TÉCNICO LISBOA

Extended Abstract

Catalogue of diagnosis techniques on old buildings

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1 Introduction

In Portugal, the policy followed in recent decades was clearly encouraging new construction, leaving in the background the rehabilitation of old buildings. According to INE data through the 2011 census, there is a strong relationship between the age of the buildings and their condition, revealing that the buildings built until 1945 only 36% had no major repair needs and about 10% had become very degraded or repair needs (INE 2011).

In general, old buildings are those whose construction is based on the use of traditional technologies, including the use of wood, and mortared stone masonry as predominant materials. They are distinguished by their construction technology, which remained without major changes until the appearance of concrete (Appleton 2003).

In Portugal, the rehabilitation actions undertaken throughout the twentieth century, focused primarily on the historical heritage - the monuments, and only in the 70's begins to recognize the importance of rehabilitating the urban heritage as a whole (Ferreira and Brito 2007).

In the rehabilitation process, it is essential to identify the anomalies and their extension in order to be able to act in a rational and effective way and safely guarantee the success of rehabilitation interventions.

Sometimes the determination of the causes of anomalies in buildings is quite complex. It is not always possible to identify a unique and clear cause, given the wide variety of elements and materials that make up a building, requiring a knowledge of the technical materials, construction methods and many available test techniques. Therefore, with this work, is important to systematize the information in order to database the sheets with technical information for the diagnosis applicable to old buildings.

2 Description, pathology and diagnosis of old buildings

2.1 Description and defects of old buildings

The old buildings are distinguished for its traditional construction technology and materials used, presenting as the most common materials, wood, mortar, ceramic brick and stone. The old buildings can be those constructed until 1945, that includes "Pombaline" buildings, "gaioleiros" and "card" buildings. Recent buildings are considered

to be those built after 1945, the buildings of “old reinforced concrete "and" recent reinforced concrete " (Cóias 2006).

The main constructive elements of old buildings and materials that constitute them, and a summary of the most common defects, are presented on the next table

Table 2.1 – Constructive elements and summary of most common defects in old buildings elements (Appleton 2003, Aguiar 1997, Freitas et al., 2012, Cóias 2006, Magalhães 2002, Pinho 2000, Veiga 2012)

Constructive element		Materials used	Anomalies
Foundations	Direct:	Carved stoned masonry, or mortared brick	Settlement, section loss,
	Semi-Directs:	Stoned masonry, or mortared brick	Settlement, section loss,
	Indirect:	Pine wood, oak or olive	Rottenness, section loss
Exterior Walls	Facade e back wall	Stoned masonry (limestone, granite, schist), may include wood pieces	Cracking, disintegration, crushing
	Gable	Irregular stone masonry	Cracking, disintegration, crushing
Interior Walls	Structural walls “frontal”	"Skeleton " of wood (cone and brown) with stone masonry filler or mortared solid brick	Bulging and crushing, rottenness of the wood
	Partition walls “tabique”	Wood (cone, brown, oak)	Bulging, rottenness of the wood
Wall Coating	Interior	Mortars of sand and air lime or gypsum and in certain regions, of sand and clay	Cracking, disintegration, crushing
	Exterior	Tiles	Detachment
Wall finishing	Interior	Painting the base oils, stucco, whitewash	Deterioration of painting, humidity stains
	Exterior	Whitewash	Deterioration of whitewashing

Table 2.1 (continuation) - Constructive elements and summary of most common defects in old buildings elements (Appleton 2003, Aguiar 1997, Freitas et al., 2012, Cóias 2006, Magalhães 2002, Pinho 2000, Veiga 2012)

Constructive element		Materials used	Anomalies
Stairs	Interior	Wood, stone (up to 1st flight of stairs)	Deformation, cracking
	Exterior	Metal (steel), stone	Corrosion
Floors	Structure	Wooden floor (pitch-pine, cone, oak, pine land, land of pine) stone vaults, cast iron beams, steel	Deformation, disintegration corrosion of metallic elements
	Coating	Wood (brown, oak, pine brave, gentle pine), ceramic tiles	Cracking, detachment
Ceilings	Coating	Plaster, mortar of lime and sand	Cracking, disintegration
	Finishing	Whitewash, oil paints	Deterioration
Roof	Structure	Wood (brown, oak, pine brave, gentle pine), steel	Deformation, bulging corrosion
	Coating	Ceramic tile	Detachment
Frames		Wood (cone, “pine land”)	Rot
Stone Work		Stone (granite, marble)	Cracking, detachment

