Influencia del transporte de agua en morteros de revestimiento, en la resistencia a la adherencia

Influence of water transportation inside a mortar/block system on bonding resistance behavior

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Resumen

En el presente trabajo se determina cómo ocurre el transporte de agua, en el sistema mortero/bloque, con el objetivo de vincular el comportamiento de la resistencia a la adherencia por tracción perpendicular, con el transporte de agua y la porosidad del sustrato. Para ello fueron fabricados dos morteros con áridos de diferentes granulometrías, a los cuales se le determinó sus propiedades en estado fresco y en estado endurecido. Se determinó la cantidad de agua transportada, a partir de mediciones de humedad con sensores resistivos, en diferentes camadas de los morteros aplicados sobre sustrato de hormigón y sustrato cerámico. Los bloques de albañilería usados como sustrato, fueron caracterizados atendiendo a sus propiedades físicas, relacionadas con la absorción de agua y la porosidad. Los resultados mostraron que existe una relación directa entre el porcentaje de agua transportada en las diferentes camadas, con la resistencia a la adherencia del mortero. Comprobándose además, la no existencia de relación entre los ensayos de retención de agua del mortero y el total de agua transportada en el sistema mortero/bloque.

Palabras claves: Mortero, revestimiento, transporte, adherencia, propiedades

Abstract

In the present study was performed an evaluation of the water transport in the mortar/block system, with the objective of linking the behavior of the bond strength by perpendicular tensile stress, and with water movement and porosity of mortar. This was done by producing two mortars with aggregates of different size distribution. Properties were determined in fresh state and bond strength was measured when hardened. The water transport profile was constructed by resistive sensors for measuring moisture. Measurements were done in different coats of mortars applied on a concrete substrate and the ceramic substrate. Masonry blocks used as a substrate were characterized according to their physical properties related to water absorption and porosity. The profile leads to the transport of water affects the porosity of mortar and showed that there is a direct relationship between the percentages of water being transported at different layers, with resistance to adhesion. Was checked also the not existence of relationship between the water retention test mortar and total water transported in the mortar-block system.

Keywords: Mortar, rendering, transport, bond, properties

1. Introduction

From the very first moment after applying mortar on the masonry unit, an important change takes place in the inner material structure. This is due the transportation of water inside the mortar. Due to capillary absorption, water moves towards the porous structure and towards the exposed surface due to water absorption process. After its application, the substrate is responsible for mortar water loss, because of its water absorption capacity.

Surface substrate and its porosity characteristics, such as diameter, structure and pores distribution directly affect mortar water transportation towards substrate (Honorio and Carasek, 2010; Alves et al., 2010; Forth et al., 2000; Scartezini, 2002; Aldo Leonel Temp et al., 2013).

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As far as the mortar is concerned, water loss at the moment it gets in contact with the masonry block is quite intense. As long as the water transportation process takes place, capillary absorption tensile stress in the contact surface decreases (with the humidity percentage increase on the masonry block surface). Water availability to be transported in the mortar also decreases (de Souza et al., 2012). We shall consider that water flow does not go alone in the movement of pores structure created by absorption. This is because there are capillary strengths, physical absorption phenomena, as well as water setting due to reactions taking place due to binders (concrete and lime-stone) used to elaborate hydration products. Therefore, in the masonry block, water suction takes place when the resulting actions of this factor set are in the mortar block direction. Some of the main equations leading to partially explain such phenomenon are described by Hall (1986, 1994).

Mortar water release at the initial moments (some hours after mixing) and at early ages (first 7 days) is extremely important for the development of the coating system properties. It is also responsible for the origin of pathologies (Pereira and Bauer, 2013), such as cracking due to mortar plastic retraction (Silva and Bauer 2009; Silva et al., 2009). Retraction is caused by water release due to evaporation and due to masonry unit capillary absorption. Retraction may lead to mortar cracking. Veiga (1998) and then Silva (2009) evaluated the effect produced by retraction and they linked mortars mechanical behavior with cracking development. Similarly, Pereira (2007) carried out a detailed research on water release due to evaporation, linking this phenomenon to a de-bonding mechanism.

Other experimental techniques used to determine water transportation in fresh concrete have been employed intending to explain this phenomenon, such as neutron transmission (Groot, 1993), nuclear magnetic resonance imaging (Brocken et al., 1998), permeameter test, absorption test and pressure plate tests (Hendrickx et al., 2010).

