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Surface pathology on the walls of limestone and mortar masonry

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Abstract
The principles of this work are the study of masonry materials with a view to the conservation and rehabilitation of buildings. It is important to preserve and care for the historical heritage. Development and associated innovation require knowledge of the physical and mechanical characteristics of materials.
Situational causes of pathologies found in stone masonry can be identified by the photographs presented, showing a horizontal cracking due to physical natural actions, temperature variations and the presence of water.
The main causes of pathological changes are air pollution, but the water and the temperature also play a very important role in the development of the deterioration. The test results are essential to obtain the quality and durability of the materials of the limestone and mortar to prevent damage the water in the environment with the incorporation of paint with good quality.

Author Keywords. Durability Masonry Materials Stones, Mortar Quality and Pathology.

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1. Introduction

History shows by its natural evidence the evolution of caves, sidewalks, the consequent construction of buildings, palaces, cathedrals, bridges and viaducts, many of which are still visible today and with structural performance considered satisfactory. There were no engineering schools or interactive dissemination processes for innovations and new construction techniques that were developing, adapting and emerging (Gueviea, et al., 2007).

In Portugal, public awareness of the need to protect architectural and urban heritage has only recently begun to emerge. The combination of the disinterest of society and the government with the economic conditions of the people who remained in the historic centers led to a situation of profound degradation of several old buildings. In this context, the International Council for Monuments and Sites (ICOMOS) had already written the international charter for the safeguarding of historic cities in October 1987, seeking to promote policies for the preservation of historic centers and blocks, threatened by degradation and even destruction due to the urbanization type that emerged in the industrial era, thus intending to counter irreversible losses of a cultural, social and even economic nature (Lourenço et al., 2005).

To define the first objectives of this work, it was necessary to evaluate the data from the laboratory tests on the materials, usually in the construction of masonry that are available. Much of this information served as a basis for the identification and definition of the realization and use of the type of masonry materials to be studied, their quality and durability.

The second objective of the treatments that avoided alteration of the anomalies in the walls are the painting and the water repellent. To prevent the pathology may occur, it thus implies strategies through knowing first it rigorously and then choosing preventive intervention strategies. Strategies are sometimes contradictory to prevent walls from cracking due to thermal phenomena.

The quality, durability and low cost of the stone are the main reasons for being the most used construction material. Because the stone is widely used, we must consider the deterioration in quality and durability. With the entry into force of the euro codes for the design of buildings, the development of new materials for construction and the implementation of new solutions seems to be unquestionable. Solutions in simple and confined masonry, and even armed, will be options to consider for construction in Portugal (Eduardo et al., 2008).

The text that follows starts with a general approach, which concerns all types of walls and later focuses on the masonry of stone, which represents a very significant part of the construction of masonry walls of the house.

Even in small buildings, its application with a structural function has been forgotten the importance and the evidence that was given to them in previous times (Eduardo et al., 2008).

In cases where the coating cracks without the substrate having cracked, the causes are temperature expansion i.e., hot and cold. They are usually linked to the type of coating and application conditions but can also result from chemical or mechanical incompatibility with the substrate.

Pathology and rehabilitation of masonry walls in the case of walls, it is understood, for now, as non-structural pathology that corresponds to walls on which the stability of other construction elements does not directly depend. The origin of the problems of construction and rehabilitation of buildings in non-structural masonry is shown in (**Figure 1**)

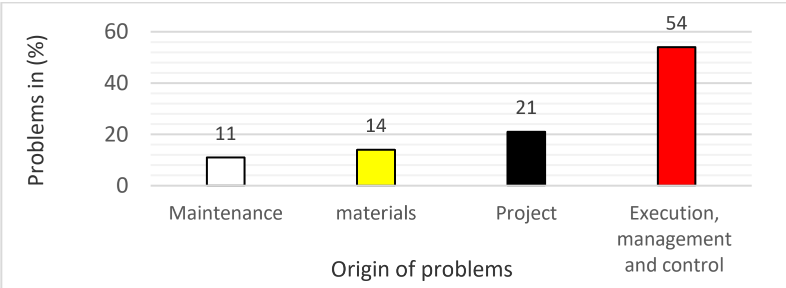

Figure 1. Synthesis of the occurrences of pathologies

Mortar is an artificial stone formed by mixing binder, sand and water, with or without the addition of adjuvants or additions, which develops its properties by hydrating or air-hardening a binder paste. Within this large group we have the mortars for coating and the mortars for assembly. The standard EN 998-1 (EN, 2003) presents the specifications of masonry lining mortars. On the other hand, the standard EN 998-2 (EN, 2003) presents the specifications of the mortars for assembly.

