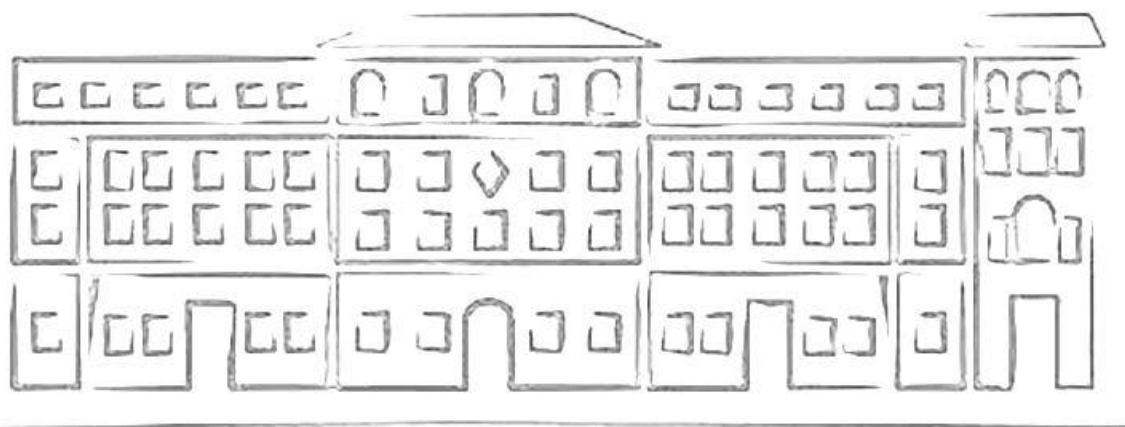


DYNAMIC MONITORING PLANT CONSISTING OF A MONODAQ E-G-METER NETWORK AT PALAZZO PAMPHILJ IN ROME

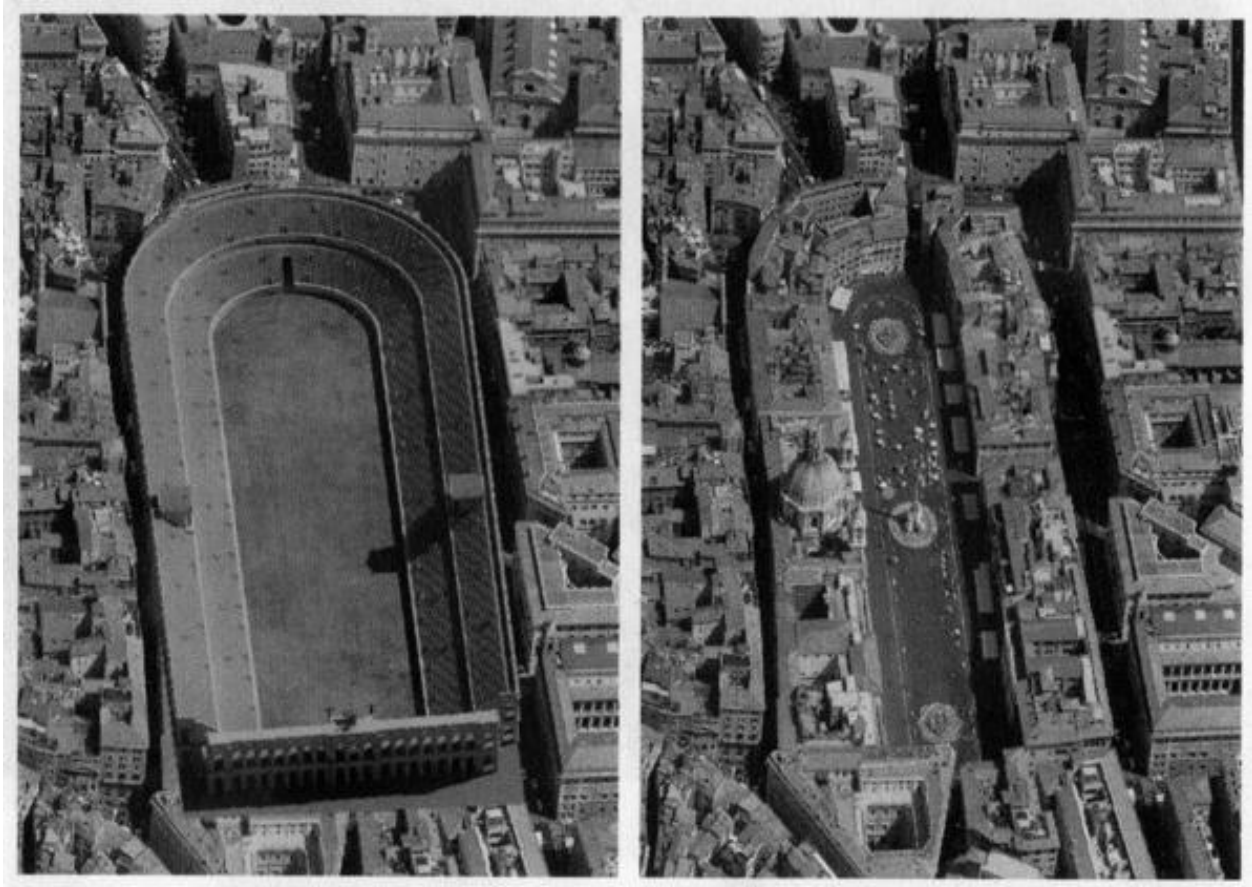


Structural monitoring services - data acquisition - non-destructive mechanical tests

Chi dice donna, dice danno/
chi dice femmina, dice malanno/
chi dice Olimpia Maidalchina, dice danno malanno e rovina.



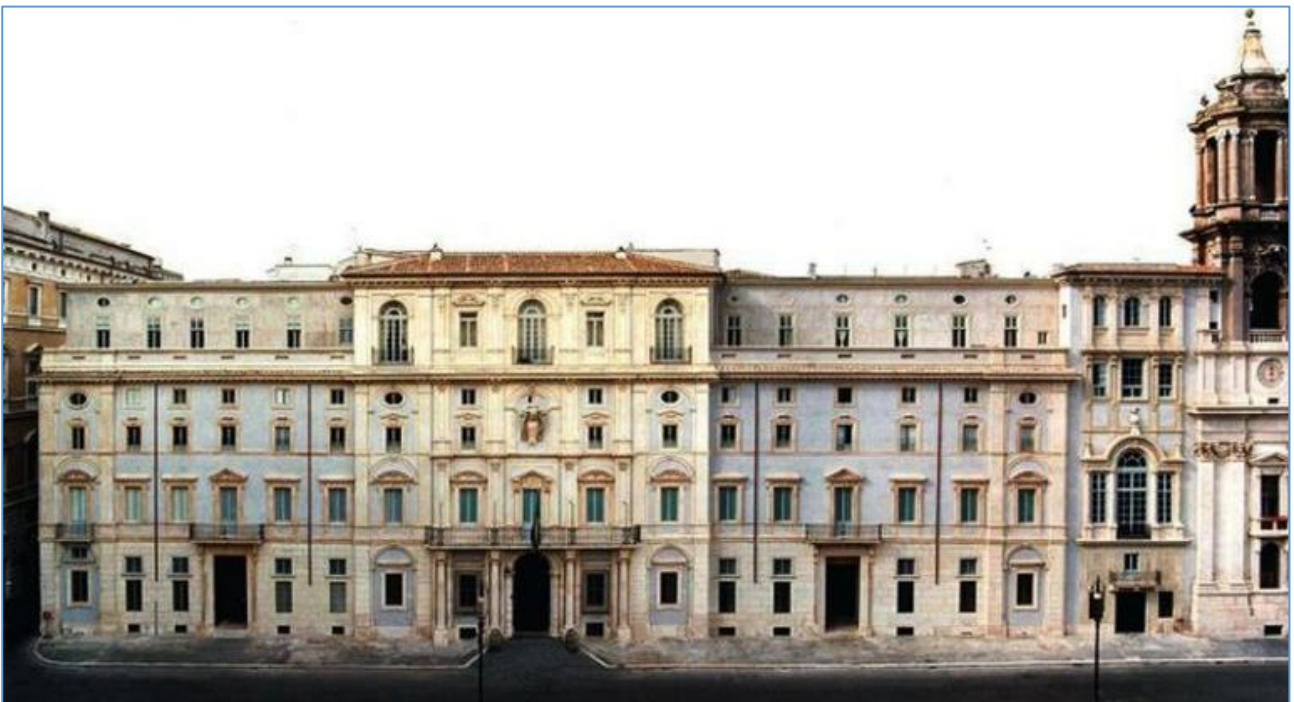
The Pamphili was a family with ambition, both for themselves and for Rome. Even before Giambattista Pamphili became pope Innocent X, the family had aspirations for refashioning the city on their own terms, or at least the part that they lived in. It began with the family's front yard, Piazza Navona, for the Rome's gran salone, intended as its most popular secular assembly room. Built in the spot where in A.D. 86 Emperor Domitian had constructed (out of brick, travertine, and concrete) a U-shaped stadium with a grandstand that seated fifteen thousand spectators, the long, nearly oval piazza has been the site of diversion of all kind, from naumachias (mock sea battles), to medieval jousts, to the more social but no less competitive amusement of parading in public wearing the finest that Rome's dressmakers and tailors could supply.



