

## **REHABILITATION OF RENDERS OF OLD BUILDINGS IN PORTUGAL: SURVEY, SUPPORTING METHODOLOGY PROPOSAL AND CASE STUDY**

### **STRUCTURED ABSTRACT**

The main purpose of the research is to present a proposal for a methodology to support the rehabilitation project of renders of old buildings in Portugal. To achieve the objective it was considered essential to define the main types of participants and aspects to integrate the proposal. The research methodology consists in an inquiry presented to professional participants in rehabilitation, a market study of materials and products available in Portugal, the design of a methodology proposal and its application to a case study. The inquiry sample totals 24 answers from the targeted professionals. A sequence of relevant supporting procedures consists in the proposal, which aims to provide a supporting methodology to decide and project in this context and also to be tested with its application to the building. This proposal was applied to an old building with load-bearing stone masonry walls and air-lime based renders.

It was concluded that the assessment of the building and external renderings' condition, its diagnosis and of the supporting walls, the definition of intervention, the specification of materials to be used and performance requirements to comply, and also plans for conservation and periodic maintenance, are crucial. From the inquiry, compatibility between materials and complementary roles and points of view of different types of participants in rehabilitation must be highlighted. A proposal for a methodology to support the project could provide useful guidance particularly for architects and construction engineers, and improve the understanding of direct participants on site, therefore contributing for the correct implementation of intervention.

**Keywords:** rehabilitation, conservation, old building, render, supporting methodology, project

## INTRODUCTION

The rehabilitation of old buildings is seen as necessary or, at least, as sufficient intervention actions to their appropriate safety, functionality and comfort, with respect to its architecture, type and construction system (Appleton, 2011; Doehne and Price, 2010; Freitas, 2012). Portugal subscribed substantially relevant charters and international recommendations in this context: the Athens Charter (1931), Athens Charter for the Restoration of Historic Monuments; the Venice Charter (1964), International Charter for the Conservation and Restoration of Monuments and Sites; later, the Burra Charter (1999), Australia ICOMOS Charter for the Conservation of Places of Cultural Significance; Cracow Charter (2000) referring to the Principles for Conservation and Restoration of Built Heritage (Román, 2002); and ICOMOS Charter (2003) referring to Principles for the Analysis, Conservation and Structural Restoration of Architectural Heritage. These charters express a clear recognition of the intrinsic value of the constructive building system together with the architectural, historical and artistic values, while a good practice of rehabilitation or conservation and the necessary involvement of multidisciplinary teams are deemed as very important (Appleton, 2011; Freitas, 2012).

The building should be understood as a whole and not as a sum of parts, some to keep and some to demolish. Much of the degradation of old buildings is not the result of low quality construction or materials used but of lack of proper maintenance and a neglected approach. Associated with the concept of rehabilitation, the authenticity in form, function, prior use, exposed surface, materials and structure of buildings is also an important factor. In line with the guidelines contained in the charters and international conventions, certain criteria must therefore be followed on keeping the safeguard of a building, such as its effectiveness, compatibility, durability, reversibility and also efficiency. In a less intrusive intervention, particularly in architectural heritage, the safeguard of a building authenticity on compliance with regulatory requirements of safety and comfort should be clear (Dester and Blockley, 1995; Freitas, 2012; Holmstrom, 2000).

Today in Europe and particularly in Portugal, the rehabilitation of monumental heritage and current old buildings is of fundamental importance on the need to provide answers to specific problems of society, as a result of changes over time in the different types of interventions developed within the engineering and architecture fields of knowledge. To design and achieve the best and most suitable solutions, the study within this scope requires the confluence of efforts of a group of specialists in several scientific areas and it also requires a multidisciplinary knowledge of professional participants in the complex exercise of conservation and rehabilitation of buildings (Freitas, 2012; Veiga, 2009).

The exterior wall renders have an important role in the conservation of buildings because their main requirement is the protection of masonries, exercising a decisive influence in its major properties and functionality. They also constitute an aesthetic value related to architecture and have a considerable impact on the constructions' image. However, being very exposed elements they are strongly subject to degradation agents (Gaspar and Brito, 2005; Mosqueraa *et al.*, 2002; Rodrigues *et al.*, 2011; Watt, 1999).

When degraded, the option of conservation of ancient renders must consider some factors such as their historical and architectural value, state of conservation, historical authenticity of existing materials

and availability of resources for its implementation, relating with the scope of sustainability, economy and durability (Arizzi *et al.*, 2012; Cultrone *et al.*, 2007; Flores-Colen and Brito, 2012; Veiga, 2003). The study of ancient renders also allows the knowledge about the history of the building. On one hand, materials, techniques, textures and colours, and, on the other hand, the proper global functioning of walls resulting from compatibility between materials and constructive solutions, are not just part of history and collective memory, but they constitute important objects of study of the history of materials and construction technologies, being values that should be uphold and preserved (Flores-Colen *et al.*, 2006; Groot *et al.*, 2000; Veiga, 2003).

A correct and effective intervention on wall renders of old buildings requires a mastery of certain aspects: (i) knowledge of the existing renders, their composition and state of conservation, as well as the corresponding load-bearing walls; (ii) knowledge of the possible intervention strategies, mastery of applicable techniques and apprehension of criteria that supports the option; (iii) knowledge of suitable, effective and durable repair solutions; (iv) evaluation criteria of compatibility, suitability and durability of repair solutions and (v) maintenance plans of existing solutions (Veiga, 2009).

