Characterization of Stone and Mortar Decay – Casa Major Pessoa, Aveiro

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ABSTRACT: Casa Major Pessoa is one of the most remarkable *Art Nouveau* buildings in the city of Aveiro, a town that is especially well known in Portugal for its heritage representative of this artistic style. This house was private property until recent years and when it became vacant its decay process began, favoured by enclosure and lack of maintenance. Recently, the building, classified as of Public Interest, was bought by the Town Hall in order to create an *Art Noveau* Museum. The severe degradation present throughout the house and specifically on its richly decorated façades led to a study investigating the state of decay of different materials. Samples were extracted from exterior stone elements, both interior glaze-supporting mortars and exterior mortars. Analysis included x-ray diffractometry (XRD), atomic absorption spectrometry (AAS), and scanning electron microscopy (SEM) performed both in stone and mortars. Results revealed the presence of salts in most samples, with a prevalence of thenardite and gypsum. Their presence can be attributed to the action of maritime aerosol, combined with traffic pollution, with a variable influence on materials related to exposure conditions.

1 CASA MAJOR PESSOA – GENERAL CHARACTERIZATION

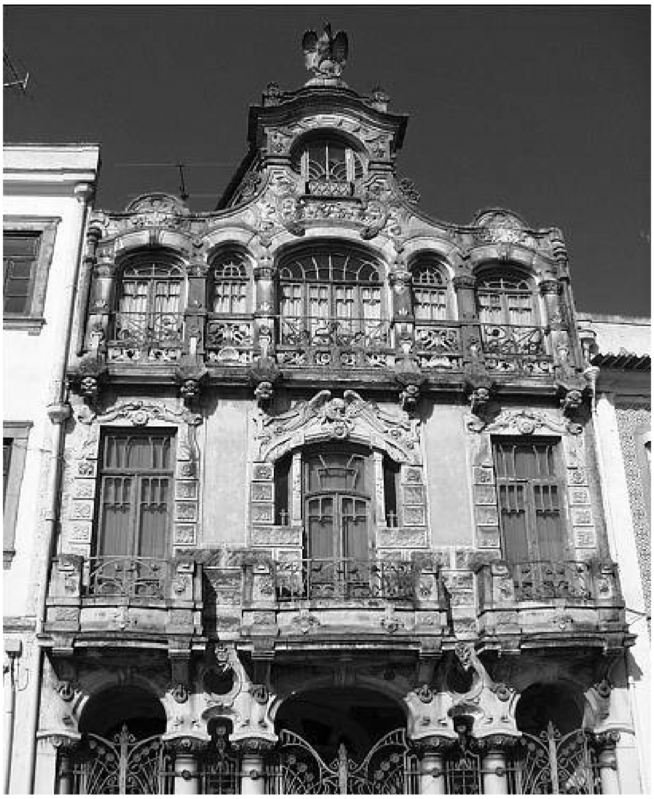

Figure 1. Main façade of Casa Major Pessoa

Completed in 1909, the house named as Casa Major Pessoa was the property of Mário Belmonte Pessoa, a wealthy businessman who commissioned its construction to Silva Rocha and Ernesto Korrodi, both well known for the implementation of the *Art Noveau* style. This building was used a family residence until recent times, when vacant and closed, was bought by the Town Hall.

The architectural elements that follow this early 20th Century style, widespread through Europe, are best expressed in the stone compositions of the façades (Fig.1) and glazed tiles present both in the exterior (front porch) and on the first floor.

Figure 2. Glazed tiles from the front porch

These tiles, made in 1907, are attributed to the artist Licínio Pinto who worked in the Fonte Nova Factory and was responsible for many *Art Noveau* works in Aveiro. They depict natural scenes, with animals and vegetation, following the artistic standards of the time (Fig. 2).

Calcareous stone was used in both façades, in columns, arches and carved elements depicting flowers. The stone from the façade of Major Pessoa building is a Bajocian limestone from the Ançã - Cantanhede region, 50 km south of Aveiro, usually named "Pedra de Ançã". This limestone is fine and soft and shows a micritic matrix; it is easily workable and its application is very usual in decorative building elements, although it is highly susceptible to weathering. The columns from the backyard are made of Lioz like limestones (from the south of Portugal), they are very hard and suitable for structural elements, with a micritic matrix and sparitic nodules. On the ground floor, in the rear part of the building, granite stone was used to surround the basement doors.

2 STUDY AIM

The area where the building stands has a profusion of *Art Noveau* buildings, many of which present similar pathology patterns and some of which have been subject to previous interventions including cleaning and consolidation. With the aim of transforming this house into a Museum, the present study was requested in order to characterize the state of preservation of the house in terms of stone and mortar elements, identifying the main factors that had led to severe decay and forming a basis for *a posteriori* intervention.

