6.2.8.1 In-depth analysis in the framework of BIM modeling through "3muri software", analysis and investigations into possible masonry collapse scenarios

By the same logic as the first case study was treated, here too it was judged to perform non-linear analyzes with 3Muri software v.13 academic version. In difference to the first case, non-linear analyzes were performed here with etabs software, but the focus in this paragraph is to find and specifically investigate the mechanisms of collapse and harmful cracks only for masonry panels, since the 3Muri software is specialized for these types of investigations, even modeling the object with the geometric data explained above, with the same parameters of the materials according to laboratory tests and with the same loads situations.

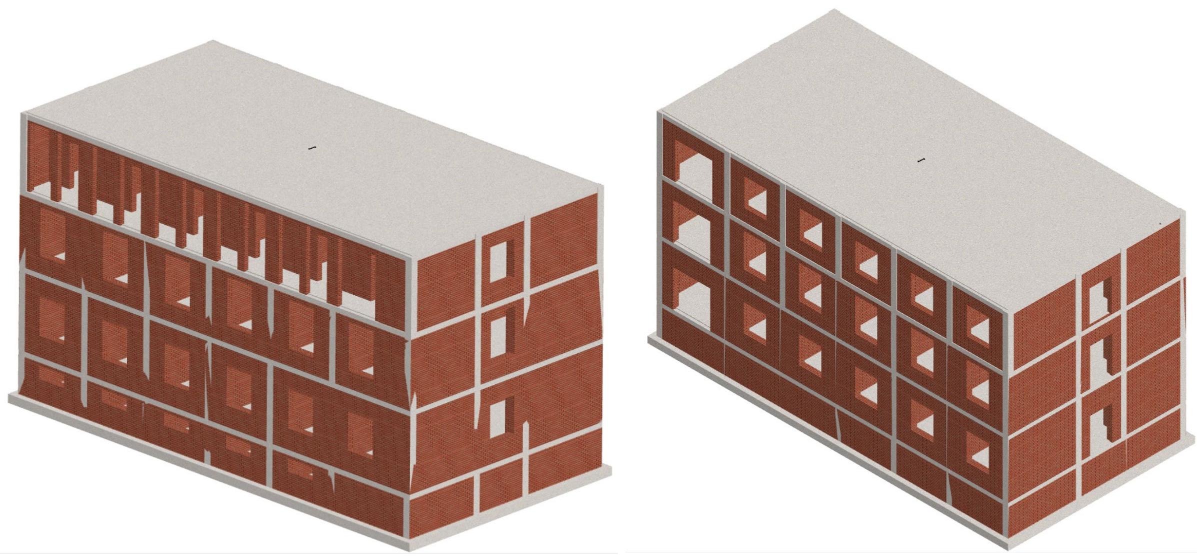


Figure 129. Axonometric model worked in 3Muri software, specifically the western block of the Building complex which currently belongs to the Dean's Office of the Faculty of Electrical Engineering

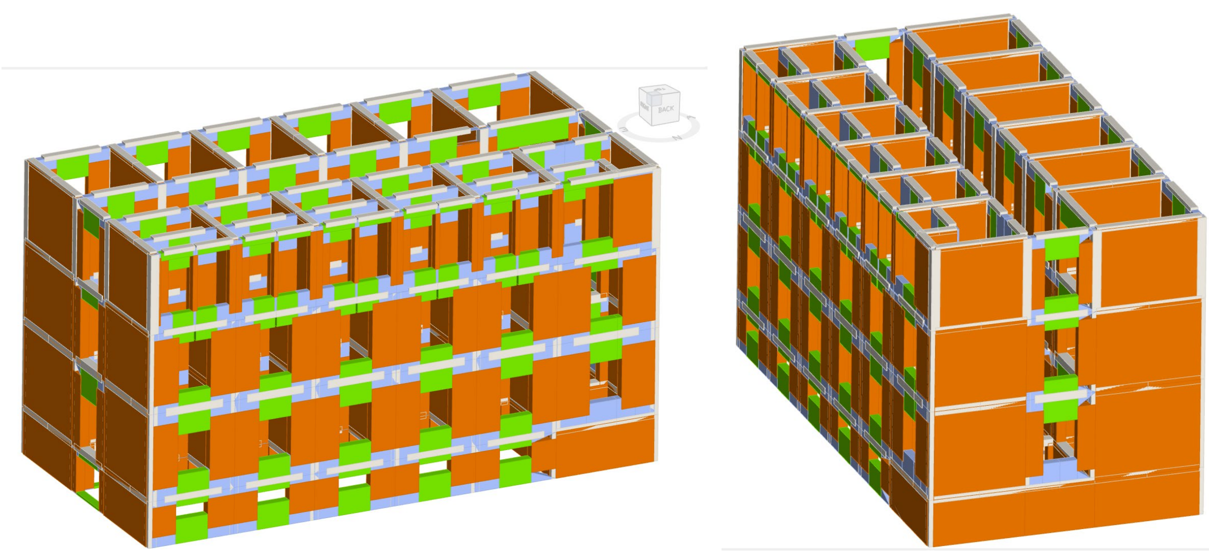


Figure 130. Axonometric model of the western block worked in 3Muri software, where the transformation of the panels was performed, through the Mesh process

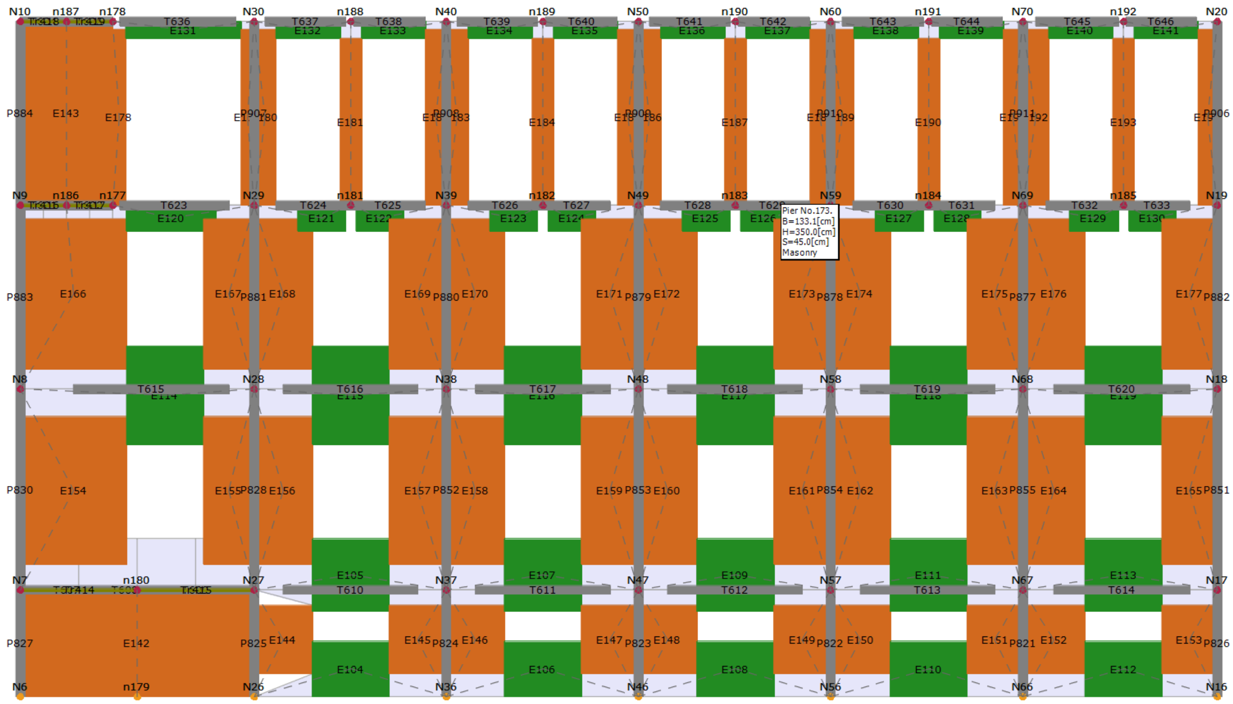


Figure 131. Numerical model of the main facade processed in 3Muri software

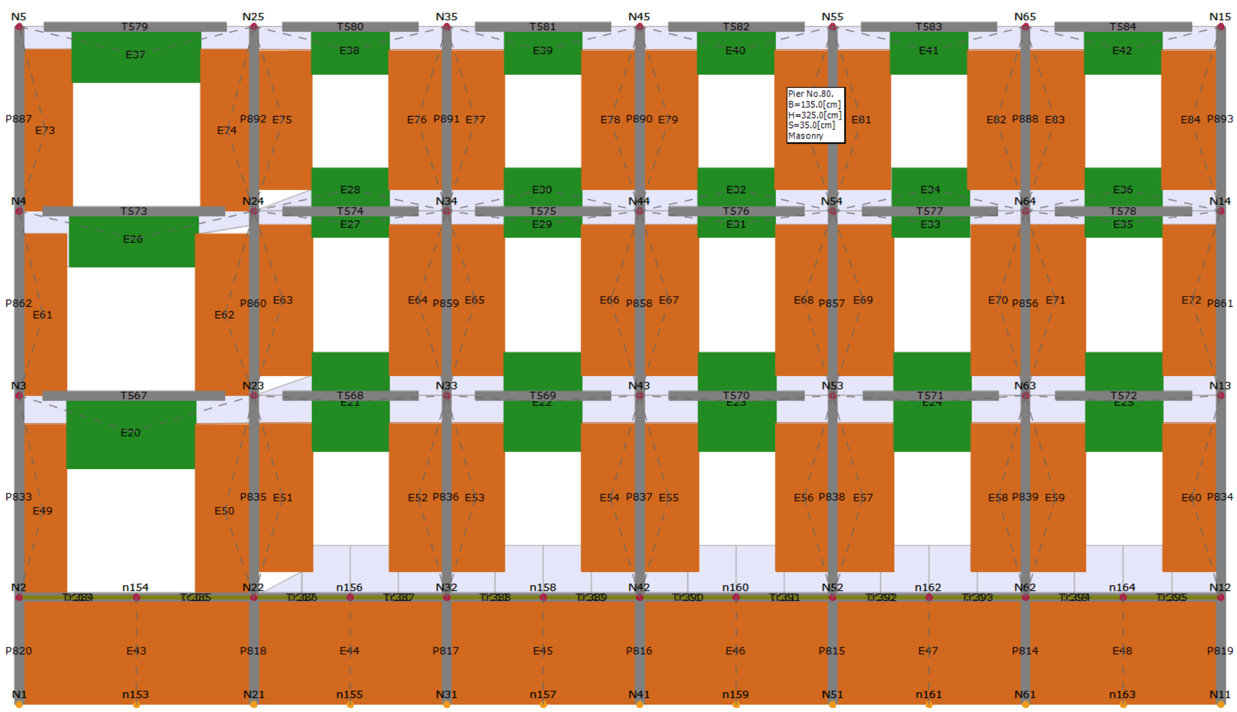


Figure 132. Numerical model of the back facade processed in 3Muri software

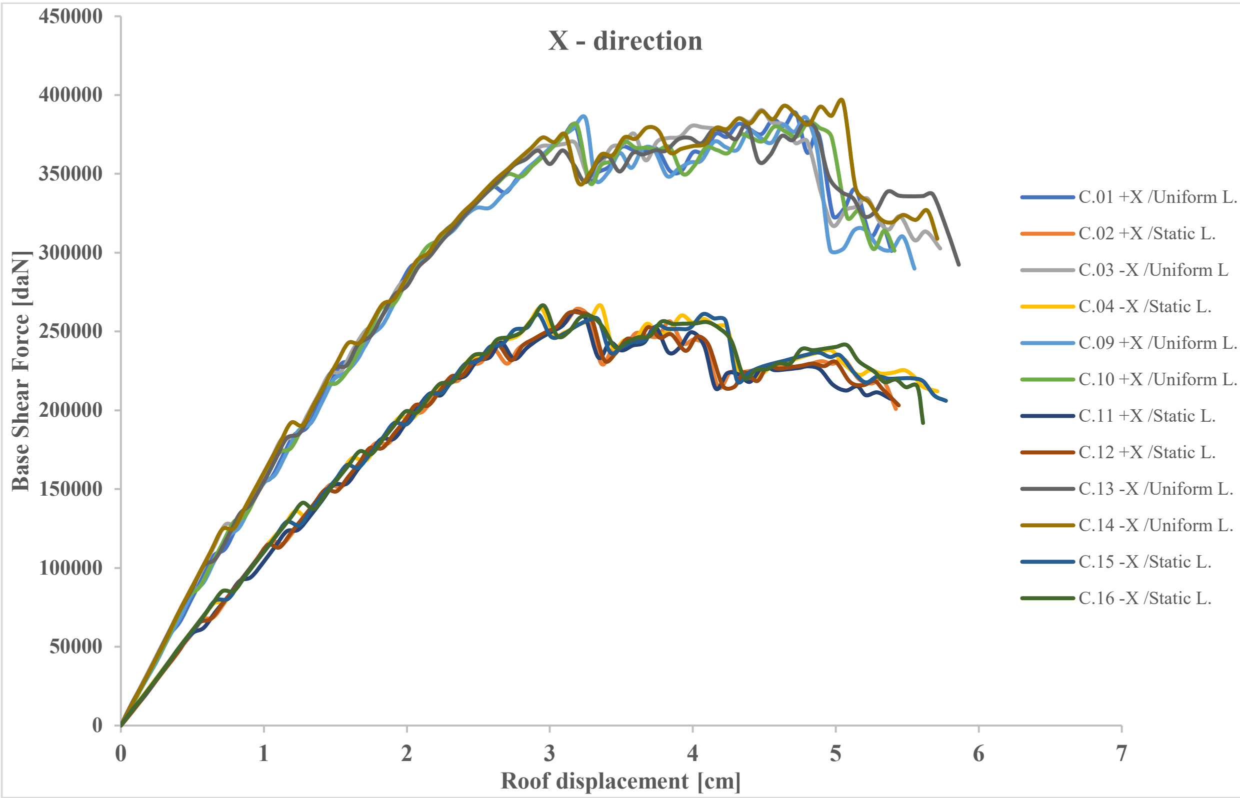


Figure 133. +X and -X direction combined capacity diagrams, processed from 3Muri numerical data

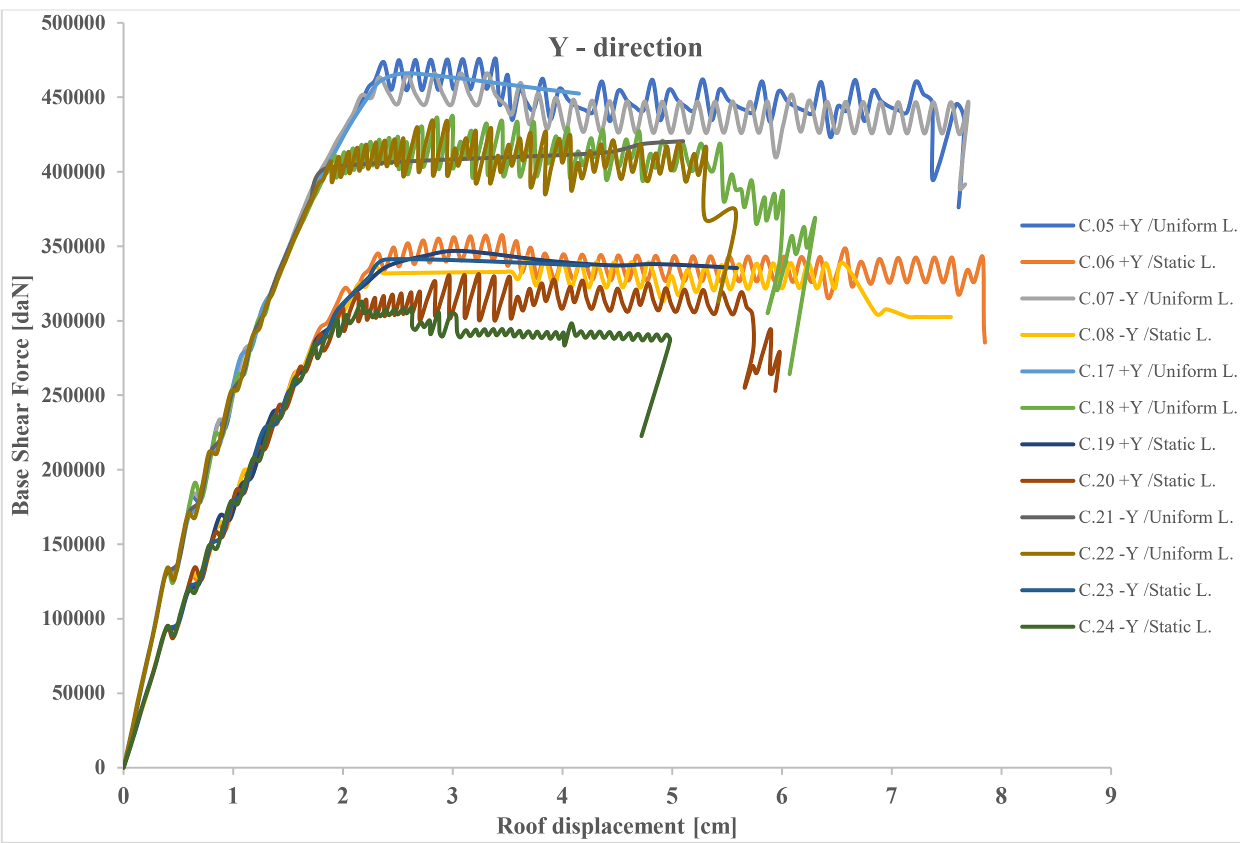
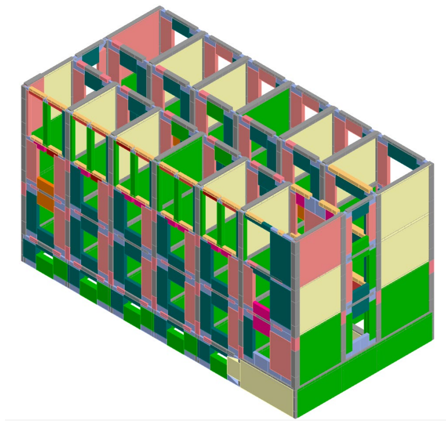
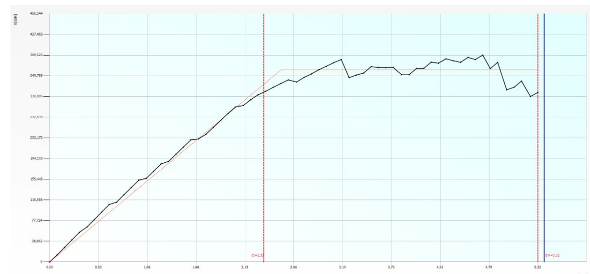
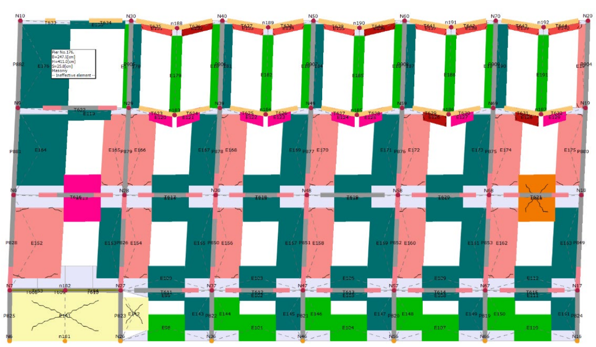
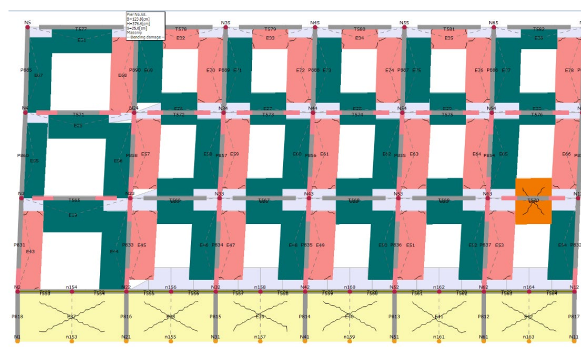
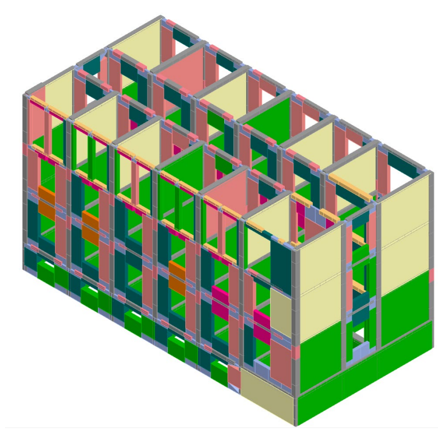
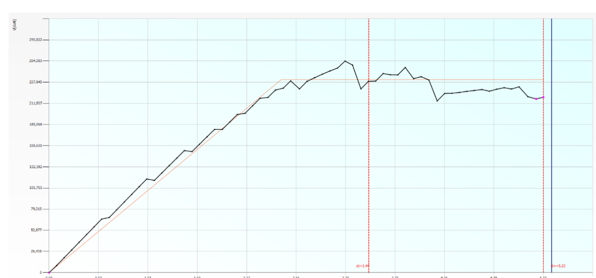
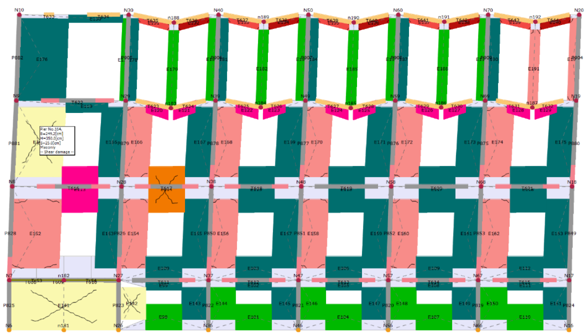
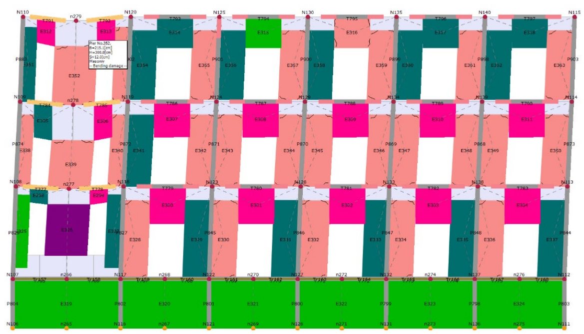


Figure 134. +Y and -Y direction combined capacity diagrams, processed from 3Muri numerical data

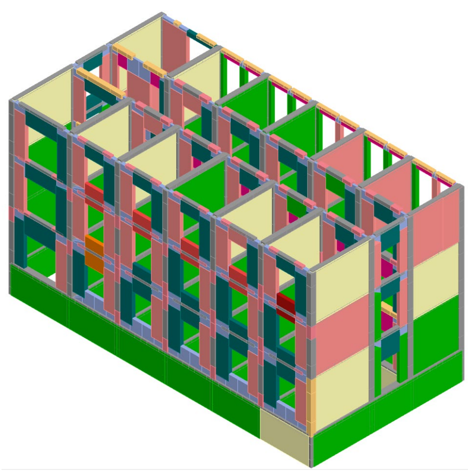
The next step is to extract and interpret the results of nonlinear pushover analysis through 3Muri software. Capacity curves are extracted in V-Δ format, specifically combinations of curves according to X and Y direction, after 24 analyzes performed as follows:

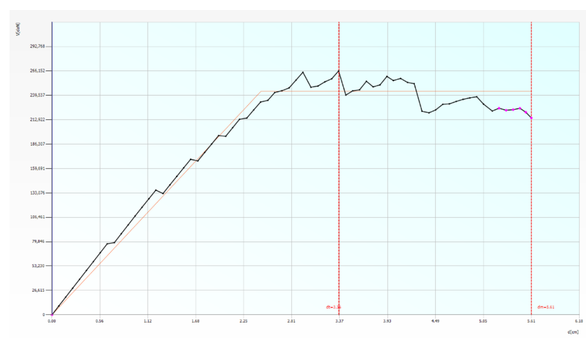
Table 20. Summary table of results analyzed in 3Muri software, focused on the most problematic steps

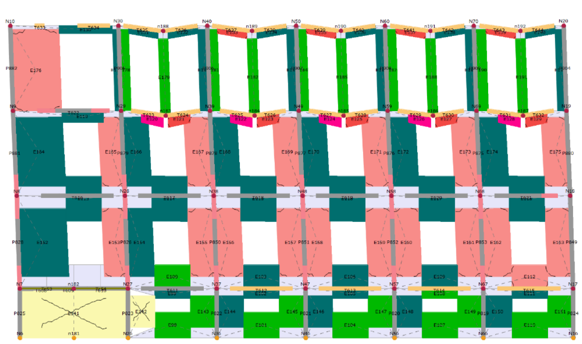
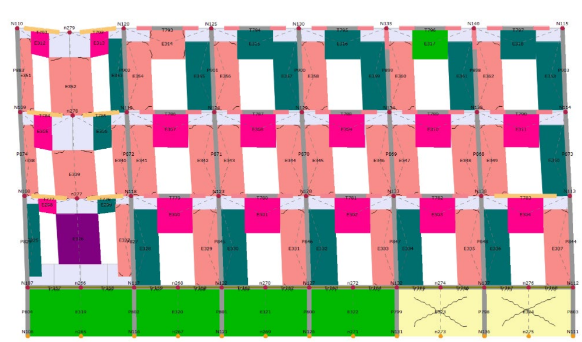
<table>
<tr><th>No</th><th>Seism dir.</th><th>Seismic load</th><th>α NC</th><th>α SD</th><th>α DL</th><th>d_m/d_t NC</th><th>Capacity curves</th></tr>
<tr><td>1</td><td>+X</td><td>Uniform</td><td>1.971</td><td>1.900</td><td>1.703</td><td>2.083</td><td>Capacity curve / analysis no.01 / +X direction</td></tr>
<tr><td colspan="7"></td><td></td></tr>
<tr><td colspan="7">Analysis-01/Mechanism no.1 /Main façade masonry /seismic dir.+X/seismic load =uniform plot</td><td>Analysis-01/Mechanism no.4 /Back façade masonry /seismic dir.+X/seismic load =uniform plot</td></tr>
<tr><td colspan="7"></td><td></td></tr>
<tr><th>No</th><th>Seism dir.</th><th>Seismic load</th><th>α NC</th><th>α SD</th><th>α DL</th><th>d_m/d_t NC</th><th>Capacity curves</th></tr>
<tr><td>2</td><td>+X</td><td>Static forces</td><td>1.546</td><td>1.450</td><td>1.209</td><td>1.549</td><td>Capacity curve no.02 / analysis no.02 / +X dir.</td></tr>
<tr><td colspan="7"></td><td></td></tr>
</table>

Analysis-02/Mechanism no.1 /Main façade masonry /seismic dir.+X/seismic load =static	Analysis-02/Mechanism no.2 /Internal hall masonry /seismic dir.+X/seismic load =static
	

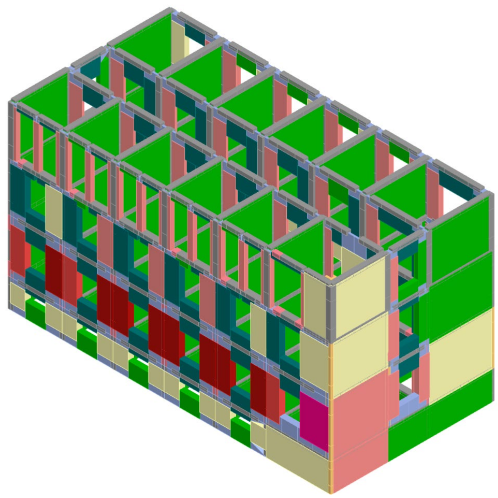
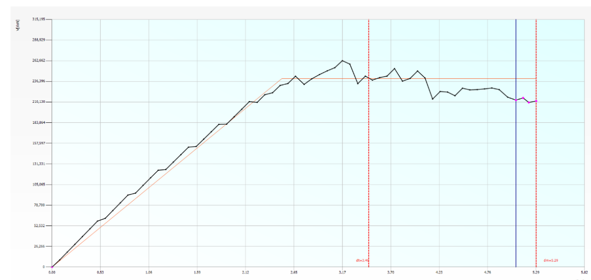
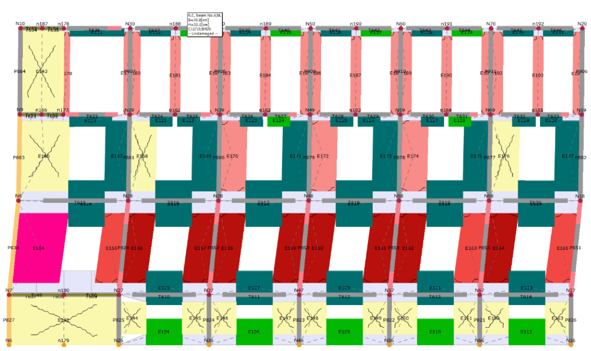
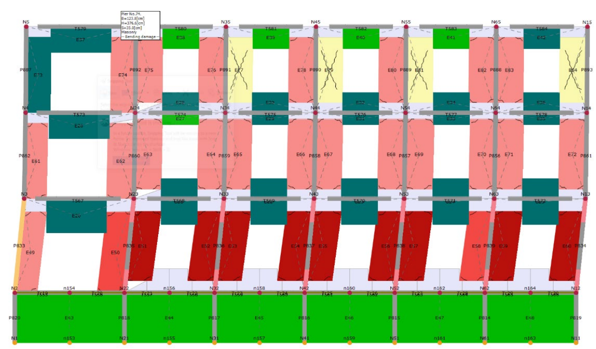
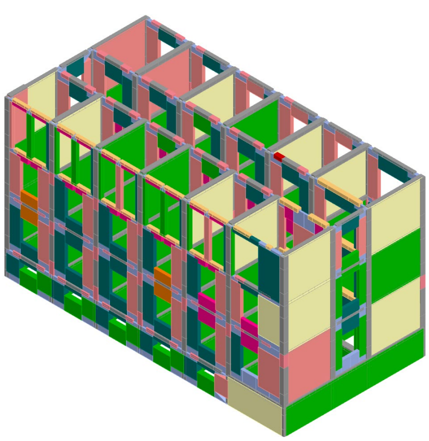
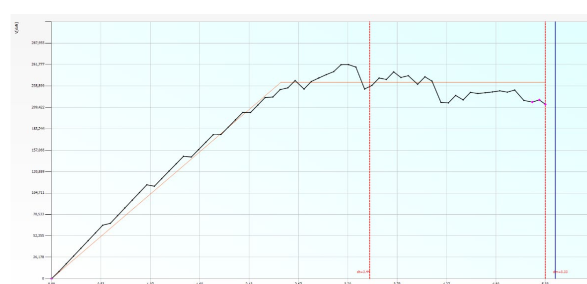
No	Seism dir.	Seismic load	α NC	α SD	α DL	d_m/d_t NC	Capacity curves
3	-X	Uniform	2.182	2.105	1.822	2.416	
4	-X	Static forces	1.665	1.564	1.217	1.670	Capacity curves



