

# THE IMPORTANCE OF THE PREVIOUS STUDIES IN THE INTERVENTIONS OF REBURFISHMENT: A PRACTICAL CASE, THE MAJOR SEMINAR OF COMILLAS (CANTABRIA, SPAIN)

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## ABSTRACT

As the first step to the rehabilitation of a construction is necessary to know, in depth, the condition in which it is, so that the research that is going to be carried out, normally important in this type of works, is done by the sufficient guarantees.

Such knowledge is obtained through the called "Previous studies before the Refurbishment". From now, we are going to refer different aspects which we consider of interest and we will centre our attention on a construction: The Major Seminar of Comillas (Cantabria, Spain), which is a modernist building (ends of the XIXth) where the Architect Lluís Domènech i Montaner (author of other buildings like the Hospital Sant Pau of Barcelona and The Palau of the Catalan Music, both Patrimony of the Humanity) took part. The ideas that underlie in our work can be extrapolated easily to other buildings and civil structures (bridges, etc.).

In the development of the communication there will be exposed, closely, how we made the studies in relation with the analysis of several constructive elements (floors, masonry walls, vaults of the church of the Major Seminar, the Catalan vault which constitute the slab of building's ground floor, etc.).

### 1.- Introduction

The buildings of architectural heritage are subject to a number of difficulties in diagnosis and refurbishment. An example is limiting the application of regulatory requirements and guidelines in force in the general area of construction. This makes it desirable and necessary to formulate recommendations to ensure the application of rational methods of analysis and refurbishment.

Firstly, there is concern that conservation, consolidation and refurbishment of architectural heritage requires a multidisciplinary treatment, which must be focusing on the intervention from the viewpoint of integrity with the cultural context to which it belongs. It is important to have a team of researchers who have a range of appropriate skills in relation to building characteristics, and also led by someone with appropriate expertise to be able to articulate all the conclusions reached.

As a result, there is a need to implement methodologies [7, 8] that may facilitate communication between professionals from different fields of knowledge involved, to reduce the subjectivity inherent in each professional and avoiding that, depending on technicians involved, different approaches raised in the studies (historical approach, engineering approach, etc.). The objective is to take the studies of each group in order to obtain more data entry and, thus, to enrich the contents and conclusions before the intervention phase (design and work of refurbishment).

The peculiarities of the structures involved in heritage buildings, with its complex history, requires that the studies and proposals are organized into well-defined phases, similar to those used in medicine [6] (knowledge, diagnosis, therapy and control), applied to the search for relevant data and information.

To achieve an optimal balance between cost and performance, and produce the least possible impact on the architectural heritage, using funds available in a rational manner, it is usually necessary to repeat these stages of study within a continuous process (Fig. 1).