Masonry construction process with the entry into force of the euro codes for the design of buildings, the development of new materials for construction and the implementation of new solutions seems to be unquestionable.

The stone is a natural product obtained by underground exploration or in open quarry and converted into masonry units through a production process. Depending on the characteristics of the rocks and the conditions that governed their genesis, three major types can be distinguished: magmatic, sedimentary, and metamorphic rocks (Pereira, 2005).

The text that follows starts with a general approach, which concerns all types of walls and later focuses on the masonry of stone, which represents a very significant part of the construction of masonry walls.

The stones used in the construction are porphyry granites, basalt, limestone, sandstone, shale and marble. These materials have great application in civil construction. Masonry and stonework are agglomerated with stones on top of each other (**Figure 2**) (Eduardo et al., 2008).

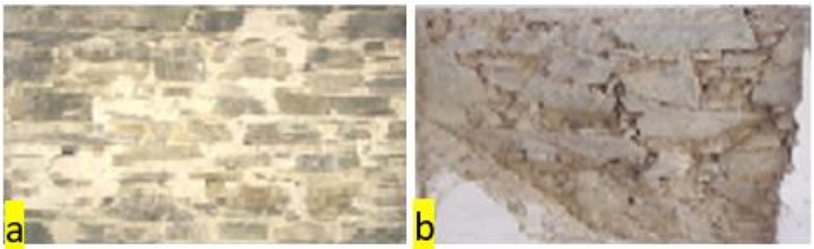

Figure 2. Masonry stone types of construction: a) lime joint walls and b) small stone walls in the clay joint

Pathology in masonry walls, the main causes of alteration of the stones are the action of chemical agents from the atmosphere (carbon dioxide and sulfur dioxide) chemical agents from the materials themselves and from the soil, physical agents (water, temperature, wind and living organisms).

Treatments to prevent the alteration of stones are painting, and water repellent. The rocks formed in each environment remain stable and reflect the characteristics of that environment. Anomalies can occur in different ways, depending on the part affected, the functions that are affected, as well as the nature of the materials and construction techniques used, causes and periods of occurrence (Eduardo et al., 2008).

Observation makes it possible to verify the extent of the theme with matters relating to the pathology of masonry walls, which would imply the analysis and discussion of vast areas of knowledge in several domains of the construction sciences: building materials, building physics, building technology and resistance of materials.

The cracking of the coverings may or may not be associated with the cracking of the substrate (masonry itself). In cases in which the coating cracks without the substrate has cracked, the causes are generally linked to the type of coating and the application conditions, but they can also result from chemical or mechanical incompatibility with the substrate (Araujo et al., 2008).

However, over the last few decades, this concept has lost real meaning, with the growing diversity of construction and material solutions and the characterization of the workforce. Thus, preventing pathology now implies, in many cases, knowing it rigorously and choosing preventive intervention strategies. The strategies - sometimes contradictory to prevent cracking of walls due to phenomena of thermal origin.

2. Materials and Methods

2.1. Materials

In addition to Portland cement (CEM I), EN 197-1 (BS-EN, 2011) has other cements that can be used in civil construction.

As shown in Fig. 3a shows some cements manufactured in Portugal. It is widely used in general for buildings that do not have specific requirements, such as houses, tall buildings, bridges, roads and highways.

The fine aggregates (**Figure 3**b) were duly used as natural sands for laying mixtures. Aggregates can be called fine (larger particle size less than or equal to 4 mm) or coarse (larger particle size greater than or equal to 4 mm and smaller particle size greater than or equal to 2 mm).

An important factor is the origin of the water used. According to IPQ (2003) in their number of the NP EN 1008, they have governed the application of liquid in concrete and made considerations regarding the origin of the selected water (**Figure 3**c).

The stones used in the construction are porphyry granites, basalt, limestone, sandstone, shale and marble. These materials have great application in civil construction (**Figure 3**d).

Figure 3. Materials use in the construction:
a) cements, b) sand, c) water and d) stones

2.2. Methodology

The specimens indicated in (**Table 1**) were substituted previously prepared for carrying out various tests, this preparation includes cutting some specimens, grinding, and smoothing the faces with a mortar like the strength of these materials. It was therefore necessary to proceed with the mechanical analysis of this mortar. After the final preparation of all specimens, they were submitted to evaluation tests: i) mechanical requirements of cement, granulometric analysis, mechanical strength of limestones and mortars (compression, bending), ii) water absorption by capillarity and immersion, absorption of sodium sulfate capillarity and immersion of limestone test iii) both performed with sodium sulfate.

