TÉCNICO LISBOA

"Rising damp in masonry walls of old buildings"

Rui Jorge de Morais Monteiro Torres

Extended abstract

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ABSTRACT

Structural Dampness is considered one of the most common and major causes of degradation in the buildings.

In turn the rising damp from soils manifests itself commonly in the walls and floors of buildings, through migration by capillary action, along the porous structure of the materials that constitute the constructions.

The issue of rising damp has been a concern since ancient times and leads to the occurrence of multiple anomalies, resulting in a considerable decrease of the conditions of building habitability.

Several laboratory tests were performed on a specimen of stone masonry and mortar of hydraulic lime and sand, representative of this type of old building walls, to assess the progression of rising damp, as well as it's behavior on certain implemented measures.

1 – INTRODUCTION

Water (under various natural states and through different mechanisms) is a very active and prominent factor in the degradation of buildings.

According to Freitas *et al* [1], the mechanisms that determine the transport of moisture in elements construction are complex.

From the physical point of view it is considered that there are three fundamental mechanisms fixing humidity:

- hygroscopicity ;
- condensation;
- and capillarity

These three mechanisms can explain, in most cases, the variation of the amount of moisture in building materials with porous structure.

According to Freitas [2], in buildings humidity, in general, the walls and in particular affect the parameters regarding durability, leakage, deterioration of the appearance as well as the thermal performance of materials and components construction.

2 – RISING DAMP

According to Young [3], rising damp is caused by capillary suction of the fine pores or voids that occur in all masonry materials. The capillaries draw water from the soils beneath a building against the force of gravity, leading to damp zones at the base of walls.

Salt attack is the decay of masonry materials such as stone, brick and mortar by soluble salts forming crystals within the pores of the masonry. As the salt crystals grow the masonry is disrupted and decays by fretting and loss of surface skins.

The salt commonly comes from the soils beneath and is carried up into walls by rising damp. When the dampness evaporates from the walls, the salts are left behind, slowly accumulating to the point where there are sufficient to cause damage.

Repeated wetting and drying with seasonal changes leads to the cyclic precipitation of salts and the progressive decay of the masonry.

During a dry period, when the water evaporates from the wall, the salt will be left behind (as salts can't evaporate) and the salt solution in the wall will become more concentrated.

As more salts are brought into the wall, the salt solutions are further concentrated as the moisture evaporates. When the solution reaches a condition known as saturation, or super-saturation (depending on the type of salt), crystals will begin to form.

When the rate of evaporation from the wall surface is low (such as in humid climates, or in cellars and basements with little air movement) the evaporative front may be at or very near the surface, in which case salt crystals will grow as long thin needles, extruding from the wall face.

This is known as efflorescence and is commonly seen as a restively harmless white powder on the surface of new wall.

However, when the rate of evaporation is much greater, the evaporative front will be inside the wall and salts will crystallise within the pores of the masonry (sub-florescence).

The force exerted by rapidly crystallising salts is very high and sufficient to disrupt even the strongest masonry material.

Crystal growth leads to either grain-by-grain loosening, which produces fretting and crumbling of the surface (particularly to soft mortars) or to delamination of a complete skin. (Figure 1)