The interventions in renders of old buildings must be based on functional requirements and be as less intrusive as possible, respecting scientifically defined criteria and selecting both the techniques and the materials according to compatibility requirements (Faria Rodrigues and Henriques, 2004; Faria Rodrigues *et al.*, 2008; Schueremans *et al.*, 2011; Veiga *et al.*, 2004; Veiga *et al.*, 2010). Following the identification of the original rendering mortar general composition and its mechanical and physical properties (different from the original ones), it is important to include in the project the characteristics of the repair or substitution mortar to apply. It is essential to analyse its compatibility with the load-bearing wall (often constituted by rubble stone masonry, with high percentage of mortar) from a mechanical, chemical, physical, geometric and aesthetic point of view, to maintain suitable levels of performance (Arizzi and Cultrone, 2012; Hughes and Válek, 2003; Stefanidou and Papayianni, 2005; Válek *et al.*, 2000).

In this context, it is therefore important to revive the traditional technologies within air-lime mortars from different points of view, among others: (i) constructive, for natural compatibility with the old constructions and their constructive techniques; (ii) aesthetic, to ensure harmony with traditional surroundings in a vernacular way and (iii) historical, to provide historical and social continuity to the interventions (Aguar, 2001).

The correct characterisation of the state of conservation of mortars, as well as type and severity of the degradation, are of major importance to a correct decision regarding the type of intervention to implement (Gaspar and Brito, 2005; Van Hees, 2000). Faced with an existing render, a decision must be taken, based on scientific criteria, regarding to which strategy should be adopted: (i) conservation; (ii) specific repair with use of materials and technologies similar to the pre-existing components; (iii) substitution requiring the use of compatible materials and technology.

Therefore, the conservation and rehabilitation of old buildings require a good knowledge of renders within lime mortars and their masonries. The study with regard to the state of conservation of buildings

and particularly of its wall renders allows to obtain essential indications regarding the strategy to be adopted and the materials and techniques to be used, suitable for the intended intervention, appropriate and effective. A design project must be the basis for the whole conservation and rehabilitation process and the different stages must be carefully planned and implemented (Veiga *et al.*, 2004). This paper proposes a clarification of the relevant criteria and procedures that should be followed at the stage of conception, considering the compatibility of the various wall constituents of old buildings and their rendering mortars.

Several supporting methodologies to the rehabilitation of old buildings, refer to the anomalies on the construction, its state of conservation (Leitão and Almeida, 2004; Rodrigues *et al.*, 2011) and the inspection and diagnosis, as well as the intervention of rehabilitation in constructions (Dekker, 2004). More specifically concerning the mortars and renderings, there are various regarding the study and characterisation of old mortars (Arioglu and Acun, 2006; Barbero-Barrera *et al.*, 2014; Veiga *et al.*, 2004) and the evaluation of exterior wall renders (Veiga, 2009). Nevertheless, these methodologies are generally for a diagnosis and an intervention on the building or specifically for an analysis and characterisation of old mortars. Thus, there is a need to develop a proposal for a methodology which embraces the complete process of a rehabilitation project of renders of old buildings, from general to particular.

Based on the integrated understanding of rehabilitation intervention in an old building, with load-bearing stone masonry and air-lime based renders, the work presented in this paper has as main objectives: (i) the definition of the relevant aspects to the rehabilitation of renders of old walls, relying on a comprehensive survey addressed to several groups of professional participants; (ii) the presentation of a proposal for a methodology to support the rehabilitation project of wall renders of old buildings; (iii) the application of the proposed methodology to a case study. Technology, performance and durability of renders in construction and especially material compatibility are the scope of this work. The acquired and systematized knowledge during the work development permits an overview of the problem and a suitable and applicable methodology proposal. These aspects are relevant to the methodological approach of various professional participants in rehabilitation of old buildings and hence are worth the investigation about this subject.

## **RESEARCH METHODOLOGY**

The definition of the main types of participants and aspects for rehabilitation and conservation of old building renders to integrate the proposal is essential for the research. The research methodology consists in an inquiry presented to several professional participants in rehabilitation, a market study of materials and products at a national level in Portugal, the establishment of a methodology proposal and its application to a case study. Based on the state of the art and the related research after contact with participants, the proposal aims to provide a supporting methodology to decide and project in this context, consisting in a sequence of relevant auxiliary procedures.

## **Analysis of procedures used by professional participants and market study of materials and products**

The first step of the research methodology is presented, consisting in an inquiry to several professional participants covering the best practices and main concerns about the procedures applied by them when designing the project or implementing the intervention, in order to obtain a comprehensive assessment in terms of state of practice of those directly involved in the process of rehabilitation. This step is crucial to contribute in a significant way for the building up of the proposal for a methodology to support the project of rehabilitation of wall renders of old buildings.

Based on the studies presented in the previous section, the identification of the relevant aspects for analysing the building, the definition of type of intervention in wall renders, the identification of the relevant participants in terms of rehabilitation, the selection of the sample for the study and the validation of these aspects need to be performed. The inquiry was build up based on these aspects in order to categorize the procedures performed by the selected participants in the rehabilitation and conservation of old buildings. It included questions from general to particular, embracing each step of the approach, project and intervention of rehabilitation of renders of old buildings.

