FLOW IN POROUS ELEMENTS: A THEORETICAL AND EXPERIMENTAL ANALYSIS OF THE EFFECTS OF THE CAPILLARY EFFORTS CAUSED BY WATER PERCOLATION IN MASONRY POROUS ELEMENTS

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ABSTRACT

The identification of cracks in masonry bricks is quite common, not only after the edification but also during the process. Moistness absorbed by the elements of the wall (bricks and mortar) is one those factors. This moistness comes from the air, rain, soil absorption and even the excess of water in the laying mortar. In contact with the wall porous elements, the moistness will contribute to the capillary percolation, giving berth to considerable internal efforts which will induce the presence of cracks. This study leads to an analysis for the obtainment of fluid pressure and velocity medium values, measuring the deformation of the elements. The paper brings the equating to predict and estimate the velocities and efforts medium values in the ceramics elements. The flow in porous elements is studied and a proposal of modeling to estimate Velocities and Efforts values is presented.

Keywords: Porous means, water percolation, higroscopy, masonry ceramics elements.

NOMENCLATURE

A	section, area, mm2
Av	area of emptiness, mm2
d, Dp	medium diameter of the particle, mm
e	width of the fissure, mm
F_{Re}	coefficient of correction of the Reynolds
h, h_h	length, cm
i	load loss for unit of length, atm/cm
J	relationship isometric
K	coefficient of permeability, mm/s
L, l	length, mm
P, P_0,	pressure, kgf/mm2
Q, q	out flow, ml/s or cm3/s
Re, Re'	Number of Reynolds
t	time, s
Ts	superficial tension, mg/mm2
U_0	speed initial mm/s
Vmed	speed medium mm/s
V	speed no dimensional
Vc, υ	speed critical mm/s
W_{med}	dimensional medium speed, cm/s
x, y, z,u, v, w	ortogonal components
x1, y1 z1	no dimensional components

Greek symbols

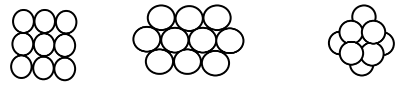
α	angle, degrees
μ	dynamic viscosity, kg/mm.s
ρ	specific mass
ψ	esfericidade
σ	tension of deformation, kgf/mm2
Δ L	deformation mm
γ_a	dilation coefficient, °C^{-1}

Subscripts

$\perp$	perpendicular
$\|\|$	parallel
T	traversal
L	longitudinal
H	horizon

INTRODUCTION

Porous means are synthetic or natural materials with a set of pores, through which a significant volume of fluid can travel across. Sand, some rocky structures, some ceramics and the human liver are examples of these means. When traveling across a porous mean, the fluid utilizes the empty spaces between the particles. The sizes of the empty spaces, or pores, followed by the flowing fluids depend on variable factors such as particle size, sphericity and rugosity of its surface. It is quite difficult to determine the fluid linear velocity through the spaces. However, it can be expressed in function of the superficial linear velocity of the distance traveled like the one of a fluid through a non-blocked up total transversal section, as if the body comprised several infinitely small and parallel thick sections. This difficulty is due to the fact that the great majority of the porous means is formed by particle random arrangements. Figure 1 represents graphically possible and theoretical arrangements when taken in consideration the spherical shape and uniform size particles.



(a) (b) (c)

a) cubic arrangement – free channel
b) orthorhombic arrangement – open channel
c) orthorhombic arrangement – blocked channel

Figure 1. Physical arrangements of particles considered to be spherical

It will be considered in this paper the free channel cubic arrangement (Fig. 1a), for the clay particle sphericity factor and size is very small (<0,005 mm mean diameter), Therefore, the porosity values, when considered as empty spaces in porous mean straight section are about the double as it will be shown in the theoretical modeling for estimation in Section 2.

When the particle spherical shape is taken in account for the study of the porosity of the mean, it is necessary to have in mind its sphericity. This could be utilized as an approach for determination of the porosity if the particles were the same size. But this does not exactly happen. In order to determine the existing empty spaces in a porous body section (for instance, the transversal one), the volumetric porosity coefficient is used, which is the relation between the existing empty volumes in the porous mean total volume and this total volume. The porosity coefficient, or simply Porosity, depends on the mean granulometric composition and on the particles arrangement; if the particles are spherical, for instance, the porosity will be respectively 0,476 in a cubic shape arrangement, 0,3954 in a orthorhombic shape, 0,3019 in a tetragonal shape and 0,2595 in a rhombohedric shape (Brown, 1963).

