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AMBIENT VIBRATIONAL CHARACTERIZATION OF THE NOSSA SENHORA DAS DORES CHURCH

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Abstract. The present paper shows the vibrational characterization tests of a clay brick heritage construction from XIX century, the Nossa Senhora das Dores Church, placed in Sobral, Brazil. In this study the calibration of the 3D finite element numerical model of the church was performed through ambient vibrational testing using the first three natural frequencies identified. The obtained results, namely the natural frequencies identified, and the calibrated model intends to give a contribute for understanding of the structural behavior of the Brazilian heritage constructions, and introduces relevant information for be used for safety assessment of the church along the time.

Keywords: dynamic identification, ambient vibration testing, heritage construction, FEA, OMA.

Introduction

Heritage constructions (HC) have become an interesting and challenge field for engineering advances due to high variability and complexity of its structural systems and the current necessity of to implement news techniques for non-destructive assessment opened to be integrate with structural monitoring systems. In this way, vibrational methods are one of the most employed techniques for non-destructive assessment reported in the literature (Rytter 1993; Boscato *et al.* 2016; Mesquita *et al.* 2017).

In fact, vibrational testing had been applied in different types of structures in order to collect data for dynamic characterization (Beskhyroun *et al*. 2012; Magalhães *et al*. 2012; Martins *et al.* 2014), especially due to possibility of to characterize globally the structures (Yun *et al.* 2011) and in the case of ambient vibration characterization because they allow the structural characterization without no excitation equipment (Gentile, Saisi 2007). The recent developments on sensors devices, data processing tools, and its application on buildings and infrastructures allowed overcoming several technical issues on this field (Ivanovic *et al*. 2000; Brownjohn 2003; Spencer *et al*. 2004; Hans *et al.* 2005), however cases involving vibration characterization of HC had been rarely reported in the literature, especially out of European zone (Mesquita *et al.* 2016).

Ambient vibration measurements were obtained and analyzed by (Potenza *et al.* 2015) for to characterize and monitoring the Basilica di Santa Maria Col-

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lemaggio, in Italy. The partial collapse of the church after L'Aquila earthquake in 2009, make increase the uncertainties on its structural behavior, motivating the necessity of characterization and monitoring of this historical construction from Italian Romanesque period. The church was instrument by accelerometers and the data collected allowed the dynamic characterization of the church. The contributions of this work can be summarized in terms of the dynamic behavior identification of the church, as well by description of the strategies employed for vibrational testing.

Essentially, the identification of the structural dynamic properties are an useful tool for safety analysis, making possible the investigation of damages influence on global behavior of structures, as previously demonstrated (Potenza *et al.* 2015). Moreover, this tool can also provide useful information for be used in support of structural risk reduction, as for instance for be used in accordance with proceedings described in (dei Ministri 2011) and (CIB 2010).

In (Gentile, Saisi 2007), an ambient vibration testing was carried out in order to provide complementary information on the bell-tower of the Cathedral of Monza, Italy. This work presented a simplified methodology for dynamic characterization based on data come from Operational Modal Analysis (OMA), and the results allowed optimizing a 3D finite element model for be used in the support of the safety analysis of the tower under different loadings conditions. The authors highlight that this approach seems a promising way of to assess HC globally, especially for to analysis the impact of hypothetic scenarios of damage to structural safety.

Optimized procedures for dynamic identification of heritage constructions are described in (Boscato *et al.* 2016). In this report the authors provided useful information for ambient vibration characterization of churches, towers and palaces, as for instance the general range of fundamental frequencies found experimentally, namely standing between 2.5 Hz and 7 Hz, while the frequencies around 1.50 Hz are mostly related with domes and façades. Moreover, the authors highlight the existence of a lack of knowledge on structural behavior of heritage construction, making necessary some efforts by technical-scientific community, to overpass this issue.

The present work was developed with the main aim of identifying the dynamic properties of the Nossa Senhora das Dores Church, located in Sobral, Brazil, through a theoretical-experimental based strategy. In the paper, an ambient vibration procedure was carried out to identify the natural frequencies of the Nossa Senhora das Dores Church (see Fig. 1), in order to collect information for updating a 3D finite element model that will allow to proceed with assessment of the structural condition of the church. The ambient

