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The Importance of the Damage's Map in Identifying Pathologies on Historical Buildings: A Study of the Carmo's Church – Olinda – PE

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Abstract: The damage map is an important tool for the investigation of the conservation state of a building, especially when the surveyed element is a property with historical preservation interest. Thereby, we consider that the full understanding of the construction techniques is crucial to diagnose anomalies found in the facades of the buildings. It is very important to know the materials used in the construction and the routine of building maintenance. It is also necessary to emphasize the importance of having historical information about interventions and modifications that the building's structure suffered over the years in order to obtain data and requirements for the complete configuration of the analyzed building. This article results from a master's research in progress and it aims to present the process of the development of a damage map, seeking its implementation in a real case study, the facades of the Carmo's Church in the city of Olinda. There are three reasons why we chose this church to study. First, this building is inserted in the Historic Centre of the Town of Olinda, which is inscribed on the UNESCO's World Heritage list since 1982; second it was built in 1588 configuring the oldest church of the Carmelite Order in Brazil and finally the building has been restored and recovered recently in July 2012 and it is observed that, after four years, we observe some pathological manifestations in their facades.

Key words: Damage maps, pathology, diagnosis, church, patrimony.

1. Introduction

Generally, the structures degradation processes are directly related to the exposure of buildings to physical, chemical and biological agents that are found in nature and in their own building materials. So the structure is exposed to endogenous mechanisms that damage the structure from the elements found in the chemical and mineralogical composition of building materials. Also, the structures are exposed to exogenous mechanisms that are the action of man and climate on structure, the presence of pathological microorganisms, and the [1] urban transformation of the architectural environment.

Therefore, the diagnosis of these anomalies found in a building should be properly grounded in critical and investigative analysis of the cause of the problem in order to propose the most effective treatment to recover those damaged materials.

In this regard, it is necessary that surveys of pathological manifestations and documents produced from those surveys are objective, clear and remove any doubts that may arise regarding its interpretation.

One of these documents, that was originated from surveys and inspections in the buildings, is the damage map. Damage maps are fundamental tools for the investigation of the building conservation, especially when the surveyed element is a historical property where the interventions and the materials used gain important highlight in the diagnostic phase.

Although damage map is a crucial tool for the investigation, there is no regulation that would indicate or determine what the best way to be produced. Sometimes, it makes it difficult to the restorer's interpretations of the damage found in the inspected structures.

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Based on what was said before, this article results from a master's research in progress and it aims to show the development process of a damage map based on the methodologies adopted by Iphan, seeking its implementation in a real case study, the facades the Carmo's Church in the city of Olinda – PE.

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2. Characterization of Building in Study

2.1 Brief History of the Building

The Carmo's Church had its construction started after the arrival of the Carmelite Fathers in Brazil in mid-1580, which the plans of the time also included the construction of a convent that was started to be built in 1583, as highlighted in Ref. [1]. According to Ref. [2], this building is the oldest temple of the Carmelite Order built in Brazil.

The construction works of the convent and the Church lasted several years mainly due to the Dutch invasion in 1630 when the Church and the convent were ransacked and set on fire, leaving little of the originally planned structure. The Church had the largest bell of the city which was removed and turned into weapons by Dutch troops.

According to Ref. [3], after the collapse of the Dutch control, the reconstruction works were resumed only in the second half of Sec. XVII, due to internal differences in the Carmelite Order. Already at the beginning of Sec. XVIII were finalized the crownings of bell towers, and the gable design and lintels of the windows modernized the aesthetic standards of Pernambuco Baroque. The work developed from the mid-Sec. XVIII to its end, included internal ornaments works of the main altar and central aisle.

In 1907, the Franciscan monastery, which is illustrated in Figure 1, was demolished by order of the Olinda´s mayor, because it had structural problems, constituting a serious threat to the population and the Carmo's Church itself [4]. Today, we can see some vestiges of of the ordinance hall and the old foundation of the Convent in the site (see Figure 2).

By the year 2000, Carmo's Church suffered several interventions, undergoing restoration process and stabilization of embankments where the building rests. Olinda´s mayor had to rebuild the embankments and reinforce the foundations and the bell tower to east that was compromised (Figure 3). The restoration and recovery services lasted about 10 years, when the

Fig. 1 Old Carmo's Church with Carmelite Convent.
Source: Cultural Foundation of the City of Recife (FCCR).

Fig. 2 Current Carmo's Church: vestiges of the Carmelite Convent.
Source: Authors.

Fig. 3 Structural Damage in the Church of Carmo's in the middle of the year 2000.
Source: Public Collection of Olinda.

Fig. 4 Current damages in the Carmo's Church.
Source: Authors.

church was returned to the population. However, after only four years of restoration work, some anomalies in the facades can be observed.

2.2 Architectural and Constructive Features

The Carmo's Church is one of the most beautiful representations of the Brazilian colonial architecture religious being a very important place to be preserved. The building is protected by a federal law implemented by the federal government through the Instituto do Patrimônio Histórico e Artístico Nacional (National Institute of Historical and Artistic Heritage – IPHAN) on October 5, 1938 and it has an important role in the Historic Centre of the Town of Olinda, which is inscribed in the UNESCO's World Heritage list in 1982.

