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A study of the adhesion between hydraulic mortars and concrete

J. BARROSO DE AGUIAR [1,*] and M. DANIELA CRUZ [2]

[1] *Civil Engineering Department, University of Minho, Azurém, 4800 Guimarães, Portugal*

[2] *Mechanical Engineering Department, University of Minho, Azurém, 4800 Guimarães, Portugal*

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Abstract—Knowledge of the adhesion properties of materials is necessary for many applications. When one has to cover a wall or a concrete pavement with mortar, it is necessary to pay attention to the adhesion between the two materials, otherwise one can have some problems such as the delamination of the two materials after application. We present here a study of the adhesion between hydraulic mortars and concrete. Mortars with permeability-reducing admixtures were used. This type of mortar is used to reduce the possibility of water infiltration in construction. Mortars should be impermeable but this should not affect the adhesion. To measure the adhesion, we used the pull-off test. The results show a decrease in the adhesion strength with increasing permeability-reducing admixture dosage, except for one of the admixtures used. We believe that this result is a consequence of the decrease in porosity caused by the use of a more waterproofing admixture and that a higher dosage contributes to the increase of admixture at the interface. To confirm this, we performed a microscopic analysis of the failure surfaces of the mortars. The decrease in porosity was well seen in this analysis. However, this characteristic of mortars is not the only one that affects adhesion. The composition of the admixture is very important as we found different adhesion strengths, for similar porosity, with different admixtures.

Keywords: Mortar; hydraulic; concrete; adhesion; waterproofing; porosity; admixture; image processing.

1. INTRODUCTION

To coat a wall or a pavement, one can use a hydraulic mortar and the good adhesion of the mortar to its basis is very important. The basis could be hydraulic concrete. The adhesion between these two materials is influenced by their compositions.

For the production of hydraulic materials, one can use admixtures with conventional materials (cement, water, and aggregates). The admixtures are used to alter some characteristics, mentioned later, and there is a great variety of chemical

*To whom correspondence should be addressed. E-mail: aguiar@eng.uminho.pt

admixtures for hydraulic materials [1, 2]. Usually the admixtures are classified with respect to the characteristic effects of their use. One has, for example, air-entraining, accelerating, water-reducing, set-controlling, and permeability-reducing admixtures.

The name of the admixture is related to the characteristic that it affects. It is important however, to verify what happens with other characteristics. Adhesion is, in our opinion, one characteristic that is necessary to control.

To reduce permeability, one generally uses polymer-emulsion admixtures. The polymer particles coalesce into a continuous film, which reduces the permeability by sealing air voids and blocking microcracks [3, 4].

The adhesion of mortars to their basis is a problem that has still not been well studied; however, one can find a few studies dealing with this problem. Adhesion control is also necessary for repair mortars, which are normally more complex in their constitution. These sometimes include silica fume or different admixtures, such as water-reducing or permeability-reducing [5]. Sometimes it is necessary to use an adhesive epoxy [6] to increase adhesion.

2. TESTS

The adhesion test used was the pull-off method (Fig. 1). The pull-off test is used to determine the resistance to tension of paint or covering coats of thickness t (Fig. 1), applied to a concrete surface, dry or wet. The concrete has height c. The steel cylinder has a diameter d and height h. The depth of the circular hole is $t + s$.

The concrete used was a C16/20 made in the laboratory [7]. We used a mortar of Portland cement and all the proportions were those recommended for normal mortar [8]. Three permeability-reducing admixtures were used. Admixture 1 was polymer-emulsion based. Admixture 2 was a calcium stearate with a mineral charge. Admixture 3 was a combination of water-reducing and synthetic air-entraining agents, stearates, and a mineral charge. Three different percentages of admixtures, by weight, were used (2, 4, and 6%, related to the weight of cement). The quantity 2% is recommended by the producer of the admixtures.

The concrete specimens were 20 × 20 × 10 cm in size. The mortar was applied when the concrete had set for 28 days. We applied the mortar on the concrete in a

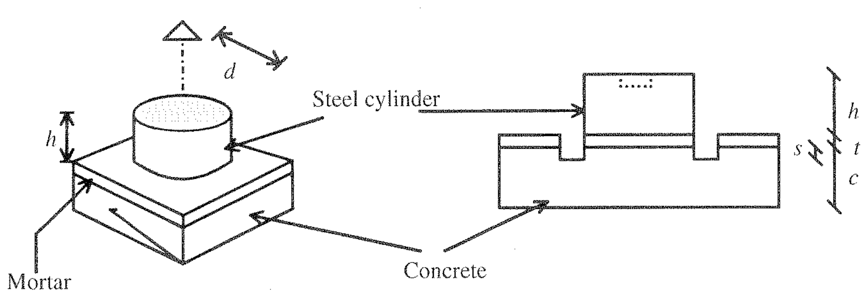

Figure 1. Schematic diagram of the pull-off test.