As far as masonry mortars are concerned, Carasek (1996) demonstrated the importance of water transportation for the substrate, evidencing the creation of hydration products (mainly ettringite) on ceramic blocks pores, together with the importance of mortars pores and block pores for the development of bonding. Recent researches, developing a micro-structural analysis of the mortar/block interface, demonstrate that the size, shape and orientation of ettringite crystals in a given area, determine at a large extent the bonding resistance of the rendering mortar (Junior and Gomes, 2009). In other cases, the increased bonding resistance is attributed to the utilization of a water repellent additive, which repels water from the interface so that spaces are filled up with fine aggregates, thus hardening this area (Costa and John, 2013). Other authors consider that fine aggregate percentage in the mortar is the most influencing factor, because of the effect it provokes on water/cement ratio and on mortar porosity (Miranda and Selmo, 2006). These parameters can be associated with the mortar ability to transport water towards substrate. Recent researches proved that filler type (Martínez et al., 2013)

is a determinant factor of this and other properties, such as water retention and mortar retraction.

This research determines how and the volume of water transported from the mortar towards the substrate. It also connects bonding resistance behavior of different masonry mortars with water transportation in the mortar/block system. Furthermore, it was proved that there is no relationship between the mortar water retention test and the volume of water transported in the mortar/block system.

2. Materials and methods

2.1 Materials and dosages

Rendering mortars were prepared by using Portland cement with lime-stone filler (CP II-F-32, made in Brazil, equivalent to CEM II/A-L), also including air hydrated lime aggregate and two sands from natural origin. Above materials are usually employed for the elaboration of rendering mortars and they are easily obtained in the region where the research was conducted. Table 1 shows the chemical composition of binders.

Tabla 1. Composición química del cemento y la cal
Table 1. Chemical composition of cement and lime-stone aggregate

Materiales/ Materials (%)	SiO ₂	Fe ₂ O ₃	Al ₂ O ₃	CaO	MgO	SO ₃	Na ₂ O	K ₂ O	Cal libre/ Free lime- stone	Pérdida por ignición/ Ignition loss	Residuo Insoluble/ Non- soluble residue
Cimento/Cement	25.95	3.25	4.68	52.99	4.05	2.81	0.34	0.77	1.13	5.16	1.38
Cal	1.28	0.21	0.00	71.98	0.54	0.37	0.05	0.09	24.14	1.28	-

Table 2 shows the physical properties of bonding agents used for mortar calculation and dosages.

Tabla 2. Propiedades físicas de los aglomerantes
Table 2. Physical properties of bonding agents

Propiedades/ Properties	Método/Methods	Resultados/Results	
		Cemento/Cement	Cal/Lime-stone
Densidad Aparente/ Apparent density	NBR 7215 (ABNT1982)	0.98 kg/dm ³	0.59 kg/dm ³
Peso Específico/ Specific weight	NBR 9676 (ABNT1987)	3.05 kg/dm ³	2.23 kg/dm ³
% pasa tamiz #200/% passing sieve #200	NBR 11579 (ABNT2012)	2.90%	4.90%
	NBR 9289 (ABNT2000)		

The aggregates employed correspond to average size sands from alluvial deposits, classified under NBR 7211 (ABNT, 1993). Their properties are shown on Table 3.

Tabla 3. Resultados de la caracterización de las arenas
Table 3. Results from sand characterization

Propiedades/ Properties	Método/Methods	Resultados/Results	
		Ar1	Ar2
Módulo de Finura/	NBR NM 248 (ABNT,2003)	2.12	2.40
% pasa tamiz/	NBR NM 46 (ABNT,2003)	4	3.4
Densidad aparente (g/cm ³)/	NBR NM 45 (ABNT,2006)	1.36	1.44
Peso Específico (g/cm ³)/	NBR NM 52 (ABNT,2009)	2.64	2.64
Índice de vacíos (%)/	NBR NM 45 (ABNT,2006)	48	43
Coefficiente de uniformidad/	-	3.5	4.4

These two types of sand were selected because of their grain size differences, which might influence water transportation. They were used to elaborate mortars with similar water/aggregate ratio and identical fine aggregates content, which are one of the main parameters determining variations of mortars properties. In such a case, parameters will be constant; so as to determine the influence the sand fineness module has on the mortar water transportation towards the substrate; as well as the influence derived from the type of substrate.