Ancient stadium dating back to Roman times and current bird's eye view

The Pamphili had been a presence in Rome for centuries (since the 1400s when the family moved from Gubbio, one of the ancient towns in Umbria) and, over the years, its members began to buy property around the Piazza Navona and its neighboring square, the Piazza Pasquino, where in the early 1500s an ancient stone statue was uncovered nearby, on which the Romans used to hang satiric, mocking commentary (often in verse) about the city's great and powerful, a practice that irritated pope and prince alike and gave rise to the word "pasquinate". Even before Innocent became pope, The Pamphili began consolidate their property holdings. In the autumn of 1644 Cardinal Giambattista Pamphili's nephew Camillo Pamphili and his mother, Donna Olimpia, bought land next to the cardinal house with the idea to combining their properties in the sestiere into one large palace that fronted onto Piazza Navona. They envisioned a magnificent showplace that would house one of Rome's leading families in what was the largest civic space in the city. Perhaps the

family member most interested in the structure was Donna Olimpia Maidalchini Pamphili¹, Innocent's sister in law. This determined formidable woman, whose first husband, Pamphilio, Innocent's older brother died in 1639, became the palazzo's most notorious resident, though not for her piety or her charitably works. Born in 1591 in Viterbo, she came from a relatively simply background and was known for being intelligent if not particularly refined. By the standards of the day she was thought somewhat mannish as hunting was one of his favorite diversions. Covetous, even ruthless, she was known for being disgustedly greedy, and for craving wealth and power. And trough the force of her personality and an advantageous marriage, she managed to achieve both. Perhaps most important to the million and a half souls who lived in the Papal State, her influence over her brother-in-law was alarming and unpredictable. It was said that no one could get to the pope without first getting through her. Many Cardinals knew of the dangers that donna Olimpia's presence in Innocent's sphere raised. They knew that she had load money to her brother-in-law from her personal fortune earlier in his career as a papal diplomat, and they warned him about her sister-in-law. But Innocent paid no attention. Upon his election, Donna Olimpia instantly became one of the most powerful people in Rome, certainly the city's most powerful woman.



Prospectus of Palazzo Pamphilj on Piazza Navona, from via del Pasquino to the church of S.Agnese in Agone

The Pamphilj family had high hopes for their new palazzo. To design and build it, the family selected Girolamo Rainaldi and his son Carlo, known for their cautious and correct approach to design. The family also appointed a commission to work with the Rainaldi to oversee the project. Borromini was one of those. The pope and his family choose a long and narrow site that ran along the southwestern side of the piazza, combining several small houses that the Pamphili owned. For the palazzo's main façade facing the piazza, the Rainaldi signed a lugubrious, four-story structure with a belvedere that sits atop the center section of the building above the roofline, giving the whole front a vertiginous

¹ "Whoever says woman, says damage / whoever says female, says illness / whoever says Olimpia Maidalchina, says damage, illness and ruin"; this is the full text, of which usually only the initial part is used; it was a public warning to Pope Innocent X, to let him know that the Roman people hated his sister-in-law.

appearance. It looks as if it's about to topple into the piazza. Dozens of windows in a variety of sizes and shapes – rectangles, squares and ovals; some wide; some narrow, some tucked under cornices like pigeons seeking shelter from the rain – march across of the building in straight lines, like army regiments in search of their commanding officers. Ornament is understated, even dull; over than the carved papal coat of arms, which hangs above the central window of the piano nobile, the only other decorative elements that draw the eye are the four columns supporting the palazzo's central balcony above the main door, which are said to have been taken from St. Peter's.

