growth of compressive strength from 7 to 28 past days relates to the samples with water-cement ratio of 0.50.

Table 6: Improved compressive strength after aging 7, 28 and 91 days for various water-cement

Improvement of compressive strength after 91 days, percentage	Improvement of compressive strength after 28 days, percentage	Improvement of compressive strength of 7 days, percentage	Water-Cement ratio, W/C
35.17	37.94	34.39	0.33
27.95	30.28	27.22	0.36
18.73	20.82	18.72	0.40
11.19	12.03	12.21	0.44

Table 7: Abrasion depth according to water-cement ratio.

Water-cement ratio, W/C	0.33	0.36	0.40	0.44	0.50
Average abrasion depth (mm)	0.723	0.860	1.01	1.103	1.132

Table 8: Percentage of abrasion strength improvement versus the concrete with variable water-cement ratio

Percentage of abrasion strength improved	Water-cement ratio, W/C
36.13	0.33
24.03	0.36
10.78	0.40
2.56	0.44

- The most growth of compressive strength from 7 to 28 past days relates to the samples with water-cement ratio of 0.33.
- The growth of compressive strength for the sample aged 28 to 91 days for all of the sample concretes remained fixed without any significant changes.
- The total shape of curve for sample with the age of 7, 28 and 91 days was almost the same.
- By increasing the water-cement ratio, compressive strength curves of samples for the age of 7 and 28 past days approached to the same value.

Abrasion Strength Experiments: The abrasion strength experiments were conducted; the following results are summarized in Table 7 as stated as follows:

RESULTS AND DISCUSSION

Figure 1 depicts the variation of compressive strength with respect to water- cement ratio for samples after duration of 7, 28 and 91 days.

Figure 2 shows the compressive strength improved while reduction of water-cement ratio in nano silica concrete caused the compressive and abrasion strength will increase. By reduction of water-cement ratio from 0.50 to 0.33, the 7 days compressive strength of concrete increases to 34.39. Also, reduction of water-cement ratio from 0.50 to 0.33 after 28 days compressive strength of concrete increased to 37.94. The reduction of water-cement ratio from 0.50 to 0.33 after 91 days compressive strength of concrete increased to 35.17. Reduction of water-cement ratio from 0.50 to 0.33, the abrasion strength of concrete improved to 36.13%. An increase in water-cement ratio from 0.33 to 0.50, the gradient of depth of abrasion curve will decrease little by little. This matter is related to two-phase nature of concrete in abrasion (mortar phase and aggregate phase) that the more water-cement ratio increases, the abrasion

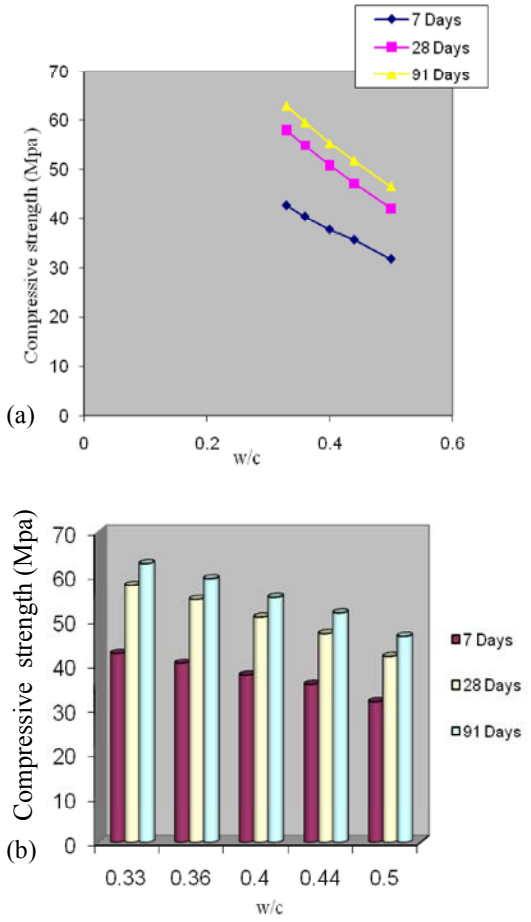

Fig. 1: Variation of compressive strength with respect to water- cement ratio for samples after duration of 7, 28 and 91 days

