

An Experimental Study on How Treated Bases Influence the Adhesion of Mortar Coatings

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ABSTRACT

Over the years, a growing number of problems have been observed related to adhesion failure between mortar coatings and concrete bases. This problem has been aggravated by the use of concrete with increasingly high levels of resistance, and by the elevated number of mold reuses, motivated by the construction of multi-story buildings and the use of release agents with a lower degree of water dilution, which, evidently, provides greater insulation of the base. One alternative encountered to alleviate this problem is the use of rough textured molds, providing a greater contact surface in order to provide the system with a greater area of adhesion between the components. This experimental study presents a comparative evaluation of the adhesion between mortar coatings on concrete bases made with two different levels of mold roughness. The study confirms the hypothesis that surface roughness provides greater efficiency, and also considers the need of further study in order to demonstrate its economic viability.

KEYWORDS

Adhesion, Coating, Substrate, Surface roughness, Mold release agent.

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1 INTRODUCTION

Throughout the world, improved techniques for constructing multi-storey buildings are continually under development, in the constant search for higher productivity, solutions to prevent problems, and yet with a focus on questions related to the environment and sustainability.

In the case of buildings executed in reinforced concrete, one of the issues under constant discussion is related to the durability of structural elements, where every effort is made to relate the expected service life with exposure conditions and aggressiveness of the environment. Accordingly, the most commonly used instruments are the increased thickness of concrete coating over the armature, as well as the adoption of lower cement/water ratios, which normally result in increased mechanical strength.

Although such actions help to provide greater protection to the reinforced concrete structure, they also generate great concern regarding the fixation of mortar coatings on the bases, which present a significant decrease in porosity, thus rendering the mortar fixation difficult by physico-chemical adhesion. Over time, this loss of adherence compromises the durability of the coating, which can cause detachments, as described by Mansur et al. [2006].

Therefore, the proposal of this article is to study the benefits obtained in the adhesion of mortar coatings by increasing the contact area of mortar with the concrete base, obtained by using rough textured molds.

2 THEORETICAL REVIEW

The study of the fixation between mortar coatings and bases with differing characteristics has been the object of discussion amongst several groups in Brazil over the last few years. This phenomenon, of an essentially mechanical nature, arises when the mortar paste penetrates the pores of the substrate, forming rigid support structures after cement hydration.

One theoretical model, known as the “theory of active pores”, helps to gain a better understanding of this behavior [Carasek, 2007]. According to the model, the paste flows from the pores with the largest diameter, as in the case of fresh mortar, to the pores with the smallest diameter, as in the case of the substrate. However, certain factors may interfere with this flow, such as hydration of the mortar cement (which tends gradually to reduce its porosity), aggregate gradation, and substrate roughness, amongst others [Scartezini, 2001].

In the case of executing buildings with a reinforced concrete structure with masonry walls, it may be noted that there are substrates which present different characteristics, especially concerning water absorption and surface roughness, and that have a strong influence on the anchorage of mortar coatings.

Another complicating factor is that, due to land scarcity in urban centers, urban growth has occurred with the construction of increasingly taller and slender buildings [Fonte et al. 2005], provoking high levels of lateral displacement, which has had an immediate reflection in the adhered outer coatings fixed to the buildings.

In multi-storey buildings where reinforced concrete is molded on-site, all efforts are made to use the same mold during the entire execution of the structure. This has forced construction companies to increase the number of times they reuse molds, and so have introduced more durable parts, with greater protection against water infiltration and the use of more efficient mold release agents [Costa e Silva, 2008]. In both situations, at the end of the process the concrete surface is much smoother, which also hinders the adhesion of mortar coatings. It decreases the penetration flow of the mortar paste into the pores of the concrete, reducing the physical adhesion, which is the base of the theoretical model known as “theory of active pores”. Therefore, the influence of substrate roughness

(the reinforced concrete structure) has been the target of researchers, such as Dancygier et al. [2009], who managed to obtain a good performance from mortar coatings applied to mechanically treated bases with a chipping hammer and brushing immediately after the molds are removed, one day after casting.

3 EXPERIMENT

3.1 Experimental planning

In order to conduct the experimental study, a sample of concrete was prepared with two different types of molds, with the aim of providing potential contact areas⁵ of the separate substrates, in order to receive the mortar coating.

Thus, the adopted study variables were the potential contact area of the substrate with mortar coating, obtained from using two different types of molds (open texture and closed texture⁶), and the use and non-use of a mold release agent before placing the concrete.