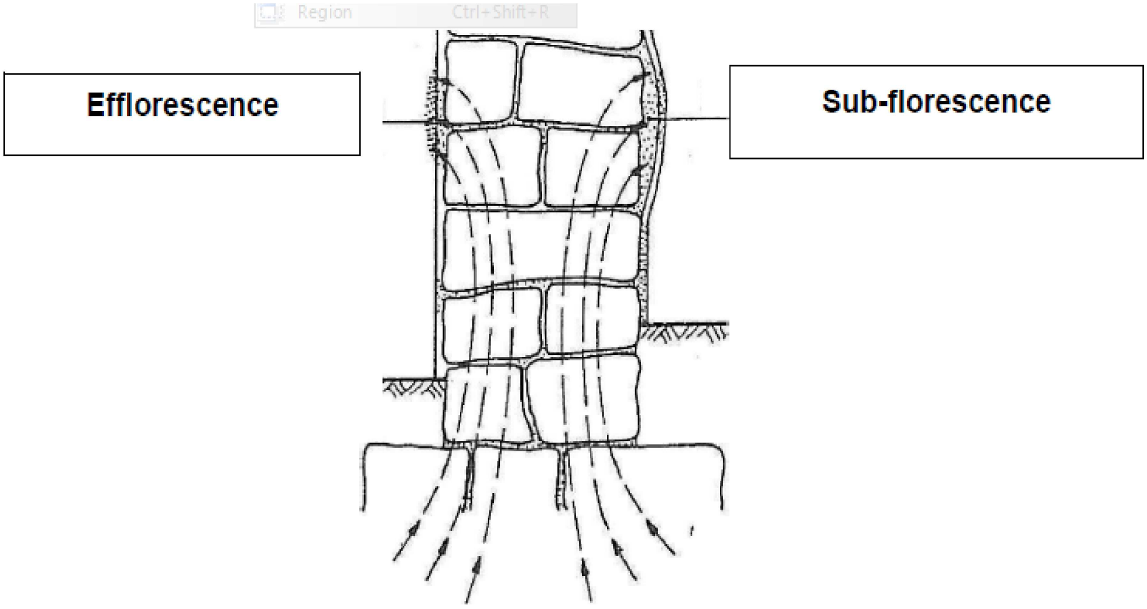


Figure 1 – Formation mechanism of efflorescence and sub-florescence. [4]

Cyclic wetting and drying is an important driver of salt attack decay. When salts first disrupt masonry they enlarge the pores slightly. After a cycle of wetting and drying, salts fill the enlarged pores and the new crystal growth further disrupts the masonry and enlarges the pores some more. Each cycle may produce only tiny changes, but cumulatively they result in the progressive decay of the masonry material.

The amount of salt required to cause damage will vary and will depend on the type of salts, the nature and condition of the masonry, including its pore structure (pore size and distribution) and the cohesive strength of the material.

Rising damp is caused by capillary action (or suction) drawing water from the ground through the network of pores in a permeable masonry material. Capillary suction becomes stronger as the pore size gets smaller. If the pore size is fine enough damp may rise many metres in a wall, until the upward suction is balanced by the downward pull of gravity.

In practice, the height to which water will rise in a wall is limited by the rate of evaporation of water from the wall surfaces. The evaporation rate for external surfaces is related to the nature of the masonry materials, surface coatings, climate, season and siting.

3 – TRIALS PROCEDURE

To reach the goal several studies were carried out the behavior of five types of walls subjected to rising damp.

Samples	Wall description
1 a)	Specimen of stone masonry with lime mortar, in natural environment - dimensions 0.60x0.40x1.00 m³;
1 b)	Specimen of stone masonry with lime mortar, in humid chamber - dimensions 0.60x0.40x1.00 m³;
2	Specimen of stone masonry with lime mortar rendering, in humid chamber - dimensions 0.60x0.40x1.00 m³; Lime mortar rendering on Surface “A” - 1 part natural hydraulic lime, 3 parts fine sand; Surface “A” – Lime mortar rendering starts from the base.
3	Specimen of stone masonry with lime mortar rendering, in humid chamber - dimensions 0.60x0.40x1.00 m³; Lime mortar rendering on Surface “A” - 1 part natural hydraulic lime, 3 parts fine sand; Surface A – Lime mortar rendering starts at 0,15 m from the base.
4	Specimen of stone masonry with lime mortar rendering, in humid chamber - dimensions 0.60x0.40x1.00 m³; Lime mortar rendering on Surface “A” - 1 part natural hydraulic lime, 3 parts fine sand; Surface “B” – Two layers of rubber paint plus the surface coated with lime mortar rendering (1 part natural hydraulic lime, 3 parts fine sand); Surface “A” – Lime mortar rendering starts at 0,15 m from the base; Surface “B” – Lime mortar rendering starts at 0,15 m from the base.