Materials	Types of the test	Specimens	Dimensions (mm) Length. x Width. x Height.		
Limestone moca cream	Capillarity Absorption	A	150	150	57
		B	100	100	57
	Compressive Strength	A	57	57	57
Mortars specimens	Compressive Strength	A	50	50	50
	Water absorption and compressive strength	A	100	100	100
		B	40	40	160

Table 1. Replaced samples for testing

In the case of limestone, it was necessary to cut to suit the specimens to the equipment, in this case they were dimensions with representative portions, (for example, cubes) (**Table 1**), obtained by cutting in different positions, as established in EN 771-5 (EN, 2003) and normal dimension for mortars (**Table 1**).

Place of obtaining research samples, that is, wall (limestone mocha crème and mortar of accents and plasters) was obtained through the photographs and visual analysis on the stone walls. The most dominant materials visualization process done on built wall stones.

Laboratory test of the moca crème limestone was conducted at the Laboratory of Civil Engineering Department, University of Minho, Campus Azurêm, Guimarães, Portugal since earliest of September until end of December 2009.

All tests by limestone moca crème and mortar, were performed based on the EN standard procedure.

The cement testing method based on EN 197-1 (BS-EN, 2011) includes mechanical, physical and durability requirements.

The granulometric analysis of the sand was carried out according to the standard EN 933-1 (EN, 2002).

The determination of the physical and mechanical properties of the aggregates, are specified according to the standard EN 1097 -6 (EN, 2000).

The determination of the compressive strengths of moca cream limestone for masonry was carried out in accordance with EN 772-1 (EN, 2002), which aims to specify a method for determining the compressive strength of natural stone.

The method of testing the flexural strength of the hardened mortar for masonry was carried out according to EN 1015-11 (EN, 1999).

The test pieces were dried to constant mass in a ventilated oven at a temperature of 70° C ± 5 ° C for the limestone moca crème and mortars. The constant mass was reached when the loss of mass between the two determinations did not exceed 0.1% of the total mass. This during the drying process in two consecutive weighing with a 24-hour interval. The test procedure consisted of allowing the test pieces to cool to room temperature, measuring the dimensions of the faces to be immersed according to the principles presented in EN772-16 (EN, 2002) and calculating their gross area.

The determination of water absorption by immersion was carried out in accordance with standard EN 1097-6 (EN, 2000).

The sodium sulphate alteration test for moca creme limestone masonry materials was carried out according to EN 1378 (EN, 1976) with adaptations. For this test a saturated solution of sodium sulfates was used. This solution was the mixture of sodium sulfate (NaSO4) with drinking water, for its realization a mechanical mixer was used to help dissolve the sodium sulfate, this mixture was made at a temperature of 20° C. The concentrations of the mixtures were 190 g / l (specific norm: 350 g / l or 750 g / l of water at 20° C), this was kept in water at a temperature of 25 ° C-30 ° C and stirred regularly, until the saturation revealed by the permanence of undissolved crystals is reached.

The volume of the sulfate solution used was equal to 5x the volume of the immersed specimens, they were covered with saturated solution at least 25 mm. The container was always covered to prevent evaporation of the solution and the entry of impurities.

During the test, the density remained between 1.15 and 1.17 at a temperature of 21° C ± 1° C.

During the test, the temperature was maintained at about 19 to 22 ° C to prevent crystallization of sodium sulfate. After preparing the solution, the specimens were placed in the tank with saturated solution, this for 24 hours (the standard provides for 16 to 18 hours), to accelerate the degradation. After this time, the specimens were removed from the tank, allowed to drain for 20 to 25 minutes and placed in the oven at 105 ± 5 ° C for all specimens.

The use of saturated solutions for resistance to sodium sulfate was carried out by adapting a Portuguese standard EN-1378 (EN, 1976) and EN 772 – 11 (EN, 2002) applicable to mortars and absorption of water by capillarity.

3. Experimental works in the laboratory and discussion result

3.1. Mechanical and physical results of cements EN 197-1

Regarding the mechanical requirements, three reference resistance classes are provided: class 32.5, class 42.5, and class 52.5 (**Table 2**). The reference strength of a cement is the compressive strength at 28 days according to EN 196-1 (EN, 2006). The mechanical requirements expressed as specified characteristic values for 28 days between 42,5 to 62,5 MPa.

