Digital Twin to HBIM with Matterport Engine
Remondini Palace, Bologna, Italy – Preservation and restoration with seismic retrofitting

Winner of BIM&DIGITAL Awards 20

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ABSTRACT

The design of this work makes it possible to try a new BIM flow. The reverse engineering, obtained through the creation of a Digital Twin with immersive navigation, shareable and accessible via web and designed through LIDAR scans with cloud processing, gives life to new ways of designing, making accessible technologies until now unsustainable for small projects. The Digital Twin managed with the e-Building cloud platform makes it highly scalable.

1. Remondini Palace

The building, situated in San Giovanni in Persiceto (BO) Italy, in Circonvallazione V. Veneto, today known as Remondini Palace, is part of the property complex and subject of the Remondini family bequest to the Congregation of the Minimal Sisters of the Addolorata.
The building goes back to 1600, it is under the tutelage of the Superintendency (Legislation 42/2004 “Cultural heritage and landscape Code”) and it is part of a larger urban redevelopment of the whole Remondini area.

The building is located immediately south of the historic center of San Giovanni in Persiceto (BO), just outside the so called “Porta di Sopra” (Porta Victoria). The area belonging to the building, which once extended beyond the current borders, occupying the area between Via Castagnolo and Via della Pace, is known as the former "Orti di Caprara", from the name of the Bolognese senatorial family previous owner. The main facade of the palace is not facing the center of San Giovanni, therefore not towards the Ring road and the City gate (Porta), but it faces the garden, which overlooks with a small balcony on the first floor, supported by shaped corbels and embellished with a cast iron balustrade.

The building is characterized by a regular plan of rectangular shape and it is on three levels above ground: two for residential use to which is added an attic of considerable internal height. The covered part is shaped like a pavilion, with brick tile roof.

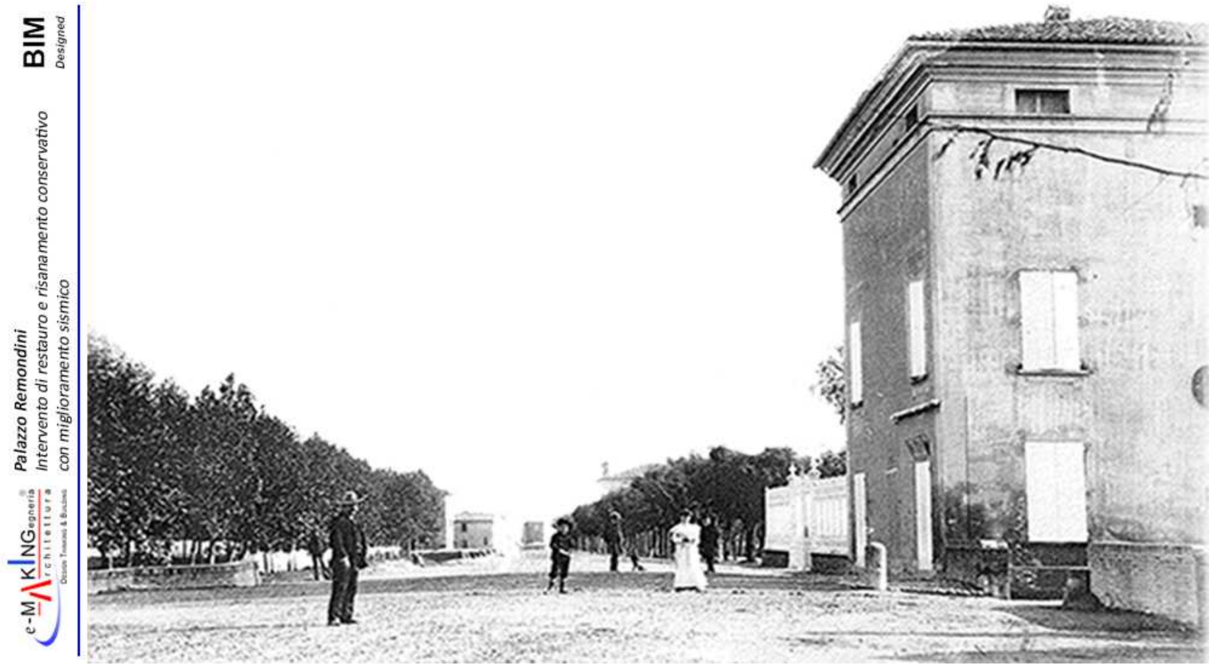

Fig. 1 – *Remondini Palace – historical photo before 1911.*

Fig. 2 – *Remondini Palace – current photo – winter - 2018.*

In 2018, the Municipality issued a contingent and urgent order to secure the building, as the property was in extremely critical conditions, in an advanced state of decay and with the presence of big collapses.

Fig. 3 – *Portion of the first and second floor collapsed.*

Fig. 4 – *Portion of the roof collapsed.*

Based on the problems and vulnerabilities encountered, a restoration and conservative rehabilitation project with seismic retrofitting was defined, consisting of a series of interventions that allowed the elimination, or at least the mitigation of all the deficiencies found, including those not "numerically measurable", but extremely dangerous in case of earthquakes, obtaining an increase in the overall safety of the building in compliance with current regulations on the subject, with a measured balance between conservation and technological innovation.

2. Planning and management flow

2.1. Digital Twin to Point Cloud

The Reverse Engineering activity was performed starting from the construction of an immersive navigation model (Digital Twin), obtained with the aid of a technology based on laser scanner combined with photogrammetry, processed in the Cloud with deep neural networks, provided by the American company Matterport Inc, with which e-Making Srl has started an important collaboration that has led to the development of the “e-Building” Cloud platform for managing models and creating a “digital drawer”.
The instruments used for the surveys are the *Leica BLK360* and the Matterport Pro2 camera.