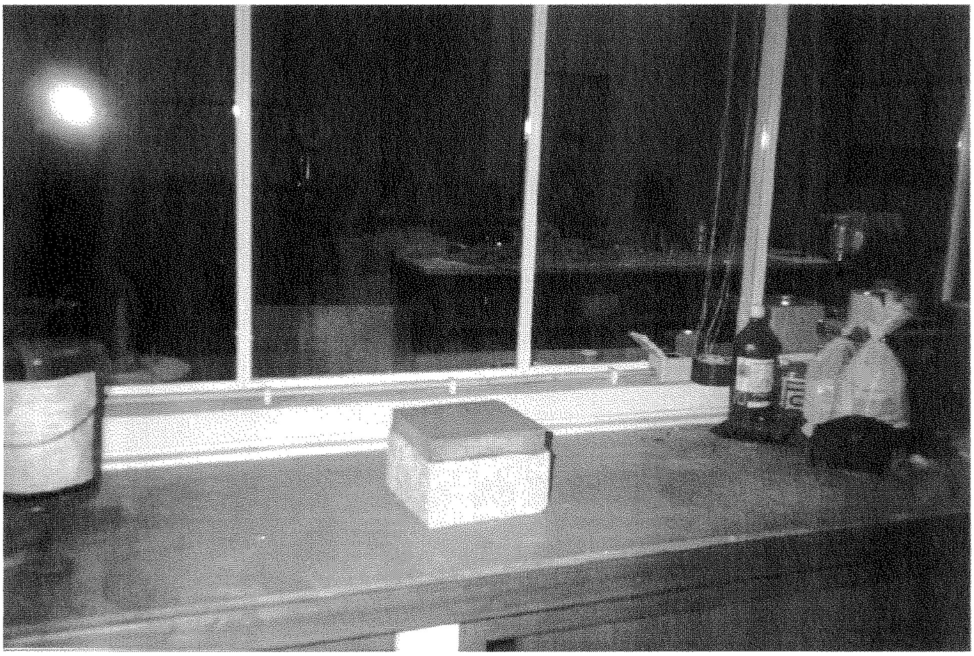

Figure 2. Specimen composed of concrete and mortar. (This figure is published in colour on http://www.vsppub.com/jconts/JAST)

casting face of area $20 \times 20\ cm^2$ (Fig. 2). Before applying the mortar, the concrete surface was wetted to avoid the absorption of water present in the fresh mortar. The thickness of the mortar layer was 3 cm.

The pull-off tests were carried out 14 days after the application of mortar. The specimens were prepared for these tests, by making a circular hole of diameter 5 cm and depth 6 cm with a drilling machine (Fig. 3). After that, we glued, with epoxy, cylindrical metallic pieces (Fig. 4). These pieces have a hole where we fastened the screw of the pull-off machine (Fig. 5).

The pull-off tests were performed with the application of tension loads increasing gradually until rupture. The rupture strengths were noted and the locus of rupture in each case was analysed.

3. RESULTS AND DISCUSSION

As we used three percentages of permeability-reducing admixtures, it was possible to obtain the variation of adhesion strength with the quantity (%) of admixtures (Fig. 6). All the ruptures were interfacial between the mortar and concrete.

As can be seen in Fig. 6, when the admixture (1 and 2) quantity increases, the adhesion strength decreases. However, admixture 3 shows an increase in adhesion strength with the admixture quantity.