The groups of professional participants in rehabilitation (and respective number of answered inquiries) in the sample include: (i) architects (5); (ii) engineers (1); (iii) project managers (3); (iv) conservator-restorers (3); (v) technical consultants (6); (vi) promoters and construction owners (4); (vii) construction site managers and contractors (6) and (viii) suppliers and producers of construction materials (9). The sample totals 24 answers from the targeted professionals. Some of these participants are included in more than one category (Figure 1).

From this sample, one can conclude that, not surprisingly, people involved in the rehabilitation of old buildings agree in the majority of the procedures. The specification of materials and their adequacy to the project and the construction, as well as the evaluation of the state of conservation of the building walls and of their renders were the two common aspects answered by the majority of the participants regarding their importance for the intervention in conservation and rehabilitation of old renders. The availability of resources, materials, techniques and labour was the least consensual among the participants but still more than half of the collected answers.

All the professionals answered that the type of anomalies is the most important aspect in the process of characterisation of the state of conservation of renders. This characterisation is of great importance for a sensible decision on the type of intervention to perform, according to Veiga (2003). Furthermore, the thickness, type and number of the layers of the renders for characterisation at a later stage are the most important aspects that the team designing the project should identify when defining the actions to be performed, followed by the set of tests to use. Slightly more than a half of the sample also chose the application points, while only 30% referred the tests phasing as the most important, especially construction site managers and contractors (Figure 2).

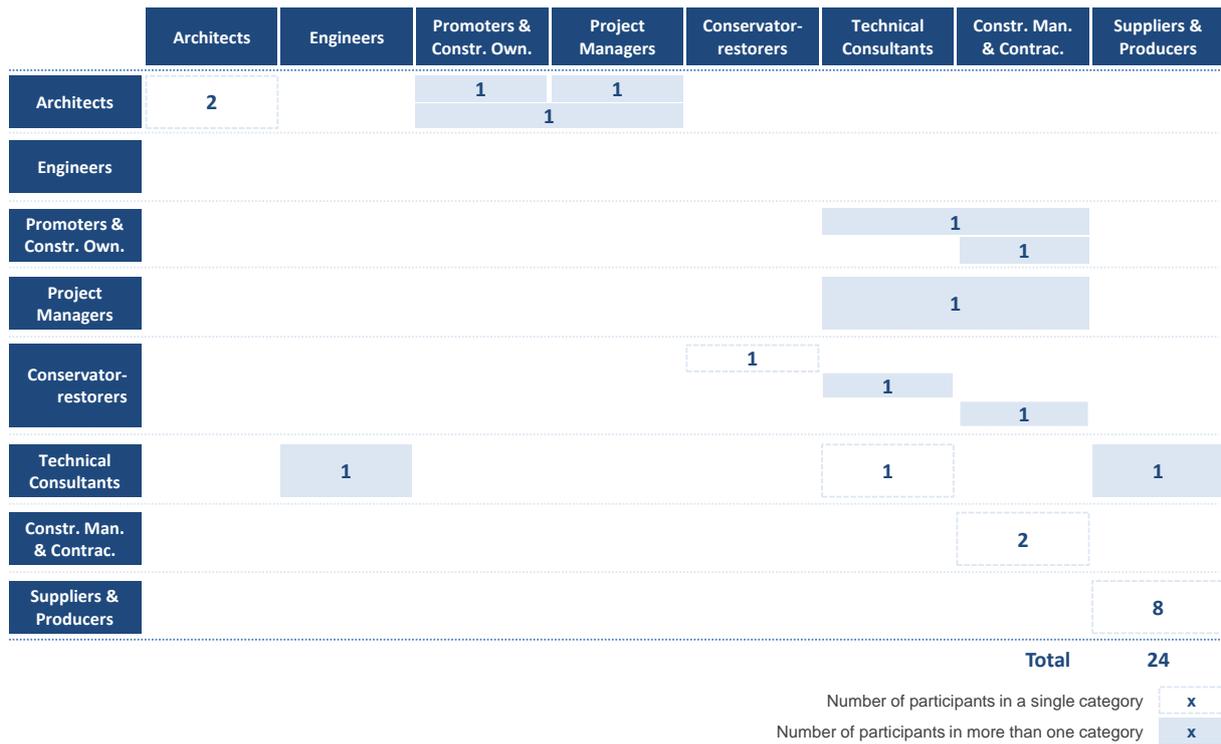


Figure 1 - Sample of professional participants in rehabilitation by category

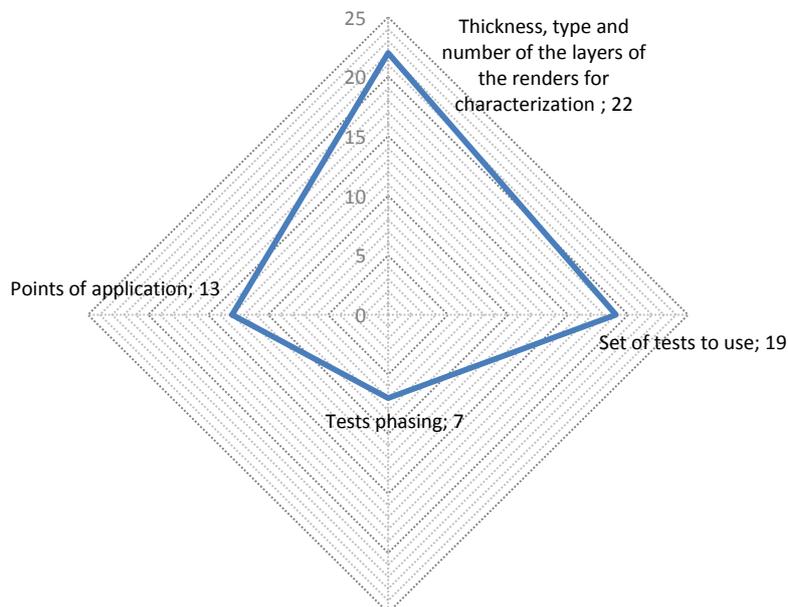


Figure 2 - Aspects pointed to be identified by the team designing the project when defining the actions to be performed

