# The Restoration of Santa Maria delle Grazie: The New Life of an Ancient Church

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ABSTRACT: *Europe is rich in monumental buildings that characterise the lives of small, medium and large communities. These elements strongly typify territories they insist on and often represent their symbols. These buildings' value is not only defined by their historical nature. Like a magnifying glass, the studies of such types of structures allow us to scrutinise arts, technologies and construction techniques. Often, intervening to restore them instead of erecting new buildings represents an opportunity for the entire community to retrace the history of master artisans and architects of distant epochs. Restoration, therefore, represents a moment of cultural deepening and enrichment of society as a whole. The case study presented in this paper is an example of this approach. In addition to the political will to return a historical monument to a small community, the restoration work created a symbiosis between ancient construction techniques and new technologies, giving the building a new life.*
*Carrying out structural investigations on various portions of the structure after an in-depth historical study, technicians tried to investigate the story and the mechanical behaviour of materials.*
*The masonries were reinforced with widespread interventions using the FRCM (Fiber-Reinforced Cementitious Matrix) technique. The monumental complex has numerous buttresses and arches, all reinforced with diffuse and punctual interventions to ensure their consolidation and structural improvement. Floors have been reinforced, and the roof was entirely rebuilt. In addition to the reinforcement goal, these interventions have boosted the box-like behaviour.*
*"The Santa Maria delle Grazie" monument is also the subject of an experimental monitoring campaign that involves the use of fibre optic sensors integrated within the cement matrix to consolidate the wall faces.*
*The building presented in this paper represents an enlightened example where technological innovations have made it possible to realise a project path catalysing effectiveness in both architectural and structural terms*

KEYWORDS: Masonry restoration, Structural Analysis, Cultural Heritage, Structural Health Monitoring

## INTRODUCTION

Europe is rich in monumental buildings that characterise the lives of small, medium and large communities. These elements strongly typify territories they insist on and often represent their symbols. Cultural heritage offers people a link to social values, beliefs, religions and customs, which enables them to identify with other populations of similar backgrounds while gaining a sense of unity and belonging.

A better understanding of previous generations and history that has characterised them up to today allows them to obtain their identity (Rouhi et al. 2022; Guadagnuolo et al. 2020). Their link with the past reflects in their present, leading to the future.

The monumental buildings' value is not only defined by their historical nature. Like a magnifying glass, the studies of such types of structures allow us to scrutinise arts, technologies and construction techniques (Frunzio and Di Gennaro 2018). Recovering historic sites and buildings is an opportunity for communities to strengthen their identity and affirm the link with their historical and cultural roots. Therefore, the renewed functionality of the buildings is not a mere rebirth of ancient remains but an absolute path of knowledge and revitalisation of what has often been lost (Frunzio et al. 2022). Intervening to restore monuments instead of erecting new buildings allows for retracing the history of master artisans and architects of distant epochs. Restoration, therefore, represents a moment of cultural deepening and enrichment of society as a whole (Elliotis 2022; Gunes et al. 2021).

There are many methodologies of approach and intervention for cultural heritage buildings. The case study presented in this article represents a transversal approach between the desire to preserve and revive what was with the creation of something new wholly detached from the original building.

## 1. THE MONUMENTAL SITE OF SANTA MARIA DELLE GRAZIE

The municipality of Barano d'Ischia is in the southeastern part of the island of Ischia near the city of Naples in the south of Italy. Its territory develops in length, starting from the Maronti beach towards the interior of the island until it reaches the municipality of Ischia with which it borders (Figure 1). From a geomorphological point of view, the city presents many hills with a marked agricultural configuration and numerous quarries. The formation of which is linked to landslides that have occurred over time. The first certain news that we have of the settlement dates back to the Greeks, who built a nymphaeum next to the source of Nitrodi, which they entrusted to the protection of the nymphs and Apollo. The vocation of the municipality is mainly of an agricultural and touristic nature. Most of the territory is cultivated with vines, and wine is among the most marketed products on the whole island, while the thermal springs, together with the beauties of the coast, attract large numbers of tourists. The complex annexed to the former Church of Santa Maria delle Grazie is located on via Duca degli Abruzzi, a panoramic road that leads from the city centre to the mouth of the Arso crater.