In 1646, perhaps because he was unhappy with how the palazzo was progressing, the Pope Innocent X, probably on the advice of Virgilio Spada, called in Borromini. Every Thursday between April and June 1646 a committee, consisting of Girolamo and Carlo Rainaldi, Borromini, a master mason named Ludovico and Donna Olimpia representative met to discuss the details of the palazzo design's and construction and how they were to be carried out. Whether he was asked to by the pope or his family, or whether he couldn't simply help himself, Borromini designed several version of the new palazzo. One of his ideas was to arrange the place around a long court with apsed ends, essentially an extended oval, which called to mind the shape of Piazza Navona.



Main entrance of the building and portion of the Cortona Gallery, with the grandeur of the Serlian window

Such a concept, if it had been built, would also be comparisons with the Sapienza, whose courtyard (just one street away from Piazza Navona) also has an inviting, curving end, which Borromini had used as the façade for Sant'Ivo. In the end the pope Innocent opted for the Rainaldi's more conventional approach to the palazzo, but his prudence didn't keep Borromini from having some influence in the interior and let him design the the gallery, known as "sala grande", the palazzo's most impressive room.

The gallery is a room of superlatives, of grandeur and invention. It is long, running from the front of the palazzo, and takes up much of the north wing's "piano nobile". It shares its outer wall with the

southern edge of the complex of the church of Sant'Agnese in Agone, which the Pamphili also had built. Its decoration is splendid: strikingly opulent and gracefully elegant in equal measure. By the standards of other Roman palaces, the walls are austere, even plain: painted a uniform color (at one time they were a rich crimson) they stand in serene contrast to the ornate, highly distinctive door casings of white and gold that frame the doors and statuary niches along the walls. At the far end of the gallery, underneath the barrel vaulting and looking out onto the Navona's square, Borromini placed a huge Serlian window². It is a tall arched center window flanked by two narrower, flat-topped windows half as wide as the center one. Framing the windows are four small twisting stone columns on low bases, and topping the entire arrangement in an elaborate border with the pope's crest perched above the central window, like an eagle to pounce on an unsuspecting prey. Above the doors are astonishing inventions - fantastic confections of sculptures and decor, panache and swagger. Curved, scroll like pediments, painted and gilded, press up toward the ceiling like parachutes waiting for a breeze. Just below them are round recesses painted a luminous Byzantine gold.