Regarding the use of experimental techniques for the characterisation of the building walls and the renders, the majority said they assess physical and mechanical properties using *in situ* tests on the old render, more common when compared to laboratory tests (Lanas and Alvarez, 2003). From the *in situ*

tests, the majority classified the moisture of the load-bearing walls and their deformations as very important or important.

It is positive to note that the majority of the professionals in the sample (87%) confirmed that they always, or at least regularly, include drawings and specifications having taken into account the nature of the load-bearing wall, exposure conditions and also the requirements, type of rendering and finishing in the project. The participants that answered positively to this question are architects, engineers and technical consultants, as expected, as they develop a better understanding of the process and a better quality assurance of further implementation of the intervention by the participants directly involved.

There is no clear preference between ready-mixed products or traditional products dosed on site. However, architects, technical consultants, conservator-restorers and promoters and construction owners rather use the latter method, which demonstrate not only their concerns and choices for what is traditional and adapted to the specificities of the render and the particular job but also the lack of specific or adequate ready-mixed solutions, at least for their knowledge. Although the results of the inquiry show that architects/technical consultants/conservator-restorers and promoters/construction owners prefer using traditional products, it is recognised that in practice sometimes the interests of these two groups (technicians and promoters/construction owners) are not convergent, mainly due to different budgetary and timing restrictions or concerns in quality of interventions. On the other hand, suppliers and producers of construction materials choose ready-mixed products, as expected in particular because of the short time of the works nowadays and which are easy to apply. It should also be highlighted that, for 30% of the sample, the choice depends on the specificity of the situation and intervention. To note that the prescription for volumetric ratio is very limited, contrary to the intended prescription, the performance requirements specification, for example according to EN 998-1:2010 (*Specification for mortar for masonry - Part 1: Rendering and plastering mortar*) that is the basis for CE Mark for ready-mixed products.

All the professionals said they always, or at least regularly, specify the materials and products to be used, which is seen as positive to ensure an adequate project and correct implementation of the interventions. However, this situation demonstrates prescriptive specification instead of performance specification, which would be more directly linked with the real behaviour on site. It would attribute more responsibility to the construction site managers and contractors (workers directly involved in the job) in putting in place the requirements previously defined by the architects and engineers of the project than with the typical technical characteristics of the material *per se*.

Including a technical data sheet in the specification for quality control and warranty of the work does not seem to be a common understanding among the different professionals in the sample, even within the same group of participants, although the majority (67%) has answered positively to this question. The variation in the answers can lead to think that the usefulness and importance given to this element is open to challenge among respondents, mainly technical consultants, promoters and construction owners, as well as construction site managers and contractors.

It is shown that in the specification of the material or product, 96% of the professionals agreed on the importance of identifying its scope of application. Among the respondents, this was the criteria most commonly considered, as opposed to its cost, deemed as less important, although this also has relevance in the process. Suppliers and producers of construction materials, as well as construction site managers and contractors, did not choose the volumetric binder:sand ratio of mortars as an important criterion. This is due to the fact that these groups had previously showed their preference for ready-mixed mortars or products. To note also that 61% specify the composition of the mortar to use, and frequently the volumetric ratio, in the case of mortars dosed on site. From the study of old renders the authors know that the constitution of their regulation and protection layers corresponds, for example, to lime mortar and sand with the volumetric binder:sand ratio between 1:1 and 1:5 of air-lime:sand, according to Flores-Colen and Brito (2012). However, the question remains among the participants for the recommendation of the volumetric ratio. All these professionals said they also include a technical description of the technologies to use in the application.

Moreover, from the professionals who chose the products dosed on site the majority (62% of the answers) always (“yes”) or “regularly” prescribe the application of more than one layer (Figure 3). Instead, ready-mixed products have additions and adjuvants that allow the application in just one layer. Although the reasons chosen to do it vary among the professionals, the majority agrees that it can prevent cracks due to shrinkage, except suppliers and producers of construction materials. One of the reasons for making traditional renders with more than one layer results from the fact that, if only one would be applied, the characteristics required are not fully achieved, including the low tendency to cracks due to shrinkage. Additionally, the European standard EN 13914-1:2005 (*Design, preparation and application of external rendering and internal plastering - External rendering*) recommends aspects related to the conception, preparation and application of rendering mortars, which states that these renders must be composed of at least two layers.