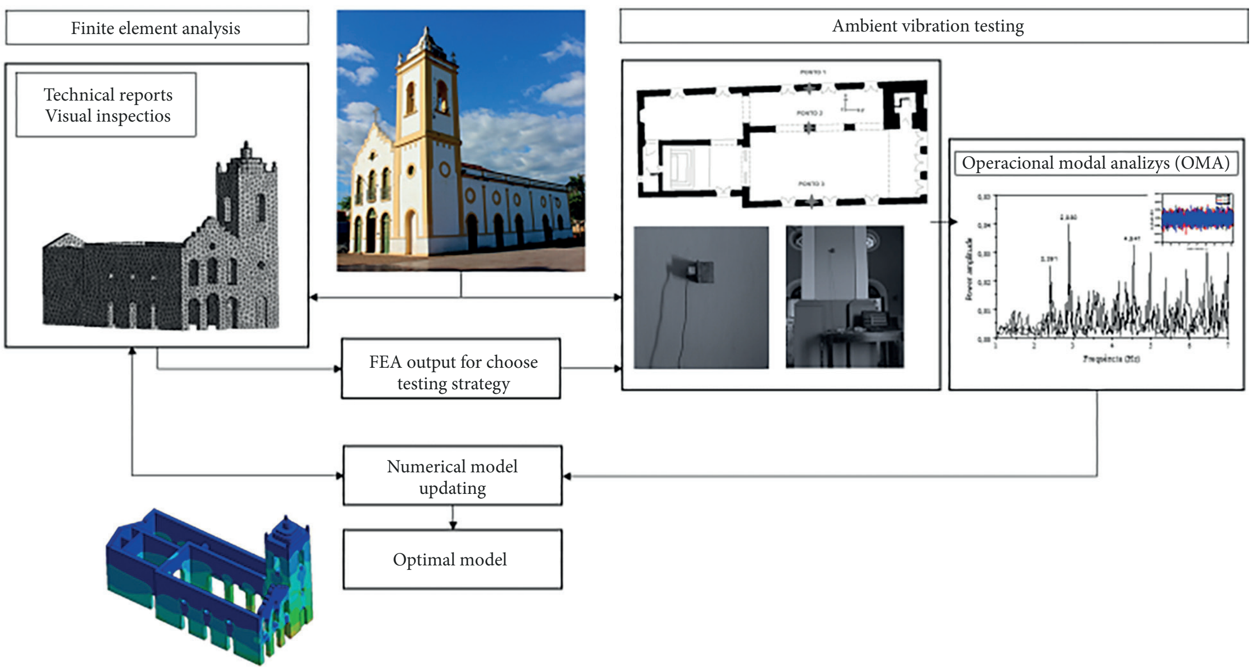

Fig. 1. Ambient vibration procedure used for Nossa Senhora das Dores Church characterization

vibration procedure carried out in this work included the following main steps:

i. Finite Element Analysis (FEA);
ii. Ambient vibration testing;
iii. Operational modal analysis;
iv. Numerical model updating.

Additionally, no report was identified in the technical literature concerning ambient vibration characterization of Brazilians HC by OMA, making from this work an important contribution for study and understanding of the structural behavior of Brazilian ancient structures.

1. Theoretical background

Operational Modal Analysis is based on the measurement of structural modal responses only due to the action of ambient and operational forces. This method is usually employed for modal characterization of large constructions, as bridges, towers, offshore structures and buildings, considering that the environmental and operational forces (random forces) are sufficient for the structural excitation (Magalhães *et al.* 2012).

Essentially, the modal parameters collected in field measurements are commonly used for calibrating numerical models, and one of the primary data analyses methods applied is the Fast Fourier Transform (FFT).

The FFT can be understood as a Fourier series which the periodic signal is the sum of an infinite number of harmonic signals, or in another words, using the FFT function the time domain signals recorded in field can be resolved in terms of its frequency components (Magalhães 2010) and can be obtained by the Expression 1, where $F(x)$ is the FFT function, L is the interval analyzed (in this ranging $-L \le x \le L$) and a and b are coefficients according to interval L.

$$F(x)=a_0+\sum_{n=1}^{\infty}\left(a_n\cos\frac{n\pi x}{L}+b_n\sin\frac{n\pi x}{L}\right). \quad (1)$$

One of the simplest method used in OMA is the peak-picking, employed for identification of the frequency of vibrations in OMA, basically due to the fact that this method consists in the identification of the peaks of the frequency spectrum obtained by the processed power spectrum domain data.

The relation between the random excitation forces $F(t)$ and the spectral responses $X(t)$ can be described in the frequency domain through the Frequency Response Function (*FRF*), $H(w)$, according to Expression 2, where $SFF(w)$ and $S_{XX}(w)$ are the PSD matrices of the random excitation forces and spectral response, and T indicated conjugate and transpose operation (Le, Tamura 2009).

$$S_{XX}(w)=H(w)S_{FF}(w)H^T(w). \quad (2)$$

However, the FRF can be also described in partial fraction, as pole/residue, as suggested by (Brincker *et al.* 2001) and presented by Expression 3, where N is the number of modes, i is the index of mode, A_i and λ_i are residue and pole, respectively, when $A_i = \gamma_i\phi_i\phi_i^*$ and $\lambda_i=\zeta_i w_i + jw_i\sqrt{1-\zeta_i^2}$, noting that ζ_i represents the modal damping ratio, and γ_i and ϕ_i are the scaling factor and modal shape vector, respectively. So, this is a modal decomposition of the spectral matrix and the expressions 7 and 8 can be directly related, under the hypothesis of independent white noise input.

$$H(w)=\sum_{i=1}^{N}\left(\frac{A_i}{jw-\lambda_i}+\frac{A_i^*}{jw-\lambda_i^*}\right)=\sum_{i=1}^{N}\left(\frac{\gamma_i\phi_i\phi_i^*}{jw-\lambda_i}+\frac{\gamma_i^*\phi_i^*\phi_i^{*T}}{jw-\lambda_i^*}\right). \quad (3)$$

2. The Nossa Senhora das Dores Church

Nossa Senhora das Dores Church (Fig. 2) is a clay brick historical structure, built on 1880s, placed at Sobral downtown, near of the Acaraú river. Sobral is located at north of Ceará State, in Brazil, 230 Km away from Fortaleza. The city was founded on XVII century, and presents one of the biggest historical centers of Brazil, with over around 1200 buildings classified since 2009 by *Instituto do Patrimônio Histórico e*

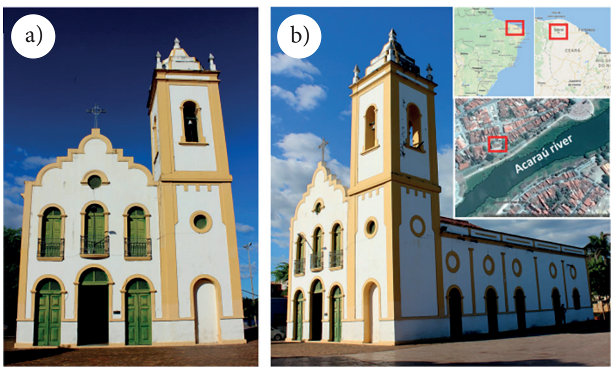

Fig. 2. Nossa Senhora das Dores Church: a) main façade and b) lateral view of the church

Artístico Nacional (IPHAN). Since 2008, some seismic events had been registered at Sobral region, and the continuous monitoring had confirmed that its occurrence is each more often.