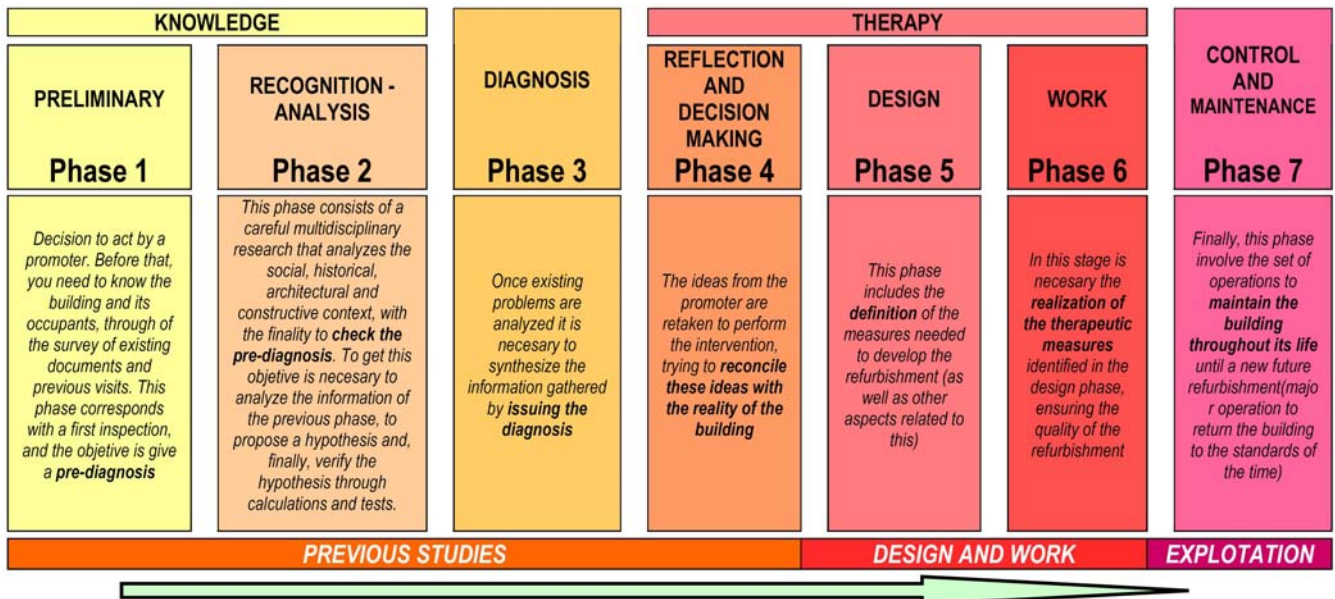


Fig.1 “Logical process of refurbishment in heritage buildings”

Furthermore, it should refer to each specific building must be found the scale and depth of each of the stages proposed in the previous figure.

It should be noted that acting on these principles involves an arduous task to raise awareness. First of them of the technical staff, because their university education is focused on the construction of new buildings and on techniques do not accepted in building heritage, and in parallel of the community, because it is essential that it recognizes the value of its architecture. In this regard, it is important to propose mechanisms for active community participation in decision making.



Fig. 2 “Major Seminary of Comillas”



Fig. 3 “Auditorium”

The "previous studies" are the combination of phases related to the knowledge of the building and its users [1, 2] previously to the design stage. In the same way that a surgeon before to intervene a patient must have a thorough knowledge of the evils which suffers based on the previous study developed by technical specialists (analysis, medical tests, etc..), in order to guide an appropriate therapeutics applicable in a building, before to refurbishment (design and construction phases), it must perform a series of studies, multidisciplinary, which promote understanding of the construction and allow to focus the refurbishment appropriately (both in cost of money and time).

In this regard, and to illustrate the refurbishment methodology proposed (which emphasize the importance of the phase of the previous studies) we are going to expose a summary of

the main work undertaken and the main conclusions reached during the execution of the studies in the Major Seminary of Comillas (Cantabria).

## 2.- The Major Seminary of Comillas

The Major Seminary (Fig. 2) is a Modernist building (late nineteenth century), which partly involved the architect Lluís Domènech i Montaner (author of among other buildings of the Hospital Sant Pau in Barcelona, World Heritage Site).

The building is divided into two cloisters and a central volume in which the elements are placed in architectural and artistic quality, the church, the hall, the vestry and the auditorium (Fig. 3).

The building occupies a rectangular area approximately 100 m x 65 m, with two inner courtyards of some approximate dimensions of 35 m x 25 m, flanking a church that occupies the centre of the building. The building consists of ground floor and three floors with two little towers side at the corners of the south facade and other one located above the main entrance. The wall structure consists in irregular limestone masonry with lime mortar and ornaments of solid bricks. Sometimes you can see as the masonry wall is framed by a sandstone ashlar, which in some cases are replaced, from a certain height, by solid bricks coated with lime mortar.