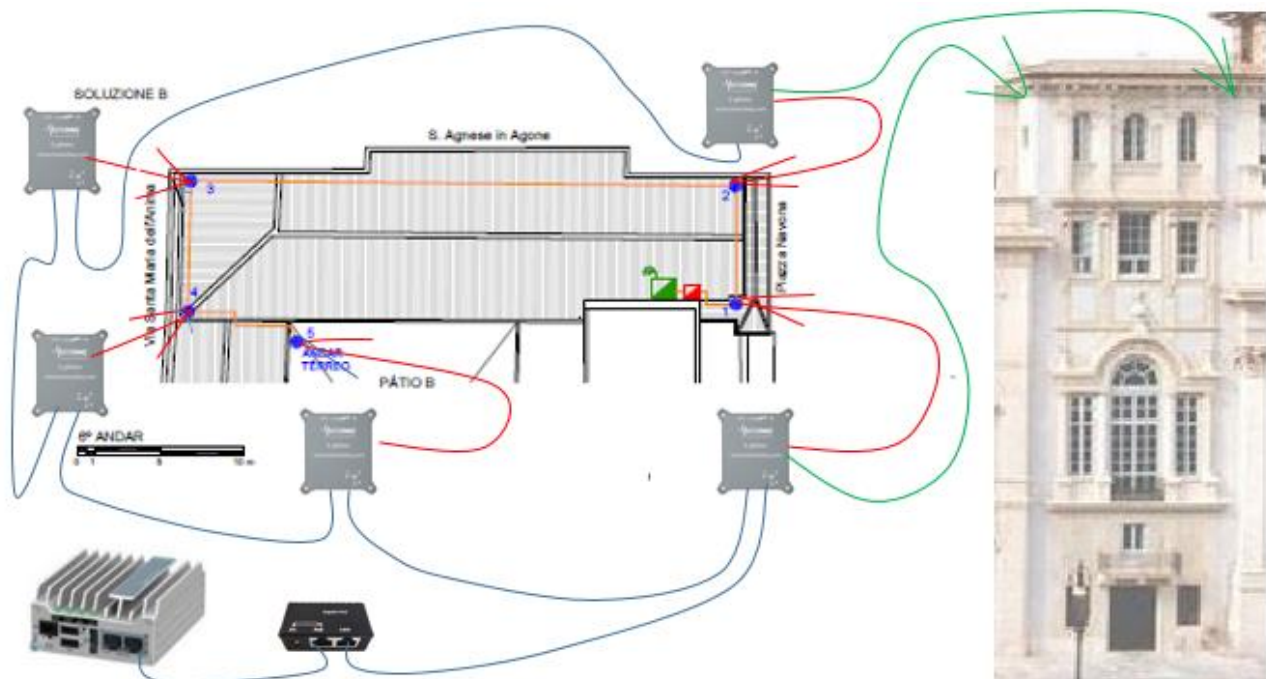
Magnificence of the Cortona gallery

Standing in each niche in a white marble bust, which stares down reproachfully at anyone with the temerity to stroll the richly polished, honey-colored parquet floor below. Such embellishments

² Such a window was named after Sebastiano Serlio, the sixteenth-century Italian architect and theorist, and was popularized by the Venetian architect Andrea Palladio, which is why today they are also called Palladian windows.

aren't typical of Borromini; they look fussier than his other work. It's possible that he may have incorporated into the design for the gallery's door frames some of the flavor of the magnificent fresco on the ceiling of The Apotheosis of Aeneas by Pietro da Cortona, which is the room triumph and his treasure. Painted by the same artist whose fresco of The Triumph of Divine Providence draws the eye upward at the Palazzo Barberini, this huge painting is a stunning display of virtuoso technique and dynastic propaganda. At the emotional center of the fresco is Innocent himself, depicted as the god Neptune, who is, in the words of one historian, "quelling the tumult of the winds with consummate stillness of attitude and gesture, restoring calm, order and peace in his empire solely by the power of his speech".

The Embassy of Brazil in Italy, which is based in Palazzo Pamphilj, at the beginning of this year entrusted ESSEBI with the installation of a dynamic monitoring system in the area above the Cortona Gallery, in contiguity and adherence with the church of S. Agnese in Agone, the most precious portion of the whole artifact. And ESSEBI activated immediately starting from last february, putting in place Dewesoft equipment, certainly among the most suitable of what was available on the market to be used in a building of such importance.



Layout of the dynamic monitoring system in the attic above the Cortona gallery

The system consists of four Monodaq E-g-meter modules positioned in the attic at the four vertices and a fifth sensor positioned on the ground, at the service entrance, with the primary purpose of capturing possible seismic events with trigger storage. The modules connected in series with a LAN network and Ethercat protocol and powered by a PoE are connected to a PC, equipped with a router, remotely accessible with an internet connection. The Dewesoft X software resident on the PC allows the management of data acquisition and storage at different levels of complexity.

To date, a couple of seismic events have been recorded, the most significant of which is the one that happened the past 3 April in full lockdown for COVID with epicenter in Marcellina, about 32 kilometers from Piazza Navona. Despite this distance, certainly significant, and the magnitude of 3 ML, far from prohibitive, the oscillation of the portion of the building under control, as evidenced

