

Sensorial identity of ruins: Vibroacoustic features of the roofless medieval Chapel of Madonna del Fieno (Fisciano, Italy)

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Abstract – This study explores the vibroacoustic characteristics of the roofless Chapel of Madonna del Fieno (Fisciano municipality, Campania Region, Italy), a church dating back to the 14th century. This partially ruined architecture, despite its poor preservation, still contributes to the perceived identity of the place. However, such a *genius loci*, as an immaterial component of cultural heritage, is not only determined by the vision of the structure, but also by the acoustic perceptions inside its spaces, which could be further valorized in the future. This research investigates the vibroacoustic characteristics of the space through a series of *in situ* measurements, in integration with a structural-acoustic finite element model to simulate the sound-structure interaction within this open-air environment. The integrated metrological experimental and modelling procedure, whose results are detailed here, offers a new perspective for characterizing and preserving the immaterial heritage of sound in partially destroyed historical sites.

I. INTRODUCTION

Cultural heritage structures, immersed in a landscape and interacting with the variable local environmental conditions, contribute to shaping the identity of a space, creating a *genius loci*, that triggers the sense of identity for inhabitants of a certain place, like a city or a village [1]. Then, the fruition of such spaces and structures, even if abandoned, as well as the possibility of performing certain activities, becomes a relevant element, that shapes the immaterial dimension of such heritage sites [2].

The sensorial interaction with these spaces immersed in a certain landscape doesn't occur only visually, but also through other senses and, ultimately, through the whole body. Consequently, the vibro-acoustic identity of a space (the vibro-acoustic landscape) [3] can become an important factor to be understood and valorized as an immaterial heritage element, in the case of sites whose symbolic value is recognized by a community. This is the case, for example, of the partially abandoned roofless

chapel of *Madonna del Fieno*, located in the Municipality of Fisciano (Campania Region, Italy) [4].



Figure 1. The main façade of the Chapel of Madonna del Fieno

The church foundation dates to the 14th century. Situated at the border between rural and urban contexts and overlooking a wide valley, the chapel offers a unique opportunity to analyze how the loss of its roof and interior furnishings has transformed its interior vibroacoustic features.

Through a combination of *in situ* acoustic recordings, 3D digital modeling, and numerical simulations, the study explores the acoustic patterns of this space, shaped by a combination of structural and environmental conditions. Despite the loss of its ceiling and many of its surfaces, the chapel still exhibits distinguishable acoustic signatures, shaped by its surviving tuff masonry, polychrome floor, and residual architectural elements such as the apse and partition wall.

By integrating vibroacoustic measurements with historical-architectural data and environmental context, the research contributes to a hard metrology approach to the vibroacoustic component of immaterial cultural heritage. Thus, the case of *Madonna del Fieno* becomes a prototype for future investigations into the “vibro-acoustic

life” of roofless or ruined worship spaces and their improved fruition.

II. DESCRIPTION OF THE CASE STUDY

The Chapel of *Madonna del Fieno*, currently in a state of abandonment and decay, consists of four main elements: the chapel, the bell tower, the rectory, and a crypt, all positioned at different elevations due to a height difference of more than 5 meters between the adjacent streets.

The chapel has an almost square plan, built using local grey tuff masonry, with elements from different construction phases. A central partition wall with arches divides the interior space, which still preserves late 19th century features, such as a polychrome marble altar and ceramic floor tiles in Vietri style. Several wall openings have been walled up over time. The original pitched wooden roof was removed for safety reasons, leaving only rusted iron tie rods and exposing the interior to direct sunlight and weather, which dramatically transforms the acoustic and visual experience.

The bell tower, also made of grey tuff blocks, rises to a height of approximately 14 meters and is structured over three levels, now inaccessible due to the collapse of internal timber floors and stairs. The rectory is a two-story structure with a small courtyard, and the crypt is a barrel-vaulted underground space with minimal finishing.

Documented as early as 1309, the complex underwent expansions between the 14th and 19th centuries. It was severely damaged during the 1980 Irpinia earthquake and only partially cleared and stabilized in 2019.

III. MATERIALS AND METHODS

The current configuration, with no ceiling or upper enclosures, allows for the direct interaction between environmental acoustic sources and the remaining structural envelope. This condition was considered particularly suitable for investigating how acoustic responses interact with the structure of a roofless sacred space.

Thus, the qualitative and quantitative metrological approach to the acoustic sensorial identity for the studied ruin consists in the characterization of the interaction between the background environmental noise and the structure of the ruin.

For such a purpose, no artificial source has been used. Instead, this preliminary research consisted in the sampling of background environmental noise, using a class-I measure microphone UMIK-I. Recordings were made at a sampling rate of 48 kHz and a 24-bit resolution to ensure accurate capture of the harmonic content in the audible range.