2.2 Diagnosis techniques on old buildings

The diagnosis techniques are any type of test performed on a sample in order to evaluate their properties. There are different ways of classification of diagnosis techniques distinguished by different authors as follows (Cóias 2006, Paiva 2006):

- Site where the technique is performed (in situ or in the laboratory);
- Size of the destruction of the element in analysis (non-destructive, partially destructive, destructive);
- Principles on which they are based (sensorial, mechanical, thermal, chemical, electrical, magnetic, electromagnetic, ultrasonic, radioactive and others);
- Type of results (properties to be evaluated);
- Building elements and components that can be applied (as a structural element structural or not);

- Activity which that they intervene (quality control, inspection of buildings, check the application of regulations, among others);
- The set of "issues", "objects" and "activities", that is, a set of assumptions to be tested, which are not mutually exclusive

The diagnosis techniques based function principles considered on this work are: sensory perception techniques, mechanical action techniques, propagation of elastic waves techniques, propagation of electromagnetic radiation techniques, chemical reactions techniques, electrical effects techniques, detection and vibration analysis techniques and hydrodynamic techniques. The next table summarizes the diagnostic techniques on the catalogue, in the main elements of old buildings.

2.3 Analysis methods and diagnosis of existing defects

In the old buildings is vital to ensure a regular and ongoing maintenance. Because of a variety of specific cases of problems that may occur, it is necessary to seek a systematic diagnosis of defects that may contribute to their degradation. For that reason, some information has been systematized, in which each country has created over the years, its own database catalogues of defects in buildings.

A few examples of the most relevant methods of analysis and diagnosis known, both internationally and nationally, are featured in the next below. This examples systematize the information through sheets, that is the objective of work, produce a model type sheet of diagnostic techniques:

- Diagnosis techniques sheets and Inspection and testing sheets like: “Survey Information Sheets” published by CIB in 2013, “Fichas de inspeção e ensaio” developed by Cóias (2006) and “Fichas de técnicas de diagnóstico” proposed by Abreu (2013)
- Defects sheets, such as: Defect Action Sheet – DAS” prepared by the English BRE (Building Research Establishment) in 1982, “Cases of Failure Information Sheet” published by CIB (Conseil International du Bâtiment) in 1993, DPE – “Metodologia de Diagnóstico de Patologias em Edifícios” by Rui Calejo in 2001, FDI – “Fichas de Diagnóstico e de Intervenção” by por Vítor Abrantes, Rui Calejo e Helena Corvacho in 2003
- Rehabilitation sheet: Fichas de Reparação de Anomalias” prepared by LNEC (Laboratório Nacional de Engenharia Civil) in 1985, QCE – “Metodologia de Quantificação Causa – Efeito” by Alfredo Soeiro e Rui Taborda in 1994

Table 2.2 - Synthesis of application of diagnosis techniques on the main elements of an old building (Cóias, 2006; Flores-Colen, 2009; Freitas, et al. 2012, Abrantes 2012)

Technique	Foundations	Resistant walls		Floor	
		Structure	Coating	Structure	Coating
Photogrammetric survey	X	X	X	X	X
Inspection with video camera of small diameter	X	X		X	
Acoustic detection of insects xylophagous		X		X	
Measurement of the surface density wood elements with *Pylodin*		X	X	X	X
Assessment of wood elements integrity with *Resistograph*		X	X	X	X
Trial with flat jack		X			
Trial with double flat jacks		X			
Trials with plan jacks		X			
Trial with dilatometer on masonry		X			
Ultrasonic Test		X			
Sonic Test		X			
Sonic tomography		X			
Impact-eco test		X			
Radiography on wooden structures		X			
Vibration measurement afar using laser technology		X			
Analysis and monitoring vibrations in structures		X			

Table 2.3 - Synthesis of application of diagnosis techniques on the main elements of an old building (Cóias, 2006; Flores-Colen, 2009; Freitas, et al. 2012, Abrantes 2012)