The Permeability Coefficient (K) expresses the mean percolation capacity, which is determined by measuring the flow, volume of water that crosses the porous mean and dividing it by the mean transversal section. This coefficient is also function of the loss of charge, of the porous mean layer thickness and of the mean temperature. For Darcy, it can be determined by the expression:

$$K = \frac{Q}{A} \cdot \frac{e}{\Delta_P} \quad \text{ou} \quad Q = KiA \qquad (1)(2)$$

being i=Δ h / L (loss of cargo per unit of length), where Q is the outflow, A is the transversal section, and is the mean thickness and Δ_p the charge loss. Allen Hazen suggests another formula that conditions the mean and the temperature. In this formula, the mean granulometry is represented by the diameter of the particles that correspond to a specific percentage of the whole. This dimension is represented by the diameter of the particles which are bigger than the ones that make up 10% of the weight of the material. The formula of Hazen is:

$$K = cd_{10}^2\left(0{,}7 + 0{,}03t\right) \text{ [m/dia]} \qquad (3)$$

where the coefficient that depends on the mean, varying from 700 to 1000 for the clean and uniform sand, 400 for the dirty sand (granulometry) in mm and t is the temperature in ºC. Table 1 shows permeability values for some porous means (Neves, 1982).

TYPES OF WATER PRESENT IN THE POROUS MEANS.

The flowing of water through a permeable system, porous mean, is named Percolation or Infiltration. The dispersion of the moistness in the porous mean occurs in the three phases: solid, liquid and gaseous. These phases can be found at the same time. The liquid phase is the most common one. The moistness may reach the materials in a natural way when they are submitted to conditions such as rain, snow, environment air moistness and by capillarity when submerse. It can also be moisten in the industrial or manufacturing processing. The masonry components (bricks, ceramics elements, mortar, etc.) undergo a moistening process while being placed. The amount of water absorbed by a material depends basically on two factors: porosity and capillarity.

The waters in the porous bodies may be classified as Free water, Capillary water, Adhesive water, Hygroscopic water and Constitution water. Among these, hygroscopic, free and capillary water are the ones that can be evaporated by heat, when submitted to temperatures above 100º C. In the gaseous phase, they also fulfill the pores, water steams and combined carbons.

Table 1. Mean Diameter and Permeability Coefficient for some materials.

Porous mean	Particle Mean diameter (mm)	Permeability Coefficient K (mm/s)
Clay	<0,005	<0,01
Very fine sand	0,05~0,1	0,01
Fine	0,1~0,25	0,02~0,07
Medium	0,25~0,50	0,3~0,45
thick	0,50~1,0	0,7~1,2
gravel	1~2	5~10

FLOW IN POROUS MEANS

The fluid flow in different porous means may be studied by the Law of Darcy in its classical form, which concerns the mean fluid velocity and a direct function of pressure gradient. The flowing conditions in porous means are dependent on the nature of the particle, forms and on the dimensions of the elements that constitute the mean. It is possible to know these natural parameters through comparison with the capillary tubes flow. And, having the porous different dimensions in function of the size of the particles, Muskat proposes, for a safe analogy from his experiences, that the laminar regime and that the critical water velocity correspond to the value 1 of the Reynold's number, that is,

$$\mathrm{Re}=\frac{Vc\cdot d}{\upsilon}=1 \quad \text{e} \quad \mathrm{Re'}=\frac{DpF_{\mathrm{Re}}V\rho}{\upsilon} \qquad (4)\,(5)$$

where d is the value for the particle mean diameter, v is the water kinematics coefficient and Vc the critical velocity. For a given 20º C temperature, υ = 0,01 cm^2/s, the critical velocity is Vc = 0,01/d. For porous means with 1mm particular mean diameter (thick sand), the critical velocity is about 0,1 mm/s. It is possible to reach velocities of 0,3 to 0,4 mm/s (2,5 a 3,8 m/day) without leaving the laminar regime (Neves, 1982).