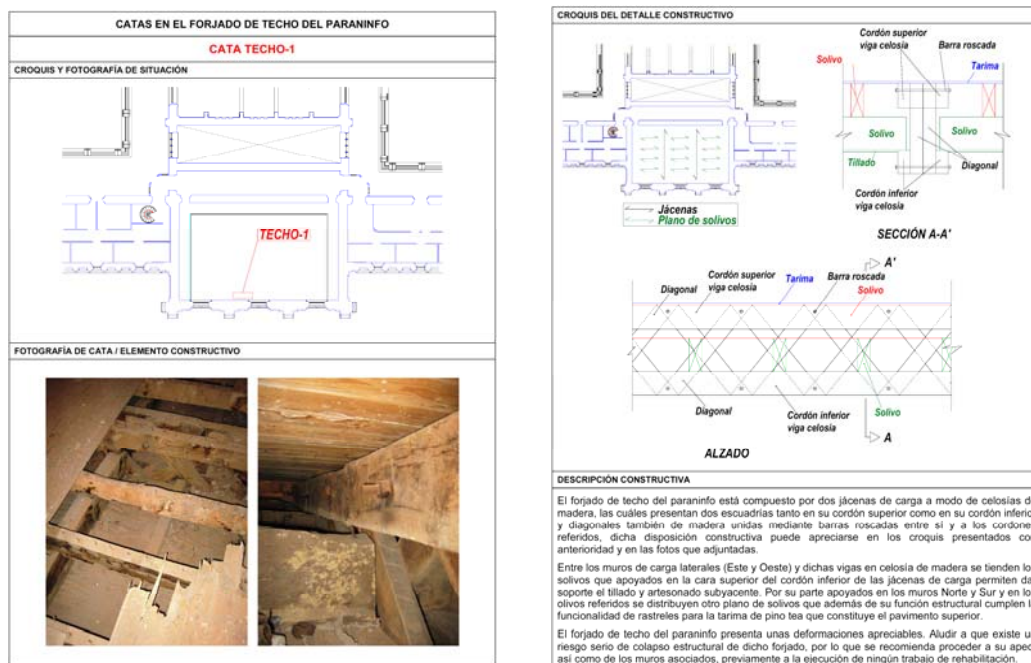


Fig. 4 "Example of sheet model, specifically of the second floor (roof) of the auditorium"

Previous studies are summarized that have been carried out by a team composed of multidisciplinary Research Group, University of Cantabria (GTED and LADICIM) and several SMEs of Cantabria: A Study of Engineering (DYNAMIS SL), a chemical company (CHEMPRO SL), a disinfection and treatment company of wood against biotic agents (Montañesa de Desinfección SL) and a quality control laboratory that specializes in the execution of geotechnical surveys (TRIAx SA). The technical coordinator of the work group was the Building Technology R+D Group of the University of Cantabria (GTED-UC) attached to the Department of Structural and Mechanical Engineering from the University concerned. As can be seen, the technicians bring together different areas of knowledge by giving the multidisciplinary study to tackle from different viewpoints and thus enriching the contents themselves with the conclusions obtain from the various facets involved.

Of all the study, in what follows, we are going to make an overview of them, as a summary.

### 3.- Conducting surveys and minor destructive testing (MDT) to identify the geometry, the constructive and mechanical characteristics of structural elements.

With these goals has been to conduct a series of surveys in strategic locations. For each of these, it was made a sheet (Fig. 4) which includes its location within the building, standard photographs of situation, detail drawings with dimensions and geometry, and a written description of it.



Fig. 5 “Details of the inspection in the underground water tank of the east cloister”



Fig. 6 “Instant during a double flat jack test”

Surveys have allowed to get a thorough knowledge of the main construction features of the building and of some pathological processes exist in the construction, such as inadequate support in the wooden beams of the structural elements that constitute the floors and other to be collected in the next section.

We also performed an inspection of the underground water tank in the east cloister (Fig. 5). For this reason and because of their special characteristics of confined space, it was thought appropriate to know the quality and characteristics of the atmosphere to ensure the safety and health of the technicians that should inspected the tank. We proceeded to measure the concentration of oxygen, carbon monoxide, carbon dioxide and certain flammable gases with the aim of assessing the potential explosive atmosphere exists. The underground water tank consists of two enclosures separated by an intermediate wall, with a total surface of 204.5 m<sup>2</sup>. The structure consists of square pillars (of 49 cm of side) which receiving the load of the vaults.



Fig. 7 “Hole Drilling test”



Fig. 8 “Impact echo test on a masonry wall”

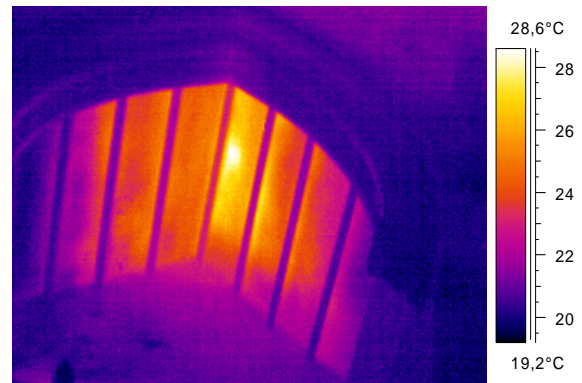


Fig. 9 “Infrared thermography on the cover of one of the domes of the Church's Seminar”

In relation to minor destructive testing [3, 4, 5] allude to several tests were made: Simple flat jacks and hole drilling (Fig. 7) to obtain tensional levels of compression, double flat jacks (Fig. 6) to obtain the elastic modulus and Poisson ratio, acoustic techniques (Fig. 8) to study the integrity of structural elements and estimate their mechanical properties, and infrared thermography (Fig. 9) to assess, qualitatively, determined phenomena involved.