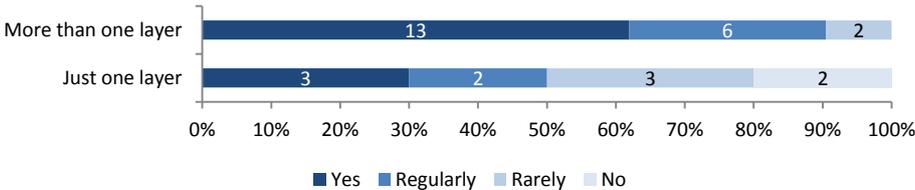


Figure 3 - Specification and implementation of external renderings

Some of the architects and engineers said they do not use the applicable standards regularly. This should be corrected in terms of the implementation of interventions in old buildings, as well as the project itself. Certain international and national standards and technical documents are applicable in this scope and should be consulted and verified, which can be related to the role of each professional to the construction site. The most important can be highlighted: EN 13914-1:2005 mentioned above on lime based rendering mortars, EN 998-1:2010 (*Specification for mortar for masonry - Part 1: Rendering and plastering mortar*) relative to mortars for masonry and mainly relevant for architects and engineers, and also EN 459-1:2010 (*Building lime - Part 1: Definitions, specifications and conformity criteria*) on building limes mainly important for constructors. In the inquiry it is shown that

suppliers and producers of construction materials, as well as architects, are within the 10% of the professionals in the sample that do not specify the requirements that the external rendering has to fulfil. This consists in a negative aspect as this last group of professionals is the one that should define and specify the requirements for the render in order to ensure that it is compatible with the performance demanded for the product or material. Apart from the general knowledge of the tests to perform or to order them, architects and engineers should have competences on how to correctly specify building materials and products and how to prevent damages. On the other hand, in the case of suppliers and construction site managers, the knowledge of requirements and testing standards is important and should be compulsory.

The consensus among the majority of the professionals in the sample around the criteria of compatibility of renders listed in the questionnaire confirms their importance. With regard to the factors that strongly influence the physical structure, performance and durability of mortars, its interaction with the load-bearing wall is the most commonly answered, followed by its method of preparation (Figure 4).

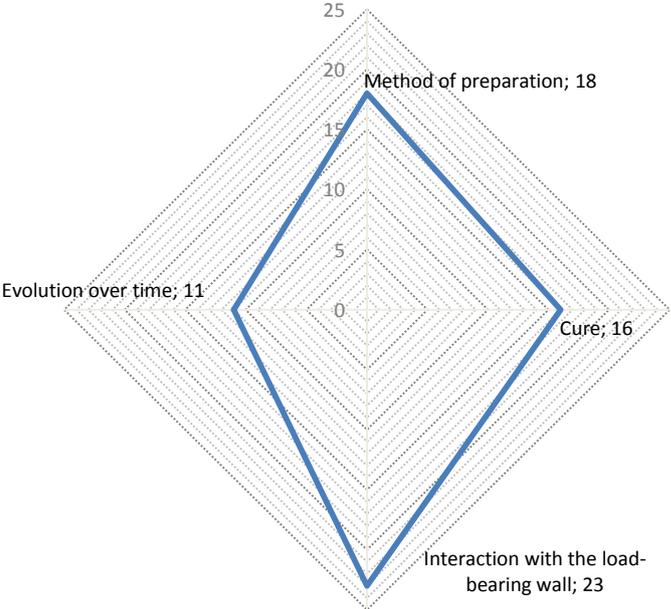


Figure 4 - Factors pointed as influencing the physical structure, performance and durability of mortars

To note that, although some isolated cases of professionals have mentioned that the substitution of the renders is often desirable, the majority agree that their conservation is the best and most favourable option in terms of durability, functionality and economy, emphasized by Veiga (2009).

At last, although the majority of the professionals covered by this sample consult several sources of information in terms of best practices of project and intervention, some still do not do it regularly. Hence, this aspect can be somehow compensated and eventually solved with the existence of a supporting document to the project that would enshrine the methodology or model to perform a correct rehabilitation of wall renders in old buildings, which should be used by all the relevant people involved. The purpose of this investigation is to actively contribute to structure and develop this methodology to be applied in practice. Thus, the next section is dedicated to the design of the proposal for the

methodology and its application to a case study in order to test and study its applicability and importance.

Concomitantly, it was also developed a market study of traditional materials and ready-mixed products in Portugal, including the identification of their producers and brands presented in the national market, as well as the description of their constitutions, properties and fields of application, according to information of the producer. It was concluded that binders and additives are traditional materials (used directly *in situ* or in ready-mixed materials) whereas mortars for renders as well as products for finishing coatings are ready-mixed products (Figure 5). In the application of the proposed methodology to the case study, in a further section, the specification of materials and products is also based on this market study.



Figure 5 - Market study of 28 specific traditional materials and ready-mixed products for repair of old renders

**Proposal for a methodology to support the project**

The main objectives of the methodology proposal are to structure and synthesize the relevant procedures for rehabilitation of renders of old building walls and constitute a support to the project in this scope. Regarding the study of the state of conservation, particularly of renders, it provides fundamental indications for the strategy to be adopted and the materials and techniques to be used in interventions. Considering the compatibility of different wall components and their rendering mortars, relevant criteria and procedures should be followed at the conception stage; therefore a clarification has been proposed. The diagram in Figure 6 summarizes the process.