Leica BLK360

Matterport Pro2

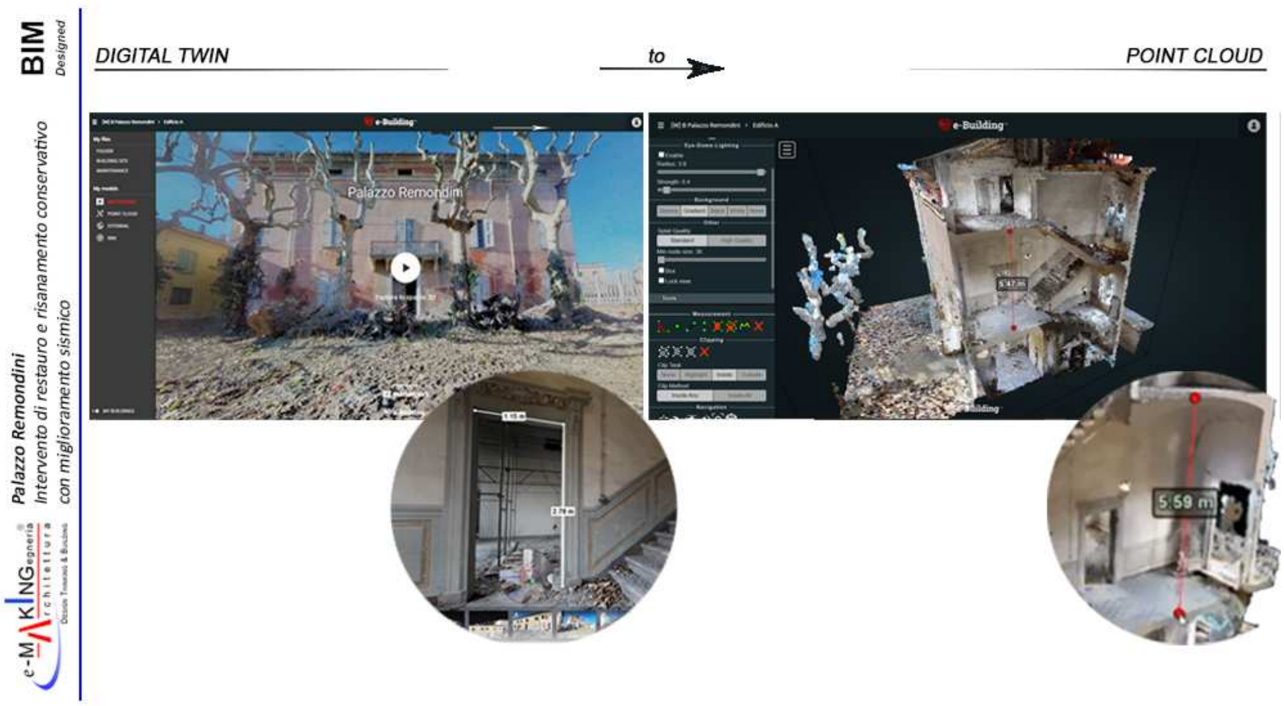

Fig. 5 – *Flow: Digital Twin to Point Cloud.*

The Model, completely navigable and measurable through the proprietary e-Building Platform, has been shared from the first stages with the entire design team, allowing virtual inspections, with a considerable reduction in time and costs related to the survey of the building and the collection of preliminary and work in progress information.

Within e-Building, the documentation collected and organized in the digital drawer, has been linked through Tags to the Model in a very simple way, thanks to a user frendly CMS, matching both the contents resident in the Platform and those coming from external sources.

The Model can be seen as a "Bim macro object" in which the informative contents, such as photos, videos, pdf, audio notes, etc, are inserted through Tags. It was found essential not only in the initial stages of data collection, but also in the later stages of design and construction, constantly updated and enriched with information.

The e-Building platform provides differentiated access rules and the CDE, referenced on the Immersive Navigation Model, results to be at the base of the Digital Folder and allows to realize a real Time Travel of the building.

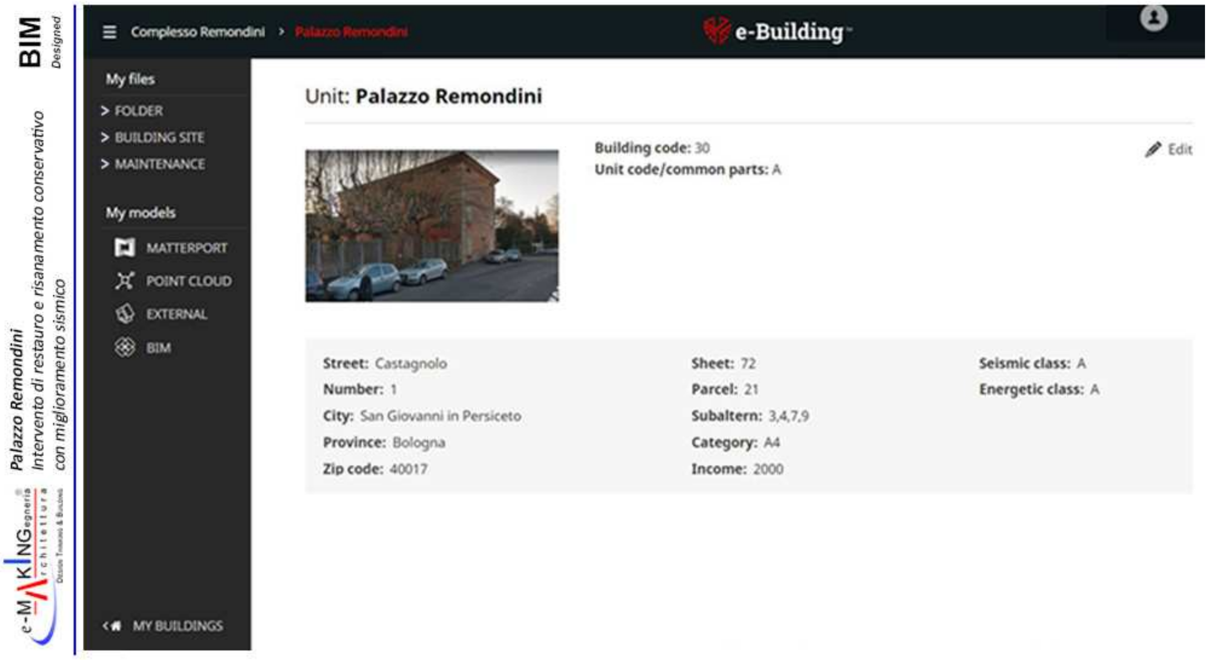

Fig. 6 – *Building card*

The structure of the Folder is made up of two macro categories:

- **My Files:** where it is possible to store, archive, visualize and manage all the contents, also geo-referenced, on the Model;
- **My Models:** where all the models can be loaded (digital twin of the actual state and "as built", point clouds, Co-Design models, BIM Models) and in which it is possible to associate different contents through Tags. All templates can also be shared for public or private viewing.

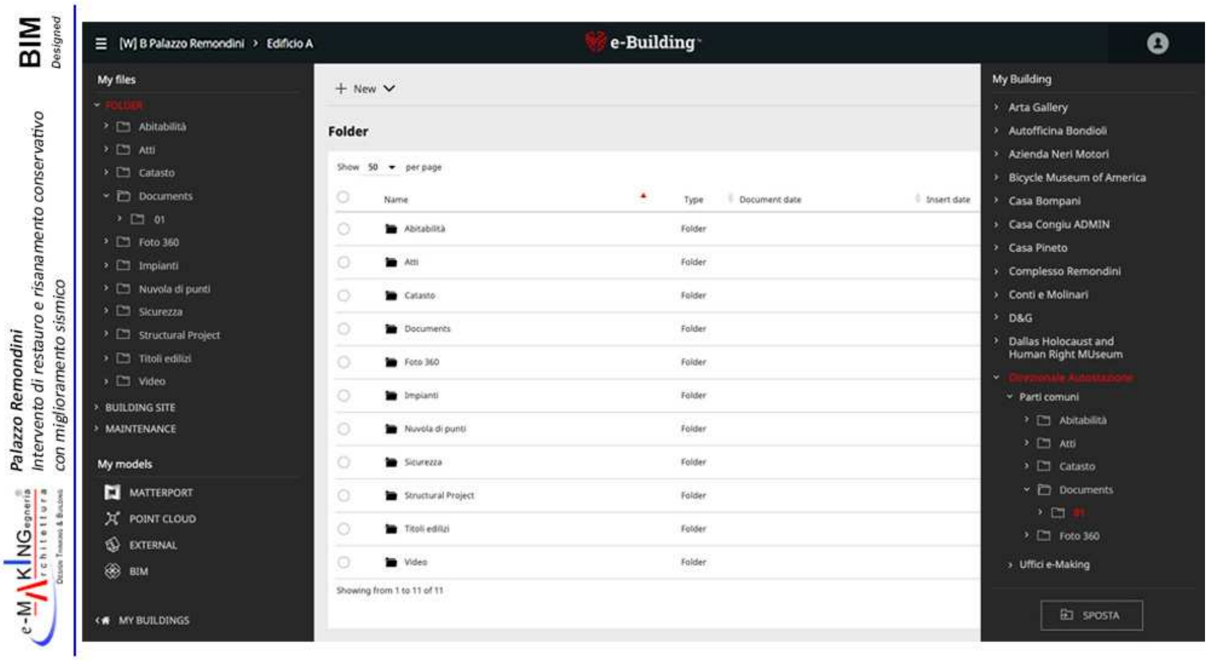

Fig. 7 – *Screen where you can view, manage and share archived documentation.*

Inside the My Files folder there are three macro areas in which you can logically store everything you want:

- **FOLDER** (Digital Drawer): all documents of general value and different formats, including pdf files, p7m files, images, video and audio files, 360° images, etc. ;
- **BUILDING SITE**: documents produced during all the activities carried out on the work during its useful life which have required the opening of a building site;
- **MAINTENANCE**: the user will be able to store all documentation relating to the routine maintenance carried out on the building.