In order to reduce the possible appearance of any other variables, a base measuring 0,80 x 0,80m was used, divided into 4 squares of 40cm each side, executed with the same mixture of concrete with an average compression strength of 25 MPa, commonly used on the local construction sites in the region (Fig. 1).



Figure 1. Image of the substrate divided into the 4 main squares.

After the base was prepared, a waiting period of 14 days (in laboratory conditions of environment – temperature 23°C and relative humidity of 90%) was observed before applying a coat of roughcast, (proportion 1:3, Portland cement: sifted coarse sand), followed by an application of grout (25mm thick) to stabilize. This final coat was applied approximately 48 hours after applying the roughcast coating. After the grout had cured for a period of 28 days, tensile tests were conducted to determine adhesion strength.

3.2 Materials used

3.2.1 Molds

The molds used in the study were composed of smooth panels, made of recycled material (75% plastic and 25% aluminum), commercially known as “ecological panels”, measuring 40x40cm, with an average thickness of 12mm (Fig. 2).

⁵ effective contact area between the base and mortar.

⁶ open texture – bass-relief measuring 15x5cm, and closed texture – bass-relief measuring 1x1cm, both with depth of 4mm.

To provide different potential contact areas, when the material was being pressed, the manufacturer was requested to create bas-relief textures (Fig. 3) with an average depth of 4mm, measuring 15x5cm, referred to as open texture, and 1x1cm, referred to as closed texture.



Figure 2. View from above of the two forms of mold used in the study.



Figure 3. Geometric detail of the textured mold with closed grooves.

From the geometrical description, a simple calculation may be made to compare the potential contact areas of the two molds, which when compared to a smooth surface, resulted in increased areas of 22.5% with the open texture and 84% with the closed texture.

3.2.2 Concrete substrate

The concrete base used in the experiment was made in the laboratory, with a unit mass ratio of 1:2:3 (CPIIF32 Portland cement: medium sifted sand: maximum size gravel 25mm), and a water/cement ratio of 0.50 (Fig. 5). The results of compressive strength obtained in cylindrical test specimens of 10x20cm demonstrated values of 25 MPa, after 28 days. During the execution, half the surfaces received an application of mineral oil release agents, as per manufacturer's instructions.



Figure 4. Condition of the mold surface (a) and of the concrete surface after demolding (b).

3.2.3 Mortar coatings

After making the base, a coat of roughcast mortar was applied in the proportion of 1:3 (CPIIF32 Portland cement: sifted coarse sand), preceded by mechanical brushing, often currently used on constructions in this region. This coating was undertaken employing the traditional system, by applying it vigorously with a trowel, preceded by a light sprinkling of water.

After 48 hours applying the coat of roughcast mortar, in order to level the surface, a coat of industrialized grout was applied, composed of cement, sand and stone dust (Fig. 6), to ensure the regularity of the surface for the assay of adherence. The quantity of water used followed the manufacturer's instructions, as described on the package, which after 28 days, recommends values according to a compression strength of 45 MPa, very important for ensuring that rupture takes place near the surface of the substrate, the object of the present study.



Figure 5. Side view of the grout used during the study.

3.3 Test methods

After a 28-day curing period of grout coating, tests were carried out to determine the direct tensile adhesion strength. These tests followed the general methods of standard EN 1015-12 (2000), although with sections of the square test units measuring 5 cm. 6 test units were tested per situation, with a total of twenty four tests, as demonstrated in Fig. 7. The calculation of bond strength was made from the real area of mortar that was cutted, sometimes larger than the area of the metal plate used for the pullout.



Figure 6. Samples prepared for the test to determine adhesion strength.

4 RESULTS AND DISCUSSIONS

The results obtained are described below in Table 1, highlighting the values of adhesion strength calculated from the charges obtained in the tests, divided by the area encountered in each sample.

Table 1. Table indicating the general results of the tensile strength tests.

Mean tension (MPa)	<i>Texture</i>			
	Open		Closed	
	with agent	without agent	with agent	without agent
	0,45	0,94	0,59	1,01

In order to obtain a better assessment of the results, a variance analysis was conducted to evaluate the influence of both the surface area, and the use of release agents on the adhesion strength encountered in the samples (Table 2). In both cases, it was proven that the variables had a significant influence on the adhesion strength, to a significance level of 95% (the calculated F value greater than the critical F value). However, the interaction analysis indicated that there was no significant evidence that the combined effects provoked by the two factors, simultaneously, influenced the adhesion strength, for the quantity of tested samples.

