Construction and Building Materials 128 (2016) 298–307

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Influence of substrate texture on the tensile and shear bond strength of rendering mortars

Carina M. Stolz [a,*], Angela B. Masuero [a], Daniel T. Pagnussat [a,b], Ana Paula Kirchheim [a]

[a] NORIE/UFRGS Building Innovation Research Unit, Department of Civil Engineering, Federal University of Rio Grande do Sul, Porto Alegre, Brazil
[b] UFRGS Coastal North Campus Interdisciplinary Department, Federal University of Rio Grande do Sul, Tramandaí, Brazil

HIGHLIGHTS

- Concentrations of an air-entraining admixture on the contact area is investigated.
- The influence of substrates textures on the contact area is analyzed.
- Rheological behavior of mortars is observed whit squeeze-flow tests.
- The tensile and shear bond strength are statistically analyzed.
- Laser Scanner 3D is identified as promising method to quantify real contact area.

ARTICLE INFO

Article history:
Received 31 March 2016
Received in revised form 29 August 2016
Accepted 20 October 2016
Available online 25 October 2016

Keywords:
Tensile bond strength
Shear bond strength
Substrate texture
Mortar renders
Rheology

ABSTRACT

This study assessed the influence of the substrate texture and rheological characteristics of mortars on the shear and tensile bond strength of rendering mortars. Concrete slabs with three different types of surface textures were used as substrate. Rendering mortars were prepared with a composition of 1:1:4 (cement: hydrated lime: dry sand, in volume – converted to mass), water/binder ratio 1.2, with different concentrations of an air-entraining admixture (0, 0.2 and 0.5%), and sand with a controlled granulometric composition, to modify the rheological properties of this material. These mortars were placed on the substrates using a device to control the force of application. The results showed that increasing the contact area in the substrate, as a result of different surface textures, does not always increase the bonding strength between the substrate and the render. Instead, the rheology of the rendering mortars seems to be the main factor controlling their bonding capacity. Depending on the substrate texture, rendering mortars with different consistencies increase the bonding strength of this type of systems. Also the workability of the rendering mortars, considering the roughness of the substrate, needs to be optimized to ensure a long-lasting life of the rendering.

1. Introduction

One of the last stages of the building process is the finishing of the surfaces using mortar renders. In Brazil, most building constructions use this type of coating indoors and on facades. However, the poor technological control and the lack of technical expertise in the field often lead to pathological manifestations that may compromise the performance of this layer.

In order to mitigate this problem, many researchers [1–6] have focused their attention on the adhesion phenomena of mortars and substrates, since problems associated with poor adhesion often decrease the market value of constructions.

Adhesion is a very complex property that is dependent on several factors, namely: a) the characteristics and properties of the porous material in contact with the mortar; b) the characteristics of mortars and their constituent materials; c) the mortar's application technique; d) the climatic conditions at the time of application and throughout the life period of the cladding or rendering, and e) the time span after mortar application [7]. Thamboo and Dhanasekar [8] also added to this list the influence of workmanship on the system execution process, specifically on the quality with the valleys of the unit surface have been filled, the degree of pressure applied and the tools used.

To improve the understanding on rendering mortars bond behavior, it is important to comprehend the influence of

* Corresponding author.
E-mail addresses: carimstolz@yahoo.com.br (C.M. Stolz), angela.masuero@ufrgs.br (A.B. Masuero), danipag@yahoo.com (D.T. Pagnussat), anapaula.k@ufrgs.br (A.P. Kirchheim).

http://dx.doi.org/10.1016/j.conbuildmat.2016.10.097
0950-0618/

microadhesion and macroadhesion. Microadhesion is created by the absorption of mortar pastes that come into contact with a porous substrate, filling the pores and creating a mechanical 'anchor' of the mortar to the substrate. Macroadhesion is characterized by the accidental or deliberate filling of protuberances and indentations found on a surface, which hold mortar projections in place by anchoring them to the surface. Even though many studies [9–11] have analyzed these properties, there still have some gaps to be filled.

Some researchers believe that to maximize the adhesion of the mortar to the substrate, large textures need to be created to increase the actual surface area that can be wetted by a given adhesive or resin [12]. However, it should be pointed out that this mechanical interlocking depends on the extension of adhesion, which is defined as the ratio between the effective contact surface and the total potential area that can be bonded [13].

In addition, Pretto [14] has published images that indicate that increasing the surface texture of a substrate is not enough if the mortar applied to the surface cannot penetrate the texture and wet the substrate. In this context, the rheological characteristics of mortars [15–18] have been investigated in order to understand their influence on the adhesion phenomenon.

Lukovic et al. [19] stated that the absorption of substrates also have influence on voids on interface. Dry substrates results in more voids on interface, because water loss by substrate reduces the effective w/c and degree of hydration of the applied material.

A recent investigation [20] showed that the surface tension of the substrate is also an influential factor in the development of the contact area in the mortar/substrate interface, in addition to the force of application and rheological properties of mortars. These results are further evidence of the complexity of the study of adhesion and interfaces, requiring further studies on the subject.