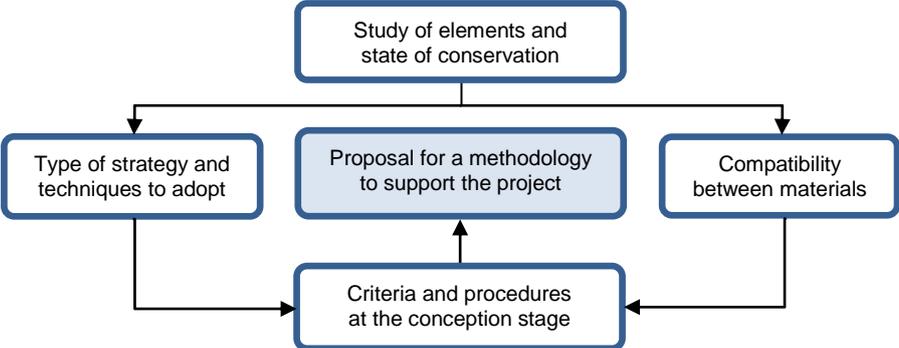


Figure 6 - Process for the development of the proposal for a methodology to support the rehabilitation project

The methodology proposal is based on the state of the art (Appleton, 2011; Arioglu and Acun, 2006; Freitas, 2012; Van Hees, 2000; Macmillan *et al.*, 2002; Veiga, 2009; Veiga *et al.*, 2004) and the related research after contact with different types of professional participants in rehabilitation specifically by the inquiry, as well as its critical analysis. This allows to establish priorities and to validate and complement the main supporting procedures to an intervention on old renders.

Thus, for this purpose, a proposal may be presented in the form of checklist with verification points of the important procedures to be followed when applicable and possible. The main steps included in that proposal are presented in Figure 7.

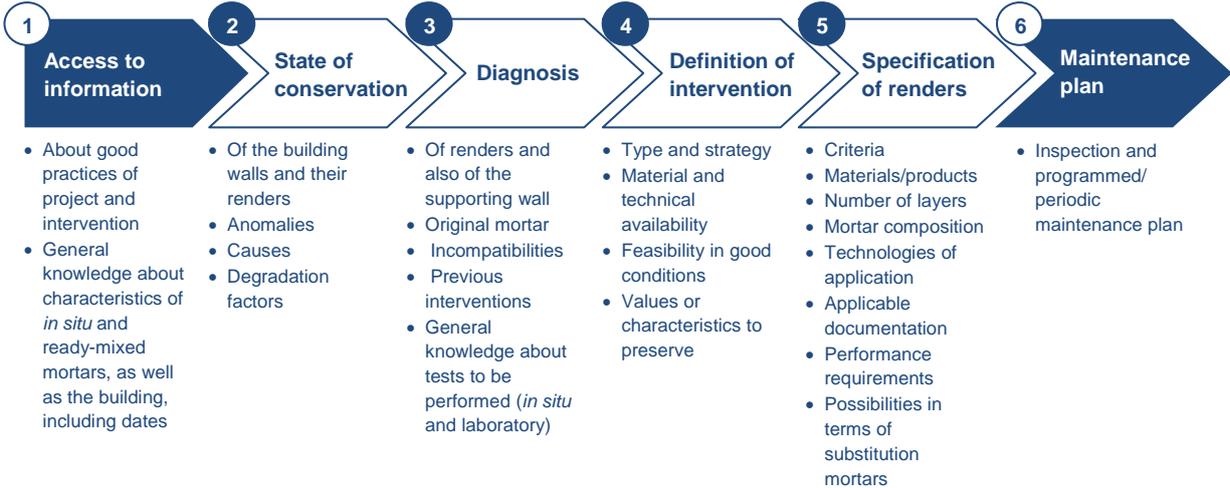


Figure 7 - Main steps of the methodology proposal

It is worth highlighting that prior to the renovation of renders it is essential to guarantee the structural stability of the supporting walls as well as the state of conservation of some construction elements which can origin greater anomalies mainly related to waterproofing, e.g. the roof. These aspects are included in both the second and third main steps of the proposed methodology (Figure 7): state of conservation and diagnosis. To note also that regarding the fifth step of the same methodology it is recommended to adjust the specification of renders to the experimental tests of the new mortars to apply.

The methodology proposal can be applied particularly to buildings within the scope of this paper. It fulfils its objective and, therefore, constitutes a supporting model to decide and project. The procedures proposed can be adjusted depending on the building and its wall renders.

**Application to a case study**

Having defined the methodology proposal to be implemented, the next step consists in its application in regard to the rehabilitation project of a case study: the Astronomy Observatory of the Lisbon Polytechnic School. Its old exterior wall renders, its historical and artistic value, as well as a major architectural potential, in addition to several anomalies which can be identified and typified by study and inspection prior to the rehabilitation justify its selection as it fits in the type of buildings within the scope of this work. The choice of this building is also due to the fact that the first author was actively

involved particularly in the initial phase - survey and inspection - and subsequent steps of the project when playing several roles in the architecture studio co-responsible for the rehabilitation project of the building. Throughout the survey and inspection, the author gathered *in situ* a set of various elements which is believed to bring an important contribution to enrich the present research.

The application of the methodology proposal begins with the access to information about good practices of project and intervention, as well as specifically about the building, which correspond to the first point of the proposal. The Astronomy Observatory is one of the heritage values of the Science Museum belonging to the old Faculty of Sciences and it is implanted in the Lisbon Botanical Garden (1873-1878). The original building (1875-1877) early started to show evidences of deterioration, mainly due to structural problems, with appearance of cracks at various locations, due to its construction on a foundation location formed of landfills. The threat of ruin was the reason to demolish the building in January of 1897 and reconstruct with a setback of eighteen meters from the adjacent wall. This building, the only Observatory for Education from the nineteenth-century still existing in Portugal, maintains the structural and constructive system of that period. Nevertheless, the building is in an advanced state of degradation, today being at risk for absence of funding for its rehabilitation. The main construction elements of the building that fall in the scope of this work are load-bearing masonry walls in irregular rubble stone and air-lime mortars. Regarding its renders and finishes, masonry walls with smooth finish of water-based paint can be highlighted (Figure 8).