The Reynolds' number, based on the particle mean diameter and dependent on factors such as: particles sphericity, rugosity and orientation or arrangement, may be estimated by the expression (5) where Dp is the particle mean diameter, V is the velocity estimated as if the flow were not porous, ρ the fluid specific mass, υ stands for the fluid kinematics viscosity and F_{Re} is a coefficient that takes in account the particle sphericity and the mean porosity (Streter, 1961). According to Dupuit (1865), v = kJ, where k is a coefficient dependent on the resistance offered by the mean and J = dh/ds is the piezometric in any given point "s" of the trajectory. In accordance with Darcy, the infiltration velocity, which is the mean velocity of the water in the mean is given by v = Q/A, where "Q" is the outflow and "A" is the porous mean total section. The mean empties section is Av = ψA where ψ corresponds to total section percentage rate. Hence,

$$Q=v\times A = k\,J \times \psi\,A \qquad (6)$$

Naming u, v, and w the velocity orthogonal components in the three Cartesian axes and putting them in the continuity equation it will be found that:

$$u=-k\frac{dh}{dx},\quad v=-k\frac{dh}{dy},\quad w=-k\frac{dh}{dz} \quad \text{e}$$

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}=\frac{\partial^2 h}{\partial x^2}+\frac{\partial^2 h}{\partial y^2}+\frac{\partial^2 h}{\partial z^2}=0 \qquad (7)$$

which shows that the movement is no rotational, once there is already a velocity potential represented by the piezometric height and the iso-piezometric surfaces are outflow lines. The determination of the existing blanks in the porous mean total transversal section provides the volumetric porosity coefficient. Experimentally, the porosity coefficient may vary from 25% to 55% from the thick to the thinner materials, with a 40% average for the uniform sand and 30% for the more compact ones (Neves, 1982). The mean Permeability Coefficient is the rate between the water outflow that crosses a transversal section toward the outflow, that is, K = Q/Ai. Table 1 shows the relation between the medium diameter of some materials and the respective Permeability Coefficient. The estimation of the porosity is not sufficient as the granulometric variation and the physical arrangement can there be found. It is known that when considering a mean straight section two velocities can be visualized, one perpendicular to the section and another one parallel to it, which could be defined as perpendicular permeability (K⊥) and parallel permeability (K‖) to the outflow direction (Freire, 1982). So, a medium velocity is always considered. Table 2 shows water critical medium Porosity and Velocity values, 20ºC temperature, through uniform granulometry materials.

Table 2. Critical Medium Velocities (mm/s) in porous materials with uniform granulometry

Porosity %	Particle mean diameter (mm)							
	0,1	0,2	0,5	1,0	2,0	4,0	10,0	20,0
25	490,0	231,0	92,5	46,2	23,1	11,6	4,6	2,5
30	358,0	179,0	71,6	36,0	18,4	9,2	3,5	1,8
35	286,0	143,0	51,4	28,6	14,5	7,1	2,8	1,4
40	231,0	115,4	46,2	23,1	11,6	5,7	2,5	1,1

(Garcez, 1970)

MECHANISM OF WATER PERCOLATION AND ITS EFFECTS

Cracks in edifications, especially in the masonry ones are observed, and they are phenomena prejudicial to the walls, roofs and framing structural and esthetic aspects, resulting from the moistness that flows through the porous materials that constitute them. The structural factor is relevant when the risk to which the structure is submitted is taken in account, where cracks cause the dislocation of efforts and reactions, besides the economical factor. This paper sought, through laboratory workbench simulations, demonstrate the effects from water percolation in porous elements and measure the efforts that cause the undesirable cracks in the masonry structures. The moistness may access the materials, causing an increase in the moistness, generating expansion and or dimensional contraction. This access may be natural, through environment moistness absorption (rain, flood, air humidity) and induced by the time the necessary mortar process takes places. The water flow through capillarity is pointed out in this work for by this flow the dimensioning of the efforts that it causes in porous materials, as consequence of the Capillary Force generated, was sought. The water rises within the “d” diameter capillary tube up to such an h_c height that the Fc capillary force vertical component be equal to the weight of the suspended column of water.