Technique	Ceilings	Partitioning walls		Roof	
	Coating	Structure	Coating	Structure	Coating
Photogrammetric survey	X	X	X	X	X
Inspection with video camera of small diameter		X		X	X
Acoustic detection of insects xylophagous	X	X		X	
Measurement of the surface density wood elements with *Pylodin*	X	X	X		
Assessment of wood elements integrity with *Resistograph*		X	X		
Trial with flat jack	X	X			
Trial with double flat jacks		X			
Trial with dilatometer on masonry		X			
Ultrasonic Test		X			
Sonic Test		X			
Sonic tomography		X			
Impact-eco test		X			
Radiography on wooden structures		X			
Vibration measurement afar using laser technology		X			
Analysis and monitoring vibrations in structures		X			

3 Design of a model sheet of diagnosis techniques

The model of diagnosis techniques sheet consists in condensing all the relevant information for each diagnostic technique in two pages. Making it essential for an easy and understanding by a user. Each page is divided into frames, for better ordering of space and preview of the technical information.

In the header, is the name of the technique and the respective numerical reference. Next are in the boxes, the elements that can be applied, the degree of technical destruction, the location of the test (*in situ* or laboratory), its operating principle, a brief description of the technique, equipment and materials needed, the advantages and limitations. The footer still puts up the principle of use and reference of the record in question.

On the second page follows the fields that relate to the cost and technical difficulty, the test procedure, measurement parameters, normative documents or technical that can be applied, the reference values or guideline and interpretation of results. The reference and technical designation is displayed in the footer, as the first page. In the sheets there is also numbered references that was used.

Briefly, the technical guide sheets contain the following information:

- Description;
- Technical destruction degree;
- Principle used;
- Building elements that can be used;
- Test Procedure;
- Cost;
- Difficulty;
- Normative documents
- Measurement parameters;
- Reference values
- Interpretation of results
- Equipment;
- Advantages;
- Disadvantages;

Thus, it’s propose the following model of diagnosis techniques sheet, in which it fields are explained.

Designation Of The Diagnosis Technique	**Ref.[a]**
DESTRUCTIVE LEVEL OF THE TECHNIQUE: ☐ **Destructive** ☐ **Semi-destructive** ☐ **Non-Destructive**	☐ ***In situ*** ☐ **Laboratory**
BUILDING ELEMENTS THAT CAN BE USED: ☐ **Walls** ☐ **Coating** ☐ **Floorings** ☐ **Ceilings** ☐ **Roofs (structure)** ☐ **Instalations** ☐ **Singular elements**	
PRINCÍPLE USED: ☐ **Sensorial perception** ☐ **Mechanical action** ☐ **Propagation of elastic waves** ☐ **Detection and vibration analysis** ☐ **Quimical reaction** ☐ **Propagation of electromagnetic radiation**	
DESCRIPTION: In this part, the technique in study will be described, summarily identifying the nature of it. It can be also identified anomalies that the test focuses on.	**EQUIPAMENT:** In this field are shown pictures and photos of equipment and materials that are used in the procedure. This field can vary according to the sheet and can be displayed some relevant details for the equipment or the results that it produces.
ADVANTEGES: In this section, is described the main advantages of this type of test, giving the user a general idea of their potential	**DISADVANTEGES:** In this case, is mentioned the main disadvantages and obstacles that occurs when occurs the test.
Ref.[a].	PRINCIPLE USED

Figure 3.1 – Sheet of diagnostic technique (first page)

COST:

☐ Economic ☐ Medium ☐ Expemsive

DIFFICULTY OF THE TEST:

☐ Low ☐ Medium ☐ High

NORMATIVE DOCUMENTS:

Ref[a]	Designation	Year

TEST PROCEDURE:

In this part, is made a description of the steps to performing the assay. These may depend on the applicable standards, previous test results or even documents prepared specifically for diagnostic technique in question.

REFERENCE VALUES:

In this field, are considered values and results based on other test, previous studies or works comparable with the results obtained in the test technique in question.

INTERPRETATION OF RESULTS:

At this stage it is necessary to analyze the results of the test to verify objectives taken into account in carrying out the technique that have been achieved, and also diagnose what was tested.

MEASUREMENT PARAMATERS:

This information tells us the parameter measured, and also how the test results are presented (in table, chart or image).

PRINCIPLE USED	Ref.[a].

