Penetrability of Chloride Ions in Concrete Protected by an Acrylic Painting

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ABSTRACT

In order do decrease the penetrability of chloride ions in concrete the use of paintings based on polymers can be a good solution. The use of acrylic paintings is recommended because they have good resistance to ultraviolet radiation. It is important to quantify the decrease of chloride ions penetrability obtained by the use of this kind of paintings. The durability of the polymeric paintings is another aspect that needs to be analysed. In this study an acrylic painting was used to protect the concrete and decrease the penetrability of chloride ions. The concrete used was a C12/15, with a cement content of 280 kg/m^3 and a water-cement ratio of 0.60. The acrylic painting was applied in concrete specimens 28 days after casting. In order to have a better protection we applied two coats separated by 5 hours. The penetrability of chloride ions was measured following the ASTM standard C 1202 – 94. Before the penetrability tests, some specimens were exposed to UV radiation. The exposition to the light occurred by cycles consisting of alternating periods of 8 hours of UV radiation at 60 ºC and 16 hours without UV radiation at 50 ºC. Three kinds of exposition were made consisting on 5, 10 and 15 cycles. The results showed always a high penetrability of chloride ions. This occurred because a poor concrete was used. The protection by an acrylic painting decreases the penetrability of chloride ions. The charge passed decreased about 32 %. However, is not possible to achieve low chloride ions penetrability only with the use of acrylic paintings. It is necessary also the use of a good concrete with low porosity. After the exposition to the UV radiation the penetrability of chlorides ions did not increase. It seems that the UV radiation does not affect the properties of the acrylic painting.

Introduction

The durability of reinforced concrete is a problem in the entire world. In some cases the deterioration appears too early [1]. The chloride ion penetrability in concrete is one of the most important factors which affect the durability of reinforced concrete [2]. In order to decrease this penetrability the use of an adequate surface protection system could be recommended [3].

A previous study [4], showed a significantly decrease of the chloride ion diffusion coefficient when an acrylic painting was used to protect the concretes. The resistance to ultraviolet radiation is one of the requirements usually established for the surface protection systems [5]. In this study this characteristic of the acrylic painting was analysed. The chloride ion penetrability was measured following an ASTM standard [6].

Tests

The concrete used had a cement dosage of 280 Kg/m^3 and a water-cement ratio of 0,60. A Portland cement was used, classified as CEM I, 42,5R [7]. Table 1 shows the composition of the concrete.

The slump of the concrete was 3 cm. With the fresh concrete, six cubic specimens with 15x15x15 cm^3 and nine cylindrical specimens with 10 cm of diameter and 20 cm of height were made. The cubic specimens were maintained inside water at 20 ± 1 ºC, for 28 days. The cylindrical specimens were maintained at these conditions, for 21 days.

The cubic specimens were used to determine the resistance class of the concrete. The results of the compression tests made at 28 days showed a C12/15 concrete [8]. For the chloride ion penetration tests the specimens need to be cylinders with 10 cm of diameter and 5 cm of height [6]. So, the cylinders with 20 cm of height were cut 21 days after casting, with a water-cooled diamond saw. Then, the specimens were conserved seven days in the laboratory, outside water.

The surface protection was made by an acrylic painting, applied 28 days after casting. Two coats were applied, as recommended by the furnisher of the product. The waiting time between coats was five hours, attending to the temperature inside the laboratory at the painting moment.

Ten days after painting, the specimens were exposed to ultraviolet radiation, inside an adequate chamber. The exposition to a xenon lamp with 60000 lm, occurred by cycles consisting of alternating periods of 8 hours of UV radiation at 60 ºC and 16 hours without UV radiation at 50 ºC. Three kinds of exposition were made consisting on 5, 10 and 15 cycles. With this number of cycles, the exposition attained the two weeks specified in an ASTM standard [9].

After the exposition to UV radiation, the penetrability of chloride ions was measured following an ASTM standard [6]. The procedure consists on the use of a specimen cell. The cylindrical specimens were disposed at the middle of the cell. One side of the cell was filled with a sodium chloride solution (3.0 % by mass in distilled water). The other side of the cell was filled with a sodium hydroxide solution (0.3 N in distilled water).

Before the tests, the specimens were conditioned in a desiccator. First, the side surfaces were brushed with a rapid setting coating. After, the specimens were placed in a vaccuum desicator. Both end faces of specimens must be exposed. The desiccator was sealed and the vacuum applied for three hours. The pressure decreased till 133 Pa, within a few minutes.

After the three hours, with vaccum pump still runing, sufficient de-aerated water to cover specimens, was drained in the desiccator. The water was drained by the water stopcock. This operation was made in a way that did not allow air to enter desiccator trough this stopcock. After the draining of water, the water stopcock was closed and the vaccuum pump was allowed to run for one additional hour.