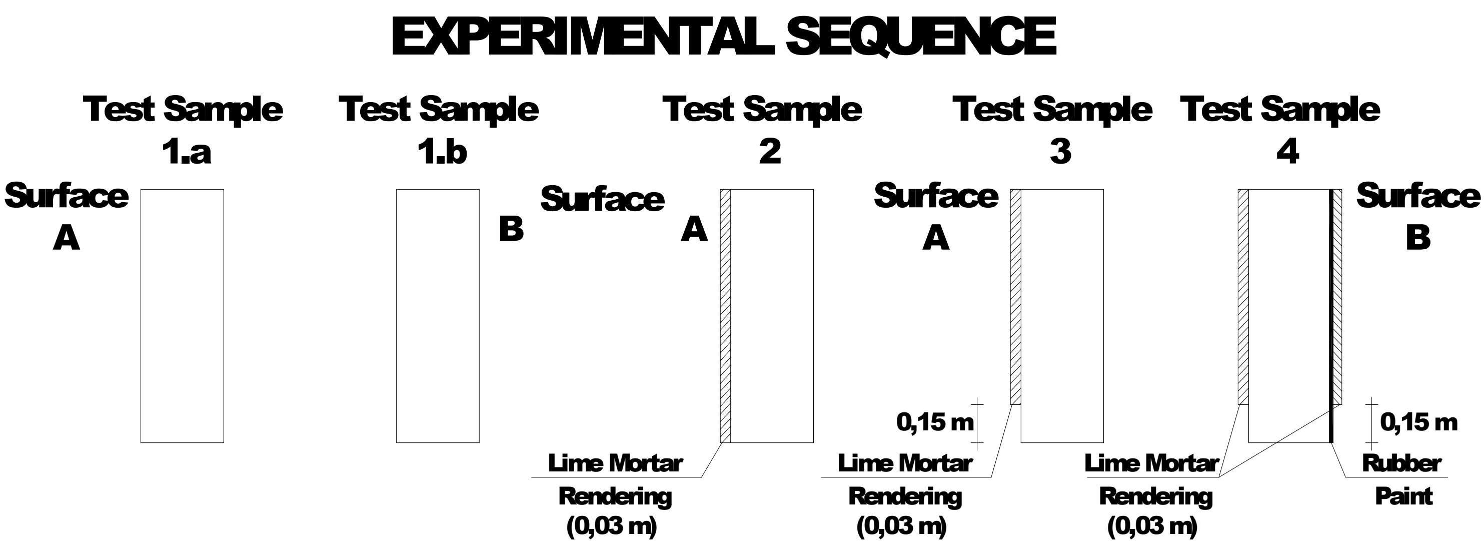


Figure 2 – Experimental Sequence

Sample 1.a) – Experiment 1

This first experiment consisted on immerging a masonry wall on a 3 cm water receptacle.

The test was carried out in the civil engineering construction lab located in Instituto Superior Técnico, conducted at an environmental temperature. Daily registers were made on the height of the rising damp as well on surface "A".

This experience is of major interest to the acquaintance of the behavior of a masonry wall without lime mortar rendering to the rising damp.

The trial stopped when the water absorption reached a level (stable level), in this case meaning the masonry wall's total height of 49.0 cm by its total saturation.

Sample 1.b) – Experiment 2

This second experiment consisted on immerging a masonry wall on a 7.5 cm water receptacle.

It was decided to put the sample into a controlled chamber saturated by 100% relative humidity and at a stable temperature of 21º C, ensuring that the masonry wall sample was submitted to the worst humidity conditions.

By the fact that the chamber was sprinkled every ten minutes, the sample had to be protected by an impermeable coating to make sure nothing would get wet.

Daily registers were made on the height of the rising damp as well on surface "B".

This experience is of major interest to the acquaintance of the behavior of a masonry wall without lime mortar rendering to the rising damp, into a controlled chamber saturated.

The trial stopped when the water absorption reached a level (stable level), in this case meaning the masonry wall's total height of 60.0 cm by its total saturation.

Sample 2 – Experiment 3

This third experiment consisted on immerging a masonry wall on a 7.5 cm water receptacle.

It was decided to maintain the sample into a controlled chamber saturated by 100% relative humidity and at a stable temperature of 21º C.

After reaching the end of experiment 2, a lime mortar rendering was applied in surface "A" of the masonry wall to be compared with sample 1.b).

Daily registers were made on the height of the rising damp as well on "A" surface.

This experience is of major interest to the acquaintance of the behavior of a masonry wall with lime mortar rendering on surface "A" to the rising damp, into a controlled chamber saturated.

The trial stopped when the water absorption reached a level (stable level), in this case meaning the masonry wall's total height of 79.5 cm by its total saturation.

Sample 3 – Experiment 4

This fourth experiment consisted on immerging a masonry wall on a 7.5 cm water receptacle.

It was decided to maintain the sample into a controlled chamber saturated by 100% relative humidity and at a stable temperature of 21º C.

After reaching the end of experiment 3, the sample was submitted to rehabilitation procedure consisting in the surface "A" of the masonry wall, the lime mortar rendering was maintained but the 15 cm bottom was removed, preventing direct contact with water (Fig. 2).

Daily registers were made on the height of the rising damp as well on surface "A".

This experience is of major interest to the acquaintance of the behavior of a masonry wall with lime mortar rendering on surface "A" as a method of comparison with sample 2.

The trial stopped when the water absorption reached a level (stable level), in this case meaning the masonry wall's total height of 58.5 cm by its total saturation.

Sample 4 – Experiment 5

This fifth experiment consisted on immerging a masonry wall on a 7.5 cm water receptacle

It was decided to maintain the sample into a controlled chamber saturated by 100% relative humidity and at a stable temperature of 21º C.

