Original Article

Inglesinhos convent: Compatible renders and other measures to mitigate water capillary rising problems

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ABSTRACT In Portugal, conservation and refurbishment interventions on monuments (churches, convents, palaces and fortresses), as well as on historical centers (dwelling buildings), have been assuming increasing relevance. In order to guarantee the present requirements of habitability and aesthetic appearance of the monument without changing its essential character, in conservation interventions, it is necessary to implement wall-covering solutions compatible with the background and the pre-existing materials. In this work, the application to a case study of a diagnosis methodology for the definition of the probable causes of the anomalies and for the evaluation of the state of conservation of renders and plasters is described. The measures adopted for the repair of the anomalies are presented and aim at controlling the causes and minimizing their effects.
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INTRODUCTION

The English College, or 'Inglesinhos Convent', as it is referred to by the people of Lisbon, is located in the middle of Bairro Alto, in the historical center of Lisbon. It is considered a reference because of its localization, architectural beauty and decorative elements. The beginning of the construction dates back to the seventeenth century, in 1622. It was built as a school for the English secular priests, named 'St Peter's and St Paul's College' but known as Inglesinhos Convent (Figure 1).

Later, in 1644, a church adjacent to the main building was built, with interior walls covered with plaster simulating stones of different colors, creating a space full of beauty and technic and aesthetic singularity (Figure 2).

In 1755, the great Lisbon earthquake took place, resulting in the building suffering several areas of damage, and thus it underwent various interventions. By the eighteenth century the English College had built a high reputation in the Iberian Peninsula, and many

Figure 1: Inglesinhos convent: views before and after the intervention.

Figure 2: Church with lime plaster simulating marble.

Figure 3: Lacuna in the interior glazed tiles ('azulejos') showing the old lime plaster.

foreigners, especially Spanish people, came to study at this institution. Only in the late nineteenth century, in 1898, was the decorative program of the church finished.

In the twentieth century, in 1973, the English College was closed, but before this James Sullivan, the last Principal, requested from the Municipality of Lisbon information 'on the conditions for him to order the preparation of a plan for new buildings intended for housing or offices or mixed use and complementary services'. The intention of preserving the noble building by giving it some use that would keep it alive was obvious in the Principal's request.

Although transformed, the old convent and English College maintained its nobility and turned to be a milestone in the urban net of one of the most ancient Lisbon quarters (DGEMN 1, 2009).

The building plan is composed of rectangles and is organized into large circulation and distribution corridors; the ground floor roof is executed in groined vaults. The old renders and plasters were based on lime mortars, with a pinkish coloration, as it was possible to observe in a lacuna existent in the entrance hall wall cover, constituted by beautiful ancient glazed tiles ('azulejos') (Figure 3).

In 2004, the building was sold and a project was approved to convert the monument into a luxurious housing building. Before the beginning of the works, the roof had remained in poor condition for a long period of time, allowing water infiltration to reach the vaults that form the ceilings of the ground floor. During the refurbishment works, the old renders and plasters based on air lime were removed and substituted with new ones, composed of lime and cement, in the interior and exterior of the building. The new renders presented shrinkage cracking after application, and were treated with a synthetic product designed to reduce shrinkage. A polymeric paint was used as finishing.

Before the end of the works, several anomalies occurred, related to the presence of moisture in the walls.

The construction company – Edifer Construções – asked the National Laboratory of Civil Engineering (LNEC) to identify the causes of the anomalies and to propose repair measures.

In the following sections, the actions undertaken to establish a diagnosis of the situation and to find the main causes of the anomalies, as well as the measures taken by the construction company to perform repairs, are briefly described.

STATE OF CONSERVATION OF RENDERS AND PLASTERS

Several anomalies appeared after application of the new renders and plasters: dark moisture stains, salt efflorescences, loss of cohesion of the paint, blisterings and detachment of the paint (Figures 4–6).

Figure 4: Efflorescences in the rendering cracks.

Figure 5: Detachments (large lacuna) of internal finishing.

Figure 6: Detachment of the render painting.