The temple has gable and facade in Baroque style, with some Renaissance traits. Its choir windows are decorated with stonework and the niche is among them also displays a beautiful stone work [3].

The inside building's decoration is simple. However, it highlights the altarpieces of the main altar and side chapels. According to Ref. [4], the Church interior is grand, treated with great erudition, where a soft light, filtered through the few openings, models and sets the empty architecture, full of great mystic value.

Under the constructive aspects, it can be inferred that the construction of the Carmo's Church adopted the same building typologies of the Brazilian colonial period, inherited from Portuguese and native Indians. In this case, they adopted large stones for master or structural walls and bricks or adobe for internal walls.

The Figure 5 presented below shows the Floor Plan of the building which can be seen projecting from the ruins of the former convent of the Carmelite Third Order. It is noticed that the main walls that support the

loads from the bell towers and coverage are very thick. The stone used in the construction of this building was the type limestone (though there is stonework in marble ornaments near the main altar), as attest [5]. Limestone is a sedimentary rock type that has low strength and high porosity, and it was used throughout all the masonry work at the facades of the Carmo's Church.

3. Survey the Damage

The process of surveying the anomalies to prepare the damage map was divided into three steps: identification of pathological problem, marking the plants of the facades of these anomalies and photograph of pathological manifestations.

Identification of pathological problem was the first stage. In this stage, we performed a touch-visual inspection in the lower regions and a visual inspection, using equipment that allowed the approach, on the tops of the four facades of the Carmo's church. In the second stage, we marked the anomalies identified in the first

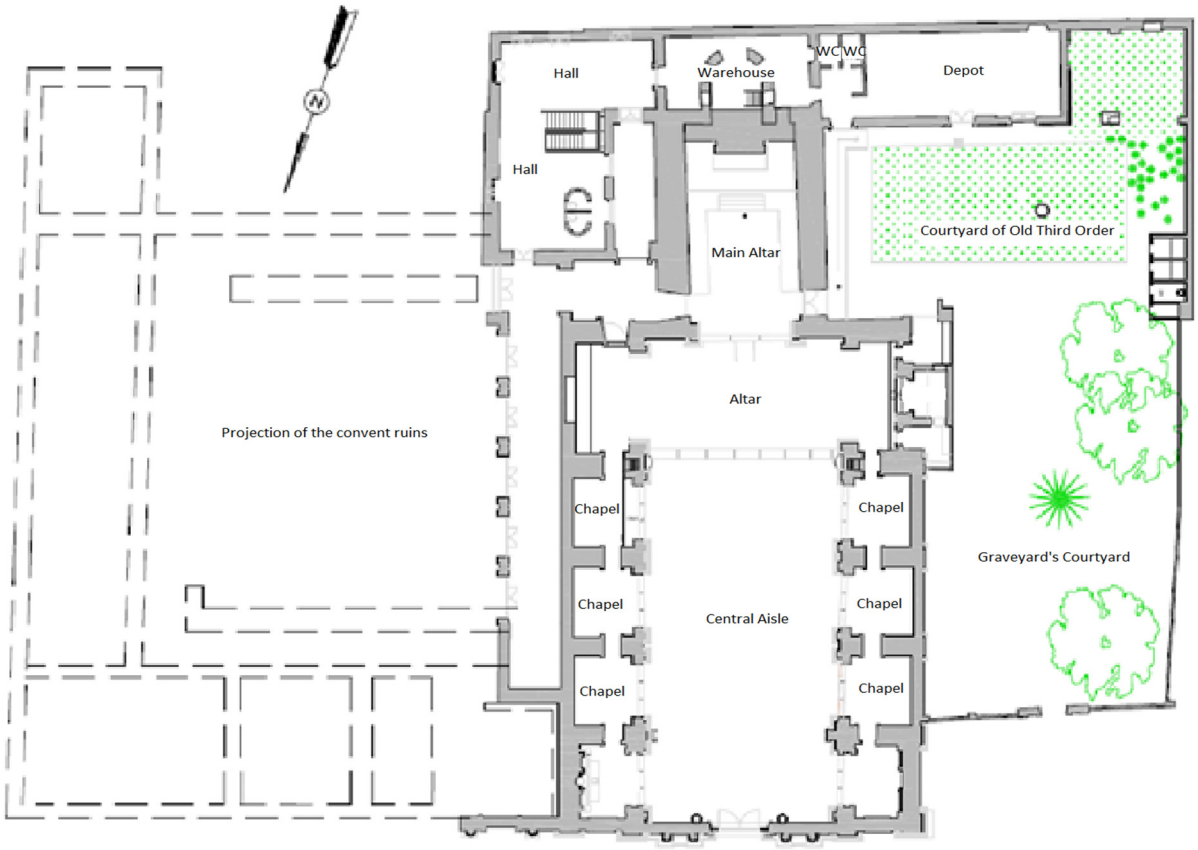

Fig. 5 Ground floor (no scale) of the Ground Floor of the Nossa Senhora do Carmo's Church.
Source: IPHAN (adapted).

stage with different colors on the printed plans of the facades taking care to mark the exact locations of the injuries. Then, in the third stage, we took some pictures of these anomalies in order to identify the type of pathological problem as well as the correct location of these manifestations.