After reaching the end of experiment 4, the sample was submitted to a new rehabilitation procedure to consisting in surface "B" two layers of rubber paint were applied directly on the old lime mortar rendering. In surface "B" of the masonry wall, the lime mortar rendering was maintained but the 15 cm bottom was removed, preventing direct contact with water (Fig. 2).

Daily registers were made on the height of the rising damp as well on "B" surface.

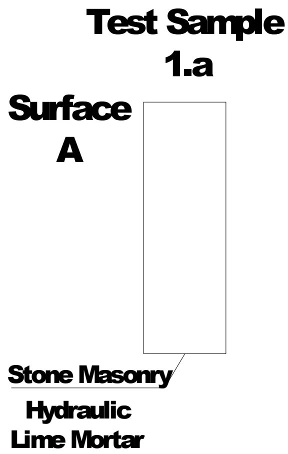
This experience is of major interest to the acquaintance of the behavior of a masonry wall with lime mortar rendering on surface "A" as a method of comparison with sample 3.

The trial stopped when the water absorption on surface "B", don't appear to have any signs of rising damp.

4 – RESULTS

Sample 1.a) – Experiment 1

Date	18/02	18/02	18/02	18/02	19/02	20/02	21/02	22/02	25/02	26/02	27/02
Hours	12:00	13:00	15:30	17:00	16:30	14:00	16:00	14:30	16:30	14:15	15:00
Room temperature	15 ℃	15 ℃	15 ℃	15 ℃	17 ℃	17 ℃	18 ℃	16 ℃	14 ℃	13 ℃	12 ℃
Water level in the tank	---	0,3	0,5	1,2	1,5	1,7	1,6	1,5	1,5	2,0	2,7
Water level in the tank after refilling (cm)	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0
Maximum height by capillarity in Surface "A" (cm)	---	13,0	19,0	21,0	28,5	30,0	32,0	35,0	36,0	37,0	37,0



Date	28/02	01/03	04/03	05/03	06/03	07/03	08/03	11/03	12/03	13/03	14/03	15/03
Hours	15:00	15:00	15:00	15:15	15:00	15:30	15:30	15:30	15:00	15:15	15:30	14:00
Room temperature	12 ℃	14 ℃	14 ℃	16 ℃	17 ℃	17 ℃	18 ℃	17 ℃	16 ℃	14 ℃	14 ℃	15 ℃
Water level in the tank	2,8	2,0	2,9	2,6	2,4	2,0	2,8	2,8	2,3	2,6	2,6	2,7
Water level in the tank after refilling (cm)	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0
Maximum height by capillarity in Surface "A" (cm)	37,0	38,0	39,0	43,0	44,5	48,0	49,0	49,0	49,0	49,0	49,0	49,0

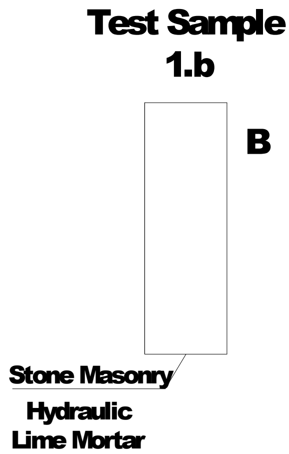

Fig. 3 – After 1 hour.


Fig. 4 – After 5 hours.


Fig. 5 – After 15 days.

Sample 1.b) – Experiment 2

Date	17/04	17/04	17/04	17/04	18/04	19/04	22/04	23/02	24/04	25/04	26/04
Hours	13:00	14:30	15:30	18:00	14:00	13:45	13:30	13:15	13:45	---	14:15
Maximum height by capillarity in Surface "B" (cm)	---	10,0	13,5	16,0	41,5	41,5	47,5	48,5	49,0	Public Holiday	49,0
Average height by capillarity in Surface "B" (cm)	---	9,5	9,8	10,2	18,7	22,8	29,2	30,4	31,3	Public Holiday	32,4
Rising damp Areas in Surface "B" (cm2)	---	570	588	612	1.122	1.368	1.750	1.821	1.872	Public Holiday	1.936
Water level in the tank after refilling (cm)	7,5	7,5	7,5	7,5	7,5	7,5	7,5	7,5	7,5	---	7,5