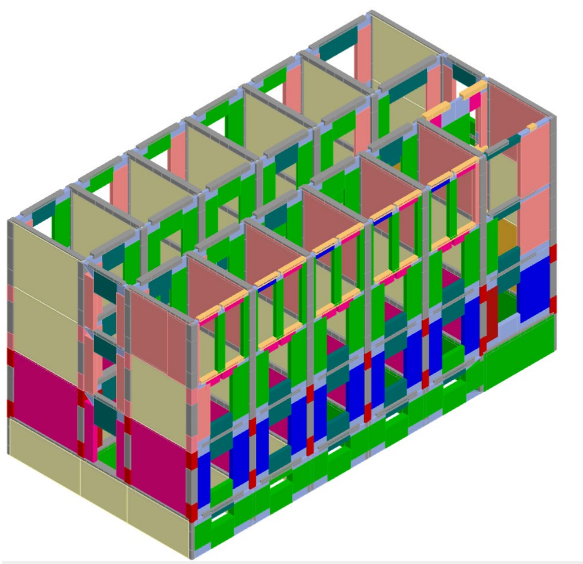


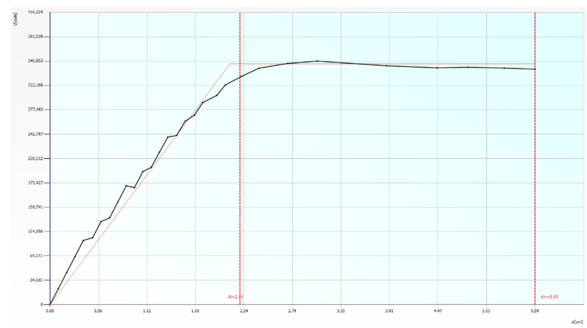
Analysis-04/Mechanism no.1 /Main façade masonry /seismic dir.-X/seismic load =static	Analysis-04/Mechanism no.2 /Internal hall masonry /seismic dir.-X/seismic load =static
	

No	Seism dir.	Seismic load	α NC	α SD	α DL	d_m/d_t NC	Capacity curves
5	+Y	Uniform	3.792	3.682	2.104	4.987	
6	+Y	Static forces	3.139	3.001	1.575	3.630	
7	-Y	Uniform	2.720	2.606	1.054	3.046	
8	-Y	Static forces	2.997	2.866	1.530	3.427	

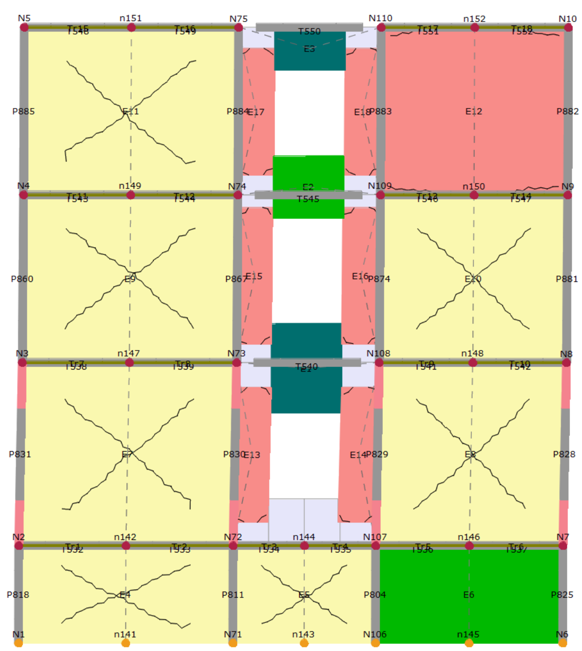
<table>
<tr><td>9</td><td>+X</td><td>Uniform</td><td>2.101</td><td>2.027</td><td>1.830</td><td>2.298</td><td></td></tr>
<tr><td>10</td><td>+X</td><td>Uniform</td><td>2.054</td><td>1.983</td><td>1.842</td><td>2.244</td><td></td></tr>
<tr><td>No</td><td>Seism dir.</td><td>Seismic load</td><td>α NC</td><td>α SD</td><td>α DL</td><td>d_m/d_t NC</td><td>Capacity curves</td></tr>
<tr><td>11</td><td>+X</td><td>Static forces</td><td>1.129</td><td>1.033</td><td>0.910</td><td>1.129</td><td>Capacity curve no.11 / analysis no.11 / +X dir.</td></tr>
<tr><td colspan="7"></td><td></td></tr>
<tr><td colspan="7">Analysis-11/Mechanism no.1 /Main façade masonry /seismic dir.+X/seismic load =static</td><td>Analysis-11/Mechanism no.4 /Back façade masonry /seismic dir.+X/seismic load =static</td></tr>
<tr><td colspan="7"></td><td></td></tr>
<tr><td>No</td><td>Seism dir.</td><td>Seismic load</td><td>α NC</td><td>α SD</td><td>α DL</td><td>d_m/d_t NC</td><td>Capacity curves</td></tr>
<tr><td>12</td><td>+X</td><td>Static forces</td><td>1.552</td><td>1.455</td><td>1.201</td><td>1.549</td><td>Capacity curve no.12 / analysis no.12 / +X dir.</td></tr>
<tr><td colspan="7"></td><td></td></tr>
<tr><td>No</td><td>Seism dir.</td><td>Seismic load</td><td>α NC</td><td>α SD</td><td>α DL</td><td>d_m/d_t NC</td><td>Capacity curves</td></tr>
</table>

13	-X	Uniform	2.226	2.145	1.793	2.470	
14	-X	Uniform	2.175	2.099	1.853	2.400	
15	-X	Static forces	1.688	1.585	1.204	1.693	
16	-X	Static forces	1.647	1.546	1.224	1.653	
17	+Y	Uniform	2.265	2.254	2.154	2.730	
18	+Y	Uniform	3.180	3.097	1.918	4.145	
No	**Seism dir.**	**Seismic load**	**α NC**	**α SD**	**α DL**	**d_m/d_t NC**	**Capacity curves**
19	+Y	Static forces	2.268	2.184	1.595	2.553	

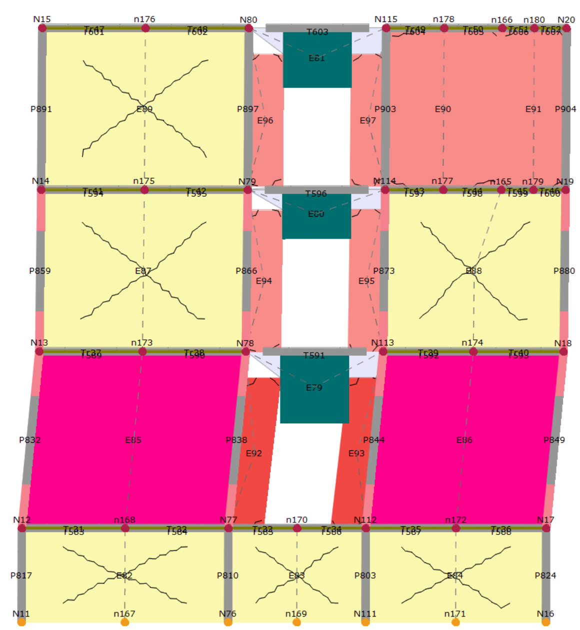




Analysis-19/Mechanism no.5 /West side façade masonry /seismic dir.+Y/seismic load =static



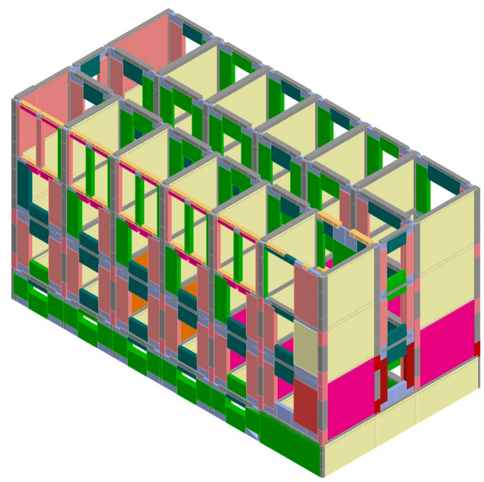
Analysis-19/Mechanism no.11 /East side façade masonry /seismic dir.+Y/seismic load =static

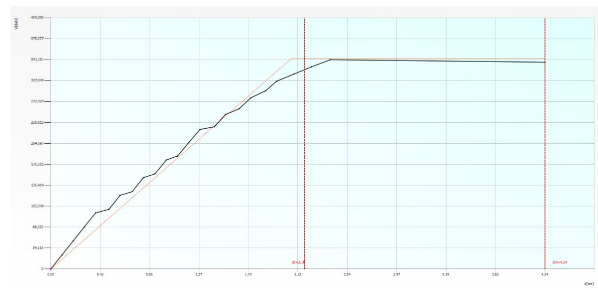


No	**Seism dir.**	**Seismic load**	**α NC**	**α SD**	**α DL**	**d_m/d_t NC**	**Capacity curves**

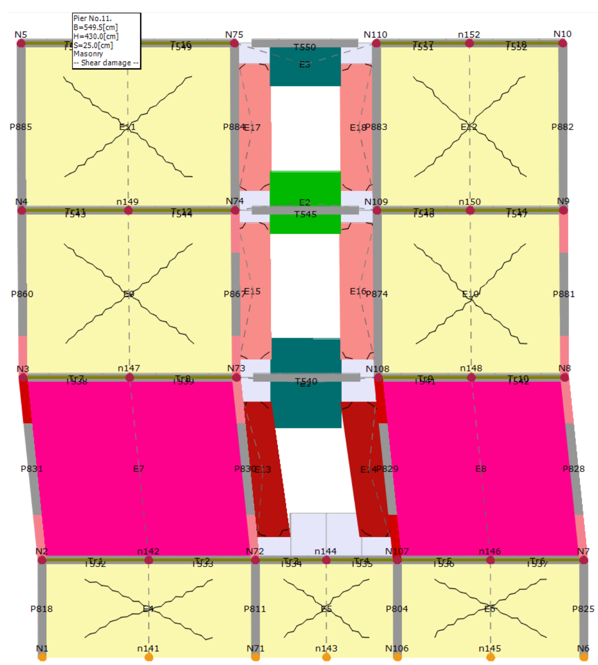
20	+Y	Static forces	2.430	2.333	1.467	2.731	
21	-Y	Uniform	2.689	2.641	1.917	3.446	
22	-Y	Uniform	2.876	2.813	1.905	3.720	

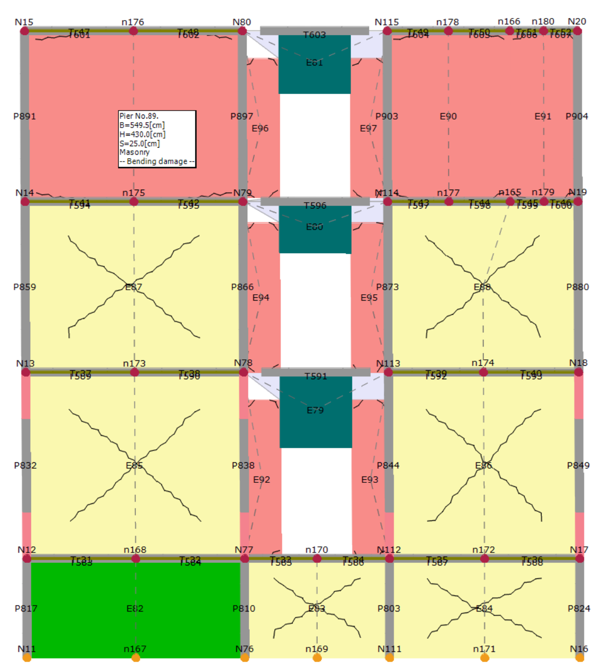
No	Seism dir.	Seismic load	α NC	α SD	α DL	d_m/d_t NC	Capacity curves
23	-Y	Static forces	1.070	1.018	0.894	1.945	Capacity curve no.23 / analysis no.23 / -Y dir.



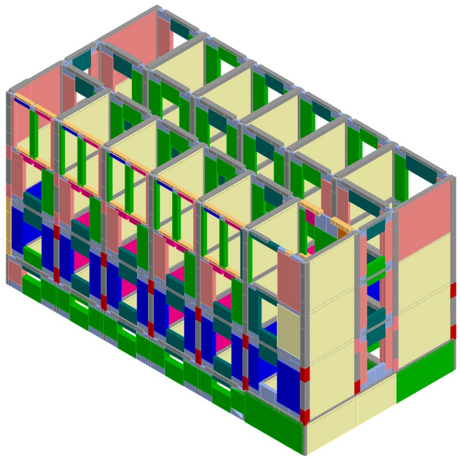


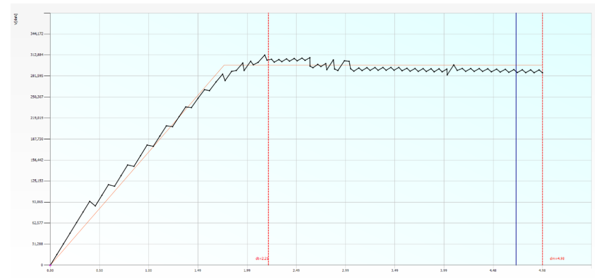
Analysis-23/Mechanism no.5 /West side façade masonry /seismic dir.-Y/seismic load =static	Analysis-23/Mechanism no.11 /East side façade masonry /seismic dir.-Y/seismic load =static





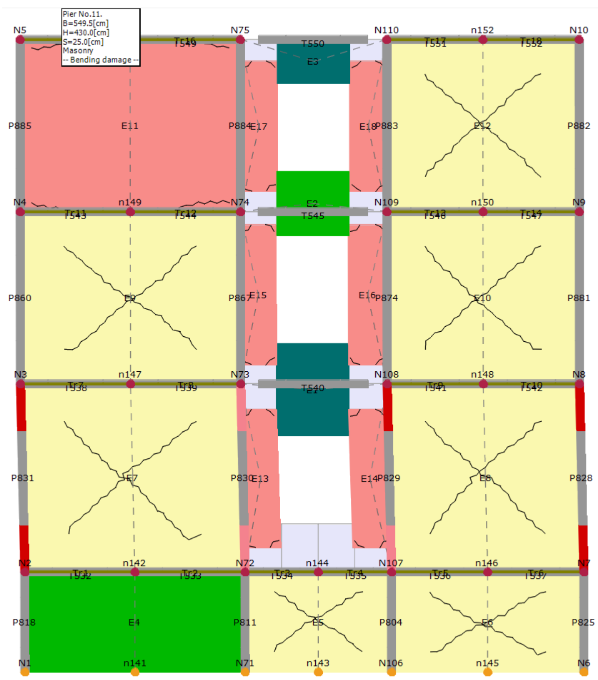
No	Seism dir.	Seismic load	α NC	α SD	α DL	d_m/d_t NC	Capacity curves
24	-Y	Static forces	1.047	0.991	0.985	2.253	Capacity curve no.24 / analysis no.24 / -Y dir.

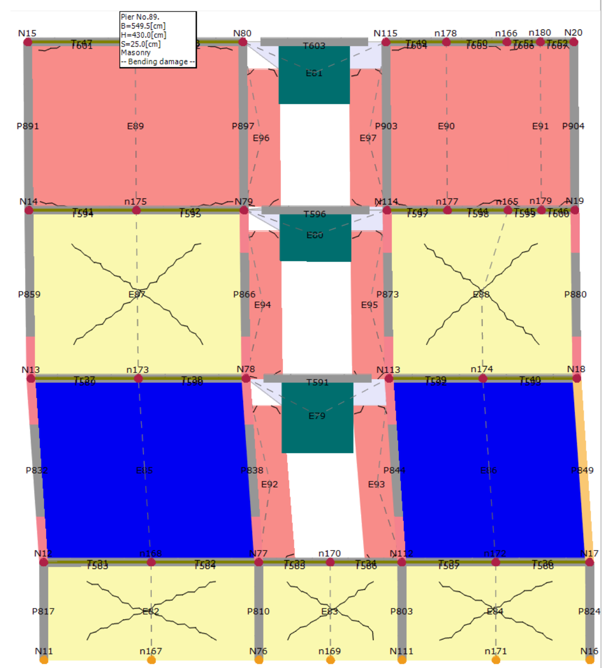




Analysis-24/Mechanism no.5 /West side façade masonry /seismic dir.-Y/seismic load =static

Analysis-24/Mechanism no.11 /East side façade masonry /seismic dir.-Y/seismic load =static





According to the 3Muri software protocol, 24 analyzes were performed, in the framework of nonlinear pushover simulations. The analyzes were performed in seismic combinations according to eurocode-8 and in two general directions ± X and ± Y. From the initial table generated in the program, the structure shows a satisfactory performance in the global aspect, but several steps have been identified where the structure shows problems in reaction, also masonry parts with pronounced fragility against these actions, which are part of the discussion for further investigation. . We can distinguish the analysis no.11 in the + X direction where the structure shows weakness mainly in the masonry of longitudinal facades, while the analysis no.23 / 24 in the -Y direction where the problems are localized mainly in the masonry of the transverse facades.

6.2.8.2 Efficient intervention strategy, aimed at increasing the seismic performance

After the situation presented above by identifying the most fragile areas of the masonry, at this stage it is continued with an retrofitting strategy. Also in this case the proposals are conceived in such a way that they do not affect the aesthetics of the building facades, but at the same time significantly increase the performance of the structure. The FRCM reinforcement is recommended, where this reinforcing layer is added to the panel in its inner part. The selected material for simulations is "Mapegrid G220, Mapei" with the following data:

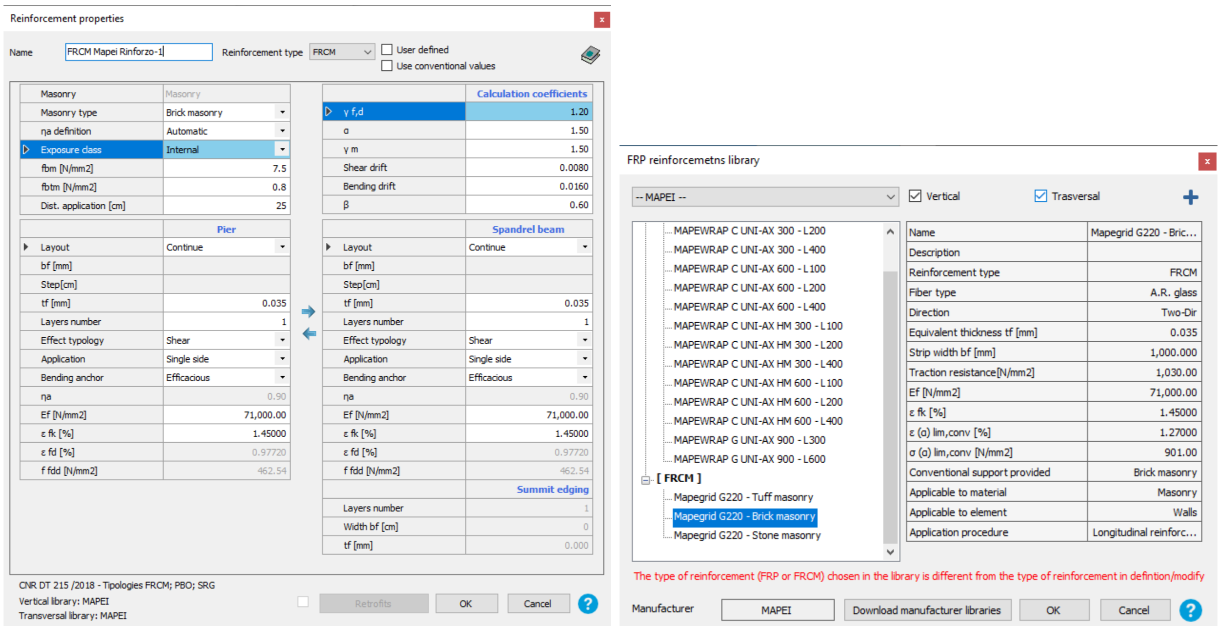


Figure 135. Physico-mechanical parameters and characteristics of the recommended reinforcement layer "Mapegrid g220", according to the database used in 3Muri software libraries

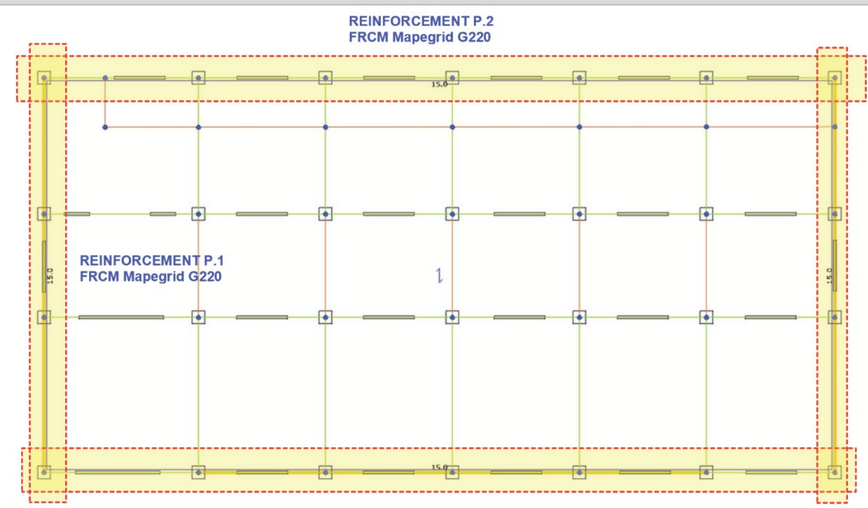
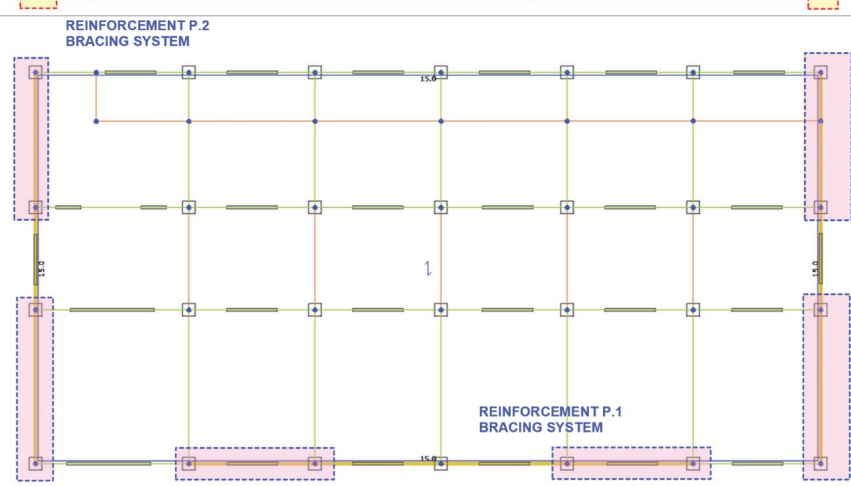
Table 21. Technical data according to Mapei quality standard (Mapei, 2019)

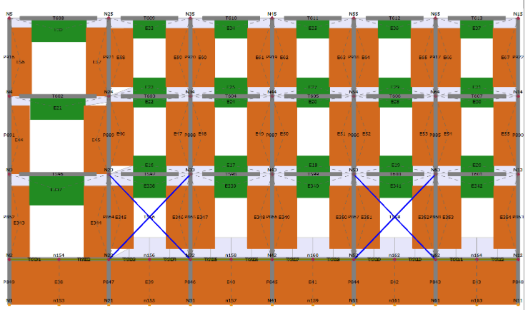
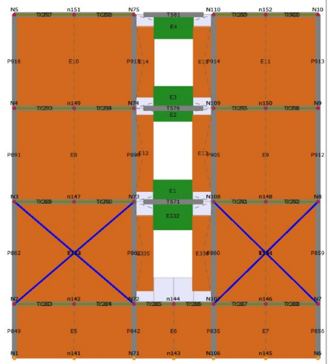
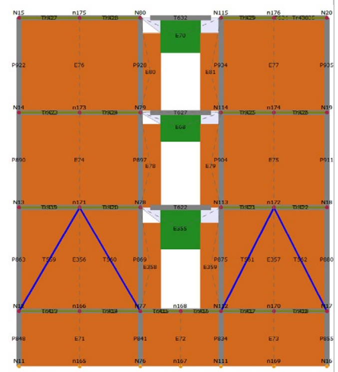
Technical data	
Tipo di fibra:	fibre di vetro A.R.
Contenuto di ossido di zirconio (ZrO_2) (%):	17
Grammatura (g/m2):	225
Dimensione delle maglie (mm):	25 x 25
Application data	
Resistenza a trazione (kN/m):	45
Modulo elastico (GPa):	72
Area resistente per unita di larghezza (mm2/m):	35,27
Spessore equivalente di tessuto secco (mm):	0,035
Allungamento a rottura (%):	1,8

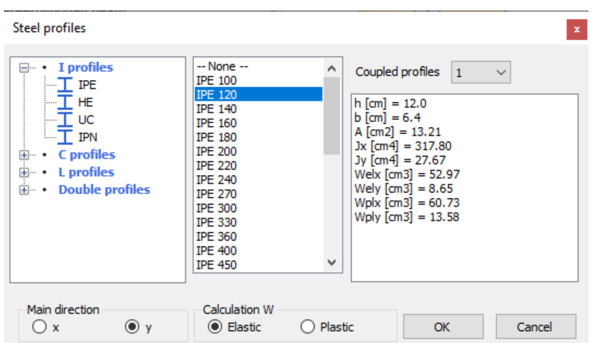
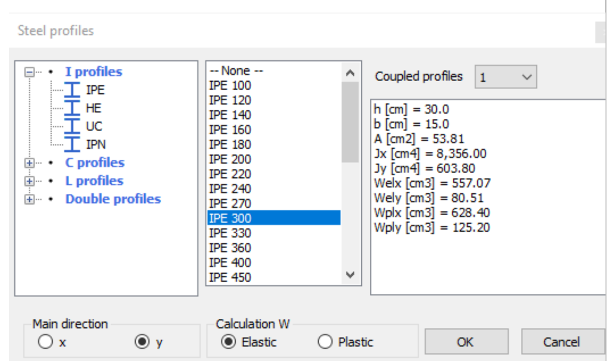
The application of reinforcement is asymmetric in this case, and is configured in such a way as to test and increase the effectiveness of the recommendations for intervention. Always with the logic of maintaining the symmetrical distribution of masses and rigidities of the structure.

Examining the most fragile areas of the masonry, the logic of the interventions is based on the reinforcement of the masonry with FRCM type Mapegrid G220. This intervention has been applied in the main facade, north direction, which corresponds to panel no.04 in the software, only on the ground floor. FRCM was also applied on the south façade from behind, corresponding to panel no.02 at ground floor level. To avoid the mechanism of collapse, seeing from the simulations that this intervention is not enough in the back facade, two pairs of steel bracing systems have been added with the data presented in table 20. Also in the side, east and west facades, corresponding to panels no.01 and 03, FRCM reinforcements and two different steel-bracing configurations were applied to avoid the possible collapse mechanism found by the investigations. The general schemes for configuration of interventions are given in the table below:

Table 22. Graphic representation of configurations in plan and height of reinforcing elements

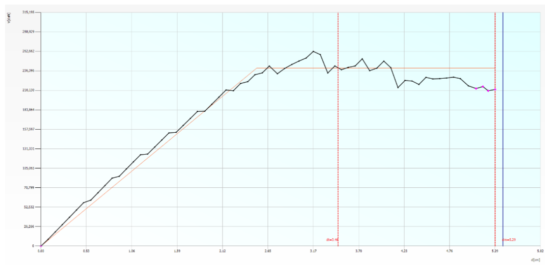
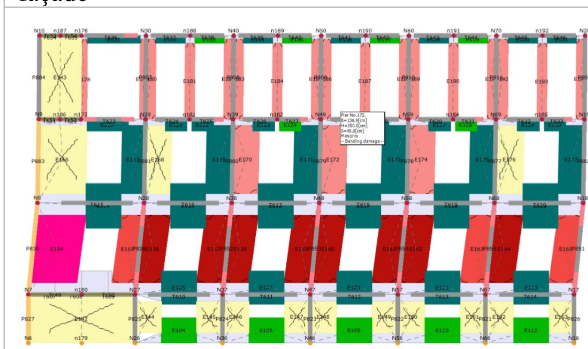
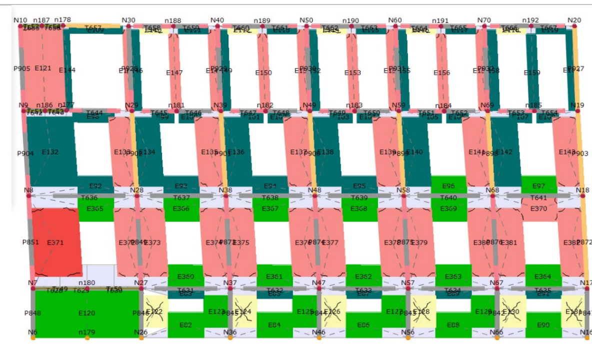
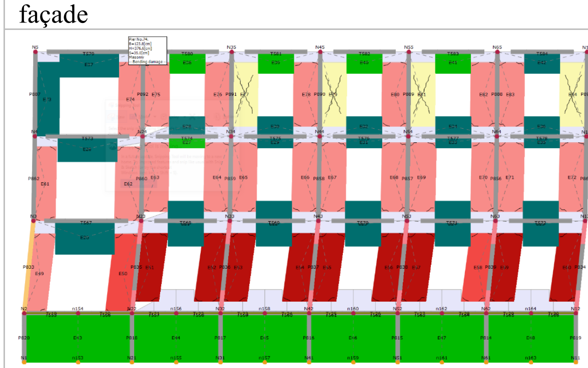
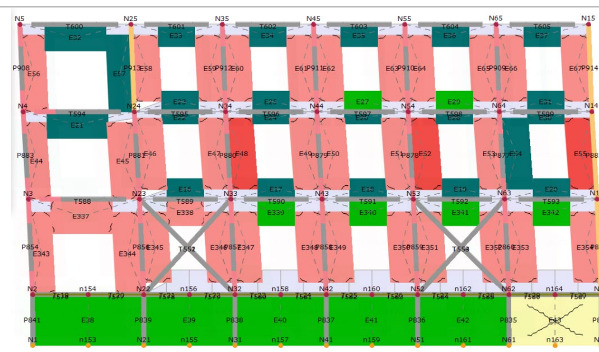
* Positioning of the panels where the intervention was applied, ** Data on their geometric configuration	
	Plan configuration and positioning of FRCM intervention
	Plan configuration and positioning of Bracing systems intervention

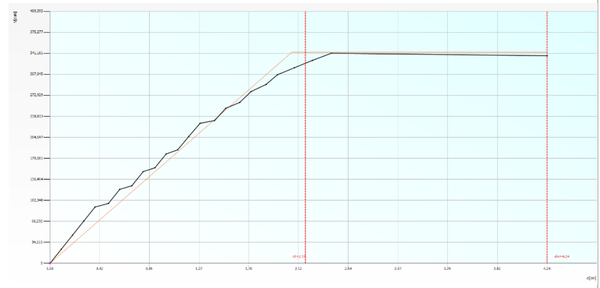
Bracing system application and configuration in panel no.02 of the back façade /south side	Bracing system application and configuration in panel no.01 of the side façade /west side	Bracing system application and configuration in panel no.03 of the side façade /east side
		

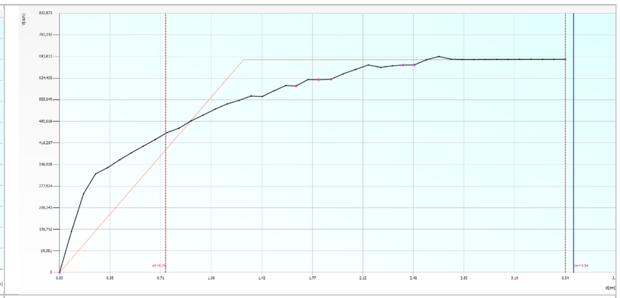
Numerical data and technical parameters of profiles, used on the southern longitudinal façade	Numerical data and technical parameters of profiles, used on side facades, east and west dir.
	

