THE INFLUENCES OF SILICA FUME AND CURING TEMPERATURE ON WATER PERMEABILITY OF CONCRETE

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ABSTRACT

An experimental study was carried out to determine the influence of Silica Fume (SF) and curing temperature on Water Permeability of Concrete (WPC). Concrete samples were in the form of cylinders and the Germanns Water Permeability Test was carried out on these samples after they had been isothermally water cured in four different temperatures of 5°C, 22°C, 39°C and 52°C up to the age of 28 days. The SF content of these cylinders were 0%, 5% and 10% of the cement content used. Results indicated that the WPC decreased as the SF content of the mix increased. However, as the curing temperature increased up to room temperature of 22°C, WPC decreased but as the curing temperature was increased further, WPC started to increase. This paper mainly presents the influence of SF on WPC, but also describes the adverse effect of high curing temperature on WPC.

Keywords: silica fume, water permeability, water curing, isothermal, Germanns water permeability test

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INTRODUCTION

Permeability is the ease with which liquids or gasses can travel through concrete. This property is of interest in relation to the water tightness of liquid retaining structures and to chemical attack. It is necessary for concrete to be reliable and to withstand the conditions it has been designed for, to have trouble free service life. Thus, it needs to be durable. Durability is achieved through resistance of adverse external environmental conditions as well as adverse internal conditions of concrete. In both cases, the impermeability of concrete is important to avoid deterioration of concrete. [1,2,4]

Concrete Permeability

The penetration of solutions into concrete depends on its permeability and as this results many adverse effects that are not desired. Concrete which are permeable may have cracks during freezing and thawing. Through time, these cracks may increase in size to affect the strength of concrete. Also, the penetration of chlorides, water, etc. through these cracks may lead to corrosion of reinforcement to cause loss of strength. Another cause of permeability of concrete is the pores within the cement matrix. The causes of these voids are mainly; non-optimum water-cement ratio, incomplete compaction, bleeding, adverse curing techniques and temperatures, rate of hydration and material size distribution. Due to these adverse effects, preventive measures must be taken to avoid these problems such as optimim w/c ratio value, optimum compaction time, or/and adding mineral admixtures. [1,2]

Isothermally Curing of the Concrete in Water Tanks of Different Temperatures

After casting the concrete, during the early stages of hardening, curing methods are applied to maintain the concrete in continuous moist condition so that the originally water filled voids of the cement paste has been filled by the products of cement hydration. And it is a known fact that the hydration of cement can only take place in water filled capillaries. Curing can either be applied by preventing water evaporation by the provision of some suitable protective covering or by a much more practical on site method of repeatedly wetting the surface of concrete by water. But there has not been sufficient attention given to the influence of curing temperature of concrete. Rise in curing temperature speeds up the chemical reactions of hydration which leads to an increase in early strength gain but this may lead to adverse effect on the later strengths if the temperature is extremely high. So the optimum curing temperatures should be used to have higher strength and less amount of pores , thus lower permeability, for both precast and on site concrete. [1,2]

Silica Fume Usage in Concrete

Silica Fume is considered to be a man-made pozzolan that has high potential in concrete industry. It is the by-product of the manufacture of element Silicon and Ferro-Silicon alloys. The particle size of silicon dioxide is approximately 1/100 of a typical type-I Portland cement and the average particle diameter is about 0.1 μm. Silica fume has proven to densify the paste when mixed with ordinary Portland Cement due to its high reactivity with Calcium Hydroxide which is released by the hydration of the cement to produce extra C-S-H gel. These effects lead to pore refinement of the cement paste and densification in the interfacial zone between aggregates and cement paste to improve the bond, thus increasing the strength, the durability and impermeability of concrete. However, it should be kept in mind that excessive usage of silica fume can cause adverse effect due to replacement of cement particles with silica fume, and this may result lack of hydration in those areas. [1]

Measurement of Concrete Permeability

The permeability of concrete may be measured through simple laboratory or site experiments. These tests generally measures the depth of water penetration under pressure. Germanns Water Permeability Tester is one of the practical kits to measure microcracking and porosities of concrete surface on site, which gives an idea about the water permeability of that concrete as well as surface porosity and absorption. [5] The test is performed for three days, each day applying different pressures to the concrete, 1.5 Bar, 2.5 Bar and 3.0 Bar respectively. After the third day, the cylinder is broken axially and the visual depth of water penetration is measured. A watertight concrete should not exhibit penetration deeper than 20 mm, after the 3 day applied pressure. For comparison, the flux "q" (mm/sec) for a given water pressure may be calculated using the mentioned procedure with the following equation:

$$q = [\, B\,(g_1 - g_2) / At \,] \qquad (1)$$

where;

q = the flux (mm/sec)
B = area of the micro-meter pin being pressed into the chamber water, 78.6 mm ^{2} for a 10 mm pin diameter
A = the water pressure surface area, 3018 mm ^{2} (gasket inner diameter 62 mm)
g_1 = the micrometer gauge readings in mm, before (taken 20 mm)
g_2 = the micrometer gauge readings in mm, after
t = the time that the test is performed (seconds)