Once the work is completed the documentation and templates will form the Digital Folder, to be used for future management and maintenance.

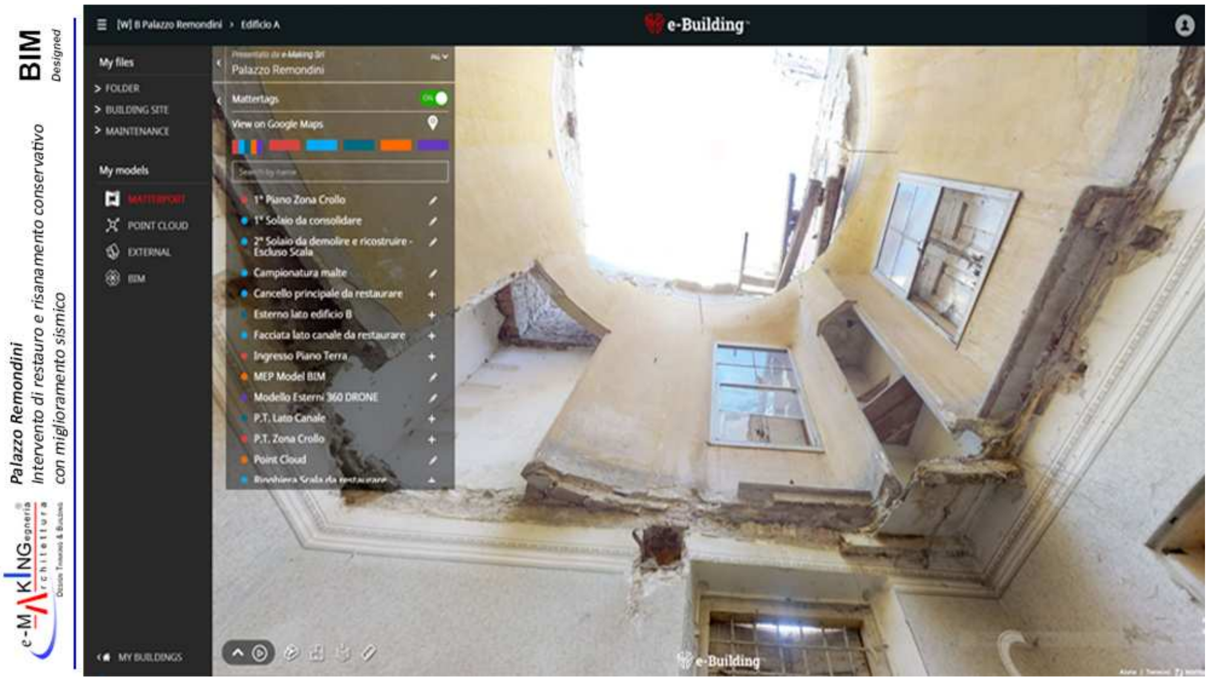

Fig. 8 – *The information collected was organized and made available through Tags on the Model.*

From the Digital Twin was extracted the point cloud used in the BIM flow of integrated design (Architectural-Structural-MEP).

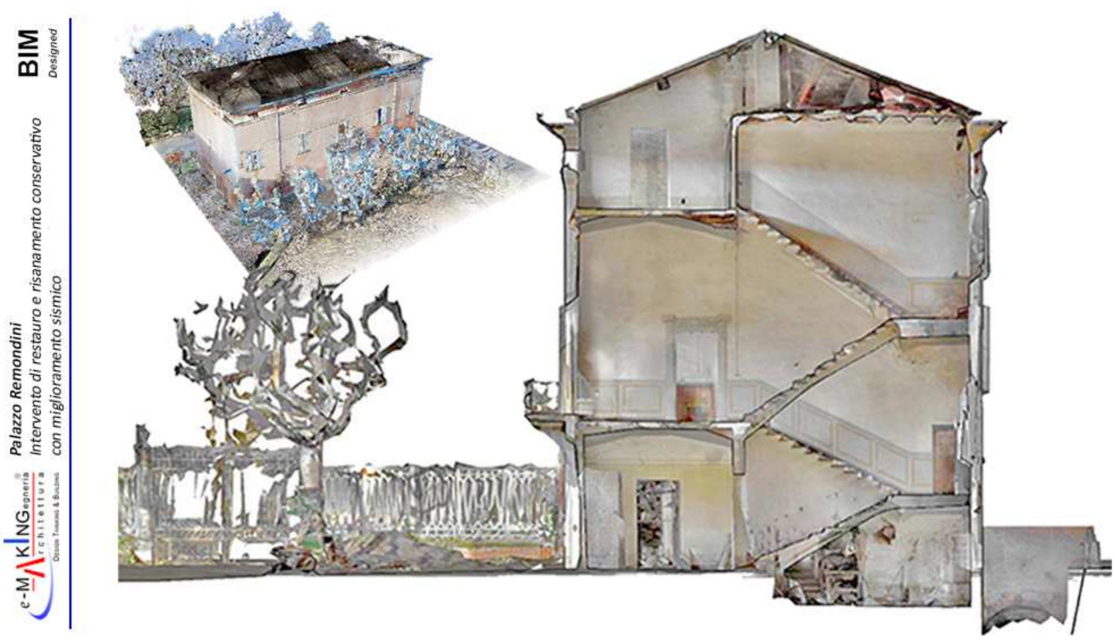

Fig. 9 – *Extraction from Digital Twin of the point cloud used in the BIM design flow.*

2.2. Point Cloud to Bim Arch./Str./Mep

The second phase of the process is the transition from the point cloud to BIM environment integrated design (architectural, structural and mep), conducted in a HBIM[i] perspective with the construction of models for architectural, seismic, plant simulations and sustainability.

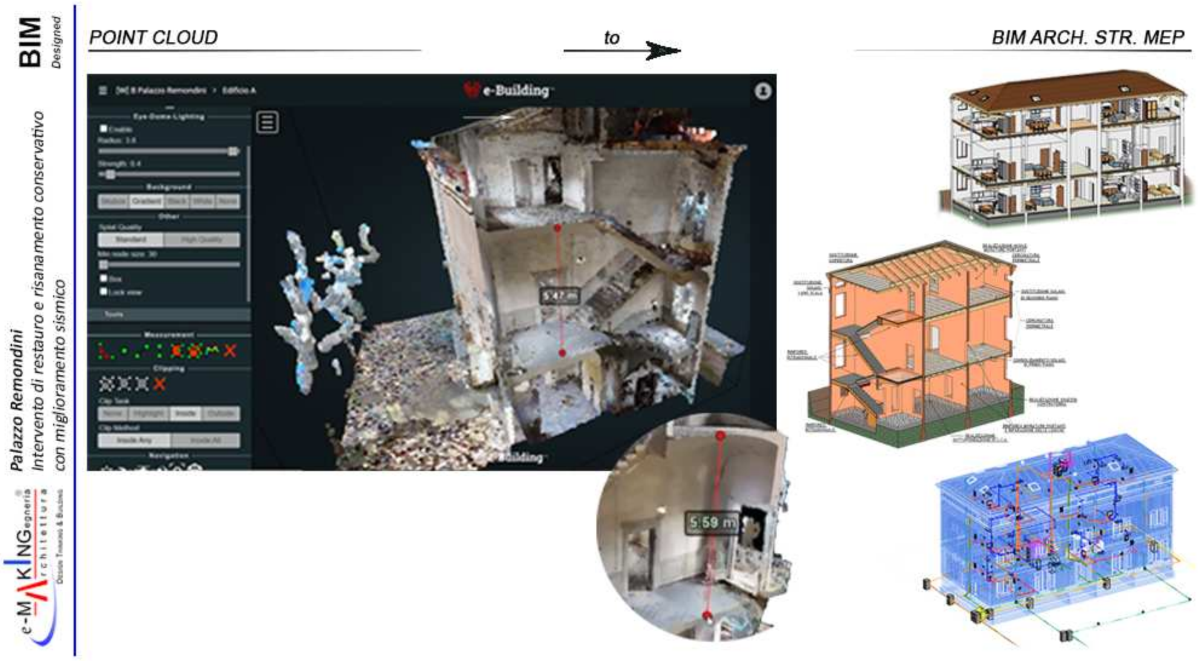

Fig. 10 – *Flow: Point Cloud to BIM environment integrated design.*

The use of the CDE allowed a faster and more continuous collaboration during the design phase. It was possible to work synchronously in the development of the project and its multidisciplinary entirety, with a significant reduction in time and costs. The execution of the clash detection in the various phases of the design allowed the optimization of the MEP system distribution and the elimination of the criticalities and inconsistencies between the architectural, structural and plant design before the construction works were carried out.