3 STONE AND MORTAR DECAY-CHARACTERIZATION

The building has a small front porch, leading to the road, where decay is especially severe. This porch is particularly rich in *Art Noveau* elements, visible in the rounded shapes of the stone, and the floral elements carved both in the column capitals and in the arched doorway. All of the stone elements display decay , ranging from slight to severe.

The stone surrounding the main doorway has suffered interventions since its construction, visible in a layer of cement mortar that was executed over part of the stone (Fig. 4). The main pathologies present are identified as scaling (Figs 3 and 4), cracking (Fig.5) and granular disintegration (Fig. 6) (NORMAL, 88).

Figure 3. Scaling on calcareous stone

Figure 4. View of cement mortar layer between stone and lime mortar layer

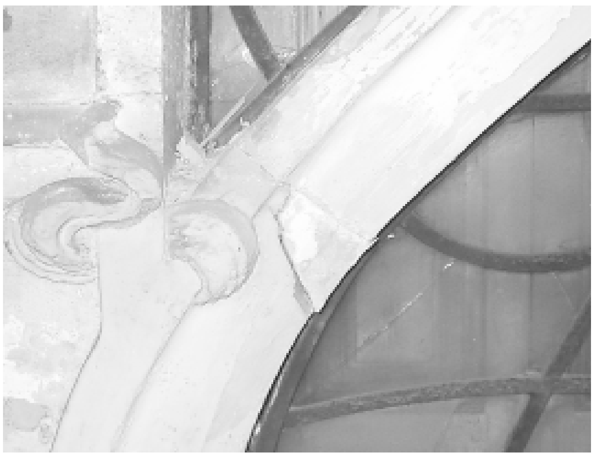

Figure 5. Cracking

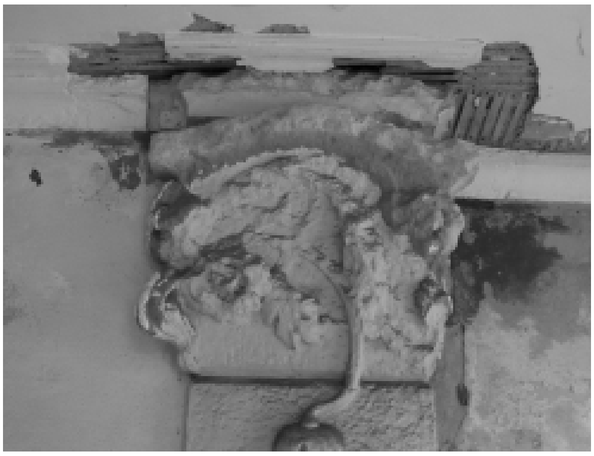

Figure 6. Disintegration

On the main façade, which overlooks the road, column capitals and corbels have evident black crusts (Figs 7 and 8).

Figure 7. Black crust

Figure 8. Black crust

The rear façade, leading to a small garden is not as richly decorated as the front. The use of stone is less abundant: calcareous stone was used on the first floor, surrounding windows (Fig. 9) and granite was used on the ground floor around doors. Both show signs of decay, as columns exhibit sanding and the granite is scaling.

Figure 9. Column granular esintegration

Mortar was used as a render both in the exterior and interior, over extremely heterogeneous walls, made from adobe, burnt brick and panelled walls filled with earth and lime. Renders on the main façade are in a good conservation state. However, this is not the case on the other side of the building, where the render is sometimes missing (Fig.10) and where cement mortars have been used as replacement mortars in some cases.

Figure 10. Areas of missing render

Glazed tiles from interior rooms situated on the first floor and possessing an extremely rich decoration were removed and supporting mortars (Fig.11) were studied.

4 SAMPLING PROCEDURE AND STUDY METHODOLOGY

Samples of both stone and mortar were collected, in order to include the various pathologies and different degradation states. Stone samples were removed from the following areas:

- samples of scaled calcareous stone were taken from the front porch representing two main zones: S1 (Fig.3) from areas with no

apparent prior intervention, S2 (Fig.4) of stone beneath and around intervention with cement mortar
- black crusts on the façade (surface samples), representing two distinct zones: S4 withdrawn from below the balcony (Fig. 7) and S5 collected from a decorated stone capital (Fig. 8)
- columns with accentuated sanding on the rear façade (S6, Fig. 9)
- granite scaled stone on the rear façade (S7)

Mortars, both interior and exterior generally presented a satisfactory state on preliminary visual observation. During sampling, the main façade mortars proved extremely sound; on the other face, however, lacks in small, punctual areas with posterior intervention using cement mortars were registered. A sample with various layers corresponding to different materials and/or interventions (M1, M2, M3) was taken from that façade (Fig. 10). A glazed-tile supporting mortar (M4) was extracted for analysis in order to provide information on its actual state and composition, allowing for the formulation of substitute mortar, if necessary.

