Adhesion Study at Advanced Ages in Multipurpose Mortars

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Abstract One of the parameters used in the study of mortars is the adhesion resistance, which indicates how much the mortar adhered to the substrate. The usual study is done at 28 days, to worldwide standardization. Few researchers study the adhesion of mortars to ages other than 28 days. In this scenario, the adhesion strength tests of conventional mortar with a 1:1:6 mass scale (cement, and sand) at 7, 14, 28, 56, 91, 182 and 364 days were performed in order to understand the behavior of this material. The usual characterization tests of the mortars were carried out to correlate the values obtained with the adhesion results. The obtained results demonstrate that the mortar continues to gain resistance with the passage of time. For the trait studied the gain was considerable, indicating that over time the cement continues to hydrate, reacting and contributing to the strength of the material.

Keywords Mortar · Adhesion · Advanced ages

Introduction

Adhesion is one of the most important parameters when analyzing the performance of a multipurpose mortar, which is a type of mortar used for both wall cladding and ceramic tile laying. Although it is a property of great relevance in the studies of this

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type of material, it is extremely complex the understanding about the functioning of the adhesion mechanisms, since several factors interfere in the study of such property.

It is known that four basic mechanisms of adhesion between mortar and porous substrates can be identified, as in the case of blocks and ceramic bricks: first adhesion occurs by initial adhesion between the substrate and the mortar, then the adhesion is processed due to suction capillary, identified by the transport of fine materials to the interface between the two materials, followed by an equilibrium mechanism that occurs between the moisture of the mortar and the substrate studied, and finally the adhesion is due to the hydration of the cement present in the mortar, with formation of a cohesive solid phase between mortar and substrate [1].

Traction adhesion tests are the main parameters for evaluating the performance of multiple use mortars, although there is a great variation in the results found by different authors. These differences can be justified by several factors, which interfere in the execution of the test, and consequently in the comparison of results between different authors, among which can be cited:

- Differences in properties among the mortars studied: factors such as the initial adhesion that the mortar under study has as the substrate, which is strongly influenced by the rheological characteristics of the mortar interfere in the results of adhesion found by different authors [2]. Another factor that also interferes is the water retention that the mortar presents, because it has a great correlation with the suction that the substrate presents.
- Substrate properties: the properties of the substrate interfere with the adhesion mechanisms between this material and mortar, since factors such as porosity, capillary suction and substrate roughness interfere directly with the adhesion values found by different authors.
- Execution of the test: was verified in studies that the parameters of the test interfered directly with the adhesion values found [3]. Factors such as the shape of the specimens used, eccentricity, type of equipment and loading rate cause an unmanage in the results obtained in these tests.
- Impact energy: it is characterized by the kinetic energy with which the portion of mortar thrown reaches the base, and depends on several factors, such as the launching force and the portion of mortar that is thrown on the substrate, which vary from operator to operator. Therefore, it is extremely complicated to compare results of adhesion tests performed by different researchers [2, 4–6].
- Climatic conditions: the conditions of temperature, relative humidity and ventilation directly interfere with the curing conditions that the mortar will suffer, especially for outdoor environments. In this way the comparison between adhesion results obtained for mortars made in different geographic regions is subject to the differentiated climatic conditions of each of these regions [7–9].

Another great factor that interferes in the adhesion resistance between mortar and substrate is the time factor, since the cement present in the mortar continues to undergo the hydration process throughout the ages, even in the advanced ones, which can generate the idea that the mortar will continue to gain resistance over time. However the weather conditions which will be subject to mortar over time may have the opposite effect on this material. That is, due to rainy conditions and exposure to the sun it may be that the resistance of the mortar actually decreases with the passage of a certain age.

Thus, the objective of this work is to verify and analyze the adhesion strength to the traction of a mortar of multiple external use throughout the advanced ages, with the intention of understanding if the mortar continues to increase its resistance thanks to the hydration of the cement, if the mortar maintains the resistance without changes, or even if mortar presents a decrease in resistance due to exposure to external degradation agents, such as temperature variation, rainfall and sun incidence.

Materials and Methods

Thus, the objective of this work is to verify and analyze the adhesion strength to the traction of a mortar of multiple external use throughout the advanced ages, with the intention of understanding if the mortar continues to increase its resistance thanks to the hydration of the cement, if the mortar maintains the resistance without changes, or even if mortar presents a decrease in resistance due to exposure to external degradation agents, such as temperature variation, rainfall and sun incidence. The mortar in the 1:1:6 (cement: hydrated lime: sand) mortar was characterized according to the parameters required by the Brazilian standards highlighted in Table 1.

After curing times, namely 7, 14, 28, 56, 91, 192 and 364 days, the mortar systems were tested for tensile strength. The adhesion test is performed in the following manner: a chipped masonry wall is performed to receive the coatings and to serve as the substrate in the assay. On this substrate is executed a coat of mortar of the trait studied in the form of a plaster.

After the cure time, a glass saw is used to drill the specimens. According to the Brazilian standard, at least 12 specimens should be analyzed. After the drilling,

Table 1 Characterization of mortar 1:1:6 (cement: hydrated lime: sand)

Parameter	Value obtained	Norm
Relation w/c	0.80	NBR 13276:2016 [10]
Built-in airflow	7.8%	NBR 13278:2005 [11]
Capillarity	13.94	NBR 15259:2005 [12]
Density in hardened state	1.91 g/cm^3	NBR 13280:2005 [13]
Density in the fresh state	2.03 g/cm^3	NBR 13278:2005 [11]
Water retention	93.22%	NBR 13277:2005 [14]
Compressive strength 28 days	4.08 MPa	NBR 13279:2005 [15]
Tensile strength at flexion 28 days	1.12 MPa	NBR 13279:2005 [15]

Fig. 1 Adhesive device

metallic pellets are bonded to each of the specimens using an epoxy adhesive that must have a higher resistance than the coating. After 24 h of application of the adhesive, the test can be performed using a pull-out equipment as shown in Fig. 1. The equipment records the pulling force applied to the mortar to cause its breakage, which force is then converted into resistance.