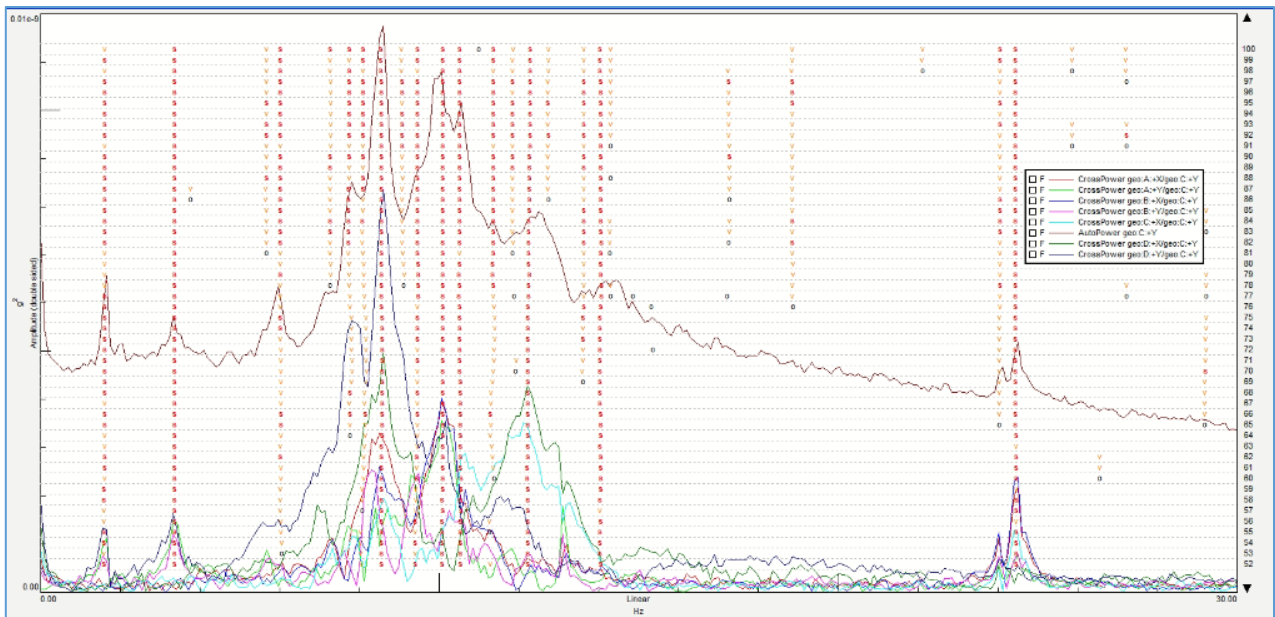
by the wave trains shown below, was significant. The phenomenon of extremely limited duration (11 s) has manifested itself with a considerable amplification, most likely due to the poor characteristics of the alluvial type of soil, which characterizes the riverbed of the Tiber (where Piazza Navona is located). And it is the amplifying effects of the ground, which tend to enhance seismic phenomena that occur at a considerable distance with considerable vibratory effects that often affect the building, which prompted the embassy technicians to implement a permanent dynamic control, as a predictive means.



Time histories of the seismic event of Marcellina

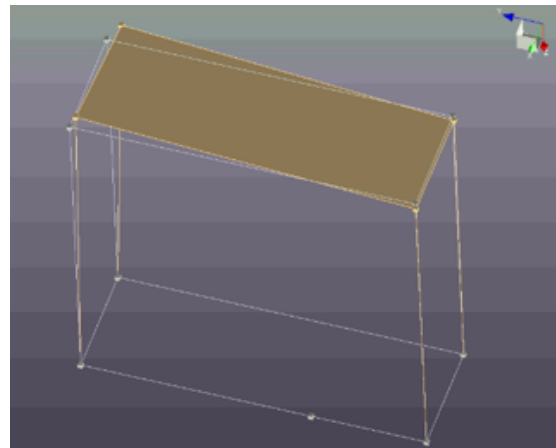
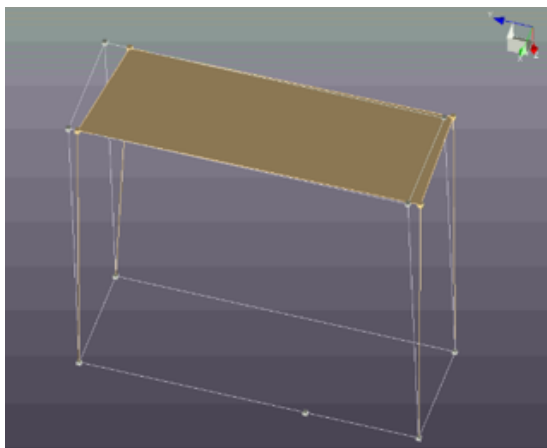
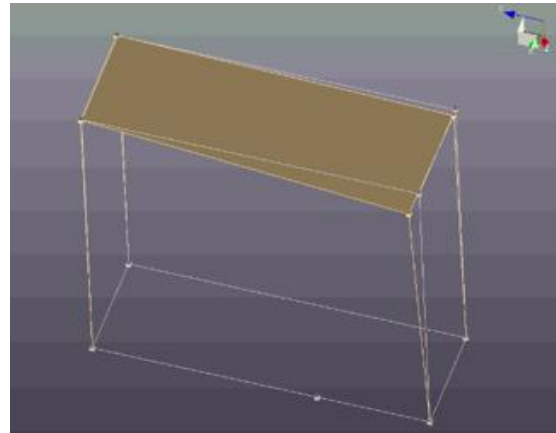
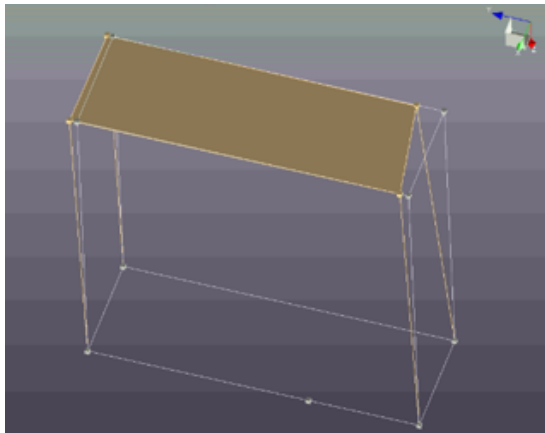
In addition to allowing the trigger storage of seismic events with the possibility therefore of evaluating the actual behavior of the portion of interest when subjected to significant shaking, the monitoring system has another significant prerogative. That of enabling periodic modal analyzes with the sole environmental excitement. And the most amazing aspect is precisely the use of modules with MEMS accelerometers for carrying out OMA analyzes, something that only some time ago would have been unthinkable, especially for masonry constructions, which are characterized by their high stiffness and therefore low excitability. This was possible thanks to the potential and reliability of the Monodaq E-g-meters, equipped with chips with a high signal-to-noise ratio and above all provided with high-performance conditioning electronics.