The church façade presents two levels, the first with three arched doors, and the second level with the arched windows aligned with the doors of the first level. The façade can be characterized as architectural neoclassic style, however the lateral bell-tower (Fig. 2b) does not follow the same architectural style, because its construction just was finished in 1924.

The church presents a regular geometry with 26.17 m of length and 11.87 m of width, and a maximum high of 20.50 m (the tower), and it is divided in a Central Nave separated from a Lateral Nave by two columns and three arches, the Coro-Alto, the lateral bell-tower, the Altar-Mor and an office (in the end of the building). The Figure 3 shown a schematic view of the geometry of the Nossa Senhora das Dores Church, while Figure 4 presents details of the interior of the church.

A visual inspection carried out, on the Nossa Senhora das Dores Church, allowed the identification of the main damages present on the façades and to build a damage map, shown by Figure 5. Firstly, the damages will be not considered in the FEA, however the damage mapping will be used as support for interpretation of the numerical model results. The main damages identified on the church are related with cracks (surrounding the opened areas), biological attacks and mortar detachment. In general, these damages are related with material decaying, and does not present risk to structural safety of the church. Figure 6 illustrates the type of damages found on the church.

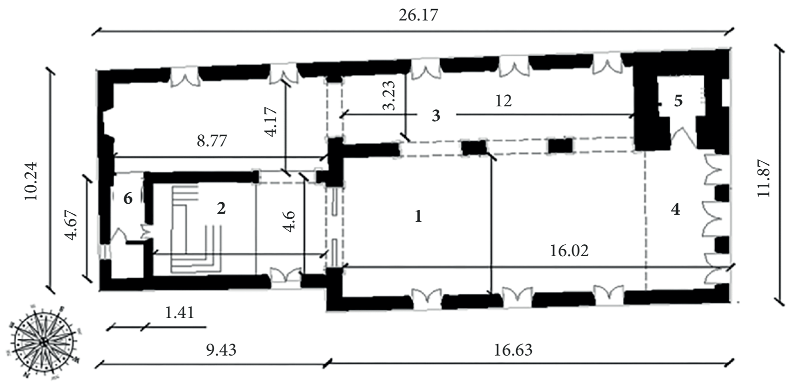

Fig. 3. Schematic cut of geometry of the Nossa Senhora das Dores Church, where 1 is the Central Nave, 2 is the Altar-Mor, 3 is the lateral Nave, 4 – is the Coro-Alto, 5 is the bell-tower and 6 is the office

Fig. 4. Interior of the Nossa Senhora do Rosário Church: a) Altar-Mor; b) Central Nave and Coro Alto; c) columns and arches and d) lateral Nave