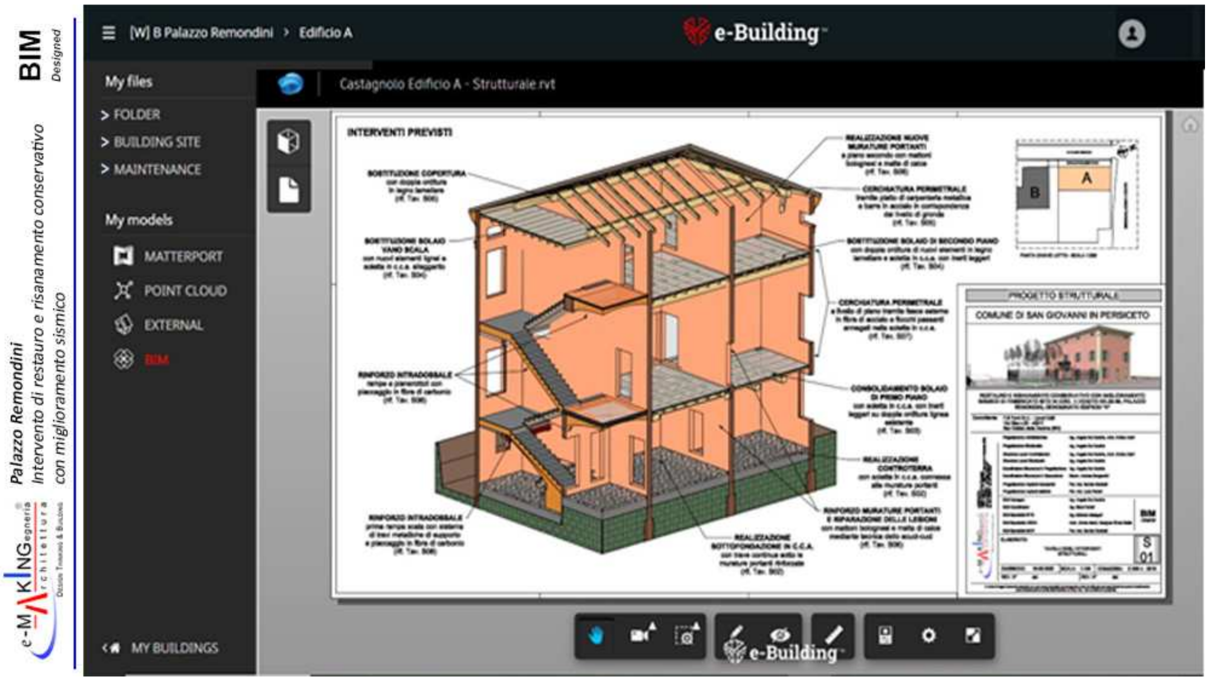

Fig. 11 – *View of the BIM Structural Model, displayed directly in the Platform.*

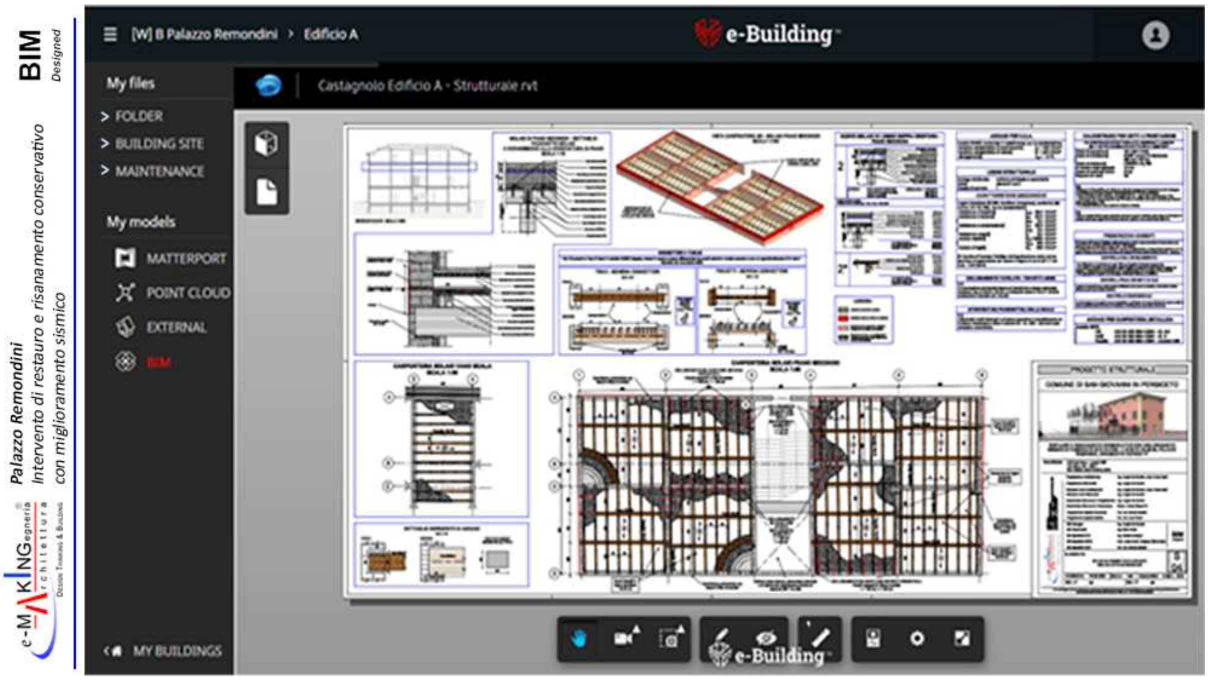

Fig. 12 – *View of the BIM Structural Model, displayed directly in the Platform.*

2.2.1. BIM environment integrated design

Architectural design

The architectural design provided for the preservation and restoration of the building in compliance with the protection constraints, maintaining the current intended use as a residence.

Fig. 13 – *Project view.*

Fig. 14 – *BIM modelling - preservation of the existing architectural layout.*

Life Cycle Assessment e sustainability

The building, located in an area near the city center, had been left in a state of neglect for several years in a place that we could define "suspended", waiting for a new location. The rehabilitation of this site through an "urban mending" operation will contribute to a sustainable development with zero land consumption and a redevelopment of the area able of acting as a driver for urban regeneration.

The Life Cycle Assessment also demonstrated the low impact of construction on the environment. The refinement of the project through the BIM flow has led to a more sustainable design.