Thus, this study aims to analyze the influence of the interactions between the potential contact area of substrates (with different textures) and the mortar rheology on the tensile and shear bond strength of rendering mortars.

2. Experimental methods

The experimental program proposed in this research is presented in Fig. 1. Three rendering mortars, with different percentages of air entrained additive (AEA) were produced and applied to concrete substrates imprinted with three different textures. After curing, these rendering systems were submitted to tensile and shear bond strength tests.

2.1. Materials

Concrete slab substrates were produced using commercial Portland CPII-Z cement (compound with 6–14% of pozzolan, similar to C150 – ASTM standard and CEM I – EN 197). Quartz sand with a specific mass of 2.50 g/cm^3 and fineness modulus 2.50 and a crushed basalt with specific mass 2.98 g/cm^3 and maximum nominal size of 9.5 mm, were used as fine and coarse aggregate, respectively.

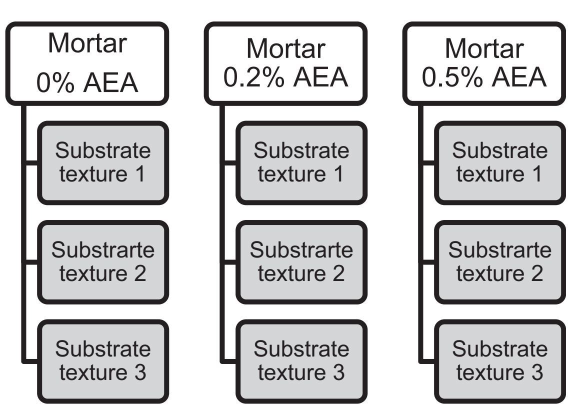

Fig. 1. Experimental program.

The mortars were produced with commercial Portland CP-IV pozzolanic grade cement (equivalent to the American IP (MS) grade), and a calcitic lime (specific mass 2.37 g/cm^3, mean particle size 22.4 μm), which complied with the limits set by Brazilian standards. The quartz sand used to prepare mortars had a composition of 25% of sands, retained in sieves #1.2; 0.6; 0.3 and 0.15 mm (specific mass 2.50 g/cm^3, fineness modulus 3.19).

In addition, to produce mortars with different rheological characteristics, air entrained admixture (AEA) was added in three different percentages (in relation to the amount of cement) of: 0%, 0.2% and 0.5%. The AEA is a vegetable-based resin admixture, with plasticizer action. Its density ranges from 0.99 to 1.01 kg/dm^3 and it has a solids content between 5 and 6.5%, according fabricant information.

The chemical composition and physical properties of the cements and lime used for the concrete slabs and for the production of mortar renders are presented in Tables 1 and 2.

2.2. Sample preparation

Concrete slabs of 25 × 35 × 5 cm^3 were cast as substrates, with an average compressive strength of 35 ± 5 MPa after 28 days of curing, as indicated in Table 3. This mix design was achieved using the method proposed by Helene and Terzian [21].

In order to modify the substrate roughness and evaluate the effect of potential mechanical interlocking with increased contact areas, the bottom of the concrete formworks was covered with polymeric material, imprinting textures in the slabs. Three different surface textures (Fig. 2) were applied: texture 1 – smooth, texture 2 – diamond shaped and texture 3 – coin shaped.

All concretes slab were wet-cured in a controlled temperature chamber at 23 ± 2 °C for 28 days.

These textures were digitalized with a Tecnodrill tridimensional laser scanner, model Digimill (3D), with a 50 mm lens and 0.2 mm precision between points. The cloud points resulting from the digitalization were treated with the Geomagic Studio 10 software to generate images (Fig. 3). These image areas were quantified and compared to analyze the corresponding potential contact areas of each texture surface. The results showed that, through potential contact areas, the diamond shaped texture presented an increase of 2.08% when compared to the smooth texture. The coin shaped texture presented an increase of 5.53% when compared to the smooth texture. However, the coin shaped texture exhibited a potential contact area of 3.27% higher when compared to the diamond shaped texture.

Mortars renderings were prepared with a composition of 1:1:4 (cement: hydrated lime: dry sand, in volume – converted to mass in the laboratory) and 1.2 w/b ratio, according to the Brazilian Standard NBR 13276/05.

Mortars were applied to the concrete slabs using a device called "drop box", illustrated in Fig. 4. This device allows you to adjust the height from which the mortar is dropped over the substrate and, therefore, to control the application energy during the rendering process. In this study, a fixed drop height of one meter was used to achieve a constant applied energy of 10 J. No slurries were used in this study, and then the interaction between rendering mortars and substrate could be assessed without the use of any kind of priming. After the application of the rendering mortars, the concrete slabs with the mortar layer were cured in a controlled temperature chamber for 28 days at 23 ± 2 °C and a relative humidity of 60 ± 5%.