Figure 1: Site localization (Source: Authors 2022)

The complex of buildings is a construction whose original intended use was religious—built at the behest of the Baldino family, who lived in the annex behind the church. The Church of S. Maria delle Grazie was founded by Gioacchino Baldino between 1830 and 1835: the official nature of the testamentary deed, in which he claims to have built it "with the sweat of his brow", categorically denies the hypothesis of a dating around the middle of the eighteenth century (1740), supported by Onofrio Buonocore and Filomena Sardella in their texts (Buonocare 1930; Sardella 1985), and which was also supported by traditional knowledge "oral" of the same descendants of the family, Mrs Aniello and Raffaella Baldino. It was probably the direct observation of the decorative parts of the building, attributable to a late Baroque style, that allowed erroneous information to be handed down for so many years.

The Chapel and the Sacristy placed next to it are undoubtedly contemporary; the only elements presumably added later, due to the noticeable formal differences with the rest, are the coffered ceiling placed under the roof slab and the wooden choir loft with the helical access staircase (D'Ascia 1867).

In 1883 the Chapel, like the entire building of which it is part, was damaged by the disastrous earthquake that struck Casamicciola Terme. No restoration work is documented, at least until 1889, moreover: the brothers Vincenzo, Gaspare, and Mattia Baldino, in a letter to the Episcopal Curia of Ischia written in that year, state that they have not yet carried out suitable restoration work because they lacked sufficient funds. However, it is considered probable that a consolidation intervention, albeit minimal, was carried out in the following years, just as it is not possible to attribute to that seismic event the instability that still today interests the artefact. It was certainly open to worship until the first decades of the twentieth century, as the local elders recall, and as can be read from the archival documents, which make the closure of the church coincide with the death of R.do Mattia Baldino, which took place in 1920.

In the first decades of the last century, the transfer of family residence to another municipality on the island, in addition to the continuous hereditary disputes that developed within the family, led to the progressive abandonment of the complex.

The lack of maintenance over the course of several decades is certainly the main cause of the strong deterioration in progress. For example, the fall of roof tiles and purlins and their accumulation on the underlying wooden floor caused them to break through in the long run, which involved the coffered ceiling itself. In 1992 the last heirs, Aniello and Raffaella Baldino, sold the entire complex, including the Chapel, to the Municipality of Barano.

### 1.1 Initial conditions of the structure

The building is a masonry structure consisting of a ground floor which develops at a positive level of about 70 centimetres with respect to the street level and two other levels below. The structure is made of Arso lava stone, and lime mortar, with some parts arranged in regular blocks and others chaotically. The horizontals were made up of stone barrels, cross vaults, and wooden floors.
The state of the structure was very poor, and the whole complex was almost completely obstructed by weeds, which had grown freely over the years of neglect (Figure 2). It was clearly was evidently affected by widespread instability and collapses that did not allow entry for a complete and exhaustive analysis of the actual general conditions in the first stage of the study.