#### 4.- Study of the pathological processes: recommendations for action

We performed a systematic record of the various defects and deficiencies found in the walls structures of the Seminary, both in the four exterior facades, on several walls (north, south and west) of the west cloister, and the west wall of the east cloister.

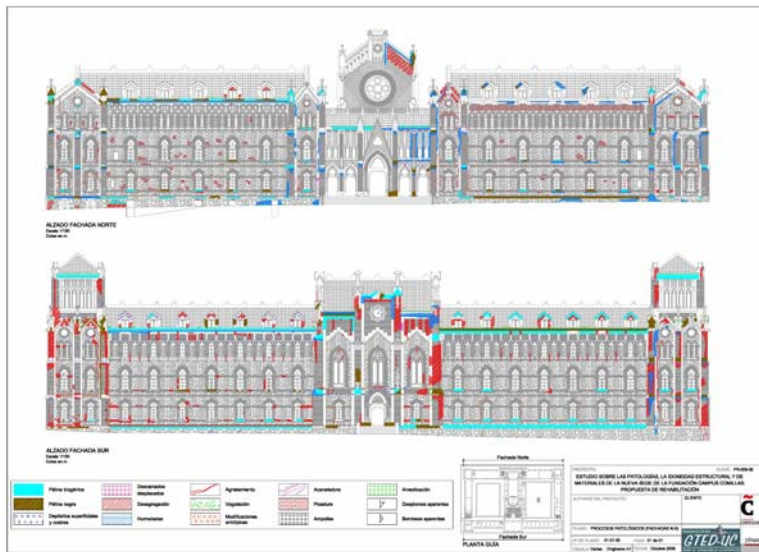
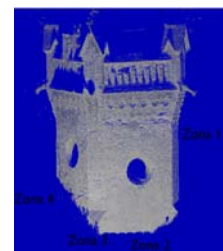


Fig. 10 “Survey of pathological processes of the north facade (top) and the south facade (below) of the Major Seminary of Comillas”



Fig. 11 y 12 “3D laser scanner”



The process for carrying out this work was a detailed visual inspection. With the information obtained was an uprising of the pathological processes involved (Fig. 10). Similarly attached photos of every detail of the pathological condition and its location within each wall. Finally, it was attached, in the form of sheet, a description of each pathological process and the causes attributable most likely related with each injury.

In addition, the pathological processes on the walls structures in question, also conducted a study focusing on the most common injuries detected in the bays surrounding the cloisters, in the SW tower, and other pathological processes significant detected, localized in specific areas of the building, during visits inspection.

In the same way it was proposed recommendations for action (therapeutic) to correct the defects identified previously. In relation, as support of the process related, it was needed to develop an uprising by 3D laser scanner (Fig. 11 and 12) of certain construction elements (primarily in the clock tower and south facade).

In what follows, it addresses the more serious pathological processes in relation to the structural stability of the building.

##### 4.1.- Eccentric support of trusses on the walls of the bays surrounding the cloisters

In relation to this process it is referring to widespread cracking were found in all bays motivated by the eccentric support (whose structural design is considered unfortunate) and aggravated by the cutting of the tendons existing at top, which occurs at a moment of history, this action has broken the link necessary in the structure and, in relation, it due to the deformations associated with the structural pattern of eccentric supporting the roof, there have been significant vertical cracking in the masonry wall, maximum amplitude at the top.

##### 4.2.- Pathological processes related to wood floors

An excessive deformation of the floor has leads to inclined cracking.