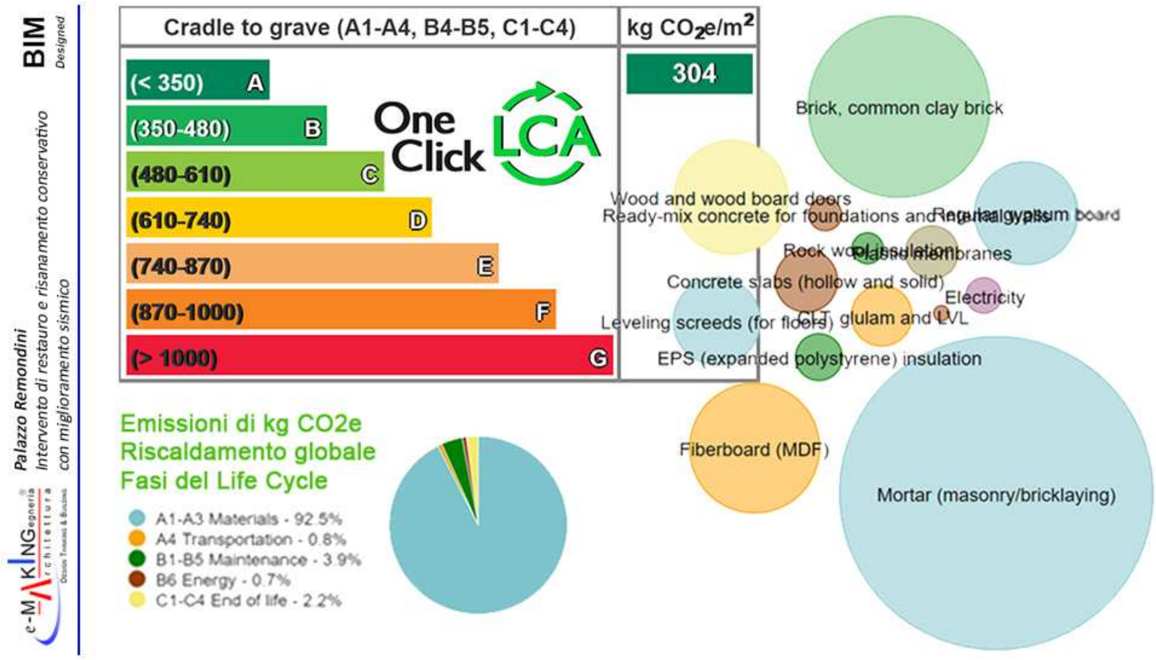

Fig. 15 – *Life Cycle Assessment.*

It has been decided to integrate the BIM process and the LCA (Life Cycle Assessment) since the beginning, in the phases in which the highest potential can be found in terms of ability in influencing the design. The tool used for the LCA (Autodesk Revit plugin – One Click LCA) had direct access to the information of the BIM models allowing the simulations needed for the optimization of the design.

Structural Design

The seismic retrofitting project has made it possible to achieve high levels of seismic safety, not obvious for buildings of this type, through targeted interventions, including:
- floor bandages with unidirectional UHTSS galvanized steel fibre sheets, connected to the floors by fibre thread connecting system, also in galvanized steel fibre sheets, embedded in the floor light reinforced concrete slab;
- top hoops, to support the new wooden roof, with a combination of wooden beam and overlapping steel plate, which ensure a dynamic behavior that respects the deformation of existing walls;
- insertion of carbon fibre fabrics in the sub structure of stairs vaults, to maintain the existing pavings;
- reconstruction and reinforcement of floors with mixed wood-concrete structure in order to make a semi-rigid plane membrane.

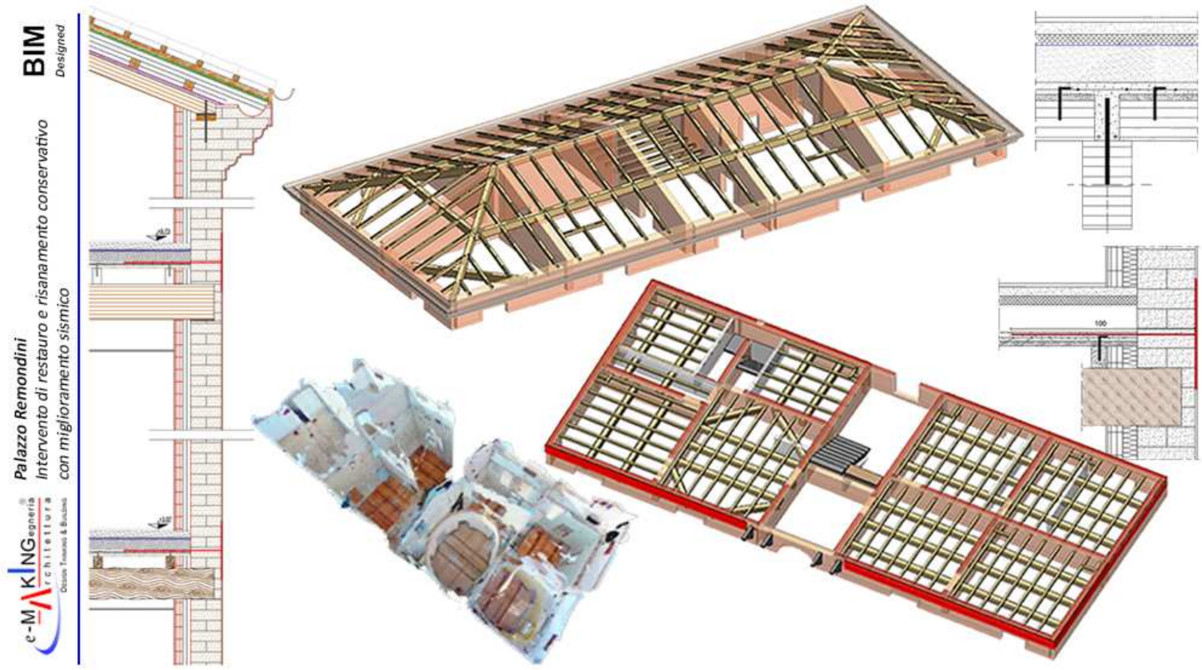

Fig. 16 – *Structural Design - interventions on floors and roofing.*

Plant Design

From the energy point of view, different solutions have been adopted to make the building very low energy consumption, having taken particular care in the design of the enclosures through the realization of internal counter-parks with an interposed insulating layer, which have led to many benefits, such as:
- Reduction of energy consumption;
- Passage systems, avoiding to touch the bearing masonry;
- Significant increase in environmental comfort.

The plant components, such as heat pumps for power generation and integration with condensing boilers, were placed inside the architectural layout, while the underfloor heating and cooling system allowed the rooms to be free of visible heating/cooling units.