All samples were subjected to x-ray diffraction (XRD) in order to obtain their mineralogical composition, and to atomic absorption spectroscopy (AAS) and Flame Photometry in order to determine soluble salt content. Soluble salts may not be detected by XRD analysis as they vary from crystalline to soluble states. Additionally, AAS is a helpful tool in the detection of nitrate salts that are usually in solution. In order to minimize damage to decayed materials, some samples were necessarily small. For that reason, AAS was performed only on a few samples.

SEM analysis was performed on stone and mortar samples as a complementary analysis, confirming stone and mortar composition and permitting the visual observation of crystallized salt formations.

Acid dissolution was performed on mortars in order to determine binder/aggregate ratios and particle size analysis was executed on the residue.

4 RESULTS

Results of XRD analysis are displayed in Table1 and Table 2 whilst AAS analysis results figure in Table 3.

Table 1. Mineralogical composition of mortars

Location	Mortar description/ Designation	Mineralogical composition
Rear façade Exterior	Exterior layer, probably cement mortar/**M1**	Quartz, K Felspars, Calcite, Plagioclase, Anhydrite, Gypsum, Dolomite, Siderite
Rear façade Exterior	Intermediate white layer, probably lime mortar/**M2**	Gypsum, Calcite, Quartz, K Feldspars, Thenardite, Halite, Anhydrite
Rear façade Exterior	Interior layer, yellowish/**M3**	Quartz, Calcite, K Feldspars, Anhydrite, Halite. Carnalite
Interior First floor	Mortar used for glazed tiles support/**M4**	Quartz Calcite K Feldspars Anhydrite

Table 2. Mineralogical composition of degraded stone

Location	Stone type/ Designation	Pathology	Mineralogical composition
Front porch	Calcareous/S1	Scaling	Calcite, Gypsum, Quartz, K Feldspars, Anhydrite, Rodocrosite
Front porch	Calcareous/S2	Scaling	Calcite, Quartz
Front porch	Calcareous/S3	Disintegration	Thenardite, Calcite, Mirabilite, Quartz, Gypsum, Argill.Minerals
Main façade Exterior	Calcareous/S4	Black crust	Calcite, Gypsum, Quartz, K Feldspars, Thenardite, Argill.Min.
Main façade Exterior	Calcareous/S5	Black crust	Calcite, Gypsum, Quartz, Anhydrite, Siderite
Rear façade Exterior	Calcareous/S6	Sanding	Calcite
Rear façade Exterior porch	Granite/S7	Scaling	Quartz, Plagioclase, K Feldspars, Micas, Gypsum, Anhydrite, Kaolinite, Siderite

Table 3. Chemical analysis

Designation	Cond. µS/cm	Cl mg	NO_3 mg	SO_4 mg	Na mg	K mg	Ca mg	Mg mg
S1	4520	840	333	2876	690	88	724	73
S2	1465	371	220	34	205	28	140	6
S6	1528	247	86	1174	135	19	412	7
M3	3190	683	370	728	373	61	451	9
M4	240	29	16	165	36	19	6	0

These analyses show the existence of a considerable amount of soluble salts in the exterior mortar M3, mainly chlorides and sulphates. This is also expressed in the XRD analysis, by the existence of gypsum, anhydrite, thenadite and carnallite in the various layers of the exterior mortar. Interior mortar M4 has few soluble salts and in mineralogical terms, it has the composition of a usual mortar with a calcareous binder.

Analyses show higher discrepancies between the various stone samples. Analysis by x-ray diffraction shows thenardite (Na_2SO_4) as the main mineral in sample S3. In other samples gypsum (or its anhydrous form, anhydrite) is the main mineral associated with the degradation process. Also thenardite co-exists in sample S4, taken from a black crust in the exterior. Mirabilite ($Na_2SO_4.10H_2O$), a form of hydrated thenardite is present only in sample S3, whilst siderite is present in low quantities in samples S5 and S7.

Chemical analysis also confirm a high quantity of soluble salts in stone, mainly as sulphates, chlorides and nitrates. This was particularly evident for sample S6, in which only calcite was found using XRD, but which shows the highest SO_4 content, indicating the presence of soluble salts.

Analysis of samples by SEM allowed clear identification of crystallized salts, such as the presence of gypsum needles in mortar M2 (Fig. 11).