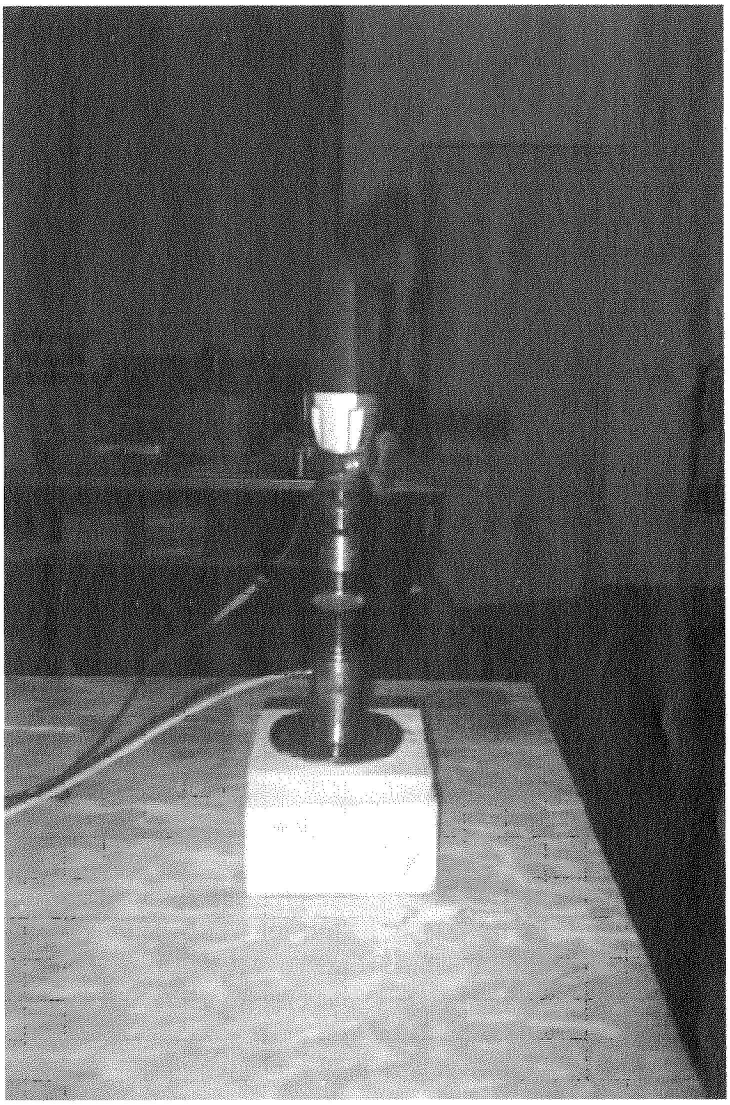

Figure 3. Drilling a circular hole in the mortar and concrete. (This figure is published in colour on http://www.vsppub.com/jconts/JAST)

The adhesion is normally dependent on the porosity of the materials. Usually it increases with increasing porosity. As we used permeability-reducing admixtures, a reduction in the porosity was expected with the increase of admixture quantity.

To quantify the porosity of the mortars, we used an image processing system and the mortars' failure surfaces after the adhesion tests were analysed.

The image processing system has a good resolution (256 grey scale) and uses a digitizing board of 1024 × 1024 × 24 bits. A video camera and a microscope were used as the image collector system. The magnification was about 8 ×. Special indirect lighting had to be used in order to get some shadows within the voids.

