A STUDY OF SOME COMMERCIAL PERMEABILITY REDUCING ADMIXTURES

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ABSTRACT

Reduction of permeability is an important aim to ensure that concrete structures remain durable throughout their service life. Some commercially available permeability reducing admixtures were tested. It was found that all admixtures reduced compressive strength, absorption and air permeability. The degree of reduction depended on the admixture in question. The reduction in strength was observed because no advantage was taken of the water reducing properties of the admixtures in the mix design. An experimental parameter is proposed for evaluating the quality of concrete to take into account both strength and durability properties.

دراسة بعض الاضافات التجارية لتقليل نفاذية الخرسانة

ان تقليل نفاذية الخرسانة هو من العوامل الهامة التي تضمن بقاء المباني في حالة مناسبة طوال فترة الاستخدام. في هذا البحث تمت دراسه بعض الاضافات التجارية التي يزعم المنتجون انها تقلل من نفاذية الخرسانة. وجد ان استخدام الاضافات ادي الى تقليل اجهاد الكسر؛ معامل التشرب و نفاذية الخرسانة بدرجات مختلفة حسب نوع الاضافة. لوحظ ان تقليل اجهاد الكسر كان بفعل عدم الاستفادة من ان

الاضافات تقلل من كمية ماء الخلط اللازم للحصول على تشغيلية معينة. ويقترح معامل جديد للدلالة على جودة الخرسانة وذلك بأخذ اجهاد الكسر و تحمل الخرسانة للزمن في الاعتبار.

INTRODUCTION

Permeability of concrete is one of the properties that control the movement of fluids and aggressive agents from the environment to the interior parts of the concrete. It is an important factor influencing the durability and serviceability of concrete structures insitu. With the advances in cement manufacturing processes, which lead to the use of more slender concrete members [1] and the utilization of mixes with lower cement content [2], permeability assumed an even greater importance. The use of concrete in severe environments where exposure to aggressive substances and pollutants may be encountered. The lack of attention to controlling permeability in such situations has lead to many failures due to durability problems.

There are many ways for reducing permeability. The most traditional of these is reducing the w/c ratio. The use of superplasticisers will allow placing concrete's with very low w/c ratios [3]. Mineral admixtures, such as fly ash, silica fume and slag produce additional hydration products which contribute to the reduction in permeability by pore blockages [4]. Finally, polymer admixtures such as latexes were found to reduce permeability as the polymer particles coalesce into a continuous film sealing air voids and blocking microcracks [5, 6].

A latex is a polymer system consisting of very small (0.05 to 1.0 mm diameter) spherical particles of high molecular weight polymers held in suspension in water by the use of surface active agents [7]. The latex is formed by emulsion polymerization of the monomer. The properties of the concrete modified with latex have been compared with concrete of similar mix design [8]. The latex modified concrete showed an increase in flexural, tensile and bond strengths, lower moduli of elasticity, increased durability and reduced permeability characteristics, compared to conventional concrete. Field tests indicate that permeability performance of latex modified concrete has far exceeded the criteria established in the initial evaluation. Latex modified concrete has been successfully used in bridge deck overlays, parking garages, floors, precast operations and patching of concrete surfaces.

The aim of the work presented here is to evaluate some commercially available permeability reducing polymer admixtures in. Four admixtures from four different companies are examined. Concrete samples made with these admixtures are tested for strength, absorption and air permeability.

MATERIALS

Cement

The cement used in preparing the test specimens was a "Rapid Hardening Portland Cement" conforming to ASTM C150, Type III [9] and was packed in 50 Kg paper bags.

Aggregates

The coarse aggregates used was uncrushed gravel with a maximum size of 25 mm. The gravel was washed thoroughly before use. The fine aggregates used was natural desert sand. The sand was washed and dried prior to use.

Water

Tap water was used for mixing and curing the test specimens.

Admixtures

Four admixtures form four different companies were used in preparing the test specimens. No information on their generic types was given in the product data sheets. However, all manufacturers state that the admixtures should be used to produce water proof concrete. The admixtures will be given the codes A,B,C and D in this investigation.