Results and Discussion

The results of characterization of the mortar used to carry out the tests are indicated in Table 1. As can be seen by analyzing the data in the table, it is a standard mortar commonly used in civil construction.

The results obtained for the twelve specimens of each age, as well as their statistical treatment, are shown in Table 2.

Analyzing the results found for adhesion at different ages and using Duncan's proposed mean difference analysis, it is easy to see that mortar continues to gain resistance to adhesion over different ages. This is because the cement present in this mortar continues to moisturize even at later ages. Therefore, for the region of Campos

Table 2 Data obtained for different ages

Age	7 days	14 days	28 days	56 days	91 days	182 days	364 days
01	0.05	0.12	0.33	0.46	0.51	0.72	0.66
02	0.06	0.08	0.25	0.35	0.40	0.58	0.72
03	0.08	0.08	0.43	0.60	0.39	0.57	0.66
04	0.10	0.15	0.32	0.44	0.38	0.81	0.72
05	0.07	0.06	0.26	0.36	0.48	0.62	0.82
06	0.10	0.08	0.19	0.16	0.48	0.61	0.96
07	0.04	0.10	0.18	0.26	0.47	0.56	0.92
08	0.12	0.06	0.24	0.34	0.43	0.62	0.90
09	0.04	0.07	0.38	0.53	0.53	0.83	0.96
10	0.09	0.16	0.15	0.21	0.38	0.80	1.02
11	0.08	0.06	0.34	0.47	0.51	0.64	1.08
12	0.06	0.13	0.13	0.18	0.32	0.73	1.07
Average	0.07	0.10	0.27	0.36	0.44	0.67	0.88
Duncan	E	E	D	C	C	B	A

dos Goytacazes, under the climatic conditions analyzed, there is no depredation of the resistance and consequently loss of adhesion between substrate and mortar.

Thus, it refutes the idea that the mortar will have loss of resistance due to the climatic actions of temperature, insolation and rain for this specific case of study, since in the present study the hydration of the cement had greater significance in the resistance of the mortars than the action of time.

It is also emphasized that in the first ages, 7 and 14 days, the resistance gain is negligible, since there was no significant difference for the average resistance obtained in these two ages. With this, it is evident that the hydration of the cement is more intense after 14 days, since at 28 days there was a significant gain of tensile strength.

At the age of 56 days until the age of 91 days there was also no significant gain in resistance, which is evidenced by Duncan's analysis. It is likely that during this period the cement hydration has entered the dormancy stage, where the hydration reactions are decelerated. Analyzing the literature, an explanation for this is found: in cement mortars and hydrated lime, late ettringite formation is common due to the compounds that do not react completely in the early ages. This late ettringite reduces the resistance of mortars since its structure is rod-shaped, causing internal stresses detrimental to the material. It is noteworthy that these reactions commonly occur in ages between 60 to 80 days, as observed in this study. After this period, the ettringite decomposes and the cement hydration reaction proceeds [16–18].

After the dormancy period, the mortar again underwent hydration reactions, and its resistance increased until the last analyzed age at 364 days. The graph presented in Fig. 2 demonstrates how it was the tendency of resistance gain to adhesion to mortar, where it is observed that obviously this phenomenon does not follow a

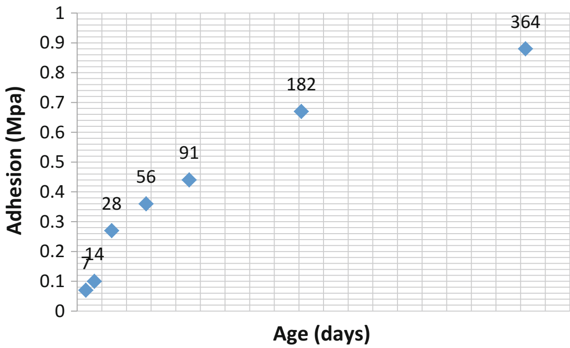

Fig. 2 Resistance to adhesion of the mortar studied

linear trend, since the reactions that modify the resistance of the mortar present great complexity and do not follow trends obvious and simple.

Conclusion

Through this study it was possible to conclude:

- Statistical analysis by the Duncan method for separation of averages shows that the mortar presents resistance gain to adhesion with the advancement of the studied ages.
- The increase in resistance is justified by the hydration of cement that continues to occur even in advanced ages.
- In the early ages, 7 and 14 days, the increase in resistance is negligible, indicating that cement hydration at these early ages has not reached levels of great relevance.
- After the 28 days, it is possible to increase the resistance to the adhesion of the mortar, until the ages of 56 and 91 days when the cement hydration is reduced, it is a period of dormancy in the mortar.
- From the period of 182 days until the last analyzed period, at 364 days, the mortar continued to have a resistance to adhesion.
- For the mortar studied, the hydration of the cement presented a greater contribution than the external factors of insolation, rainfall and temperature variation. This is perceived by the resistance gain that the mortar presented.

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