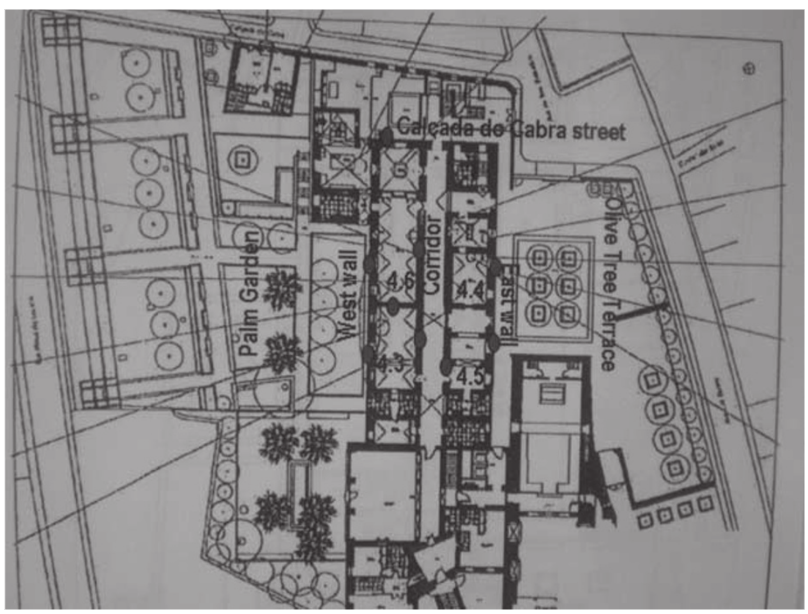

Figure 7: Plan of the ground floor with the tests localization.

METHODOLOGY OF DIAGNOSIS

A methodology of diagnosis based on the history of the building and on the results of non-destructive *in situ* tests was adopted. Several *in situ* tests were applied to evaluate the origin, localization and distribution of moisture in the walls: a portable humidimeter to determine the superficial moisture content, strip tests for the semi-quantitative identification of salts, a pendular Schmidt impact hammer and a Durometer Shore A for the assessment of variations in mechanical strength.

EXPERIMENTAL PROGRAM AND RESULTS

The tests were carried out in several internal and external walls, whose localization is illustrated in Figures 7 and 8, for the ground floor and the first floor, respectively.

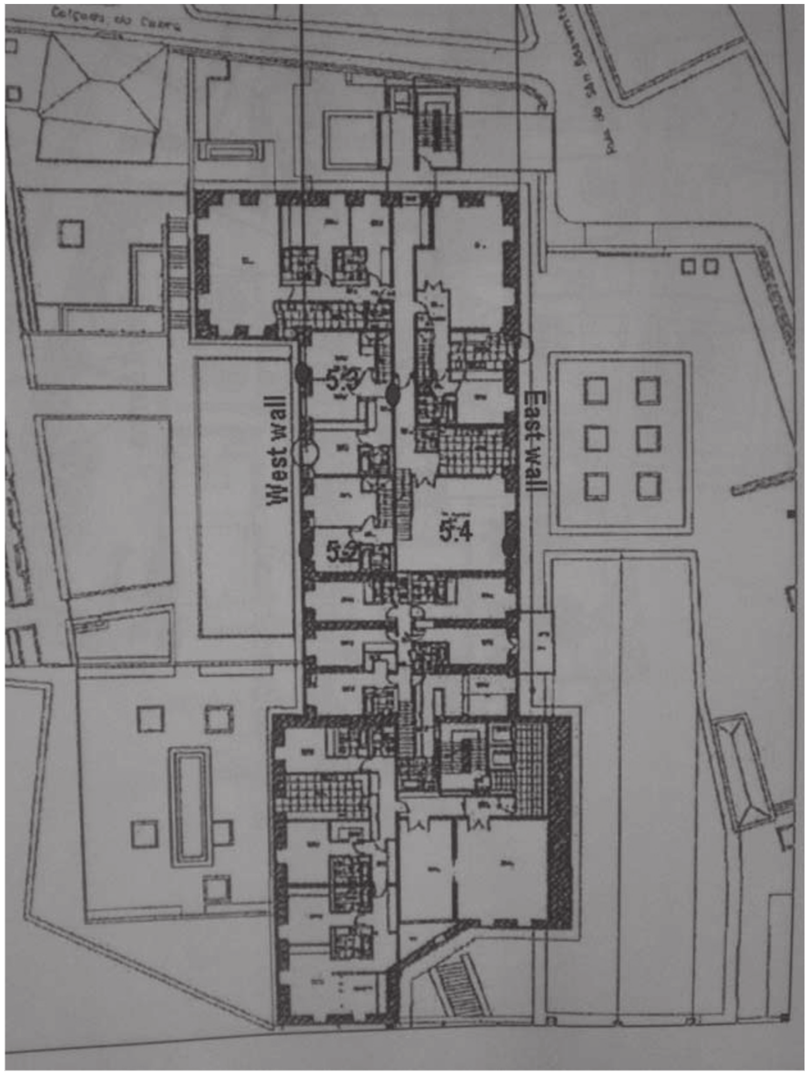

Figure 8: Plan of the first floor with the tests localization.