Finally, in order to record the damage found, we elaborated the Damage Identification Form (DIF). This document is an important contribution to record the pathological manifestations promoting their respective diagnosis, since the DIF organizes the findings of surveys allowing comparisons

The damage identification form proposed in this article relates the damage of facade elements by separating them into (i) damage occurring on the walls (when it focuses on existing anomalies especially in plasters), (ii) damage occurred in masonry and (iii) damage occurring in frames. Then, each detected The stone used in the construction of this building was the type limestone (though there is stonework in marble ornaments near the main altar), as attest [5]. Limestone is a sedimentary rock type that has low strength and high porosity, and it was used throughout all the masonry work at the facades of the Carmo's Church.

Based on other surveys like [6] and [7] the anomalies were represented with a specified symbol so that we have a pattern representation for the pathological manifestations.

It is noteworthy that the inspection method used for the investigation of anomalies found is classified in Ref. [8] as an indirect method and seeks, through non-destructive actions, analysis of historical documents

and interpretation of the data found, base assumptions and conclusions about diagnostics of building damage in the study.

It also worth mentioning that the investigations were restricted only to the facades of the building so that the cover and the inside of the Church in the study were not surveyed for the preparation of this article

Thus, we can say that the pathological problems more observed in the facades of the Carmo's Church were dirt, vegetation, cracks and moisture. Also, it is found in the east facade, west and north, black crust recurrences. During the surveys were also found pieces of reinforced concrete with high state of reinforcement corrosion and wood rot in a northern front door. In the figures below are presents succinctly the Damage Identification Form of the pathological manifestations found in the analyzed facades.

Regarding the organization of the DIF, we showed a damage list, relevant photos of those damages and the date on which we surveyed so that you can establish a relationship between the building of the state of degradation and the time that it has been inspected, as shown in Figure 6. The period in which the construction was inspected is important to be shown because there is the possibility of evolution of damage since the pathological manifestations tend to develop in hostile.

The Figure 7 shows the East Facade's DIF, where it is observed that the pathological problems more incidents in this building are damp stains, dirt, cracks in the plaster, the presence of vegetation and corrosion of reinforcement.

DAMAGE IDENTIFICATION FORM

Building: NOSSA SENHORA DO CARMO'S CHURCH

Adress: Carmo Square, s/n - Olinda - PE - Brazil

Date of survey: may/16

NORTH FACADE

DAMAGES TO WALLS (MASONRY)	OCURRENCY AND SIMBOLOGY
1.GROUT'S DISPLACEMENT	X
2.GROUT'S DISPLACEMENT WITH EXPOSED MASONRY	
3.FIRE ACTION'S STAINS	
4. MOISTURE STAINS	X
5. BIODEGRADATION (FUNGI AND ALGAE)	X
6.VEGETATION	X
7. DIRT ACUMULATION (DIRTINESS)	X
8.EFFLORESCENCE (SALINIZATION)	X
9.SURFACE FISSURES (NON-ESTRUCTURAL)	X
10.ESTRUCTURAL FISSURES (SHELVES AND TRINKS)	
11.INTERVENTION WITH CEMENT/MORTAR	
12. VANDALISM (GRAFFITI)	
13. STEEL REINFORCEMENT'S CORROSION	
STONEWORK'S DAMAGES	
1. ALVEOLIZATION	
2. GRANULAR DISAGGREGATION	X
3. PITTING	
4. SECTION LOSS/LACQUES	
5. ESFOLIATION	
6. DARK CRUST	
SQUADRON'S DAMAGES	
1. TERMITE'S ATACKS	
2. MOLD	
3. WOOD DEGRADATION	X

Fig. 6 DIF of Our Lady of Carmo's's Church – North Facede.

