

Influence of Granulometry of the Small Aggregate on the Permeability of Wall Cement Coating

Kaylla Gomes Mesquita, Pedro Felix Liotto, Fabrício Rodrigues Amorim, Sara dos Santos Santarém, David Barbosa de Alencar

Academic Department of the FAMETRO University Center, Brazil

Abstract— The performance of the vertical sealing elements is determined by the level of protection to which they are subjected. Construction processes are changing and cementitious coatings are increasingly taking place among current construction options. On the other hand, the weather has its increasingly aggressive and more evident incidence. The performance standard sets the guidelines for seal manufacturers to meet expected quality standards. Given the above comes the importance of evaluating the best particle size composition to obtain the ideal mortar manufacture. Water transport mechanisms are the actors in this permeability process with the effective participation of diffusion and capillarity. The present study proposes observations about the water absorption of cementitious coatings manufactured with three sand granulometry (fine aggregate). The mixture containing the fine sand obtained the lowest absorption while the mixture with the highest grain size presented the highest absorption and the highest flow rates.

Keywords— Particle size, permeability and performance.

I. INTRODUCTION

Masonry, like all building systems, plays the important role of building protection. The external environment is endowed with weather such as solar radiation, wind, rain and noise that generate various pathologies in the building affecting its integrity, therefore its durability. Therefore, the function of masonry, mentioned above, is to provide sufficient isolation of buildings with the external environment, to ensure the comfort and safety of its users.

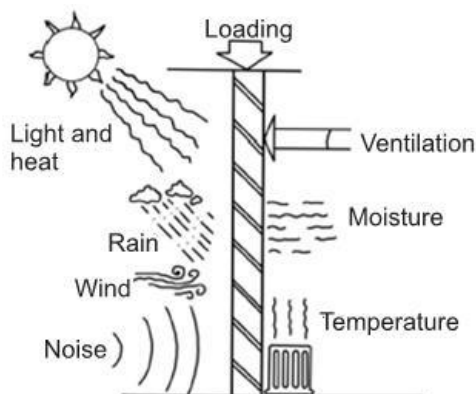


Fig.1: Protective behavior of masonry

Source: Polisseni

One of the biggest problems with buildings is the pathological manifestations caused by moisture. The

humidification of masonry can be manifested from rising ground source, rainwater absorption and penetration, condensation, due to hygroscopicity of materials and accidental. Among these sources, the most frequent sources are soil ascension and rainwater absorption and penetration (1).

Masonry is a building system with subsystems. The structure of the masonry is composed by the ceramic block materials and the mortar that has the function of bonding and gluing the blocks. Over this subsystem is installed the slat subsystem which has the function of creating a porous surface to serve as a bond to the plaster. The function of the plaster is to realize the protection of the entire system as well as confer aesthetics.

Plaster is an element made of mortar. Mortars are cementitious compounds made from binder (cement), fine aggregate (sand), water and additions. Because it is heterogeneous material its characterization is difficult and its structure is complex. Each of its materials has specific characteristics and properties that combine to give the product different properties (2).

One of these properties we can cite is permeability. The present term is used to characterize the conductivity of a porous medium with respect to penetration by a Newtonian fluid, considering that this flux has laminar characteristic (3). For such observation the permeability is

essentially dependent on the fluid properties and the permeation mechanism.

With the permeability evaluation it is possible to obtain some indicators such as: porosity, particle packing, pore moisture, mechanical resistance, cracking and others. The porosity of the coating is intrinsically related to its composition, its execution procedure and the curing process. Responsible for openings that allow water to penetrate, it directly interferes with the durability of the coating.

The porosity of mortars and consequently their performance is affected by the characteristics of the components used. The type of binder, the mineralogical nature and the grain size of the sands and any additions are some of these characteristics that should be observed in mortars.

The performance standard has the necessary prerequisites to guarantee the durability of the elements of a building. Not unlike this, the durability of masonry is evaluated on its aspects. Among such aspects, this standard recommends the sealing of the sealing elements, giving the coatings the ability to be more or less leakproof (4).

Understanding that porosity is influenced by, among other factors, the fine particle size (sand) particle size, the present work intends to analyze the influence of the fine size particle size that constitute the masonry mortar.