The portable humidimeter (Figure 9) – Tramex CRH – is a device used to evaluate water content in walls (Henriques, 2001; Massari and Massari, 1993; and Veiga *et al*, 2009). This test was performed in several internal and external walls, at different heights – 0.30 m and 1.80 m from the pavement – and in two different conditions – dry weather and after a rainy week – in order to determine the possible origin of the water. The results of these measurements are summarized in Tables 1 and 2.

The comparative analyses of the results reported that the walls of the ground floor experienced higher humidity than those of the higher floors. The interior walls were found to have high moisture contents, almost as high as those of the external walls. This moisture increased after rainy periods. In the interior walls and some exterior walls, the humidity content was higher at the base, decreasing towards the top of the walls. High moisture contents were concentrated at the base of the vaults and in other places, especially near the windows and under the cornice. These results showed that the main water source is not infiltration by exterior walls, and that there is capillary rising water

Figure 9: Evaluation of the moisture content with portable humidimeter.

from foundations as well as moisture from the roof vaults. They also show the effect of some particular constructive issues that favor water retention.

With the strip tests (Figure 10), information on the type of salts present was obtained, as well as information on the degree of contamination, based on semi-quantitative determination of the ions associated with the type of salt (Borrelli, 1999 and Veiga *et al*, 2009). The results of these measurements are summarized in Table 3.

The salts present were found to be mainly sulphates (large content in one of the interior walls) and chlorides, but some nitrates were also detected. Their presence was probably due to the interaction of contaminated water from the ground, to the presence of cement in the mortars and to the existence of salts in other wall materials or in the ground. Salts can be transported in a porous material only if dissolved in water (Lubelli *et al*, 2006), and thus their presence indicates water transport through the walls. Despite the lower dissolution rate of sulphates, when compared with the other salts present, the circulation of water in the walls can promote their dissolution and dissemination (Ottosen *et al*, 2008).

The tests with the pendular Schmidt impact hammer (Figure 11) – Schmidt PM – and those with the Durometer Shore A (Tavares and Veiga, 2007) (Figure 12) based on ASTM D22240, were performed to assess the strength of the superficial layers of renders, in order to verify how the moisture content affected the mortars' cohesion. The results are summarized in Tables 4 and 5.

The tests showed the reduction in mechanical strength and cohesion of the degraded renders, by comparison with measurements performed on experimental panels made *in situ* and with determinations carried out in previous case studies on sound mortars (Tavares *et al*, 2008). The tests with the pendular Schmidt hammer were more expressive than those with the Durometer, which affects more superficial layers.

CAUSES OF THE ANOMALIES

After observation of the wall coverings, the analysis of their state of conservation and the discussion of the *in situ* test results, it was possible to identify the most probable causes of

Table 1: Average results, with portable humidimeter, in the interior wall surfaces

Local identification	*Walls identification*	*Height to the pavement (m)*	*Moisture measurements (%)*	
			1st measure (dry period)	*2nd measure (after rainy week)*
4th Floor				
Apartment 4.6 (old Canteen)	West wall (exterior wall)	0.30	3.5	4.6
		1.80	5.5	6.9
	South wall	0.30	6.1	5.3
		1.80	5.3	5.7
	East wall (contiguous to the corridor)	0.30	6.3	6.9
		1.80	6.3	6.9
Corridor	West wall (contiguous to the apartment 4.6)	0.30	3.5	6.5
		1.80	6.9	2.8
	East wall (contiguous to the apartment 4.5)	0.30	ND	6.5
		1.00	3.5	ND
		1.80	ND	2.8
Apartment 4.5	East wall (exterior wall)	0.30	3.6	5.0
		1.00	3.7	ND
		1.80	ND	5.5
Apartment 4.4 (around 0.60 m under the exterior ground)	East wall (exterior wall)	0.30	ND	6.9
		1.80		3.9
Apartment 4.3 (recently repainted)	West wall (exterior wall)	0.30	ND	5.4
		1.80	ND	5.7
	East wall (contiguous to the corridor)	0.30	ND	6.5
		1.80	ND	2.9
5th Floor				
Apartment 5.3	West wall (exterior wall)	0.30	5.3	6.6
		1.80	2.5	2.6
	East wall (contiguous to the corridor)	0.30	3.2	3.5
		1.80	0.3	1.5
Corridor	West wall (contiguous to the apartment 5.3)	0.30	4.6	ND
		1.80	3.4	ND
	East wall (contiguous to the apartment 4.5)	0.30	0.8	ND
		1.80	0.6	ND
Apartment 5.4	East wall (exterior wall)	0.30	2.7	ND
		1.00	2.9	ND
Apartment 5.2	East wall (exterior wall)	0.30	ND	2.4
		1.80	ND	2.3
6th Floor				
Apartment 6.3	West wall (exterior wall)	0.30	2.3	2.4
		1.80	4.0	2.3