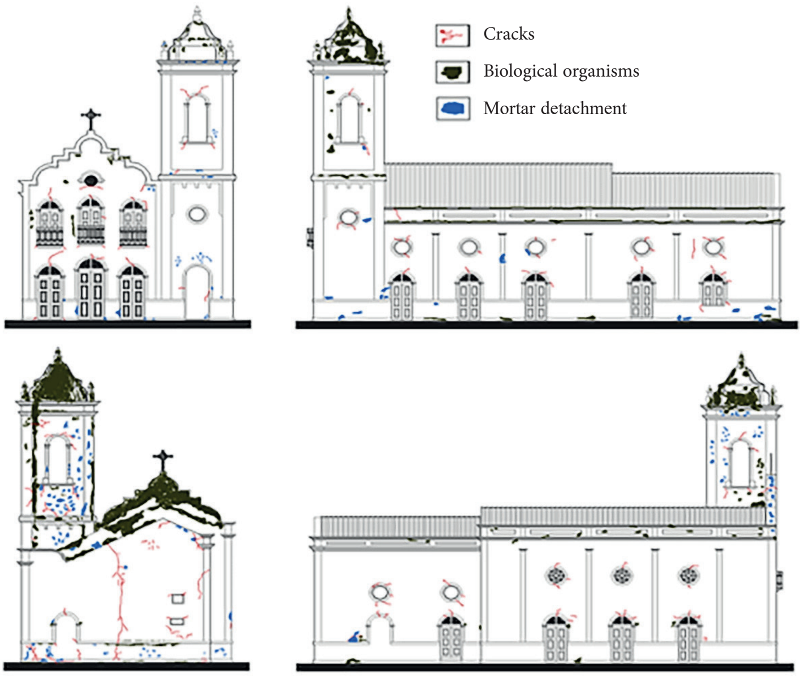

Fig. 5. Damages mapping of Nossa Senhora das Dores Church

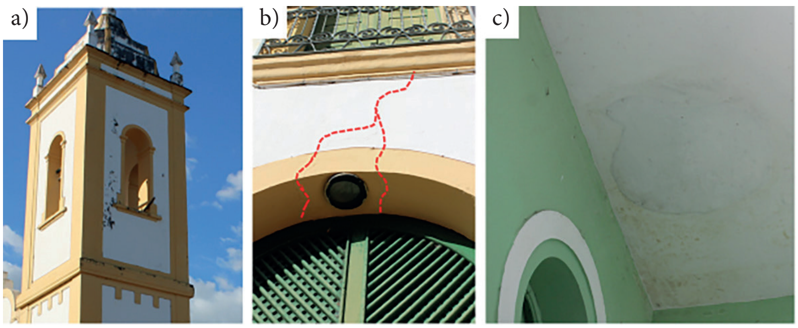

Fig. 6. Examples of the damages found during the inspection on Nossa Senhora das Dores Church: a) degradation by biological action; b) cracks in the arches and c) humidity presence in the slab roof

3. Finite element modeling

Before the ambient vibration testing be carried out on the Nossa Senhora das Dores Church, a 3D (Fig. 7) model was built based on the geometric survey. Some simplifications were done in the numerical model to reduce possible discontinuities in the finite element frame, as for instance the roofs and the Coro-Alto were not considered for the model. In the same direction, the architectural details in the main façade were simplified, and a constant thickness of 0.60 m was adopted to the walls. Exceptionally, the walls indicated in the Figure 7b, at the end of the Altar-Mor and the wall inside of the office, presents thickness of 0.35 m and 0.15 m, respectively.

The stairs, the timber structure of the Coro-Alto, and the roofs were not modeled, however equivalent loads and mass were considered in the numerical model. The reinforced-concrete stair presents a "L" form and goes on till maximum high of 10.00 m. This way,

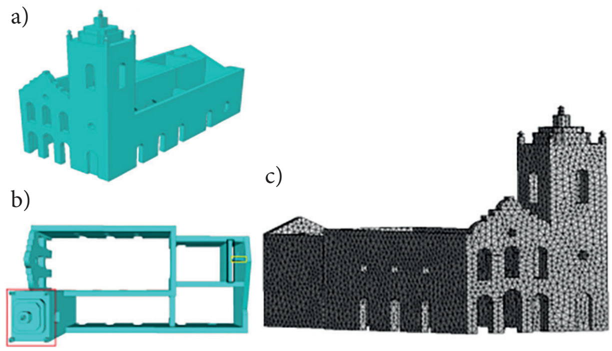

Fig. 7. 3D finite element model of the Nossa Senhora das Dores Church: a) lateral view of 3D model; b) top view of the 3D model and c) 3D model with finite element frame

according to NBR 6120 (ABNT 1980), the stair loading was assumed as 3 kN/m^2, and it was uniformly distributed at the top surface of the four tower walls. For the Coro Alto loading a timber type Pine was considered and its specific weigh, γ, of 5 kN/m^3 (ABNT 1980) was used for calculate its load, taking into account the geometric measures of the Coro Alto. This way, for each support of the Coro Alto floor, a load of 1.75 kN/m^2 was applied. Following, the roof consists in a timber structure, where the ceiling tiles are supported, and in the bottom a ceiling plaster, usually adopted in the region, is fixed in the timber structure. For the ceiling plaster a loading value of 0.60 kN/m^2 was adopted, the same value adopted by (Branco 2007). For the roof load was stated as 1.30 kN/m^2, the same value adopted in (Neves 2008). Moreover, an additional loading of 0.75 N/m^2 was applied on the roof. This way, the total loading of the roof was of 2.65 N/m^2, and that value of load was distributed along of the walls that support the roofs element.

Concerning the mechanical properties of the clay brick used, initially were considered the values reported in the literature due to the impossibility of to proceed with *in situ* mechanical characterization. The Elastic Modulus (E), Specific Weight (W) and the compressive strength (f_m) were stated based in (Ministero Delle Infrastrutture E Dei Trasporti 2008). The Poisson coefficient (ν) was adopted as 0.20, according to (Branco 2007; Delgado 2013; Ortega *et al.* 2015). The tensile strength was stated as 5% of the compressive strength, as usually is adopted in analytic software as 3muri (STA Data 20017). Table 1 summarizes the mechanical properties of the clay brick masonries adopted in the numerical model.

Table 1. Mechanical properties of the clay brick masonries adopted to numerical model

E (GPa)	W (kN/m^3)	f_m (MPa)	f_t (MPa)	ν
1.50	18.00	3.20	0.16	0.20

The FEA was performed with Ansys®, and the numerical model of the Nossa Senhora das Dores Church resulted in 93380 nodes, 53889 tetrahedral elements with 6 degrees of freedom each one. The element SOLID187 was used due to his compatibility with irregular and curved surfaces. The details of the finite element frame can be observed through Figure 7c. The church footing was considered with fixed translations and the numerical model was considered as unique solid.

