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Effect of Water-Cement Ratio on Abrasive Strength, Porosity and Permeability of Nano-Silica Concrete

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Abstract: Today, due to rapid development of construction of hydraulic structures like dams, the constituent material used in concrete and its durability in these kinds of structures has gained dominant interests and importance. One of the important factors of concrete durability in these structures is its resistance against abrasion due to crash of particles carried out as hydrated crystalline particulate matter. To enhance the abrasion resistance of concrete, different methods have been offered and investigated by many researchers/ The aim of present article is to investigate the important parameter i.e. water-cement ratio on abrasive strength, porosity and the coefficient of hydraulic conductivity of nanosilica concrete. The water-cement ratio is one of the key factors effecting on concrete properties. Abrasive resistance, porosity, efficiency and like all are directly or indirectly affected by the above parameters. In engineering work the underlying assumption is the fact that the compressive strength of the concrete gained on a specific temperature depends on two factors including water cement ratio and degree of density. The fine nanosilica powder originated from the furnace of alloy manufacturers enriched super-pozzolan mixed with cement mortar made an improved concrete with high strength and abrasive resistance. Furthermore, the nanosilica being extremely fine particles can easily penetrate through entire concrete pores; resulted in reduction of permeability and porosity of concrete.

Key words: Abrasive strength · Hydraulic conductivity coefficient · Hydraulic structure Nanosilica concrete · Porosity · Water-cement ratio

INTRODUCTION

Due to the economic importance of dams in a country; it is considered as strategic structures; so they are required to possess appropriate durability [1, 2]. In recent decade, the effect of nanosilica particles as fillers in pozzolanic concrete has been investigated [3,4]. Nanosilica cement blend has generated great interesting research for the fabrication of high strength hydraulic structures [5, 6]. Nano-silica powder as a filler is used to enhance the abrasive and compressive strength of concrete [7-9]. Effect of noano-structured material such as nanosilica and a desired water-cement ratio enhanced the physical properties of the novel cement composite [10,11]. Among the factors affecting durability and efficiency of these concrete structures; one can mention the effect of water cement ratio in abrasive strength, porosity and permeability of nano-silica used in manufacturing of durable concrete [12,13]. Therefore, it seems important that due to the high and rather modern concrete technology advance research and serious investigations may required on special concrete samples for hydraulic dam [14,15].

In traditional cements in order to obtain the high strength of concrete and durability, the water-cement ratio kept constant [3, 10, 16-20]. However the water cement ratio has to be situated based on microcrystallinity and the nature or composition of cement used in concrete sample [21-23]. The amount of water and cement in the mixture depend on the identified size of aggregates, sands and nanosilica composition [3, 4, 8, 10, 23].

In the present study, the ratios of water-cement were varied in order to examine and evaluate abrasive and compressive strength of the concrete samples. These effective factors may be influential parameters on sample concrete. The main advantages of use of nano-silica concrete would be high abrasive strength, reducing permeability and porosity.

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MATERIALS AND METHODS

Experimental: The prepared concrete samples contained 3% nanosilica and the water-cement ratios in the mixture were aviated from 0.33, 0.36, 0.40, 0.44 and 0.5. Other composition of the mixture were kept constant in all concrete samples. The following experiments were preformed on concrete samples.

- Wet-Sand Blast technique was used to identify the strength of concrete. The abrasive strength of block samples of $15\times15\times15$ cm^3 after duration of 28 days were determined.
- Penetration Method was used to determine the hydraulic conductivity coefficient of cylindrical shape samples with the height and diameter of 10 and 10cm after duration of 28 days.

Nanosilica Concrete Mixture: In preparation of samples of nanosilica concrete mixture, the following components were considered:

- Slump of samples were within the range of 60-100 mm.
- The rock materials were non-ballast materials.
- At most, the diagonal of aggregates were 20 mm.
- The consumed cement was regular Portland cement Type I.
- The fixed amount of nanosilica in all samples were used; 3% nano-power added to the mixture of cement and aggregates.
- Particular compressive strength of sample after age of 28 past days were determined to be 35 Mpa.
- The water-cement ratio was varied and the ratio in the range of 0.33 to 0.50 were experimented.
- In order to reach the desired fluidity and high performance of concrete sample, the super-plasticizer, the FABCRET was used.

RESULTS AND DISCUSSION

Abrasive Strength Experiment: The abrasive strength experiments were preformed and the extracted results are summarized in Table 1.

