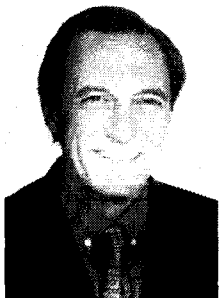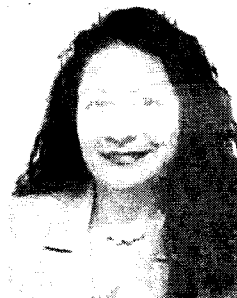# Directives for a Correct Diagnosis

Linhas de Orientação para um Diagnóstico Correcto

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Abstract: A special *Working Group*, to study and develop standards related to *Building Restoration, Rehabilitation and Maintenance*, was formed in January 2001 in AENOR (Spanish Association for Codes and Standards) under the management of the Department of Building Construction of the School of Architecture of Madrid (DCTA-UPM). Three subgroups were organized to deal with different topics: *Diagnosis, Techniques and Materials*, and *Maintenance*.

In this paper the different topics in which the Diagnosis Subgroup is working are described: historical studies, constructive description of the building and building pathology. These will be basic to carry out a correct diagnosis of any type of building, whether it is historic or not. In the development of such topics, the recognizable architectural values are justified as they are prior to the diagnosis stage.

As an example of the subgroup work, several pathology cards are shown which include: longitudinal cracks of mechanical origin in beams of concrete structures, façade closings and claddings, and general symptoms of installation services.

Keywords: Building Restoration, Rehabilitation, Maintenance, Diagnosis, Pathology

0. INTRODUCTION

"Diagnosis" is used here as the analysis and interpretation of the results from the study developed prior to the intervention −in old as well as new buildings- identifying the current state of the building and considering three aspects:

−The building as a *piece of Architectural Heritage* (historical as well as Artistic)
−The building as a *functional object* (Habitability)
−The building as a *physical object* (Construction)

Therefore, carrying out a diagnosis should integrate several disciplines in order to adjust the present state of the building with its historical background. The building itself offers a direct information, sometimes very complete, regarding its structure and the envelope, apart from its urban and landscape environment. In addition, indirect information is to be found in historical and technical documents from the archives or other related sources.
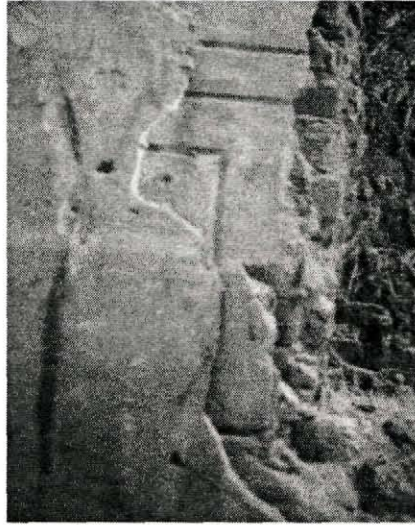

Fig. 1 – Lime and gypsum claddings of the 14th. century Church of San Pedro de los Francos, Calatayud, Spain

All this information will allow us to identify the historical, technical and architectural values to be preserved or repaired, and the need of technical and functional works to be accomplished in order to restore and rehabilitate the building.

Also, information about the functional characteristics of the building has to be collected, as well as construction failures and defects that define the pathology of the building. Through these, the pathological processes and their repair possibilities will be known, so as to propose the different techniques to be used.

As a consequence, taking into account all these aspects and trying to help professionals to achieve a correct diagnosis, the following chapters were defined for the Diagnosis Directives document:

Chapter 1.   **Historical, Archaeological and Documental Studies**
Chapter 2.   **Constructive Description of the Building**
Chapter 3.   **Pathological Processes Analysis**
Chapter 4.   **Diagnosis**

Their content can be summarized as follows:

1. HISTORICAL, ARCHAEOLOGICAL AND DOCUMENTAL STUDIES

These studies must help to determine the importance of the historical, artistic, constructive and environmental values of the building, as well as to obtain its *"historical sequence"*. The final study must be based on objective evidences and not on hypothesis. Its importance strives upon the fact that it holds the age of the building or of the original elements, as well as of the historical additions, showing crafts or industries already disappeared.

Includes a description of the type of historical and documental studies recommended to be done on the building in any case, mainly when historical and artistical values are considered.