Figure 3.1 (continuation) - Sheet of diagnostic technique (back)

4 Catalogue of diagnosis techniques

The catalogue of diagnosis techniques for old buildings were organized according to a sequential numbering, with a code for each category, respecting the principle of use.

The catalogue consists in 16 sheets organized according to the respective principles of use (sensorial perception, mechanical action, propagation of electromagnetic radiation, chemical reactions, detection and vibration analysis techniques), to provide a quick and expeditious consultation. Below is presented general index of the sheets of diagnostic techniques developed.

Table 4.1 - Summary of diagnostic techniques sheets developed

Reference	Diagnostic techinque
TPS – Techniques of Sensory Perception	
01 TPS	Inspection with video camera of small diameter
02 TPS	Photogrammetric survey on old buildings
03 TPS	Acoustic detection of insects *xylophagous*
TAM – Techniques of Mechanical Action	
04 TAM	Measurement of the surface density wood elements with *Pylodin*
05 TAM	Assessment of wood elements integrity with *Resistograph*
06 TAM	Trial with flat jack
07 TAM	Trial with double flat jacks
08 TAM	Trial with dilatometer on masonry
TPOE – Techniques of Propagation of Elastic Waves	
09 TPOE	Sonic tomography on masonry
10 TPOE	Ultrasonic test on masonry
11 TPOE	Sonic testo n masonry
12 TPOE	Impact-eco test
TPRE – Techniques of Propagation of Electromagnetic Radiation	
13 TPRE	Vibration measurement from afar using laser technology
14 TPRE	Radiography on wooden structures
TRQ – Techniques of Chemical Reaction	
15 TRQ	Humidity measurement on inner walls
TDAV – Techniques of detection and vibration analysis	
16 TDAV	Analysis and monitoring vibrations in structures

Some of the developed sheets are the result of improvements of sheets initially proposed in the master's thesis conducted by Abreu (2013) and Machado (2014), in particular, the sheets 01 TPS, 02 TPS, 04 TAM, 08 TAM, 09 TPOE, 11 TPOE, 12 TPOE, 13 TPRE, 14 TPRE, 15 TRQ, 16 TDAV. The other five sheets present undeveloped subjects 03 TPS, 05 TAM, 06 TAM, 07, TAM e 10 TPOE.

The sheets were organized with sequential numbering, followed by the techniques respective codes, so it can be added sheets in future works.

5 Conclusions

The development of the catalog of diagnostic techniques consists in systematize information that allows to analyze the defects and the conditions in the building in order to simplify the work of an engineering technical inspection. The knowledge of the constructive typification, the frequent defects that appear on that constructive elements and an understanding of the various existing diagnosis techniques is important for the correct diagnosis of defects on an old building.

Considering the constitution of an old building, it was briefly described its constituent elements and also each type of old building, and the major changes that have occurred in the on such buildings, and also the most common anomalies:

- was defined as old buildings, pre-pombalinos (before the 1755 earthquake), pombalinos (the XVIII and XIX century.), gaioleiro (end of XIX to 30-40’s), and plate buildings (30-50‘s);
- in the characterization of an old building was considered: foundations; resistant walls; the division walls; coatings and finishes for walls; the stairs; floors, coatings and finishing of floors, ceilings, their coatings and finishes, covers and coatings; the window frames; the masonry; the singular elements; and facilities
- the water action is one of the main problems creating anomalies on old buildings, like humidity stains, disintegration, cracking, etc.

It was identified appropriate diagnostic techniques for old buildings, structured, organized and classified by the principles on which they are based, specifically in terms of sensory perception, mechanical action, propagation of elastic waves, electromagnetic radiation propagation, chemical reactions and detection and vibration analysis. Despite been followed this sheet structure, it was exposed the sheets of the methods of analysis and diagnosis of anomalies that appear more frequently in old buildings. They are generally sheets, catalogues, tables of different organizations and countries.

The main objective of this work was achieved, that resulted on the sheet, which integrates the key topics of each diagnostic technique easy to understand. Thus being able to inform with an objective and systematic manner the technicians of rehabilitation construction, not just of old buildings, although the subject focus in this type of building. It was elaborated 16 sheets of diagnosis techniques, that are organized in a catalogue according to a codification based on the techniques principle of use.

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