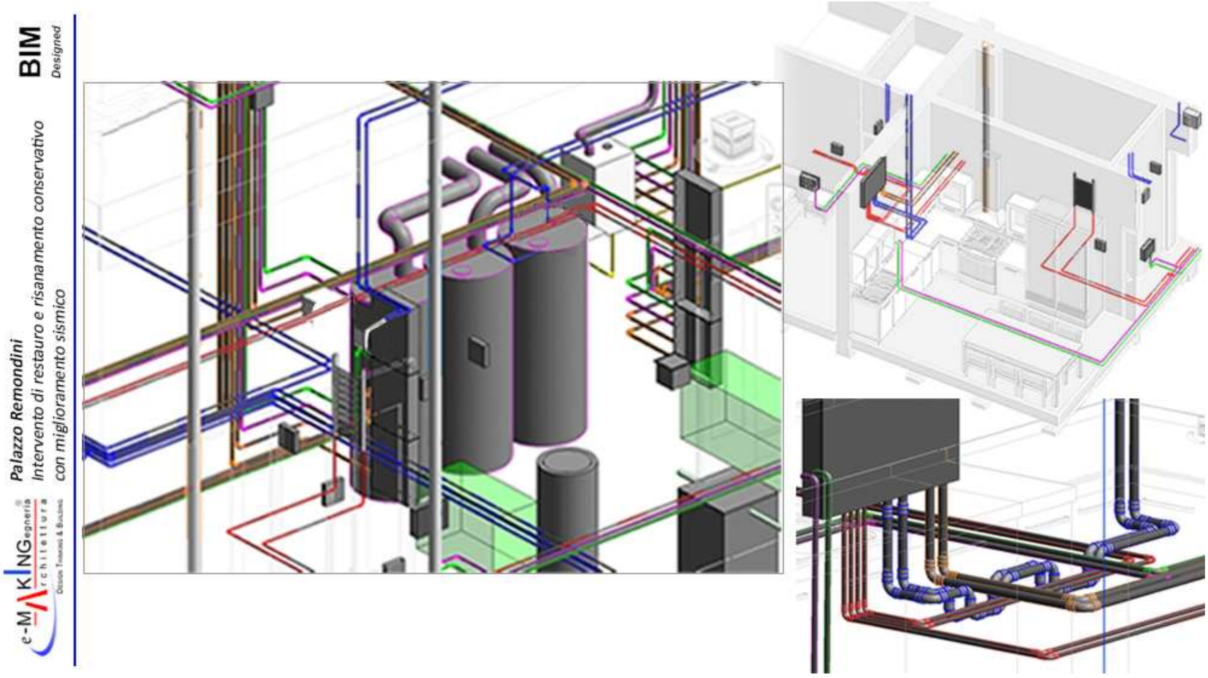

Fig. 17 – *Thermal power plant located in the under stair closet.*

Fig. 18 – *Internal counter-parks with an interposed insulating layer.*

2.3. Bim Arch. to Co-Design Model

Starting from the architectural model, an immersive navigation model has been created with a Co-Design function, usable through the web, produced with external software, but always managed in the Platform, in which there is the possibility of:

- uploading projects with pre-set material choices that the user can test in real time (e.g.: the colour of the furniture in the kitchen, floors, fixtures, etc.)
- freely navigate the model;
- activate the virtual tour through the menu, taking in predefined views or through automatic tour, which can be interrupted at any time to continue according to your choices.

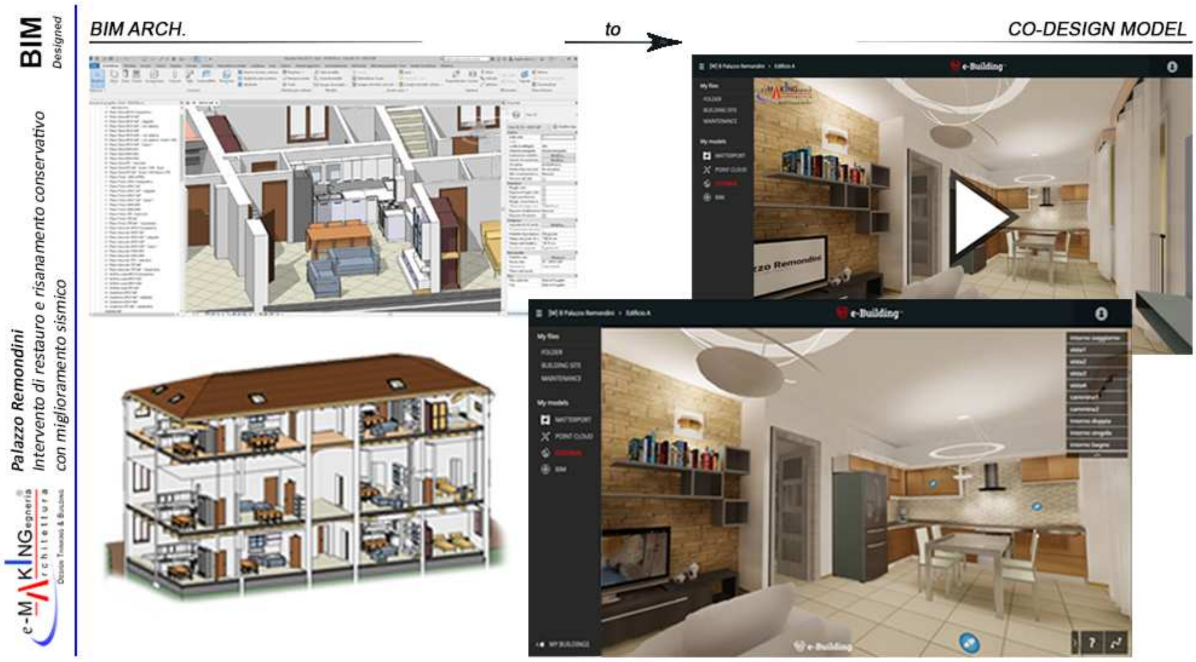

Fig. 19 – *Flow: BIM Architectural Model to Co-Design Model.*

In general, this configurator can be used to simulate the choices provided for in the Specifications, such as floors, walls, doors, bathroom fittings, etc. with the possibility to see in real time the different proposals. It is also used for design activities in interventions on both public and private areas.

2.4. Building Site to Digital Twin As-Built

The flow continues with the building site: the works are constantly kept documented with surveys carried out with the same combined technology, which returns digital models of “as built” for different disciplines (Stru - Mep - Arch).

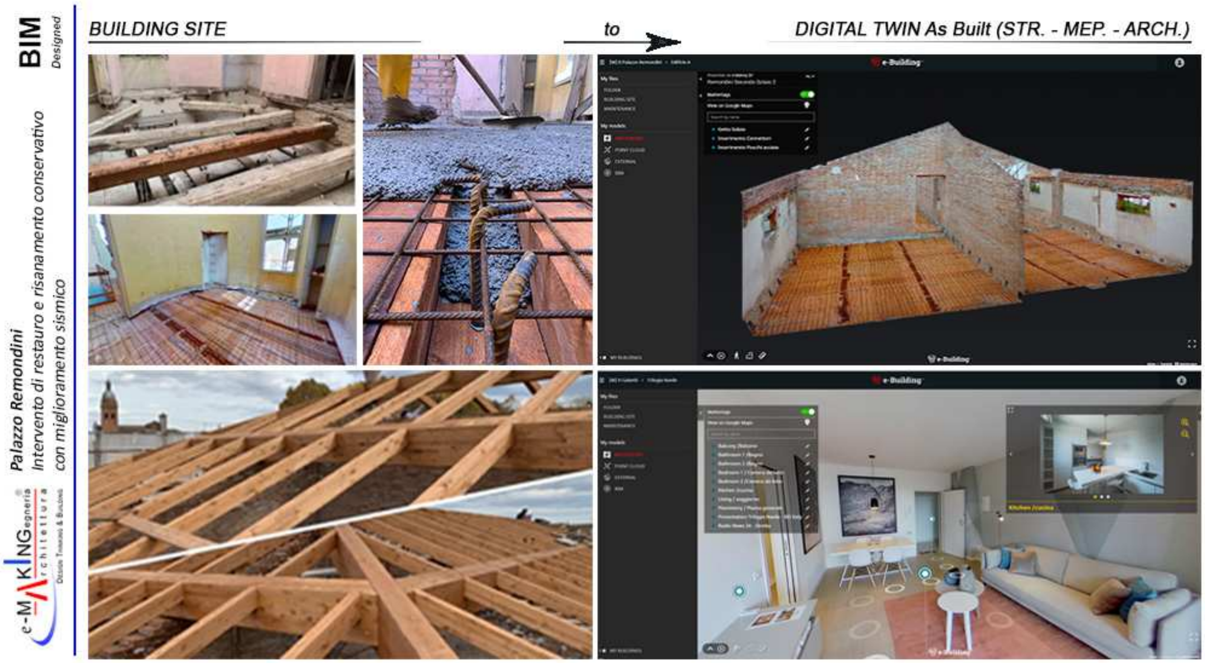

Fig. 20 – *Flow: building site to Digital Twin “as built” (Str. – Mep. – Arch.)*

The use of the immersive navigation model has proven to be a very effective tool thanks to which it is possible to have the documentation of the construction site, always available, saved and organized in the same moment in which it is produced.