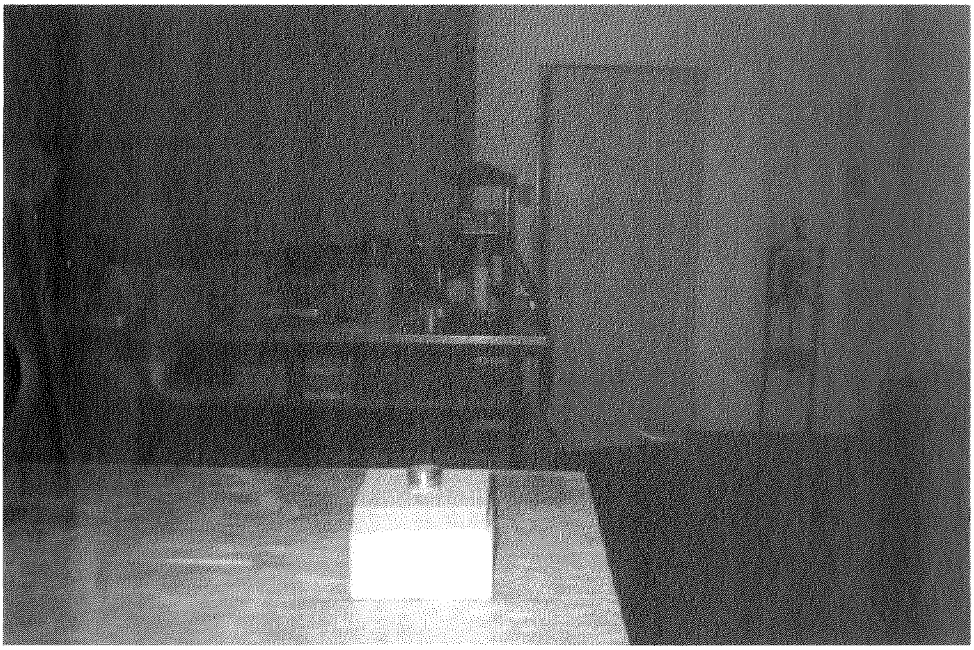

Figure 4. Specimen with a metallic adapter.
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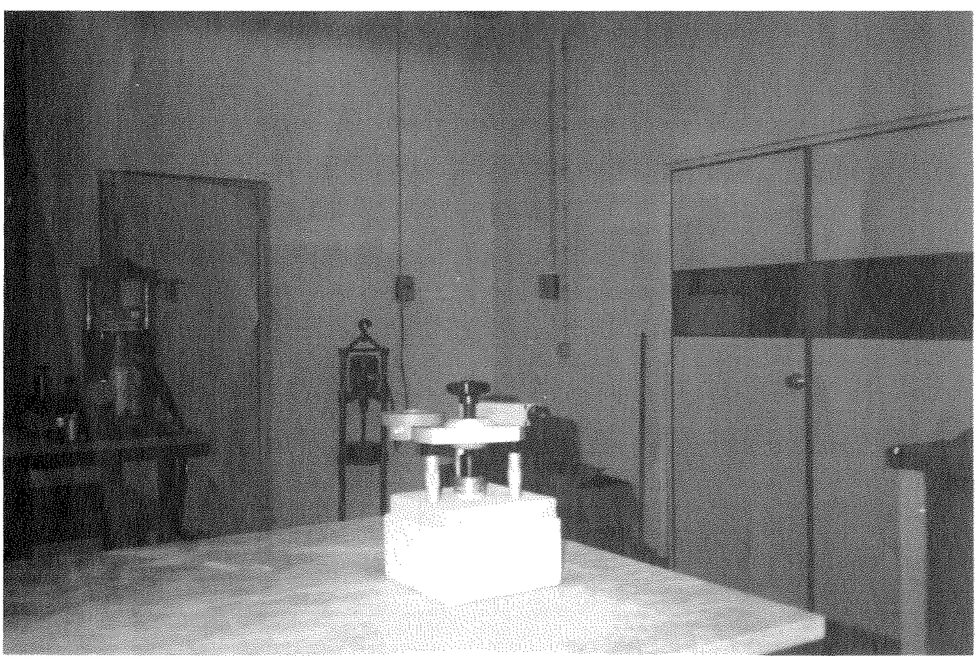

Figure 5. Pull-off test in progress.
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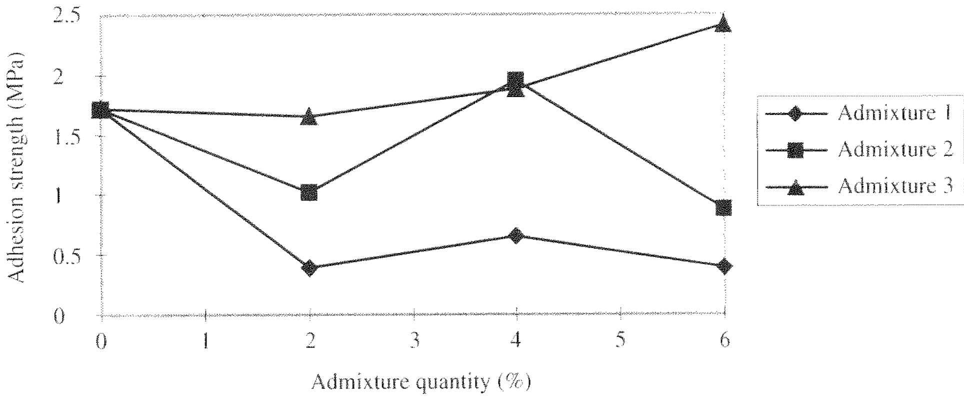
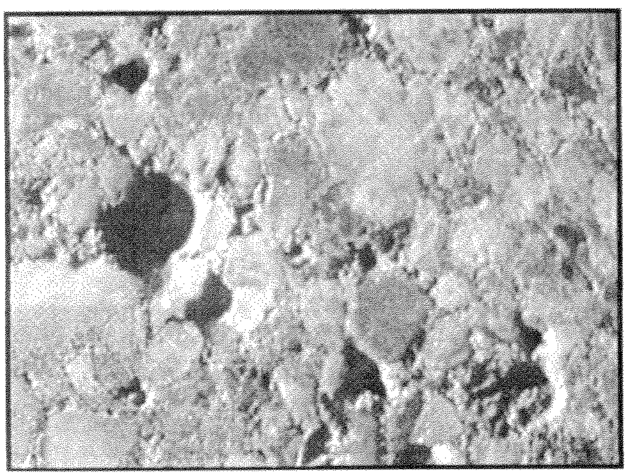


Figure 6. Variation of the adhesion strength with the quantity (%) of the admixture.