3.2. Particle size analysis of sand

The results of the granulometric analysis shown in (**Figure 4**) and the result is normal or standard.

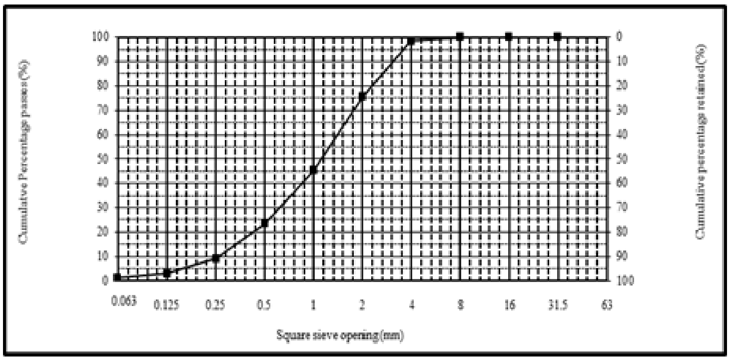

Figure 4. Granulometric analysis of the sand

3.3. Determination of the characteristics of limestones

3.3.1. Determination of compressive strength of limestone

The compressive strengths to obtain results with a significant sample, the minimum number of test pieces must be (6) six as indicated in the standard, (**Table 2**).

Limestone moca creme						
Reference	1	2	3	4	5	6
Specimen mass (g)	456.3	447.1	442.9	450.7	448.2	446.4
Type of rupture	Normal	Normal	Normal	Normal	Normal	Normal
Breaking load (N)	194900	187900	174900	169600	188900	184300
Breaking stress (MPa)	60.0	57.8	53.8	52.2	58.1	56.7
Average (MPa)	56.5					
NB: Test date 24-03-2010, and storage condition is moist, The dimensions are 57x57x57 mm Straight section is 3249						

Table 2. Result of compressive strength of limestone moca crème

3.3.2. Determination of water absorption by limestone capillarity

The objective and the field of work specify the method of determining the water absorption coefficient by capillarity for masonry stone. After obtaining the constant mass, the capillarity rate was tested as shown in the (**Table 3**).

Reference	1	2	3	⍰⍰ts0)	(ms0s-mdry,s)/As Average (A,B,C)	Cw,S
Constant mass (g)	3117.8	3175.2	3153.3			
Immersion time (min) - ts0	Weight after immersion time (g)					
1	3119.3	3186.5	3166.6	7.8	490.4	55.9
3	3127.4	3194.4	3172.9	13.4	820.7	
5	3135.0	3206.5	3179.9	17.3	1216.3	
10	3143.2	3209.2	3187.6	24.5	1491.9	
15	3152.8	3218.8	3197.3	30.0	1920.0	
30	3170.7	3235.7	3214.7	42.4	2693.3	
60	3186.3	3250.5	3229.3	60.0	3360.0	

180	3198.5	3262.7	3241.3	103.9	3899.3	-
480	3237.0	3301.5	3278.2	169.7	5591.1	-
1440	3239.2	3305.0	3280.7	293.9	5712.6	-
2880	3240.2	3306.1	3281.7	415.7	5758.5	-
4320	3240.4	3306.2	3281.7	509.1	5763.0	-

Table 3. Result of water absorption by capillary action of the stones 150x150x57mm

For the knowledge of some phenomena existing in the absorption, a probe was used to monitor the temperature, and the relative humidity of the test specimens inside the box. As can be seen in (**Figure 5**), the probe presented the following results: the temperature in the range of 17ºC to 23ºC; the relative humidity with a range of 90 to 95%.