1.1.   Historic-documental studies
Comprises the study of the building through the conventional historic methodology, that is, consulting of archives, libraries, historic photographs and newspapers, etc.

1.2.   Historic-artistic studies
Study of the values of the building that give it some type of singularity regarding historical and artistic aspects, or values related to tradition and identity. It can be studied through ornamentation, heraldry, stylistics, symbolism, etc.

1.3.   Historic-constructive studies
Analysis of the original systems, techniques and materials as a part of the fundamental historic elements of he building, especially those to be removed during the estimated intervention.

1.4.   Historic-archaeological studies
Archaeological analysis of the subsoil, as well as the wall facings, following the stratigraphic methodology and searching the physical state of the materials and elements.

1.5.   Archaeometric studies
Includes the physico-chemical analysis of the archaeological materials; anthropology, C-14 dating, dendrochronology, thermo luminescence, mensiochronology, pollen analysis, etc.

2. CONSTRUCTIVE DESCRIPTION OF THE BUILDING

The first direct data of the study to be considered includes the technical and functional situation of the building at the moment to be studied. It is the main part of the analysis mentioned above, and must indicate the condition of the building and its environment, to be incorporated in the diagnosis. This will facilitate the understanding of the pathological problems and helps in the decision taking for the intervention.

In order to do so, three items are included in this chapter:

2.1.   Constructive description

A complete recording of the different systems and elements of the building, should include:
– Estimated design criteria
– Materials
– General conservation state, further expanded in the next chapter (pathology analysis)
– Drawings, existing or made on purpose (photogrametry) to know the geometry of the building and its elements
– Constructive details, to explain joints
– Photographs

If project documentation is available, it should be incorporated indicating possible differences with present construction. Otherwise, measures and calculations should be done so as to have a whole knowledge of the building.

The following systems and elements are to be considered:
– *Soil*
– *Foundations*
– *Structural elements*
– *Façades (vertical closings)*
– *Roofs*
– *Carpentry and iron works*
– *Internal finishing*
– *Installations*
– *Accessibility*

2.2. Environment

The urban and landscape environment should be described so as to know the possible influence of their characteristics, covering the following aspects:
– Geographical
– Meteorological
– Artificial

2.3. Construction history

The "construction history" of the building must be included, according to the historical studies in chapter 1, mentioning:
– Construction dates
– Previous interventions and building modifications
– Functional modifications

3. PATHOLOGICAL PROCESSES ANALYSIS

In the *"reading"* of the building regarding the possible historical values, one of the most important data are the pathological processes that affect the different elements, in order to be able to know their technical condition and decide about their repair or substitution. Also the functional conditions are important to decide about the rehabilitation techniques to be used.

In this sense, all pathological processes have to be described for a better understanding of the problem and to decide the correct technical solution. According to this, in every single process the following items need to be described:

- **Origin** of the process, direct as well as indirect causes,
  - ○ *Direct causes*, every external action on the construction elements affected by the process
  - ○ *Indirect causes*, any design, material or erection mistake
- **Evolution of the process (first time, periodicity, last time)**
- **Symptom (failure)**

This chapter includes the recommendations to analyse and describe the different pathological processes found in the building. To do so, the following general scope can be mentioned, containing the main objectives of the chapter and establishing the lines to be followed in every subchapter:
- A reminder of the possible elements to be found
- A reference to the different failures caused by the pathological problems
- A list of checkings to be done and data to be taken in order to understand the origin of the problems, and therefore, the causes of the pathological processes
All this information should be summarized in charts or tables for better understanding.

The list of systems and elements to be considered are:

- **Foundations, concrete as well as masonry**
- **Structure**
  - ○ Masonry walls - Wooden elements - Concrete columns and beams - Concrete slabs - Steel columns, beams and trusses
- **Façades (non structural)**
  - ○ Walls - Veneers - Windows carpentry - Ironworks
- **Roofs**
- **Interior systems**
  - ○ Partitions - Finishing - Carpentry
- **Installations**
  - ○ Sewage - Water supply - Heating - Air conditioning - Electricity - Fire protection
- **Decoration**
  - ○ Sculptures - Paintings - Crafts

As a brief example, some parts of three subchapters are included here, referring to:

- Concrete structures – Longitudinal cracks in beams
- Façade closings (non structural) - Detachments
- Installations – General symptoms

3.1. Concrete Structures

Longitudinal cracks of mechanical origin in beams

Possible causes	Location	Data to be taken	
		Constructive details	**Testing and other**
Lack of compression strength	At the top face of the central section or at the bottom face of the support areas, without remarking the steel bars	- General dimensions of the structure - Steel reinforcement under compression in cracked beams - Evaluation of actual loads	- Compression strength of concrete - Steel strength - Design check (stress evaluation under normal loads)
Concrete plastic settlement in deep beams section	Marking main steel bars; also transversal cracks marking stirrups. Normally appearing few hours after pouring	Concrete section dimensions and steel reinforcement in cracked beams	- Water/cement ratio - Concrete consistence - Curing and compacting conditions
Lack of shear connection reinforcement in T section beams	In the connection zone between the web and the flange, in T section beams	- Concrete section dimensions and steel reinforcement in cracked beams - Actual load evaluation	- Design check (stress evaluation, mainly shear stresses) - Compression strength of concrete - Steel strength
Bond failure of tensile bars in anchorage zones	Parallel to main bars in supporting zones; can go upwards to the compression zones	- Dimensions and steel bars in cracked beams - Supporting area dimensions	- Compression strength of concrete - Steel strength - Design check (bond and anchorage length)

Longitudinal cracks in beams due to bar corrosion processes are considered in the tables corresponding to material deterioration defects.

3.2. Façade Closings and claddings

Detachments

| Location	Failure	Process and possible causes	Data to be taken
Areas near the junction between structure and closing	Detachment of veneers of any type	Breaking of the adherence system, being continuous or by anchorage points, due to grazing strength as a consequence of: - Elastic movement of the structural elements - Expansion and shrinkage of structural supporting elements - Expansion and shrinkage of veneers	*Constructive details,* - Façade composition, mainly joints with structural elements - Fixing system of the veneer; in the case of ceramic veneer, check joint in between tiles and continuity of mortar throughout - Jointing seams of the veneer, additional to the ones of the wall and structure

Top cornices and corners	Detachment or falling off of veneers and decorative elements	Previous cracks in veneer and water infiltration that becomes ice with the following consequences:
		- Breaking of the mortar adherence
		- Corrosion of steel anchorages
			Result of testing,
			- Bending and extension strength of the veneer materials
			- Pulling out strength of:
			  - Mortar to wall
			  - Tile to mortar
			  - Metallic anchorage to wall
			  - Stone plate to anchorage

General plain walls	Detachment or falling off of veneers of any type	Breaking of the adherence system, being continuous or by anchorage points, due to: - Expansion and shrinkage of veneers, with possible "histeresis" after time - Wind suction - Lack of jointing seams at the veneer	
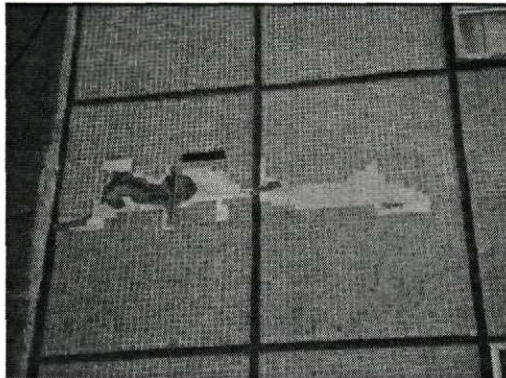
Fig. 2 – Study and diagnosis of cracks on the façade and detachment of wall mosaic cladding.

