Chiaravalle Abbey

THE RESTORATION OF A LIVING MONUMENT

MINISTERO DELLA CULTURA | SEGRETARIATO REGIONALE PER LA LOMBARDIA

PANIZZA 1914

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SANTA MARIA DI CHIARAVALLE ABBEY

The historical and social importance

Located on the outskirts of Milan, the Santa Maria di Chiaravalle Cistercian Abbey acts as a hinge between the urban fabric and the countryside to the south of the city's metropolitan area.
Founded in 1135 by Saint Bernard of Clairvaux, it is one of the most beautiful abbeys in Italy, in its Romanesque style and with its frescoes of unique beauty.
The subdivision of the space is carefully studied in proportions and light to give the rooms a mystical and unmistakable atmosphere.

The Abbey, so dear to the Milanese people, is a "living monument" that has a strong historical and social value: wanted and financed by the citizens (in particular by the Archinto and Torriani families), today is home to courses, workshops, art performances, destination of pilgrimages or simple visits for those who want to embark on a journey near in space but far in time.

After its foundation, the monastery assumed over time an increasingly prominent role in the economic balance of the Po Valley. The Cistercian monks helped to introduce in Milan a new and functional culture, capable of changing the entire image of the city. For this particular reason, unlike the canons of Saint Bernard, the Abbey has an unusual wealth of art, the result of the evolution of a cultured patronage that over the centuries has introduced changes of great value; one of them is the bell tower (Torre Nolare) built in 1329 (attributed to the Cremona based architect Francesco Pecorari), of extraordinary height and decorated with eighty columns of Candoglia marble and pinnacles of Gothic influence.

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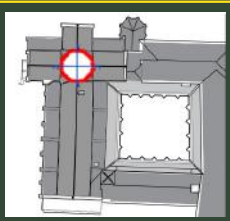
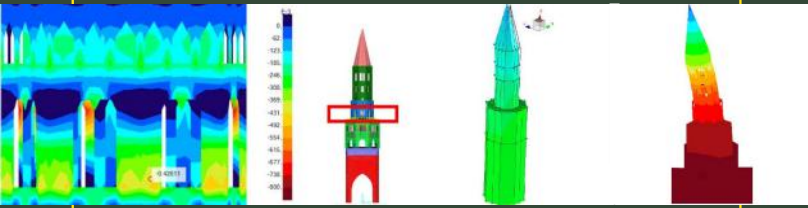
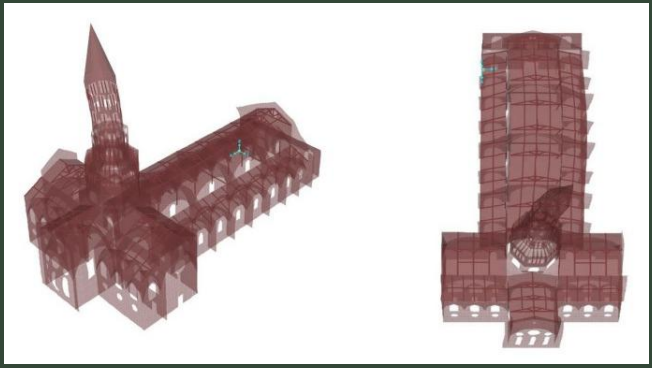
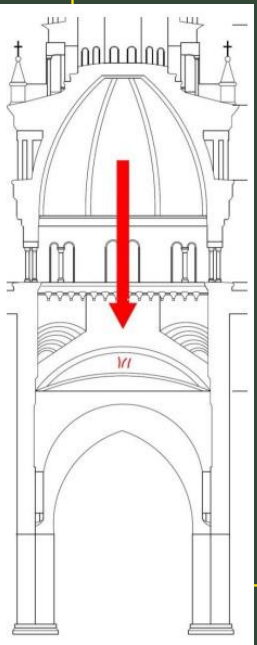


THE MONUMENT'S NEEDS



The bell tower, octagonal in plan, rises starting from the tiburium and consists of two sections, a first 4.14 meters high and a second of 12.19 meters, from which finally the terminal conical section starts, resulting in a total of 56.2 meters.
Built on several levels and in full masonry, with an average thickness of about 50 cm, it has been reworked several times over the history (especially in the last century) with massive interventions of replacement or reinforcement of the arches and pillars with stone or cement plaster.
Although the exterior is in good condition, the cylindrical and hollow inside of the tower, rithmed in the various levels by openings (mullioned windows, three-light windows and four-light windows) and slender decorative elements, needed an increase in strength, in particular at the basic interlocking.





The high mass of the tower, to which is added that of the heavy cusp at its top, has led over time to the formation of cracks and subsidence in the area of the triumphal arch and in the vaults of the presbytery and the north transept.

The considerable weight would have therefore amplified the effect of a possible seismic motion, as can be seen from the first investigations and numerical modeling that have in fact globally defined an alarming static vulnerability to horizontal loads.