4. Ambient vibrational characterization

4.1 Experimental setup and natural frequencies identification

The experimental testing was carried out according to experimental setup shown in Figure 9 in April, 28th 2016. The accelerometers positioning were defined based on previous numerical results through FEA, where the initial configurations of the modal shapes of the church were obtained. For data collect, a triaxial accelerometer, with frequencies record between 0 Hz and 100 Hz, controlled through a LabView® software (Fig. 8) developed by Institute of Telecommunications of Aveiro, was used. The data acquisition system re-

Fig. 8. Interface of the software used for data acquisition

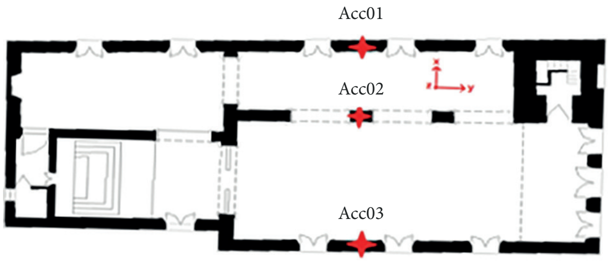

Fig. 9. Accelerometers positioning and data collecting

cord acceleration data during 10 min. The accelerometers were placed 3.00 m of high from the footing of the church, and details of the sensors positioning, and data collecting can be observed by Figure 8.

Accelerations in 3 directions were recorded during 600seconds in each measure point as assigned by Figure 9. The X direction was considered as out-of-plane of the walls (transversal direction), and Y direction was stated as in the plane of the walls (longitudinal direction), while Z was considered as vertical direction.

For OMA, the accelerations register in the X and Y direction (Fig. 10) were processed by Fast Fourier Transformer (FFT), with recurrence to commercial software *SeismoSignal*®. For that 16384 points were used, once that FFT request samples in the form 2^x, in this case 2^{14}, with a time interval of 0.001 s.

The data collect in the vertical direction (Z) were not considered in the OM, once based on the preliminary analysis, and as expected, of the signal amplitudes demonstrates that in the vertical direction the church does not present significant values in comparison with signal amplitudes observed in X and Y direction, moreover, the FEA demonstrates that in Y direction the effective modal mass is not expressive. Following, from FEA it was expected to find natural frequencies with values higher then 1.50 Hz, making possible submit the signal by a *Lowpass* and *Bandpass* filters, namely between the range from 1.00 Hz to 30.00 Hz. Additionally, the amplitude of the frequencies between 0 and 1.00 Hz were not superior to 0.01 Hz, making adequate the employment of the filters between the ranges specified.

From acceleration recorded, the data processing allowed to plot the signal in the frequency domain, as can be seen in Figure 10, and the natural frequencies in X and Y were identified through well-known *Peak Picking* method. The fundamental frequencies identified are presented in Table 2.

Table 2. Natural frequencies identified through ambient vibration testing of the Nossa Senhora das Dores Church

Mode	Frequency (Hz)	Mode type
1	2.391	Transversal bending (X direction)
2	2.880	Possible Torsional mode (X and Y direction)
3	3.125	Longitudinal bending (Y direction)
4	3.466	Longitudinal bending (Y direction)
5	4.541	Transversal bending (X direction)

Analyzing the spectrum of frequencies presented by Figure 11, it can be noted that the first five frequencies identified by OMA are between 2.00 Hz and 5.00 Hz. The first natural frequency was identified as 2.391 Hz, in transversal mode (X direction), while the second natural frequency was identified in both direction, being admitted as 2.880 Hz, in a possible torsion

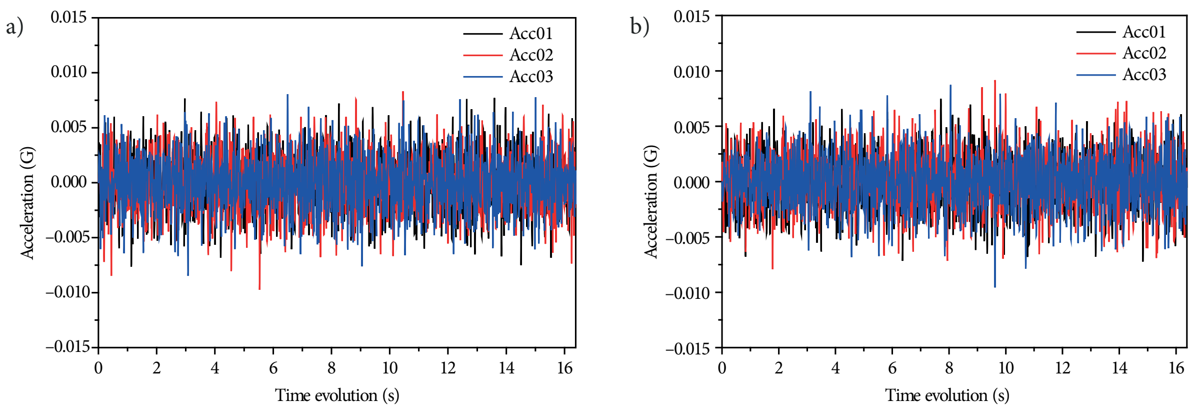

Fig. 10. Firsts 16s of the acceleration registered on Nossa Senhora das Dores Church: a) accelerations collected in X direction and b) accelerations collected in Y direction