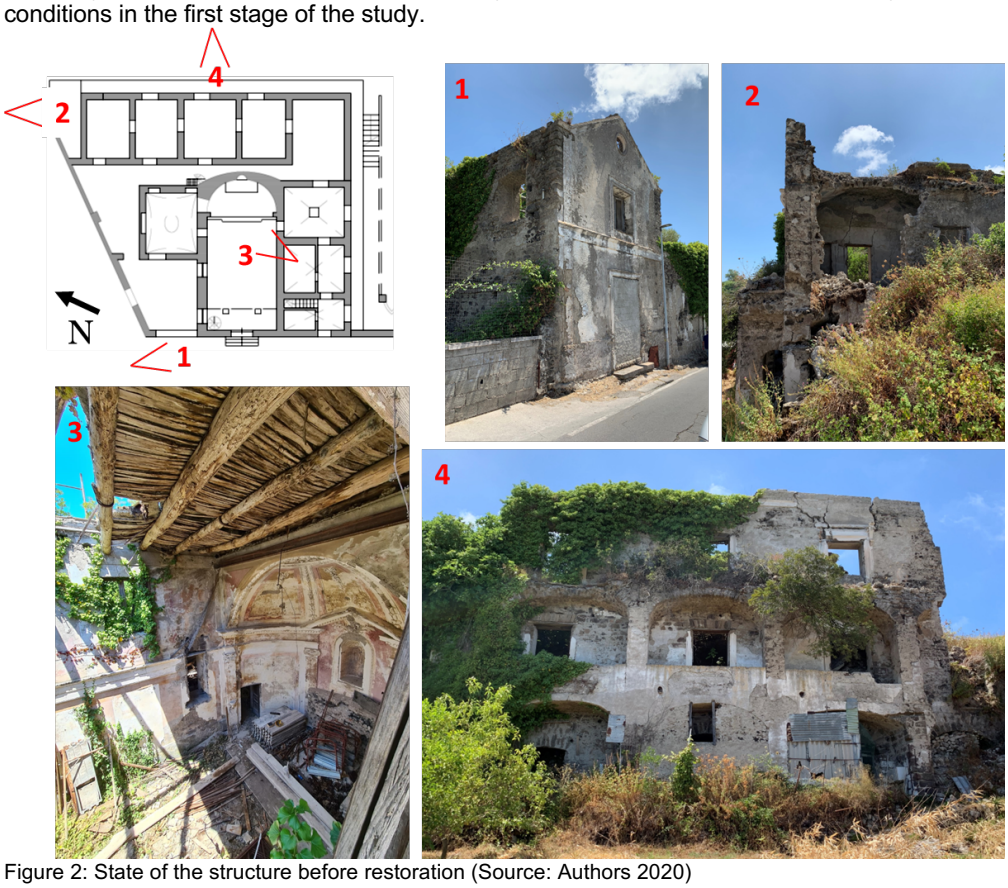

Figure 2: State of the structure before restoration (Source: Authors 2020)

Following the cleaning and safety measures, it was possible to enter all the rooms carrying out all the investigations, analyses, surveys and tests to complete the knowledge path. Both structures, masonry and vaults and elements such as mortar and the remains of original paints are investigated too.

The ground floor, occupied by the church with a rectangular apse called body A, is entirely devoid of a roof affected by a generalised collapse or completed forcibly in the safety phase. The wall structures are intact and protected by a finishing layer fresco painted plaster and enriched with various mouldings. The church's facade is almost entirely devoid of the plaster finish layer, and the entrance door initially walled up was opened with the loss of the portal, already seriously damaged by time.

Behind the church, in the block called B, there were residential areas of which today, almost exclusively the perimeter walls remain, having collapsed or demolished for safety purposes. They are exposed to atmospheric agents and affected by widespread collapses and a deep and generalised crack pattern. The first basement floor is located about three meters below road level. The side bordering the road is blind, while the other three sides open freely onto the surrounding landscape. There were mainly service areas on this floor, such as rooms, vats for vinification, kitchens and washrooms. The east and south sides were open onto panoramic balconies and loggias, which are partly collapsing. Vaults, as in the case of body B, are completely collapsed. Masonries are also affected by severe cracking phenomena, in some cases linked to the movements triggered by the collapse of the vaults, which have caused the floor's loss of cohesion and rigidity, effectively disconnecting the masonry connected to them. In the portions of plaster still intact, some traces of stucco decoration remain, but most of them are detached or affected by the attack of mould and weeds. The flatbreads on the internal and external openings are made of wood and report severe damage and sagging.

The second floor below the street, located at an altitude of about 6.50 meters lower than the street level, houses five adjoining cellar rooms, open only on the east side. The first two rooms are completely uncovered and open to the sky. The last three rooms, to the north, retain the roof vaults and the wall structures without a structural crack pattern, however seriously damaged by water infiltration and by the action of the vegetation that has developed there. Facing this last level, there is a large garden.

## 2. PROJECT PHILOSOPHY

The restoration project follows a route made of conservative strategies combined with breaking choices. While acting with respect to the original shapes and material for the church, arches, vaults and roof, a critical reconstruction will concern the parts that collapsed or are in an advanced state of decay parts . In these portions of the building, the residual original traces do not allow for a faithful reconstruction, therefore. The synergistic work put in place has led to choices that are both respectful of the static and architectural and historical needs and of the present materials, giving life to a new tailor-made project for the monument (Mancini 2021) (Figure 3).


