Journal of Colloid and Interface Science 455 (2015) 16–23

Contents lists available at ScienceDirect

Journal of Colloid and Interface Science

www.elsevier.com/locate/jcis

Analysis of main parameters affecting substrate/mortar contact area through tridimensional laser scanner

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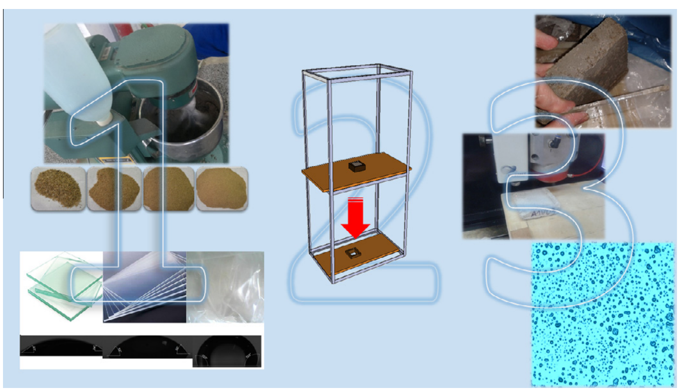
GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 4 March 2015
Accepted 14 May 2015
Available online 27 May 2015

Keywords:
Wetting
Interface
Contact area
Mortar
Granulometric composition
Sand
Laser 3D scanner
Application energy

ABSTRACT

This study assesses the influence of the granulometric composition of sand, application energy and the superficial tension of substrates on the contact area of rendering mortars. Three substrates with distinct wetting behaviors were selected and mortars were prepared with different sand compositions. Characterization tests were performed on fresh and hardened mortars, as well as the rheological characterization. Mortars were applied to substrates with two different energies. The interfacial area was then digitized with 3D scanner. Results show that variables are all of influence on the interfacial contact in the development area. Furthermore, 3D laser scanning proved to be a good method to contact area measurement.

1. Introduction

In Brazil, most building constructions use rendering mortars. However, poor technological control and the lack of technical expertise in the production of rendering mortars often produce pathological manifestations that may compromise the functions of renderings: the protection, waterproofing and aesthetic appearance of constructions.

In order to mitigate the onset of pathological manifestations, many researchers [1–5] have focused attention on the adhesion of rendering mortars because problems associated with poor adhesion often affect the value of constructions. The main concern is

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http://dx.doi.org/10.1016/j.jcis.2015.05.028
0021-9797/

with microadhesion [6] and macroadhesion [7,8], but there is little information about the behavior of rendering mortars regarding the mechanisms that affect adhesion. Microadhesion is created by the absorption of mortar pastes that come into contact with a porous substrate, with the filling of the pores creating a mechanical 'anchor' of the mortar to the substrate [9]. 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 [9].

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 [10]. 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 bond [11].

In addition, researchers [12] have 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 [13–16] have been investigated in order to understand their influence on the phenomenon of adhesion.

In addition to the texture characteristics of substrates, chemical characteristics of surfaces may also influence the development of the contact area at the interface between mortar and substrate.

Surface tension is a direct measurement of intermolecular forces as van der Waals forces and hydrogen bonds. The most common attraction forces are van der Waals forces that can be attributed to dispersion and polar forces. When liquid touches solid, opposing forces appear: on the one hand the solid tends to be surrounded by liquid molecules, decreasing the potential energy of surface molecules. On the other hand, the liquid tends to remain grouped to reduce its exterior surface. Only when the surface energy of the solid is equal to or greater than the surface tension of the liquid is disintegration of the liquid possible on the solid surface, producing wetting [10].

One way to observe the wettability of a substrate is to measure the contact angle. This parameter is defined as the angle that liquid drop shape with the solid surface in the contact zone between the two phases. It is considered that a liquid wets a solid when the contact angle between the droplet and the solid surface is smaller than 90°. Therefore, it is believed that the higher the contact angle, the less wetting of the surface [10].