The recorded audio signals, recorded in uncompressed *.wav form. Then, the digital audio signal was converted in a data file, adopting the standard function available through the software MATLAB, version 2024b.

Measurements were conducted in four symmetrical

positions inside the chapel, considering the location of the former apse, the partition wall, and the side walls as potential reflective boundaries.

A FE model of the chapel was created using ABAQUS computer program for structural-acoustic simulation [5]. Material properties of the chapel, fully embedded in an air domain, were defined for all the materials assuming isotropic and linear elastic behaviour. The material properties of the air are parametrized through its density, equal to 1.204×10^{-6} ton/mm³, while the bulk modulus is equal to 141.8 MPa. The mesh type is an 8-node linear acoustic brick, reduced integration hourglass control (AC3D8R). The air domain is considered unreflective to assume that it is infinite. An incident wave interaction is set up by locating the source point at about 1m of height in correspondence of the altar. This position corresponds to the hypothetical position of a priest, originally acting as main acoustic source inside the chapel.

IV. RESULTS AND DISCUSSION

Fig. 2 displays the structural displacement pattern of the chapel, interacting and reacting to an acoustic wave with spectral characteristics coherent with the background environmental noise of the surrounding space.

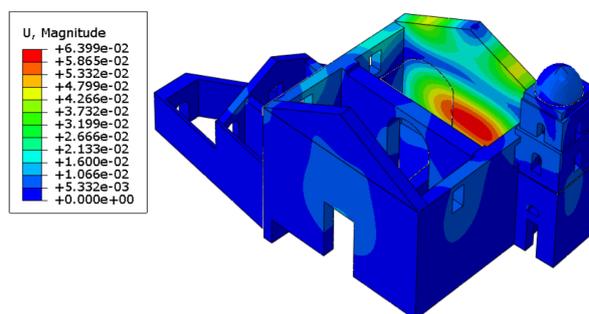


Figure 2. Structural displacement contour in relation to the interaction with environmental background noise of the surrounding area.

The result of the simulations highlights the variable structural response, that fits to its functional purposes. In fact, the main acoustic source, originally interacting with the structure (i.e., the priest close to the altar), triggers the response of the wall behind the altar, generating a higher deformation of that wall with respect to the other walls, that behave more rigidly. The higher deformation of one wall with respect to the other ones is similar to the deformation of the violin upper plate, that is more elastic, with respect to the other components of the main violin body [6,7]. This difference in elasticity, in the case of the violin, contributes to the amplification of the violin sound, as well as to its specific sound spectral features. In the case discussed here, referring to an architectural structure, there

was, at least, an implicit know-how on how to design such a structure in relation to specific functional requirements, in relation to the need of hearing the voice and sounds coming from the area of the altar. This know-how is part of the intangible dimension of the heritage asset represented by the chapel. The role of implicit design and construction know-how, as an intangible component of cultural heritage assets, was recently observed for the first time in the case of ancient Greek Doric temples [8].

The dynamic behaviour of the ruin, triggered by the environmental background noise, used as a characteristic local source, was simulated through a finite element model. The resulting behaviour of the ruin depends, from one side, on the structure design, building and degradation processes. On the other side, the resulting dynamic response depends on the space in which the ruin is located and on the surrounding environmental conditions. Consequently, it is proved that each ruin has a sensorial identity beyond the visual one, usually considered by architects.

The sensorial identity of a ruin is here identified through a quantitative metrological approach and procedure. Thus, the features of a ruin in relation to the surrounding landscape can be described beyond its aesthetic dimension. Instead, the multi-dimensional sensorial identity of a ruin can be defined by a quantitative metrological procedure. The importance of the sensorial identity of a space depends on the fact that it shapes the *genius loci*, the evolving identity of a place and a landscape. With this respect, this work constitutes a novelty in defining a metrological procedure, in relation to the vibro-acoustic parameters, to characterize the sensorial identity of a heritage asset.

As rarely proved in other works [9,10], the definition of quantitative hypotheses, that can be verified by experiments, can extend the investigation of heritage assets beyond its traditional domains, where metrology is often used limitedly to its technical ability to provide basic data on the materials, degradation and age of heritage objects. Thus, this research confirms that the definition and application of quantitative methods can support the implementation of multi- and trans-disciplinary research involving heritage experts, historians, archaeologists and experts in quantitative metrological approaches.

V. CONCLUSIONS

The preliminary results highlight the distinctive acoustic behaviour of roofless heritage spaces, where the absence of a ceiling does not eliminate reverberation phenomena but rather reshapes the recorded acoustic behaviour.

The study confirms that roofless sacred structures can retain a measurable vibroacoustic identity, which persists even after significant physical alteration. This opens new perspectives for the acoustic characterization of partially ruined cultural heritage, suggesting that sound analysis, when combined with structural modelling, can contribute to both documentation and conservation planning.

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