- Results obtained after numerical applications and simulations to find effective methods of reinforcement interventions

Table 23. Summary table with data obtained after reinforced structure simulations, value comparisons

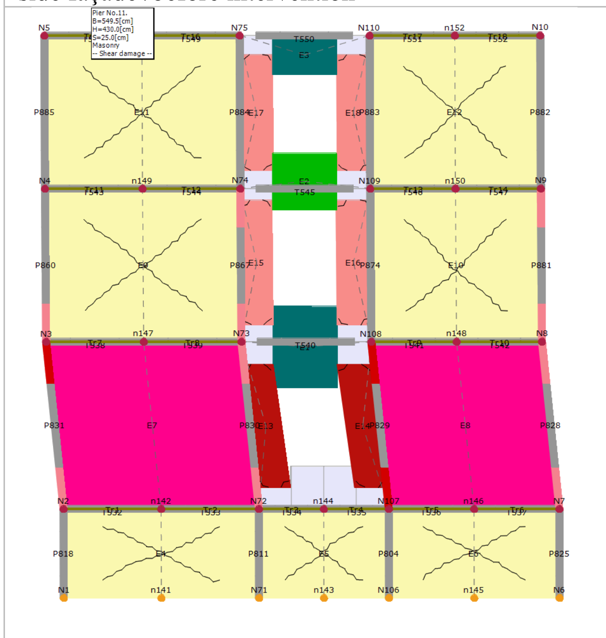
Before application Analysis no.11 +X/Static load/panel no.04, 02							**After** reinforcement application Analysis no.11 -Y/Static load/panel no.11						
No.	Seism . dir.	Seism. load	α NC	α SD	α DL	dm/dt NC	No.	Seism . dir.	Seism. load	α NC	α SD	α DL	dm/dt NC
11	+X	Static forces	1.129	1.033	0.910	1.129	**11**	+X	Static forces	2.770	2.692	1.782	3.294
													
T*=0.606s							T*=0.474s						
Panel of local mechanism model / panel.04 /main façade							Panel-04 / verified mechanism model /reinforced						
													
Panel of local mechanism model / panel.02 /back façade							Panel-02 /verified mechanism model / reinforced						
													
Before application Analysis no.23 -Y/Static load							**After** reinforcement application Analysis no.23 -Y/Static load						
No.	Seism . dir.	Seism. load	α NC	α SD	α DL	dm/dt NC	No.	Seism . dir.	Seism. load	α NC	α SD	α DL	dm/dt NC
23	-Y	Static forces	1.075	1.037	1.160	1.081	**23**	-Y	Static forces	1.741	1.671	1.671	2.842
Capacity curve							Capacity curve						

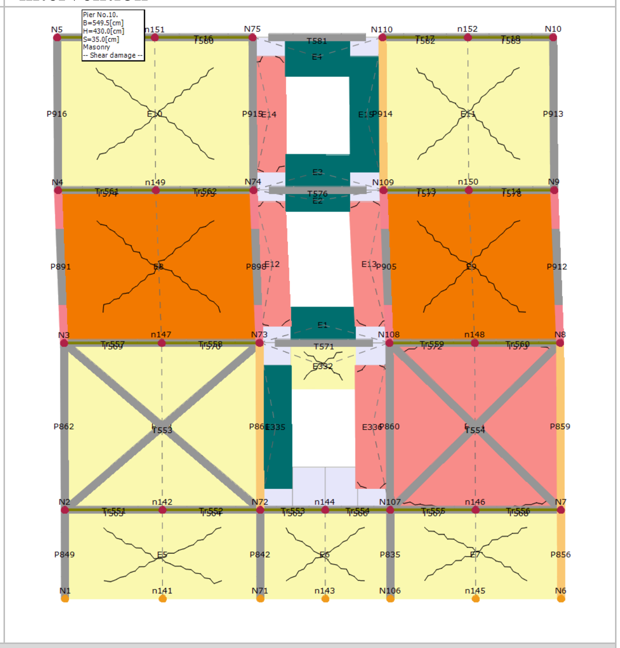




Panel of local mechanism model / panel no.01 /west side façade /before intervention

Panel verified mechanism model / panel no.01 /After intervention

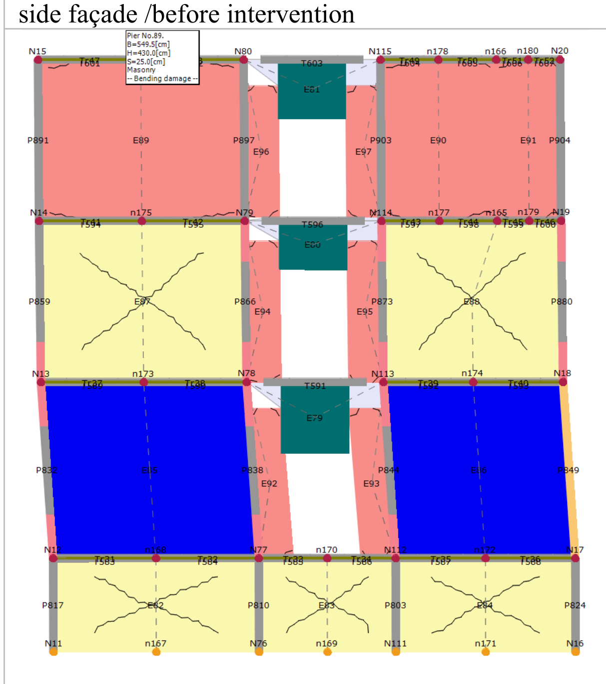


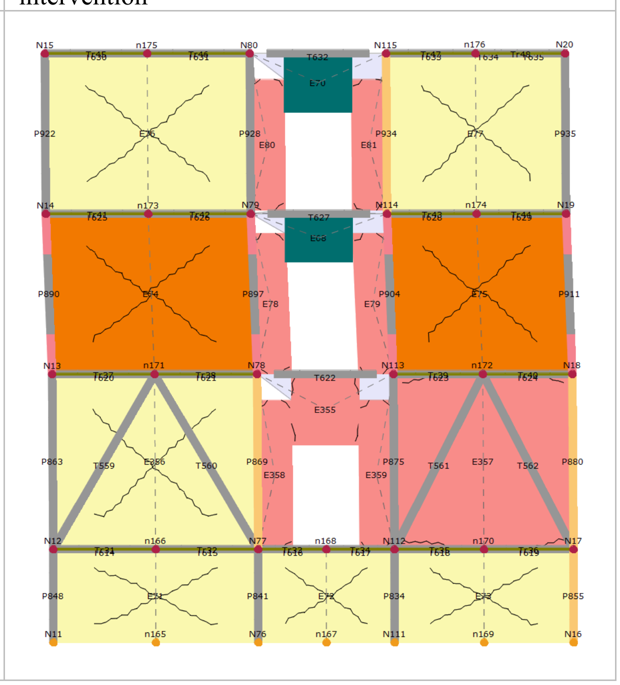


Analysis no.24

Panel of local mechanism model / panel no.03 /west side façade /before intervention

Panel verified mechanism model / panel no.03 /After intervention





6.2.9 Case II, Conclusions and recommendations

Regarding the basic parameters of the modal analysis evaluation, the periods of self-oscillations of the structure show some problems of exceeding the allowed parameters. The calculated allowable period of the structure is [T] = 0.612s while the period T_1 = 0.716s. This can be considered somewhat problematic, also considering the fact of the presence of partial torsion present in the second oscillation mode. The same phenomenon is observed even if we analyze separately from the complex, only one of the side blocks, also there is the presence of a torsion in the first two modes, although with small values this is considered problematic for a structure of such importance.

The results of seismic analysis have shown the most critical section of the building are the two joint areas between the 3 blocks, as there are differences in structure in height, although the presence of joints in the design facilitates seismic performance. In these areas, after several interventions at different times, some concentrations of stress are created. This type of stress does not create problems of structural stability but must be taken into account in the local plan, of the vulnerability of the infills.

In this case study after the analysis performed, it was shown that referring to the seismic demand according to KTP-89/2 still in force in Albania, the expected damages range from moderate to large damages, referring to the seismic performance levels. While referring to the seismic demand based on studies conducted after the 1990s (specifically seismic demands referring to Eurocode-8), RC moment frame with the presence of infills masonry built in the late 1940s have a very high probability of suffering very serious damage and occurring in "collapse threshold" in certain scenarios. Compared to other analogous researches for similar structures in the literature, a great similarity is found in the estimation of the moment of destruction of the structure, but in relation to other levels of vulnerability the changes are large, this is attributed to changes in the ways of indexation of vulnerability levels.

The displacements show a good reaction of the structure in the longitudinal plane oriented according to east-west and a slightly more fragile reaction in the transverse direction oriented north-south. The occurrence of drifts in significant values in relation to the seismic action in the y-direction can also be considered for later studies or structural retrofitting strategies.

In conclusion of this case we can say that the capacity spectrum method that is used, offers a practical and well-balanced way between the time spent and the accuracy provided. Considering more factors that affect the capacity of the structure as well as the wider scope of the study even for structures with specific configuration characteristics, are the goals of the development of this study beyond this topic. Also increase the accuracy of determining the capacity spectrum, but also indexing through simulation of damage to existing structures with the help of programs that implement BIM and more.

6.2.9.1 Interpretations related to Nonlinear static analysis "Pushover"

Static non-linear analysis, Pushover is one of the approximate method used to evaluate the existing and old structures. The methodology is used to evaluate in depth as well as in performance based seismic design. Nonlinear static analysis can be considered an improvement compared with the classic seismic or modal analysis since it allows inelastic behavior of the structure and elements. The method is simple to implement especially with rc-frames or rc-frames + infills, also provides more information's about strength, target displacements, performance point of existing structures, collapse mechanisms and scenarios, also the ductility of the structure as well as the seismic demand.

For the evaluation of seismic performance, one of the basic parameters is the "Target displacement", which in this case is theoretically analyzed in the y-direction, described as the most fragile position of the structure (referring to the longitudinal rectangular geometric configuration). So, dt* identified according to the Y-direction, respectively according to the Push-Y loading model, in numerical value is “dt*=0.0119m”, obtained graphically from the point intersection of the period T* with the bi-linearized capacity curve, which is converted according to the ADRS format[34].

From the investigations in the global aspect of the structure for possible scenarios of collapse mechanisms, we notice that one of them is the creation of plastic hinges at the upper ends of the first floor columns nodes, near the G-axis in the eastern position of the block near the seismic joint. At this level is the largest floor height 7.4m referring to the levels of the structure. Theoretically the high floor height versus 2 other floors with reduced height, favors this phenomenon and can activates the soft-story phenomenon, however in this case we must be conservative in achieving such conclusions, as the masonry infills greatly affects the performance of the frame and increases the factors resistant to this phenomenon.

However, from the analysis, interpreting the scenarios of the collapse mechanism, we are able to identify and locate the most fragile and weak part of the RC structure, especially the 4 columns where the plastic hinges are created. Exactly, this is the area where we can conceive the beginning of a possible scenario of the collapse mechanism of the building, in the future. Also in the given proposals the focus of the retrofit strategy should include in a special way the g-axis and this group of columns. For giving proposals for interventions and consolidation approaches we already have a clearer set of data related to the analyzes performed above.

Regarding the nonlinear verification procedure, such kind of checks seem to be more related with reality aspects if done rigorously with the finite elements model. This model allows to take into account the effects of the mutual link between elements, materials layers and nonlinearity, the mutual collaboration between walls of the frame, and redistribution of stresses and strains in a way easily guessed that predicts and calculates real practical consistency of the building.

[34] ADRS - Acceleration-Displacement Response Spectrum, format used for converting diagrams

6.2.9.2 Proposals for local interventions, in terms of seismic readjustment of the structure

Let's analyse the problems noticed especially in the nonlinear analysis, where are identified a group of columns (in the axes "g-1, g-2, g-3 and g-4", at the level of the first floor) in which plastic hinges are created (this was noticed between step-17 to step-20 push-Y). This makes us carefully review their performance in terms of interaction with the wall. Since the filling masonry in this case is massive with a considerable thickness, it also has a structural role, then one of the recommendations for the best retrofit strategy is to separate the RC frame from masonry panels. A recommended detail is shown in figure 138.

To move on to the recommendations, a review was conducted on the relevant investigations into this issue. The study of Tarque et al is reviewed, and in figure.136. is shown the mechanism of collapse of the masonry panel as infills within the RC frame (Tarque & Leandro, 2015), taken from study and graphically shown the results of laboratory tests for the respective models of panels, simulated. Crack pattern between masonry and infills (also, positive and negative stress distribution) are also shown, according to the third loading cycle. Regarding this analysis of mechanisms we must be clear with the typologies of local damages, in the possible scenarios of the case study. So, based on these theoretical and practical issues the following interventions aimed at seismic readjustment can be recommended, mainly in the local plan of the structure.

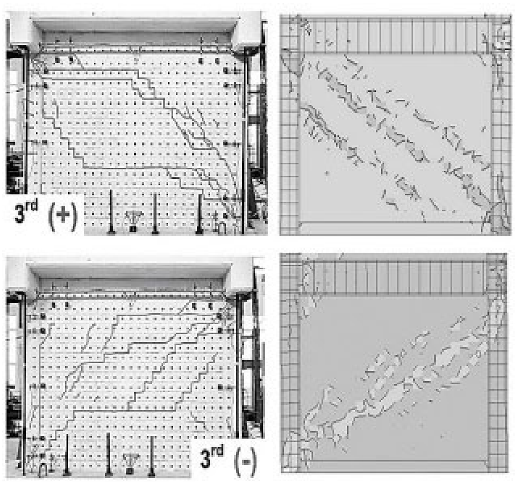


Figure 136. Crack patterns of the masonry-infilled frame test specimen and crack widths in the model during the third cycle of loading (positive and negative) (Tarque & Leandro, 2015)

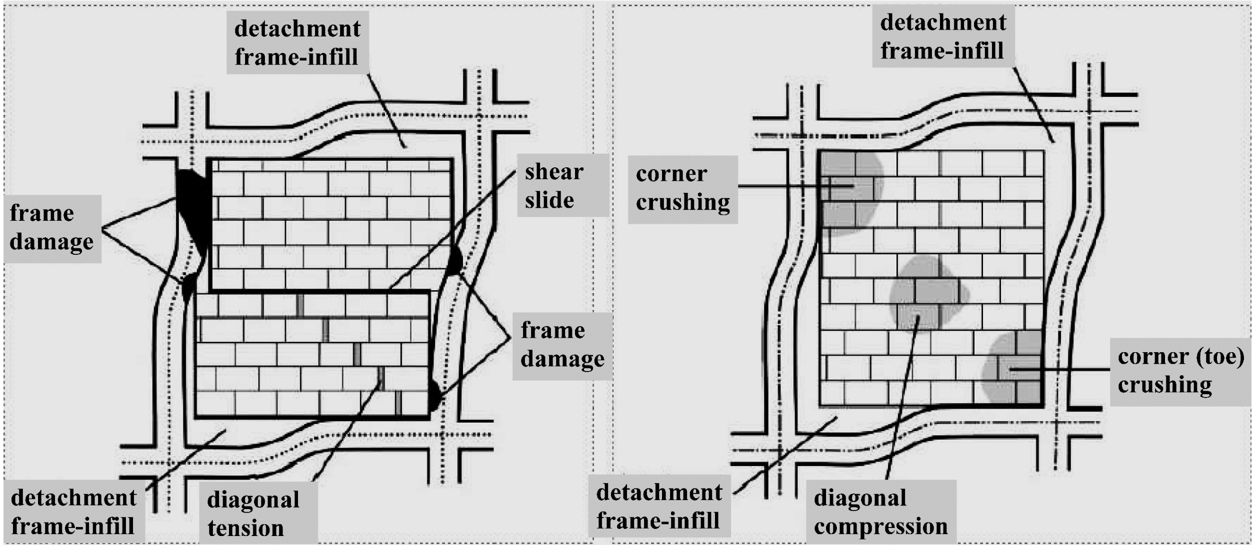


Figure 137. two typical local failure scenarios for RC-frames + infills, (first) RC-frame failure mode, shear + sliding including diagonal cracks; (second) corner crushing + diagonal compression failure mode (Asteris & Sophianopoulos, Mathematical Macromodeling of Infilled Frames: State of the Art, 2011)

To maintain their in-plane load-bearing capacity, the infills walls should not collapse due to forces out of planes. The "out of plan" collapse mechanism is a condition of the "live safety" performance level. Most design codes have long avoided considering the structural contribution of infill walls, mainly as a result of: (a) the problem being overlooked because it is not fully understood, due to the high number of variables and accumulated uncertainties; (b) the behavior of the infills masonry and its combination and co-operation with the RC-frame depends predominantly on the geometry of the frame and the type of infills wall, which necessarily reacts significantly differently in different seismic locations, with different seismic intensities. (Tarque & Leandro, 2015)

Five categories of in-plane local-failure mode referring to Asteris theory, are identified and summarized as follows: (a) Frame mechanism, consisting in the formation of plastic hinges in the beams and columns near the joints; (b) sliding shear mechanism, the infills panel experiences horizontal sliding through multiple joints; (c) diagonal cracking mechanism, a diffuse cracking along the wall panel compressed in diagonal way. It theoretically presents a diagonal pattern along the mortar joints; (d) diagonal compression mechanism, crushing of the panel geometric center. This mechanism usually occurs in slender infills type, placed eccentrically according to the axis of the RC frame, combined by out-of-plane deformations; (e) corner crushing mechanism, consists of crushing in an overloaded corner part of the infill masonry related to a biaxial compression state. This occurs in that cases when the structure has a weak infill panel linked by strong frame. (Tarque & Leandro, 2015) All of these local failure mechanisms, which were briefly summarized above, are graphically shown in figure.136.

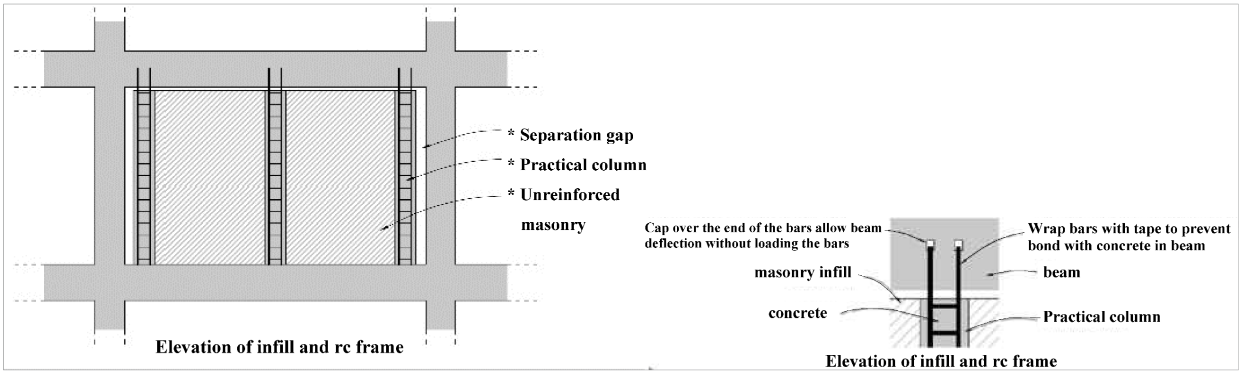


Figure 138. Suggested "masonry infill-frame" separation detail (Hollings 1981); taken from the paper (Charleson & Vesho, 2020)

After theoretically summarizing all the local mechanisms of reactions between rc-frame and infills, also after finding the results of the simulations we can analyze this intervention. This detail prevents the "infills panels" from creating a diagonal compression area "pier element", also experiencing diagonal tension area "tie element". These areas with high stress concentrations would inevitably lead to residual deformations in the wall panels, converted into significant cracks and fractures, always when unfavorable situations with simulations of strong seismic events.

Columns support and limit the infill panels work against side lateral loads (shear forces). However, this old solution is not efficient. The presence of the masonry stiffens and strengthens the beam in the same time, also, prevents normal length plastic hinges forming at beam ends during an strong earthquake shaking. Instead of distributed cracking along beams up to twice their depths, one considerable wide crack shape will form at column faces, greatly limiting the ductility capacity of the hinges at the nodes (Charleson & Vesho, 2020).

In another scenario we must emphasize the reverse case when the wall panel turns into a problem for rc-frame, emphasizing that the two elements have different behavior and performance against seismic events. The wall absorbs large shear forces and performs rigidly, while the frame moment has flexible reaction. The rigid behavior of the wall and the confrontation with the significant displacements of the frames cause collisions and damages of the frame joints at the meeting points. Solid wall-frame bonding techniques have proved problematic in many analogous theoretical cases, but also appear troubling in the results of this study.

Proposals on local interventions

After browsing the relevant literature, related to the recommendations of retrofit strategies for improving the seismic performance of masonry, will be summarized some general suggestions for improving out-of-plane performance, as below:

- strengthening the masonry using "*reinforced concrete overlays*";
- strengthening the masonry using "*fibre reinforced polymer* (FRP)", especially carbon fibber's strips (CFRP);
- overlays or near surface mounted F.R.P. strips (should be noted that FRP strips will be required on both sides, according the local failure mechanisms evidenced by simulations);
- strengthening the masonry using "*engineered cementitious composite* (ECC)" shotcrete overlays;
- removing or replacement the infill wall, when required as appropriate (in cases when retrofitting of the frame will be performed; or in cases when the wall causes serious problems to the frame, in this case it is recommended to replace the wall with a resized/redesigned panel according to the simulated model ne software).

Suggestions are also made to improve in-plane performance that involve strengthening the infill, but also include those already mentioned above. These suggestions should be done and implemented very carefully, accompanied by a detailed project, done after many simulations (before and after the intervention), to avoid damage to the primary reinforced concrete frame members of the case study.

6.2.8.1 Conclusions regarding the analysis and investigations applied in 3Muri software, recommendations for possible effective interventions

The next step is the analysis of seismic vulnerability performed with 3Muri software, checking, as a first and target step, that the value of activation of local mechanisms is not achieved (in every investigation performed); then linking it to the assessment of the overall behaviour of the structure, dealt with in chapter 6.2.7, by performing a check and parameter comparisons. The method was based on pushover nonlinear analysis results obtained on the basis of "3Muri macro-element models", which uses equivalent models with a schematic of equivalent frames. From the engineering experience of use, it seems that it is quite suitable for the description of this type of structures due to the possibility of characterizing seismic belts, rigid floor slabs and giving the possibility of masonry configurations in the presence of columns.

Even with this model, after performing 24 nonlinear pushover analysis, a table with detailed data is drawn which are found in paragraph 6.2.8.1 of this chapter. The results are satisfactory for this building, while from the local investigations of each step, some collapse mechanisms have been localized similar to those captured in the model in ETABs, specifically analysis no.11 + Xdir. and no.23 -Ydir. But if we compare with the model in Etabs here the masonry has higher expectations to be closer to the real model, considering all the equivalences performed by 3Muri. Another important finding is the difference in the value of the self-vibration period between the two models, where we have a lower value found in the 3Muri macro-element model versus the period verified in the ETABs model. This can be interpreted theoretically correctly in the 3Muri model, which considers masonry as a key structural element, compared to ETABs model which mainly consider masonry as infills, although it is modelled with layers with nonlinear data.

Later, the Pushover simulations in the building, represented in paragraph 6.2.8.1 has led to propose and apply two different reinforcement solutions for the masonry initially and the combined structure later. Respectively two-way steel strip reinforcement jacket, e type FRCM Mapegrid g220; the second solution combination between reinforcement with FRCM + Steel bracing system (this case was applied as it was not enough just to rehabilitate the masonry). The detailed parameters and numerical data generated in paragraph 6.2.8.2 show a significant increase in local capacity by avoiding the mechanisms of local collapse, also globally by significantly increasing the rigidity and strength of the structure.

In conclusion, in this case it was intended to provide the appropriate tools for an assessment of the global structural and local behaviour of the most fragile elements of the building, emphasizing the criticisms of automatic calculation methods and instructions.

6.3 CASE III - Analysis of "Ex. Opera Dopolavoro Albanese" University of Fine Arts today

On the west side of Mother Teresa Square was the Palace of the Albanian Opera of the Unemployed, designed by Italian architect Gherardo Bosio between 1939 and 1940. The T-shaped planimetric system suffered the composition of the large space of the theater with the stake longitudinal offices. Bosio had previously studied another typological imposition: a block in the courtyard with high porches on the façade of the square, positioning the theater space always at the back but parallel to the square. In the final version of the project, he decided to rotate the theater and create a very compact facade over the square, in order to oppose with its mass the permeability of the building architecture. At the back was highlighted the volumetric composition of the plastered facade bodies on a stone plinth, interrupted by stairs.

Figure 139. Opera Dopolavoro, elaborate facade fragment accompanied by the layout of the boulevard

The main façade had a heavy shade with its rhythmic cracks and cladding with polished travertine panels. While in the center, in harmony with the upper porches of the building, a crack opens in the facade with an entrance porch with five buildings. The articulation of mural plastic is completely absent, perhaps this is exactly the building that departs most from the language of the ministries of Skanderbeg Square. Instead of different planes of alignment of the façade, movements of clean masses are clearly preferred, not clearly hierarchically arranged, almost abstract in their serial language of cracks.

Denial of the dual-functionality of the façade in favor of a hidden depth of mass, the strong climbing behind the ground that becomes the architecture itself, the verticality of the cracks that clearly highlight the range of interiors, require a modern language "different" from the dream white of the Modern Movement. Bosio is certainly a modern in the conception of the project, belongs to the generation of integral architects, coming out of the schools of architecture, influenced by the thought of Giovannoni and Piacentini but who also look closely at the cultural revolution that is taking place was taking place. In fact, he is one of the founders of the "Tuscan group", leaving it later in 1933 due to disagreements with Giovanni Michelucci.

Gherardo Bosio, already a graduate of civil engineering, attended the High School of Architecture in Florence, but due to many professional commitments did not graduate, however in 1933 he entered the same school as an assistant in charge of drawing and composition. He is an integral architect in the practical sense of the Giovanni concept, he dealt with new architecture, restoration of cultural heritage, interior furniture, design, urban planning, without ever losing sight of the unity of design thought on buildings. Today the building has the function of a campus for the University of Fine Arts of Tirana. Over time the west side has expanded doubling the area of the building.

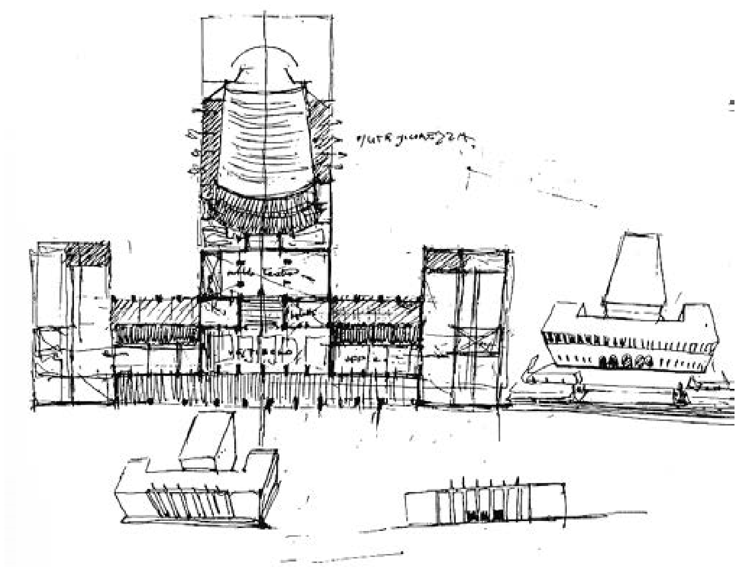


Figure 140. Sketch-concept conceived by Bosio for the design of the building (source: AQTN)

The architectural style belongs to Italian rationalism. The building consists of several blocks and in the main facade there is a main portico. The rhythm of the windows varies according to the first, second, third orders. The windows have a quadrangular frame protruding beyond the contour of the wall. The concert hall has architectural and structural values, related to its size and construction technology at that time.

6.3.1 The process of surveying, photographing and digitizing the archival project

This process just like in the previous two case studies, has been developed very carefully and in coordination and cooperation with the Cultural heritage restoration subject of Polis University. The projects received in the technical archive were analyzed, then a 3-week phase of sketching, monitoring and on-site photography took place, where the lecturers of the subject together with the students of architecture class and civil engineering class successfully completed this phase. Investigations were also carried out on reconstructions, retrofit interventions, or additions to the Building. Then the process of orthogonal photography with a drone was performed and then digitalization through the process of photogrammetry. At this stage, the orthogonal facades of the building were excavated, and carefully analyzed on each intervention. The photo album below shows fragments of this process, mainly the photographing of the object.