Also, to refer to the poor constructive solution embodied in the floors, while constructively with the aim of realizing the lowest possible edge, all load transmitted by the cargo beams to the main beams is via an indirect support in a strip of wood nailed to the main beam using tips arranged approximately every 40 cm. These elements, working to shear, are insufficient

to resist the future loads taking into account the effect of which could cause nicks in the wood.

Furthermore, based on calculations, it can be concluded that the wooden structural sections available are insufficient to keep both the state boundaries of service as last state boundaries.

#### 4.3.- Pathological processes related to the intersection of the eccentric "coronation prism" respect to the body of the towers and SW and SE

On the intersection of the "prism" with the body of the towers exist concerning local phenomena associated with the eccentric action of the prism which generate significant traction in the masonry walls which in the other hand are the cause of some of the pathological processes existing in the tower. It generates mechanisms of transmissions of eccentric loads not favourable and tend to be "open and collapses" load-bearing walls and main source of damage in these towers W and E (which led to stay first tower).

#### 4.4.- Collapse of the clock tower

The clock tower is located in the main building to one side of the main staircase.

At the level of crystals with lower volumes, North and South walls rest directly on the load bearing wall, while the east and west walls in the discharge prepared by two arches beneath each (at level 2<sup>a</sup> and 3rd floor), which encourages concentration and effort horizontal load to be offset by the shear strength of the union and counter thrusts associated with the supports. Once the loads are carried to the walls of the lower volume, these are transmitted to underlying levels while open, affecting the wall in most length, while descends the loads. In the South side of the tower the loads are transferred to lower levels through the existing masonry wall (North wall of auditorium), but with doors, that allows greater dilution of the loads in these levels. On the north side of the tower, the loads tend to focus on two stone pillars arches cut through motivating efforts horizontal east and west walls on the staircase. Finally, at ground floor level, on the south side of the tower, the loads, quite open, communicate to the field by four small section pillars and the load-bearing walls, and on the north side the loads are quite concentrate in two areas off the ground because the loads of the higher level are passed to lower level through two pillars which are the follow of the upper floor.



Fig. 13 "Example of description of the pathological process associated with the pancake detected in the clock tower"

Because at first sight appeared to detect a drop in the tower, it conducted a hypothetical analysis of movement through three-dimensional laser scanner. In that study concluded that there was a drop of 2.20 cm / m in the tested area (5 cm in total length of 2.25 m).

The most likely cause is that the pancake was due to one of the standard drawings of the tower associated with decreases differential between south and north. These declines were attributed to two causes, primarily a differential seat in the foundations of the North side respect to the South side, given the greater concentration of loads on foundations in the northern side, and secondary to a decline in the key of the arches in 1<sup>st</sup> floor, associated with a failure to counter lateral thrusts of impacting on the east and west walls of the staircase.

Regarding the lack of horizontal offsets in the arch of the main stairs, it seems that this problem was detected in the past because the tastings have been discovered the placement of three steel straps that tie the east and west walls of the staircase trying to provide the necessary horizontal offsets have been alluding.

In relation to the possible differential seat occurred in the foundation of the arch that rests on the north side of the tower (due to higher stress than in the south) are deemed to refer to it may be that in this central zone of influence of load from the clock tower is located supports the foundation (of the pillars and interior walls) not directly rest on the limestone substrate, but are based on the alluvial alteration of half-hard consistency (such and as that happened in soil pit C-9 of the campaign carried out geotechnical). In this situation, and given the greater deformability of the alluvial said that the underlying substrate would promote the development of those seats differential.

#### 4.5.- Pathological process in the auditorium area

In the south central area, around the architectural space called “auditorium”, were found several pathological processes. Next we will be given reference to them:

Deflections in excess are observed in the ceiling of the auditorium shaped (Fig. 14) due to the great length and that only exists two ready-bearing elements as a wooden lattice beam. Associated with this, it has seen a failure in the top (compression head) of one of the wooden lattice beams, it has suffered a compression instability being subjected to lateral buckling (especially severe damage as possible breakage of fragile or collapse without warning).

There are also cracking on the sides of the main facade of the building (south-west and south-east facade). In the south-west, the Fig. 15 shows a cracking amplitude very important and serious (about 6 cm and through the side wall sections): The main central facade is without link and collapsed outwards in the 3<sup>rd</sup> floor.