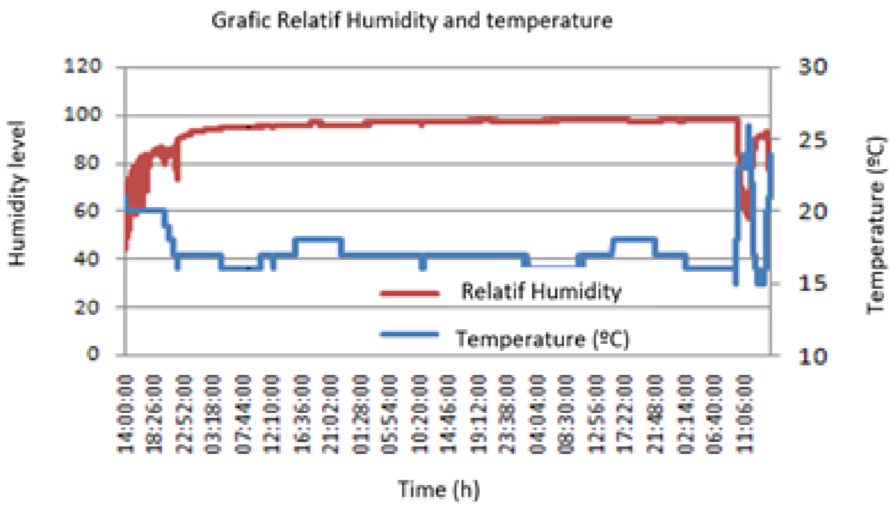

Figure 5. Graph of humidity and temperature of water absorption by capillarity

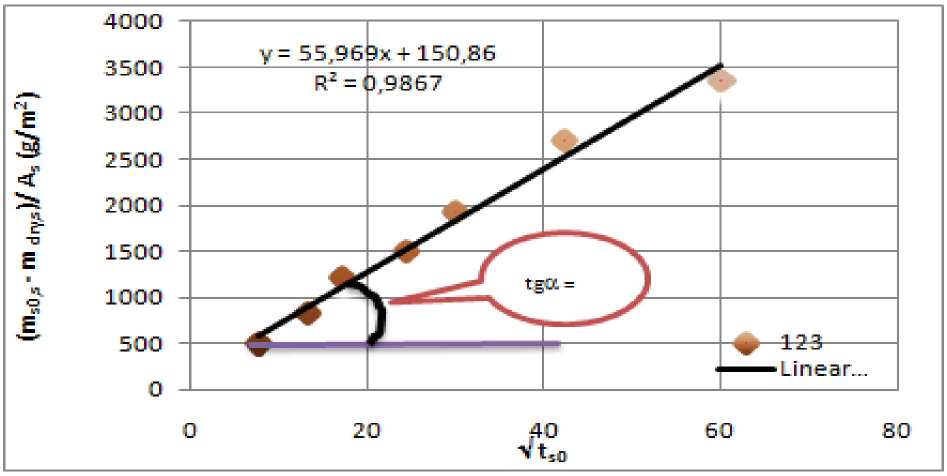

Figure 6. Result of water absorption by capillarity of moca cream limestone 150x150x57 mm with determination of the gradient of the linear part.

3.3.3. Determination of water absorption by immersion

The objective is to establish a process to determine the absorption of the stone specimen by immersion in normal or drinking water.

Result of water absorption by immersion is (A), calculated in percentage using equation 1 in (**Table 4**).

$$A = ((m1 - m3) / (m1 - m2))\ x\ 100 \quad \textbf{(1)}$$

Where:

m1 constant mass of the saturated specimen

m2 hydrostatic mass specimens in the water after saturation

m3 constant dry mass (the difference between the masses obtained in two consecutive weighing's at least 24 hours apart).

No of speci-men	Type of materials (mm)	Constant mass (g)	Mass in water (g)	Dry mass (g)	A (%)	Ave-rage (%)
		(m1)	(m2)	(m3)		
	Moca Creme Limes tone 150 x 150 x 57 mm					
1	150x150x57	3192.1	1915.9	3066.1	9.9	9.8
2	150x150x57	3252.6	1946.5	3124.4	9.8	
3	150x150x57	3281.6	1965.4	3150.6	10.0	
4	150x150x57	3191.3	1914.8	3069.8	9.5	
	Moca Creme Limes tone 100 x 100 x 57 mm					
1	100x100x57	1439.0	859.9	1377.8	10.6	10.2
2	100x100x57	1431.7	856.3	1375.6	9.8	

Table 4. Result of water absorption by immersion of limestone moca crème

3.3.4.Alteration by absorption of sodium sulfate immersion of limestone

At the end of every five cycles the test pieces were washed with drinking water and remained in the oven for 5 days to obtain the constant mass. This mass is obtained after cooling the test pieces at room temperature (**Figure 7**).

The tests provide quantitative results and qualitative changes verified in (**Table 5**).