At the end of the four hours, the pump was turned off. The air was allowed to re-enter in the desiccator. The specimens were maintained under water for 18 hours. After this period, the specimens were removed from the desicccator and placed in the cells.

The test consisted on a voltage application. The negative terminal of the power supply was connected to the side of the cell with 3.0 % NaCl solution. The positive terminal of the power supply was connected to the side of the cell with 0.3 N NaOH solution. The power supply was turned on and during 6 hours the current was measured every 30 min. Formula [1], based on the trapezoidal rule, can be used to calculate the charge passed.

$$Q = 900\ (I_0 + 2I_{30} + 2I_{60} + ... + 2I_{300} + 2I_{330} + I_{360}) \qquad [1]$$

Where:

Q - charge passed (C),

I_0 - current intensity (A) immediately after voltage was applied, and

I_t - current intensity (A) at t min after voltage was applied.

The numerical results from this test method can be used to estimate the chloride ion penetrability (Table 2) [6].

Results

The numerical results of the tests are presented in Table 3. The chloride ion penetrability can be estimated as high, for all the tests made. These results can be explained by the use of a poor concrete. The protection with an acrylic painting decrease chloride ion penetrability. The specimens with painting presented a decrease of charge passed of about 32 %, when compared with the specimens without painting.

The exposition to ultraviolet radiation did not affect the chloride ion penetrability. Figure 1 shows that the charge passed did not change significantly with the number of cycles, except for 5 cycles. The result obtained for this number of cycles is anormal. It could only be explained by some mistakes made during the tests. The charge passed through the specimens exposed to UV radiation only increase about 5 %, if the result with 5 cycles is not considered.

Conclusions

The use of any acrylic painting contributes to a decrease on the chloride ion penetrability in a concrete. The painting specimens showed a decrease of charge passed of about 32 %, when compared with the charge passed through the concrete without painting. This decrease was maintained after exposition to ultraviolet radiation.

However, the qualitative classification of chloride ion penetrability in the protected concrete is the same of the no protected concrete. The two concretes presented during the tests, high numeric values of charge passed. So, the chloride ion penetrability can be estimated as high. The use of a poor concrete is the reason for this behaviour.

In order to achieve low chloride ion penetrability, it is important the use of a good concrete with low porosity. The protection with acrylic paintings decrease the chloride ion penetrability, but can not correct all the bad properties of the concrete.

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Figure legends

Fig. 1 – Variation charge passed with number of cycles (Specimens with painting).

Table legends

Table 1 – Composition of the concrete.
Table 2 – Chloride ion penetrability based on charge passed.
Table 3 – Charge passed through the specimens.

Table 1 – Composition of the concrete.

Materials	Quantities (kg/m^3)
Aggregate 5-15	1233
Sand 0-2	731
Cement	280
Water	168

Table 2 – Chloride ion penetrability based on charge passed.

Charge passed (C)	Chloride ion penetrability
>4000	High
2000-4000	Moderate
1000-2000	Low
100-1000	Very low
<100	Negligible

Table 3 – Charge passed through the specimens.

Type of specimen	Ultraviolet exposition (number of cycles)	Charge passed (C)	Chloride ion penetrability
Without painting	0	12978	High
	10	10134	High
With painting	0	6786	High
	5	10485	High
	10	7434	High
	15	6822	High

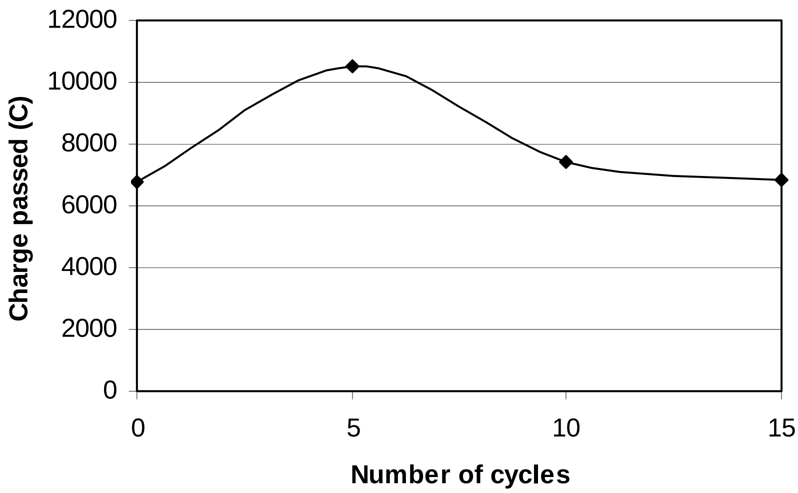

Fig. 1 – Variation of charge passed with number of cycles (Specimens with painting).