Considering all the variables that can be of influence on the interface contact, this study aims to analyze the influence of mortars with different rheology characteristics, modified by the granulometric composition of the sand, applied to substrates with different superficial tensions in the interfacial contact area.

2. Experimental program

2.1. Mortar production

A layer of mortar prepared with a composition of 1:1:6 (cement: hydrated lime: dry sand, in volume) was produced according to the Brazilian Standard NBR 13276/2005, for a 240 mm consistence index (measured in flow table, before subjecting the mortar to 30 strokes and measure the mean of three diameters of resulting circle). During mortar production, the volume composition was dosed in mass, for a better production control. The quartz sand used (specific mass 2.50 g/cm^3) consisted of three compositions of sand. All of them, with grains retained in sieves #1.2; 0.6; 0.3 and 0.15 mm. The first composition (CG1, aggregate unit mass 1.51 g/cm^3) consists of equal fractions of each sieve, 25% each. The second (CG2, aggregate unit mass 1.48 g/cm^3), with 10%, 40%, 40% and 10% of each sieve respectively, and third (CG3, aggregate unit mass 1.54 g/cm^3) with 40%, 10%, 10% and 40% of each sieve, respectively.

About sand granulometric compositions utilized, it is possible to observe that CG2 is uniform, with similar diameters grains predominance, like natural quartz available in the city of study. CG3 is not uniform with good compacity, the opposite of CG2. Finally, CG1 present a continuous granulometric composition, less uniform than others do. These affirmations can be proved by uniformity index (UI) calculation, by $UI = d_{60}/d_{10}$, where d_{60} and d_{10} are, respectively, the sieves where cumulative passing percentage of mass corresponding 60% and 10%. Granulometric composition is consider uniform when $UI < 5$, with median uniformity when $5 < UI < 15$ and no uniform when $UI > 15$. So, the uniformity index of all granulometric compositions are: CG1: 3.95 (uniform), CG2: 2.48 (uniform) and CG3: 6.28 (median uniformity).

The mortars produced with CG1, CG2 and CG3 were called A61, A62 and A63, respectively.

The cement used was Portland cement type IV (equivalent to the American IP (MS) grade), and the calcitic lime (specific mass 2.37 g/cm^3, mean particle size 22.4 μm) complied with the limits set by Brazilian standards.

The physical and chemical properties of the cement types used are shown in Table 1.

2.2. Substrate selection

Through preliminary analysis, three non-absorbent substrates with different wettability ratings were chosen: glass, acrylic, and polyethylene. These substrates were characterized by measuring the contact angle of a drop of water projected on their surface using a goniometer.

The contact angle can be measured using a drop of water (or other liquid) analyzer equipment, that makes a picture with a high-precision digital camera of surface/liquid interface. This picture enables the contact angle measure with AutoCad software, for example.

2.3. Mortar application

The mortar was applied to the substrates by means of a device called "drop box" from two fixed fall heights of thirty centimeters and one meter. A "drop box" is a simple device that allows users to adjust the height from which the mortar will be dropped onto the substrate, therefore controlling the energy applied.

To control the size and thickness of the mortar samples, we produced wood templates of 10 cm × 10 cm with a thickness of 1 cm. The bottom was covered with each of the materials of different surface tensions. For each mortar/substrate/energy combination, three blocks were cast.

Table 1
Chemical and physical properties of cement used.

Experiment		Method	Results
Blaine specific surface		NBR NM 76/98	4398.5 cm^2/g
Density		NBR NM 23/01	2.76 g/cm^3
Medium diameter		Laser diffraction	16.95 μm
Fineness sieve #200		NBR 11579/91	0.27%
Initial curing period		NBR NM 65/02	243.25 min
Final curing period		NBR NM 65/02	284.80 min
Compressive strength	7 days	NBR 7215/96	25.03 MPa
	28 days	NBR 7215/96	36.20 MPa
Insoluble residue		NBR NM 22/04	35.84%
Sulfur trioxide (SO3)		NBR NM 146/04	2.28%
Magnesium oxide (MgO)		NBR NM 14/04	4.61%
Loss on ignition			3.64%