Date	29/04	30/04	01/05	02/05	03/05	06/05	07/05
Hours	14:00	13:45	14:30	13:30	13:30	13:00	11:15
Maximum height by capillarity in Surface "B" (cm)	49,0	60,0	60,0	60,0	60,0	60,0	60,0
Average height by capillarity in Surface "B" (cm)	32,4	35,8	35,8	35,8	35,8	35,8	35,8
Rising damp Areas in Surface "B" (cm2)	1.936	2.148	2.148	2.148	2.148	2.148	2.148
Water level in the tank after refilling (cm)	7,5	7,5	7,5	7,5	7,5	7,5	7,5

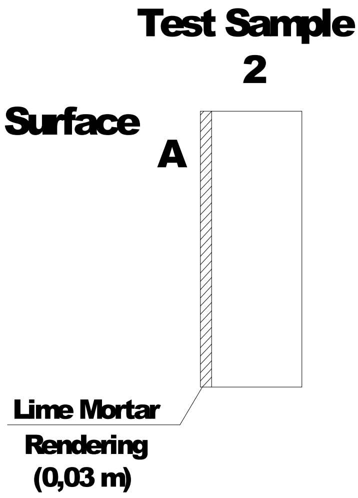
Fig. 6 – After 1 day.

Fig. 7 – After 1 days.

Fig. 8 – After 19 days.

Sample 2 – Experiment 3

Date	17/04	17/04	17/04	17/04	18/04	19/04	22/04	23/02	24/04	25/04	26/04
Hours	13:00	14:30	15:30	18:00	14:00	13:45	13:30	13:15	13:45	---	14:15
Maximum height by capillarity in Surface "A" (cm)	---	11,0	15,0	19,0	31,0	39,5	58,5	59,0	65,5	Public Holiday	74,0
Average height by capillarity in Surface "A" (cm)	---	10,0	14,8	19,0	29,3	37,3	54,2	55,1	62,9	Public Holiday	67,3
Rising damp Areas in Surface "A" (cm2)	---	600	888	972	1.758	2.238	3.252	3.306	3.774	Public Holiday	4.038
Water level in the tank after refilling (cm)	7,5	7,5	7,5	7,5	7,5	7,5	7,5	7,5	7,5	---	7,5



Date	29/04	30/04	01/05	02/05	03/05	06/05	07/05
Hours	14:00	13:45	14:30	13:30	13:30	13:00	11:15
Maximum height by capillarity in Surface "A" (cm)	79,5	79,5	79,5	79,5	79,5	79,5	79,5
Average height by capillarity in Surface "A" (cm)	71,9	74,2	74,9	76,0	76,0	76,0	76,0
Rising damp Areas in Surface "A" (cm2)	4.314	4.452	4.494	4.560	4.560	4.560	4.560
Water level in the tank after refilling (cm)	7,5	7,5	7,5	7,5	7,5	7,5	7,5


Fig. 9 – After 1 day.

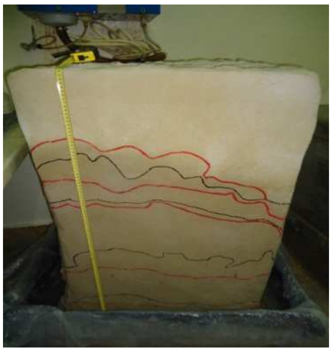


Fig. 10 – After 12 days.

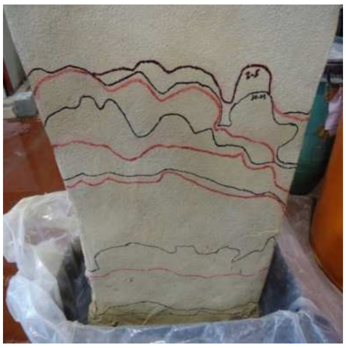
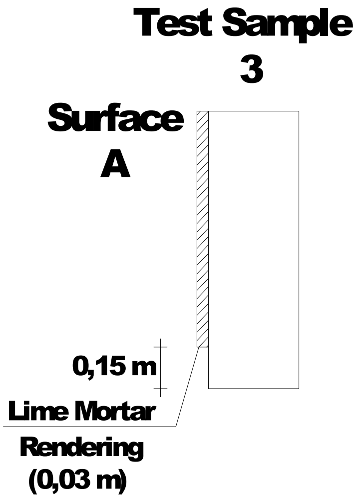


Fig. 11 – After 21 days.