Materials mixing ratios were defined in accordance with a dosage research for rendering mortars used for external walls. Ratios are based on the regulation NBR 13755 (ABNT, 1996), varying from 1:0.5:5 to 1:2:8 (cement: hydrated lime-stone: moisture average size sand, in bulk). Table 4 shows dosages employed to elaborate the two types of mortars. We observe there are slight differences in the lime content, which are necessary to maintain the mixtures with the same amount of fine material, as sand after passing through the sieve #200 has not the same material percentage. A consistency higher than 220 mm was worked out, so as to guarantee machinability in accordance with the mixing process and pouring technique. Apart from this machinability criterion, the amount of water employed had to guarantee that both mortars could have similar values for water retention tests, so as to analyze differences between such tests; measuring water transportation by using humidity sensors.

Tabla 4. Dosificación de los morteros

Table 4. Mortars Dosage

Morteros/ Mortars	Proporción en peso/ Weight ratio	Proporción en volumen/ Volume ratio	Cantidad de agua para revestir un sustrato/ Amount of water used to render a substrate
MA	1:0.73:9.27:1.97	1:1.24:6.82:1.97	1880g
MB	1:0.87:9.27:2.14	1:1.47:6.82:2.14	2043g

In addition to mortars, this research employed two types of blocks commonly used for structural masonry: ceramic and concrete blocks. The selection of such material, used as substrate, has a great importance in this research because its porous structure, surface texture and absorption characteristics determine the development of mortar properties, in the mortar/block system. Table 5 shows the properties of blocks under study.

Tabla 5. Resultados de la caracterización de los bloques

Table 5. Results from blocks characterization

Ensayo/ Test	Método/ Method	Bloque de hormigón/ Ceramic block	Bloque cerámico/ Compressive resistance
IRA/IAR (g/200cm ² /min)	ASTM C-67:12	50.2	25.5
Absorción de agua/Water absorption (%)	NBR 12118(ABNT,2013)	7.1	20.3
Resistencia a compresión/ Compressive resistance (Mpa)	NBR 12118(ABNT,2013)	4.7	4.5

Results are in accordance with the evaluation of blocks properties, at the age of 8 months. Blocks of this age were selected so as to avoid changes of properties in concrete blocks. Changes take place at early ages as the result of cement paste hydration reactions, which might influence the water transportation towards the substrate, as well as affecting the bonding resistance results.

Figure 1 shows the results from mercury-intrusion porosimetry developed on the two blocks types. We observe that ceramic block has a volume approximately three times higher than concrete block. These values are in accordance with water absorption results indicated on Table 5. On the other hand, the pores volume of interval 5 to 1000 μm , which can be classified as big capillary pores, is considerably greater in the concrete block. This explains the higher value of initial absorption rate the concrete block has, if compared to the ceramic block. In the research developed by Rato (Rato 2006), this behavior was compared among mortars. The same research yielded a direct relation between the total absorbed water and the available pores volume, as well as a direct relation between biggest size pores and the initial water absorption by capillarity.

Figura 1. Distribución de poros de los bloques
Figure 1. Pores distribution in blocks

2.2 Experimental programme

For the experimental stage, mortar specimens were elaborated, 4x4x6cm, so as to determine mortars properties, according to procedure described by the ABNT NBR 13276:2005. In order to measure water transportation, ceramic blocks and concrete blocks were coated by using a device which is a "freefall box". The rendering mortar is poured from a standard distance (50cm) in freefall, with fixed impact energy when the mortar makes contact with the block surface, in accordance with the procedure described by Paes (2004).

So as to control water transportation in mortars covering the blocks, humidity resistant sensors were developed, in order to obtain the evolution profile of water transported from fresh mortar to the porous substrate, as described by Paes (2004).