Being:

pi - the sample losses expressed as a percentage.

mi - the initial masses of the test pieces.

m'i - test masses after fine sifting.

$$Pi = ((mi - m'i) / mi)\ 100 \quad (2)$$

Specimen	Number of test pieces	Dry mass constant (g)	Immersion mass (g)	Dry mass constant (g)	Pi (%)	Average (%)
Fifth cycles						
limestone Moca creme	1	1366.4	1431	1369.9	-0.3	-0.3
	2	1371.4	1435.6	1375.2	-0.3	
	3	1397.5	1458.9	1400.6	-0.2	
	4	1384.4	1444.9	1387.7	-0.2	
	5	1362.8	1428.2	1366.5	-0.3	
Tenth cycles						
limestone Moca creme	1	1369.9	0	0	100.0	91.3
	2	1375.2	175.3	110.5	92.0	
	3	1400.6	153.4	124.8	91.1	
	4	1387.7	435.9	371.7	73.2	
	5	1366.5	0	0	100.0	

Table 5. Result of alteration by absorption of sodium sulfate by immersion

After each period (five cycles) of immersion, the test pieces were observed in order to verify cracking, exfoliation, fragmentation, crumbling or any other type of alteration. At the end of the last immersion, the changes to the test pieces were noted.

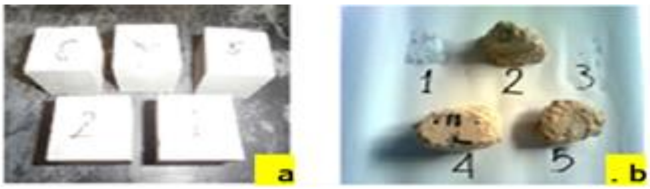

Figure 7. Visual result of tenth cycle by immersion in sodium sulfate solution

3.3.5. Alteration by absorption of sodium sulfate by capillarity of limestone

The sodium sulfate absorption tests by limestone capillarity were performed using the same test method on 3.3.4. The results were calculated quantitatively and qualitatively by the same rule in equation (2) of the sodium sulfate immersion test on the previous page (**Table 6**).

Specimen	Number of test pieces	Dry mass constant (g)	Immersion mass (g)	Dry mass constant (g)	pi (%)	Average (%)
limestone Moca creme	1	1377,8	1417,3	1353,0	1,8	2,0
	2	1375,7	1405,7	1344,8	2,2	
	3	1387,9	1376,6	1314,0	5,3	
	4	1288,0	1339,7	1306,3	-1,4	

Table 6. Result of alteration by absorption of sodium sulfate by capillarity 5 cycles

3.4. Determination of the characteristics of mortars

The determination of the characteristics of mortars and their classification depends mainly on their application. In this study we can consider mortar for masonry as the most important application. Two mortars were tested, i.e., one for laying with a 1: 4 volume trace and the other one for grinding with a 1: 3: 0.5 weight trace

3.4.1. Determination of particle density and water absorption

The results of tests on the physical and mechanical properties of mortars are normal and shown in (**Table 7**).

Calculus	Aggregates passed through 3/8" sieve (Flask Method)	River sand	Artificial sand
M1	Sample weight saturated with dry surface (g)	500.0	500.0
M3	Weight of full water bottle (g)	1240.0	1240.0
M2	Weight of the bottle filled with the saturated sample and water (g)	1542.30	1543.8
M4	Dry sample weight (g)	494.1	489.0
ρw	Specific weight of water at Test temperature (g)	1000.0	1000.0
M4 / M1+ M3 - M2 * ρw	Specific weight of dry particles (Mg/m3)	2499.5	2493.3
M4 / M4 + M3 - M2 * ρw	Specific weight impermeable materials particles (Mg/m3)	2576.4	2641.0
M1 / M1+ M3 - M2 * ρw	Specific weight of waterproof material of particles (Mg/m3)	2529.3	2549.2
100*M1 - M4 / m4	Water Absorption (%)	1.2	2.2

Table 7. Results of tests on physical and mechanical properties of aggregates

3.4.2. Determination of flexural strength of mortar

The principle of flexural strength of the mortar is determined by three loading points of a hardened mortar prism till failure. The compressive strength of the mortar is determined in two parts resulting from the flexural strength test.

The test samples must be 160 x 40 x 40 mm prisms; composed of three samples tested for flexion that will give two halves each specimen, added together will give six samples that will be tested for compression.

Calculation and expression of results, flexural strength (ff), in N / mm2, using the following equation 3:

$$ff = 1{,}5\,FL/bd2\,(N/mm2) \quad (3)$$

F is the maximum load applied to the specimen in Newton (N).

L is the distance between the ages of the support rollers in millimeters (mm).

b is the width of the sample in millimeters (mm).

d is the depth of the specimen in millimeters.

Calculation of the results of compressive strength F / A in (N / mm^2)

The results of the flexural strength and compression of the mix mortars in volume (1: 4) are shown in (**Table 8**).