Table 2. Results of the variance analysis.

Source of variance	SS	df	MS	F	P-	Critical F
Open texture	0.065104	1	0.065104	4.919401	0.038298	4.351243
Treatment of base	1.246704	1	1.246704	94.20345	5.21E-09	4.351243
Interactions	0.005104	1	0.005104	0.385681	0.541592	4.351243
Inside	0.264683	20	0.013234			
Total	1.581596	23				

With regard to the absolute values, the graph presented in Fig. 8 clearly illustrates the encountered mean values.

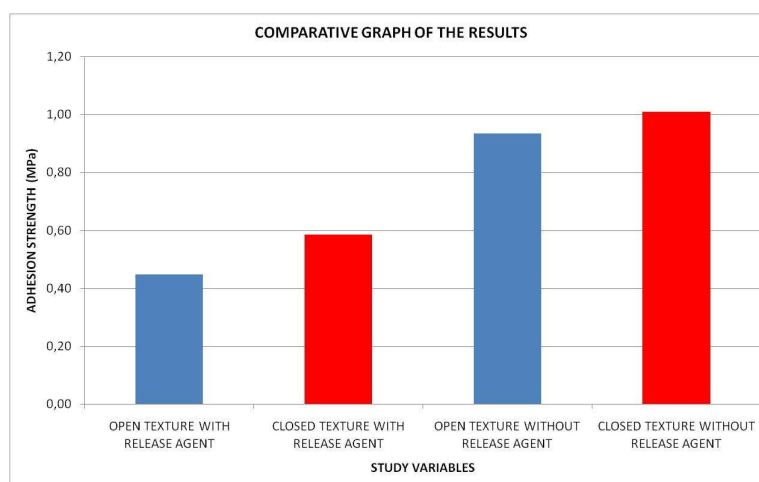


Figure 7. Comparative graph of the results obtained in the tensile adhesion strength test.

In the assessment of the use of release agents, an absolute percentage difference was recorded of 52%, with open texture and 42% with closed texture, increment values considered very significant.

With regard to the increase in the potential contact areas, the obtained increments were 30% and 8%, for the cases with and without release agents, respectively. It is important to emphasize that these

gains may also be considered relevant for the performance of the coating throughout time, especially concerning the conservation of the adhesion between the coatings submitted to repetitive shear fatigue tests, for example.



Figure 8. Condition of the main rupture occurring on the interface between the roughcast and the concrete substrate.

In addition to the absolute results, it is also important to assess the form of rupture encountered in the samples, which represents the most fragile link in the system (Fig. 9). From amongst the tested samples, the rupture was mostly encountered on the interface between the roughcast mortar and the substrate. It is noteworthy that the gain in tensile adhesion strength was not in the same relative proportion as the increment in the calculated area. It is believed however, that the greatest benefit achieved with the growth of the area should be what is referred to as shear strength, a particular property that has been under discussion by several research groups [Naderi, 2005], although not directly assessed in the present study.

5. CONCLUSIONS

Based on the discussions presented throughout this article, and on the obtained test results, it is possible to highlight a number of considerations, judged as being relevant for analysis:

- An increase of the potential contact area between the mortar coating and the substrate resulted in an absolute increase in the direct tensile adhesion strength, indicating that it would be appropriate to conduct further studies to encounter alternatives for molds with rough textured surfaces to produce concrete elements for buildings.
- The prospect exists of an even greater influence of the potential contact area of the mortar on the behavior of the shear strength, which was not assessed during this study. As an additional activity, it is recommended that new studies address the assessment of this increase in the area of mortar coating adhesion.
- The use of release agents in the mold proved to be very influential in the tensile adhesion strength, consequently, further complementary studies should be conducted in order to help develop molds that may be used in a more efficient manner (durability, stability) but without the need of this particular product.
- Because the mold used in this study is composed of polymers and aluminum, it presents a lower absorption of water, which reduces the necessity of using release agents. Another major aspect of its manufacture is that, contrary to what occurs in wooden molds, the pressure only causes an impression on the surface, without causing any tearing on the surface layer of wood, which may allow water to enter and thus lower the durability of the product.
- Data on the economic viability presented in the study must be confirmed for each case, especially with regard to durability (number of reuses) as presented by the supplier.

It is important to highlight that the results and discussions presented herein refer to the conditions and materials used in the experimental study, and should not be taken as definitive without the confirmation of further studies conducted with other variables not addressed by the present study.

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