$$F_c \cdot \cos\alpha = \Pi d \cdot T_s \cdot \cos\alpha = \frac{\Pi d^2}{4} h_c \gamma_a \Rightarrow$$

$$h_c = \frac{4T_s}{d\gamma_a}\cos\alpha \qquad (8)$$

T_S = water superficial tension ≅ 0,076 g/cm = 8 mg/mm (Building R. Establishmente, 1979) or, for practical purposes, considering water T_S and γ_a it can be found:

$$h_h \max. = \frac{0{,}306}{d} \text{ (d em cm)} \qquad (9)$$

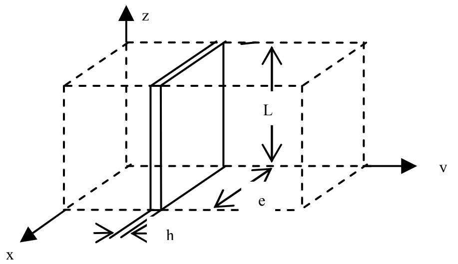
Thus, $h_c$max. In clay bodies (ordinary brick walls) with solid particles showing diameter inferior to 0,005 mm may reach a height of 30 cm or above. This is a condition sufficient for the generation of capillary efforts that cause cracks from the water that percolates, due to the soil moistness. The deformations herein mentioned do not take in account the thermal deformations which are also responsible for movements in the material whose linear thermal dilation coefficient is (4 – 12) x 10^{-6} for the natural rocks, (7 – 14) x 10^{-6} ºC^{-1} for the composed based on cement and of (5 – 14) x 10^{-6} ºC^{-1} for the bricks and blocks (Tomaz, 1989).

THEORETICAL MODELING FOR CALCULATION – PROPOSAL

For the determination of the composition, volume occupied by empties and volume of solid particles of a porous mean, it will be disregard the irregular form of the clay particle, considering it spherical, and consequently understood the physical arrangement of the distribution among them as free passage cubic. This can be stated because for particles with medium diameter < 0,005 mm, like the clay situation, the empty spaces can be considered capillary ones. Thus, the particles will be arranged as in Figure 1. Between the theoretical configurations, cubic and orthorhombic, there is a relation of approximately twice the empty spaces for the first one. If this is linked to the random particles bulk, it can be verified the large diversity of the expected results.

FORMULATION FOR VELOCITY AND OUTFLOW CALCULATIONS.

According to Houpert (1975), Streter (1961) and Pferffemann (1968), a formulation can be made to estimate porous mean outflow values, considering a very thin crack along an axis, according to what is demonstrated in Figure 3 which follows:



Obs: The profile will be considered independent from γ (smaller thickness). Contour conditions: For Z = 0 ⇒ P = P_0 where P_0 = pressure on xy plan P_2 = pressure on top of figure Z = L ⇒ P = P_2 ($P_2 < P_0$)

Figure 2. Diagram of an element which may represent a pore

.

Considering the equation of Navier-Stokes in its general form, and performing a quantity order analysis in the terms, an equation can be obtained that responds, in a satisfactory way, to the outflow values in a crack with the characteristics shown in Figure 2.

$$\rho\frac{D\vec{V}}{Dt} + \rho\vec{V}\left(\nabla\vec{V}\right) = \rho\vec{g} - \nabla P + \mu\nabla^2\vec{V} \qquad (10)$$

By performing the considerations of analysis of the terms it is possible to come to the equations with the purpose of solution:

$$\frac{\partial P}{\partial z} = \upsilon\frac{\partial^2 V}{\partial x^2} \;;\; \frac{\partial P}{\partial z} = A \;;\; \upsilon\frac{\partial^2 V}{\partial x^2} = A \;;$$

$$P = P_0 - \frac{P_1 - P_2}{L} z \;;\; V = \frac{1}{\upsilon} A \frac{x^2}{2} + Bx + C \qquad (11)$$

Therefore,

$$V = \frac{1}{2\upsilon}\frac{P_0 - P_2}{L}\left(\frac{e^2}{4} - x^2\right) \qquad (12)$$

(also called Equation of Navier-Poisson) that deals with the velocity profile varying in x in the crack. Estimating now the outflow that crosses the crack along z:

$$q = \int V dA \Rightarrow q = 2\int_0^{\frac{e}{2}} bVdx \Rightarrow q = be\frac{e^2}{12}\cdot\frac{1}{\upsilon}\cdot\frac{(P_1 - P_2)}{L} \qquad (13)$$

By considering a circular crack, the same formulation involving the radius can be obtained. But the most important situation resides in the case where the body (porous element) has "n" cracks, that is, the flow through the body will be: Q = nq. Q, then, will be directly proportional to the A passage area, to the pressure gradient $(P_1 - P_2)/L$ and inversely proportional to the fluid υ viscosity. But the body with n cracks is nothing more than the porous element with "K" permeability. By adapting the υ kinematics viscosity to the μ dynamic viscosity, the formula that considers the porosity global effect is:

$$Q = \frac{KA}{\mu}\frac{dP}{dz} \qquad (14)$$

where: Q = outflow; K = permeability; A = area transversal to the flow; μ = kinematics viscosity and dP/dz = pressure gradient that pushes the flow.