PREPARATION OF THE TEST SPECIMENS

The mixes were designed in accordance with the DOE (British method), [10]. The mixes had w/c ratios of 0.4 or 0.6 and the slump ranged from 10 to 30 mm. Batch quantities of the mixes are shown in Table 1, and the admixture dosages are shown in Table 2.

The concrete specimens were 150 mm cubes. Ten specimens were made from each mix (w/c = 0.4 or 0.6, control mix and mixes containing one of the four types of admixtures) giving 100 samples in total. The mixing and casting of the specimens was carried out in accordance with ASTM C192-900 [11]. The specimens were kept in their moulds for one day and then they were demoulded and transferred to a water curing tank until the time of testing.

TEST TECHNIQUES

Compressive Strength Test

The specimens were tested for compressive strength at 3, 7 and 14 days. Two specimens from each mix were tested at each age. The test machine was a 2000 KN capacity automatic device .

Absorption Test

The absorption test was carried out in accordance with ASTM C642-82 [12]. Two specimens from each mix were tested at the age of 14 days. The method involves drying the specimens in an oven at a temperature of 100 ^{o} C till constant weight. The specimens are then immersed in water to constant weight. Finally, the specimens are boiled in water for 5 hours. Weighing the specimens at each of the three stages allows the calculation of the absorption percentages as follows :

$$\text{Absorption after Immersion} = \frac{\text{Weight after immersion - dry weight}}{\text{dry weight}} \times 100$$

$$\text{Absorption after Boiling} = \frac{\text{Weight after boiling - dry weight}}{\text{dry weight}} \times 100$$

Air Permeability Test

The air permeability test apparatus was developed earlier [13]. It consists of a hand operated air compressor, a non returnable valve, to prevent compressed air from dissipating back through the fittings, and a pressure gauge (up to 10 kg/cm^2) to indicate the compressed air pressure. The pipes and fittings are made of copper shaped and connected by welding. The test apparatus is shown in Figure 1.

To determine the air permeability of a specimen, a 12 mm x 50 mm hole is drilled into one of the cube surfaces. The debris is cleaned from the hole. A 13 x 20 mm steel insert is fixed in the hole using rapid setting adhesive and left ϕmm for about 15 minutes. Air is compressed into the cavity using the hand operated compressor after connecting the copper pipes. The pressure is raised to 2.5 kg/cm^2. The elapsed time for the pressure to decay from 2.5 to 1.5 kg/cm^2 is measured and considered as the impermeability index of concrete.

RESULTS AND DISCUSSION

Results of the Compressive Strength Test

The compressive strength test results are shown in Figure 2. Figure 2 (a) shows the results for specimens having w/c = 0.4, whereas Figure 2 (b) displays the results for samples with w/c = 0.6. The control rapid hardening Portland cement (RHPC) concrete exhibited the highest strength at all ages. The use of permeability reducing admixtures reduced the strength to varying degrees. The highest and lowest strengths were found in specimens containing admixtures D and B respectively. Other concretes were in between. Latex admixtures contain about 50% water by weight [8]. Therefore the inclusion of latex in concrete reduces the water demand of the mix. The design of mixes (containing admixtures A, B, C and D) in the present investigation did not take this into account for ease of comparison with the control concrete. It is indicated that properly mixes designed to the same workability would have little or no reduction in strength when the admixtures are included.

The increase in maturity (or the extension in moist curing) has affected the specimens in different ways. The strength of RHPC concrete significantly improved with curing. Those containing the admixtures (especially A and B) did not exhibit a significant increase in strength upon extended curing. Therefore such admixtures would be useful in cases where limited or no curing is expected.

To study the relative effect of w/c ratio in the mixes with or without the admixtures, the results for the control mix and that containing admixture A are examined at the age of 14 days. The difference in strength between the w/c = 0.4 and w/c = 0.6 concretes was 187 and 77 Kg/cm^2 , respectively. This means that the control RHPC concrete suffered a greater loss in strength when the w/c ratio was increased compared to the mix with admixture A. Specimens with other admixtures also exhibited a similar behavior, but to lesser degrees. This indicates that accidental additions of water to concrete have a more damaging effect on mixes without the permeability reducing admixtures.