Sensors (Figure 2) start under a saturation condition (humidity 100%), which is compatible with the humidity conditions of mortar just mixed. As long as water is transported towards the substrate, humidity contained by sensors start decreasing, therefore, 100 less the sensor reading indicates the percentage of water transported by the litter per unit of time. Concrete block is coated in a relative humidity environment at 100% and water is transported from the mortar towards the block (blocks are dry at the moment of mortar application). Sensors record humidity from the position they were fixed (close to the surface, at the intermediate upper and lower litter and in the mortar/block interface). This arrangement was set for the study of four litters: upper, intermediate-upper, intermediate-lower and interface. Sensor recordings were defined by means of the interrelation analysis between electric current and humidity, where each sensor has its own calibration curve. Sensors were installed with the assistance of a metal structure, inside a template, which also defined the total thickness of mortar coating (50mm), as shown on Figure 2. For this coating thickness, eight sensors were fixed (two per litter), i.e. two of them fixed close to the surface; two in the intermediate-upper litter; two in the intermediate lower litter and two in the interface template litter.

Figura 2. Posición de los sensores para la medición del transporte de agua
Figure 2. Arrangement of Sensors for measuring water transportation

After pouring mortar on blocks, this arrangement was placed inside a hermetically sealed container keeping relative humidity close to 100%, as shown on Figure 3. This procedure was carried out to quantify water transportation by suction in the block, thus avoiding water loss from the mortar due to evaporation.

Figura 3. Equipamiento para la medición del transporte de agua en el mortero
Figure 3. Device used to measure water transportation in the mortar

Recordings for the evaluation of water transportation from the fresh mortar were carried out during the first nine hours (540 minutes), totalizing 25 humidity recordings from each litter. In the first half an hour, recordings were made every 2.5 minutes, later they were recorded every 10, 30 and 50 minutes. During the total 9-hour period, an important portion of water had already been transported to the substrate (generally, more than 65%). Independently from the rest of variables involved, this enables us to establish a correlation between such behavior and the coating performance, taking into account that the two mortars were elaborated using the same binder agents and; that they were exposed to similar conditions during recordings and after those were completed. From mortars obtaining similar bonding resistance and water transportation values, at the age of 28 days, different samples were extracted so as to determine porosity, by using mercury-intrusion porosimetry, with the purpose of explaining their behavior.

3. Results and discussion

In order to determine how does water transportation from the mortar towards the substrate take place and its potential relationship with water retention tests, as well as the relation between water transportation values and mortar bonding values; the results from mortars characterization, from water transportation and bonding values obtained by two mortars in different substrates are shown and discussed below.

3.1 Results from mortars characterization

Table 6 shows the results from the mortar evaluation in fresh and hardened conditions. We shall observe that consistency values are higher than 220mm diameter on the fluidity device, as previously defined by this study. Mortar MB happened to be more fluid, due to a higher amount of water to compensate the higher content of lime-stone aggregate, which is necessary to maintain the total fine aggregate content under steady condition, thus guaranteeing similar results from water retention tests.

Tabla 6. Propiedades físicas de los aglomerantes
Table 6. Physical properties of bonding agents

Estado/ Condition	Propiedades/ Properties	Método/Methods	Morteros/Results	
			MA	MB
Fresco/ Fresh	Consistencia (Penetración de cono)/ Consistency (Cone penetration) (mm)	BS 1377/75	22.0	29.0
	Fluidez (mesa)/ Fluidity (mm)	NBR 13276 (2005)	221	252
	Tensión de corte (Ensayo Vane)/ Shear tensile stress (kPa)	ASTM D 4648-00	1.19	1.51
	Aire incorporado/ Incorporated air (%)	NBR 13278 (2005)	5	6.5
	Retención de agua (papel filtro)/ Water retention (paper filter) (%)	NBR 13277 (2005)	88	89
	Retención de agua (embudo)-15 minutos/ Water retention (funnel)-15 minutes (%)	NBR 13277 (2005)	69	70
Endurecido/Hardened	Densidad/ Density (g/cm ³)	NBR 13278 (2005)	1.88	1.89
	Resistencia a compresión/ Compressive resistance (Mpa)		2.82	3.55
	Resistencia a tracción/ Tensile stress (Mpa)		1.07	1.17
	Módulo de elasticidad/ Elasticity modulus (Mpa)		7710	8680

As it was previously defined, we confirmed that tests related to water retention, such as the funnel test and paper filter test showed similar results for the two mortars. This case indicates that conditions mortars undergo to retrieve water from their inside are not enough to provoke differences in the behavior of these mortars (differing by sand fineness module and w/c ratio). For these test conditions, it seems to be that the utilization of an equal amount of fine aggregates in mortars was the factor that influenced this property the most. Although mechanical properties of mortar B are slightly higher than mortar A, they can be considered as equal, since both classify under the Brazilian standard as mortar type P3-R2, in regards to compressive resistance and tensile strength, respectively.