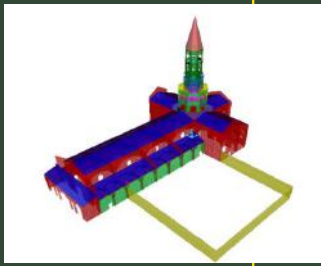
Further investigations culminated with the return of graphic models have allowed to identify in the tower the weakest part of the Abbey in the event of an earthquake, with the wall sections that would be solicited well beyond the limit values allowed by law.

THE CONSOLIDATION PROJECT

Identification of the tower's behaviour under stress and development of the solution

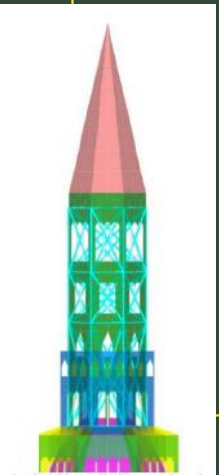
Based on the results of the analyses and the general vulnerability studies, the project idea was conducted and developed on a further series of prior investigations to the consolidation and restoration interventions. These focused purely on geometric aspects, returning, after a 3D scanner relief, two elaborate graphs for the sections and the plan of the bell tower.
An overall analysis of the forms of degradation, both structural (such as lesions, subsidence, erosion) and superficial (such as incoherent deposits, gaps, stains, plant colonies), culminated with three mappings of the degradation.

The latest analyses, focused on the diagnosis of construction materials, were dynamic tests: sonic tests, jack tests, petrographic investigations, seismic investigations MASW (Multichannel Analysis of Surface Waves), environmental dynamic tests, carried out together to characterize the mechanical properties of the constituent elements of the monument so as to be able to predict with great confidence their behavior when subjected to seismic stress.



The structural and 3D model of the bell tower, obtained after these last diagnostic analyses through the SAP2000 software (ideal for the analysis and design of any type of structural system), has identified in the three-light opening layer the more fragile area.

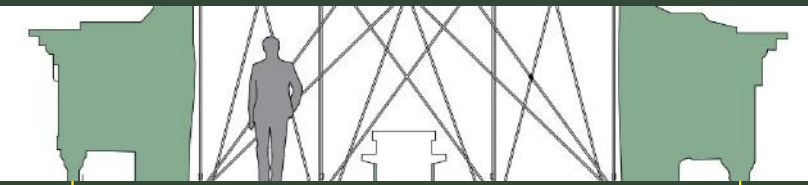
It was therefore necessary and urgent to implement a consolidation that would act on the major issues highlighted in the diagnostic phase, or those placed in correspondence, not surprisingly, of the thinnest and less thick portions of masonry.



The idea of the intervention had therefore to be realized in a proposal able to reconcile the structural needs of the tower with the criteria of non-invasiveness, lightness and reversibility.

Not wanting to modify the historical and architectural authenticity of the monument, the best design choice for the seismic consolidation turned out to be an innovative structure, inside the tower, in stainless steel cables and integral to the masonry.

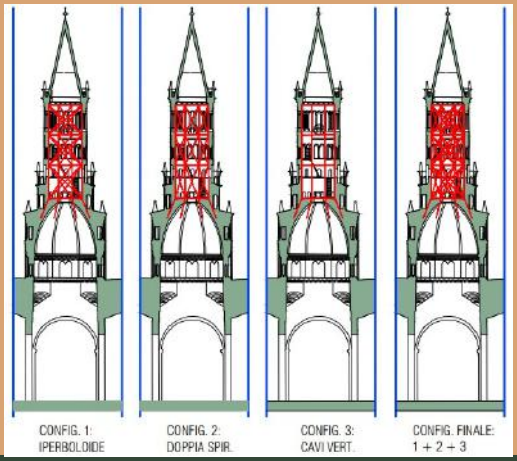
This structure will allow not only the confinement of the work, but also to make it faster and easier in its lay, mitigating it with the reduced space available.



Prof. Eng. Lorenzo Jurina and Eng. Edoardo Radaelli, creators of this unprecedented consolidation, define it as a parabolic hyperboloid (HYPAR), a sort of "hourglass" system that, in the event of an earthquake, will be able to counterbalance the compression of the masonry on both sides of the tower.

To minimize the effort state and the displacements resulting from any stress, the structure is composed as a mixed solution, obtained from the sum of three configurations of arrangement of the cables:

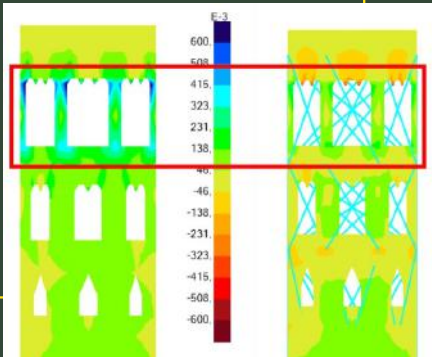
1. For greater resistance to cutting, four horizontal metal hoops will be inserted inside the tower, consisting of a pair of stainless steel bars anchored by means of special plates, placed at the top of each level of the octagon that outlines the plant.
The circles will then be connected to each other by three orders of steel cables arranged diagonally: from each vertex (and therefore from each plate) will start two inclined cables such as to reach the two edges opposite to both the upper and lower level.