However, it becomes important to prepare a model where the porosity effect can be considered from the beginning, that is, in the starting differential equation (Francis, 1980), (Whifaker, 1982). To do this, it is necessary to consider the following equation, taking in account the same axis of Figure (4).

$$\frac{\mu W}{\rho K} = -\frac{1}{\rho}\frac{\partial P}{\partial z} \rightarrow W = -\frac{K}{\mu}\frac{\partial P}{\partial z}$$

$$WA = -\frac{KA}{\mu}\frac{\partial P}{\partial z} \quad \rightarrow \quad Q = -\frac{KA}{\mu}\frac{\partial P}{\partial z} \qquad (15)$$

Writing the equation of Navier-Stokes with the term of Darcy, $\frac{\mu W}{\rho K}$, the following result is obtained, according to Carroci (14), Zanardi (15) and Aquino (16):

$$\frac{\partial W}{\partial t} + u\frac{\partial W}{\partial x} + v\frac{\partial W}{\partial y} + w\frac{\partial W}{\partial z} = -\frac{1}{\rho}\frac{\partial P}{\partial z} + \upsilon\left[\frac{\partial^2 W}{\partial x^2} + \frac{\partial^2 W}{\partial y^2} + \frac{\partial^2 W}{\partial z^2}\right] - \frac{\mu W}{\rho K} \qquad (16)$$

Considerations: permanent flow: $\frac{\partial}{\partial t} = 0$, one-dimensional flow: u = v = 0, uncompressed flow: ρ = cte., completely developed flow: $\frac{\partial W}{\partial z} = \frac{\partial W}{\partial y} = 0$ (very small). Therefore: $\upsilon\frac{\partial^2 W}{\partial x^2} - \frac{\mu W}{\rho K} = \frac{1}{\rho}\frac{\partial P}{\partial z}$ (17)

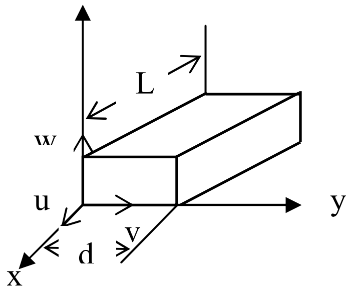


Figure 4. Porous element (brick)

Considering the contour conditions in $x=0 \Rightarrow W = U_0 = Q/A_v$ and $P = P_0$ $x=L \Rightarrow W = U_0 = Q/A_v$, admitting the adimensional variables below, according to Schilichting, Equation (15),

$$V = \frac{W}{U_0} \qquad x_1 = \frac{x}{L} \qquad z_1 = \frac{z}{L}$$

$$P_1 = \frac{P}{\rho U_0^2} \qquad (18)$$

where U_0 is the velocity of reference in z=0. Hence, the equation (18) becomes:

$$\upsilon\frac{\partial^2 W}{\partial x^2} - \frac{\mu W}{\rho K} = \frac{\partial P}{\partial z} \quad \text{(multiplying by } \rho\text{)} \rightarrow$$

$$\upsilon\rho\frac{\partial^2 W}{\partial x^2} - \frac{\mu W}{K} = \frac{\partial P}{\partial z}\rho \qquad (19)$$

and substituting in (18) it is found:

$\mu\frac{\partial^2 W}{\partial x^2} - \frac{\mu W}{K} = \frac{\partial P}{\partial z}$ that multiplied by L^2, divided by μ, rearranged and added to Uo comes to:

$$\frac{\partial^2 V}{\partial x_1^2} - \frac{L^2}{K}V = \frac{\rho U_0 L}{\mu}\frac{\partial P_1}{\partial z_1} \qquad (20)$$

Equation (20) shows the profile of the Variation of Velocity in an no dimensioalized field and some parameters important to the porous mean flow, as for instance:

$a^2 = \frac{L^2}{K} =$ porosity parameter and

$b = \frac{\rho U_0 L}{\mu}\frac{\partial P_1}{\partial z_1} =$ pressure parameter.