3.3. Installations

General symptoms

Symptom/failure	Possible causes
Lack of water tightness: - To fluids (liquid or gas) - To odour	- Material breaking (pipes, special pieces, etc) - Lack of union (joints failure) - Material hair cracks and cracks - Material degradation - Lack of hydraulic closings at the edges - Lack of water tightness in closings of collection box and wells
Lack of pressure	- Insufficient pressure entrance (Excess or default) - Inadequate design - Default of equipment or function - Squashing - Obstruction - Lack of air tightness (in gas pipes)
Inadequate temperature	- Default of production system - Excessive loss of heat (lack of isolation) - Default of regulation and mixture systems
Inexistence or breakdown	- Inadequate design - Inadequate arrangement or modification - Default of equipment or function
Incorrect functioning	- Inadequate arrangement or modification - Inadequate design - Default of equipment or function - Inadequate external environment (ventilation)
Obstructions	- Inadequate maintenance (cleaning of filters, pipes, etc.) - Chemical degradation - External elements incorporated - Internal sediments in pipes and ducts
Deformations: - Squashing - Bulging and warping - Collapsing - Breaking	- Structure or partition movements - Lack of anchorages - Movement of pipes (expanding and shrinking) - External actions (impacts, cuts, squash, etc) - Material degradation (physical or chemical)
Detachments	- Lack or default of anchorages
Section diminishment	- Internal sediments in pipes and ducts - Chemical degradation of material due to water quality - Inadequate arrangement or modification (change of section) - Squashing - External elements incorporated
Noises and vibrations	- Default of equipment or function - Lack of anchorages - Lack of isolation at the bottom of sewage pipes - Excessive slope of sewers - Lack of ventilation in sewage pipes - Insufficient section in air condition ducts or diffusers

4. DIAGNOSIS

As has already been said, the diagnosis is the final and most important stage and implies an exhaustive analysis of all the data and information obtained in the previous chapters. The objective is to make a correct interpretation of these data, and not simply to present them. This implies a wide knowledge in the "art of construction" and in the "building pathology", as well as in the proper technical solutions for a correct building rehabilitation.

Therefore, the participation of architects, historians, archaeologists, documentalists, engineers, and other specialists becomes convenient, and many times necessary. In this sense, a glossary related with these topics may be of great help.

Different phases can be considered in the development of a diagnosis:
- *Prediagnosis*, based on a brief study of the building and its environment. Generally a visual analysis and a quick study of the existing documents. It can be considered as a previous step in order to establish the hypothesis to be followed during the technical and scientific studies of the building
- *Diagnosis*, properly speaking, based on the studies mentioned in chapters 1, 2 and 3 of these directives. Also, different aspects can be presented, according to the type of building, its historical and artistic values and the proposed rehabilitation:
  o *"Architectural diagnosis"*, to recognize the importance of the type of building as a heritage piece, as well as its historic and artistic values
  o *"Constructive and structural diagnosis"*, to determine the materials an their physical and chemical performance, as well as the importance of the constructive and technical values
  o *"Pathology diagnosis"*, to acknowledge the failures, the pathological processes and their possible solutions, in agreement with the previous diagnosis.
- *Post diagnosis* as a tracking of the works on site to obtain possible new data that could change the original conclusions.

To obtain the final conclusions, a cross analysis of all data becomes essential, coordinating the different partial diagnosis, which might have been done by different professionals. After this stage, the possible interventions start being defined. For example the archaeological information is a must in any case, whereas the obligation to preserve it depends on the symbolic value attributed to it.

5. CONCLUSIONS

As a conclusion, in the case of historical buildings, conservations become important in order to extend their life, and in any type of building, functionality results essential when deciding rehabilitation works. As a consequence, several conservation and maintenance activities should be considered in the diagnosis:

a) *Conservation*; collection of activities on the building (permanent or isolated) in order to keep its integrity and functionality, attending to its values. The following can be considered:

- *Restoration*, to recover the historical and artistic values of the building or any one of its parts.

Fig. 3 – Roof restoration of the church of San Pedro de los Francos.

– *Rehabilitation,* to recover the functionality of the building or to adapt it to a new use
– *Repair*, to eliminate the causes that originate the pathological processes and to arrange the failures

b) ***Maintenance***; periodical control works after the rehabilitation, to prevent the pathological processes and failures, and to assure the correct functionality of the building.

In each one of them, the adequate technical solution must be decided, in agreement with the diagnosis and with the result of the interpretation of the building and its documents. The architectural and technical values must be respected, and the new elements and actions must be identified.

Finally, the analysis carried out will allow us to define the different rehabilitation activities that need to be standardised, which can be related to two different fields: to the data recollection techniques, and to the conservation techniques. Nevertheless, these new standards will be part of the work of the *Techniques and Materials* subgroup. On the other hand, the study of the guidelines will let us to establish the need of maintenance and preservation techniques to be defined in the buildings after the rehabilitation process, which will be part of the work of the *Maintenance* subgroup.

6. ACKNOWLEDGMENTS