Figure 1 depicts the abrasion depth against water-cement ratio. Considering the diagram with increasing the ration of water-cement, the abrasion depth increases. As the water cement ratio increased from 0.33 to 0.5, the abrasion depth gradually is reduced. This can be linked to the two-phase (mortar phase and aggregates phase) nature of concrete in abrasion. The more water-cement ratio increases, the less abrasive strength of mortar phase resulted but the abrasive strength of concrete inclines towards the abrasive strength of aggregates. As water

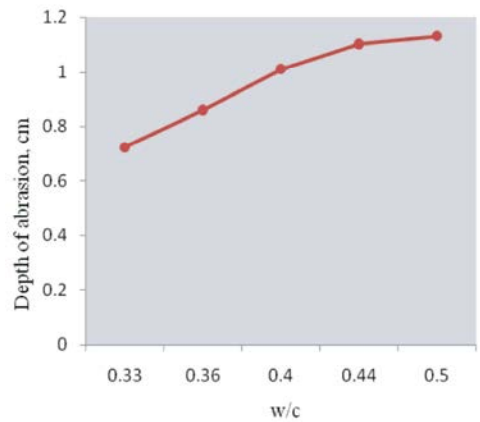

Fig. 1: Depth of abrasion with respect to water-cement ratio

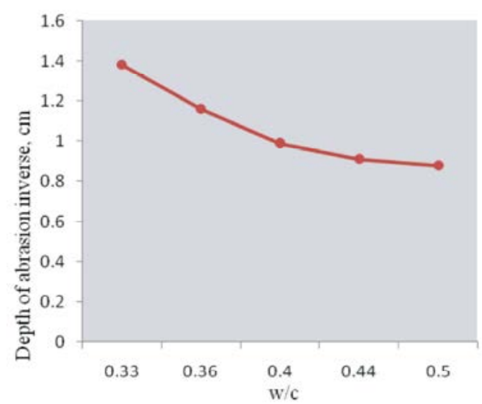

Fig. 2: Depth of abrasion with respect to water-cement ratio

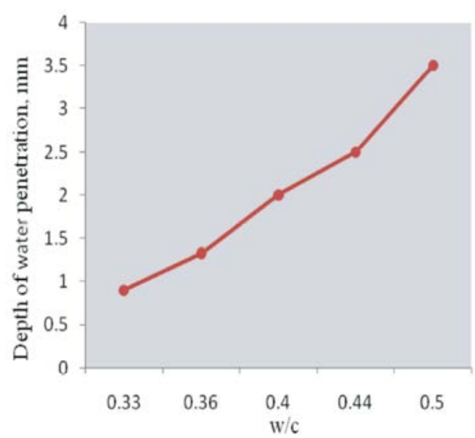

Fig. 3: The depth of water permeability with respect to water-cement ratio

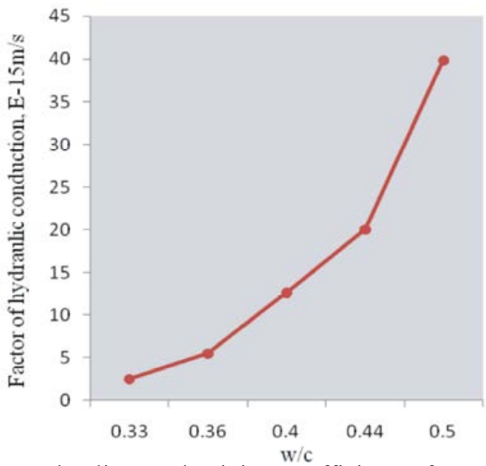

Fig. 4: Hydraulic conductivity coefficient of concrete with respect to water-cement ratio

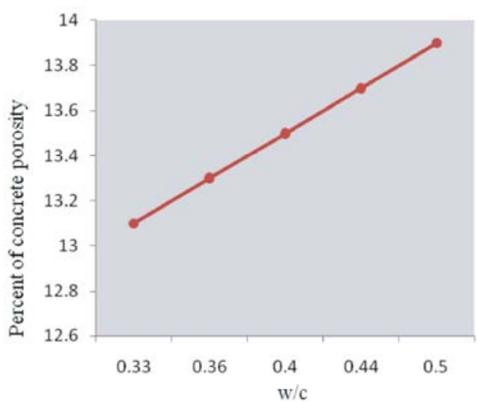

Fig. 5: The fluctuation diagram of concrete porosity with respect to water-cement ratio

cement ratio gradually increased to 0.5, the depth of abrasion may reached to maximum value where it is level off and stays relatively to a stabilized value. It seems that the maximum value for abrasive strength achieved for water-cement is about 0.5.