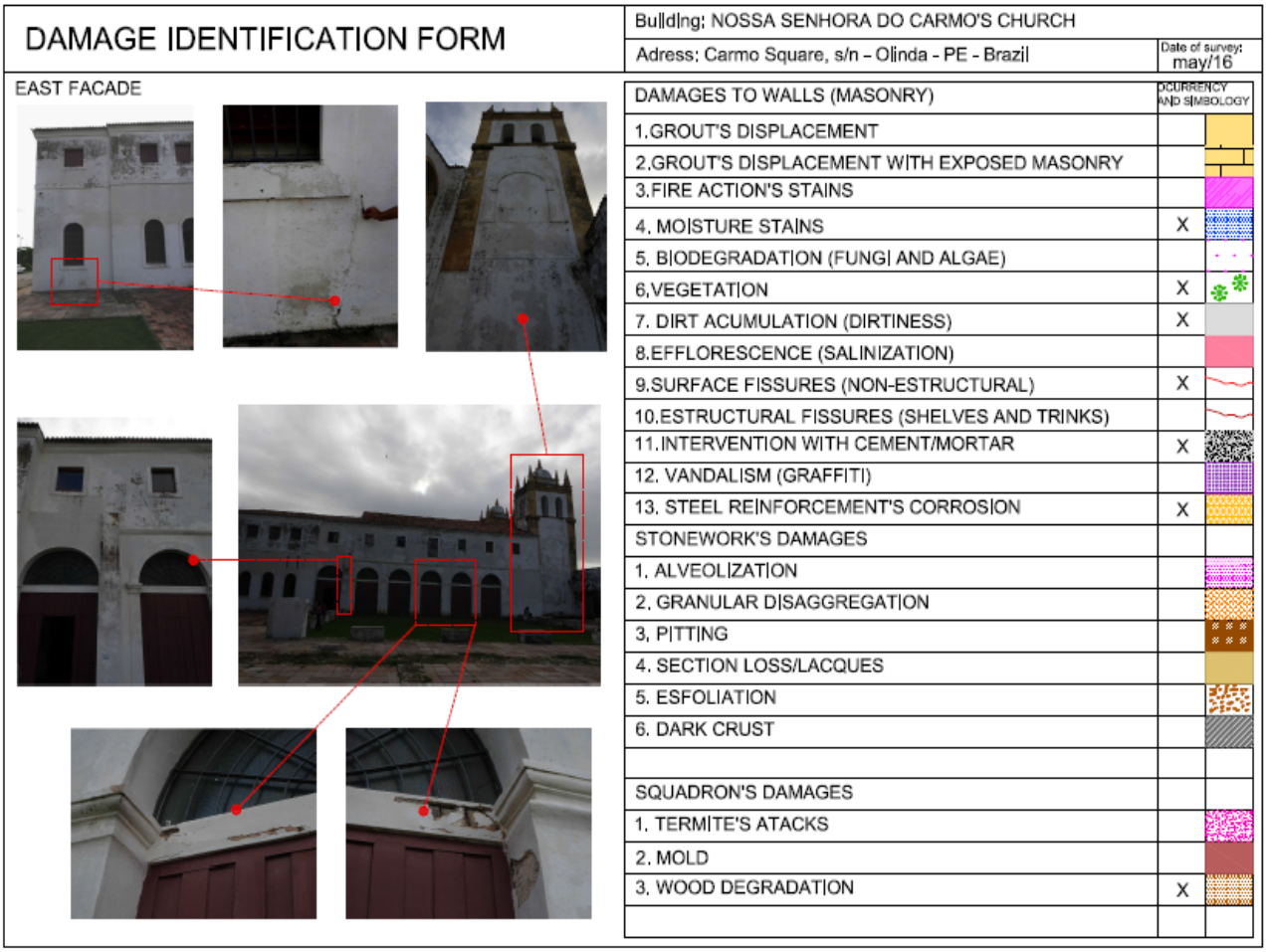

Fig. 7 DIF of Our Lady of Carmo's Church – East Facede.

The use of reinforced concrete, evidenced by the presence of reinforcement corrosion, indicates an intervention in the structure with the use of building technologies nonexistent at the time of construction of the temple. Thus, treatment of this pathological manifestation should be done as soon as possible and so as not to interfere with the safety preserving the architectural features of the facade.

It is noteworthy that the East facade of the building has a higher incidence of salt spray, given that Carmo's Church is located in a coastal area. Thus, the reinforced concrete structures are more likely to degenerative action of chlorides and cycles wetting and drying produced by the rains.

Thereby, the correction of corrosion points found in the inspection of the East facade must be treated as soon as possible in order to avoid loss of steel section, stirrups breaking and peeling of more areas.

In the south facade, there were also damp stains with dirt, including damp stains upward along the full length of the facade (see Figure 8).

Also, there were some changes to the initial design of the building, some door openings were sealed, and some windows could not be opened anymore. We did not get the information about the interventions implemented, which made it difficult to identify the material that was used to seal these elements. We believe that the material used was probably a high porosity and high permeability since there were some damp stains in areas where these changes were made.

DAMAGE IDENTIFICATION FORM

Building: NOSSA SENHORA DO CARMO'S CHURCH

Adress: Carmo Square, s/n - Olinda - PE - Brazil

Date of survey: may/16

SOUTH FACADE

DAMAGES TO WALLS (MASONRY)	OCURRENCY AND SIMBOLOGY
1.GROUT'S DISPLACEMENT	
2.GROUT'S DISPLACEMENT WITH EXPOSED MASONRY	
3.FIRE ACTION'S STAINS	
4. MOISTURE STAINS	X
5. BIODEGRADATION (FUNGI AND ALGAE)	
6.VEGETATION	X
7. DIRT ACUMULATION (DIRTINESS)	X
8.EFFLORESCENCE (SALINIZATION)	
9.SURFACE FISSURES (NON-ESTRUCTURAL)	X
10.ESTRUCTURAL FISSURES (SHELVES AND TRINKS)	X
11.INTERVENTION WITH CEMENT/MORTAR	
12. VANDALISM (GRAFFITI)	
13. STEEL REINFORCEMENT'S CORROSION	
STONEWORK'S DAMAGES	
1. ALVEOLIZATION	
2. GRANULAR DISAGGREGATION	
3. PITTING	
4. SECTION LOSS/LACQUES	
5. ESFOLIATION	
6. DARK CRUST	
SQUADRON'S DAMAGES	
1. TERMITE'S ATACKS	
2. MOLD	
3. WOOD DEGRADATION	X

Fig. 8 DIF of Our Lady of Carmo's Church – South Facede.

Another issue identified is the appearance of a vertical crack with thickness ranging from 0.5mm to 2mm found near the tank wall (south facade). As the Carmo's Church has a history of structural problems arising from settlements, having gone through a strengthening of foundations in mid-2001, it is necessary to consider this problem by monitoring this fissure in order to identify their origin.