Among the various methods used by researchers, the burette method was chosen to be used. This method consists of the use of a hermetically sealed wall box with sufficient insulation and a graduated glass bar at the top. The function performed in the system is to ensure uniform pressure, showing fluid displacement. Such a methodology is suggested by the performance standard in Annex C of Part 4.

In order to achieve the objective thus set, considering the chosen methodology, the specific objectives were listed. The first objective was to model the different types of coatings for the analysis. For these coatings will be considered three particle sizes: thin, medium and coarse. The coatings were applied on an external masonry that is influenced by the weather.

The second was to build the burette box suggested by the details of NBR 15575/2008. This objective has a high degree of importance and determinant for the results, as it is not a material that was acquired ready, requiring to be made.

The third is to perform the simulations and record the data provided by the burette. The simulations were performed at time intervals: 1h, 2h, 3h, 4h, 5h, 6h, 7h and 8h.

The fourth objective was to analyze the data obtained with comparisons between the different types of coatings. In order to determine the real effect was applied variance analysis where it is possible to evaluate by the effect and residual graph the influence.

II. BIBLIOGRAPHIC REFERENCE

2.1 Performance Standard

Performance standard NBR 15.554-4 of 2013 (4) seeks to foster concerns with the expected life, performance, efficiency, sustainability and maintenance of housing buildings. In summary we can say that it is the quality factor of the building delivered to the user that is in question.

This standard presents user requirements that must be met to promote safety, livability and sustainability. In safety the standard exhibits structural safety, fire safety and safety in use and operation. For habitability are presented items of weathertightness, thermal performance, acoustic performance, lighting performance, health, hygiene and air quality, functionality and accessibility, tactile and anthropodynamic comfort. In terms of sustainability, the keys to be observed are durability, maintainability and environmental impact.

For the Standard, in VUP (design lifetime) definitions, three key concepts are worked on: defects in system or element performance failure; ease of maintenance and repair in the event of performance failure; the cost of correcting the failure, including the cost of correcting other affected subsystems.

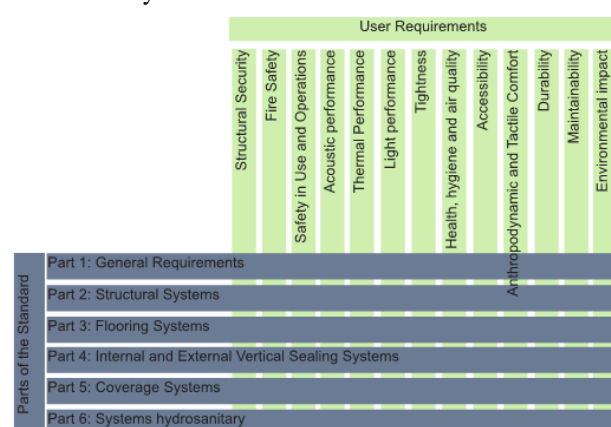


Fig.2: Standard Matrix.

Source: Own Author

Interior and exterior vertical fence systems (SVVIE) are defined by the standard as parts of the housing building that vertically limit the building and its environments, such as facades, walls or internal partitions. Therefore, for vertical seals the prerequisites and guidelines are presented

in Part 4: SVVIE Internal and External Vertical Sealing Systems.

The standard sets out in part 4, item 10, the requirements for water infiltration into sealing systems. As a main recommendation the standard makes it clear that fences must be watertight from rain or other sources. The standard goes on to explain that the seals should not have infiltrations on their inner surfaces that provide sprinkling or dripping or formation of adherent water droplets, and classifies the test conditions according to the regions of Brazil.

2.2 Moisture in buildings

The action of water is responsible for many damages found in buildings, often presenting itself as the main driver of some deterioration mechanisms. Sometimes only moisture causes damage, but in other cases it is combined with potentializing factors (5) (6).

The presence of water in buildings, for Solomon (7), is from the beginning of its construction work until the moisture generated by rainwater that penetrates through the building elements, through the absorption moisture and capillarity of the water present in the soil. Two other classifications punctuated by the author are condensation humidity caused by water vapors and accidental humidity generated by leaks.

The pathological events are the result of rainwater actions combined with the characteristics of the materials used in vertical fence systems. Observing the materials on a microscopic scale, one can see defects exploited by the waters. These pathologies that sealing systems present due to the presence of water shorten the service life and thus the minimum required performance.