Figure 3: Project rendering (Source: Mancini 2021)

The renovated architectural organism, not emptied of its primitive character, will be used for accommodation and cultural activities. Therefore, a complete redefinition of both horizontal and vertical internal spaces was carried out to allow better usability of the environments and better accessibility of all the areas covered by the intervention. To this end, multipurpose rooms have been provided for cultural, congress, educational and exhibition activities, as well as a series of meeting spaces such as bars and restaurants. The design choices are also dictated by the need to make the architectural complex compatible with the new intended use and compliant with Italian technical regulations regarding accessibility, safety and fire prevention. The plant and functional adaptation will also be carried out concerning the intended use.

In general, the built heritage, due to the values it represents and the role it plays in the life of the communities, can be considered a common asset whose use can represent a reason for union and socio-cultural identity. The built cultural heritage constitutes a fundamental resource for territorial systems and local communities to preserve their evolutionary possibilities and for development purposes. From this point of view, safeguarding cultural resources, such as the monument analysed in this work, must translate into the search for a balance between conservative and transformative demands. The aim is, therefore, to preserve the building and, at the same time, satisfy the functional needs. In this process, the heritage's ability to evolve takes on the character of an added value since it allows the full potential of the existing to be exploited through contemporary and relevant forms of use for the population.

## 3. TECHNICAL SOLUTIONS FOR THE RESTORATION

The restoration strategies aim to reconfigure the building respecting its original shapes apart from the reconstruction of the collapsed and huge deteriorated portions, which will be reconstituted differently. Space has been given to reversible interventions regarding the monumental asset where possible. Furthermore, the structural aspects are aimed at not substantially modifying the static structure of the building, avoiding the onset of stress states significantly different from those to which the structural system is "accustomed".

The structural consolidation intervention was tackled to improve both the static and seismic capacity of the building. It is, therefore, possible to identify two levels of intervention, the first aimed at building on a global scale and the second at the mechanisms of local influence.

The first level involved a widespread consolidation of the masonry in terms of increasing in-plane and out-of-plane strength by plating with the FRCM technique performed with basalt meshes and inorganic matrix. The box-like behaviour has been improved by connecting masonry hammers and angles and inserting cross-link chains.

To preserve the memory of the original collapsed roof, the new structure retraces the ancient one by using the same timber essence and static scheme. This choice allows the structure to keep a similar load distribution (Frunzio and Di Gennaro 2018). That could have happened for different positioning of trusses or considering static schemes not adherent to the original ones. A steel housing cap for the truss heads and plates for installing transverse steel chains is arranged. Thanks to this system of chains, the reduction of the thrusts of the truss and the seismic improvement of the entire structure will be guaranteed at the same time since the box-like behaviour of the masonry is favoured. The key-plate of the chains will be incorporated undercut, thus resulting in utterly invisible from the outside. The insertion of head braces in the initial and final spans also conveys the improvement of the seismic behaviour of the roof.

The execution of timber roof rebuilding has generated quite a few problems due to the need to mobilise significant elements with trucks of considerable size compared to the small streets of the village of Barano. The wooden components were factory pre-assembled and positioned at the work site with skill thanks to the high competence of the workers of the company carrying out the work (Figure 4).