Sample 3 – Experiment 4

Date	10/06	11/06	12/06	13/06	14/06	17/06	18/06	19/06	20/06	21/06	24/06
Hours	---	15:00	16:00	14:00	15:00	13:30	14:00	16:45	12:45	12:45	16:30
Maximum height by capillarity in Surface "A" (cm)	Public Holiday	---	24,0	28,0	35,0	41,0	42,0	42,0	43,0	46,0	58,5
Average height by capillarity in Surface "A" (cm)	Public Holiday	---	16,4	17,7	19,3	22,0	22,6	29,0	30,8	32,2	39,8
Rising damp Areas in Surface "A" (cm2)	Public Holiday	---	85,8	160	260	421	458	837	945	1.033	1.490
Water level in the tank after refilling (cm)	---	7,5	7,5	7,5	7,5	7,5	7,5	7,5	7,5	7,5	7,5



Date	25/06	26/06	27/06	28/06	01/07	02/07
Hours	16:00	10:45	11:15	14:00	10:15	10:00
Maximum height by capillarity in Surface "A" (cm)	58,5	58,5	58,5	58,5	58,5	58,5
Average height by capillarity in Surface "A" (cm)	42,5	43,3	43,3	43,3	43,3	43,3
Rising damp Areas in Surface "A" (cm2)	1.649	1.700	1.700	1.700	1.700	1.700
Water level in the tank after refilling (cm)	7,5	7,5	7,5	7,5	7,5	7,5

Fig. 12 – After 1 day.

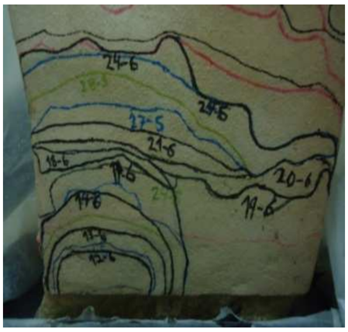


Fig. 13 – After 13 days.

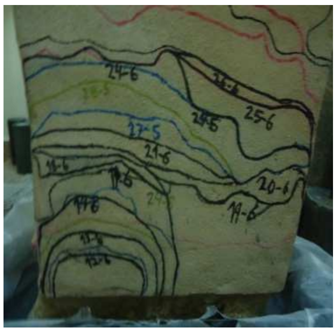
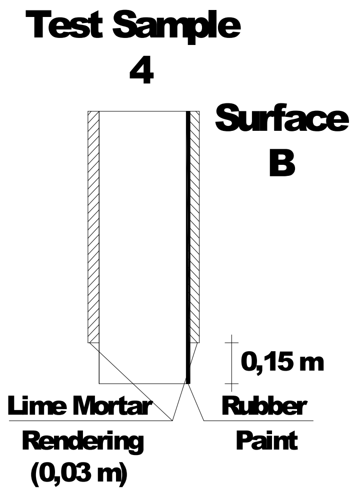


Fig. 14 – After 20 days.

Sample 4 – Experiment 5

Date	16/09	17/09	18/09	19/09	20/09	23/09	24/09	25/09	26/09	27/09
Hours	11:30	11:00	10:00	11:00	14:30	14:30	11:00	10:30	11:00	11:30
Maximum height by capillarity in Surface "B" (cm)	---	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Average height by capillarity in Surface "B" (cm)	---	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Rising damp Areas in Surface "B" (cm2)	---	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Water level in the tank after refilling (cm)	7,5	7,5	7,5	7,5	7,5	7,5	7,5	7,5	7,5	7,5



In surface “B” two layers of rubber paint were applied directly on the old lime mortar rendering. (Fig. 15)

Fig. 15 – Rubber paint applied to the Surface “B”.

Fig. 16 – After 1 day.

Fig. 17 – After 4 days.

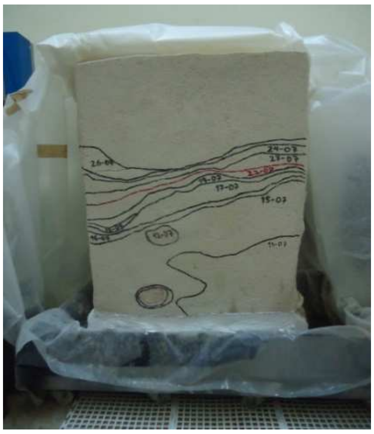


Fig. 18 – After 7 days.

5 – CONCLUSIONS

Sample 1.a) – Experiment 1

Most likely the sample reached a balance between the amount of water absorbed and the amount of water evaporated daily, preventing the maximum height of rising damp to arrive at higher levels. The highest level of rising damp in natural environment corresponded to 49,0 cm.

Sample 1.b) – Experiment 2

The heterogeneity of the material explains the existence of an intermediate step (5 days). The highest level of rising damp in a controlled environment corresponded to 60,0 cm.