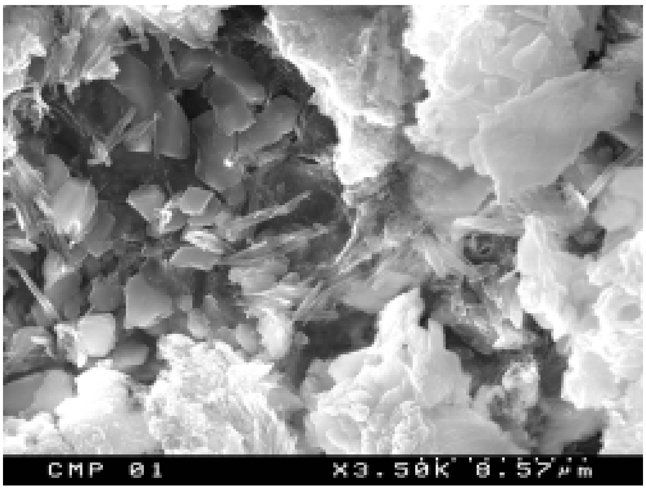

Figure 11. Presence of gypsum in mortar M2

Acid etching provided binder/aggregate ratios (in weight) of 79/21 and 71/29 for mortars M3 and M4, respectively. Similar patterns of particle size distribution were found on both samples and results for sample M4 are shown in Figure 12.

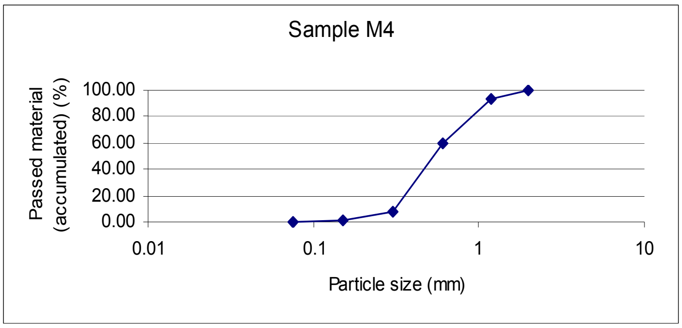

Figure 12. Particle size distribution of mortar M4

5 ANALYSIS OF RESULTS

The location of the house is an important factor in the understanding of the present decay. Aveiro is not distant from the sea and the land in between is used for salt extraction. The town is full of canals, one of which passes in front of Casa Major Pessoa. Additionally, the main façade looks over a road that nowadays carries considerable traffic.

Due to the height at which pathologies occur, effects of water by capillary action were not considered. Thus, the effect of atmospheric pollution and climatic factors must have a considerable impact on the prsent state of stone elements. Data from the University of Aveiro's climatic station, shows that temperatures in Winter months usually range from 5-15ºC, and in Summer from 15-25ºC. Humidity varies between 60% and 99% in Winter and 70% and 99% in Summer. An additional factor that might have influenced the deterioration process is the bad state of the roof, that for some time permitted continuous water infiltration.

The simultaneous presence of the minerals thenardite and mirabilite at disintegration sites, indicates that a transition between hydrated and non-hydrated phase might have a strong influence on decay. Some authors maintain that damage is caused by thenardite dissolution and precipitation of thenardite and mirabilite at temperatures below 32.4ºC (Rodriguez-Navarro 2000, Tsui 2003), in accordance with Aveiro's temperature range.

Black crusts are mainly composed of calcite and gypsum. Sample S4 contains thenardite and sample S5 contains anhydrite. As AAS was not performed on these samples, their nitrate content is unknown. However, the location of the house and mineralogic composition of crusts suggest a pattern similar to that of calcareous stones subject to air pollution and salt contamination (Aires-Barros 2001, Maravelaki-Kalaitzaki 1998).

5 CONCLUSION

Atmospheric pollution, with emission of SO_2 and NO_x particles into the atmosphere by traffic (Charola 2004, Primerano 2000) and NaCl present in maritime aerosol are, together with water infiltration and thermohygrometric conditions (Bernal, 2004), responsible for the various types of pathologies present in both mortars and stones on the external parts of the house. Different combinations of these factors due to a variable exposure in different parts of the stone and mortar elements have created unevenness in mortar contents of different salts. Thenardite is a typical result of the simultaneous action of maritime aerosol and traffic pollution on calcareous stones. Gypsum, usually a major component of black crusts, is mainly due to the effect of air pollution on rocks. The co-existence of NaCl and gypsum favours the dissolution of this latter mineral, creating a process of solubility and precipitation in a high relative humidity range of 75% to 100% (Aires-Barros, 2001), which is quite typical of the Aveiro region. Dissolution/precipation are the causes of tensions formed inside the stones leading to their decay, that is rapidly increased if *in situ* conditions are maintained and no intervention is performed.

Substitution of extremely degraded stone is inevitable and consolidation procedures must be considered, although they pose a delicate problem when dealing with calcareous stone (Canas 2003, Rodrigues 2001).

Mortars were briefly characterized for possible substitution, which may be necessary due to their high salt content.

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