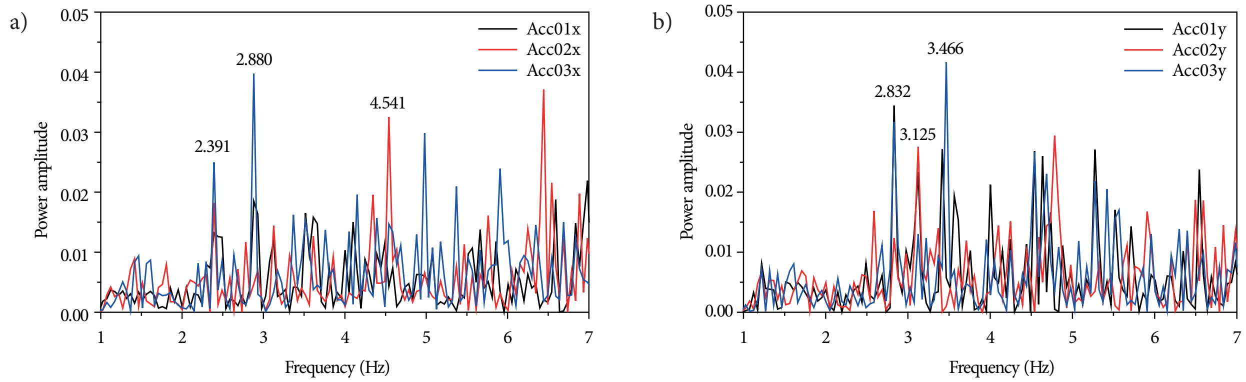

Fig. 11. Frequencies spectrum obtained by OMA of the Nossa Senhora das Dores Church

configuration. The third and fourth frequencies, respectively 3.125 Hz and 3.466 Hz were observed in Y direction, characterized by a longitudinal mode, while the fifth fundamental frequency was characterized as 4.541 Hz, in a transversal mode.

4.2. Numerical model updating

The numerical model updating of the Nossa Senhora das Dores Church was done based on natural frequencies obtained by OMA. The first three natural frequencies were considered sufficient for calibrating the numerical model, where the mechanical properties shown in Table 1 were kept. The Elastic modulus was selected has "updating parameter" and interactively modified to minimize the differences between the natural frequencies obtained by FEA and OMA. This way, the Elastic modulus ranged between 1.50 GPa till maximum value of 1.80 GPa, stated as maximum value of Elastic modulus for masonries, according to (Ministero Delle Infrastrutture E Dei Trasporti 2008). After some adjusts proceeding, the optimal value of Elastic modulus was stated as 1.70 GPa and then, the first numerical frequencies were obtained and compared with frequencies obtained by OMA, as shown Table 3.

The difference between the dynamic properties obtained by FEA and OMA can be related with uncertainties during the modeling process, as for instance the mechanical properties of the material and geometry simplification. In literature, it is usual the recurrence to ambient vibration testing information for calibrating numerical models, and the natural frequencies presents the summarized information of the modal parameters of the structure (Brownjohn 2003; Gentile, Saisi 2007; Magalhães *et al.* 2012; Ubertini *et al.* 2013). Usually, 5% is the maximum acceptable divergence between the experimental and numerical frequencies after numerical model calibration. In this work, the maximum divergence between the frequencies analyzed was of 2.63%, bellow of the limit of error of 5%. The mechanical properties of the clay brick masonries after numerical model updating are presented in Table 4.

With the updated numerical model, the firsts twenty natural frequencies and natural mode shapes were obtained, as well the percentage of effective modal mass for each modal shape of the Nossa Senhora das Dores Church (see Table 5).

The sum of effective modal mass for the first twenty modal shapes in the directions X, Y and Z are 72.930%, 61.675% and 0.151% respectively. The direction X presents the higher percentage of effective modal mass indicating that the modal displacements in the transversal direction of the church can be more easy found, as initially indicated by first fundamental frequency identified by OMA. The Y direction also

Table 3. Comparison between FEA and OMA frequencies

Mode	OMA frequencies (Hz)	FEA frequencies (Hz)	Error (%)
1	2.391	2.403	0.502
2	2.880	2.806	2.637
3	3.125	3.084	1.329

Table 4. Mechanical properties of the numerical model after updating

<table>
<tr><th>E (GPa)</th><th>W (kN/m³)</th><th>f_m (MPa)</th><th>f_t (MPa)</th><th>ν</th><th></th></tr>
<tr><td>1.70</td><td rowspan="2">18.00</td><td rowspan="2">3.20</td><td rowspan="2">0.16</td><td rowspan="2">0.20</td><td>Updated</td></tr>
<tr><td>1.50</td><td>Initial values</td></tr>
<tr><td>~12% variation</td><td colspan="5"></td></tr>
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Table 5. Modal informations of the Nossa Senhora das Dores Church

Mode	Frequency	Period	Effective modal mass		
	f (Hz)	T (s)	U_x (%)	U_y (%)	U_z (%)
1	2.403	0.416	13.533	0.219	0.000
2	2.806	0.356	20.969	3.020	0.003
3	3.084	0.324	7.241	16.007	0.010
4	3.342	0.299	0.022	4.951	0.008
5	3.796	0.263	3.031	0.008	0.000
6	4.925	0.203	3.571	0.211	0.000
7	5.547	0.180	7.051	2.271	0.001
8	6.229	0.161	0.581	2.311	0.001
9	6.753	0.148	0.628	0.558	0.001
10	7.247	0.138	0.019	4.143	0.003
11	7.867	0.127	3.864	0.147	0.000
12	8.192	0.122	0.993	0.013	0.001
13	8.591	0.116	1.437	0.212	0.000
14	8.763	0.114	0.943	0.729	0.003
15	8.924	0.112	0.950	0.001	0.001
16	9.275	0.108	0.720	4.703	0.001
17	9.463	0.106	1.851	13.502	0.049
18	9.907	0.101	0.526	8.546	0.026
19	10.341	0.097	4.412	0.062	0.027
20	10.835	0.092	0.588	0.060	0.017