(a)



(b)

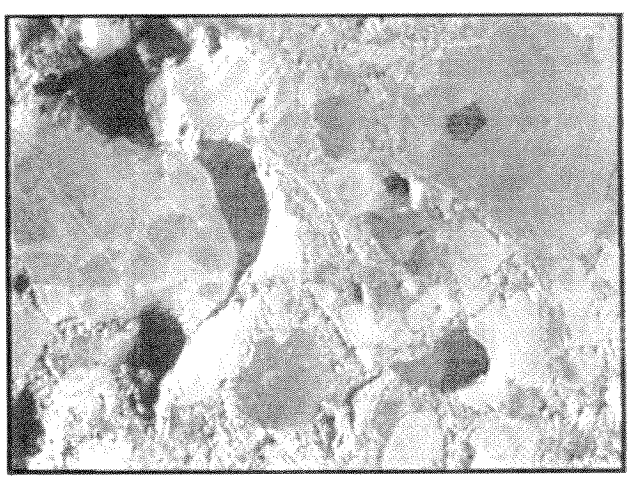


Figure 7. Images (magnification 8×) of normal mortar (without an admixture). (a) Specimen 1; (b) specimen 2.

(a)

(b)

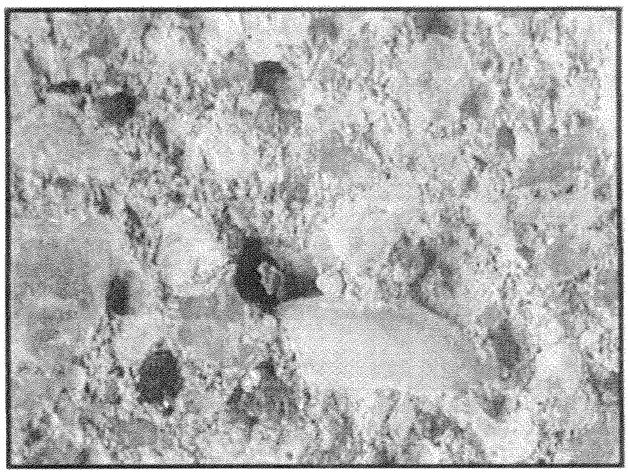


Figure 8. Images (magnification 8×) of the mortar with admixture 1 (6%). (a) Specimen 10; (b) specimen 11.

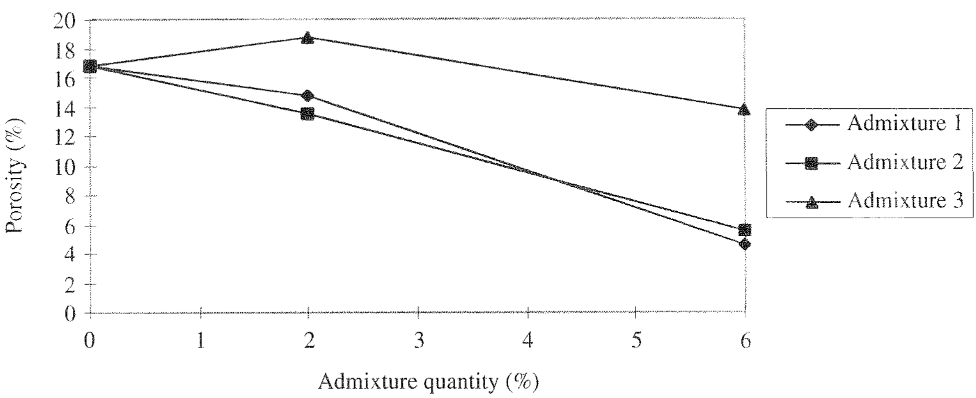


Figure 9. Variation of the porosity with the admixture quantity.