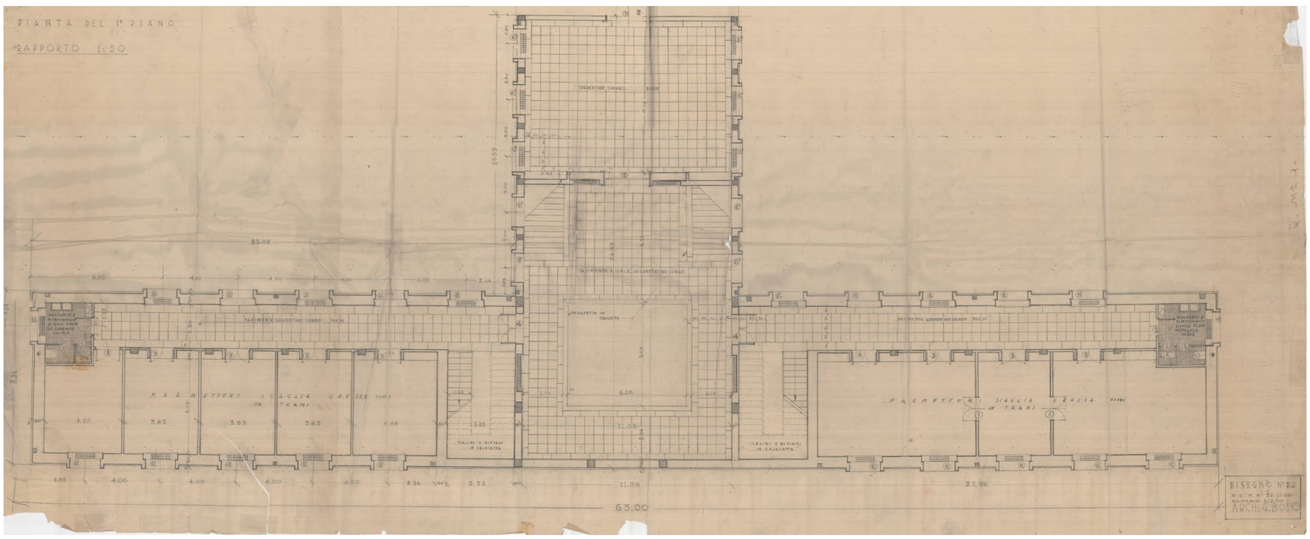


Figure 141. Main plan of the building, Bosio drawings (source: AQTN)

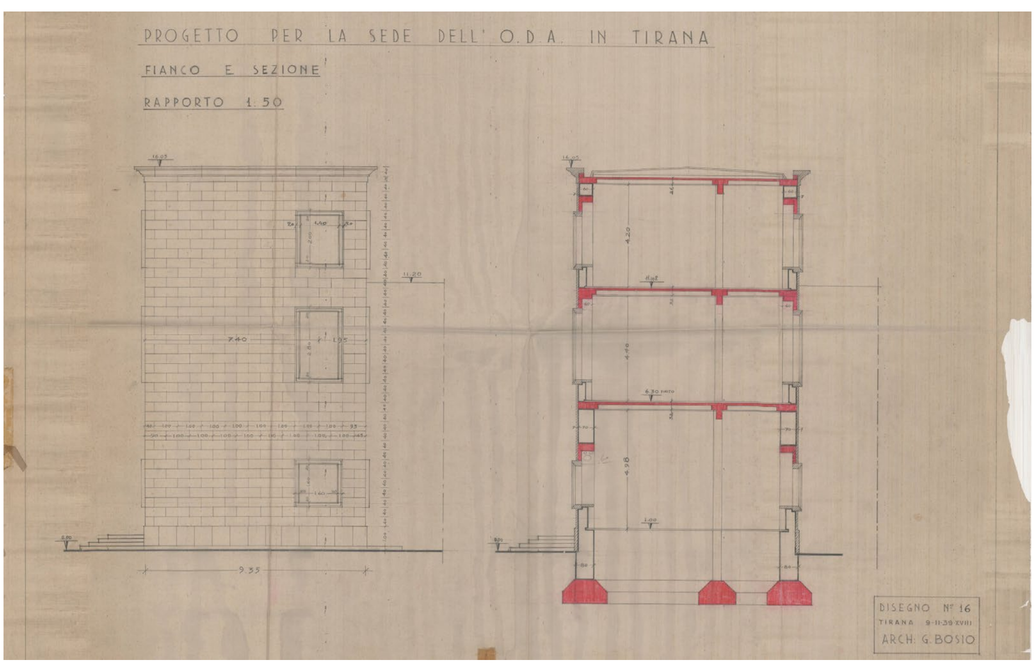


Figure 142. Side view of the building combined with main section-cut (source: AQTN)

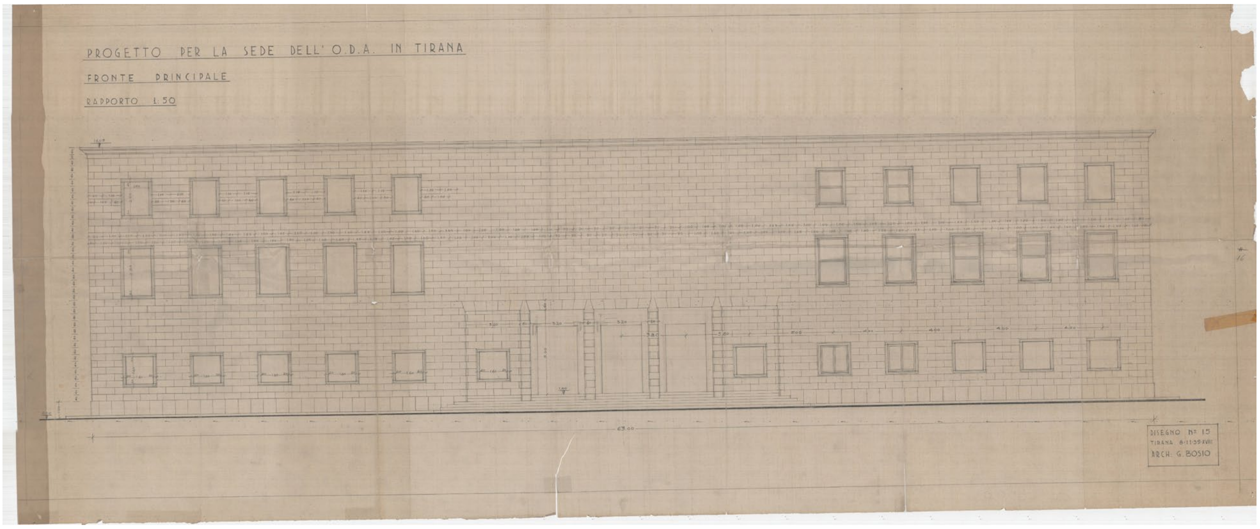


Figure 143. University of fine arts Main façade (source: AQTN)

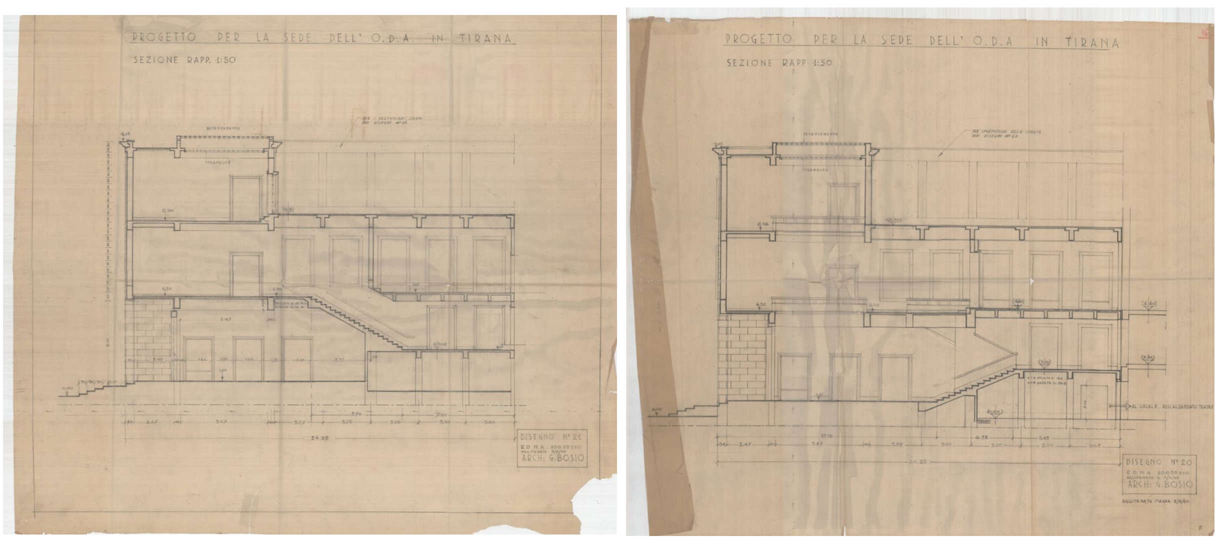


Figure 144. Two secondary section cuts of the building (source: AQTN)

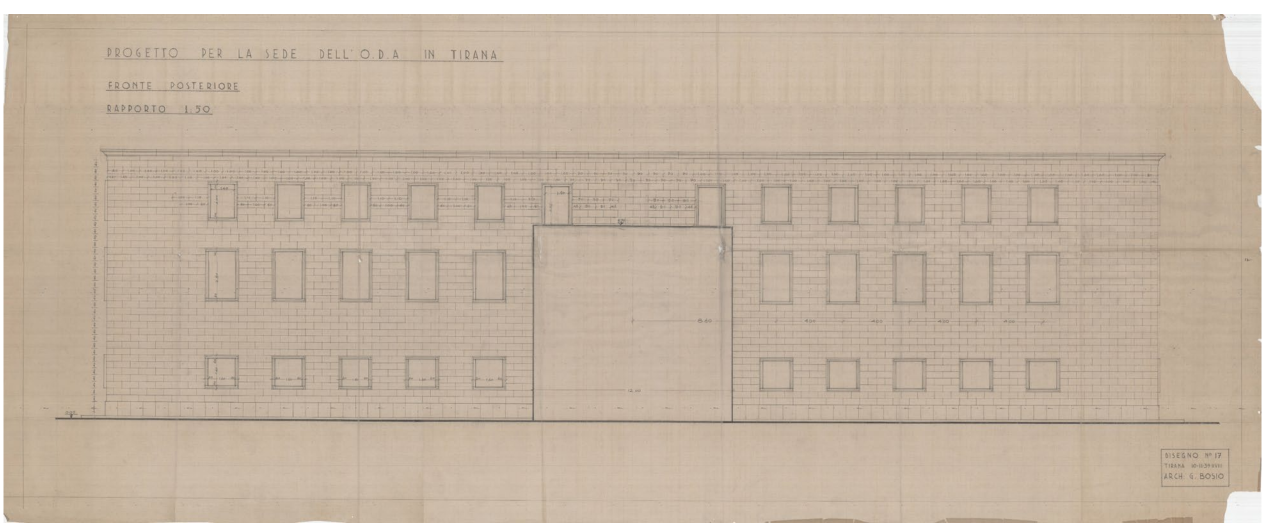


Figure 145. Back facade of the building (source: AQTN)

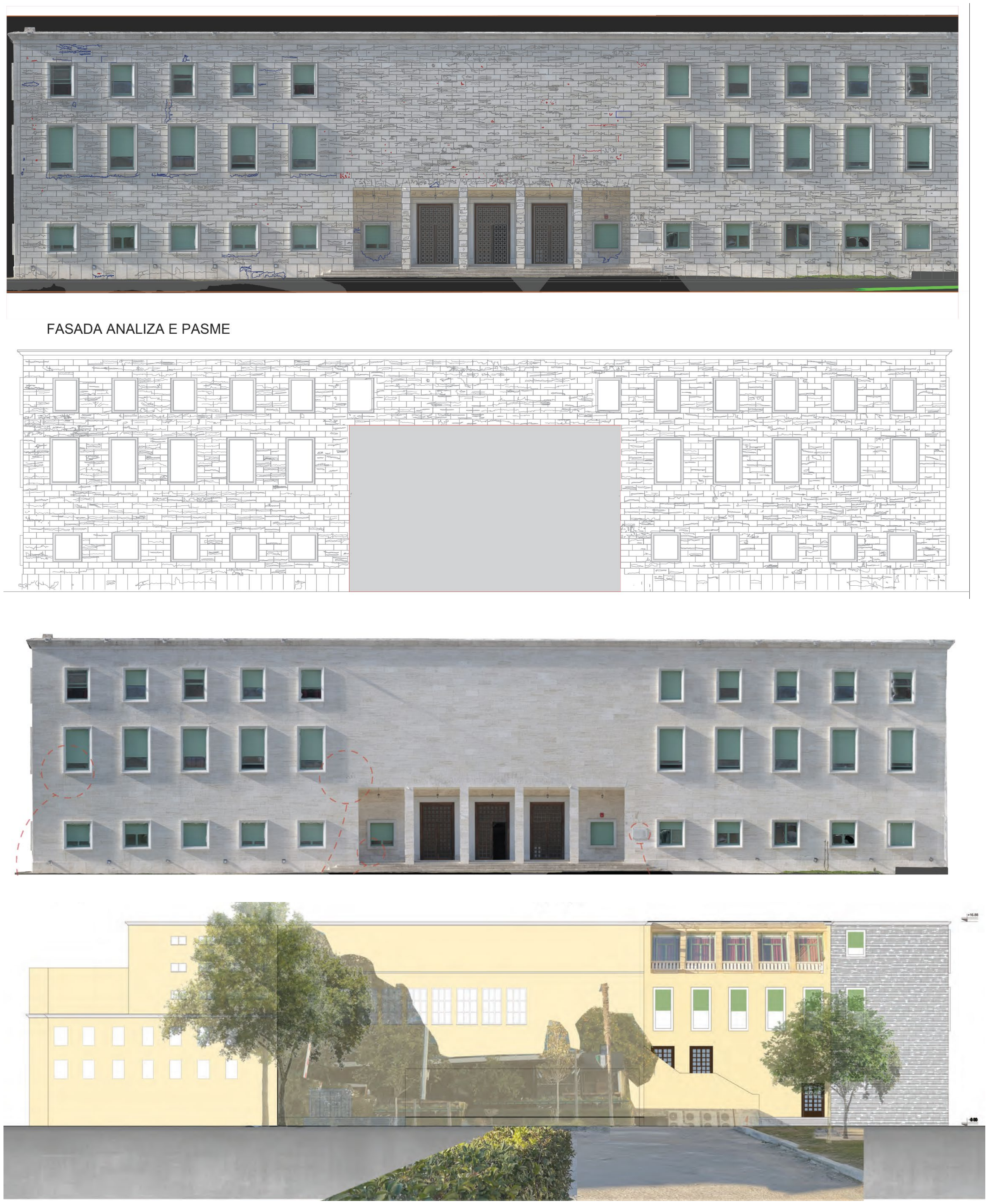


Figure 146. Survey of the main façade through forogrammetry; sketching of marble panels; and extraction of the complete model of the southern façade after filling in the missing parts

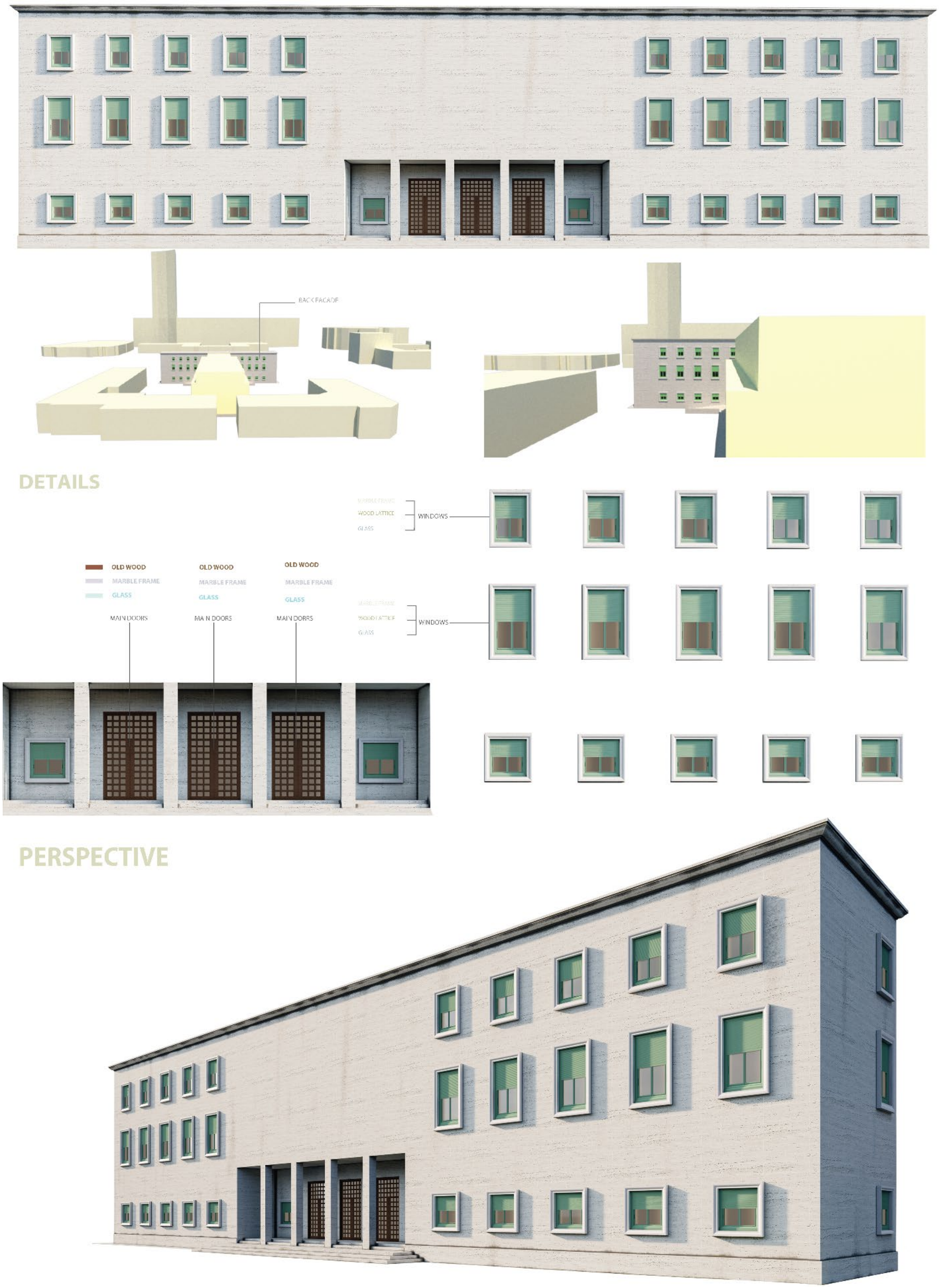


Figure 147. Architectural Survey process, facades, doors, windows and 3d-model reworked (Credits: K. Guraleci)

Figure 148. Details and photo collage of the exterior and interior of the building (Credits: H. Bendaj)

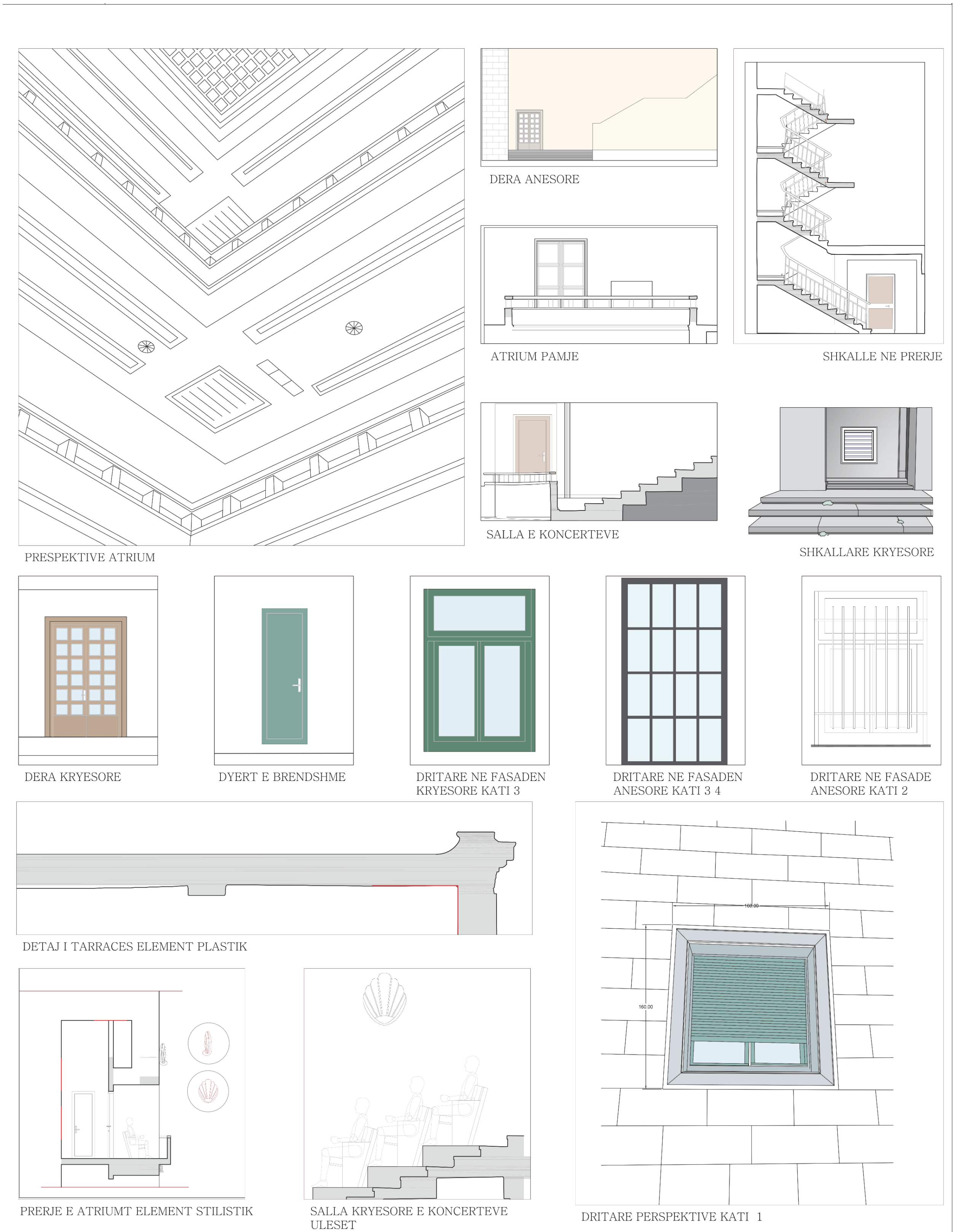


Figure 149. Architectural details extracted from the on-site survey process. Marble staircase detail, decorative door and frame detail, parapet detail, section-cut atrium detail, decorative window and frame detail, atrium sketch and interior of the building

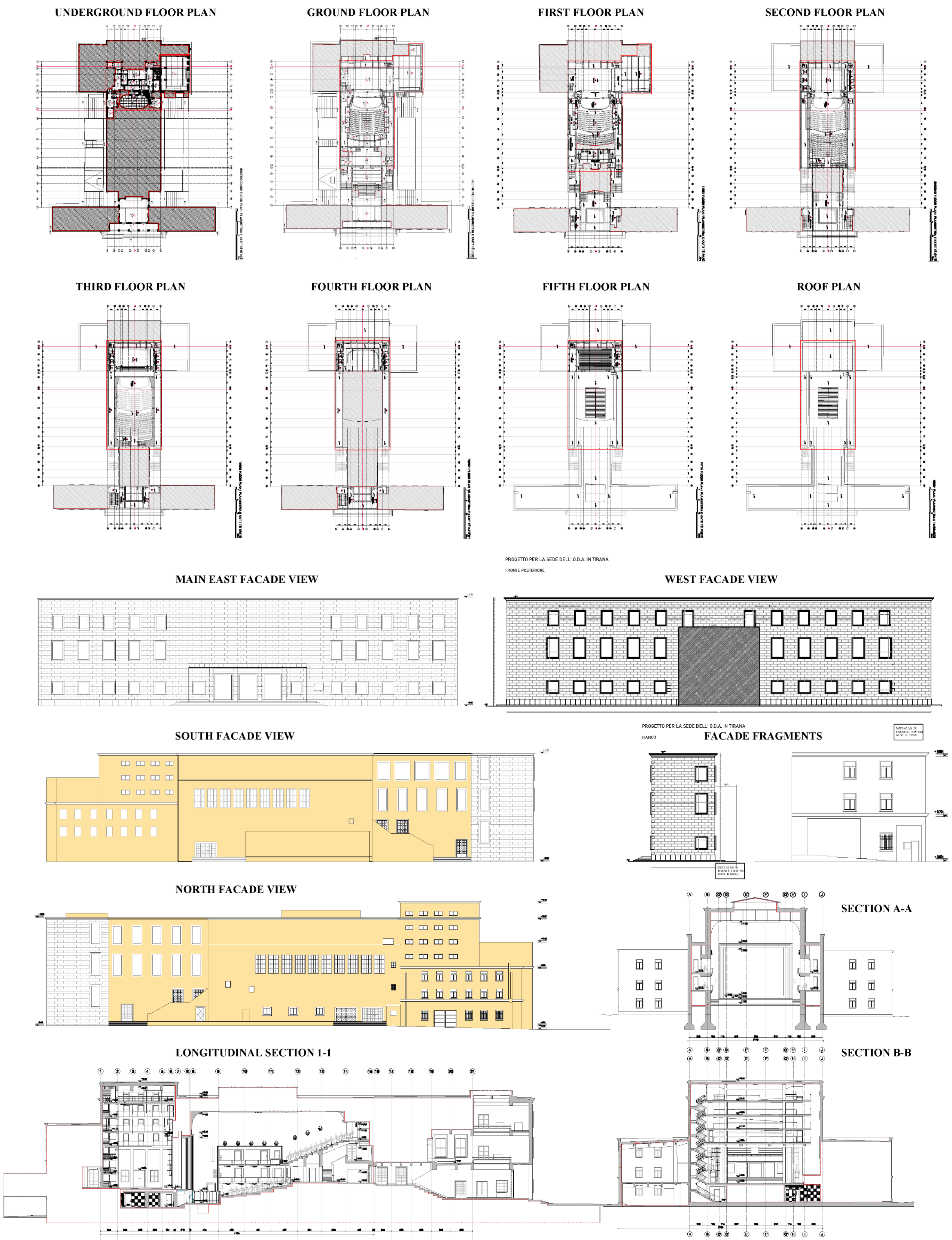
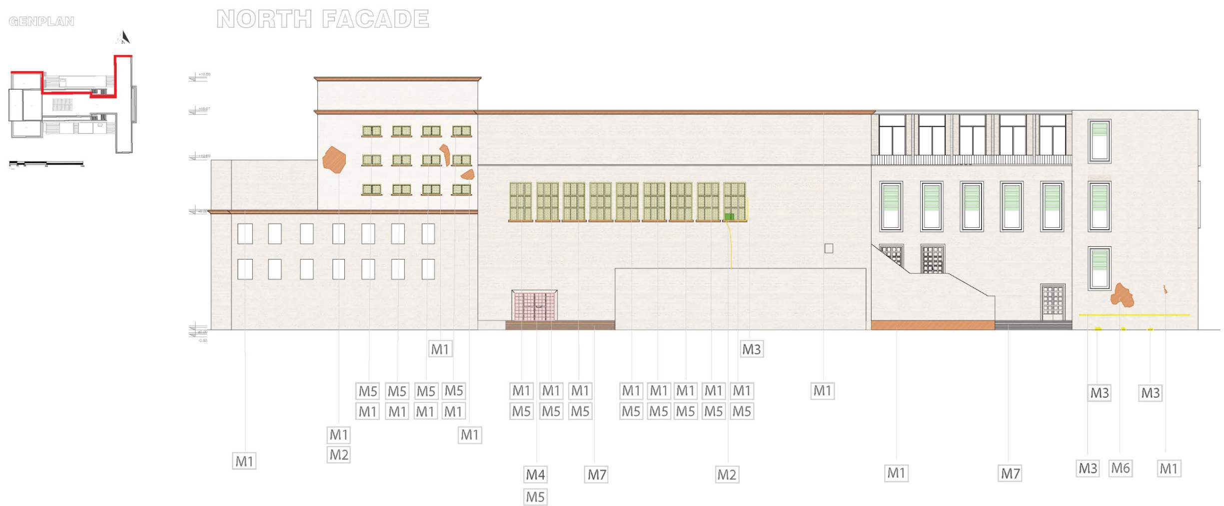


Figure 150. Architectural plans, sections & facades, re-worked in accordance with original archival drawings, part of the documentation and digitalization of archival projects (elaborated by the author)



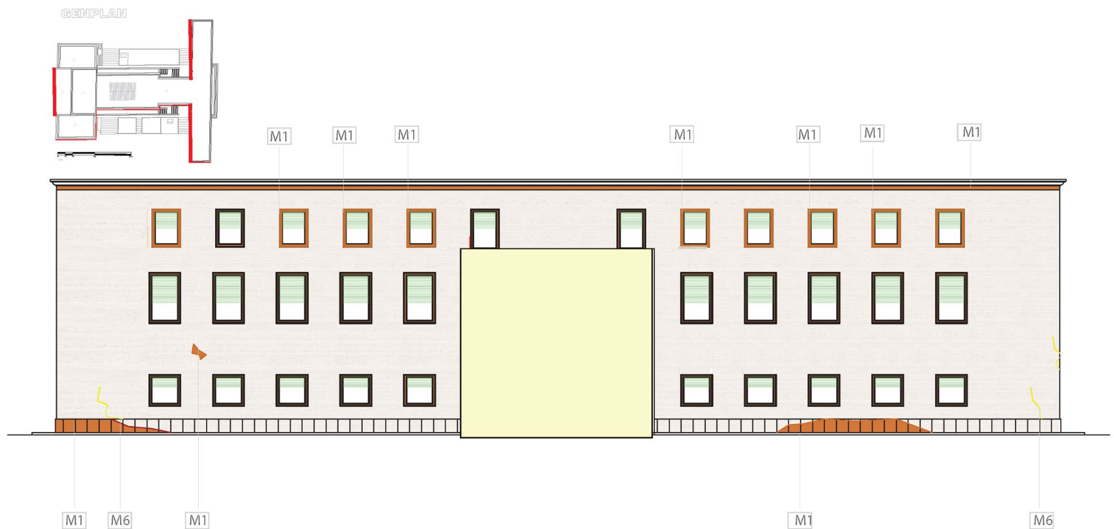
LEGEND :

• M1 MOISTURE AND IMPURITIES LAGESHTIA DHE PAPASTERTITE	• M2 PLANTS ELEMENTS IN FACADE ELEMENTE BIMESIE NE FASADE	• M3 INSTALLATIONS IN FACADE INSTALIME NE DUKJE	M4 NON ORIGINAL ELEMENTS ELEMENTE JOORIGJINAL
• M5 DEGRADIMI I ELEMENTEVE ORIGJINAL	• M6 PARASITIC VEGETATION VEGJETACION PARAZITUES	• M7 OBJECT EXTENSION ZGJERIMI I OBJEKTEVE	• M8 INTERVENTION IN TIME

	MATERIALS	CHARACTERISTICS	IMPROVEMENT
• M1	MOISTURE AND IMPURITIES LAGESHTIA DHE PAPASTERTITE	• Mold on the walls • Poor waterproofing of the foundation • Poor basement waterproofing • Drainage system breakdown • Insufficient or inadequate ventilation	• Removal of superficial deposits with soft brushes • Application of compresses with deionized water • Rinse with deionized water to remove residues
		• Wrong installation of double-glazed windows , installation of closed double-glazed windows or poor quality seals . • Optimal humidity level	
			PROTECTION
			• Spray application of organic protective products , fluorocarbon polymers which prevent the passage of gas and water vapor in the porosity.

Figure 151. Analysis panel on the north façade, investigations on a group of degradation issues, part.01 (credits: Guraleci & Vrenozi)

MASONRY ANALYSIS



LEGEND :

- MOISTURE AND IMPURITIES — • M1 LAGESHTIA DHE PAPASTERTITE
- PLANTS ELEMENTS IN FACADE — • M2 ELEMENTE BIMESIE NE FASADE
- INSTALLATIONS IN FACADE — • M3 INSTALIME NE DUKJE
- NON ORIGINAL ELEMENTS — • M4 ELEMENTE JOORIGJINAL
- • M5 DEGRADIMI I ELEMENTEVE ORIGJINAL
- PARASITIC VEGETATION — • M6 VEGJETACION PARAZITUES
- OBJECT EXTENSION — • M7 ZGJERIMI I OBJEKTEVE
- INTERVENTION IN TIME — • M8

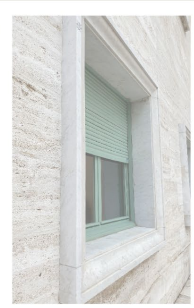
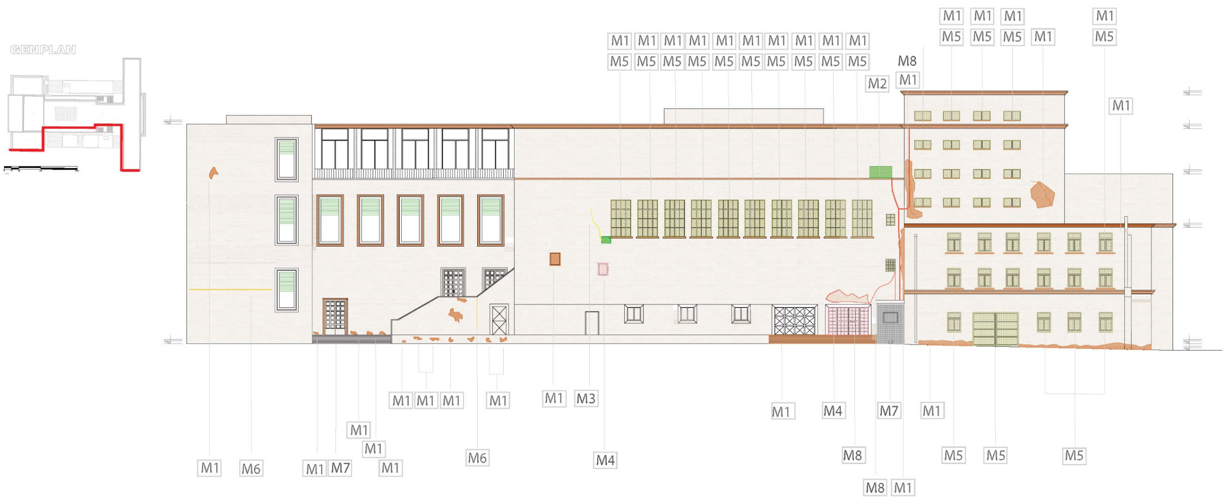
	MATERIALS	MATERIALS	MATERIALS
• M4		 	 
• M5			

Figure 152. Analysis panel on the east main façade, investigations on degradation issues, part.02

MASONRY ANALYSIS



LEGEND :

- M1 — MOISTURE AND IMPURITIES / LAGESHTIA DHE PAPASTERTITE
- M2 — PLANTS ELEMENTS IN FACADE / ELEMENTE BIMESIE NE FASADE
- M3 — INSTALLATIONS IN FACADE / INSTALIME NE DUKJE
- M4 — NON ORIGINAL ELEMENTS / ELEMENTE JOORIGJINAL
- M5 — DEGRADIMI I ELEMENTEVE ORIGJINAL
- M6 — PARASITIC VEGETATION / VEGJETACION PARAZITUES
- M7 — OBJECT EXTENSION / ZGJERIMI I OBJEKTEVE
- M8 — INTERVENTION IN TIME

	MATERIALS	CHARACTERISTICS	IMPROVEMENT
• M2	PLANTS ELEMENTS IN FACADE ELEMENTE BIMESIE NE FASADE	• Plants in facade are dirty and not aesthetic . • Create moses .	• Ceresit CT 99 destroys the mold. it destroys microorganisms, bacteria, etc. Can be applied to interior and exterior walls of the building.
			