Results of the Absorption Test

The results of the absorption test are shown in Figure 3. Figure 3 (a) shows the absorption results for specimens after immersion, whereas Figure 3 (b) displays the results for samples after immersion and boiling. It can be seen that the concrete containing admixture A exhibited the least absorption for both w/c ratios. This was followed by the concrete containing admixtures B and C. The concrete containing admixture D had an absorption comparable to that of the RHPC concrete.

In general boiling seamed to reduce the absorption of the specimens. This may be due to the expulsion of water at high temperatures from the concrete pores or the blocking of cavities due to hydration during the boiling process.

It would be desirable, from the durability point of view, for the concrete to have high strength and low absorption. The author proposes a parameter equals to the ratio of strength to absorption to give an idea about the overall quality of the concrete. The higher this parameter the better the mix. The proposed parameter is tabulated in Table 3. Such a parameter, if widely adopted, would become a valuable tool for quality control exercises which currently rely in strength alone as a sole criteria for concrete suitability. The proposed parameter can be calculated easily since the absorption test is simple to perform and does not require any additional apparatus to what already exists in most concrete technology laboratories.

Results of the Air Permeability Test

The impermeability index is plotted in Figure 4, for the different mixes in this investigation. It should be noted that the higher the index (e.g. the longer the time needed for the pressure to decay), the better the concrete as this indicates that the compressed air is having difficulty in moving within the specimen due to the lack of open capillaries capable of supporting fluid flow. It can be seen from Figure 4 that the trend of the results is similar to the absorption findings. All concretes with admixtures exhibited a reduction in permeability compared to the control concrete.

It is interesting to note that the reduction in w/c from 0.6 to 0.4 lead to 40 % reduction in air permeability. The use of admixtures, however, reduced the air permeability by 10 to 40 % depending on the admixture used. This means that the reduction in w/c ratio is just as important as using the permeability reducing admixtures. This could be because the water reducing effect of the admixtures was not taken into account in the mix design. But the author believes that the performance of the admixtures tested in this investigation need to be improved if they are to live up to their names as water proofing admixtures.

CONCLUSIONS

The use of permeability reducing admixtures has resulted in some strength 1
reduction in the mixes prepared in this investigation. This may be due to the fact that the water reducing properties of the admixtures were not taken into account in the mix design.

The mixes containing the permeability reducing admixtures were found to 2
possess better strengths than the control mixes at high w/c ratio or when the curing was limited. Therefore, theses mixes would exhibit better performance in the cases of accidental water additions or limited curing.

The absorption of the concrete specimens, measured in accordance with ASTM 3
C642 - 82, was reduced to varying degrees with the use of permeability reducing admixtures.

A concrete quality index is proposed (equals to the ratio between strength and 4
absorption). The index would be a valuable addition to quality control exercises which currently rely on strength alone as a measure of concrete suitability.

Air permeability, determined using the locally developed test apparatus, of the 5
mixes containing the admixtures was lower than that of the control mix. However, it was found that the reduction in the w/c ratio would result in a reduction in air permeability of the same order of magnitude as the use of permeability reducing admixtures. The author believes that the performance of all commercial admixtures tested would need to be improved to become truly water proof admixtures.

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Table 1 Batch quantities for the mixes prepared for this investigation

	Batch Quantities for 1 m^3 (Kg/m^3)						
W/C	**Water**	**Cement**	**Fine Aggregate**	**Coarse Aggregates**			**Mix Proportions W:C:FA:CA**
				> 25 mm	**19-25 mm**	**<19 mm**	
0.4	160	400	650	660	324	216	0.4 : 1 : 1.6 : 3
0.6	150	250	750	701	344	230	0.6 : 1 : 3 : 5.1

Table 2 Permeability reducing admixture dosages used in this investigation

	Admixture Quantity for 1 m^3 of mix			
W/C	**Admixture A (L/m^3)**	**Admixture B (Kg/m^3)**	**Admixture C (Kg/m^3)**	**Admixture D (Kg/m^3)**
0.4	6	2	2	2
0.6	6	1.25	1.25	1.25

Table 3 Concrete quality index values for the concrete mixes

	Concrete Quality Index	
Concrete Mix	**W/C = 0.4**	**W/C = 0.6**
Control	94	49
Admixture A	198	98
Admixture B	108	35
Admixture C	93	46
Admixture D	71	45