Figure 2 shows the inverse relations between the abrasion depth and water-cement ratio. Since the concrete abrasive strength has an inverse relationship with the depth of abrasion; therefore, the presentation of data demonstrate that as the water-cement ratio increased the abrasive strength decreased. The abrasive strength improvements and data for average permeability depth for variable water- cement ratio are summarized in Table 2.

Hydraulic Conductivity Coefficient: Figure 3 displays the water permeability depth based on different amounts of water-cement ratios. The presented data indicated that as the amount of water permeability depth was increased as the water-cement ratio increased.

Table 1: The abrasive strength experiment for samples with variable water-cement ratio

Water-cement ratio, W/C	0.33	0.36	0.40	0.44	0.50
Average Abrasive Strength, mm	0.72	0.86	1.01	1.103	1.132

Table 2: Abrasive strength improvement and average permeability depth for variable water-cement ratio

Water-cement ratio, W/C	Abrasive Strength Improvement, %	Average Permeability Depth, mm
0.33	36.13	0.81
0.36	24.03	1.21
0.40	10.78	1.75
0.44	2.56	2.12
0.50	2.23	3.13

Table 3: Hydraulic conductivity coefficient and porosity of concrete against water-cement ratio

Water-cement ratio, W/C	Hydraulic conductivity coefficient of cement, m/s	Porosity of concrete, %
0.33	2×10^{-15}	13
0.36	4.53×10^{-15}	13.21
0.40	9.63×10^{-15}	13.42
0.44	14.35×10^{-15}	13.63
0.50	31.71×10^{-15}	13.82

Table 4: The required values for computing hydraulic conductivity coefficient and porosity of concrete

Permeability time,s	Height arising from water pressure, m	Cement specific weight, g/cm`	Cement degree of hydration, %
259200	82.36	3.15	80

Figure 4 shows the amounts of the hydraulic conductivity coefficient of the concrete based on different amounts of water-cement ratios. The presented data indicated that as the water-cement ratio increased the hydraulic conductivity coefficient of the concrete also increased.

Figure 5 displays the curve changes for concrete porosity based on different amounts of water-cement ratios. The obtained data shows that by increasing water-cement ratio the porosity of the concrete is increased. Table 3 summarized values of the hydraulic conductivity coefficient and porosity of concrete with respect to water-cement ratio

To obtain the hydraulic conductivity coefficient and porosity of nanosilica concrete the following data presented in Table 4 may required to obtain the computed values for hydraulic conductivity coefficient and porosity of concrete.

It is notable that for computing the conductivity coefficient and porosity of concrete the following formula is used.

$$K_p = \frac{h_p^2 V}{2Th}$$

where $K_p$is the permeability coefficient of concrete, m/s; $h_p$is water permeability depth, w; T: water permeability time, sec; h: height arising from pressure, m; V: concrete porosity and in the formula for porosity is given as follows:

$$V = \frac{(w/c)\times(100-36.15 \times \alpha)}{(w+100/g)}$$

Where w/c is water-cement ratio; α is cement hydration degree; w is gravity water of concrete, kg/m^3 and g is cement specific weight, g/cm^3.

CONCLUSION

Reduction of water-cement ratio in nanosilica concrete caused the abrasive strength increases but the conductivity coefficient and the porosity of the nanosilica concrete deceased. By reduction of water-cement ratio from 0.50 to 0.33, the abrasive strength of concrete was improved by 36%. Also, reduction of water-cement ratio from 0.50 to 0.33, the hydraulic conductivity coefficient of the concrete reduces from 31.71×10^{-15} to 2×10^{-15} m/sec.I addition, the porosity of the concrete was reduced to 13% while the reduction of water-cement ratio from 0.50 to 0.33 occurred. The abrasion depth was gradually reduced as the water-cement ratio increased (from 0.33 to 0.50). This matter can be linked to the two-phase nature of concrete in abrasion (mortar phase and aggregates' phase) that the more water-cement ratio increases, the less abrasive strength of mortar phase resulted; but, the abrasive strength of concrete reduced towards the abrasive strength of aggregates. Wet Sand Blast was a suitable technique to evaluate the strength of concrete against water, since this method remarkably can simulate the erosion caused in concrete.

Penetration Method is a suitable approach for evaluation of concrete permeability, because this method is desired for the ratio of water depth in the concrete to the concrete cylinder height is negligible and this fact is achieved in nanosilica concretes. To enhance the abrasive strength of concrete, it is necessary to upgrade the mortar phase and the aggregates' phase together. Mortar phase can be enhanced by reduction of water-cement ratio, using nanosilica, suitable curing and also aggregate phase was 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 so the silice sand should be shot under water and in less than 90-degree angle.

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