• M3	INSTALLATIONS IN FACADE INSTALIME NE DUKJE 	• Installations in facade are not aesthetic • Deform the look in facade	• To improve the apparent mounting on facade

Figure 153. Analysis panel on the north façade, investigations on a group of degradation issues, part.03

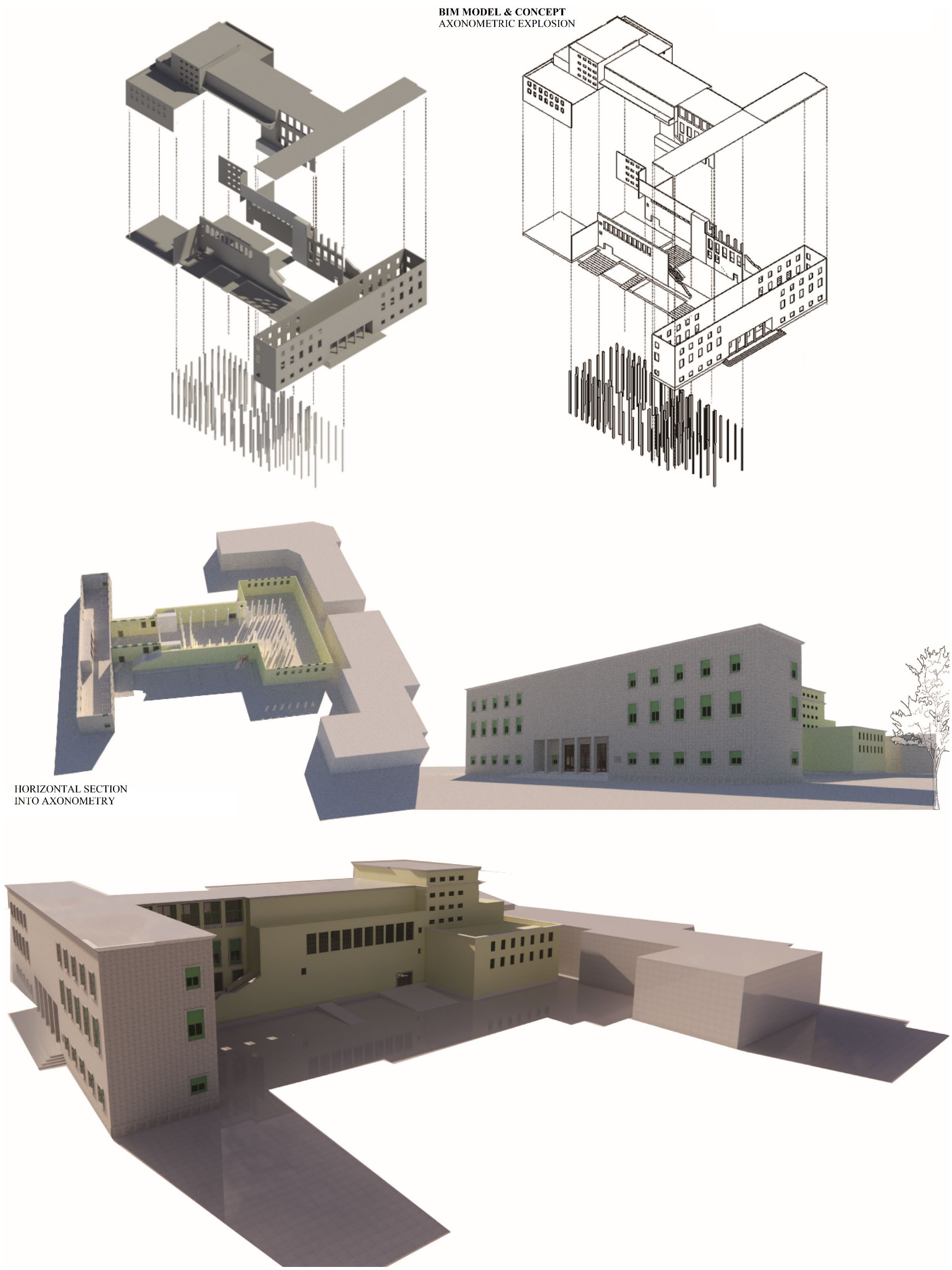


Figure 154. Theoretical concept of the BIM model for this case, through Exploded Axonometry

6.3.2 Theoretical interpretations of the structural concept of the building

The central block, in front of "Mother Teresa" square, consists of unreinforced masonry structure, with 2 different thicknesses according to 2 levels. Masonry up to level +1.10 which is considered the visible upper level of the foundation, has a thickness of 72cm. Above this level the wall thickness is uniform with a thickness of 45cm. The wall is structural and alternates with holes which serve as windows of the building. Vertical wall panels are continuous, and in engineering analysis are considered "Pier" elements, so in the equivalent model in the software have the role of vertical columns.

Wall panels over window openings are structural elements which also consider bending aspects, so in modeling they are considered "spandrels" elements. The foundation typology of this block are "massive continuous stone foundation", which follow the shape of structural walls with a thickness of 72cm. Depth of foundation is in the quota -1.00m below ground level. Building slabs are an essential element in the conception and configuration of the supporting structure. Slabs are considered by the design as solid elements of the horizontal plate type, in the model they are shell type with a thickness of 18cm. Slabs are supported on the contour of the masonry, oriented in the shortest direction and are the main element in withstanding horizontal forces, emphasizing seismic forces. They are elements with considerable rigidity for the building and play a key role in the seismic performance of the building.

After the process of surveying and analysis on the structure of the back block, where the concert hall is located, we have other interesting features. Concert hall has geometric dimensions in the plan "29.30m x 15.70m", and dimensions in height of 12.00m. The vertical retaining structure consists of the same brick wall with a thickness of 45cm, combined with concrete columns with dimensions 45x45cm. Inside the hall there are some transverse walls with a thickness of 25cm, which also serve as a rigid rib for the vertical structure. Regarding the analysis of the cover, it is realized with a "cassette slab or big waffle slab", ie a shell type sole, placed on reinforced concrete beams which are positioned in two directions. The beams of this floor are placed every 1.8m from each other. The dimensions of these beams under the slab are 45cm x 70cm. The slab is placed and fixed to the contour of the wall, and the waffle spaces are empty.

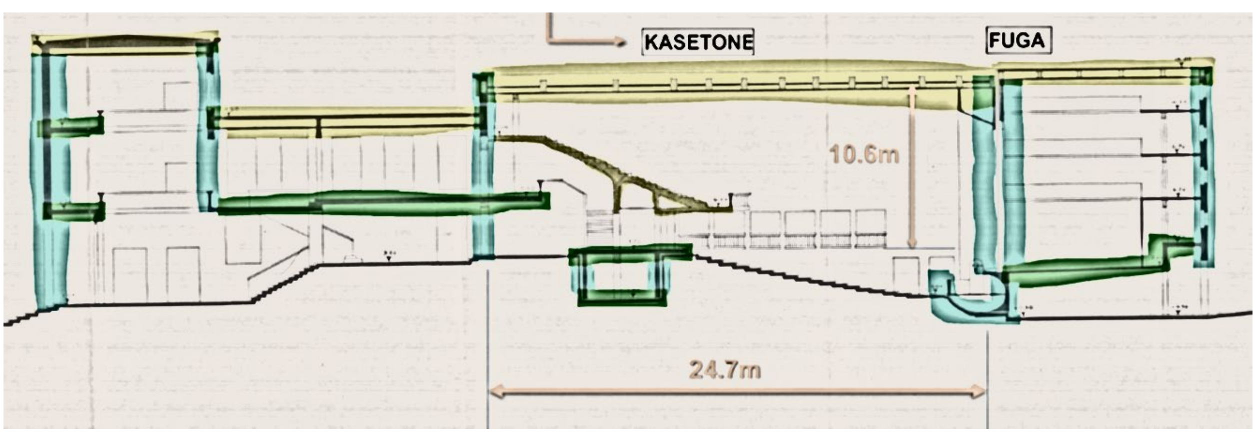


Figure 155. Re-conception and analysis of the structural project according to Bosio (souce: AQTN)

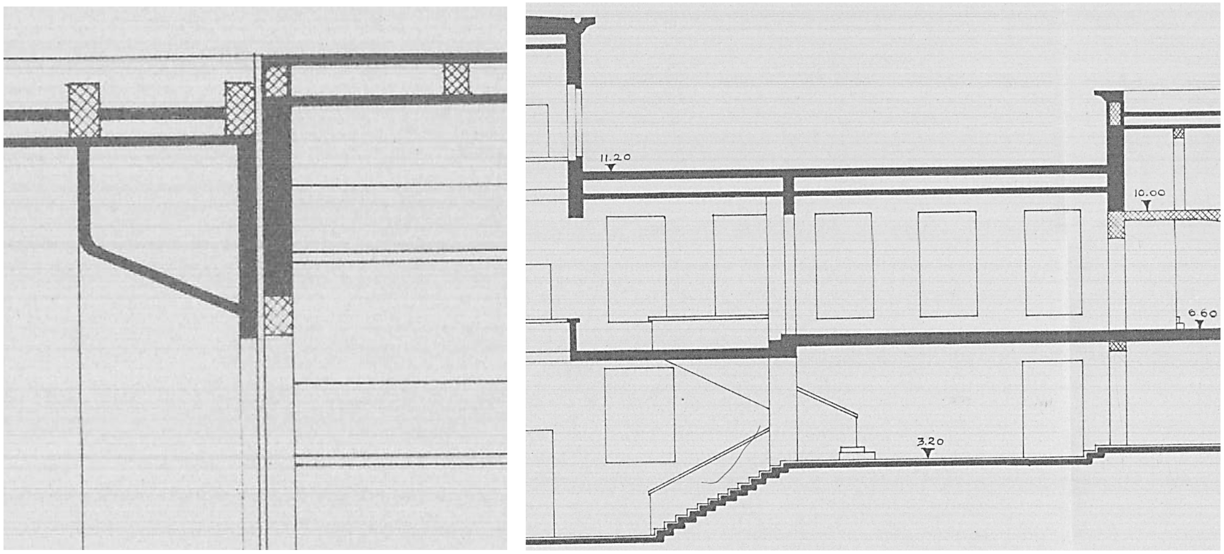


Figure 156. Seismic gap detail between two blocks of the building (left), The 2-storey part that makes the connection between the main block A and the concert hall in block B (right) (source: AQTN)

From the analysis of the project of G. Bosio, it is clearly understood his engineering logic, for dividing the blocks with a seismic joint in the middle. This is very important as it gives freedom of movement to two blocks during a seismic event, where it should be noted that block A near the square "Mother Teresa", has a horizontal longitudinal rectangular configuration, while block B of the concert hall has a vertical longitudinal configuration and normally their reactions are different during a seismic event. For further findings and interpretations are made after analysis and model simulations in the following software.

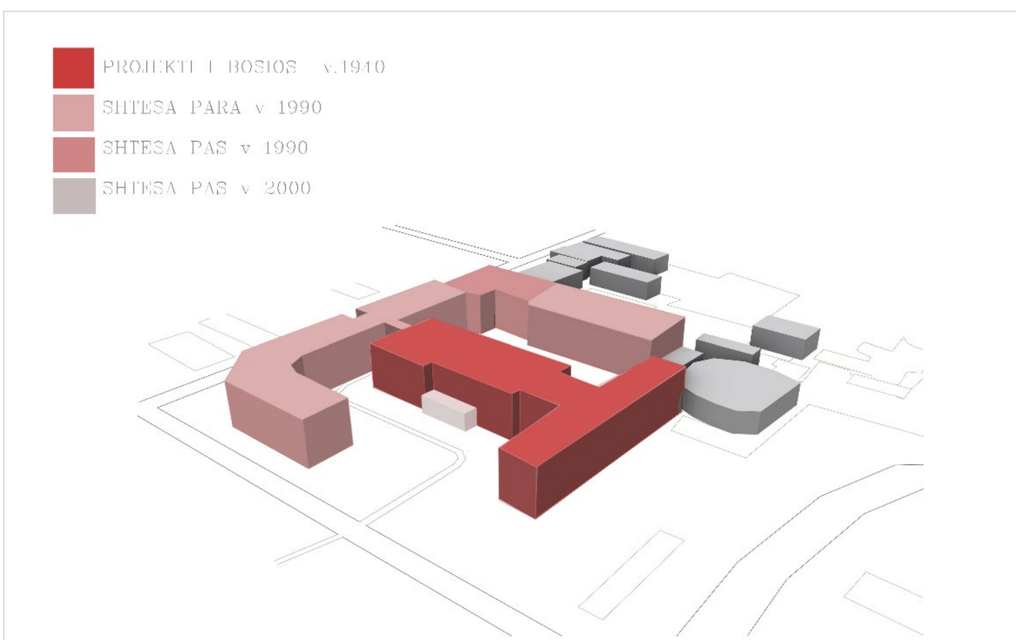


Figure 157. The full complex of the University of Arts campus today and the relevant legend according to the time of construction. Orientation diagrams on block stratification (Credits E. Mucollari, K. Como)

Figure 158. Photo taken during the construction of the campus of the University of Arts (source: AQTN)

6.3.3 Concepts on the methodology of the calculation F.e.m.[35] Model

In this method the structural system is discretized in equivalent deformable horizontal and vertical frames, connected by solid joints. The method is preferred compared to micro-modeling approaches due to the complexity of the nonlinear characterization material and the numerous computational parameters. Most macro element modeling approaches make general theoretical assumptions about off-plane collapse mechanisms, a common mode of collapse in existing masonry structures. Idealizations in modeling the action of rigid slab in the horizontal structural system are also quite empirical. The following analysis examines the results of macro element modeling and analysis, particularly in terms of global capacity and damage mechanisms, masonry crack investigations, and collapse scenarios.

The model used in the Etabs v.19 program is two-dimensional, capable of simulating the planned behavior of masonry panels. The wall is modeled as a vertical shell element with 2 thicknesses at different levels according to the project. Meanwhile, the panel is converted into vertical blocks of the “pier” type, which receives the static vertical load, and horizontal “spandrel” elements type over the windows, where the bending is taken into consideration. The slabs are modeled as horizontal shell elements in bending, with a thickness of 18cm. The roof of Concert hall is modeled with a horizontal shell and under this layer are placed cross beams in two directions with dimensions 45x70cm, every 1.8m from each other. Under the foundations are placed springs with the simulation of the ground-foundation interaction. The modeling of the finite elements is done manually and the dimensions of the finite element are 1x1m, while generating of finite element MESH [36] is done automatically in the program. Initially the model was fully simulated, considering all the component blocks of the building. At some specific stages of seismic analysis, especially when analyzing stress-strain distribution in wall panels,

[35] F..E.M. – Finite element modelling, is a method for numerically solving differential equations arising in civil engineering and mathematical modeling of elements

[36] Mesh process – used to subdivide the CAD model into smaller domains called elements, over which a set of equations are solved. These equations approximately represent the governing equation of interest via a set of polynomial functions defined over each element.

the model is considered separate. This is not a limitation, but is considered as such to focus on the relevant points where data are required for analysis.

Only the reaction of the main block with a façade oriented by Mother Teresa Square was analyzed in the etabs. Since the blocks are separated by seismic joints, the reaction of this block can also be investigated simply, considered separate from the other blocks of the complex. In this modeling the same methodology is followed according to the model F.e.m. explained above. We emphasize that in models simulated we have some limitations. These restrictions consist of not being included in the analysis of buildings near this case-study. It is about buildings and other blocks, part of the university campus built in later periods. These buildings are considered only in the architectural aspect of the stratification analysis over the years.

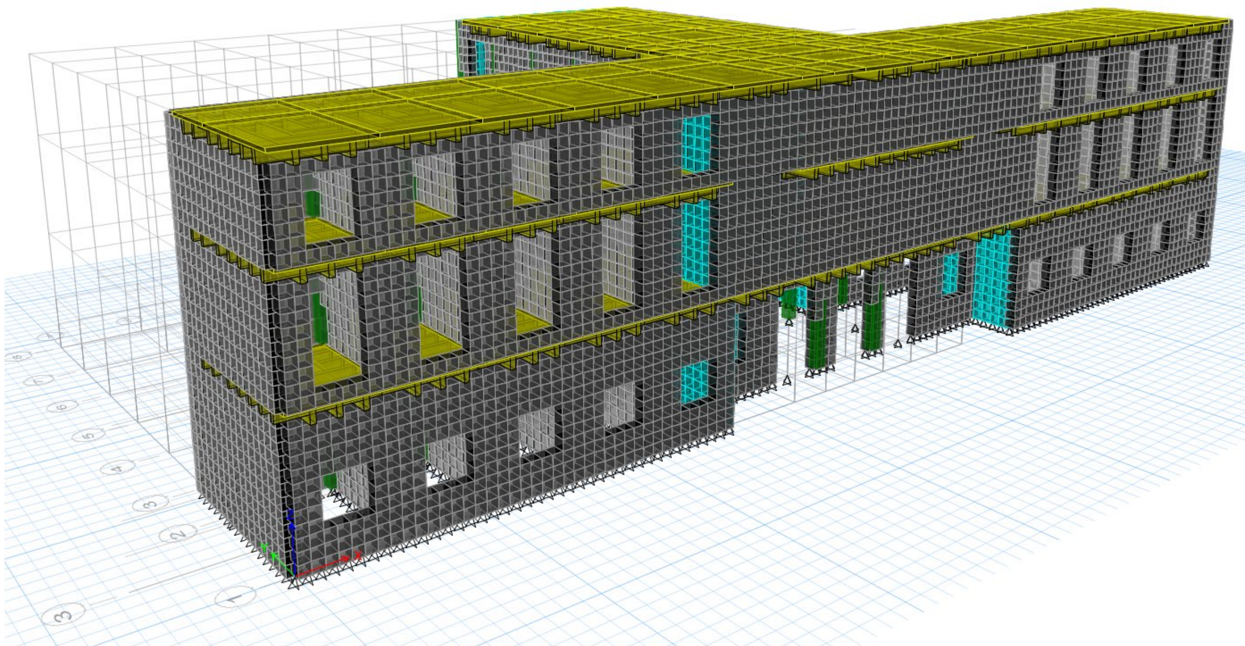


Figure 159. 3D F.e.m. model on ETABS v.19 related to main building of University of fine Arts (author)

6.3.3.1 Modeling of piers

In the proposed model, which was explained above is considered the Pier collapse mechanism shown in (figure.160) and a biaxial interaction between the load as the axial force and the bending moment (NM), including the forces axial and shear force (NV) which have also been considered.

Panel bending behavior: Pier bending behavior is expressed in terms of a moment curvature relationship, starting from the one-axial law of stress-strain diagram shown in (figure 162).

Shearing behavior: Pier shear behavior is modeled as elasto-plastic (figure 162), with the ultimate shear V_u taken as the minimum between the failure for diagonal cracking V_d and the failure for sliding V_s.

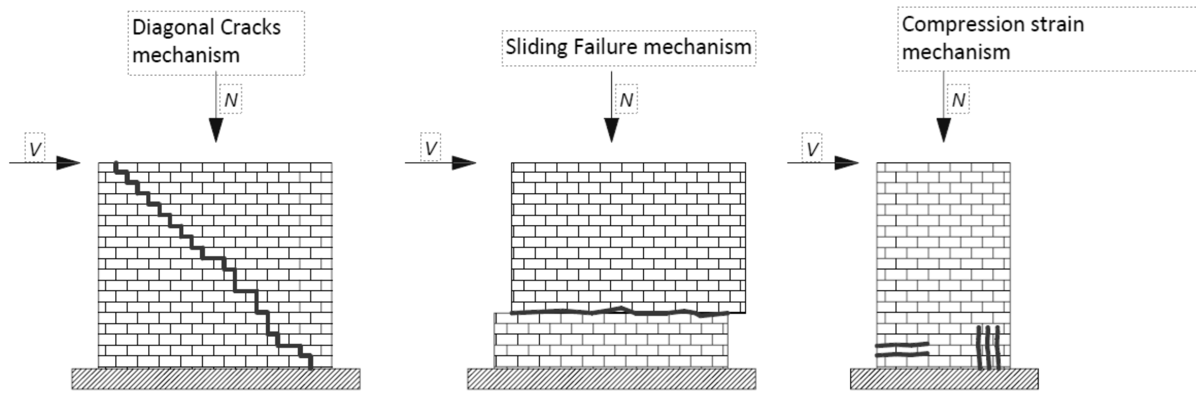


Figure 160. Piers failure mechanisms. Diagonal cracks, sliding and bending failure

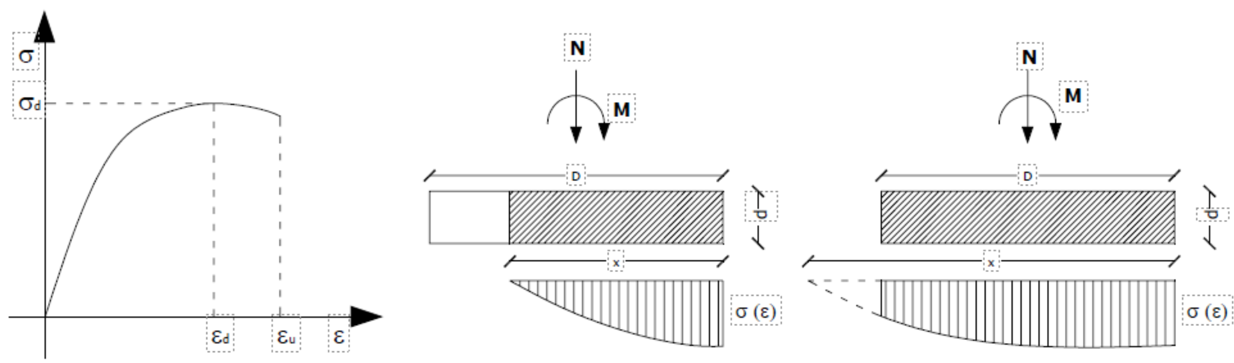


Figure 161. Stress-Strain relationship diagram in compression. Stress-strain diagram for Uncracked and cracked masonry panel cross section

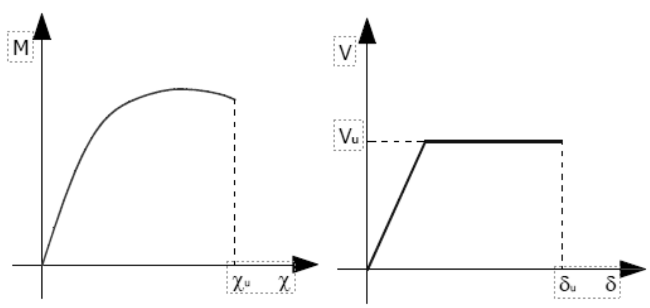


Figure 162. Moment curvature and Shear displacement curves equivalent for piers panel

6.3.3.2 Spandrels modelling

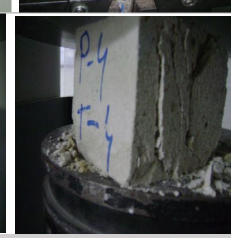
The behavior of spandrels is a very essential aspect in equivalent frame models of a masonry structure. Spandrels play a fundamental role in the seismic behavior of masonry, as they model the joint between the panels and the pier boundary conditions.

There are many experimental results which are of great importance, to determine the behavior of spandrels, which is significantly different from that of vertical elements, because under seismic loads, spandrels are subject to shear force and bending and from the most important aspects , they are subjected to a very small, negligible axial force. The collapse of the spandrel usually occurs according to two mechanisms: oscillation and diagonal rupture. Slip collapse, in fact, cannot occur due to various phenomena occurring in the area between the end parts of the spandrels and the adjacent Pier. Failure cannot occur given the very low axial forces acting.

6.3.4 Tabular summary of mechanical data of materials related to the third case study

By the same logic as in paragraph 6.2.5, also in this case laboratory tests were performed on site. Cylindrical concrete samples were taken, which were tested in compression, steel samples which were tested in tensile strength, and white cubic brick samples were taken in 4 positions on the perimeter wall of the basement which was tested by compression test.

Table 24. Table of mechanical data of laboratory tests, for third case study (Altea & geostudio, 2019)

Material	Resistance (MPa)	Failure load (kN)	Type of test performed	Sample image
Concrete	28		*Compression test results for cylindrical concrete sample-1*	 
Steel for mild rebars	346.85		*Tensile Test of Steel Rebar used, sample-1 of mild steel rebars*	 
Silicate brick	18.35	276.4	*Compression test results for cubic white brick sample -1*	 
* Also in this case after the investigation, the steel used in reinforcement is "mild steel rebar"				

6.3.4.1 Data on the dimensions of the basic elements, interpretations on structural solutions

Ground floor and first brick wall with thickness t = 72 cm.
Upper floors brick wall t = 45 cm.
At the top of the masonry of each floor there are concrete belts (70x20) and (60x20) depending on the thickness of the wall. The slabs are thicker. (h = 18cm)

To be mentioned is the structural solution of the concert hall, which is a space 27 meters long and 17.5m wide. This space has been solved by the engineers with a cassette slab, consisting of primary and secondary beams with a depth of 60-80cm, with empty spaces between them of 80x80cm. This can be considered very innovative for the time and is modeled as a "big waffle-slab", with the parameters explained above in the diagram and numerical data.

6.3.4.2 Summary of spectral data used in the seismic analysis

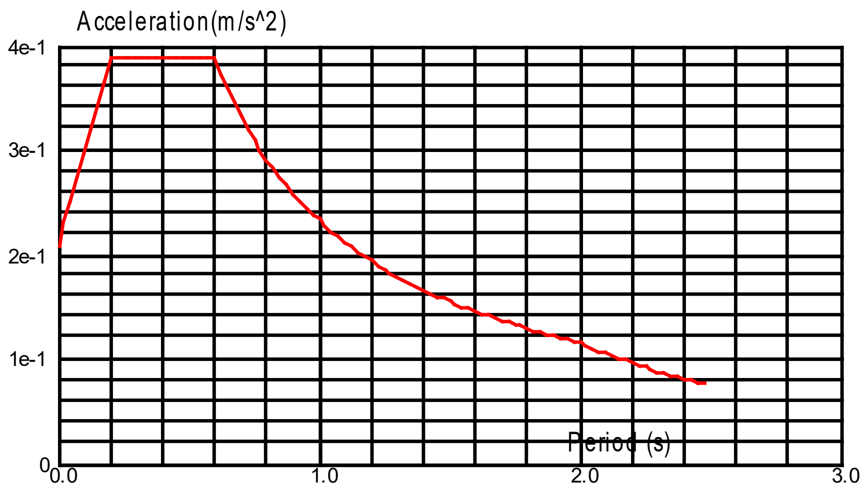


Figure 163. Diagram of design spectrum used for seismic analysis and simulations

Basement general data used in the software:
Site: C
Spectrum type: 1
Direction: Horizontal
Behavior factor: 2.000

Elastic Spectrum used parameters:
Acceleration: ag=0.270
Damping: ζ=5.00 %
Damping correction: η= [10/(5+ζ)]0,5 =1.000
S =1.150; β =0.200; TB =0.200; TC =0.600; TD =2.000

6.3.5 Seismic Analysis and Results

Given the above methodology, this cultural heritage structure was primarily analyzed to define seismic parameters and their walls carrying capacity. Modal analysis was performed to determine the basic vibration modes and natural frequencies of the structure during free vibrations. The purpose of this analysis is to obtain the maximum response of the structure in each of its important ways, which are then summarized in a technically appropriate manner. Modal analysis of the structure involves different modes of vibration in a combined manner.