The waters are pushed through the façade openings by forces resulting from the kinetic energy of raindrops, capillary rising forces, gravitational forces, and wind pressure forces (5). Rain is explained by the author as the most common agent to cause moisture because its main factors include direction, wind speed and intensity of precipitation.

Winds are also presented by Rodrigues (8) as the main agent of rainwater penetration in buildings. And it states that without the winds the rains would happen vertically, wetting the facades little. After taking an approach on the types of precipitation, Rodrigues explains that the wind puts pressure on the facades and generates water films on the surface of materials.

Bauer (9), describes that raindrops are deflected by variable air currents, i.e. winds, in order to change the downward trajectory and being inclined arrive at the vertical face of the buildings. The factor that determines

whether the drops are more or less deflected is their size, the author explains.

For Solomon (7), cementitious materials have small voids called pores. For Hattge (10), it is necessary for materials to have accessible pores for water molecules to penetrate, or cracks in the surface.

Solomon (7) explains that the interconnected pores form an internal network allowing water to pass through. Also, according to the author, they are hygroscopic and attract air humidity meaning moisture content. Thus, in addition to the pores the moisture content depends on the relative humidity of the ambient air. This relative air humidity, the author explains, is the ratio between air pressure and air saturation vapor pressure at the same temperature.

2.3 External forces and water transport mechanisms

The external forces are directly linked with the transport mechanisms since they are naturally the generators of large amount of moisture. The external forces acting on the façades are mostly and most significant from nature, that is, with or without the help of man will be present subjecting the cementitious coatings to various water transport characteristics.

The external forces to which the façades of buildings are exposed. The action of the wind that casts rainwater on the façades of buildings and the gravity that acts on surface water runoff are pointed by the author as external force agents (1). The author also argues that, when finding a crack or crack in the façade, water penetrates. Thus, to allow water to penetrate a building, the author presents three basic conditions: water on the surface; openings such as cracks and cracks; forces that push water through these openings. He goes on to comment that there are four forces pushing water: forces resulting from the kinetic energy of raindrops; capillary aspiration forces; forces of gravity; and wind pressure forces.

Studying the mechanisms of water transport in masonry, Monticelo (5) verifies water vapor diffusion, convection and capillarity. All observed mechanisms have two important actors: microscopic interstices in the material, i.e., failures in the microstructure of the material and the pressure caused by external forces.

Whereas for Sentone (11), water transport can occur by three phenomena: diffusion, capillarity and permeability. These phenomena, according to the author are determined by the porous structure of the materials and their driving forces.

2.4 Diffusion

Diffusion is the pursuit of equalizing the difference of two concentrations between two components. The

diffusion of water vapor is presented with a classic example, since it has happened between two gas mixtures: dry air and water vapor. When they come in contact there will be the transport of molecules that will happen until the concentration differences disappear (8).

The concept of diffusion in materials. Setting the definition, the author infers that there is a natural tendency for molecules to migrate from regions of higher concentration to smaller ones in order for equilibrium to occur. And it remembers that for the destination to succeed successfully it must be empty and in the migrating atoms there must be enough energy to break the bonds with the neighbors and generate the dragging movement (11).

And, it continues to define the factors influencing diffusion, as the phenomenon occurs in greater intensity for some materials than others. Temperature is pointed by him as the major influence on the process because it is able to provide activation energy for the process to be started (11).

Hygroscopicity is commented on as the property is related, by the author, to diffusion. He explains that hygroscopic humidity is a consequence of the diffusion of moisture in the air that passes into the material through the pores. However, the author distinguishes that humidity occurring in a short period of time, such as that occasionally found in bathrooms, has little influence on the humidity of the material. The author also recommends that, in order not to have problems with mold or mold in the materials, one should limit the relative humidity inside the buildings or be careful not to remain high for long periods (1).

2.5 Convection

Convection is characterized by the passage of water vapor molecules through the fluid carried by the relative movement of the particles of that fluid itself. When it comes to masonry, the author explains that it is a phenomenon that occurs mainly in hollow walls and that if the inner faces enclosing the air layer are at different temperatures, convection currents will arise that will carry water vapor to the surface. colder (8).