Sample 2 – Experiment 3

Significant does the homogeneity of the materials constitute the layer of plaster on to the sample. With the construction of plaster over the entire surface "A", increases significantly in 32.5% the maximum height of rising damp.

The results rise from 60,0 cm (Sample 1.b) – Experiment 2) to 79,5 cm (Sample 2 – Experiment 3).

It was concluded that homogenization and decreasing size of the pores in lime mortar rendering on surface “A”, the greater height of rising damp.

It is also concluded that – highly porous material – in lime mortar rendering on surface “A”, was a major vehicle to rising damp.

Sample 3 – Experiment 4

The lime mortar rendering was maintained but the 15 cm bottom was removed, preventing direct contact with water. So the maximum height of rising damp was significantly reduced in 26.4%, moving from 79.5 cm (Sample 2 – Experiment 3) to 58,5 cm (Sample 3 – Experiment 4).

Prior execution of the work associated to experiment 4 has a very low cost.

Sample 4 – Experiment 5

The values of rising damp obtained in this test are null, thus constituting a very interesting and promising solution in the treatment of moisture in masonry walls of old buildings.
Prior execution of the work associated to experiment 5 has an acceptable cost to final results.

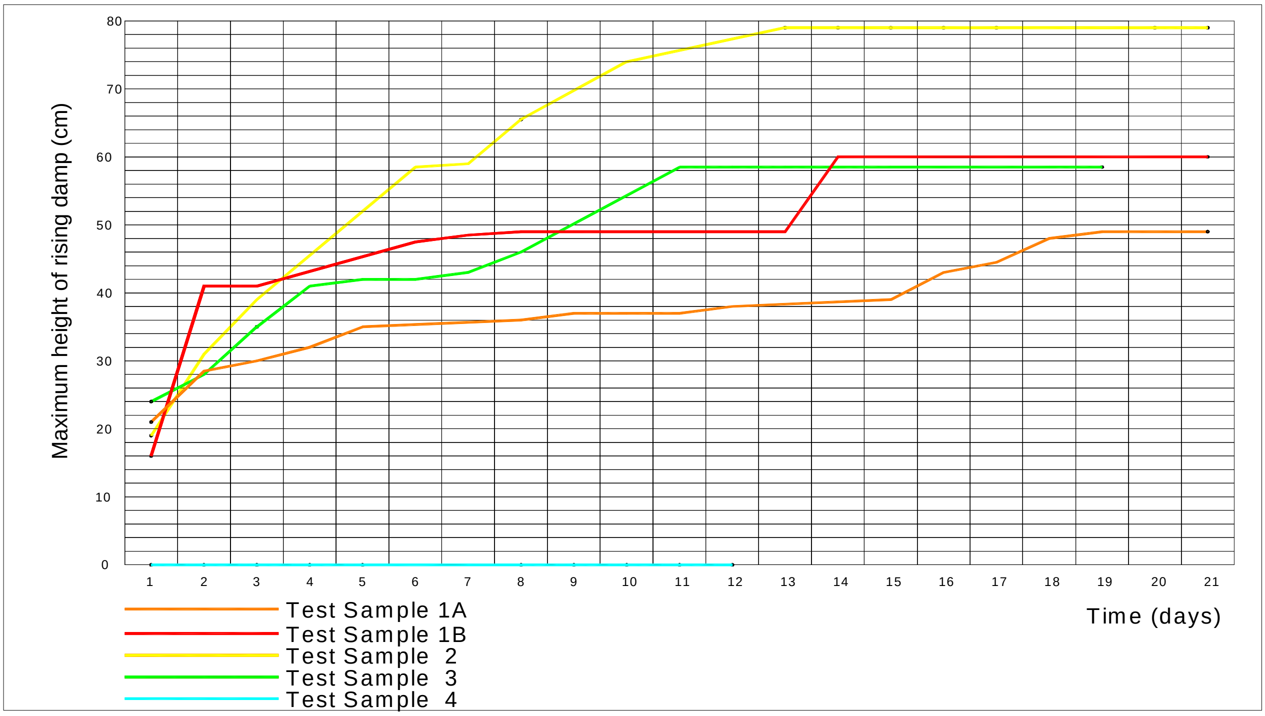


Figure 19 – Maximum height of rising damp in stone masonry with hydraulic lime mortar