The deductive process followed has led to the conclusion that the main cause is associated with the rupture in the plane of greatest weakness of the walls perpendicular to the facade to the south wind suction is subjected to it in its central zone, as given the current configuration of the building most of the traction efforts generated are to be transmitted to the walls.



Fig. 14 “Lateral buckling cord compression from one of the main beams”

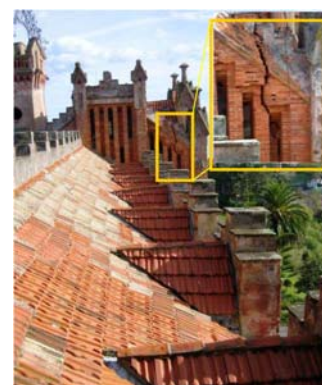


Fig. 15 “Overview of the South facade crack from the West tower”

#### 4.6.- Pathological process in the North facade

In relation to the central North facade (access to the church) cracking has been observed that increase in amplitude as it stands.

There are pathological processes associated with sucking wind, horizontal thrusts not compensate and bad attachment between the north facade’s wall and the perpendicular walls that forms the staircase attached to the church. Important cracking were observed in the side walls. After making three surveys and remove the revoke it is found that such cracks

have a large amplitude (Fig. 16) and depth, even in some cases are interns in the entire thickness of the wall.

In turn, the floor of the north staircase had been subjected to a shift and realignment. The slenderness of the arches represents the line of pressures associated with the efforts it has to withstand (weight and over-use) is forced at its very thick, so that a horizontal movement towards the outside wall of the north facade to cause the line pressure cannot be contained in the existing thickness, laminate sections of the ladder as manifested by cracking (plastic hinge) that just like the cracking of the walls in cross-gain amplitude as it rises.

## 5.- Structural study of the walls and foundation

In this sense it carried out the structural study of the Northeast bay's elements because it have the highest distance between the supports of the floor, and tower SW.

An evaluation by manual calculation of average tension pressure levels in service charges associated with weight and overloading of use, taking into account the effects of the eccentricity of the floors, has been taken for each bearing walls of the bay.

In the same way, through a bar model, the pressure levels in service associated with the actions of wind were assessed, both at present and in the future situation.

For the future situation was considered that all existing floors have been demolished and rebuilt in reinforced concrete. Under these assumptions the structural pattern varies, while the floors have the capacity to transmit loads across the length of the wall to behave as rigid diaphragms that transmit a horizontal transverse link wall, through mechanisms of bending and shear above, offer great stability to the building against such requests (for this is cross-checked against the walls shearing efforts).

In relation to the walls of the Northwest bay was concluded that all the verifications for the control stresses analyzed are satisfied.

For its part, in connection with the verification of structural load-bearing walls of the SW tower can be concluded that, in general, all the assessments made in the control stresses points in relation with compression mechanisms were ok. Also in the plane of intersection between the coronation prism and the bearing walls underlying the major tractions occurs in the central part of the wall and not on the corners, because in these, the charges associated with the pinnacles helps focus from loads applied in this plane, the eccentricity of the resultant reduced significantly and therefore the traction produced.

Given the need to compensate these traction efforts some solutions for possible reinforcement were proposed. One possible solution mentioned (Fig. 17) is the provision of a chain of tied reinforced concrete that hooping the four walls, a reinforced concrete floor with embedded armed timely two-way which fix (at the level of each nerve) in the hooping and a tight well-anchored vertical masonry wall or at the lower level floor.

Is also convenient to record that regard is clear from his examination for a hypothetical future situation in which all existing floors have been demolished and rebuilt in reinforced concrete.



Fig. 16 "Taste and cracking on the west wall of the East staircase. Landing between 2nd and 3rd floor"

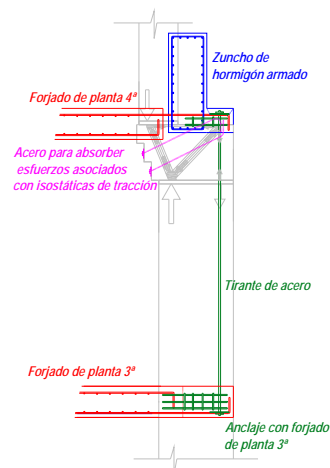


Fig. 17 "Drawings relating to the possible reinforcement of the union area of coronation prism and body of the tower"

## 6.- Structural study of other building elements

We also performed the verification of various structural zones of the building. Among the areas tested include the following:

- The church (Fig. 18) which includes a main structure formed by buttresses and arches along the top, floors, roof trusses and towers of the same.
- In South Central Zone, which is formed by the entrance hall, auditorium, roof and clock tower, also examines the facade that closes these volumes.
- Wooden floors of the building.
- Underground water tank situated in one of the cloisters of the building.