The figure 9 shows the DIF of the West Facade. The anomalies frame is similar to other facades. However, there was more damage in the structure of the masonry in this facade than the others with granular breakdown, pitting and section loss (gaps).

We can also see in the DIF of the west facade that the process of penetration from the soil capillary water was intensified by building metal ramp that, in the time of rain, splashes on the facade. Thus, it is observed at this point the development of molds and slime.

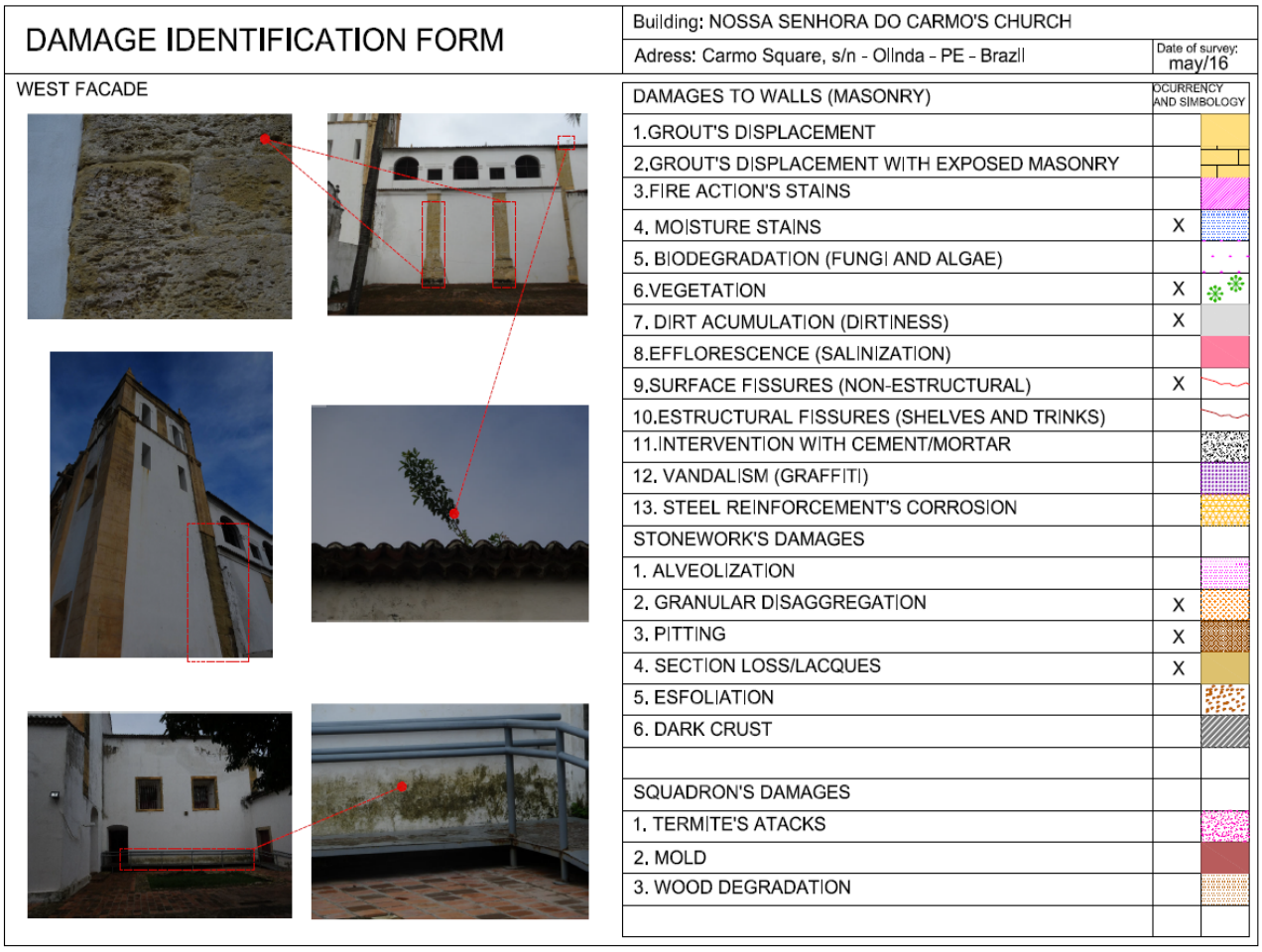

Fig. 9 DIF of Our Lady of Carmo's Church – West Facede.

4. Damage Map's Elaboration

Ref. [8] defines damage map as the graphic-photographic representation, synoptic, that are illustrated, discriminated, rigorous and thoroughly all deteriorations manifestations of the building in order to synthesize the results of investigations of structural and functional changes in the materials, in technical, systems and building components.

The same author also alerts to the fact that we cannot confuse the terms damage map and mapping damage, because the first is the document or set of documents illustrating the building conservation status of specific date. Mapping damage consists of one phase of a survey, which we survey, research and produce data to create the damage map.

Therefore, to prepare damage maps is essential to collect information of the building studied so that we can better understand the pathological problems that can be found in the damage survey phase. Thus, the construction methods, the history of interventions and understanding of the area where the building is located are key factors for the analysis of pathological manifestations.

So we need some documents to create Damage Map like the DIF of each facade analyzed (with the identification of a symbol for each damage found), the photographic reports and notes on the historical data and construction materials of the building under study.