2. To ensure resistance to bending and torsion, some cables will be arranged according to a "double spiral" geometry such as to form vertical "X", parallel and adjacent to the frame of the masonry.

3. To increase the compression component, reducing at the same time the tractions in the presence of bending, eight cables will be inserted in the vertical position, subjected like those of the previous configurations to a voltage of 25kN.

By using light materials, the structure retains its ductility, without any significant increase in overall stiffness. By conjoining mainly the walls in the thinnest areas, the cables will guarantee the tower to maintain a box-like behaviour, drastically reducing its tensile efforts.



THE RESTORATION PROJECT OF THE BELL TOWER

In parallel with the static necessities, the investigations and analyses carried out in advance have clarified the urgency with which it is necessary to operate the safety of the elevations of the tower, in particular for the numerous stone and terracotta elements that are cracking and detaching in substantial parts.

The restoration project, advise by Archt. Paola Bassani, aims to preserve the nineteenth/twentieth century additions together with the most significant stratifications, thus renouncing the completion of these missing or deficient parts (even if decorative) especially where it is not necessary in terms of functionality, safety and the guarantee of the durability of the intervention.

In general, restoration work consists of:

• A pre-consolidation of decose surfaces, with suspension of nanosilica in aqueous solution for silicate stones, with ammonium phosphate for carbonate stones.

• A structural consolidation of the walls with GeoCalce® FL Antiseismic, carried out with punctual injections for the restoration of the joints between the bricks.

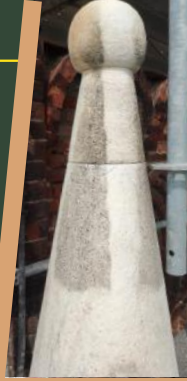
• A structural consolidation of surface level with GeoCalce® F Antiseismic to restore the structural continuity of the walls subject to the erosive action of atmospheric agents.

• A wet cleaning to soften the black crusts, as well as to nebulize and consequently dissolve the surface deposits.

• The application, by spray and brush, of a biocidal solution with a wide spectrum of action, sometimes intervening with mechanical removals on the colonies more attached to the surfaces.

• A punctual cleaning with the use of ammonium carbonate compresses, always with the possibility of mechanically removing the most attached deposits with a scalpel, small spatulas and brushes.

• A specific passivation treatment for metal parts with rust converter.



THE SUSTAINABLE NATURE OF THE PROPOSED METHODOLOGIES

On the occasion of the 800 years since its consecration, which took place on May 2, 1221, the Abbey gives its tower a complete restoration and a new internal armor to safeguard it.

The works, financed by the Segretariato Regionale del Ministero della Cultura per la Lombardia, through Law 232/2016 (article 1, par. 140), were carried out under the direction of the Superintendent for the Metropolitan City of Milan, Archt. Antonella Ranaldi, and of the Archt. Paolo Savio.

The start of the restoration site took place in January 2021 with the construction of the complex scaffolding system managed by the company Panizza1914 srl.

The interventions of restoration, conservation and consolidation are performed by Cores4N srl, active in the sector since 1985.

Now in its second generation, the company combines the technical ability to manage traditional interventions with an in-depth study of new technological systems and a strong awareness on the use of new eco-sustainable materials, to ensure a highly durable intervention through reversible and sustainable actions.

An example of this is the choice of mortars used, carried out in relation to the Green Building Rating, a tool that encourages and rewards operators in the construction and historical restoration sector to go even beyond the limits of sustainability, by encouraging the companies to undertake new paths for the training of workforce and the planning of their business strategies.

For the restoration were used mortars BioCalce Pietra®, Geocalce® F Antiseismic and GeoCalce® FL Antiseismic of the brand Kerakoll SpA (evaluated with the highest level of GBR) which contain only raw materials of natural origin and recycled minerals, have a reduced environmental impact in their emissions of CO_2 and volatile organic compounds (VOCs) and are recyclable as inert at the end of their life cycle.

Another sustainable solution is the application of a water-repellent gel for natural stone, plaster and terracotta: this is the Siox-5 RE10S of the brand Siltea srl, a protectant based on sol-gel technology, reversible and highly vapor permeable.

Colourless and transparent, it is composed of a mineral solution based on silica conveyed by isopropyl alcohol, does not contain solvents harmful to health and the environment and does not contain PBT (persistent, bioaccumulative and toxic) substances.

The professionalism and expertise that distinguish Cores4N srl will not only allow the completion of a modern restoration and an innovative consolidation system, but at the same time will guarantee to the secular bell tower to improve the structural capabilities and overcome with resilience all the interventions carried out.

Our future finds its roots in the past

CORES4N