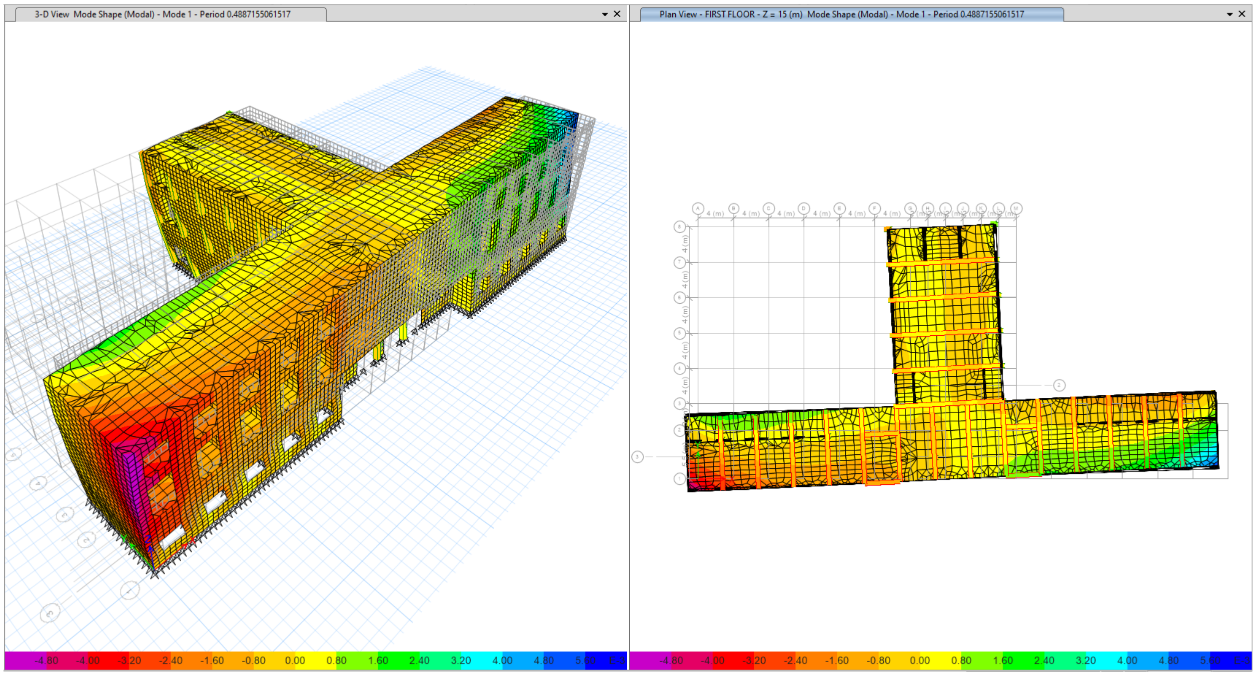


Figure 164. First mode of vibration from modal analysis (ETABS v.19)

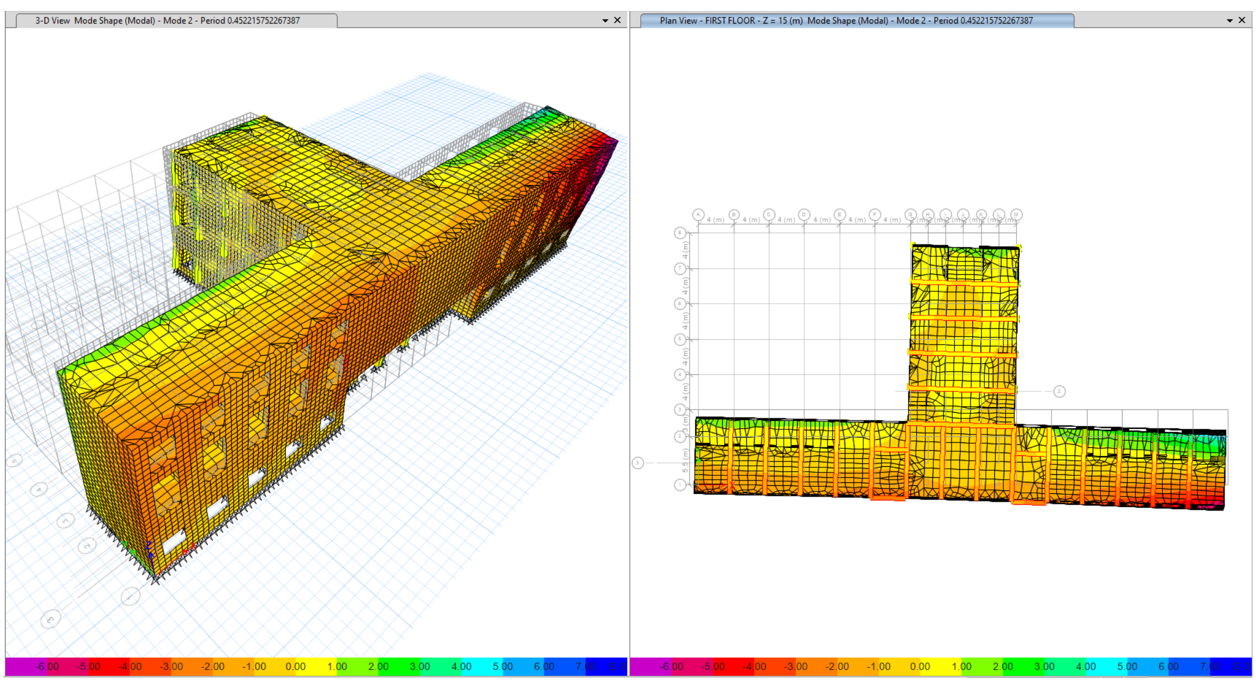


Figure 165. Second mode of vibration from modal analysis (ETABS v.19)

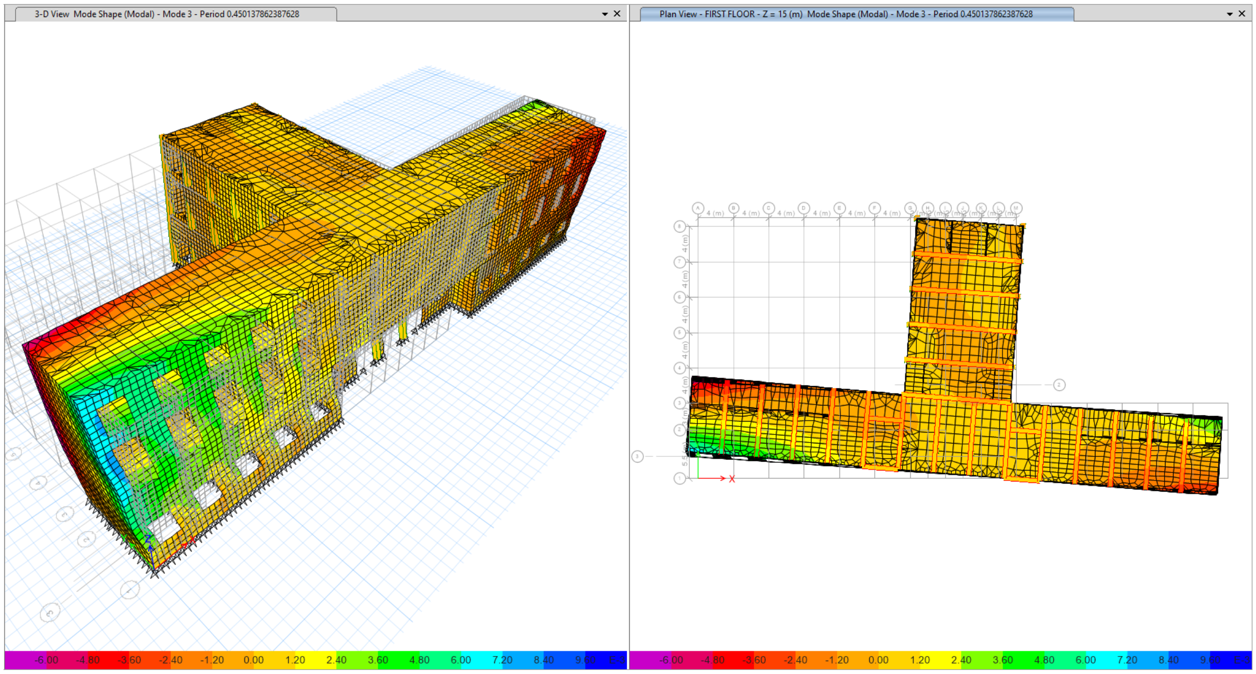


Figure 166. Third mode of vibration from modal analysis (ETABS v.19)

Table 25. Modal periods and modal participating mass ratios (ETABS v.19)

Case	Mode	Period sec	UX	UY	SumUX	SumUY	RX	RY	SumRX	SumRY
Modal	1	0.489	0.7402	2.573E-05	0.7402	2.573E-05	7.622E-06	0.2231	7.622E-06	0.2231
Modal	2	0.452	0.0223	0.8224	0.7625	0.8224	0.2811	0.0063	0.2811	0.2294
Modal	3	0.45	0.1767	0.0978	0.9391	0.9202	0.0331	0.0486	0.3143	0.278
Modal	4	0.208	1.17E-06	0.0006	0.9391	0.9208	0.0004	6.814E-07	0.3146	0.278
Modal	5	0.186	3.312E-05	0	0.9392	0.9208	1.537E-06	0.0059	0.3146	0.2839
Modal	6	0.168	0.0493	7.554E-06	0.9885	0.9208	0.0001	0.5376	0.3147	0.8216
Modal	7	0.155	0.0002	0.0752	0.9887	0.996	0.6555	0.0022	0.9703	0.8238
Modal	8	0.151	0.0094	0.0007	0.9981	0.9966	0.0063	0.1523	0.9766	0.9761
Modal	9	0.115	0.0005	0.0001	0.9986	0.9967	0.0035	0.006	0.98	0.9821
Modal	10	0.115	0.0002	0.0003	0.9988	0.997	0.0106	0.0025	0.9907	0.9847
Modal	11	0.101	0.0005	4.316E-06	0.9993	0.997	1.125E-05	0.0069	0.9907	0.9915
Modal	12	0.094	6.002E-06	0.0011	0.9993	0.9981	0.0006	0.0001	0.9913	0.9916

Calculation methodology related to allowed period: $[T] = 0.075 * H_b^{0.75}$ (CEN Eurocode 8, Eurocode 8: Design of structures for earthquake resistance -Part 1: General rules, seismic actions and rules for buildings, 2008)

First mode: $T1=0.489s \approx [T]$ Translation move on X-direction, presence of torsion
Second mode: $T2=0.452s$ Translation move on Y-direction, presence of torsion
Third mode: $T3=0.450s$ Rotation move

6.3.5.1 Local results and diagrams

The following section will present diagrams related to the seismic response of perimeter masonry and results related to the distribution of stress-strain in the most delicate parts of the main facade of the building. The investigation of these parameters in the facade is the basis of the methodology followed in this case study.

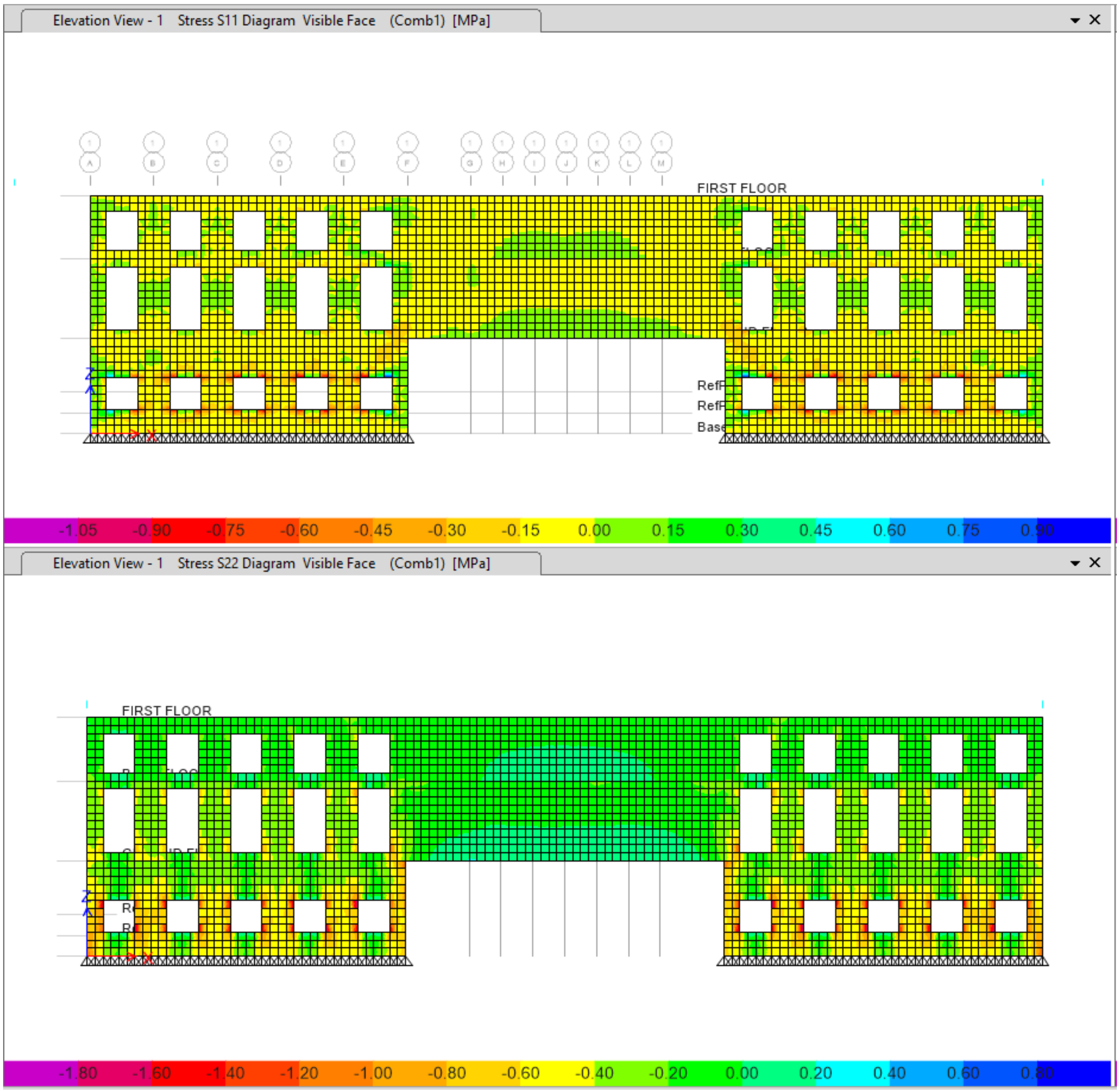


Figure 167. Stress S1-1 and S2-2 distribution on the main façade, according comb-1 (ETABS v.19)

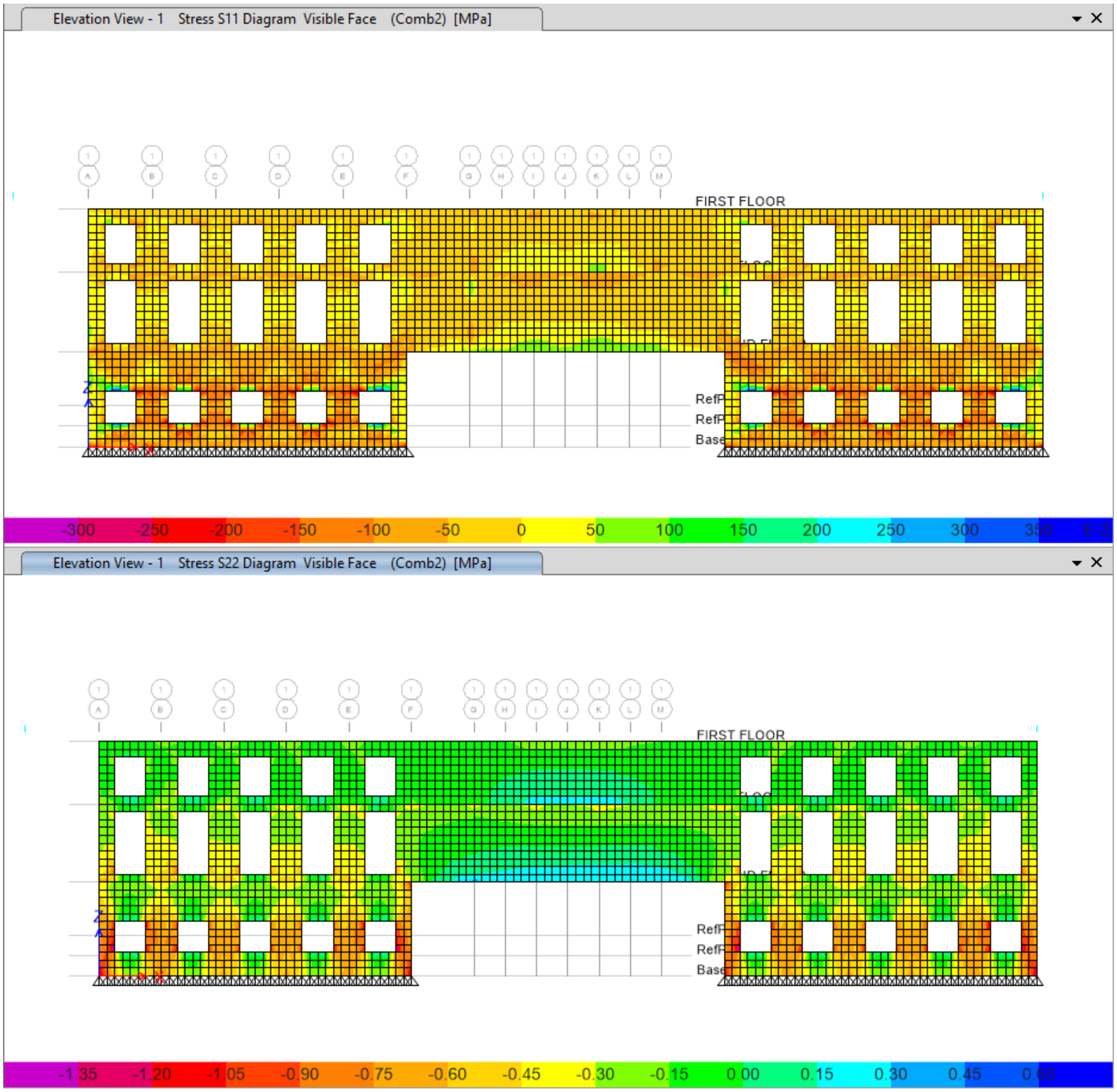


Figure 168. Stress S1-1 and S2-2 distribution on the main façade, according comb-2 (ETABS v.19)

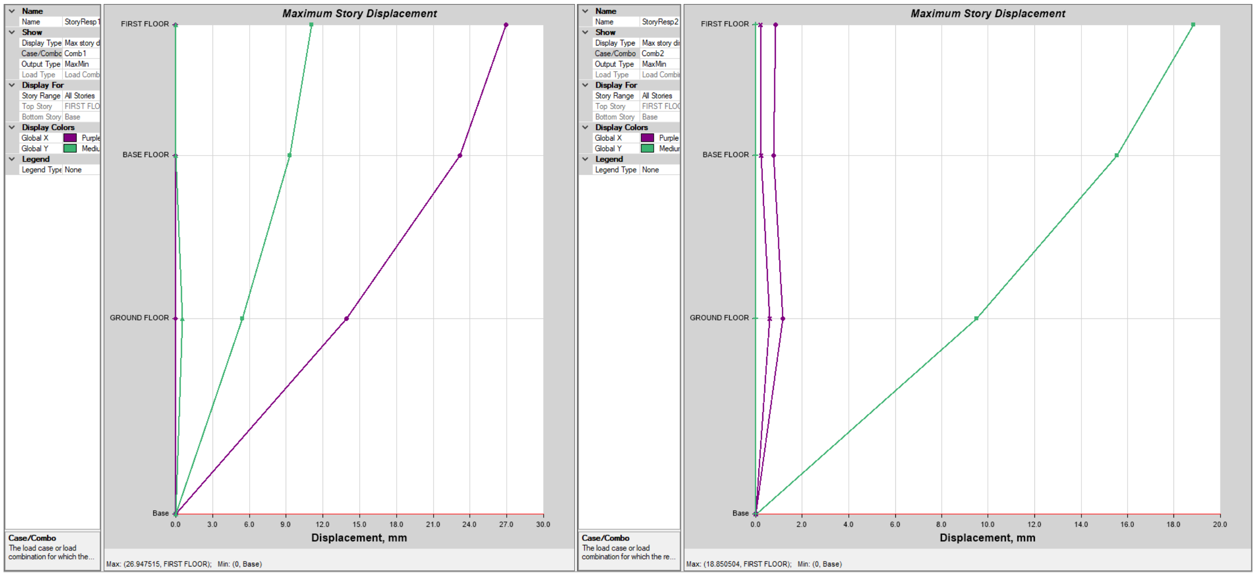


Figure 169. Story displacement diagrams, according to seismic comb-1 and comb-2 (ETABS v.19)

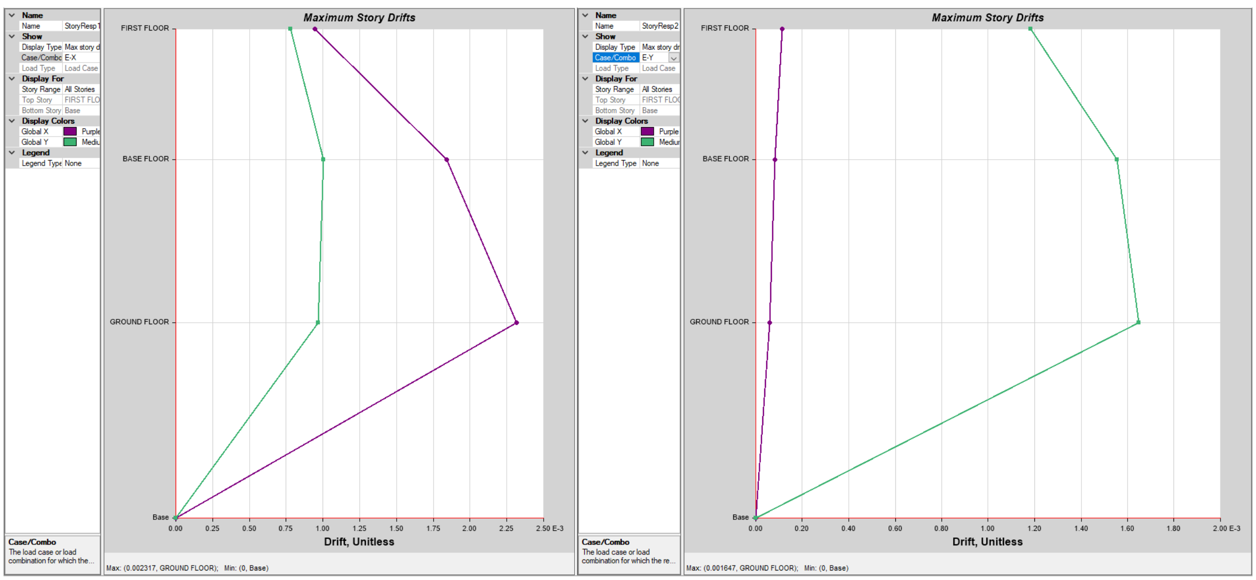


Figure 170. Story drifts diagrams, according to seismic E-x and E-y (ETABS v.19)

Comments the results of the local analysis of the facades masonry:

The maximum displacement values are observed in the global-x direction according to the seismic combination 1, specifically in this direction the maximum displacement of the building at the top reaches the value $\delta = 27$mm. According to seismic combination 2, the building is maximally displaced at the top in the global-y direction up to $\delta = 18.5$mm. These displacements are directly related to the geometric configuration of the building in the plan and the distribution of masses against seismic actions, part of the combinations.

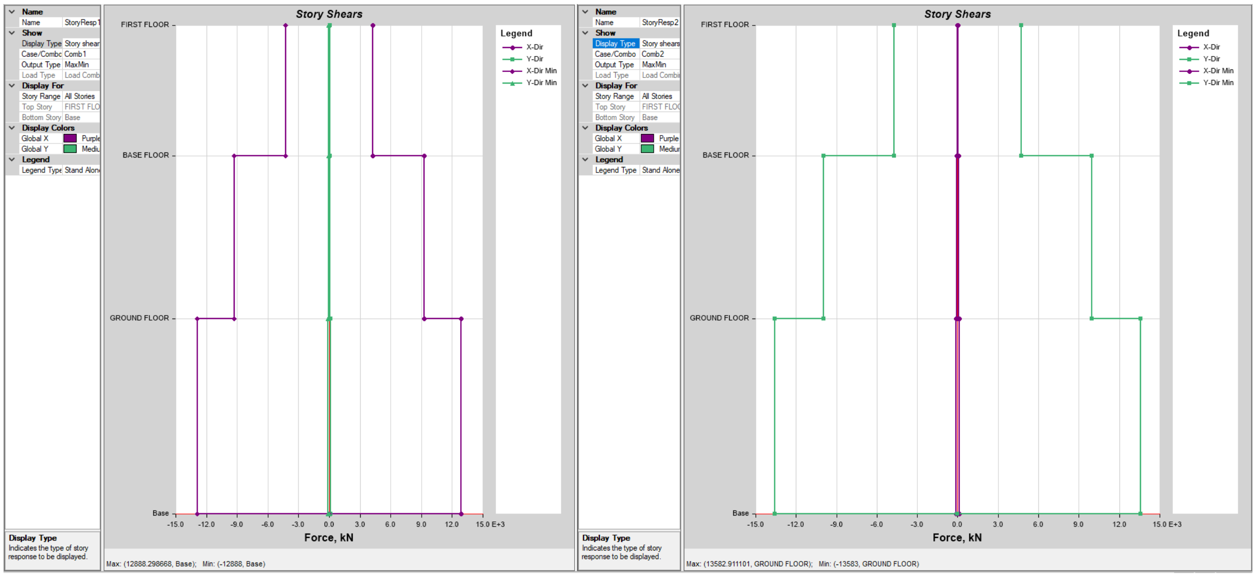


Figure 171. Story shear force local diagrams, according to seismic comb-1 and comb-2 (ETABS v.19)

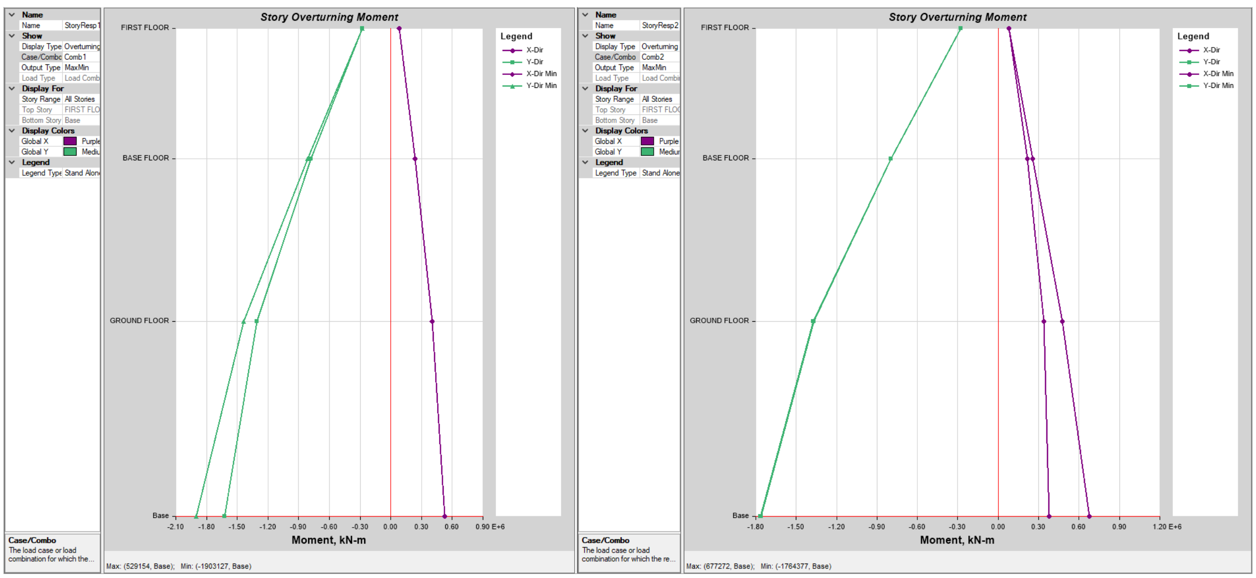


Figure 172. Story overturning moment diagrams, according to seismic comb-1 and comb-2 (ETABS v.19)

6.3.5.1 In-depth analysis in the framework of BIM modeling through “3muri software”, analysis and investigations into possible masonry collapse scenarios

By the same logic as the first case study was treated, here too it was judged to perform non-linear analyzes with 3Muri software v.13 academic version. In this case study, in the simulations performed with etabs software only linear seismic analyzes were performed, where a series of modal parameters were treated. Thus, through 3Muri software, in this paragraph an attempt is made to investigate in more depth the mechanisms of masonry collapse.

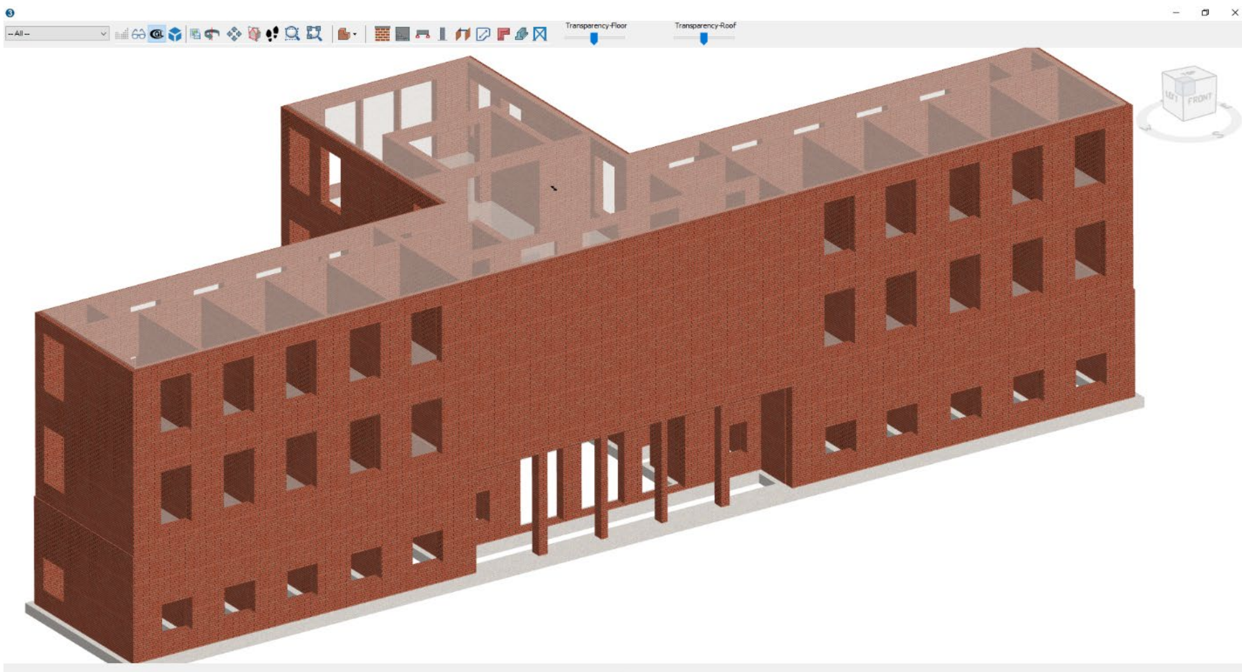


Figure 173. Architectural model created in 3Muri software, axonometric view of the structure

Figure 174. Presentation of two axonometric front views of the model created in 3Muri software

The model in "3Muri software", presented in (figure 173) is created on the geometric data of the current project, analyzing the materials of the architectural survey, recently performed in the building. Regarding the limitations, it is emphasized that only half of the complex of buildings has been modeled, specifically the main block near the "Mother Teresa" square, in the east position of the building. The vertical block is also modeled, which connects this central block with the western block of the concert hall, the interruption of the object is done exactly in the position of connecting the blocks, near the seismic joint.