3.2 Water transportation

By using the humidity sensor recordings, the amount of water transported was classified into three water flow regimes: Regime (R1) from 0 to 5 minutes, Regime 2 (R2) from 5 to 60 minutes, Regime 3 (R3) from 60 to 540 minutes, in accordance with the research developed by Paes 2004. Table 7 shows the results of water transportation for both mortars, on different substrates of the four defined litters.

Tabla 7. Resultados de la medición del transporte de agua en las camadas de los morteros por tipo de sustrato**Table 7.** Results from water transportation recordings on mortar litters per type of substrate

Sustrato/ Substrate	Mortero/ Mortar	Régimen/ Regime	Tiempo/ Time (min)	Índice de agua transportada/ Transported water index (g/min172)				Agua transportada/ Transported water (%)			
				Sup/ Upper	Inter-sup/ Interm.upper	Inter-inf/ Interm.lower	Inter-fas/ Interface	Sup/ Upper	Inter-sup/ Interm.upper	Inter-inf/ Interm.lower	Inter-fas/ Interface
Bloque Cerámico (BC)/ Ceramic Block (BC)	MA	R1	0 a 5	17	25	42	59	2 (38g)	3 (56g)	5 (94g)	7 (132g)
		R2	5 a 60	71	74	76	81	28 (526g)	29 (546g)	30 (564g)	32 (601g)
		R3	60 a 540	21	22	22	23	25 (470g)	26 (488g)	26 (489g)	27 (508g)
		Total (1880g)						55 (1034g)	58 (1090g)	61 (1147g)	66 (1241g)
	MB	R1	0 a 5	55	64	64	82	6 (123g)	7 (143g)	7 (143g)	9 (184g)
		R2	5 a 60	94	91	97	94	34 (694g)	33 (674g)	36 (716g)	34 (696g)
		R3	60 a 540	13	13	13	15	14 (286g)	14 (286g)	14 (286g)	16 (327g)
		Total (2043g)						54 (1103g)	54 (1103g)	57 (1145g)	59 (1207g)
Bloque de Hormigón (BH)/ Concrete Block (CB)	MA	R1	0 a 5	51	59	67	93	6 (113g)	7 (132g)	8 (150g)	11 (207g)
		R2	5 a 60	89	91	91	94	35 (658g)	36 (676g)	36 (677g)	37 (696g)
		R3	60 a 540	17	18	19	21	20 (376g)	21 (395g)	22 (414g)	21 (470g)
		Total (1880g)						61 (1147g)	64 (1203g)	66 (1241g)	69 (1373g)
	MB	R1	0 a 5	91	101	110	128	10 (204g)	11 (226g)	12 (246g)	14 (286g)
		R2	5 a 60	91	97	103	107	33 (674g)	36 (716g)	37 (766g)	39 (797g)
		R3	60 a 540	21	20	20	19	23 (470g)	21 (429g)	21 (429g)	20 (408g)
		Total (2043g)						66 (1348g)	68 (1371g)	70 (1441g)	73 (1491g)

Sup: Camada superior/ Upper: Upper litter

Inter-sup: Camada intermedia superior/ Inter-upp: intermediate upper litter

Inter-inf: Camada intermedia inferior/ Inter-lower: intermediate lower litter

Inter-fas: Camada de la interfase/ Interface: interface litter

According to results obtained for water transportation, we observe that the greatest differences are caused by the type of substrate where mortars are placed. When the same mortar (A as well as B) is applied on the concrete block substrate, there is greater water transportation than when applied on a ceramic block substrate. The water transportation index shows that transportation speed in concrete block is quite intense for regimes 1 and 2: the litters close to the interface. This is due to the higher initial absorption rate developed by the concrete block compared to the ceramic block; because the concrete block has interconnected pores of bigger size and higher volume (see critical porosity on Figure 1). We observe that the amount of transported water is not directly related with total porosity and, consequently, it is not connected with the substrate total absorption rate; because water flow depends on the pores size and their interconnection, as bigger size pores increase capillary absorption tension, which facilitates water movement.