strength of mortar phase decreases but the abrasion strength of concrete tends to abrasion strength of aggregates. The Water Sand Blast way is the suitable method for evaluating the abrasion strength of concrete against water, because this method to a great extant can simulate the real abrasion made in concrete. To enhance the abrasion strength of concrete, it is necessary to enhance the mortar phase and the aggregate phase with each other. Mortar phase can be enhanced by reduction of water-cement ratio, using nano silica, suitable curing and so on, also aggregate phase can be enhanced by abrasion-resistant aggregates like granite aggregates. The condition of conducting abrasion experiment can be more approximated to the real condition of concrete abrasion against water. To do this the silice sand should be shot under water and in less than 90 degree angle.

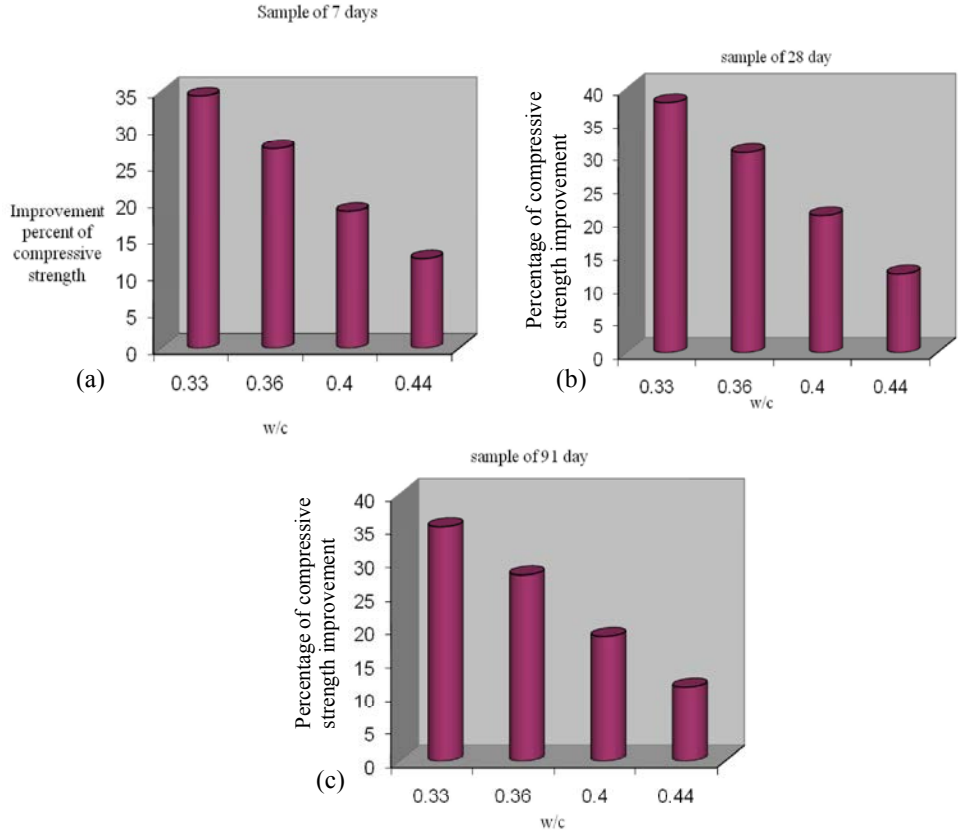

Fig. 2: Compressive strength improvement after a. 7 days; b. 28 days; c. 91 days

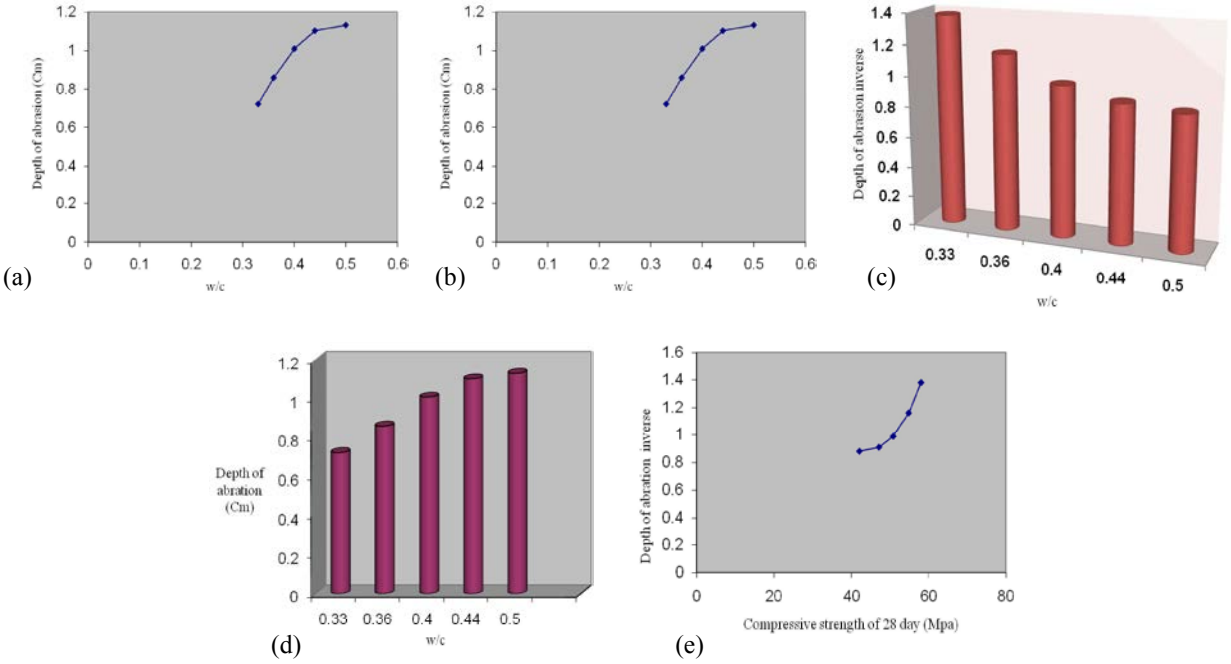

Fig. 3: Depth of abrasion with respect to water-cement ratio (3a to 3d), e: with respect to compressive strength

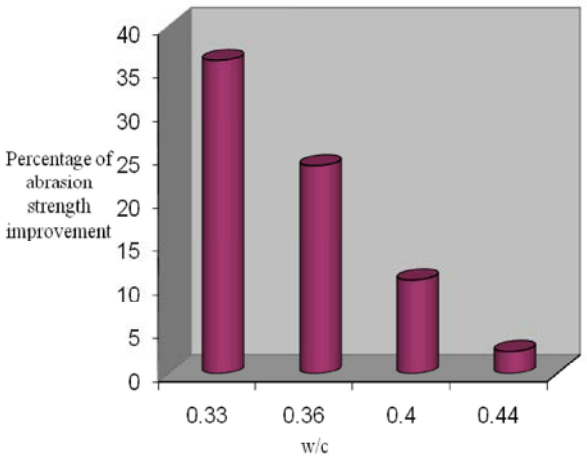

Fig. 4: The percentage of abrasion strength improvement

By increase of compressive strength of concrete, the abrasion strength increases. According to particular notable level of nano silica (180m^2 /g) and the need for great water to reach the desired fluidity, 3% is the most suitable amount of it, that this aount of nano silica is optimum and the more amounts of it have negative effects to fluidity and performance of concrete.

Figure 3 presents the depth of abrasion with respect to water-cement ratio. These figures show the barometer of abrasion depth against water-cement ratio. According to these barometers, due to increase of water-cement ratio, the depth of abrasion increased. According to the Figure; increase of water-cement ratio from0.33 to 0.50, the gradient of depth of abrasion curve will decrease little by little. This matter cab be related to two-phase nature of concrete (mortar phase and aggregate phase) in abrasion. The more water-cement ratio increases, the abrasion strength of mortar phase decreases but the abrasion strength of concrete tends to abrasion strength of aggregates. The concave of curve is on bottom position and the curve within the water-cement ratio of 0.33 to 0.50 is maximized. It seems that the maximum of curve in accordance to water-cement ratio will be within 0.50. The photo of depth of abrasion against water-cement ratio. Cause the abrasion strength of concrete has contradictory relations to depth of abrasion, so the mentioned shapes to some extent can show the changes of abrasion strength curve. According to these shapes, by increase of water-cement ratio, the abrasion strength decreases.

Figure 4 shows the percent of abrasion strength improvement in relation to concrete with water-cement of 0.50.

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