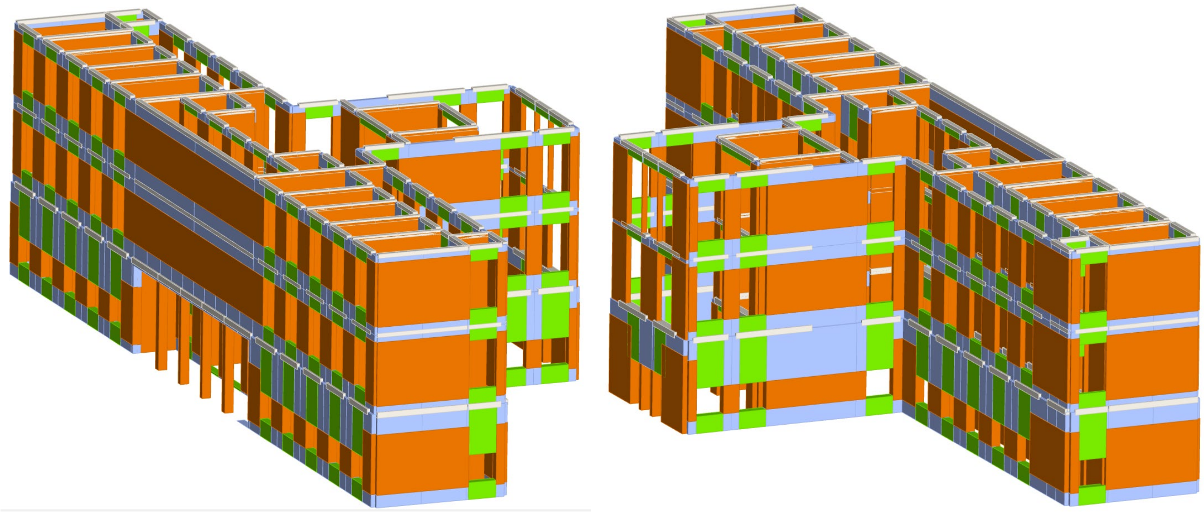


Figure 175. Numerical model according to the equivalence performed in 3Muri software, axonometric view of the block at two different angles

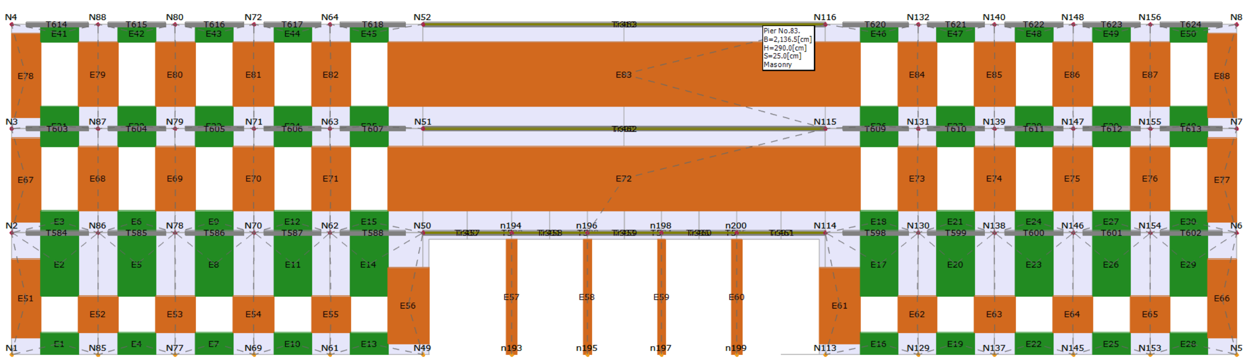


Figure 176. Numerical model according to the equivalence performed in 3Muri software, view of the main facade positioned in the east direction

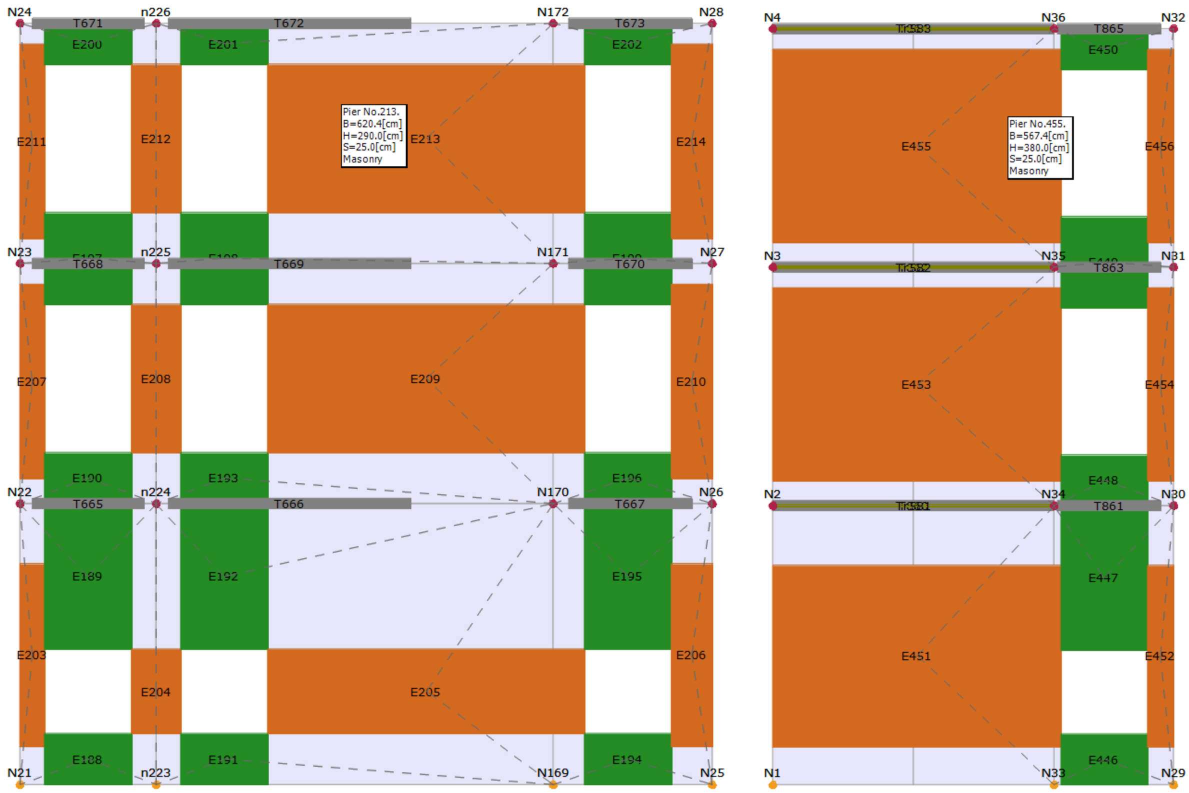


Figure 177. Numerical model according to the equivalence performed in 3Muri software, (a) view of the facade in the position of the connecting block, (b) view of the front facade

- Results generated after performing nonlinear analyzes simulated in 3Muri software

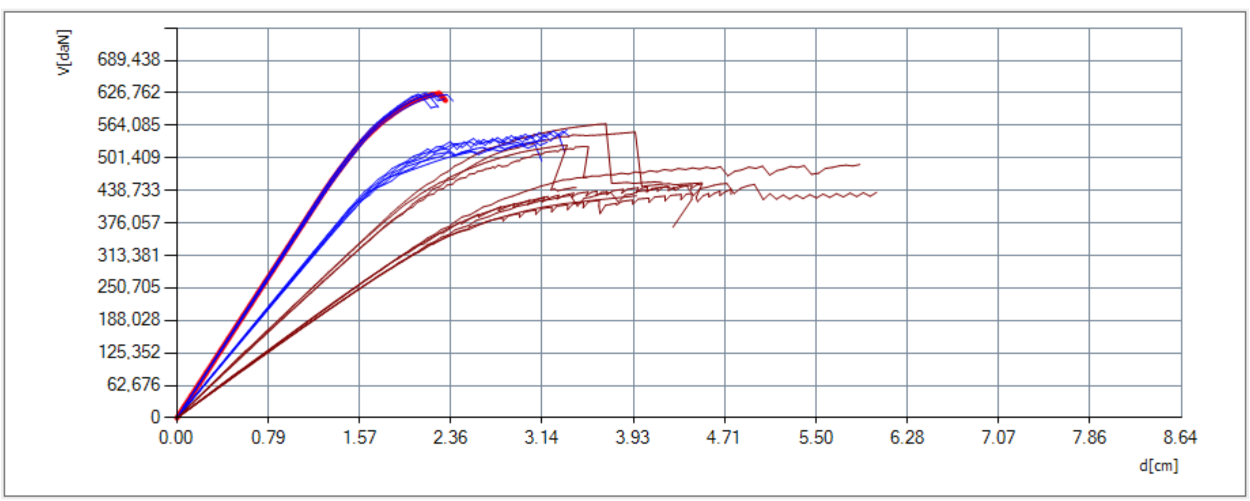


Figure 178. Summary table of capacity curves V-Δ, extracted in combination by 3Muri software for 24 analyzes performed in both seismic directions

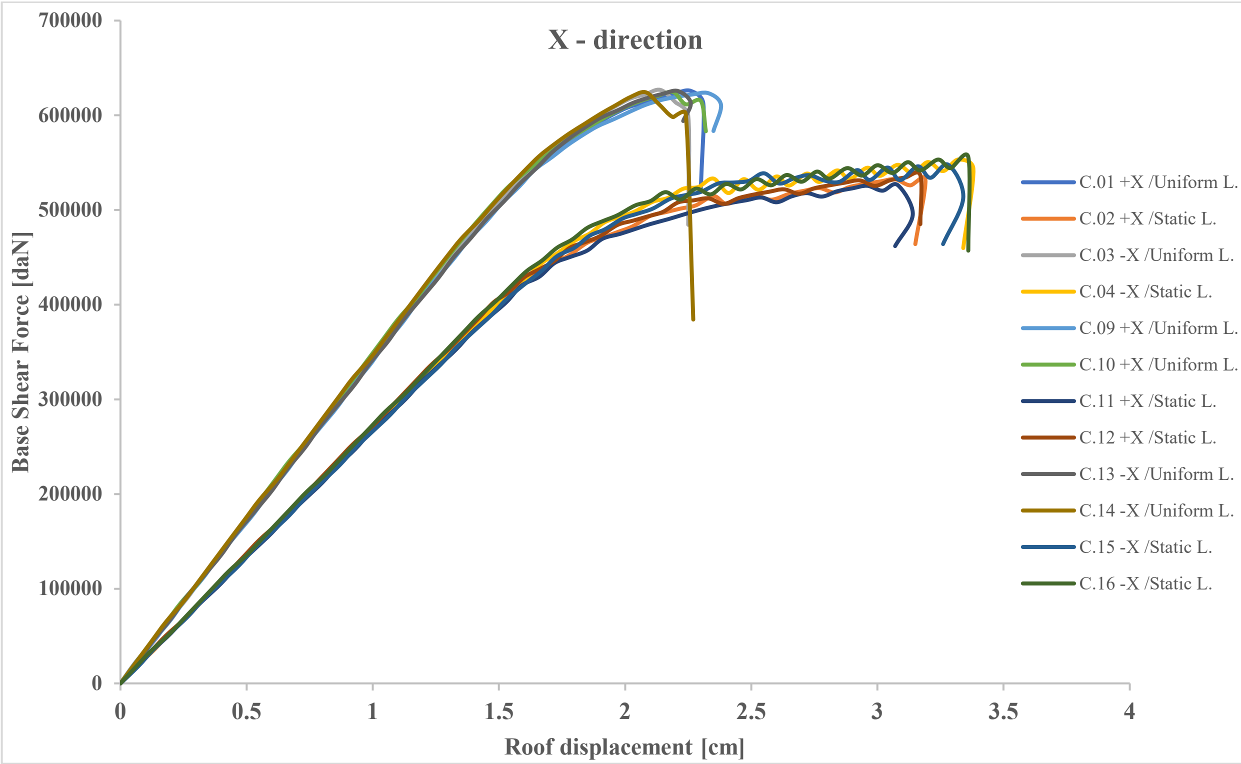


Figure 179. +X and -X direction combined capacity diagrams, processed from 3Muri numerical data

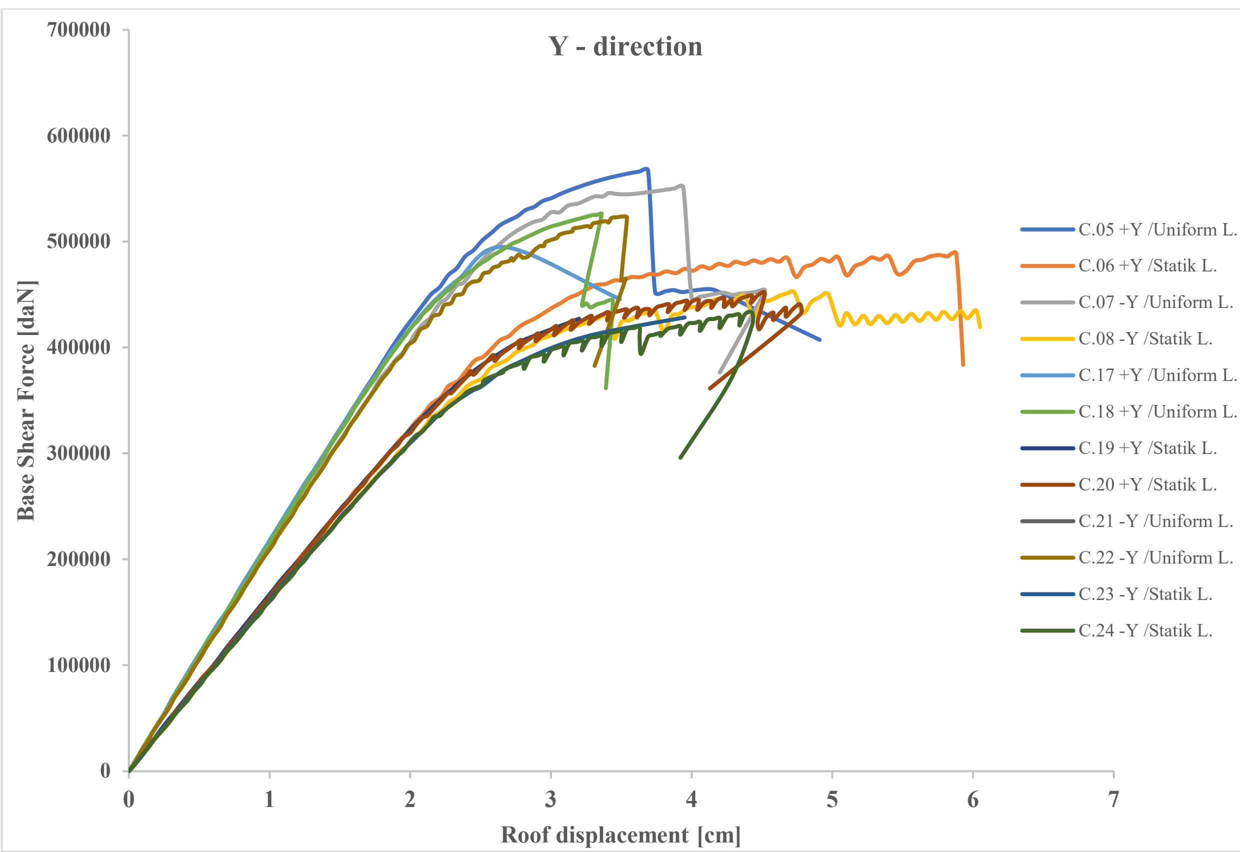
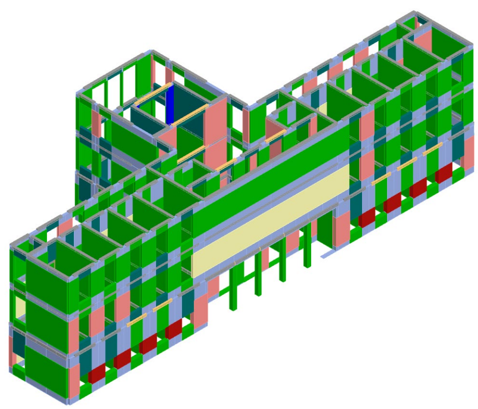
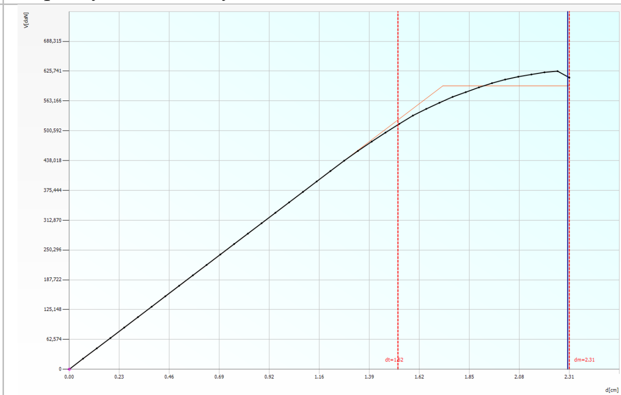
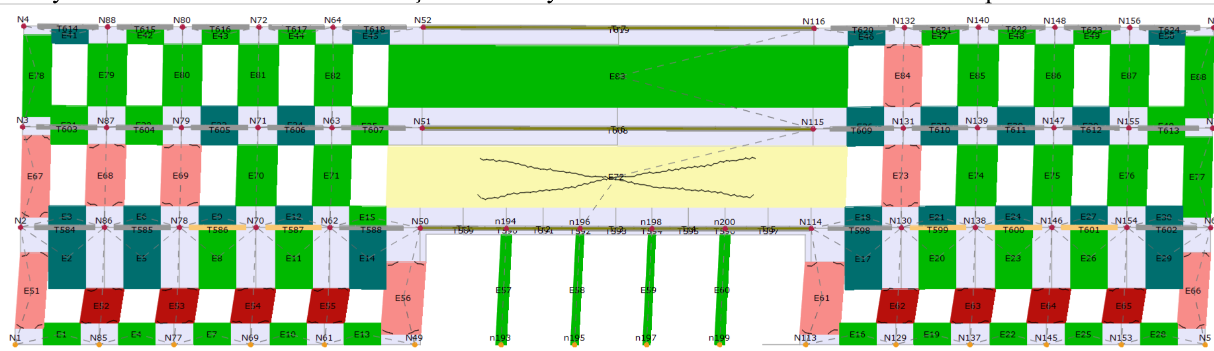
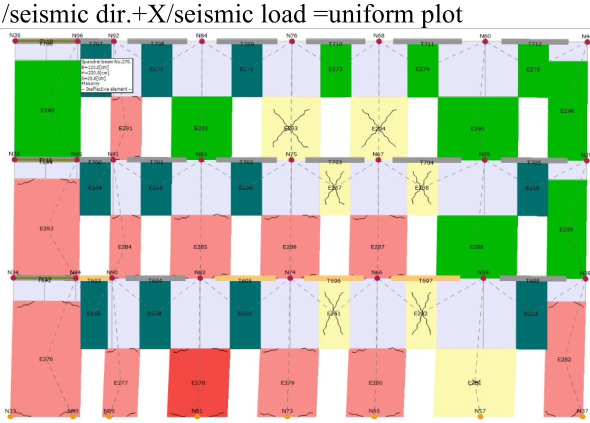
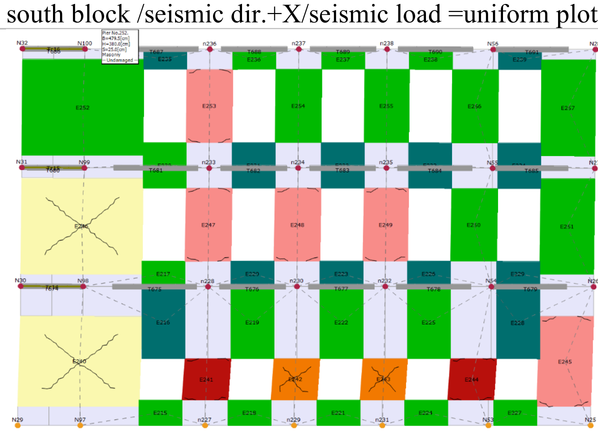


Figure 180. +Y and -Y direction combined capacity diagrams, processed from 3Muri numerical data

Table 26. Summary table of results obtained by 3Muri software, focused on nonlinear simulations of the most problematic steps

<table>
<tr><th>No</th><th>Seism dir.</th><th>Seismic load</th><th>α NC</th><th>α SD</th><th>α DL</th><th>dm/dt NC</th><th>Capacity curves</th></tr>
<tr><td>1</td><td>+X</td><td>Uniform</td><td>1.429</td><td>1.425</td><td>1.894</td><td>1.520</td><td>Capacity curve / analysis no.01 / +X direction</td></tr>
<tr><td colspan="7"></td><td>
dt=1.52cm [NC], dm=2.31cm [NC], T*=0.38s</td></tr>
<tr><td colspan="8">Analysis-01/Mechanism no.1 /Main façade masonry /seismic dir.+X/seismic load =uniform plot</td></tr>
<tr><td colspan="8"></td></tr>
<tr><td colspan="7">Analysis-01/Mechanism no.2 /Internal hall masonry /seismic dir.+X/seismic load =uniform plot</td><td>Analysis-01/Mechanism no.3 /Back façade, part of south block /seismic dir.+X/seismic load =uniform plot</td></tr>
<tr><td colspan="7"></td><td></td></tr>
<tr><th>No</th><th>Seism dir.</th><th>Seismic load</th><th>α NC</th><th>α SD</th><th>α DL</th><th>dm/dt NC</th><th>Capacity curves</th></tr>
<tr><td>13</td><td>-X</td><td>Uniform</td><td>1.296</td><td>1.282</td><td>1.804</td><td>1.468</td><td>Capacity curve / analysis no.13 / -X direction</td></tr>
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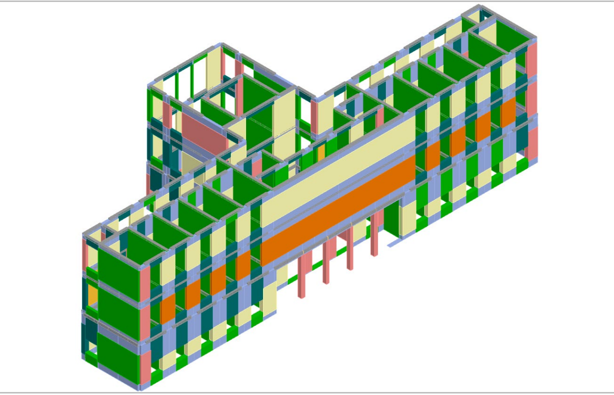
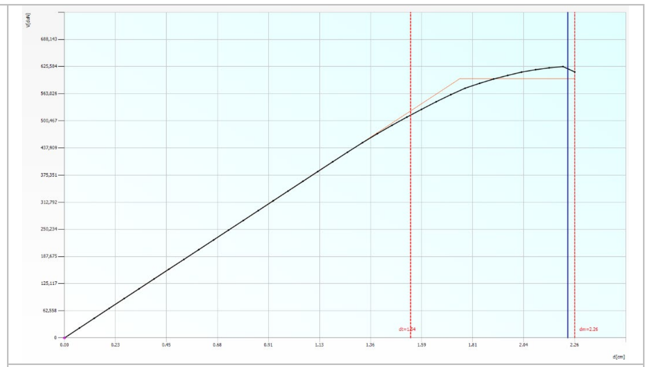
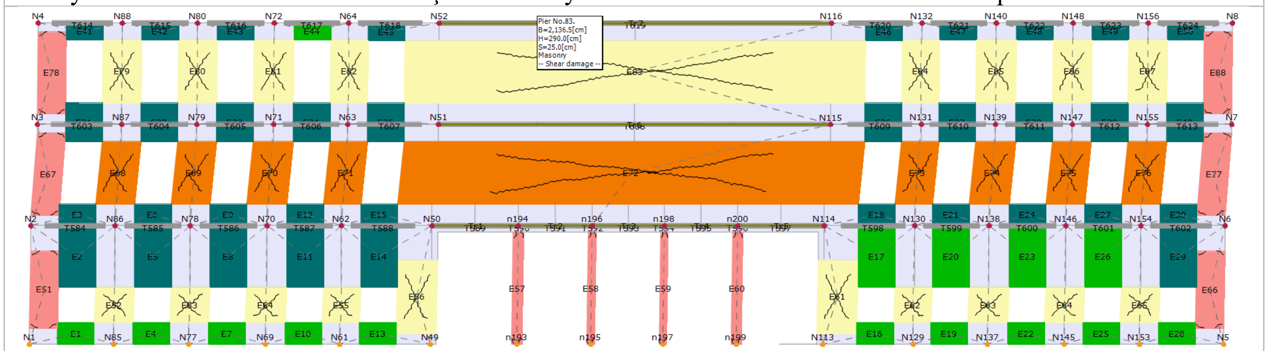


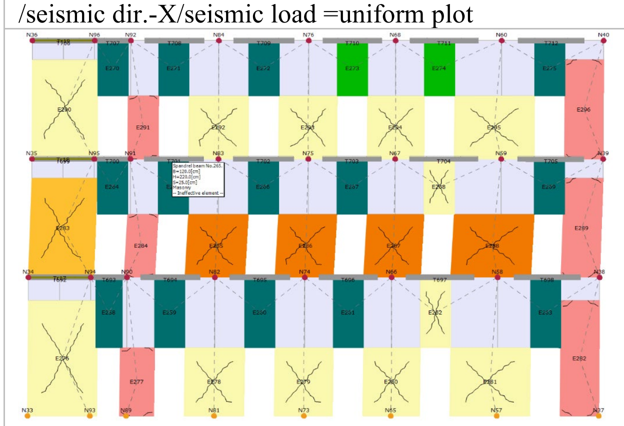


dt=1.54cm [NC], dm=2.26cm [NC], T*=0.382s

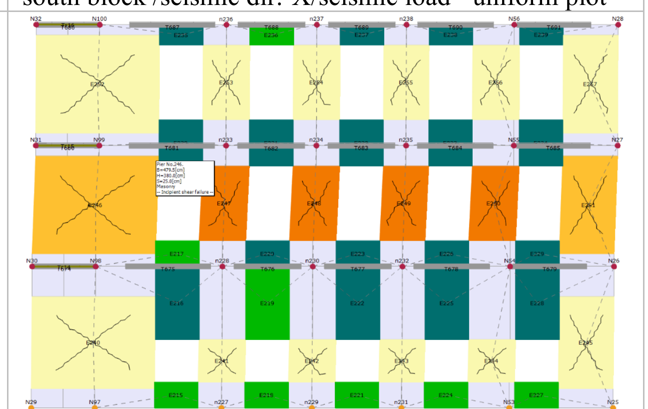
Analysis-13/Mechanism no.1 /Main façade masonry /seismic dir.-X/seismic load =uniform plot



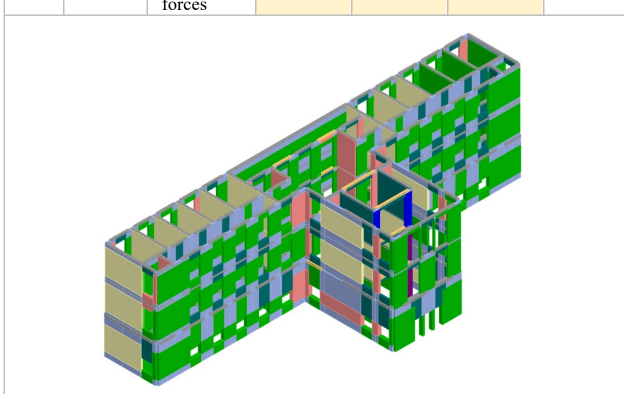
Analysis-13/Mechanism no.2 /Internal hall masonry /seismic dir.-X/seismic load =uniform plot

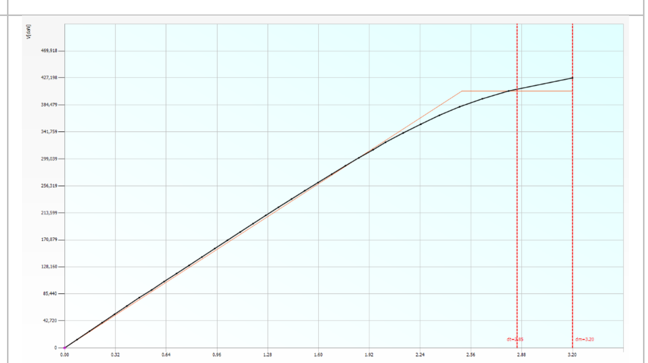


Analysis-13/Mechanism no.3 /Back façade, part of south block /seismic dir.-X/seismic load =uniform plot

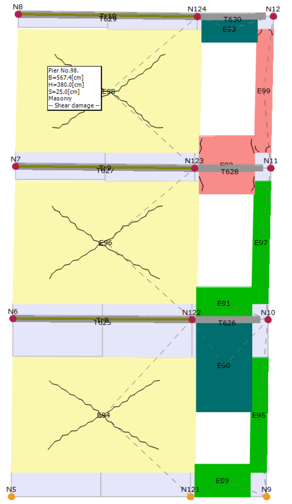
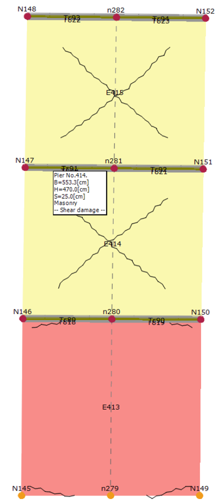
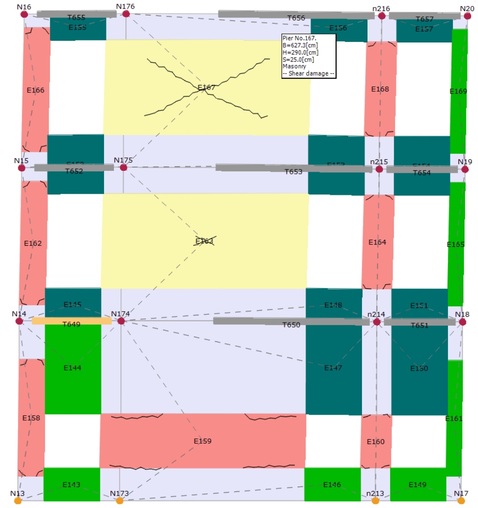


No	Seism dir.	Seismic load	α NC	α SD	α DL	dm/dt NC	Capacity curves
19	+Y	Static forces	1.022	1.042	1.363	1.123	Capacity curve / analysis no.19 / +Y direction

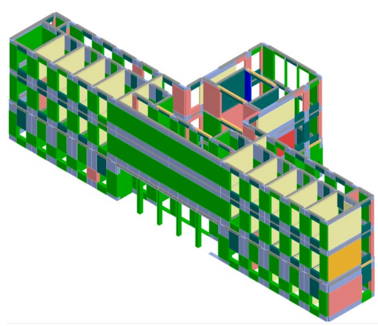


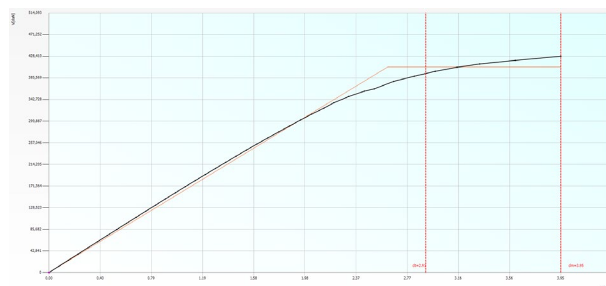


dt=2.85cm [NC], dm=3.20cm [NC], *T*=0.526s*

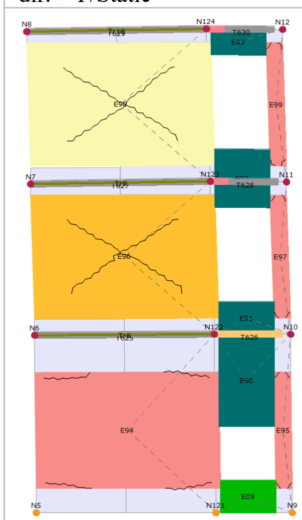
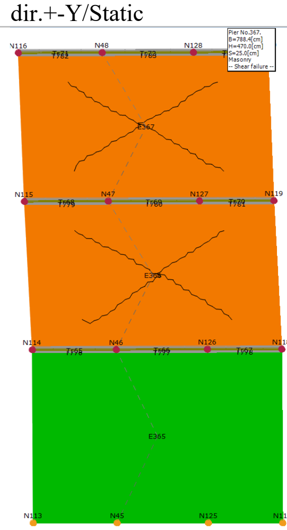
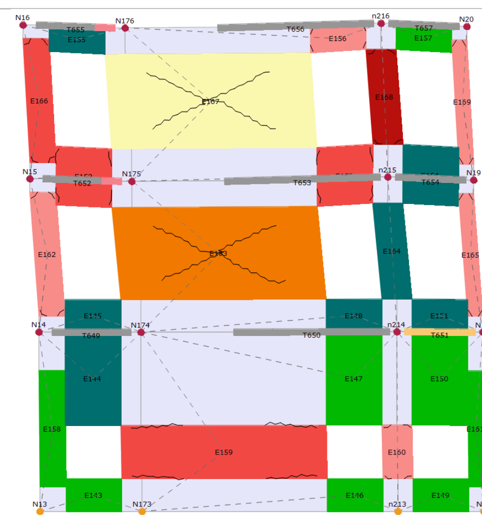
Analysis-19/North side façade Mechanism /seismic dir.+Y	Analysis-19/ P-23 internal panel Mechanism /seismic dir.+Y	Analysis-19/ P-06 South façade of the intermediate block - Mechanism /Internal/seismic dir.+Y
		

No	Seism dir.	Seismic load	α NC	α SD	α DL	dm/dt NC	Capacity curves
23	-Y	Static forces	1.358	1.273	1.499	1.357	Capacity curve / analysis no.23 / -Y direction





dt=2.91cm [NC], dm=3.95cm [NC], *T*=0.538s*

Analysis-23/ P-02 North side façade Mechanism /seismic dir.+-Y/Static	Analysis-23/ P-18 internal panel Mechanism /seismic dir.+-Y/Static	Analysis-23/ P-04 perimetral panel Mechanism / North façade of the intermediate block/seismic dir.+-Y/Static
		

6.3.6 Conclusions and recommendations for the third case, regarding seismic simulations

The seismic and structural safety assessment of a heritage building has been carried out by including in the study various interrelated phases that include the basic knowledge of the building and the investigation of its seismic performance. The application of this approach methodology in the case of the University of Arts, located near Mother Teresa Square, showed that the construction knowledge and technology phase is a fundamental step towards assessing its structural behavior. An accurate critical-architectural-historical analysis, a detailed investigation of previous geometric studies, characteristics of materials, basement data and a meticulous construction of the cracking model allow to minimize the structural studies (and thus intervention strategies) in the cultural heritage building , thus preserving its necessarily history, and cultural identity. Advancing further, with an accurate assessment of the structural evolution of the building over time, limits the costs for the investigation phase leading to a more accurate seismic analysis of the structure .

The model used for the analysis seems to effectively interpret the actual state and realistic behavior of the structure in its current geometric and physical configuration. Through the seismic analysis performed, a result is obtained, in terms of the progression of cracking patterns and scenarios, a great resemblance appears to what is actually located in the structure. The circumstances for which this result was obtained taking into account the state of dead loads of the structure, and some of the impacts of recent seismic events.