The dynamic signals, acquired and stored with the Dewesoft X software, were subsequently processed with the Siemens Testlab Operational Modal Analysis software. In this environment, the extraction of modal forms took place using the Polymax algorithm, based on the least squares method and operating in the frequency domain. One of the stabilization diagrams shown below, made with respect to a reference point, highlights the sharpness of the peaks and the consequent clear definition of the natural frequencies. The sequences of letters “s” along the vertical also indicate the stability of modal shapes, corresponding to interpolating polynomials with not excessively high degrees (second ordinate, on the right).



Stabilization diagram

Due to the fact of having instrumented only one level of the building, the one that can be defined as rigid for the presence of a crowning slab placed at the top immediately under the roof, the modal research was directed to the first two flexural shapes, along the two main directions of inertia, and to the first torsional shape.



Graphical wireframe representation of the first four modal shapes

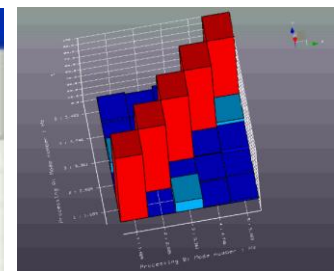
<i>Mode</i>	<i>Frequency [Hz]</i>	<i>Damping [%]</i>	<i>Shape description</i>
I	1,6	1,2	Traslational in Y direction
II	2,5	1,3	Traslational in X with torsional component
III	3,4	2,6	Traslational in X direction
IV	4,8	0,4	Torsional

Modal parameters of the first four shapes

The first modal form strangely manifests itself along the long side of the galleryl which apparently seems to be the one of greater stiffness. In fact, the gallery must be considered united, without interruption, with the rest of the building (and perhaps also with the church of S. Agnese in Agone) such that direction Y is the least rigid. Low dampings is compatible with a masonry construction.

The modal shapes have been validated through the passing of progressive sifting and the fullfilling of different indicators.

Compact Mode Complexity				
	Property Reference	Frequency	NPC (%)	NPD (°)
1	Node1	1.609 Hz	98.126	11.658
2	Node2	2.505 Hz	99.394	5.968
3	Node3	3.381 Hz	98.195	9.254
4	Node4	4.746 Hz	96.166	13.146



Complexity indicators such as Modal Phase Collinearity and Mean Phase Deviation and AutoMAC

With this first OMA analysis a sort of zero point was made and a real dynamic identity card of the portion of the building was defined. The modal parameters thus determined, which fully define the dynamic beaviour, must remain unchanged over time to signify the maintenance of a good level of health of the artifact. In the event that, in analyzes carried out in subsequent times, they should change, a wake-up call should click indicating that something is wrong. More in-depth analyzes and investigations should then be launched aimed at quantitatively circumscribing the problems in progress and for the time being identified only qualitatively.

Thus, a powerful means of investigation is configured that in a predictive manner could allow the identification of structural problems when they first manifest themselves at an embryonic level, with a consequent capacity for intervention in a phase in which success can be guaranteed with high probability.