This differentiated behavior on identical mortars, in different substrates, under the same application conditions (2-3) has been studied by diverse research jobs (31-33). In this way, and although it was not the purpose of this research, it is worthwhile mentioning that the substrate surface treatment also involves properties differences on the mortar applied on the same type of substrate using different treatments.

When comparing mortars (A and B) behaviors, applied in the same substrates, there are differences on water transportation values for the case of concrete block. In this case, it is clear that mortar B, in all litters, shows greater water flow, which increases in direction from the surface litter towards the interface litter. As mortars dosage keeps the water/aggregate rate constant with similar amount of fine aggregates, the main difference lies in the grain size distribution of the sand employed. We observe on Table 3, that the sand employed for mortar B is thicker, therefore, authors consider that the factor conditioning the highest water flow in mortar B is the grain size distribution, which is determined by the sand fineness module in this case. Greater size grains facilitated water transportation; this behavior was not observed during water retention tests. It was also observed that mortar water retention was practically identical, thus leading us to the conclusion that having different absorption profiles for a given substrate reflects that water retention test – in the way it is performed – is not capable of identifying the actual behavior of water transportation on mortars subjected to suction.

The initial absorption rate is reduced in the ceramic block, while absorption takes longer, and it can be higher than in the concrete block. There are no significant differences on the water transportation values for mortars A and B; when they are applied on the ceramic block values are quite similar, which is produced by the decrease of initial absorption rate of the ceramic block in comparison to the concrete block.

3.3 Bonding resistance by perpendicular tensile stress

In the result obtained for bonding resistance there was an effective contribution made by water transportation (towards the substrate). Such result cannot only be explained by bonding or water transportation results or different factors involved in the system. It was proven that there is a direct relationship between these two factors, which are supported by other studies (Aldo et al., 2013; Peas, 2004; Pereira, 2007; Pereira and Bauer, 2013).

Figure 4 shows the results of bonding resistance by perpendicular tensile stress. In the four cases the prevailing cracking was cohesive (by mortar). The figure shows the average values and the interval corresponding to a probability of 95%.

Figura 4. Resistencia a la adherencia de los morteros
Figure 4. Mortars bonding resistance

We observe that in both mortar types (A and B) the bonding resistance was significantly higher when they were applied on the concrete substrate, in comparison to the ceramic substrate. It was proven that there is a direct relationship between this property and the total amount of water transported, being in all cases higher in the concrete block for the same type of mortar. By comparing mortars, it was also proven that in the case of concrete substrate, mortar B transported more water towards the substrate because the sand employed in the elaboration had a higher fineness module. Mortar B obtained higher values for bonding resistance, while the ceramic substrate did not show significant values. Above agrees with the proximity values of water transportation obtained in this case, where the maximum difference found in the total water transportation for mortar litters was 6%, which corresponds to the surface litter.

4. Conclusions

The main conclusions reached from results analysis on mortars properties, water transportation values and mortars bonding resistance in the two substrate types are the following:

- By recording humidity percentage using resistant sensors, placed in the rendering coating in fresh condition, it is possible to determine the amount of water transported by the mortar, in the very first hours after its application.
- The case under study showed a direct relationship between transported water in different litters and the mortar bonding resistance.
- The amount of transported water by the same mortar in different substrates depended on the size and volume of the substrate critical porosity; therefore, in all cases the highest values of transported water were obtained from rendering blocks.

- *The higher fineness module of sand employed with mortar B seems to be responsible for higher values of transported water and bonding resistance obtained by mortar B compared to mortar A in the concrete block.*
- *Results proved that there is no relationship between the mortar water retention test and the total amount of transported water in the mortar/block system.*