No dimensionalized contour conditions: for $x_1 = 0 \Rightarrow V = 1$ and for $x_1 = 1 \Rightarrow V = 1$.
Thus, equation (21) may be written as it follows:

$$\frac{\partial^2 V}{\partial x_1^2} - a^2 V = b$$ for which the analytic solution is:

$$V = A_1 e^{ax_1} + A_2 e^{-ax_1} - \frac{b}{a^2} \tag{21}$$

It must be made a reiterated calculation, that is, to correct the pressure field, factor b and next to recalculate V, until V_{medium} value be close to 1. Then:

$$A_1 = \frac{\left[1 + \frac{b}{a^2}\right]}{\left[1 + \frac{\left(1 - e^{aL}\right)}{\left(e^{-aL} - 1\right)}\right]};$$

$$A_2 = \left[\frac{1 + \frac{b}{a^2}}{1 + \frac{\left(1 - e^{aL}\right)}{\left(e^{-aL} - 1\right)}}\right] \cdot \left[\frac{\left(1 - e^{aL}\right)}{\left(e^{-aL} - 1\right)}\right] \tag{22}$$

EXPERIMENTAL AND THEORETICAL RESULTS

A) Experimental Results

Deformations in experimental bodies (bricks, brick walls and mortar blocks) were performed in the longitudinal, transversal and horizontal dimensions, when submitted to the moistness by water dripping, under slow and continuous way. In the calculations and roundness accuracy in centesimo was considered. In order to determine the deformations, a testing bench was built, to allow the confinement of the experimental body in three of its sides. Thus, all deformation to which the body was submitted was measured in the three faces opposite to the fixed ones by three comparison clocks Mitutoyo MD.2046 – 10 mm – 0,01, mounted in magnetic foundations, with the feeler gauges perpendicular to the non-confined faces. For the moistness of the experimental body, a glass graduated burette was utilized, with water dripping regulated for all the absorption to happen by capillarity. The results of the experiments are presented in the tables as it follows:

Table 3. Determination of Dry and Moist Weights, Empties Volumes and Deformations

Column	(1)	(2)	(3) = (2) - (1)	(4) Deformation (mm)		
Test Boby	Dry weight (g)	Wet weight (g)	Empties volumes (ml)	Trans-versal ΔL_T	Longi-tudinal ΔL_L	Hori-zontal ΔL_H
1	1391,4	1702,6	311,2	0,040	0,020	0,010
2	1279,1	1595,4	316,3	0,030	0,010	0,010
3	1342,6	1625,3	282,7	0,035	0,020	0,020
Average (*)	1337,7	1641,1	303,4	0,035	0,016	0,013
7(block)	1289,8	1490,6	200,8	0,050	0,030	0,010

*The mean values were estimated by taking in account only c.p. nº 1, 2 and 3.

Table 4. Dry and Moist Weights, Empties Volumes and Wall Deformations

Column Test body	(1)	(2)	(3)= (2)-(1)	Deformação (mm)		
	Dry weight (g)	Wet weight (g)	Empties volumes (ml)	Trans-versall ΔL_T	Longi-tudinal ΔL_L	Hori-zontal ΔL_H
10	16 580	19410	2 830	0,180	0,025	0,050

Table 5. Determination of Solid Volume and Empties of The Walls

Column	(1)	(2)	(3)	(4) = (2)-(1)
Test body	Dry weight (g)	Wet weight (g)	Sólid vol (ml)	Empties volume (ml)
4	1321,6	1621,2	924,9	299,6
5	1301,7	1607,9	933,7	306,2
6	1341,0	1636,6	916,1	295,6
Average values	1321,4	1621,9	924,9	300,5

Table 6. Determination of the Percolation Outflow and Initial Velocity.