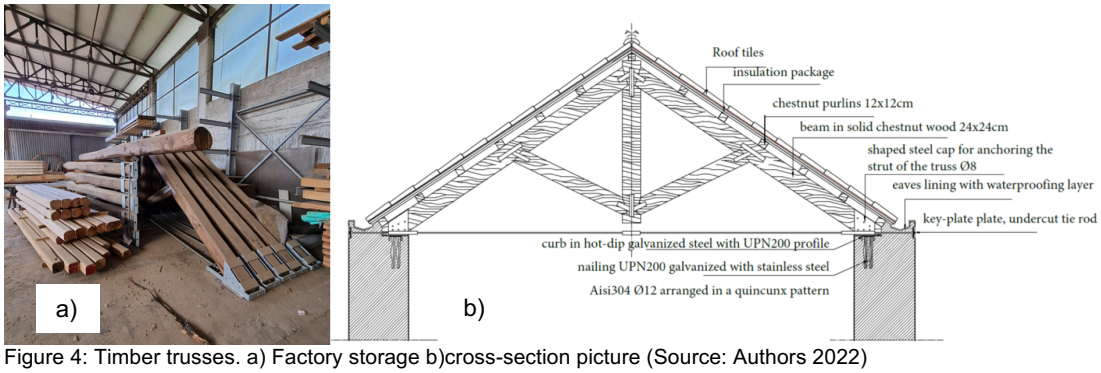

Figure 4: Timber trusses. a) Factory storage b)cross-section picture (Source: Authors 2022)

The "umbrella-knot", situated on the roof in correspondence with the passage between the apse and central nave, represents a little prodigy of the workers and is constituted by seven beams in one point converging. The figure below shows the rebuilt roof (Figure 5).

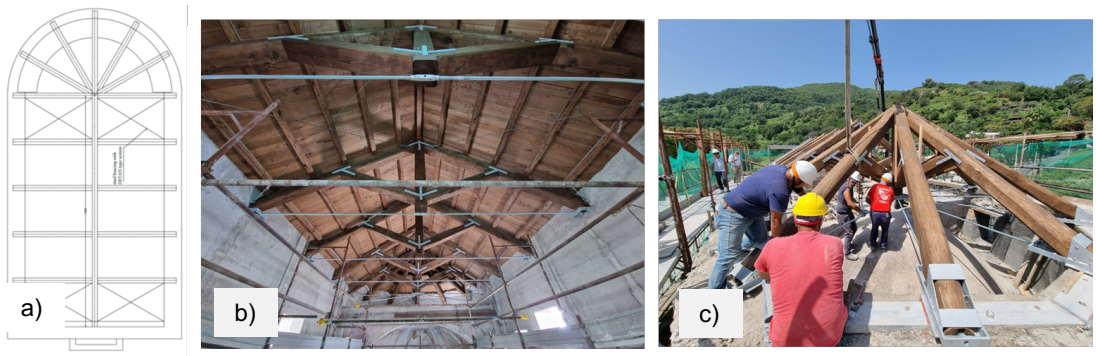


Figure 5: Timber roof structure. a) Roof scheme b) Central nave rood c) "umbrella-knot" (Source: Authors 2022)

As explained before, the building presents vaults and a plane floor. While the first ones showed a good state of conservation, the second ones mostly collapsed.

Stripes of PBO (Polybenzoxazole) fibre in an inorganic matrix realise the intrados strengthening of arches and vaults. Such intervention ensures protection for the opening of injuries and plastic hinges.

The original collapsed timber floors have been rebuilt with new floors with steel beams and a thin slab with a corrugated sheet and reinforced concrete. This choice is mainly due to the need for a structure with high load-bearing performance with an unload-bearing system of discrete type or a system where the load transfer to the masonry happens with punctual (discrete) elements such as a beam. That avoids an excess of stiffening of the floor and consequently increased bending actions on masonry walls.

The rebuilding of flatbeds requested particular attention. In the original configuration, they were simple timber solid plates of chestnut able to unload upper loads to the masonry sidelights. To preserve the aesthetical aspects of doorways, ensuring better structural behaviour, an architrave with double steel beams inserted in the masonry with solid chestnut timber boards below has been realised (Figure 6). The right transfer between architrave and masonry is guaranteed by bearing in solid bricks.