Figures 10, 11, 12 and 13 below present the damage maps created from the North facades, East, South and West, respectively, of the Carmo Church.

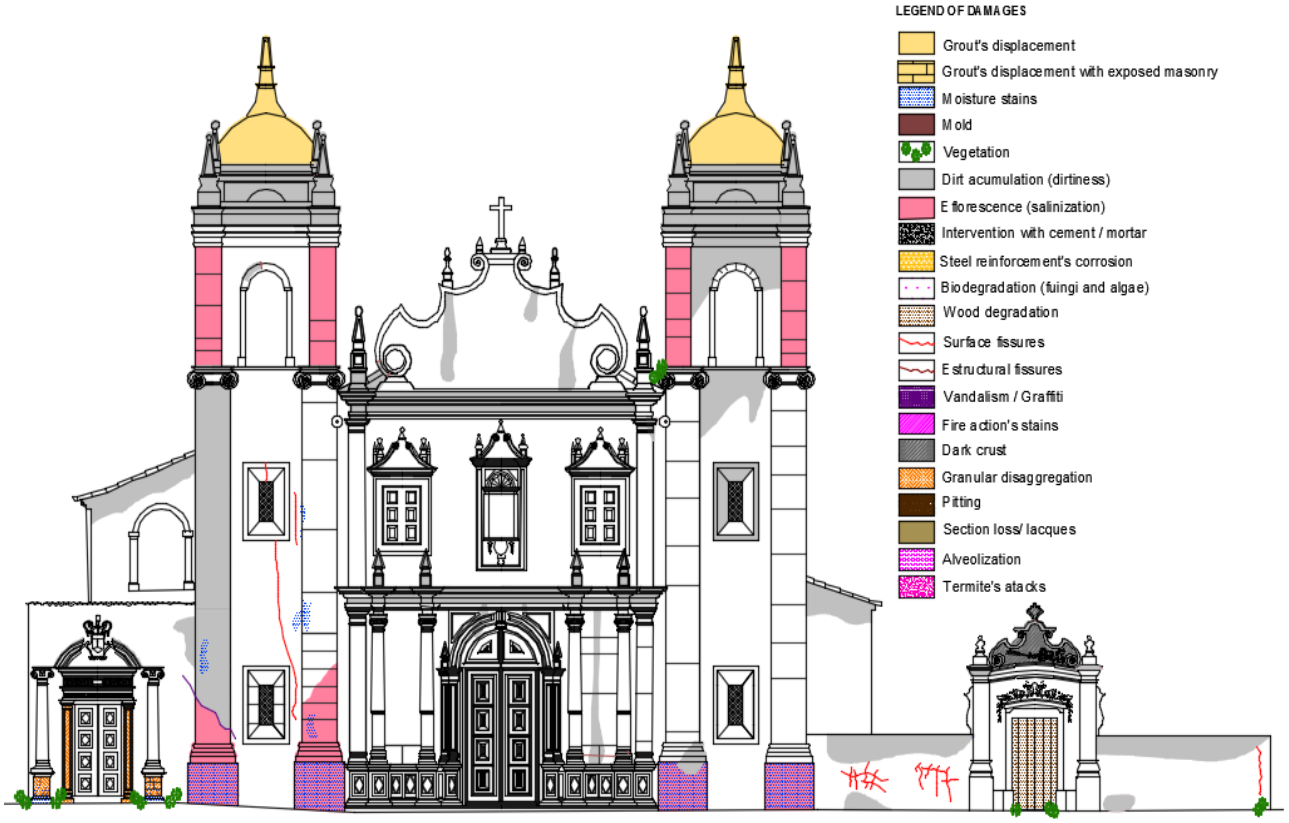

Fig. 10 Damage's Map of Our Lady of Carmo's Church – North Facede..