2.6 Capillarity

Rodrigues (8) explains that capillary absorption acts to suck water from the surface to the interior. After complete saturation the only way to continue transporting the liquid into the material is by differential force such as gravity and wind pressure. According to the author, the volume of suction water depends on the absorption force and pore size, so thin capillary pores suction little water with a high absorption force.

Whereas, the force exerted on the pores of the hydrophilic material is strong, i.e. the material is easily

wetted. The opposite of this is when the material has a weak water adhesion force, so it is more difficult for water to penetrate. This capillary absorption force, is commented by the author, as a result of the combined action between the surface tension of water and the adhesion force of water molecules on the pore walls. Finally, the author simplifies in his text saying that this adhesion force between water molecules and pore cavities are simple molecular attractions that normally the walls of materials exert (9).

2.7 Porous structure of mortars

The definition of porous structure, important for our study. For the author, a porous material is defined as one that contains interstitial spaces not filled by solid matter (pores), distributed in the solid or semi-solid matrix, or is defined as being permeable to the flow of various fluids, adopting the definition of porous material. permeable (3).

The author goes further by explaining that the porous structure of a mortar can be classified according to chemical, mineralogical and morphological aspects. And that such characteristics are dependent on the manufacturing process and the kneading process, the materials, the trace, the amount of water and the type of cure performed. Besides these commented points, for the author two other factors play particular relevance: the support and the application process, thus two mortars produced equally, will give rise to distinct hardened materials in function of these two variables.

In the work of Rato (3), a division of properties is still presented that separate the water movement conditions inside the mortars. For the author the properties are divided into macroscopic and microscopic. The macroscopic properties are porosity, the specific surface area, related to the intrinsic property of the material, and the permeability and diffusivity, related to the transport properties, already discussed in this paper. The microscopic properties are the porometry that relates to the pore grouping, and the porous network geometry that relates to the shape of the pores and the way they interconnect.

For the development of this work, it is important to be well defined that the property to be observed will be macroscopic, because it is related to porosity and is simple to measure, since the microscopic properties are more difficult to observe, need appropriate equipment. difficult to acquire.

III. MATERIALS AND METHODS

3.1 Materials

3.1.1 Cement

The cement used in the formulations of mortar cloths was Portland, named CP IV-32, manufactured by the company MIZU, widely traded in Manaus / AM. The cement was fractionated and stored in small quantities in a dry environment, besides being used within the expiration date.

3.1.2 Aggregate

The aggregate used in the production of mortars is mineral in nature and sold in Manaus / AM. The sand used as fine aggregate was taken from the natural dry land deposit acquired at the Arco Íris deposit.

As characterization of this material, the grain size test was performed to verify the distribution of the sand grain size, unit mass and specific mass. All tests will follow the procedures recommended by NBR NM 248/2003 (12); NBR NM 45/2007 (13); and NBR 9776/1987 (14), respectively.

For the preparation of mortars, the granulometric separation of the fine aggregate was performed in three strips by simple sieving. The fine particle size range of 4.8 mm to 0.05 mm shall be broken down into coarse sand (4.8 to 1.2 mm), medium sand (1.2 to 0.3 mm) and fine sand (0.3 to 0.05). The classification and decomposition of fine particle size was performed according to NBR 248/2003 (12)

3.1.3 Production of cementitious coatings

Mortar production followed the procedures described in NBR 7200: 1998 (15). Mortars with 1: 3 mass traits were produced for the plaster and 1: 5 for the plaster, considering the same a / c factor of 0.40.

The materials were mixed in an inclined shaft mixer with a capacity of 150 liters of mortar. So that there was no need to control the humidity of the small aggregates, they were put in the oven and dried for later weighing.

After the mortar manufacturing process, the masonry ceramic block coatings were placed in the external area, weathered and covered with roughcast. The fabric made of coverings has 105 x 135 cm and thickness for plaster 15 mm and plaster 20 mm.

3.1.4 Testing Equipment

The permeability test consists of subjecting a certain section of the wall to the presence of water under constant pressure, with the aid of a coupled camera.