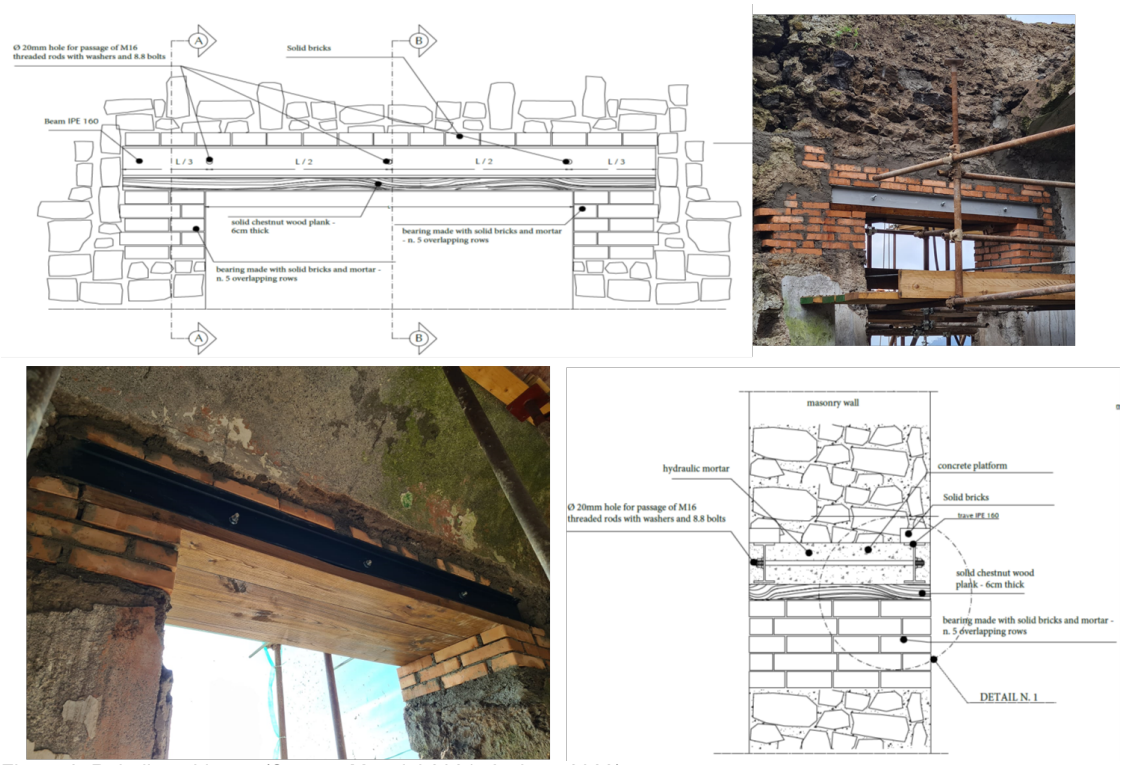


Figure 6: Rebuilt architrave (Source: Mancini 2021, Authors 2022)

The deep ageing state and the collapse of some parts of the original building determined the presence of unstable elements and portions of masonry for which unique solutions have been adopted.

In general, works that involve ancient structure requests an artisanal approach where solutions sometimes have to be found on-site rather than in the conventional workplaces of architects and engineers. That is because cultural heritage often regards buildings with features unknown in advance that trivially don't have right angles and vertical o straight surfaces…. The intervention reported below is an example of this approach born from the in-depth observation on site of the problem encountered in a masonry part at risk of collapse and for whose conservation an ad hoc solution was studied.

The intervention in detail referred to a temporary consolidation with steel beam and PBO strips in a cementitious matrix to avoid collapse preserving the masonry until the stabilising elements such as transverse walls and floors had been built (Figure 7) (Babaeidarabad et al. 2014).

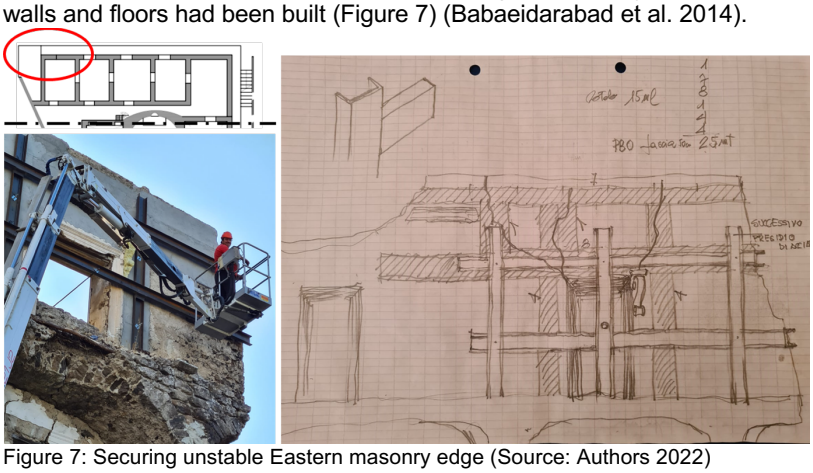

Figure 7: Securing unstable Eastern masonry edge (Source: Authors 2022)