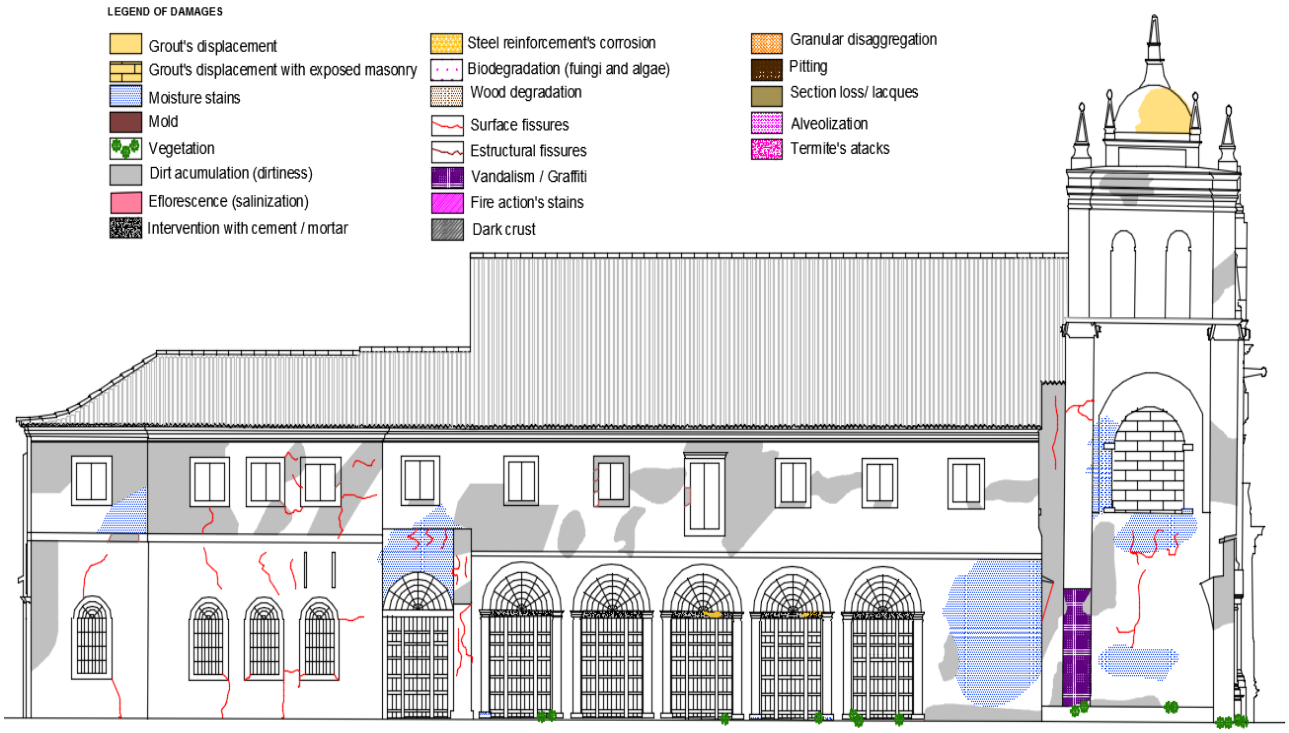

Fig.11 Damage's Map of Our Lady of Carmo's Church – East Facede..

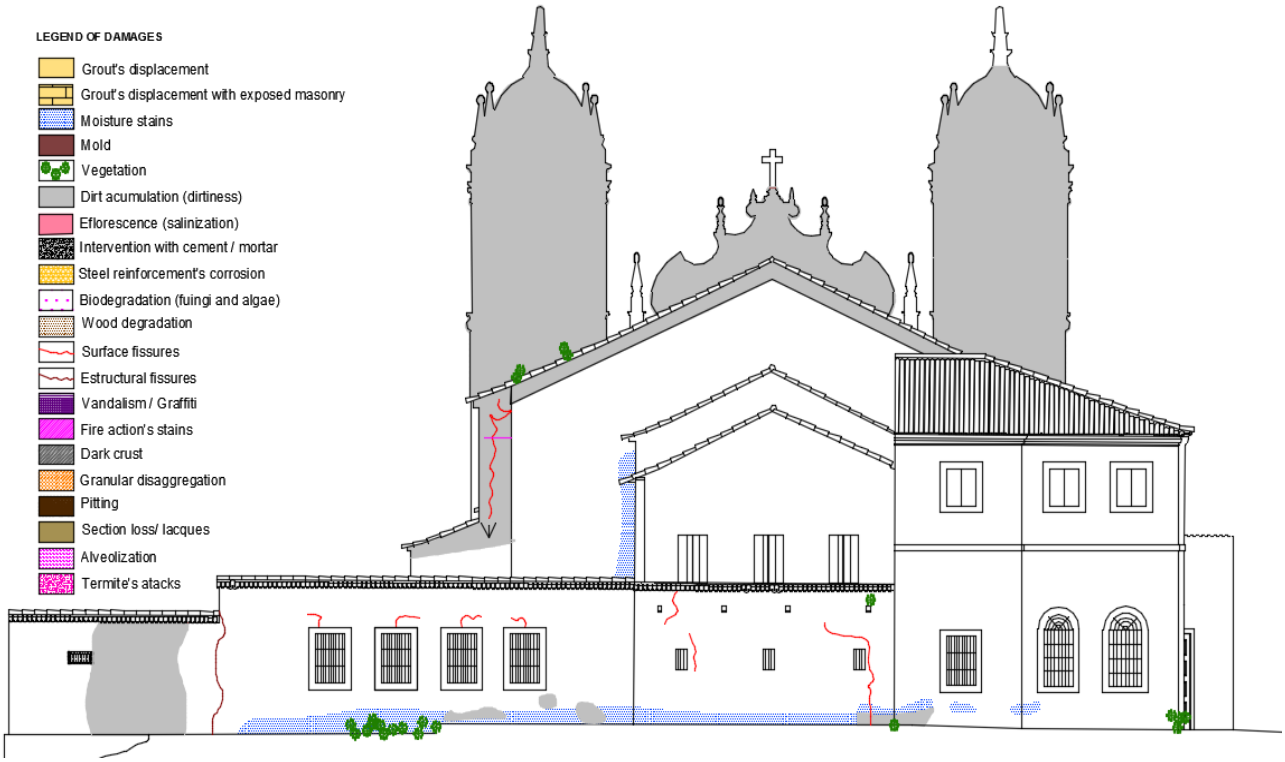

Fig. 12 Damage's Map of Our Lady of Carmo's Church – South Facede..