ND: Not determined.

Table 2: Average results with humidimeter equipment, on the façades

Local	*Wall identification*	*Height to the pavement (m)*	*Moisture measurements (%)*	
			1st measure (dry period)	*2nd measure (after rainy week)*
West exterior wall – palm tree garden	West wall (contiguous to the apartment 4.6)	0.30	4.4	4.8
		1.80	3.4	4.5
East exterior wall – olive tree terrace	Wall contiguous to the apartment 4.5	0.30	ND	4.6
		1.80	ND	4.2
North exterior wall	Calçada do Cabra street	0.30	3.6	ND

ND: Not determined.

Figure 10: Strip tests – semi-quantitative determination of salts.

Table 3: Salt identification with colorimetric-strip tests

Local identification		*Salts detected*	*Possible source*
Interior wall, apartment 4.6, South wall		Nitrates (250 mg/l); Sulphates higher than 1600 mg/l)	Possible interaction of water contaminated from the ground; Presence of cement in the mortars, or sulphates existent in other materials or in the ground.
West exterior wall (Palm tree garden)		Sulphates in quantities lower than 200 mg/l	Presence of cement in the mortars, or sulphates existent in other materials or in the ground.
North exterior wall in Calçada do Cabra Street	With painting	Chlorides between 500 and 1000 mg/l; Nitrates between 5 and 10 mg/l	Possible interaction of water contaminated from the ground.
	Without painting	Chlorides between 500 and 1000 mg/l Sulphates between 200 and 400 mg/l)	Possible interaction of water contaminated from the ground; Presence of cement on the mortars, or sulphates existent in other materials or in the ground.

the anomalies. The conclusion was that the anomalies were a consequence of the high accumulation of water in the walls and ceilings. From the distribution of moisture in the walls, the water appeared to have different origins: (i) capillary rising water from underground through foundations and walls; (ii) capillary rising water from the soil surface, owing to the accumulation of rain water near the external walls, and to the absence or disability of drainage systems; (iii) water infiltrations from the exterior with saturation of the roof over a long period before the intervention; (iv) localized infiltrations in some areas of the exterior walls; (v) localized problems in interior walls owing to rupture or defects of canalization; and (vi) condensation moisture in the interior walls (Henriques, 2001; Magalhães, 2002 and Massari and Massari, 1993).

The presence of water inside the walls was extended in time owing to difficulty in its removal through the new adopted coverings. In fact, these coverings reduced the evaporation ability, when compared with the old renders, which were based on air lime

Figure 11: Pendular Schmidt impact hammer test.

Figure 12: Durometer test.

and then more porous and permeable. The reduced ventilation in the interior of building worsened the situation (Veiga and Tavares, 2002).

REPAIR MEASURES

The repair of anomalies should be preceded, if possible, by the elimination of their causes. If this approach is not possible, it is necessary to minimize the effects of these causes and control the related symptoms (Freitas *et al*, 2002).

Table 4: Average results using pendular Schmidt impact hammer

Local	*Tested surface*			*Comparison render[b] based on cement and lime*
Exterior wall (Calçada do Cabra). Results in HV[a]	Cement and air lime-based render with acrylic paint as finishing, presenting detachments and salt efflorescences 33			40
West exterior wall – experimental panels for paintings in good condition (Palm tree garden)[a]	Synthetic finishing	Silicon painting over render	Synthetic finishing and silicate painting	
	38	43	50	

[a]Vickers HV=Hardness in degrees (kg/mm^2).

[b]Render 3 months after application, in good state of conservation, tested in another study (Veiga *et al*, 2009).