No of the specimen	Flexion result (N)	Stress (MPa)	Average (MPa)	No of specimen	Result of the compression (N)	Stress (MPa)	Average (MPa)
1	1103.2	2.6	2.6	a	13900.0	8.7	8.5
				b	14210.0	8.9	
2	1242.8	2.9		a	14580.0	9.1	
				b	14190.0	8.9	
3	1014.0	2.4		a	13910.0	8.7	
				b	11050.0	6.9	
Mortar specimens of 1600x40x40 mm							

Table 8. Results of flexural and compression strength of mortar

3.4.3. Compressive strength of mortars for grinding

Use a cement and sand mortar with minimal compressive strength. the specimens have the expected strength for the manufactured cement block (≥ 4-10 N / mm2). The weight is 450 g of cement, 1350 g of sand and 225 g of water (1: 3: 0,5).

The results of the mortar compression strengths are shown in (**Table 9**).

Reference	Plastering	Laying
Kneading date	30-03-2010	30-03-2010
Test date	01-04-2010	01-04-2010
Specimen age (days)	3	3
Storage conditions	Humidity	Humidity
Dimension (mm)	50X50X50	50X50X50
Straight section (mm2)	2500	2500
Mass of specimen (g)	0.266	0.265
Type of rupture	Normal	Normal
Burst load (kN)	40.5	44.0
Breaking stress (MPa)	16.2	17.6
Average (MPa)	16.9	

Table 9. Results of compressive strength of mix mortars by weight for plastering and laying

3.4.4. Tests for alteration by sodium sulfate by immersing mortars

The results obtained in the fifth and tenth cycles of sodium sulfate by immersion are shown in (**Table 10**).

The sulphate attack test allowed to determine the variation in mass caused by the internal expansion according to the five specimens, subject to immersion and drying cycles 10 complete cycles were performed for which the test elements were dried and moistened.

(**Figure 8**) shows the test pieces at the beginning of the 5th and 10th cycles.

Name of the specimen	Nº speci-men	Dry mass constant (g)	Immersed mass (g)	Dry mass constant (g)	pi (%)	Average (%)
Fifth cycles						
Mortar settlement	1	250.5	265	241.4	3.6	4.4
	2	254.4	266.3	242.5	4.7	
	3	257.0	267.6	244.2	5.0	
	4	253.9	267.3	242.6	4.5	
	5	249.5	263.3	239.2	4.1	
Tenth cycle						
Mortar settlement	1	241.4	209.8	195.9	18.8	19.5
	2	242.5	227.7	208.8	13.9	
	3	244.2	266.0	245.0	-0.3	
	4	242.6	162.4	148.2	38.9	
	5	239.2	190.9	176.7	26.1	

Table 10. Result of the fifth and tenth cycles of sodium sulfate absorption by immersion

Figure 8. Results of test a) beginning, b)5th cycles and c)10th cycles

3.4.5. Capillary sodium alteration test

The results of the sodium sulfate alteration test by capillarity of the mortars are shown in (**Table 11**) and equation nº 2 was used.

Name of the specimen	Nº of the specimen	Dry mass constant (g)	Immersed mass (g)	Dry mass constant (g)	pi (%)	Average (%)
Mortar settlement (40x40x160 mm)	1	459.0	0.0	0.0	100.0	86.3
	2	455.5	0.0	0.0	100.0	
	3	464.6	376.4	255.0	45.1	
	4	454.8	0.0	0.0	100.0	
Mortar settlement (100x100x100 mm)	1	1851.2	2042.7	1875.4	-1.3	-2.0
	2	1855.8	2065.8	1890.4	-1.9	
	3	1843.5	2044.3	1876.5	-1.8	
	4	1853.3	2071.1	1907.6	-2.9	

Table 11. Result of alteration of sodium sulfate by capillarity of mortars after 5 cycles

3.5. Discussion result

In order, to facilitate the analysis of the results obtained, (**Table 12**) shows the comparison of materials.

Materials	Compressive strength (MPa)	Immersions by water absorptions	Sodium sulfate by immersion Pi (%)
Limestone	56.5	10.2	91.3
Mortar laying	8.5	2.24	19.5

Table 12. Comparison of materials

In comparison, limestone has good resistance to compression but has little resistance to sodium sulfate immersion. The mortar laying has little resistance compared to limestone but is normal for all tests performed.

3.5.1. Limestone moca cream

The compressive strength of limestone is superior to the compressive strength of mortars. The attack of sodium sulphates is characterized by the chemical reaction on the limestone component, which is less in mortar. The sodium sulphate resistance of moca creme limestone is lower when compared with mortars.