## 7.- Geotechnical study

Its aim was to establish the foundation of the different parts and elements of the building, with special attention to those which might be related to structural pathology, knowing the type and bearing capacity of new supports, and discerns what may be precarious requiring reinforcing or stressed.

In relation to the geotechnical characteristics of the materials involved we want to refer that is a contact site between two rock formations:

- Sandstone little cementless and shales in the NW and N of the building.
- Limestones and dolomites in the rest of the building.

In relation to the foundation can be concluded that the type of foundation used in all cases is very similar (Fig. 19), with load bearing walls supported on ditches filled with limestone gravel, with some degree of cementation. However, the geometry and composition of the foundation differs from other points. Apparently, in all cases, with greater or lesser depth and width of the ditch limestone gravel, transferring loads to the rock substrate.

In relation to the allowable stresses associated with each rock formation, refer to the case of limestones and dolomites can be considered an allowable pressure  $P_{adm} = 1.61 \text{ N/mm}^2$  and for the case of sandstones and shales cementless the  $P_{adm} = 0.45 \text{ N/mm}^2$ .

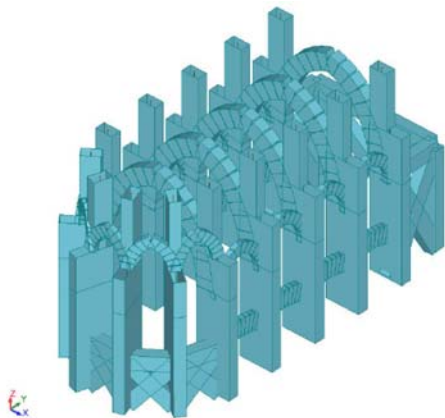


Fig. 18 "Bar model of the church's Seminary in Comillas"



Fig. 19 "Soil Pit for recognition the foundation of South facade wall"

## 8.- Study of stone materials, bricks and mortar: associated treatments.

The characterization of materials was conducted in two phases of work, comprising the first experimental characterization for physics, chemistry and mechanics of materials used in the original construction of the building, and the second phase of work, specific studies durability of the materials considered.

Have raised a series of experiments applied to each group of materials considered (stones, bricks and mortar). The characterization of the chemical composition of the materials was made by microscopy (Fig. 20), elemental microanalysis with electronic probe (EDAX) and mineralogical analysis by X-ray diffraction (XRD). The physical characterization of the rock was made with tests for the determination of apparent and relative densities, porosity and water absorption of each of them. The mechanical characterization of the elements of stone and brick was conducted by testing samples to estimate the mechanical resistance to

compression. Tests to characterize the durability of the material like frost testing and cycles of moisture/dryness, try to establish control of the mass loss of a specimen after being subjected to a cycle and the subsequent estimation the loss of mechanical properties through testing of a compression fracture after a complete cycle.

Furthermore, we examined the state of conservation of stone materials, bricks and mortar involved in the facades, to become aware of their current situation and suggest therapeutic treatments for these materials to protect and consolidate. For this, a campaign based on experimental tests of absorption and suctioning water, efflorescence and abrasion was made.

Based on these studies we recommended a reorganization of the entire package prior to treat and then perform, on brick walls of the building, a consolidation followed by a waterproof surface. The aim is to strengthen the microcrystalline structure of the bricks and reduce water absorption. In the case of limestone and marly limestone, it is recommended the application of a single hand of waterproof product, because of its low absorption in implementing the full treatment (two layers of waterproof material) is a slight alteration of the original appearance of stone (a slight rise in the tone of the same colour).

Furthermore, based on the results of abrasion resistance that are available can be concluded that the treatment slightly better abrasion resistance in all cases, which motivates a greater resistance to wind erosion of material exposed to external (important given its proximity to the beachfront).