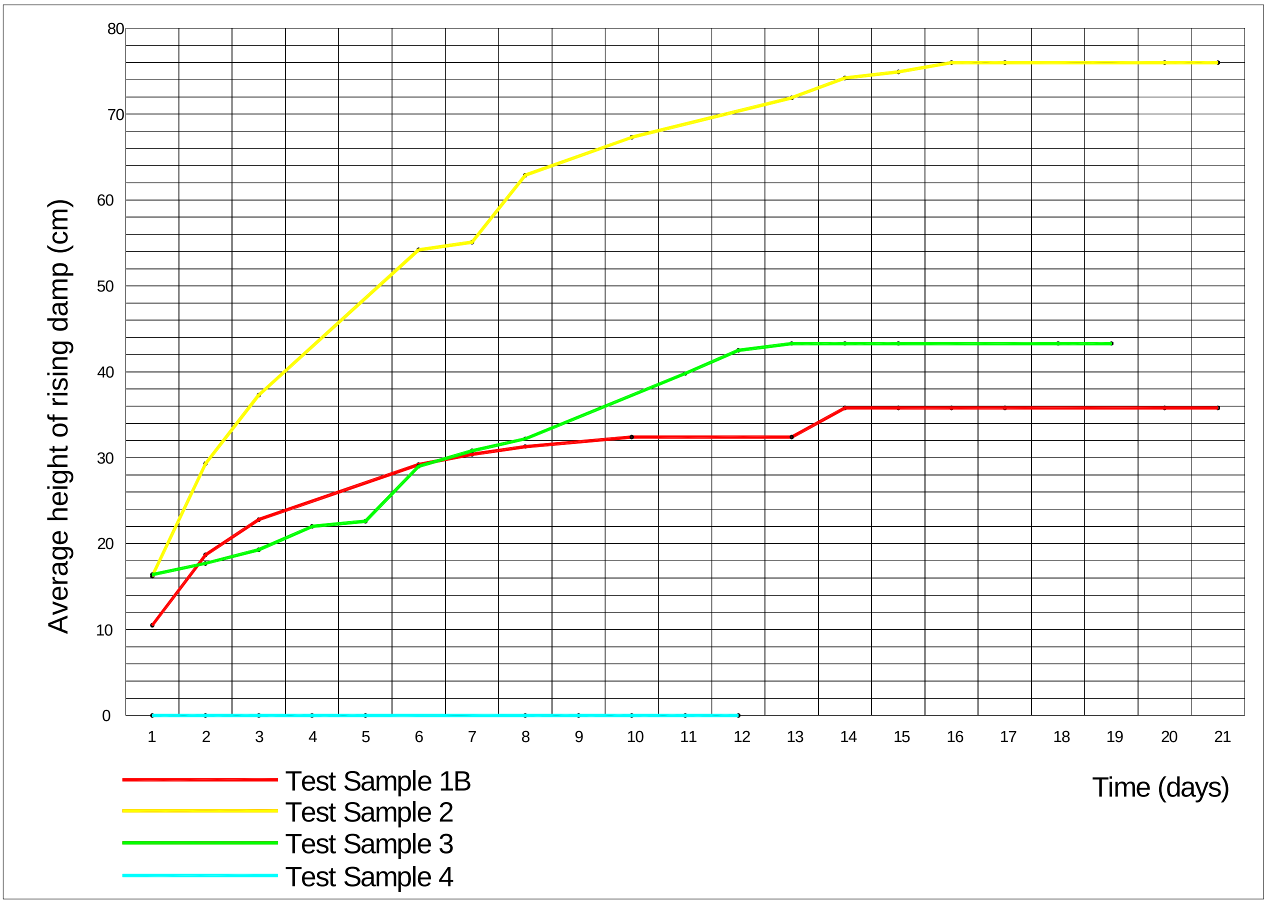


Figure 20 – Average height of rising damp in stone masonry with hydraulic lime mortar

6 – FINAL CONCLUSIONS

- It is very important to note that conditions in the humid chamber of the Construction Laboratory are more troublesome than the usual conditions in buildings. Relative humidity is 100% by the artificially created conditions for evaporation are much smaller, leading consequently higher rising damp. However despite the existence of extreme conditions in the humid chamber, these allow us to compare the various tests in the same circumstances;
- Neglecting any hygroscopicity phenomena observed in the sample (before the alleged amount of water fixed by adsorption in an environment saturated), only then were able to compare the results of the four tests carried out in a humid chamber Construction Laboratory;
- The experimental study allows us to test and compare on equal circumstances four trials in laboratory, for rising damp through the registration (maximum height) on the surface of the specimen of stone masonry with lime mortar rendering;
- The measures to combat rising damp in old buildings require prior review and study the surrounding conditions. The most successful technology could be used in an alternative perspective or even complementary to chemical barriers commonly employed within the rehabilitation of old buildings.

7 – REFERENCES

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