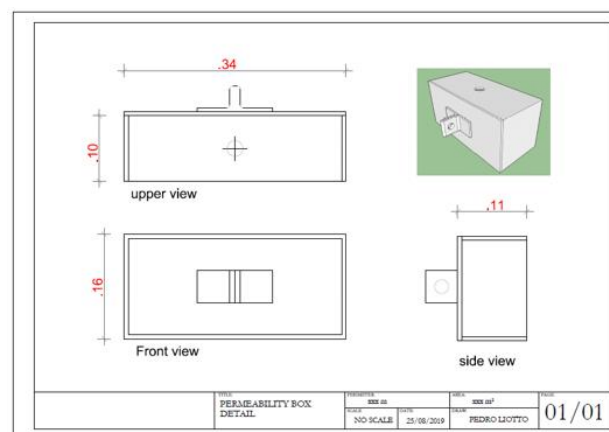


Fig.3 - Detail of the glass box for the test.

Source: Author

Annex C of Part IV of the Performance Standard sets out apparatus. The standard determines which flat dimensions, for example 34 x 16 cm, but because it is a box does not make clear the depth dimension. Therefore, it was adopted 11 cm with 8 mm glass plates. The material used for sealing between glass and the glass / mortar contact surface is silicone glue.

In the upper part of the box was made a hole of 11 mm in diameter that aims to fit and fix the graduated beaker. The box detail can be seen in the following figure.

3.1.5 Performance of the test

After the coatings were performed, the equipment was fixed to the face of the coating with the aid of silicone glue and pedestal. The curing time of the silicone glue was respected so that the box was perfectly sealed to the wall.

Then water was added to the system and introduced by the graduated pipette. The volume of water was determined by the volume of the box plus the pipette-formed water column to the 5 ml mark.

Pipette water column measurements, as stated above, were performed every hour from the first hour of the test: 1h, 2h, 3h, 4h, 5h, 6h, 7h and 8h. The assay was repeated three times, thus obtaining 24 results from each coating cloth. In order to prevent each trial from interfering with the one performed previously, an interval between each three-day repetition was determined.

IV. RESULTS AND DISCUSSION

4.1 Characteristics of materials

The following figure shows the particle size distribution curve of the sand fractions. It is possible to observe that the sand well graded and without discontinuities has the largest portion of the grains between 0.2 to 1 mm.

Table 01 sets the values of specific mass and unit mass. It can be verified that the acquired sand is within the

acceptable normative limits. These data show the degree of importance of the study, because from the data are traced the traces and the determining factor for the manufacture of mortars is the paste content.

Table.1 - Test of specific and unit mass of minute aggregate.

Feature. (kg/dm ³)	Test Method	Fine aggregate (natural sand)
Specific Mass	NBR 9776	2,60
Unitary Mass	NBR 7251	2,49

Source: Author

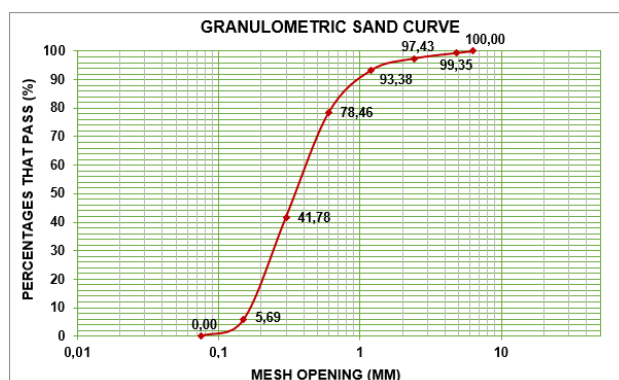


Fig.4 – Granulometric Sand Curve.

Source: Author

4.2 Absorption

The average results of the absorption measurements are expressed in Figure 04. This shows the variation of the absorption in the different mortar productions. The measurements made on mortars made of fine sand are represented in the blue curve and triangular markers. The orange curve with square markers represents the average curve of mortars made from medium sand. Point markers represent the means of absorption that the coarse sand mortar obtained in the test.