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6. Referencias/References

- Aldo Leonel Temp, A.L. et al. (2013)**, Avaliação de revestimentos de argamassas à permeabilidade e a aderência à tração, X Simpósio Brasileiro de Tecnologia das Argamassas, Fortaleza, Brasil.
- Alves A., Carasek H. y Cascudo O. (2010)**, Influência da umidade do revestimento na resistência superficial avaliada por diferentes métodos de ensaio, 3ro Congresso Portugues de Argamassas de Construção, Lisboa, Portugal.
- Brocken H.J.P. et al. (1998)**, Water extraction out of mortar during brick laying: A NMR study. *Matériaux et Constructions*, 31, 49–57.
- Carasek H. (1996)**, Aderência de argamassa à base de cimento Portland a substratos porosos – avaliação dos fatores intervenientes e contribuição ao estudo do mecanismo da ligação, São Paulo, Universidade de São Paulo.
- Costa E.B., John V.M. (2013)**, Efeito da absorção do substrato na aderência, X Simpósio Brasileiro de Tecnologia das Argamassas, Fortaleza, Brazil.
- De Souza C., Guimaraes R.P., de Carvalho M.C.R. (2012)**, Comportamento térmico de modelos em escala real construídos em alvenaria estrutural de bloco cerâmico e de concreto, 54 Congresso Brasileiro do Concreto, Maceio, Brasil.
- Forth J.P., Brooks J.J., Tapsir S.H. (2000)**, Cement & Concrete Composites, The effect of unit water absorption on long-term movements of masonry, 9465(00). <http://www.sciencedirect.com/science/article/pii/S0958946500000275>.
- Groot C.J.W.P. (1993)**, Effects of water on mortar – brick bond, Technische University Delft.
- Hall C. (1994)**, Water. Movement in Porous Building Materials XI, Capillary Absorption from a Hemispherical Cavity, 29(1), 99–104. <http://www.sciencedirect.com/science/article/pii/0360132394900582>.
- Hall C., Tse T.K.-M. (1986)**, Water movement in porous building materials—VII, The sorptivity of mortars, Building and Environment, 21(2), 113–118. <http://www.sciencedirect.com/science/article/pii/036013238690017X>
- Hendrickx R., Roels S., Van Balen K. (2010)**, Measuring the water capacity and transfer properties of fresh mortar, Cement and Concrete Research, 40(12), 1650–1655. <http://www.sciencedirect.com/science/article/pii/S000888461000178X>
- Honorio T., Carasek H. (2010)**, Influência da absorção de água do substrato na resistência superficial de revestimentos de argamassa, 3ro Congresso Portugues de Argamassas de Construção, Lisboa, Portugal.
- Junior A.N. de C., Gomes P.R. (2009)**, Caracterização microestrutural da interface argamassa mista / bloco cerâmico, VIII Simpósio Brasileiro de Tecnologia das Argamassas, Curitiba, Brasil.
- Martínez I. et al. (2013)**, A comparative analysis of the properties of recycled and natural aggregate in masonry mortars, Construction and Building Materials, 49, 384–392. <http://www.sciencedirect.com/science/article/pii/S0950061813007794>
- Miranda L.F.R., Selmo S.M.S. (2006)**, CDW recycled aggregate renderings: Part I – Analysis of the effect of materials finer than 75µm on mortar properties, Construction and Building Materials, 20(9), 615–624. <http://www.sciencedirect.com/science/article/pii/S0950061805001212>
- Paes I.N.L. (2004)**, Avaliação do transporte de água em revestimentos de argamassa nos momentos iniciais pós- aplicação, Universidade de Brasília.
- Pereira C.H.A.F. (2007)**, Contribuição ao estudo da fissuração, da retração e do mecanismo de descolamento do revestimento à base de argamassa, Brasília, Universidade de Brasília.
- Pereira C.H.A.F., Bauer E. (2013)**, Avaliação da perda de água de argamassas de revestimento por evaporação e por absorção do substrato, X Simpósio Brasileiro de Tecnologia das Argamassas, Fortaleza, Brasil.
- Rato V. (2006)**, Influência da microestrutura morfológica no comportamento de argamassas, Universidade de Nova Lisboa.
- Scartezini L.M.B. (2002)**, Influência do tipo e preparo do substrato na aderência dos revestimentos de argamassa: estudo da evolução ao longo do tempo, influência da cura e avaliação da perda de água da argamassa fresca, Universidad Federal de Goias.
- Silva F.G.S., Bauer E. (2009)**, Avaliação da fissuração em argamassas, VIII Simpósio Brasileiro de Tecnologia das Argamassas, Curitiba, Brasil.
- Silva N.G. et al. (2009)**, Metodologia para avaliação da fissuração em revestimento de argamassa, VIII Simpósio Brasileiro de Tecnologia das Argamassas. Curitiba, Brasil.
- Veiga M.R. (1998)**, Comportamento de argamassas de revestimento de paredes, Contribuição para o estudo da sua resistência a fendilhação, Universidad de Porto.