Column	1	2	3	4	5	6
Test body	Perco-lation surface (mm^2)	Empties area 21,4% (mm^2)	Absor bed water volume (ml)	Time of absortion (s)	outflow (3) ÷ (4) (ml/s)	Initial velocity (5) ÷ (2) (mm/s)
Brick 3	20 000	4 280	100	542	0,1845	4,30 $x10^{-5}$
Brick 9	20 000	4 280	100	590	0,1695	3,96 $x10^{-5}$
Mortar block 7	14 000	2 996	100	2 812	0,0452	1,50 $x10^{-5}$
brick 8 With mortar	20 000	4 280	250 (*)	4 477	0,0056	1,30 $x10^{-5}$

*Larger volume of water to allowbrick/mortar pair measurement.
**Medium velocity in Brick 3 and Brick 9 is $4{,}14x10^{-5}$ (mm/s)

Table 7. Determination of the Percolation Outflow and Medium Velocity.

Column	1	2	3	4	5	6
Test body	Wet weight Dry weight (g)	Absorbed volume (ml)	Empties area (mm^2)	Time of absortion (s)	outflow (2) ÷ (4) (ml/s)	Médium velocity (5) ÷ (3) (mm/s)
Mortar block 7	1289,8 1490,6	200,8	2 996	4 860	0,0413	1,378 $x10^{-5}$
Brick 8 with mortar	1815,6 2270,0	454,4	4 280	24 180	0,0188	0,446 $x10^{-5}$
Brick 99	1312,4 1640,3	327,9	4 280	30 660	0,0107	0,250 $x10^{-5}$

B) Theoretical Results

Determination of the Pressure and Velocity Gradients through Equation (22). With the V velocity profile, it can be then obtained the medium velocity (V_{med}) and finally estimate Q outflow.

$$V_{med.} = \frac{1}{A}\int_0^1 \left(A_1 e^{ax_1} + A_2 e^{-ax_1} - \frac{b}{a_2} \right) dA =$$

$$\frac{1}{d \cdot L}\int_0^1 \left(A_1 e^{ax_1} + A_2 e^{-ax_1} - \frac{b}{a^2} \right) d \cdot dx_1 \qquad (23)$$

$$\Rightarrow \; V_{med.} = A_1 e^{a} + A_2 e^{-a} - \frac{b}{a^2}$$ With x1varying from 0~1 Adimensional medium velocity (24)

W_{med} = Dimensional medium velocity = $(V_{med.}) \cdot U_0$ (25)

$Q = W_{med} \cdot A_T$, (26)

Where, A_T is the area transversal to the flow

$V = 0{,}35e^{ax}$

$$V = 0{,}35e^{ax_1} + 0{,}65e^{-ax_1} - 0 = 0{,}35e^{a} + 0{,}65e^{-a} - 0 =$$

$$= 7{,}46 + 0{,}03 \Rightarrow V_{med.} = 7{,}49 \qquad (27)$$

then , $W_{med.} = (V_{med.})(V_0) = (7{,}49)(4{,}14 \times 10^{-5})$

$$\Rightarrow W_{med.} = 31{,}0 \times 10^{-6} \text{ cm/s} \qquad (28)$$

$$\text{Pressure Gradients} \Rightarrow \frac{dP}{dz} = 0{,}0006\, atm/cm \qquad (29)$$

Factors: $a = 3{,}06$; $b = 5{,}72 \times 10^{-12}$; $A_1 = 0{,}35$ $A_2 = 0{,}65$ (30)

CONCLUSIONS

This paper sought to determine the efforts of the velocity and the pressures in the porous means from porous means fluid flow. Experimentally, values of efforts in clay bricks, from 80 to 3600 kgf, function f the percolation were obtained. Such efforts caused differentiated deformations in the directions length, width and height of the test body. The deformations measured varied from 0,013 to 0,035 mm for the brick, from 0,010 to 0,050 mm for the mortar and from 0,050 to 0,180 for the wall. Besides the confirmation of the results by specialized literatures, it was also searched a mathematic model founded in the equations of conservation of the fluids mechanics that could physically express the phenomenon. Such procedure demonstrated a visualization of the behavior of the fluid velocity profile in the mean as being the one of a non-plane front, traveling at an order of 3 to 4μm/s (2,5 to 3,8 m/day) in a direction propitious to the free flow, as well as internal pressures that cause very high losses of cargo in the flow. In the mathematic calculations it was verified a phase difference between the medium velocity calculated and the measurement (around 7,5 times) that was analyzed and assigned to the measurement instruments utilized, not so sophisticated as needed. However, the values measured and calculated are shown as an accepted bulk order, in function of the simplicity of the instruments utilized in the assays.

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