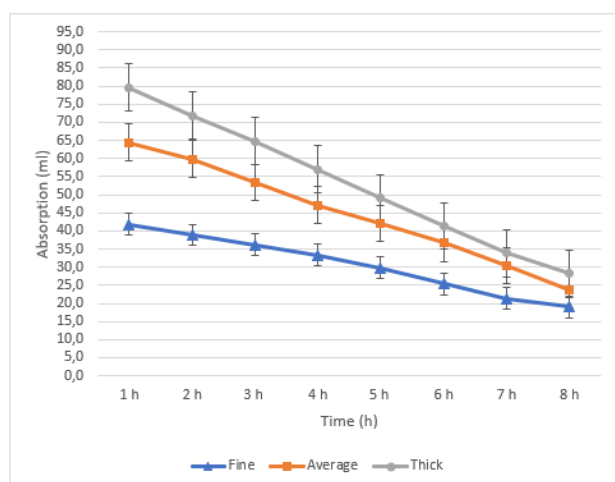


Fig.5 - Mean absorption measurements

Source: Author

The first observation to be made from figure 05 is the absorption of mortars with fine sand. These obtained lower absorption rates, thus being indicated with the best absorption results and therefore better masonry protection against water permeations. It is also possible to infer that the absorption rate is being reduced over the hours, this effect occurs because the coatings over time become saturated. Slight variations between absorption rates are notable. It can be observed that between the hours 5 and 6 was registered the largest variation displacement in the water column, being of the order of 4.5 ml / h. Explained by the transport mechanisms, because imagining the pores as conduits for transport, it is observed that as they are infiltrated, other pores are reached giving different flow rates. Mortars made with medium sand during 8 hours absorbed 22.83 ml.

By analyzing the average absorption curve of the mortars manufactured with medium sand, as shown in figure 05, we can observe, in general, that the absorption was higher than in the fine sand curve. The medium sand mortars had total absorption during the 8 hours of 40.83 ml. Also, the absorption rate is decreasing over the hours and it is possible to notice small variations in the absorption differences, being remarkable that there is no constancy in the absorption. An important factor to note is the amount of total flow absorbed. The average sand mortar curve has a higher flow than the fine sand mortar. This is due to the fact that it has a larger porosity allowing greater water flow through the transport mechanisms.

Figure 05 also shows the curve of mortars made of coarse sand presents characteristics similar to the other curves. However, it is possible to notice by observing the differences between the hours that there is a smaller variation than the others. This can be explained by the difficulty that water has to saturate the pores left in these mortars. Parallel to this the observed flow is the largest of all types of mortars. The highest peak flow recorded was on the order of 8 ml / h and occurred between the 4th and 5th hour.

Figure 06 shows the Pareto Global Average graph. The tendency that the isolated averages already represent is the tendency to decrease the absorption over time. It can also be seen from the graph that the 50% portion of water absorption happens on average at 3 o'clock, i.e. just before half the time.

Figure 07 shows the curves of mortar averages and also the global average. It can then be observed that the global average is very close to the curve of mortars manufactured with medium sand.

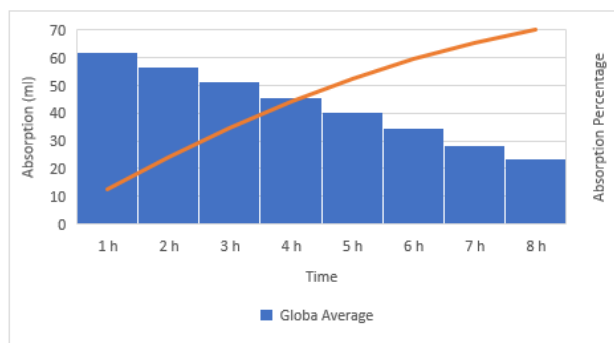


Fig.6 - Global Average Pareto Chart

Source: Author

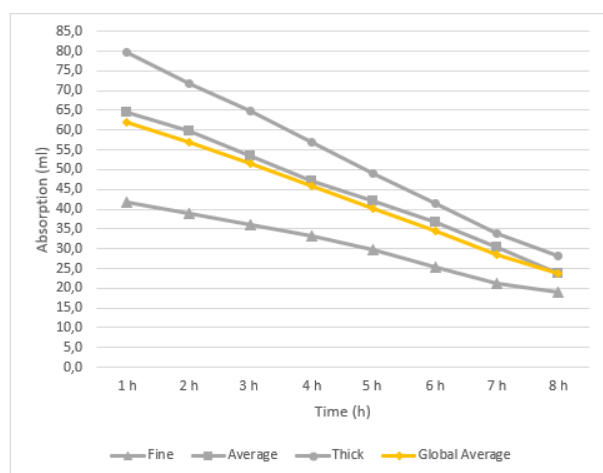


Fig.7 - Global mean absorption

Source: Author

V. CONCLUSION

The tests were carried out with maximum control and the results found clearly convey the effect that fine particle size exerts on mortar production and in particular on porosity. It is clear that the coarser sand produces more pores than fine sand and that these pores more continuously allow larger water flows through the mortars.