Table 5: Average results with Durometer

Local	*Tested surface*			*Comparison render[b] based on cement and lime*
Exterior wall (Calçada do Cabra). Results in Shore A[a]	Cement and air lime-based render with acrylic painting as finishing, presenting detachments and salt efflorescences 92			94
West exterior wall – experimental panels for paintings in good condition (Palm tree garden)	Synthetic finishing	Silicon painting	Synthetic finishing and silicate painting	
Results in Shore A[a]	90	91	95	

[a]Unit measurement scale SHORE A from 0 to 100.

[b]Render 3 months after application, in good conservation state, tested in another study (Veiga *et al*, 2009).

Figure 13: Execution of a ventilation ditch near the building façade.

Elimination of the causes

The repair of the roof, of the drainage systems and of the collectors of rainwater was performed. Drainage ditches along the exterior walls were constructed to prevent the accumulation of rainwater, and ventilation ditches were also executed in order to facilitate the evaporation at the base of the exterior walls of water rising from the ground (Figures 13 and 14). Inside the apartments, ventilation tunnels were executed under the floor of the ground floor, where perforated tubes were introduced and connected to the

Figure 14: Electric equipment to force ventilation.

Figure 15: Small tunnels were opened under the ground floor.

Figure 16: Introduction of the ventilation tube in the underground tunnels.

exterior (Figures 15 and 16) with the purpose of preventing capillary rise. In order to promote air circulation, electric fans were installed in the exterior ventilation ditches.

Minimizing the effects

The impermeable external coverings were removed – synthetic finishing, polymeric paints and other polymeric products – and were replaced by a lime-based finishing coat for the regularization of the walls and a silicate-based paint. The lime-based finishing

Figure 17: Application of the lime finishing coat.

Figure 18: Finishing with the passage of a polystyrene sponge on the mortar.

Figure 19: Application of traditional plaster on the ceiling of apartment 4.6.

coat, consisting of a thin air lime mortar, executed with siliceous sand and calcium carbonate, with volumetric dosage 1:3 (lime:aggregate), was carefully applied, with a soft squeeze with a mason trowel and periodic sprinkling of water (Figures 17 and 18). It was left to dry for 1 month before the application of the final paint.

In the internal space, ventilation during the works was achieved by opening the windows and installing portable fans. The cement and lime plaster of the walls and ceilings were removed and replaced with air lime and sand mortars, with a volumetric dosage of 1:3 (lime:aggregate), and were covered with a traditional plaster composed of gypsum and air lime (Figure 19). This traditional gypsum plaster should not to

Figure 20: General view of the final appearance of the East Façade finishing.

be painted for at least 2 years to improve the evaporation of the water retained inside the vaults and walls. A gap between the floor footers and the walls was created for ventilation of the interior walls, to allow for continuous drying of masonry over time.

CONCLUSIONS

This old convent of the seventeenth century, which underwent a refurbishment intervention to be adapted to a housing building, showed anomalies after replacing the old renders and plasters with new cement and lime mortars finished with a polymeric paint, especially owing to the excess of water in the walls and vaults. The state of conservation and the diagnosis of the causes of anomalies were established through analysis of the constructive history of the building and with recourse to *in situ* tests. Repair recommendations were then defined.

The diagnosis methodology adopted allowed for the identification of the causes and the location and quantification of effects, leading to an adjusted definition of a set of repair recommendations.

The major objectives of these measures were the increase in the water drying rate to the exterior, making it as close as possible to the capillary rising rate, and the limitation of the water volume that reaches the walls above floor.

The causes of the anomalies were eliminated whenever possible. The disfunctional systems of drainage and collection of rainwater were repaired. The impermeable renders and paintings were replaced by materials more compatible with wet walls, such as air lime mortars and silicate paints. In the interior, the plasters were replaced with lime and gypsum plasters, and ventilation was facilitated in the interior spaces.

The rising water from the ground, present in the walls, owing to water rising capillarity, was the most difficult cause to eliminate. To promote drying of the walls' bases and mitigate the effects of capillary rising, ventilation ditches were executed close to the exterior walls, and ventilation tunnels with perforated tubes and electric fans were placed along the walls of interior spaces.

The construction company, Edifer Construções, cooperated in the various stages of the study and implemented the recommended measures, despite the difficulties involved. The final aesthetic appearance of the building was close to that of the original, preserving the identity of the historic building (Figure 20). The collaboration of all intervenients in the process was crucial in achieving the elimination of anomalies with the minimum cost and delay of the works, and in promoting the success of the intervention at aesthetic and functional levels, according to the ethical principles of conservation.

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