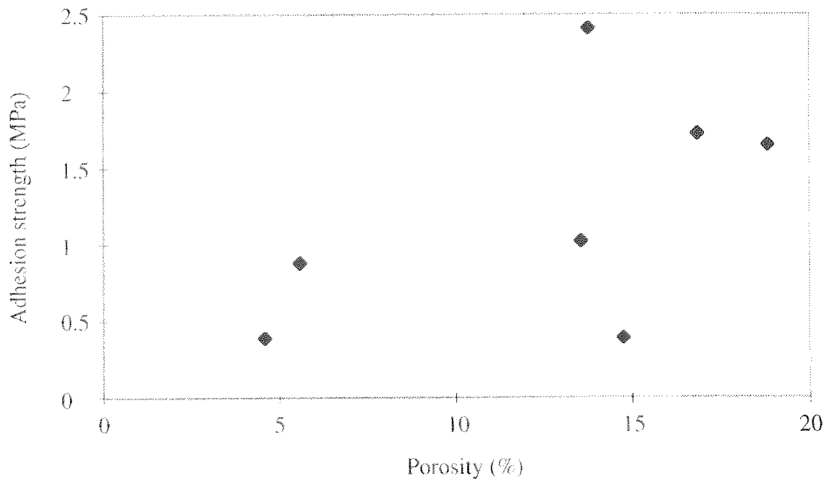


Figure 10. Variation of the adhesion strength with the porosity.

The surface images of the mortars were digitized, filtered, and segmented in two tones (as shown in Figs 7 and 8). After this operation, we were able to make the voids black over a white surface and estimate the porosity percentage on each image.

The presence of the admixtures alters the porosity; the images obtained (Figs 7 and 8) with the presence of an admixture in the mortar show that the voids (black areas) are smaller and more distributed in the surface.

The variation of the porosity with the admixture quantity (Fig. 9) shows that for admixtures 1 and 2, the porosity decreases significantly with an increase in the quantity of admixture used. For admixture 3, the porosity does not change much with the admixture quantity. A reduction in the permeability is obtained in this case, with a slight reduction in the porosity and the introduction of micro-air-bubbles. These bubbles provide closed porosity, because they have no connection with the exterior.

The variation of the adhesion strength with the porosity (Fig. 10) for the three admixtures shows that the porosity is not the only characteristic that affects adhesion. Very different adhesion strengths for the same porosity were found; however, if the porosity decreased, the adhesion also decreased.

4. CONCLUSIONS

The adhesion between a mortar and its concrete basis depends on the composition of the mortar. The use of admixtures can change the adhesion. For permeability-reducing admixtures, the porosity of the mortars decreases upon increasing the quantity of the admixture.

When the porosity decreases, normally there is a reduction in adhesion. However, we found very slight adhesion even with considerable porosity. We suppose that the addition of some permeability-reducing admixture could decrease the adhesion.

The permeability-reducing admixture alters the interface and due to its composition, it reduces the adhesion in the surrounding area. It is not easy to know the complete composition of an admixture — sometimes it is a commercial secret; so, we recommend the use of the pull-off test before using any proposed permeability-reducing admixture.

Admixture 3 is adequate because its addition to the mortar does not decrease the adhesion strength. On the contrary, we found a slight increase in adhesion, even with high quantities of this admixture.

Acknowledgement

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REFERENCES

1. Chemical admixtures for concrete, Committee Report, *ACI Mater. J.* **86**, No. 3, American Concrete Institute (ACI) (May–June 1989).
2. M. R. Rixom, *Concrete Admixtures: Use and Applications.* The Construction Press, Lancaster (1977).
3. J. E. Isenburg, D. E. Rapp, E. J. Sutton and J. W. Vanderhoff, Microstructure and strength of the bond between concrete and styrene-butadiene latex-modified mortar, *Highway Research Record No. 370.* Highway Research Board, Washington, DC (1971).
4. D. Whiting, Rapid determination of the chloride permeability of concrete, *Report No. FHWA/RD-81/119.* Federal Highway Administration, Washington, DC (1981).
5. C. Atzeni, G. Mantegazza, L. Massidda and U. Sanna, Combined effect of superplasticizer and acrylic latex in cement mortars with and without silica fume, International Conference on Superplasticizers and Other Chemical Admixtures in Concrete, Ottawa, Canada (1989).
6. B. Aguiar, Adhesion between repair mortars and concrete, International Conference on Inspection, Appraisal, Repairs and Maintenance of Buildings and Structures, Hong Kong (1995).
7. ENV 206, *Concrete — Performance, Production, Placing, and Compliance Criteria.* European Committee for Standardisation (1990).
8. EN 196-1, *Methods of Testing Cement — Determination of Strength.* European Committee for Standardisation (1990).