The different flow rates observed in mortars are directly related to the transport mechanisms, with highlights for diffusion and capillarity. Diffusion can be pointed as a determinant for more constant flow in coarse sand mortars. The capillarity generally present in all is more evident in the fine sand mortar.

The present work contributes to the clarification of the importance that mortars have in the protection of the vertical protection systems of buildings. However, further work is needed to continue the study.

The mortar porosity test is a very important test that must be developed to be added to the knowledge acquired with the present.

ACKNOWLEDGEMENTS

We thank FAMETRO for their support in allowing us to use the building materials and construction laboratories, especially Professors Sara Santarém and Fabrício Rodrigues.

REFERENCES

- [1] POLISSENI AE. Método para avaliar a capacidade impermeabilizante de revestimentos de parede: método do cachimbo. 1986;
- [2] Bauer LAF. Materiais de Construção I. 5a edição. LTC, editor. Rio de Janeiro; 2008. 488 p.
- [3] RATO VNDPM. INFLUÊNCIA DA MICROESTRUTURA MORFOLÓGICA NO COMPORTAMENTO DE ARGAMASSAS. UNIVERSIDADE NOVA DE LISBOA; 2006.
- [4] ABNT. ABNT NBR 15575-4/2013 Edificações habitacionais — Desempenho Parte 4: Sistemas de vedações verticais internas e externas - SVVIE. 2013;
- [5] MONTECIELO J, ELDER MAR. Patologias ocasionadas pela umidade nas edificações. 2016.
- [6] LERSEH IM. CONTRIBUIÇÃO PARA A IDENTIFICAÇÃO DOS PRINCIPAIS FATORES E MECANISMOS DE DEGRADAÇÃO EM EDIFICAÇÕES DO PATRIMÔNIO CULTURAL DE PORTO ALEGRE. 2003.
- [7] Salomão MC de F. Estudo da umidade ascendente em painéis de alvenaria de blocos cerâmicos. 2012;193.
- [8] Rodrigues AH. ESTANQUEIDADE DE ALVENARIA REVESTIDA COM DIFERENTES ARGAMASSAS E ACABAMENTOS: APLICAÇÃO DA NBR 15575-4 / 2008 ESTANQUEIDADE DE ALVENARIA REVESTIDA COM DIFERENTES ARGAMASSAS E ACABAMENTOS: APLICAÇÃO DA NBR 15575-4 / 2008. 2010;
- [9] Bauer E. RESISTÊNCIA A PENETRAÇÃO DA CHUVA EM FACHADAS DE ALVENARIA DE MATERIAIS CERÂMICOS - UMA ANÁLISE DE DESEMPENHO. UNIVERSIDADE FEDERAL DO RIO GRANDE DO SUL; 1988.
- [10] Hattge AF. ESTUDO COMPARATIVO SOBRE A PERMEABILIDADE ALVENARIAS EM BLOCOS DE CONCRETO. 2004;
- [11] Sentone DT. Desenvolvimento de método para medida de permeabilidade superficial de revestimentos de argamassa. 2011;
- [12] ABNT. ABNT NBR NM 248:2003 - Agregados - Determinação da composição granulométrica [Internet]. 2003. Available from: www.abnt.org.br
- [13] ABNT. ABNT NBR NM 45 - Agregados - Determinação da massa unitária e do volume de vazios. 2007.
- [14] ABNT. NBR 9776:1987 Agregados - Determinação da massa específica de agregados miúdos por meio do frasco Chapman. Rio Janeiro ABNT. 1987;5-7.
- [15] ABNT. NBR 7200:1998 - Execução de revestimento de paredes e tetos de argamassas inorgânicas - Procedimento. Abnt. 1998;13.