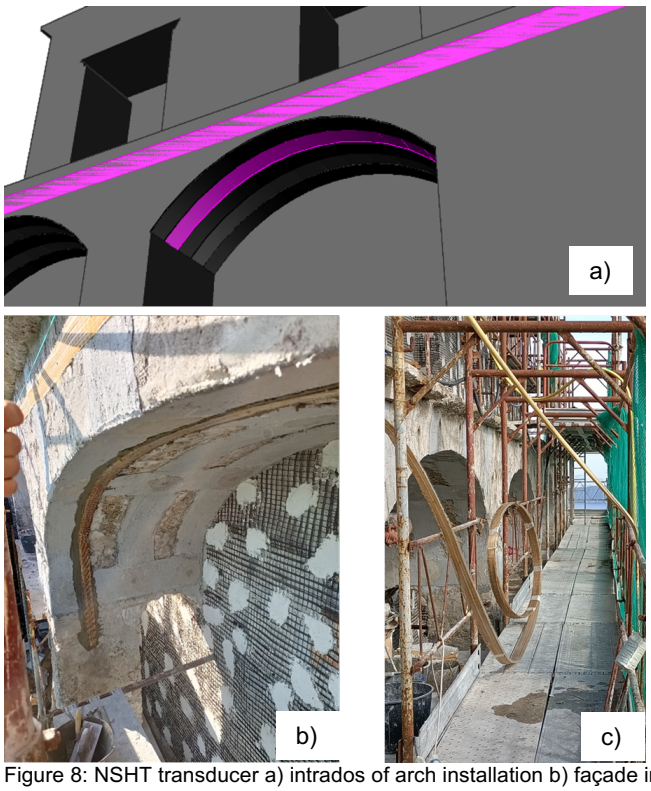


Figure 8: NSHT transducer a) intrados of arch installation b) façade installation (Source: Authors 2022)

Thanks to the synergy between the executing company, the Department of Engineering and the Department of Architectural and Industrial Design of the University of Campania Luigi Vanvitelli, the building site hosts an

experimental campaign related to a distributed optical fibre sensor for Structural Health Monitoring (R. Zona et al. 2022).

The patented transducer NSHT (Olivares et al. 2020), which core is an optical sensor based on the scattering of Brillouin phaenomena (Minutolo et al. 2020; Di Gennaro et al. 2022; Renato Zona et al. 2020), has been installed on the arcade of the Southwest front of the building to monitoring any movements due to the single instrumented arch or else of the entire arcade.

The realisation of the prototype of NSTH is the first for structural use and involves the PBO fibre to ensure the compatibility of the modulus of elasticity between the transducer and masonry.
Installation is shown in the following picture (Figure 8).

To date, a couple of measures have been performed, and no significant strain varying has been detected compared to zero detection. It is expected to complete the load test on the single instrumented arch to trial the transducer's functioning more specifically. The test will also investigate the strain distribution between the loaded instrumented arch and adjacent ones.

## CONCLUSION

In this paper, the case study of the restoration of Santa Maria delle Grazie is presented. The building is an enlightened example of restoration work where technological innovations have made it possible to realise a project path catalysing effectiveness in both architectural and structural terms. The work aims to narrate a story in a way that transcends the mere architectural and technological aspects. That is because, working on cultural heritage, every element must merge with the other, sometimes passing through the human heritage that resides in the knowledge of handed-down techniques. Today restoration works are still ongoing, and the community of Barano is waiting to reappropriate this building intended to host multipurpose spaces for cultural, congress, educational, exhibitions and a series of meeting spaces such as bars and restaurants.

The technical solutions presented are the fruit of the combined experience of the designer, the executing company and the municipal administration, which have also allowed the implementation of an experimental campaign to test an innovative technique for Structural Health monitoring involving an optical fibre sensor.

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