Figure 8 - Views of the main façade of the Astronomy Observatory

The application of the proposal for a methodology to support the project consists in the implementation of its main steps presented in Figure 7, namely: (1) access to information about good practices of project and intervention, as well as specifically about the building; (2) evaluation and characterisation of the state of conservation of the building and its wall renders; (3) diagnosis of renders particularly through visual inspection; (4) definition of type and strategy of intervention to adopt; (5) specification of renders and respective materials or products and, in some way; (6) the determination of conservation and suitable periodic maintenance to the exterior walls of the building.

Essentially for the evaluation of the geometrical characteristics of the structure and for the general identification of its materials and any pathological symptoms, the visual inspection, either simple or supported by optical devices that enhance the visual capacity, is the simplest type of inspection, which was used in the application of the proposed methodology to the case study. The planning of inspections and tests depends on the reasons that make it necessary and their circumstances,

whereas the number of tests to be performed depends on the diversity of elements for characterisation, the unitary cost of testing and the time needed to perform those tests. Therefore, and as they are very specific, *in situ* and laboratory tests were not conducted in the application of the proposal to this case study. The working methodology comprises the study of the selected building, as well as the previous interventions on it, the access to the architectural project of the two co-responsible studios “Falcão de Campos Arq.” and “Appleton e Domingos Arq.” in 2011, the contact with these and other project designers, personal experience and consultation of technical specialized bibliography.

The Astronomy Observatory has a great value at historical, scientific, iconographic and architectural levels. Notwithstanding, the existence of relevant anomalies can be noticed in the construction due to lack of maintenance, problems involving the use of the building and incorrect interventions. The main problems identified in the building are due to lack of maintenance of the constructive envelope (roofs, walls and spans), thus is detectable the lack of maintenance of exterior renders and paints. The efficiency as protector of the masonries and, consequently, of the walls against external actions, as the case of water from the soil and from rain, and the improvement of the image of the building are the renderings’ functions mostly affected. Thus, an intervention on the renders is very relevant not only as an improvement on the exterior of the building but also as a way of decreasing the moisture on its interior which often result in many indoor anomalies and hydrothermal defects.

Regarding previous interventions on the renders and finishes of the walls, there have been various changes across the building; almost all internal and external renderings were replaced. The authenticity and the technical and decorative value of the original air-lime-based wall renders had a major role in the building. However, the actual external renderings are cement-based, different from the traditional type of solution, which in a building with walls based on rubble stone and air-lime masonry mortars involves problems of incompatibility. In the same way, it can be observed in different situations from the exterior that incompatible paints were used, because of its excessive impermeable properties to water vapour. Both constitute inadequate solutions to the type of masonries and raise incompatibility issues with the construction, resulting on anomalies and consequently a later generalized deterioration (Figure 9).



Figure 9 - Anomalies on the façades of the Astronomy Observatory - Southwest view (left) and East view (right)

Based on the evaluation of the state of conservation of existing external renderings and the importance of materials and techniques used in walls, the type and strategy of intervention to adopt has been defined and should consist of their substitution for mechanical, physical and chemical compatible renders with the load-bearing walls, based on air-lime similar to the originals, as well as the use of compatible paints. Therefore, the traditional materials specified are air-lime and additives that confer hydro attributes, with the composition of 1:3 as the volumetric binder:sand ratio of mortars, whose specification was based on the above mentioned study of the Portuguese market of materials and products (Figure 5). Their technical requirements are mainly related to durability, which implies not only a good mechanical strength, internal cohesion, adherence both to the supporting wall and between layers (but not in excess) as well as good chemical resistance to the salts present in old walls, but also a good behaviour related to relatively slow water absorption, drying facility and further biological colonization resistance. The methodology proposal for an intervention regarding the exterior wall renders of the building aims at achieving the reestablishment of appropriate performance levels throughout its life cycle.

By following the majority of the proposed steps (Figure 10), the application of the methodology proposal to the case study allows for the conclusion that this is indeed not only feasible but also an important support to the conception of the project with quality and, consequently, the definition of the correct intervention of rehabilitation on renders of old buildings. A complete methodology is proposed although it can also be adjusted to the type of building, its state of conservation and specificities by adapting certain indispensable points of a correct intervention in the wall renders to the particular case. Analysing the application of the methodology proposal to the case study, it should be highlighted its feasibility and applicability, which also enhance the importance of its existence as a supporting model to improve the quality of both the project and the implementation of the intervention which should always be guaranteed.

The existence of a model or methodology to support the project, for example the presented proposal, would become very relevant and productive at different levels within this context; it would also provide a better quality of interventions of rehabilitation and conservation of renders of old buildings. First, it can constitute a support in particular for design architects and engineers to follow a possible guidance and verify the applicability of various procedures to the particularity of the building. Furthermore, providing projects with necessary and appropriate specifications can also improve the understanding of direct participants on the construction site and contribute for the correct implementation of intervention. This is a crucial aspect within the rehabilitation and conservation of this type of buildings.