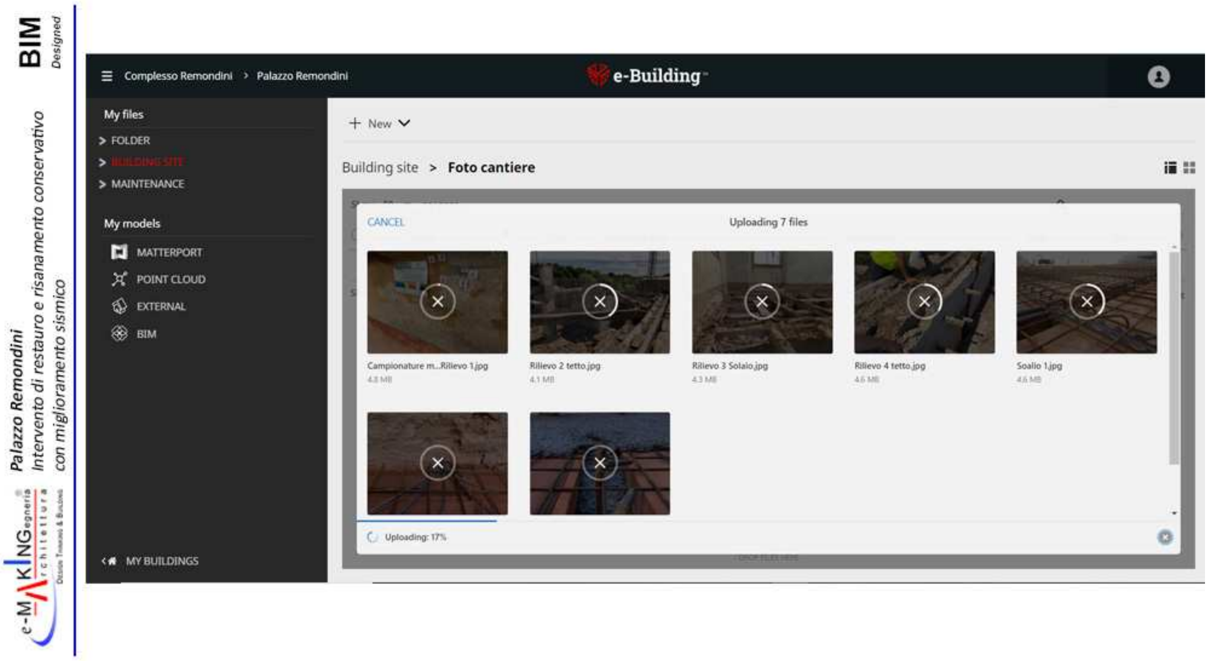

Fig. 21 – *Building site images loading.*

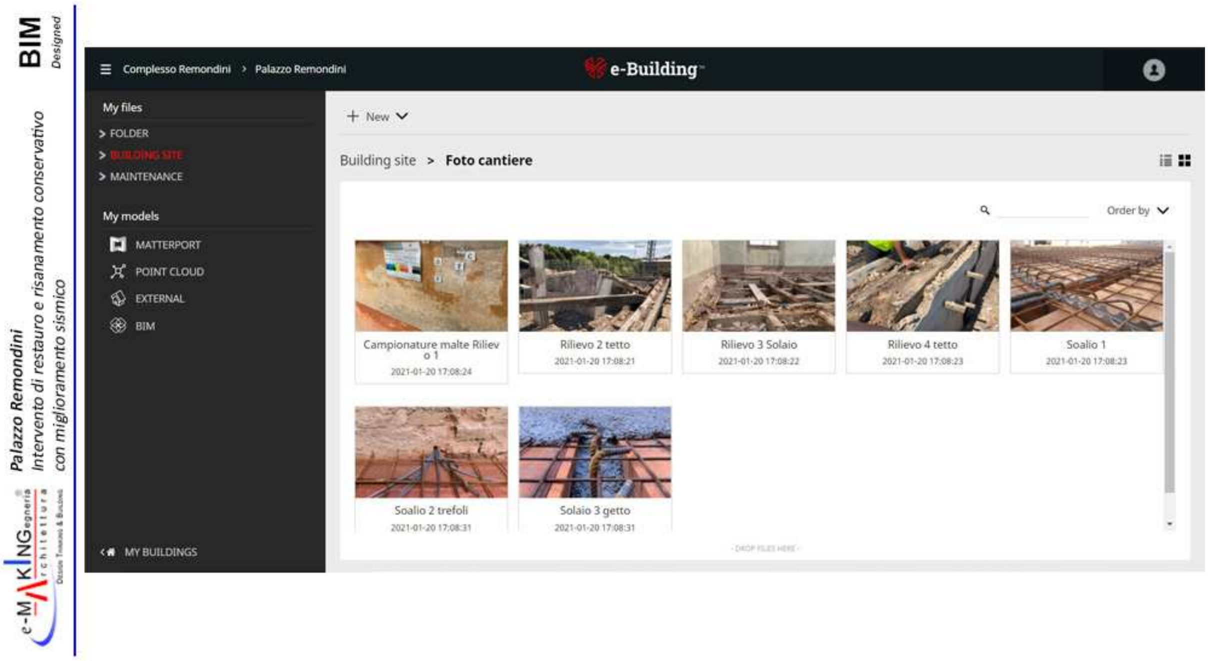

Fig. 22 – *Building site – Building site photo preview.*

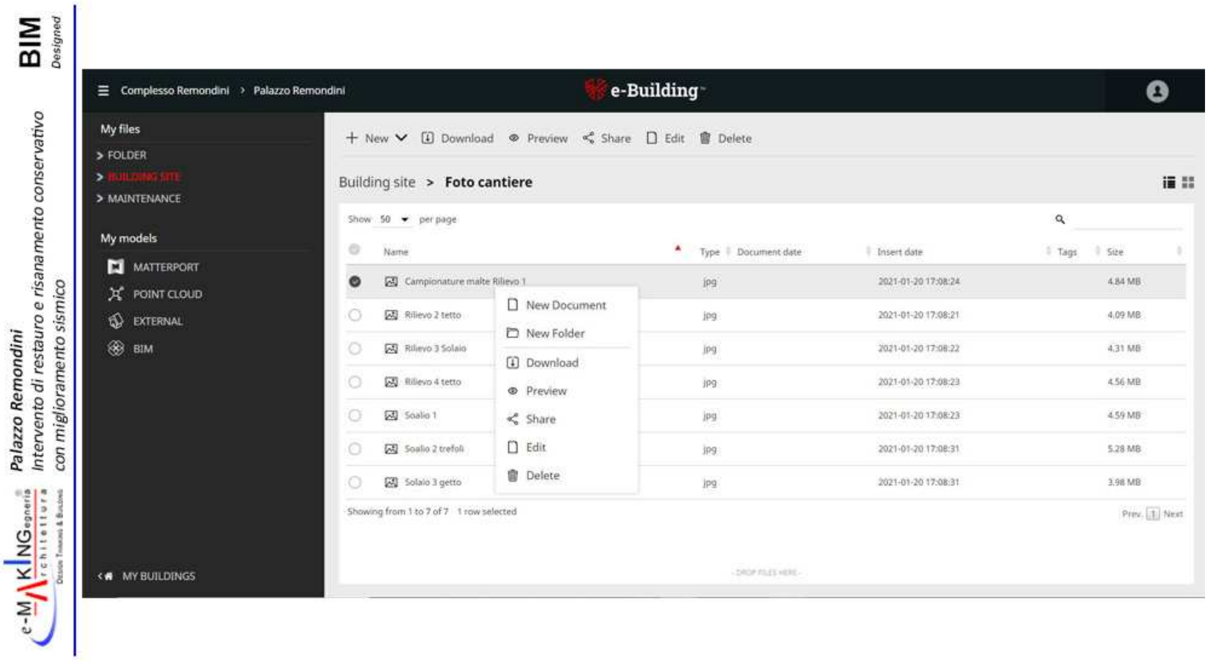

Fig. 23 – *Building site – Management documents.*

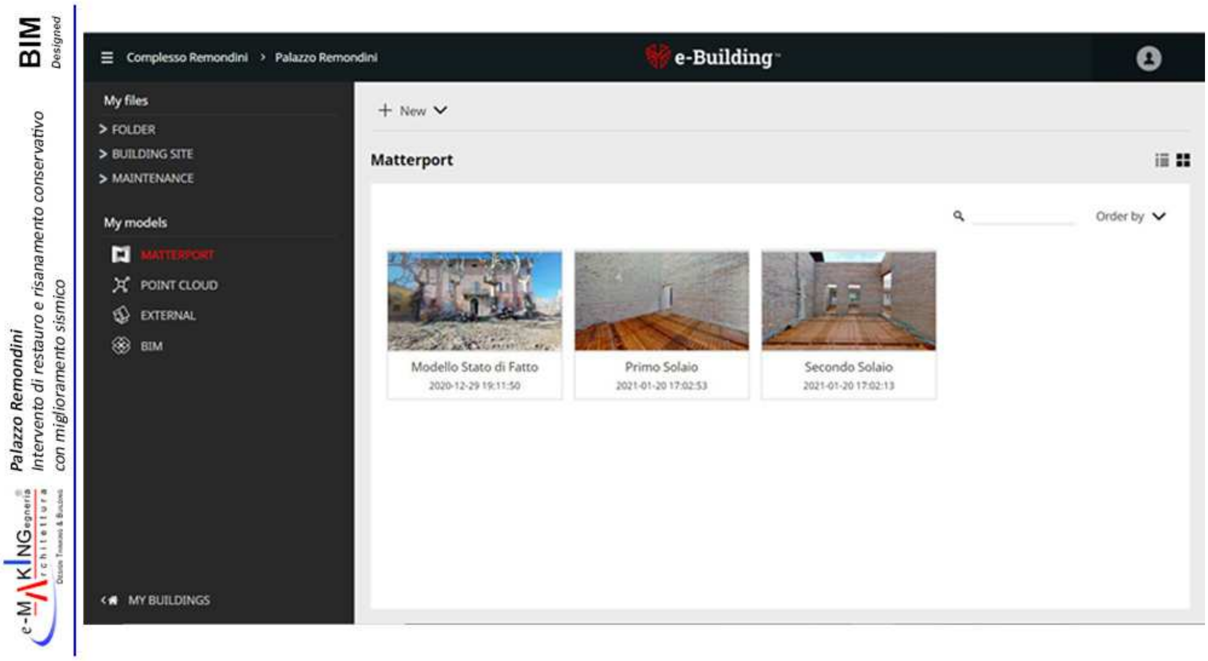

Fig. 24 – *My Models view.*

Fig. 25 – *My Models – Digital Twin view.*

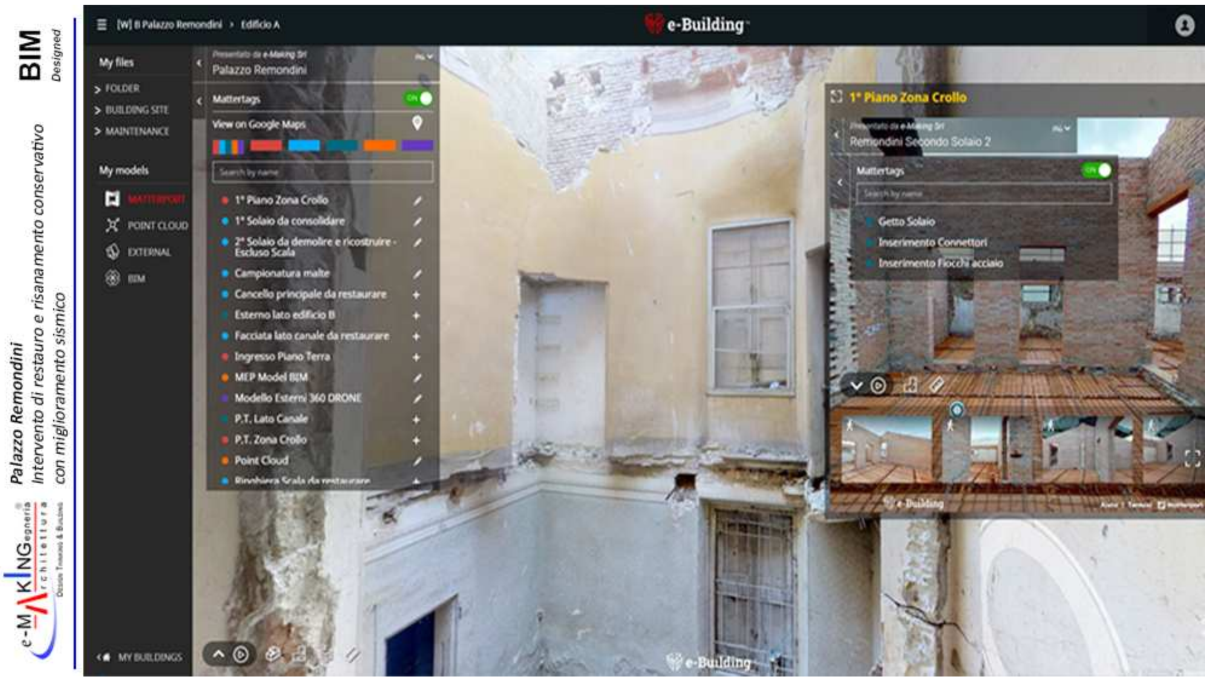

Fig. 26 – *My Models –Digital Twin view.*

At the end of the work, the models will become part of the Digital Folder, which can be easily updated by the end user in the subsequent phases of management and maintenance.

2.5. Time analysis and economic impact

Compared to traditional methodologies, with the adopted process the following activities have been carried out more efficiently:

- Survey: performed in 8h by a single operator + 2h of cloud processing. Compared to the traditional methodology, it has been achieved 70% time saving and 20% cost saving.
- Site inspections: developed the model, the following site inspections have been carried out virtually, by all members of the design team and companies concerned in the work, at zero cost from the comfort of their workstation: time saving 90%, cost saving 90%.

We obtained:

- Higher accuracy of measured data: the margin of error of acquired measurements is 0,1%. Considering an error of 5% with traditional method on highly irregular buildings, we obtained an accuracy 50 times higher, without considering the detailed acquisition of all measurements, compared to the few elements measured traditionally.
- More efficiency in document access: the information, organized in space and time, allowed a time and cost saving of 80%.

By optimizing the project, a more performing building was obtained, which means:

- More efficient building that leads to lower operating costs;
- Efficient information availability about the work, with operating costs saving;
- Energy saving;
- Greater durability of the work and lower maintenance costs;
- Ease of management with documentation always available.

Finally, the design and management flow has led to a significant reduction in the movement of people and vehicles and a very low use of paper, with a big benefit for the environment.

LINK multimedia contents:
Digital Twin, immersive navigation model
co-design model
Point Cloud
Design flow video

Workgroup:

e-Making S.r.l. (https://www.e-making.it)

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Arch. Enrico Merli
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[i] Maurice Murphy, Eugene McGovern, Sara Pavia, (2009) "Historic building information modelling (HBIM)", Structural Survey, Vol. 27 Issue: 4, pp.311-327, doi: 10.1108/02630800910985108
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