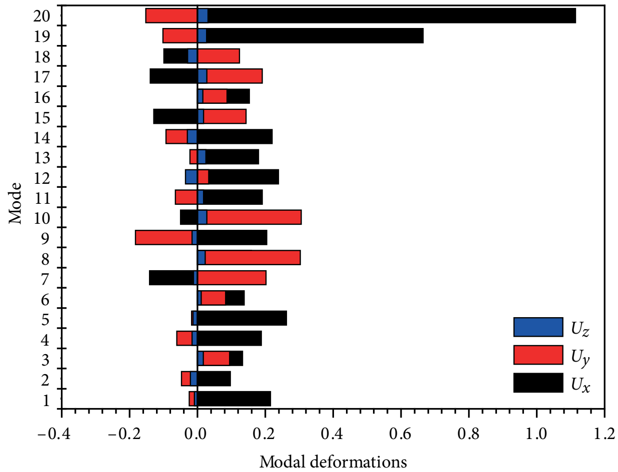

Fig. 12. Modal deformations of the first twenty modal shapes in the directions X, Y and Z

presents significant influence to modal shapes, with 11.225% less than effective modal mass from X. However, in Z direction, the effective modal mass was practically zero. The modal displacements in each one of the twenty modal shapes extracted are shown in Figure 11, indicating the effective modal mass influence for higher displacements in direction X. The negative values presented by Figure 12 indicates that the modal deformation occurred in the negative direction of the references axes adopted in this analysis.

The first three modal shapes are represented in Figure 12, where the first mode is characterized by a bending mode located in the lateral left wall, with maximum modal displacement of 0.215 in the X direction (Fig. 12a). The second modal shape of the Nossa Senhora das Dores Church (Fig. 12b) involves modal displacements in X and Y directions, characterizing a torsion mode involving the lateral left wall and the interior arched wall, and the bell-tower with maximum displacements of 0.060, in the arched wall, and 0.108, in the top of the tower. The third modal shapes (Fig. 12c) involves modal displacements mainly observed in X direction, characterizing a transversal bending mode, in the arched wall, with modal displacement of 0.133, and the bell-tower, with 0.074 of modal deformation. These modal shapes also can be used for justify the accelerometers positioning adopted during ambient vibration testing.

Moreover the 6th, 13th and 18th modal shapes requests several components of the church, characterizing global modes of the church, even with small periods. Analyzing the Figure 13 and Figure 14, it can be noted that the lateral left wall and the arched wall are the most requested elements and, consequently presents the most relevant modal displacements. The modal displacements in the latera left wall can be related with geometric properties, namely characterized as a slender element, and absence of clamping systems in the transversal direction of the church during the FEA formulation. In the arched wall, important values of modal displacements were expected, because the geometric of this type of structural elements presents more potential of deformation and torsion, as observed in (Bari, Orabona 2014).

In order to proceed with a static analysis of the Nossa Senhora das Dores Church, a numerical simulation considering the mechanical properties of the Table 4 and the dead load was carried out, the graphical results are shown by Figure 15, with linear elastic analysis. The results are presented in terms of Von-Mises stress (Fig. 15a) and normal stress in Z axes (Fig. 15b).

The Von-Mises stress can be used for identify potential zones under failure condition, as deeply discussed in (Brown, Miller 2006). Through the analysis of the Von-Mises stress distribution on the Nossa Senhora das Dores Church, it can be noted that the main stresses are located at the area surrounding the arched doors, especially in the doors of the first level of the main façade, and they occur for a maximum value of 0.58 MPa, representing 3.62 times than the tensile strength adopted in the model. This way, the static analysis noticed that the numerical model presents agreement with the church structural behavior, once that cracks founded and represented in the Figure 5 can be totally related with the tensions found by numerical analysis.

Positive values of normal stress can be mainly identified in the surrounding opened regions, as the arches in the doors and in the windows. In the main