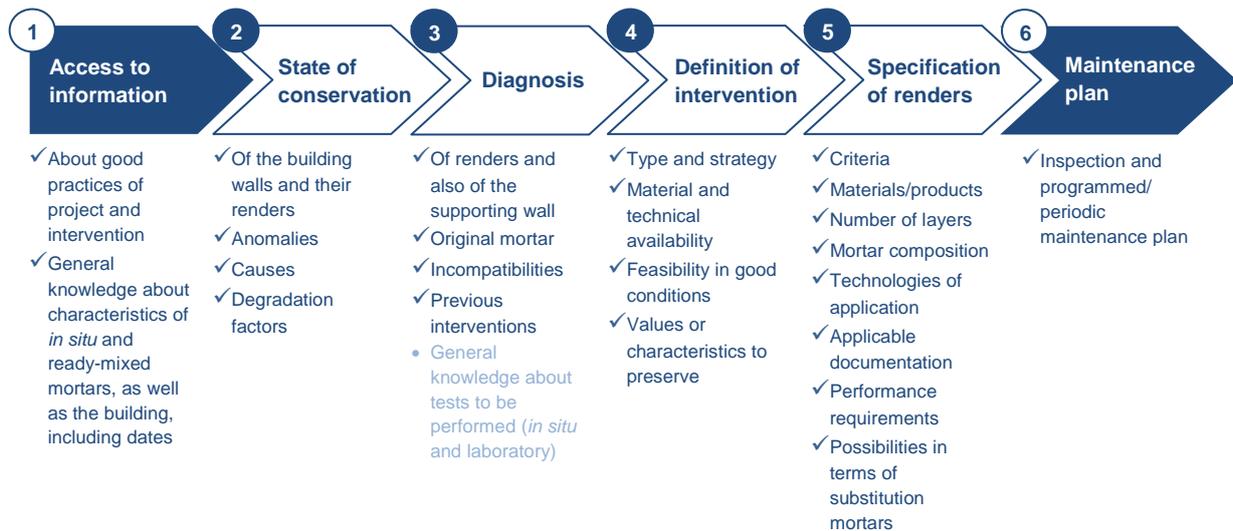


Figure 10 - Steps followed in the application of the methodology proposal to the case study

## CONCLUSION

The work presented in this paper is intended to promote a critical approach to the process of rehabilitation and conservation of an old building, consisting in a starting base for the development of an effective approach on site. This study is also intended to bring a contribution to optimize the process of characterisation, diagnosis and intervention at some stage of the rehabilitation of old buildings with an adequate approach, a proposal of relevant procedures and an applicable methodology.

It should be mentioned that this research included an inquiry to several professional participants (Figure 1) and a study of materials and products offered in the Portuguese market (Figure 5), which proved to be of relevant importance for this investigation. On the one hand, the inquiry contributed to validate the relevant procedures to the rehabilitation of renders of old buildings used by professionals and define priorities in order to propose a methodology. On the other hand, the market study allowed to have a comprehensive understanding of the set of materials and products available in Portugal, concluding that binders and additives are traditional materials whereas mortars, renders and finishes are ready-mixed products. Based on this investigation, it was concluded that when designing the rehabilitation project there are several steps that constitute crucial procedures, particularly for old renders. It is the case of the diagnosis and assessment of the condition of the building, of its external original and existent renderings and of the supporting walls, the definition of the intervention, the specification of materials to be used, as well as the performance requirements to comply with, and also the plans for conservation and periodic maintenance.

The process followed above allows to conclude on the importance of compatibility between materials, as well as on the complementary roles and points of view of different types of professional participants in the rehabilitation and conservation, hence contributing to design a proposal of an accurate supporting methodology with the relevant procedures to be applied in the project of conservation and rehabilitation of old buildings (Figure 7). This is another important contribution of this investigation.

To test the applicability of the methodology proposed, the authors chose an existing old building as a case study (Figure 10), which has proved its accuracy and importance to the identification and design of an adequate intervention, the correction of inefficiencies of the wall renders, as well as the improvement of the quality of both the project conception and the implementation of a correct intervention. It was proved that the existence of an integrated supporting methodology to the project, as proposed, can provide an appropriate and useful guidance for its correct application and procedure, particularly for architects and construction engineers. Moreover, the methodology proposed in this paper can also improve the understanding of direct participants on site and the correct implementation of the intervention.

From this research, there are still three main aspects that should be further developed in future investigations. First, the extension of the inquiry to a larger number of professional participants in the rehabilitation of wall renders of old buildings may bring additional robustness to the conclusions of the survey. Then, implementing the methodology to a broader set of buildings requiring intervention in the renders and testing its efficiency in supporting the process may prove to be important for the improvement of the methodology by widening the range of buildings covered in the tests and taking into account different types of conservation. In particular, the methodology could be applied to different buildings with distinct state of conservation and intervention in terms of wall renders, wherein the following types of situations can be highlighted: (i) other old buildings and/or monumental heritage which need to be rehabilitated, in order to understand the differences between them according to the specific needs; (ii) buildings that are being rehabilitated and where there is the possibility to compare the procedure followed with the application of the methodology; and (iii) buildings that have already been rehabilitated and where the comparison of the performance and the identification of possible improvements are relevant in case a complete and proper methodology to the project had been integrated and followed in a consistent way. Finally, the influence of renders in other constructive elements and interventions, for instance in walls and floors, should be considered in order to broaden the study and improve the methodology to enhance its capability to prevent anomalies in construction and improve the quality of interior spaces.

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