### **9.- Moisture study**

This work was entrusted to the Profs. Gerónimo Lozano and Alfonso Lozano, from the University of Oviedo. In general, from the standpoint of moisture, it is understood that the property was subject to two unfortunate interventions that, coupled with its age, the different quality in design and materials of the noble area and the rest of the building, and lack of maintenance and neglect suffered by it for more than one third of its existence, explain and justify the current situation. These interventions have been primarily the cutting of the transversal steel wire stay at the roof level. Because of that, the meetings between the roof and walls have been transformed in the process of entry of water. And secondly the modification of the pipes network and the subsequent sealing of some pipes which overloaded other pipes, and some of the gutters, which not lead the water outside, adding the water inside the building.

Based on the lesions observed after the deductive process and developed with the aid of instrumentation, can be diagnosed the existence of first and foremost a process of seepage water from the upper bound (cover and terraces) and through the mansard, they in collaboration with the action of plants. Subsequently, the infiltrated water caused other secondary processes very diverse (affection of wood components by xylophages' agents, physical processes of capillary, expansion and retraction affecting the walls, etc.).

In relation to the therapeutic application relating to pathological processes due to water, it is recommended to restructure the building to cut the inflow of water through the cracks of its walls and restore missing link, remodel the drainage of rainwater to cut leakage and eliminate the vegetation cover, waterproof terraces cloisters and thus avoid the entry of water to them, clear the transit areas around the church, installing a drainage system that collects water downspouts and cutting of the capillary rise of water.

### **10.- Degradation of structural wood study**

This study aimed to analyze the degradation of existing elements of wood in the Major Seminary of Comillas, for this, some areas was selected for sampling, where the study was more intense, as well as other specific areas. To make the analysis was performed: A visual inspection of the signs of deterioration caused by organisms attacking wood surface by observation and/or computer vision techniques (endoscope), the relative humidity measurement of the woodwork, through analysis instruments; conducting tastings with specific drills for wood to determine the hardness and the depth (pseudo non-destructive methods); sonic methods (Fig. 21) for the determination of activity of the hypothetical bodies xylophages and analysis information gathered during visits to work for the state in which the

wood is in the areas surveyed. Finally, a series of proposed solutions for further processing, adapting to each situation.

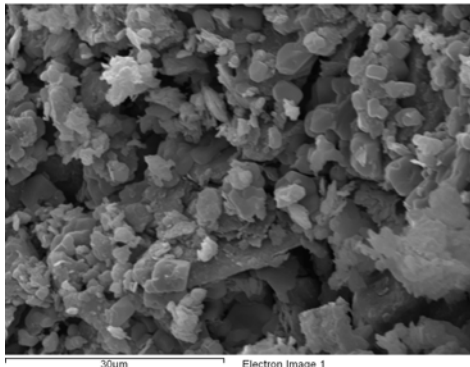


Fig. 20 "Microphotography the brick structure"



Fig. 21 "Sonic methods for the determination of activity of the hypothetical bodies xylophages"

In general, infestation which has regard to the building "Annobium" and "Lyctus" is entirely acceptable given the years of construction and is solvable with injection treatments (risk 3) and spray (risk 1 and 2) in the timber to be make rehabilitation. Fungal problems are solved, as the building and restoring the wetlands disappear, by impregnation of fungicides.

The presence of termites has detected in several areas of the building. To fix it would have to start work, before starting the rehabilitation work in the building, as the movement caused during them, which would temporarily made that the termites move to the outside termite, toward the interior of walls, free zones or work adjacent buildings, returning to the property at issue in the rehabilitation work completed. To avoid this it is necessary to begin to put baits attractive to the outside, trying to make contact with the different colonies of termites, and then begin treatment.

The wood is not likely replacement for mechanical requirements, i.e. to be retained in the restoration, it is essential to treat their protection and disposal of existing infestations, either by injection systems (heads or device) or by impregnation depending on the degree of infestation and attack affected. If using new wood during the rehabilitation work will be essential that all this wood is treated by the autoclave test vacuum system with vacuum-organic products (beams, joists, floor platform, battens, door frames, etc.) covering the type of risk 3. All new wood must be certified in the treatment effect and to guarantee the type of risk covered.

## 11.- Conclusions

Once the studies are considered the main pathological processes that had the Major Seminary of Comillas were detected, diagnosing which of them were serious and should be restructured on a project basis.

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