Then the surface permeability may be assessed by means of d'Arcys Law:

$$C_{cp} = [\, q / (\, b\,(\Delta P / L)\,)\,] \qquad (2)$$

C_{cp} = the concrete permeability coefficient (mm^2/sec.BAR)
q = the flux (mm/sec)
b = % of the concrete cement matrix, 29.6%
ΔP = the pressure selected (BAR)
L = the length the pressure is applied over (15 mm, equal to the width of the pressure gasket)

The calculations are based on the assumption that the water is flowing in the concrete parallel to the gasket, from the compression chamber to the outside. [1,5]

EXPERIMENTAL STUDY

Testing Materials and Mix Proportions

The cement used was blast furnace slag cement complying with T.S.20 – C.C.32.5. The Chemical Composition of the cement is given in Table 1. Clean and neat aggregate from a crushing plant in Besparmak Mountains of North Cyprus was used. Ordinary drinkable tap water was used for the mixes. The silica fume used was obtained from Antalya Electro-Metallurgy Industry Plant. The chemical composition of silica fume is given in Table 2. The mix proportions are given in Table 3, and the proportioning were performed by weight batching method. [1]

Experimental Testing Program and Results

Germanns Water Permeability test was carried out according to ISO/DIS 7031 and very similar to CAT.C.245-C246 Water Impermeability tests which gives the specifications according to DIN 1048, paragraph 16, part 2. With the GWT, a sealed pressure chamber is attached to the concrete surface, boiled water is filled into the chamber and required water pressure is applied to the surface. The pressure is kept constant using a micro-meter gauge with the attached pin that substitutes the water leaving the chamber, to measure the amount of water penetrating the concrete. The difference in the gauge position over a given time is taken as a measure of the water penetrability for a given water pressure. GWT is shown in Fig.1.

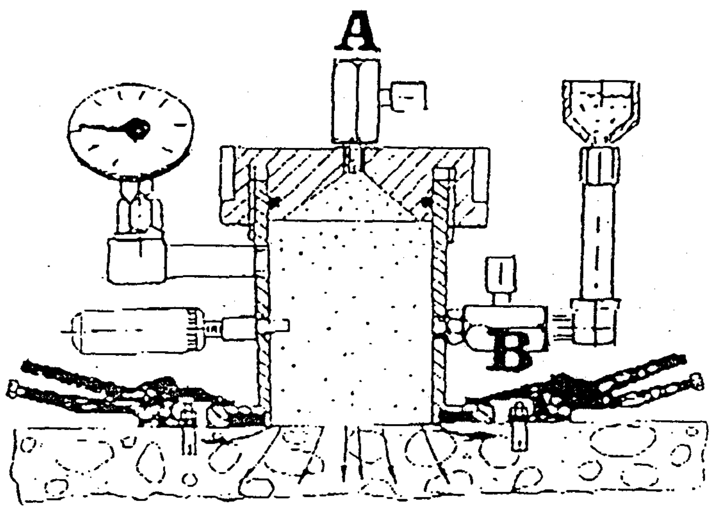

Figure 1. Testing with the GWT on a horizontal face [5]

In this test; as mentioned before, pressure is applied for three days, each day being different as; 1.5 Bar, 2.5 Bar and 3.0 Bar respectively. After the third day, the cylinder is broken axially and the visual depth of water penetration is measured. For this experiment, the tests were done on three cylinders that have been water cured in different temperatures of 5°C, 22°C, 39°C and 52°C for 28 days, each type containing 0%, 5% and 10% Silica fume, to test the influence of silica fume as well as temperature. The tested concrete were cylindrical of height 10 cm and diameter 13 cm. The results of the tests are given in Table 3.