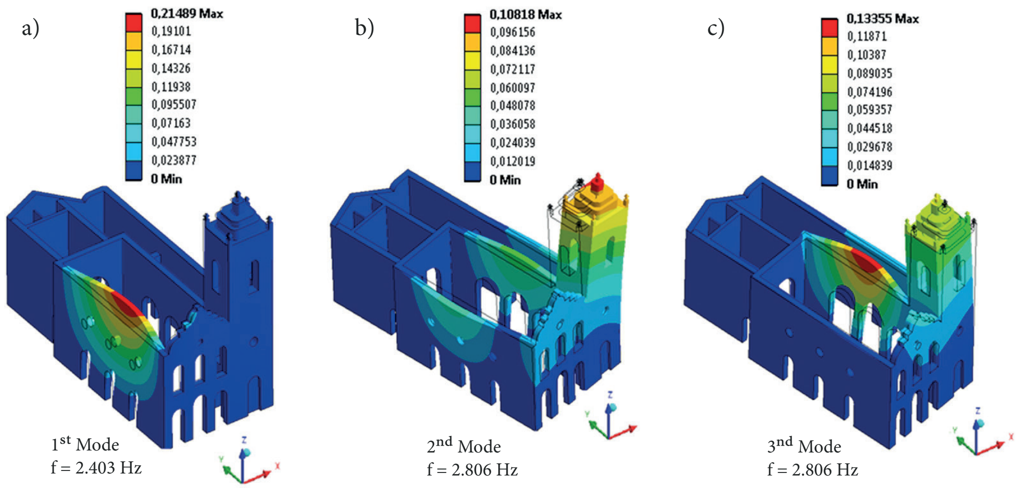

Fig. 13. First three modal shapes of the Nossa Senhora das Dores Church

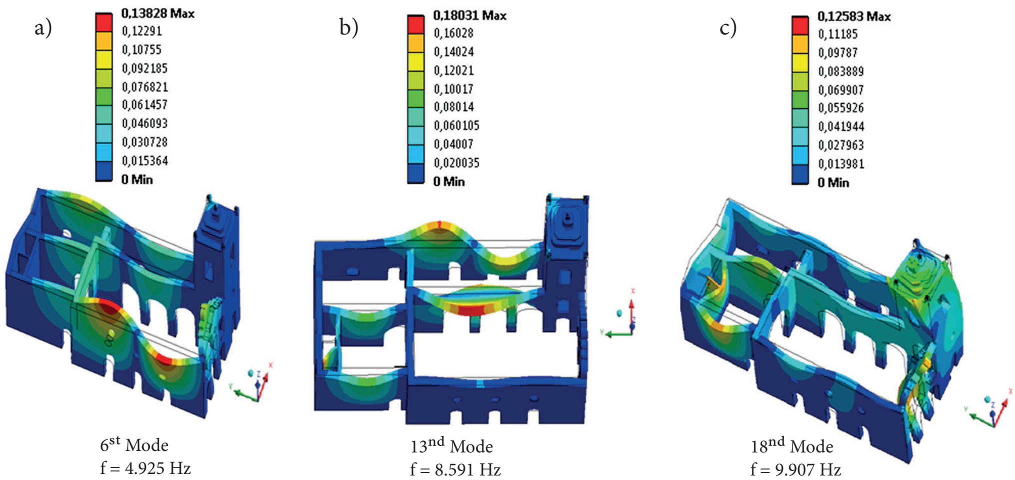

Fig. 14. 6th, 13th and 18th modal shapes of the Nossa Senhora das Dores Church

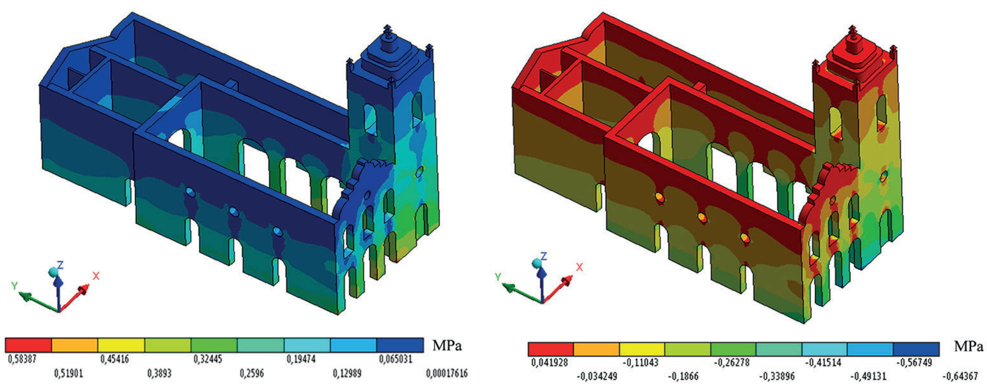

Fig. 15. Static analysis of the Nossa Senhora das Dores Church: Von-Mises stress (a) and normal stress in Z axes (b)

façades, positive values of normal stress indicated the existence of tensions specially between the top of the arches of the doors and the bottom of the windows, while negative values of normal stress are related with compression. However, 0.643 MPa was the maximum value of compressive stress in Z, while the maximum value for tension stress was identified as 0.04 MPa. These values are inferior than load capacity of the clay brick masonries, here stated as 3.20 MPa (compressive strength) and 0.16 MPa (tensile strength).

Conclusions

In this work, the ambient vibration testing of the Nossa Senhora das Dores Church, an important heritage construction for Sobral community, was carried out as way of to collect information for updating a numerical model allowing it employment in furthers hypothetic scenarios, as well to assess the degradation of the church along the time.

The numeric and experimental dynamic investigation of the Nossa Senhora das Dores Church was performed with FEA and OMA, and the strategies employed during the ambient vibration characterization was described, analyzed and the results used in the definition of the final numerical model.

While FEA allowed the correct positioning of the accelerometers in the church, the OMA permitted the identification of the first five fundamental frequencies of the church, that are 2.391 Hz, 2.880 Hz, 3.125 Hz, 3.466 Hz and 4.541 Hz, and to characterize its respective modes. Based on the natural frequencies identify by OMA, the numerical model was updating and the first twenty modal shapes information were extracted, allowing to identify that modal displacements in X axes presents a most percentage of effective modal mass for modal shapes than in Y axes. Also, the graphical representation of the first three modal shapes were obtained, as well the modes with most elements requested, namely 6^{th}, 18^{th} and 20^{th} modes.

A linear static analysis was carried out and the 3D graphic representation of the Von-Mises stresses and normal stresses (in Z axes) distribution along the church were knew. These analyses allowed to identify the maximum values of stress in the church components, as well to state that under the scenarios considered in this paper, the church is safety. And comparison between the damages found on the church with the results of the FEA, allowed to state a relation between them.

Finally, the present work contributes for knowledge acquisition on the structural behavior of Brazilian heritage construction, through description of the strategies employed and even by the dynamic information collected. The information provided by this study can be useful for safety assessment of the heritage construction under dramatic scenarios, as seismic occurrences or structural degradation, as well its can be used for support of decisions on structural maintenance and risk reduction.

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