The results obtained for the moca creme limestone are influenced by its porosity. The cracking of the moca creme limestone can result from the expansion and contraction due to the temperature change caused by the drying and humidification of the elements subjected to load and humidity, which can also accelerate expansion reactions. One of the main causes of pathological changes is air pollution, but water and temperature also play a very important role in the development of deteriorations. These factors act independently or together and cause physical and chemical transformations and tensions that triggered the degradation processes.

3.5.2. Mortars

The different types of cement and sand can be classified according to their origin and their ability to resist the attack of sulfate. To obtain the best test result for a mortar, we have to analyze the granulometry and the physical and mechanical properties of the aggregates, as well as the binders (cement) and water for their use.

The advantage of the volume trace is its use indoors or in the field of work. But its disadvantage is difficult to control because it affects both quantity and quality. The advantage of the trace in weight is to control the quantity, also increasing its quality. The downside takes time and is sometimes difficult to obtain indoors or in the field.

3.5.3. Comparison of materials

The results of water absorption by immersion and capillarity of moca creme limestones demonstrate that they absorb more water than mortars due to the volume of the specimens and the porosity of the materials.

In the tests of resistance to sodium sulfate by immersion it was found that degradation and cracking appeared in the 5th cycle and that in absorption by capillarity appeared in the 3rd cycle. The specimens that best resist the attack of sodium sulfate are the mortars, followed by the mocha cream limestone. In the sodium sulfate test, the mortars are softer than cream mocha limestone.

Sulfated water is more aggressive than normal water for degradation and cracking of masonry materials. This origin less space to accommodate the expansive reactions products in the limestone compared with the mortars.

3.5.4. Analysis of pathology study of the walls

Through photos, a study of the pathology was carried out in natural stone masonry buildings and plasters on the external walls.

The pathologies found in stone masonry shown in (**Figure 9**a), show a horizontal cracking due to natural physical actions, temperature variations and the presence of water (rain, soil moisture). In (**Figure 9**b and **9**c) by chemical actions because of the presence of water, presence of salts and acid rain and in (**Figure 9**d) by human actions because of shocks.

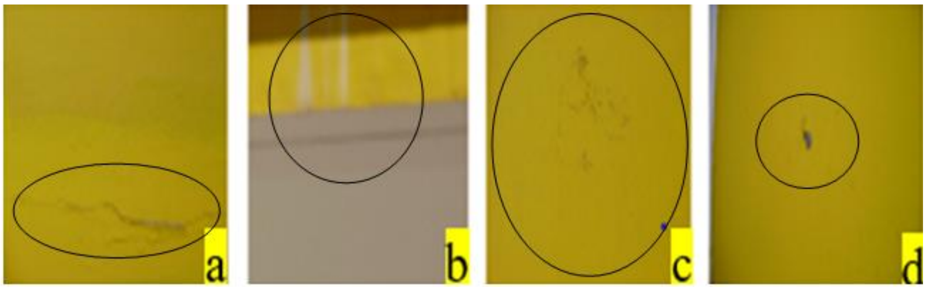

Figure 9. Pathology of stone masonry

4. Conclusions

Natural stone, as a masonry and decoration element, can be used in many application areas. It is almost always around us in commercial areas, on the facades and also in private environments. Unfortunately, little attention has been paid to the best strategy for setting natural stones without the risk of embarrassing complaints.

In most of the failures, water, climate and the environment play an important role: as a means of transport for dyes originating stains, salts or simply as responsible for damages.

From the past there is a history that marks an evolution in the use of masonry walls and at present there are economic motivations for the promotion of a more rational technology and based on constructive simplicity, justifying the investment of the technical and scientific community in general.

In terms of chemical attack, it was observed that the test pieces that do not have any type of paint showed, from the 3rd cycle onwards, some degradation and cracks in the materials such as stones and mortars.

The cracking of the moca creme limestone can result from the expansion and contractions due to the volume changes caused by the drying and humidification of the elements subjected to load and humidity, which can also accelerate expansive reactions. One of the main causes of pathological changes is air pollution, but water and temperature also play a very important role in the development of deteriorations. These factors act independently or together and cause physical and chemical transformations and tensions that triggered the degradation processes.

Water, and wind, which contain sulfate and chloride, are very aggressive, decrease and degrade the strength and adhesion of masonry materials (stone and mortar), and even cracks can appear.

The use of quality materials for more durable masonry means a longer service life and a lower consumption of resources.

To obtain the best test result for a mortar, we have to analyze the granulometry and the physical and mechanical properties of the aggregates, as well as the binders (cement) and water for their use.

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