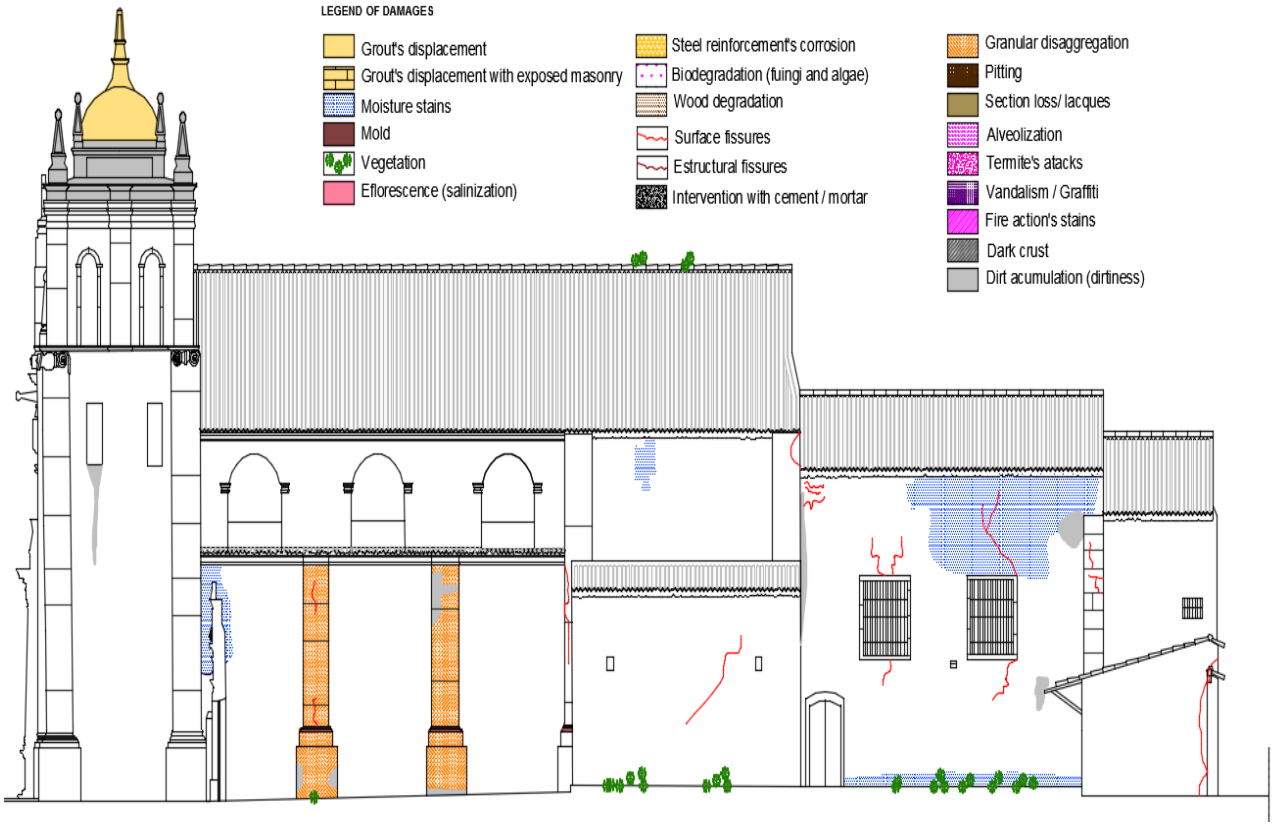

Fig. 13 Damage's Map of Our Lady of Carmo's Church – West Facede..

5. Final Considerations

It is known that the analysis of the pathological manifestation source is crucial because we can treat the problem properly and the problem will not manifest anymore.

For example, we detected corrosion in the East facade of the Carmo's Church where there was an intervention with reinforced concrete. After analyzing the area, we observed that the East facade was nearest to the ocean where occurs salt mist. It confirms the importance of the knowledge of the environment which the building is located.

Thus, the analysis of the conditions for development anomaly is essential for diagnosing the problem. Questions such as "why did this anomaly manifest in this place?" must be made so that there is an understanding of the source of pathological manifestations.

In this sense, the development of Damage Identification Form - DIF actively collaborates in the analysis of pathological problem and at the same time it is a fundamental tool in order to have a documentary record of the visits and anomalies found in the Church's structure.

After the preparation of the DIF, creating damage maps comes to simplify the visualization of each pathological manifestation showing the problems in a simple and practical way their size and location in the studied facades.

This helps significantly in determining the best therapy for the studied problems, and it also helps to identify the best plan of attack for the recovery and restoration of construction studied.

The research also leads to identify the need and importance of properly use the materials in association with the environment in which they are inserted. In our studies, specifically in the Carmo's Church, we realized that most of the observed pathological manifestations could have been avoided with the adoption of less porous and permeable materials.

Despite this perception, we do not rule out that these buildings from the colonial period were sometimes rudimentary and empirical built when the engineers would not consider the degrading action of man and the environment, the transformation of the urban atmosphere and especially the deterioration caused by the action of time itself.

Also, there is the difficulty of dealing with special interest of property preservation, considering that the laws and regulations necessary for the preservation of the property can intervene significantly in the maintenance of the building when associated with inefficient management tools heritage preservation and inappropriate restoration techniques for conservation and tumbled.

Finally, we reaffirm the importance of the damage map and damage identification form as essential tools for the diagnosis and therapy of historic buildings since they represent documentary records of the buildings degradation state.

Acknowledgments

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