Discussion of Experimental Results

The usage of silica fume was shown to give a larger amount of improvement in impermeability of water from 0% to 5% increase, but after 5% to 10% it still improved the permeability but in a smaller rate. On the other hand, the water permeability can be observed to be highly influenced by curing temperatures. As the temperature increased up to the room temperature of 22°C, the water permeability decreased as desired, but after that point on, it gave an adverse effect on the permeability in very high amounts. (see Fig. 2)

Conclusion and Recommendation

The water permeability property of concrete was examined in this study. The water curing temperature and silica fume content were important factorsin gaining the required water impermeability in these tests. Due to its extreme fineness and its reactivity with the hydration product material of cement Calcium Hydroxide, silica fume produces extra bond and fills the pores within the concrete to reduce water permeability but as this amount increases, the reduction of water permeability is slowly reduced due to the replacement of cement with silica fume, which is not very much desired. On the other side as mentioned earlier, higher curing temperatures promote early strength gain but in later ages, it leads to lower final compressive strength and higher water permeability. In this experiment, this was prooved once again. In future studies, it is recommended to repeat the procedure for different factors such as different curing ages, curing methods and temperatures. And also by the use of other mineral and chemical admixtures may be recommended for further technical studies.

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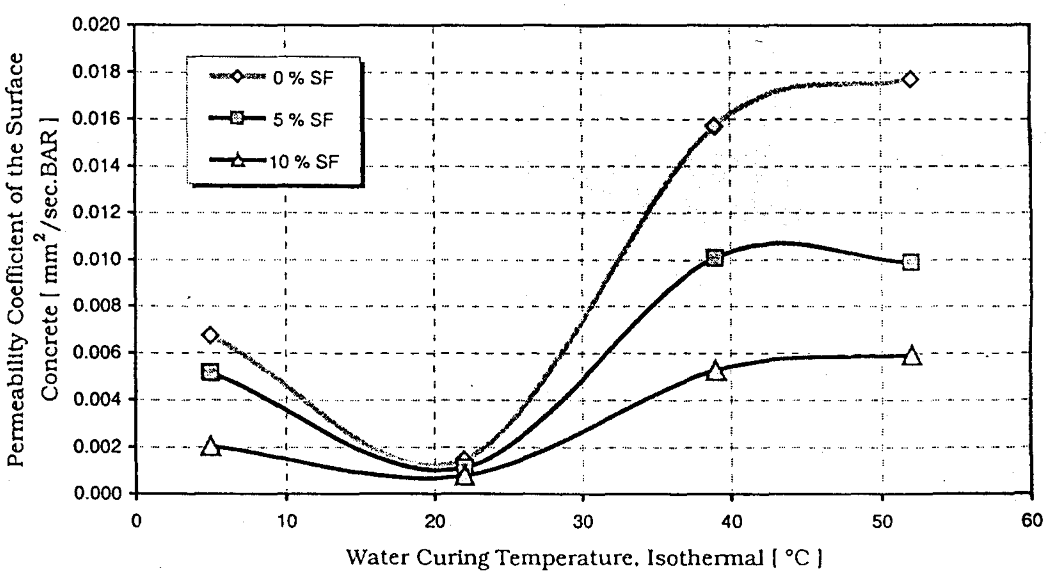

Figure 2. Water Permeability of Concrete, for different water curing temperatures & silica fume contents

Table 1. Chemical characteristics of cement and silica fume [1]

	Cement	Silica Fume
Chemical Analysis (%)		
SiO_2	26.50	97.19
Al_2O_3	4.25	1.11
Fe_2O_3	2.58	1.27
CaO	54.26	0.77
SO_3	2.32	0.53
MgO	4.04	0.00
Loss on ignition	0.73	0.56
Mineralogical characteristics		
Insoluble Residue (%)	0.84	53.85

Table 2. Mix composition of the concrete used in this experiment [1]

cement type	C.C.32.5, Portland Cement
cement [kg/m^3]	500
water/cement ratio	0.42
coarse aggregate [kg/m^3]	1090
fine aggregate [kg/m^3]	600
density [kg/m^3]	2400
comp.cube strength at 28 days [N/mm^2]	40.4

Table 3. Results of the experiments [1]

Water permeability cefficient of the surface concrete, samples cured for 28 days (Ccp) [mm^2/sec.BAR]				
CuringTemp. / Silica Fume	5°C	22°C	39°C	52°C
0 %	0.00675	0.001467	0.015713	0.017717
5 %	0.005155	0.001123	0.010091	0.009899
10 %	0.00205	0.000789	0.005262	0.005922
Compressive strength results of cubic (150x150x150mm^3) concrete samples water cured for 28 days [MPa]				
CuringTemp. / Silica Fume	5°C	22°C	39°C	52°C
0 %	26.2	40.4	53.22	50.16
5 %	38.62	50.1	51.88	50.43
10 %	41.7	50.42	51.67	51.03