Vibration periods for this object are considered within the allowable values, or very close to the displacement threshold. First period $T1 = 0489s \approx [T1] = 0.511s$. However, we cannot ignore the fact that we have the presence of rotation in the first two modes. Rotation is found with small values but also related to the large age of the structure are aspects that should be highlighted for genuine retrofit strategies. These presence of rotational tendencies in the first vibrational modes are also explained by the geometric shape of the building in the plan, which is a T-shape, separated by a seismic joint in the middle. The presence of the joint does not affect the geometric shape of the semi-T shape for the central block near Mother Teresa Square.

The behavior of more complex structural parts, mainly perimeter masonry and slab panels, was studied through a finite element analysis, the results of which (mainly static load transferred to vertical elements through support reactions) were then applied to the simplified global model .

6.3.6.1 Summaries and conclusions regarding the nonlinear simulations performed in 3Muri

Most of the damage that occurs during an earthquake is directly related to the existing condition of the building, the parameters of the materials and the maintenance history over the years. It is worth mentioning that the maintained structures, even without consolidation projects done, perform much better than the structures weakened by lack of maintenance and degradation. The resistance and performance of the structural system to resist future earthquakes can be significantly reduced if previous interventions or seismic events have weakened the structure. Also, if the parameters of the materials are deteriorated by humidity, termites, parasitic vegetation or other accidental causes. In existing cultural heritage buildings, damaged mortar joints between bricks can weaken entire building panels. From the site survey and investigations made, such problems have been identified for this case, therefore, continuous maintenance, which reduces to a maximum these problems, is essential.

It should be emphasized again that in order to have reliable results it is important to have many models and simulations performed beyond the field work for the most unfavorable situations. In this case we can conclude that the verified performance results in satisfactory levels, even if we compare the results obtained from both software's.

Various failure mechanisms and scenarios were predicted by 3Muri rating levels, summarized above in Table 26. Thus, it should be emphasized that it is necessary to develop as many theoretical and applied approaches as possible, in order to have a comprehensive result of the possible seismic performance of the masonry panels. Summarizing from 24 pushover analyzes performed, combined in both directions, only analysis no.19 + Ydir resulted in low parameters. Which means that the vulnerability index αNC and αSD have values very close to the lower limit, which provide clues for more in-depth investigations. Also in the analysis no.01 + Xdir with "Mechanism no.1 positioned in Main facade masonry", or in the analysis no.13 + Xdir where some local mechanisms with high probability of risk during a strong seismic event have been observed. The local mechanisms investigated are of the "Shear failure" type in most cases, followed by "bending damage and incipient bending failure", and in a few cases "bending failure". From the investigation of the mechanisms in most of the steps performed, it is evidenced that the most fragile part of the building is the central hall, specifically the joints at the corners of the connection between two buildings. And in such cases to avoid this problem, as an ideal recommendation would be the application of bracing systems, in two directions X and Y, in the inner part of the structure, to give sufficient rigidity to the masonry panels, also to increase global structure resistance.

To conclude, having a results report, which identifies areas of weakness, or elements with high fragility, creates the possibility of using these results to assess the effectiveness of reinforcement strategies and to contribute substantially to the design of appropriate reinforcement measures that are essential in the case of cultural heritage structures.

CHAPTER 7.

Summaries and Conclusions

7.1 Summary of final Conclusions and Recommendations

The multi-level approach followed in this study has shown its effectiveness in assessing the vulnerability of the building designed by Bosio, noting the possible applications in a wide variety of masonry cultural heritage buildings of this period in Tirana, among others. Assessing the structural and seismic safety of all these structures, requires appropriate knowledge, extensive investigations, research in archives and documentation, browsing analog studies in neighboring countries, intensive research phase, monitoring, investigation and extensive interpretation of techniques in construction, both in terms of historical reconstruction of buildings and previous restoration interventions, as well as the physical-mechanical characteristics of the material.

The engineering approach does not advance further to include possible structural rehabilitation techniques that follow the principles of minimal intervention that should always be followed when dealing with cultural heritage . But this study leaves an open path for the selection of materials and typology of retrofit interventions, which must be in accordance with the architectural heritage of Tirana, in accordance with the principles of restoration and easily movable or disassembled. This stage should usually be led by restorers, archaeologists, historians, whose main interest is the preservation of the original architecture and structure of the historic building. Recently in Albania, especially after the seismic events of 2019, the seismic safety of historic buildings has also seen the involvement of structural engineers, whose main interest is to increase the seismic safety of the architectural heritage . Engineers have been involved in this process before, but without considering in their projects the architectural value of the building where they intervene.

This professional practice, where there is fruitful cooperation between the architect-engineer node, should be intensified and deepened, especially in the architectural wealth of cities, without including monetary or political interests. Often, architectural heritage is characterized by construction techniques considered dated according to today's standards and building codes. The contrast between the needs for strengthening on the one hand and the preservation of heritage on the other must become visible and tangible. Minimally invasive interventions are recommended and preferred (e.g. introduction of new connecting rods, various injections with mortars containing fiber elements, local dismantling and reconstruction, replacement of old mortar, intervention in facades until stability is not endangered), in order to improve the mechanical quality and performance of the walls, preventing the creation of mechanisms of their collapse, based on all the theories addressed in the theoretical part of this study.

Finally, we can conclude the on-site study phase, survey process is a key aspect of this study. Through the survey it has become possible to digitize the archival project of the building, while at the same time it has become possible to build the current model of the building, which enables us to perform a confrontation between the two periods. Confrontation in architectural but also structural aspect. The field research process made possible the identification of the positive and negative sides of the interventions in the masonry, aspects on the additions and how they affect the performance of the building. The slab intervention in the concert hall has improved its local performance. Meanwhile, special attention seems to be paid to the assessment of loads related to the bearing capacity of continuous foundations. Through the field survey process, it was initially aimed and later achieved, the awareness of architecture students to in-depth study and culture of protection of cultural heritage objects, through their accurate restoration.

Along with the comments extracted and analyzed at the end of each chapter, a more concise overview is summarized here. In terms of clarity, it is worth re-emphasizing the approved research strategy:

- The first phase for each case study was “the analysis of structural typology”. Considered as one of the most important features in the study of heritage buildings in Tirana, initially addressed the historical and temporal evolution of massive masonry from the architectural, constructive, construction technologies, designers and perspectives for future plans. Recurrent damage after gravitational and seismic loads, the impact of additions, structural interventions and functional adaptations over the years were also investigated and analyzed.
- “On-site search and monitoring phase”. The difficulties presented by the review and collection of archival projects, and the need to obtain real and current data on buildings, made a good part of the study to take place on site. In this phase, several processes were developed, such as architectural survey and digitalization of archival projects, orthogonal photography with drones and processing of facades through the process of photogrammetry, processing of data on facade problems, monitoring on the parameters of masonry materials, etc. While at this stage it is worth mentioning the inclusion in the process of architecture classes, within the curriculum of the Restoration of cultural heritage, and the creation of a culture on the architectural value of the objects under study, their preservation and maintenance.
- “Numerical analysis, F.E.M. models and engineering simulations”. Based on the results of the previous step, aggregations of recent experimental results and a summary of analogous study interpretations were discussed and compared with the numerical analyzes of these three-dimensional models, part of this study.
- “Interpretation of results, and creation of a standard methodology” for the investigation of structural problems, through a delicate process including the architectural sensitivity of cultural heritage objects. Addressing the structural issue through a delicate process of identifying the values of buildings and attempting long-term intervention strategies, without affecting their aesthetics. Also treatments of engineering issues according to a matrix of combinations with theoretical principles of restoration.

In order to define the objectives of the thesis as accurately as possible, an approach with historical emphasis was treated, referring in particular to archival projects, design manuals of that period, and the study of analogous projects in this field. This research tends to provide valuable information for the structural analysis of facades, masonry and infills, from architectural geometric aspects to the study of Italian technology and building codes in the past. The results of this research are analyzed concisely in each case separately, which can represent a valuable theoretical and practical support for researchers and engineers involved in the seismic analysis of masonry for cultural heritage sites.

The on-site investigation phase and the survey process were essential to develop a valid theoretical expertise for further studies on this masonry typology. To mention what was stated at the beginning, the main purpose of this study was the simulation analysis and seismic performance of Cultural heritage buildings. The objective can be considered fulfilled, but some considerations need to be analyzed and elaborated. The main concern and limitation of this research was the implementation of FEM analyzes for seismic simulation of masonry. However, the finite element model showed expected results, and building responses, comparable to what really happened. The comparison between numerical results and on-site facade damage monitoring showed a significant correlation.

Regarding the numerical models used, great attention has been paid to the rigidity of the masonry surface elements and layers, making an addition and equivalence of layers in the model as loads. First, a simplified schematization of the masonry block model was proposed, ensuring a considerable combination of layers. Second, the effect of surface layer stiffness was discussed and tested in the first model, analyzing and investigating without significant differences in terms of failure mechanisms and bearing capacity of these panels.

In more detail, several tentative strategies were attempted to model the masonry as the load / mass accumulated and discretely between the bricks and mortar. From the point of view of safety coefficients, the application on both sides of the spandrels of the equivalent load of the horizontal layers of mortar turned out to be more conservative. Under the two boundary conditions, the most influential parameters appeared, usually represented by tensile strength and tangential stresses in the masonry panels. Also, the potential effects of damage on a larger or global scale were analyzed and observed.

Summarizing some of the aspects addressed in this study, the problems found, the limitations identified, the methodology used, analogous case studies, theoretical principles of restoration, the recommendations of the Venice Charter and driven by the challenges that arise today, we are aware that we are living in a period in which identities are characterized and become increasingly distinct. Europe and the Balkans at the moment are characterized by cultural diversity and consequently by the plurality of fundamental values in relation to dynamic, immovable and intellectual heritage, by the various meanings associated with it and consequently by conflicts of interest.

This requires all experts responsible for the preservation of cultural heritage to be increasingly sensitive to the problems and choices they have to face in order to pursue the objectives set out.

Each community, through its collective memory, history and awareness of its past, is responsible for identifying and managing its architectural heritage. This cannot be defined or solved in a fixed way, with a formula. Only the way and methodology can be determined how the heritage and its values can be identified, also the previous studies can be advanced and some of the gaps can be filled. Creating matrices where it is attempted to provide ways for the most optimal and efficient solution of these problems. Plurality in today's society also implies a great diversity of the architectural and technical concept of cultural heritage as conceived by the entire expert community and beyond. Architectural works, as the only tangible elements of heritage, are carriers of values and wealth that can change perspective over time. This variability of values that can be evidenced in architectural monuments is, from time to time, the complicated specificity of heritage in different moments of the history of our cities.

Through this dynamic transition process, each country and community develops awareness and campaigns for the need to protect the particular elements of buildings as identifiers of the values of its common architectural heritage. The methods required very carefully to achieve a correct protection must be adapted to different situations, in accordance with the basic principles of restoration, undergoing a constant process of change and updating. The careful context of selecting these values requires the preparation of a long-term conservation strategy and a set of well-structured decisions. These should be algorithmically codified in a model restoration project designed on the basis of appropriate architectural, technical and structural criteria.

- Maintenance, retrofit interventions and repairs are a key part of the architectural heritage preservation process. These intervention operations or retrofit strategies should be organized through systematic scientific research, on-site inspections, control, monitoring and testing of material samples. Possible degradation of the material should be predicted and described in detail, as well as subject to appropriate preventive measures as appropriate.
- The conservation of the identified cultural heritage should be realized through the model of a genuine restoration project, which includes strategies for its conservation in time. This restoration project should be based on a set of principles, choices and appropriate technical solutions, also be prepared within a methodological process that includes the collection of sufficient information and an in-depth knowledge of the building, parameters and technical data on materials, causes of problems and equivalent models where multiple simulations have been performed on the performance of the object under study. This process includes structural, seismic, thermal investigations, graphical and dimensional analyzes and diagrams, as well as the identification of historical significance or values, artistic and socio-cultural; The project requires the involvement of all relevant disciplines mentioned above and to be coordinated by a group of qualified persons with experience in related fields.
- Due to the vulnerability and special risk of our cultural heritage, any intervention related to it should be strictly related to the context of the location, the principles of the restoration charter, its territory and landscape. The destructive aspects of new constructions by proximity to heritage, should be limited as much as possible. Architectural artifacts and valuable elements must be fully documented and digitized for each building. As in other cases, the intervention should follow the principle of minimal intervention and should be performed by a group of experts with strictly controlled techniques and methodologies.
- Re-establishment of an entire building, destroyed due to earthquakes or natural causes, is allowed only in the presence of extraordinary social or cultural arguments, related to the identity of an entire community.
- Re-construction of all parts and elements, "in style or by style" should be avoided as much as possible. Interventions in limited parts which show architectural importance, can be accepted provided that they are based on convincing arguments, accurate documentation and indisputable reasons.
- Architectural decorations, frames and artistic artifacts strictly related to the built heritage must be preserved and treated through a specific project parametrically related to the general one. The restoration project must guarantee a correct approach to the

conservation of the entire structure, decorations and motifs, respecting the traditional techniques of the designer, also their necessary integration as an essential part of the built heritage.

- The strategy of interventions and seismic readjustment of buildings in the long run, is closely related to interdisciplinary research on materials, design codes and old technologies used in the construction, repair and restoration of built heritage. Again regarding the principles of restoration, the type of intervention selected must respect the current function and ensure compliance with existing materials, static loads, structures and architectural values. New materials to be used and new technologies must be rigorously tested , analyzed with computer models and numerous simulations performed to predict any adverse situations, BIM modeling and applications, compare parameters and adapt to real storage needs. When the in situ application of new techniques takes on a special importance for the preservation of the original variant, it is necessary to ensure a continuous monitoring of the results obtained, taking into account their timely conduct and the possibility of possible restoration. The knowledge of materials, physical-mechanical parameters, traditional construction techniques and their archival conservation in the context of modern society should be stimulated, being in itself an important component of the cultural heritage of the country .
- Regarding the recommendations and principles of the Venice Charter, the historic areas of cities, in territorial terms, represent an essential part of the heritage related to the objects under study and should be addressed in the ensemble of structures, spaces and uses, allowing the process of evolution and stages constant change. This includes all professionals, awareness and activation of the population, also requires an integrated urban planning process, within which a wide variety of interventions are placed. Interventions in buildings should always consider the reference of the city in its morphological, functional, structural, and surrounding landscape.
- The diversity of values of architectural heritage and the diversity of today's interests require a communication matrix that ensures the necessary and active participation of residents in this process, specialists in the field and administration. It is imperative for the community to create appropriate methods and structures to ensure the efficient and effective participation of individuals and the attention of institutions in this decision-making process.

Regarding the types of conclusions that were discussed above, an attempt has been made to provide an applicable methodology for dealing with a delicate issue, an efficient method for the careful handling of Tirana's heritage, and some recommendations which do not attempt to solve all the problems, but to provide innovative ideas in improving the process of restoration and conservation of architectural heritage.

The study tries to connect the Albanian context with the Italian cases to enrich the current experience, to start a new phase in the treatment of architectural heritage, with a professional spirit and without the influence of certain interests. The study through in-depth treatment of archival projects has become part of the documentation and digitalization of cultural heritage objects. Also the treatment done and the findings of this study are made fully available to other researchers to advance with other aspects more applicable in relation to the strategies and projects of restoration.

7.2 Comments and Recommendations on Modeling, findings from the interaction of data files

During this study, numerous database models were created referring to 3 case studies. 3D models and related files include geometric, graphic and numeric data. The main part of the study is based on the connection of the architectural model with the structural one by making such parameterizations to create the possibility of many simulations. The BIM and H-BIM models were carefully studied, then the essence of their methodology was taken, to become theoretically applicable to the Albanian case. However, the applicability of the methodology in a fixed way for every possible case cannot be claimed. Cultural heritage cases are specific and require detailed customized annexes or appendices to take into account a greater range of parameters. Although in this study, in the applied part, many seismic simulations have been performed, and are considered as a priority, in the context of the methodology they remain equivalent to other links, such as architectural survey, digitalization, environmental simulations or time transformation analysis of the building.

The database and numerical files of multiple 3d models cannot be effective if they are not properly interconnected with each other or without creating simulation parameterization. In the scheme of Figure.181 is shown as a set of files that supply data to the BIM model, and how the BIM model provides and receives information continuously, aiming to create frequently updated computer models, which are not only used for digitalization, digital archives or restoration projects, but also perform the role of continuous monitoring of the performance of the building.

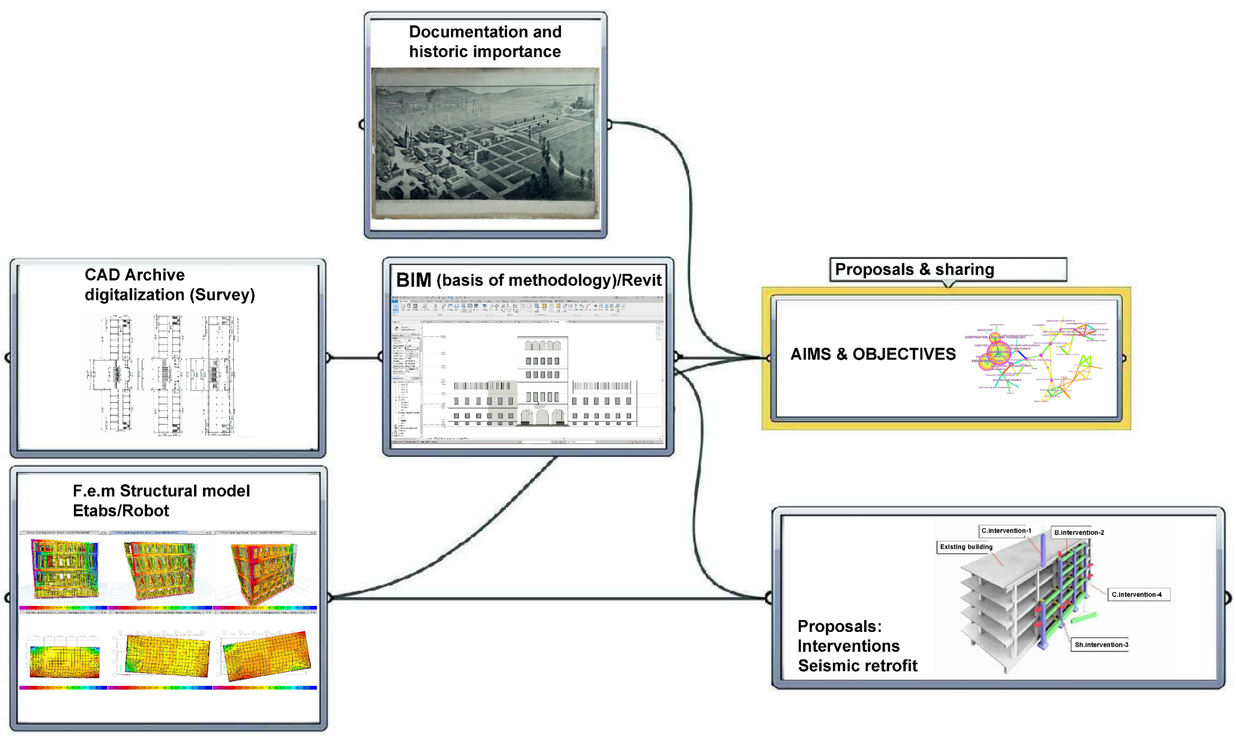


Figure 181. Interconnection of systems, explained in data file networks, referring to the second case

Based on this output scheme, it can be accepted that one of the limitations of the study is the placement of sensors currently in buildings, although many computer simulations have been done, but the part of their continuous investigation is missing. The recommendations are for each building to have sensors in the framework of structural performance, mentioning masonry monitoring, mechanical parameters of materials, displacements, distribution of stress-strain in panels, etc. The second group of sensors that are recommended is in the environmental field, such as monitoring the humidity on the surface or inside; mold, parasitic vegetation, shrinkage of concrete or masonry, monitoring of masonry performance in frost periods; various pathologies or masonry fractures due to weather; joint monitoring; etc. In this category of recommendations care should be taken in creating a central system which collects data on the server and distributes in numerical and graphical form the results required for analysis.

We can say that a new step beyond this study is the combination or parameterization of the method, specifically models, with archival projects, researches and continuous data collected from site-monitoring conducted by the institute of cultural monuments or institutional government units, the creation of an "updated digital-archive in real time" for each object of cultural heritage and their access by all professionals as stakeholders in the issue of restoration.

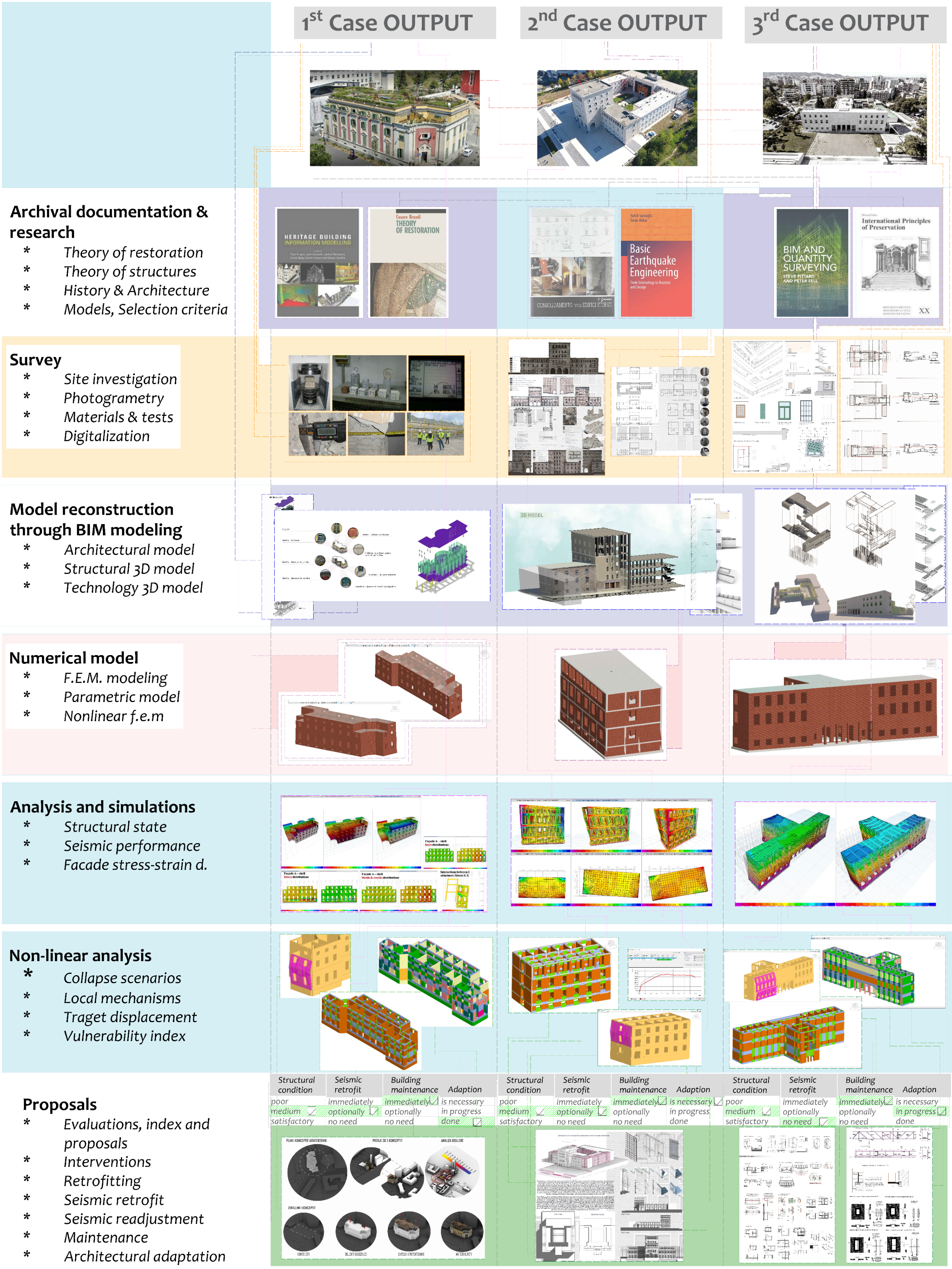


Figure 182. Summary diagram on the generated outputs for the 3 case studies, according to the methodology proposed in this thesis

The database of 3D models presented in Figure.182, is the result generated according to the applied methods BIM and F.E.M. In the analysis of this output product can be considered something more than a point-cloud obtained from site drone photography, as it gives us the opportunity to have comprehensive data and information about the geometry of the structure and its behavior, materials and their parameters, as well as relate to satellite models for simulations. So this 3d-model database, is the starting point for many structural simulations or more, such as earthquake-related simulations, structural studies or analysis, environmental simulations, energy simulations to the conservation, maintenance and intervention project of restoration. In the summary diagram with the outputs shown in Figure.170 specifically for each model analyzed according to the proposed methodology, specific evaluations are made:

- On the current state of structural performance, evaluating with three levels "poor, medium, satisfactory";
- Seismic retrofit needs assessments evaluated with three levels "immediately, optionally, no need";
- Assessments on continuous monitoring and maintenance of the building, including of particular importance the monitoring of facades, including three level assessments "immediately, optionally, no need";
- Assessments on the architectural adaptation of the building or reconfiguration in relation to the needs of the institutions for expansion, including retrofitting, side additions or temporary seasonal additions, interior architecture modifications such as wall removals or wall additions, etc. With 3 levels of evaluation "is necessary, in progress, done".

From the findings of the simulations, the structural performance was evaluated as average (starting from a conservative point of view). Beyond the concern of possible local damages, mainly the buildings show satisfactory seismic performance, so regarding the need for seismic retrofit for all three buildings, currently it’s not necessary, although detailed recommendations and proposals are given for each possible case at risk. Frequent maintenance and monitoring of all buildings has been evaluated with special importance and current needs. While for category four we have different evaluations for the buildings, ascertaining during the investigation phase that in the case of the Municipality building the adaptation has been done, mentioning the 1993 addition and the internal transformation, without forgetting the seismic performance analysis of both blocks. In the case of the Polytechnic University building, an intervention in this context is considered necessary. While for the 3rd case, the University of Arts is currently in progress a partial intervention that consists in the transformation of the concert hall in the western block. All these findings are formulated in the context of careful proposals to be considered in future studies or by the design firm which will carry out the relevant interventions.

A good relational database, which tends to store as much data as possible about heritage buildings is conceived and designed by connecting to the basic 3D model. The structure of the methodology is designed to be quite flexible for handling the large amount of data that is entered or intertwined towards the model, from multidisciplinary case studies. Choice to push the entire model data network with a central "model-BIM" database, where they interact with each other, information in the numerical and graphical database, or connection to satellite models. Referring to this, the flexibility of the system within the methodology is ensured.

The flexibility of collecting and managing basic data is essential in this methodology when it comes to handling cultural heritage buildings. The principle of methodology is sensitive to specific case studies and in addition to data collection, does not provide standard intervention solutions for each case. An attempt has been made to create an input-output system adaptable to the specific treatment requirements of each case.

The theoretical-applied platform created in the framework of the improvement of the methodology of the Restoration issue in Albania, based on theoretical studies, investigations and analysis in relation to three selected case studies, establishes a theoretical basis on which it is possible to continue the integration of other investigations. To create a complete and functional digital archive based on multidisciplinary 3D modeling, historical context, architectural surveys, typology, materials, architectural elements, structure and multidisciplinary simulations.

The methodology developed and adapted for the Albanian case offers an experimental model and an opportunity for improvement or reflection on the systematization of the required data, for the proper management of restoration processes, improvement of structural performance and adaptation of monument buildings to future plans.

The disclosed method highlights the possibilities for using BIM and fem models to address the issue of restoration. The announced target is the creation of opportunities for effective use by professionals, academic fields, as well as by government bodies or the institute of cultural monuments for the protection of heritage buildings. This is essential and only in this way can it be achieved to fully implement an application of this method in the Albanian context, achieving the creation of an effective interdisciplinary relationship.

Normally, a number of boundaries or limitations are still present in this study mainly in terms of the interconnection of modeling between software’s. While it must be acknowledged that a satisfactory level of performance of the models has been achieved in relation to the data obtained in the field during the architectural survey, or in relation to the archival projects, we can admit that an acceptable level of data integration has been achieved, indicating great potential for further developments for integration and high efficiency in the context of preservation, monitored maintenance and adaptation of cultural heritage.

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8. APPENDIXES

8.1 APPENDIX A. "The former building of National Theatre". Numerical analysis and investigations, before and after demolition - CASE IV

8.1.1 The historical and architectural context of the case

Ex "Italo-Albanian circle, Skanderbeg", the national theatre building was built in 1938 by the Milanese design company Pater, special constructions immediately behind the Ministry of Public Works. At the time of design it was a multifunctional building (with presence of a swimming pool, sports fields, restaurant, theater and some halls) organized into three buildings blocks linked organically by a porch. Regarding the Italian style of architecture of the time, the volumetric composition was strongly symmetrical, also highlighted on the I by two tower heads corresponding to the two longitudinal buildings, the internal space of the courtyard was contained between two porticoes, one longitudinal between the I towers and the other circular exedra on the back. The facades of the two longitudinal arms, symmetrical, recalled a post-futuristic language halfway between Sant'Elia and a painting by De Chirico . From the constructive point of view, it was an experimental building built with the patents of Pater Studio in a mixed structure of cement walls combined with populit panels and wood truss structure in the roof.

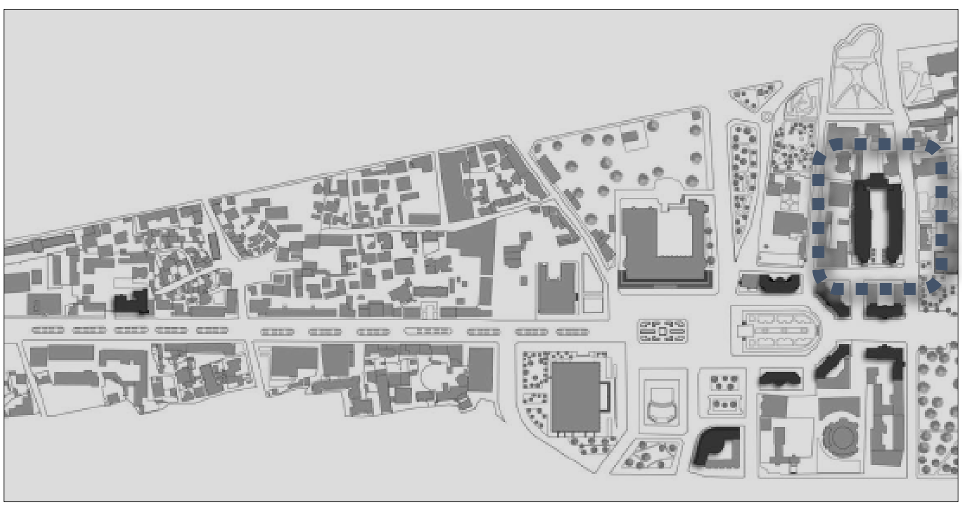

Figure 183. National theatre location and positioning with the central square (Menghini , Pashako, & Stigliano , Modern Italian architecture for the cities of Albania, 2012)

Over the years, through a difficult transition phase the building has undergone various tampering's with respect to its first configuration, as early as 1943 the Town Plan envisaged the demolition and reconstruction of the porticoes on both sides (not carried out); between 1945-1947 there was a modification of the rear porch and the architectural re-functionalization of the national theater, subsequently changes were made to the covers of the service spaces for the theater and offices; in 1954 the rear side of the courtyard was closed with a rectangular building used as a carpentry shop. Until 2020 the building houses the National Theater, externally restored, its interior is in many parts dilapidated. The new Master Plan of the center of Tirana in 2002 foresees its demolition. Unfortunately, in the spring of 2020, the building was demolished by the municipality of Tirana by a government legal order, regarding its degraded condition and its non-functionality regarding the requirements of the institution.

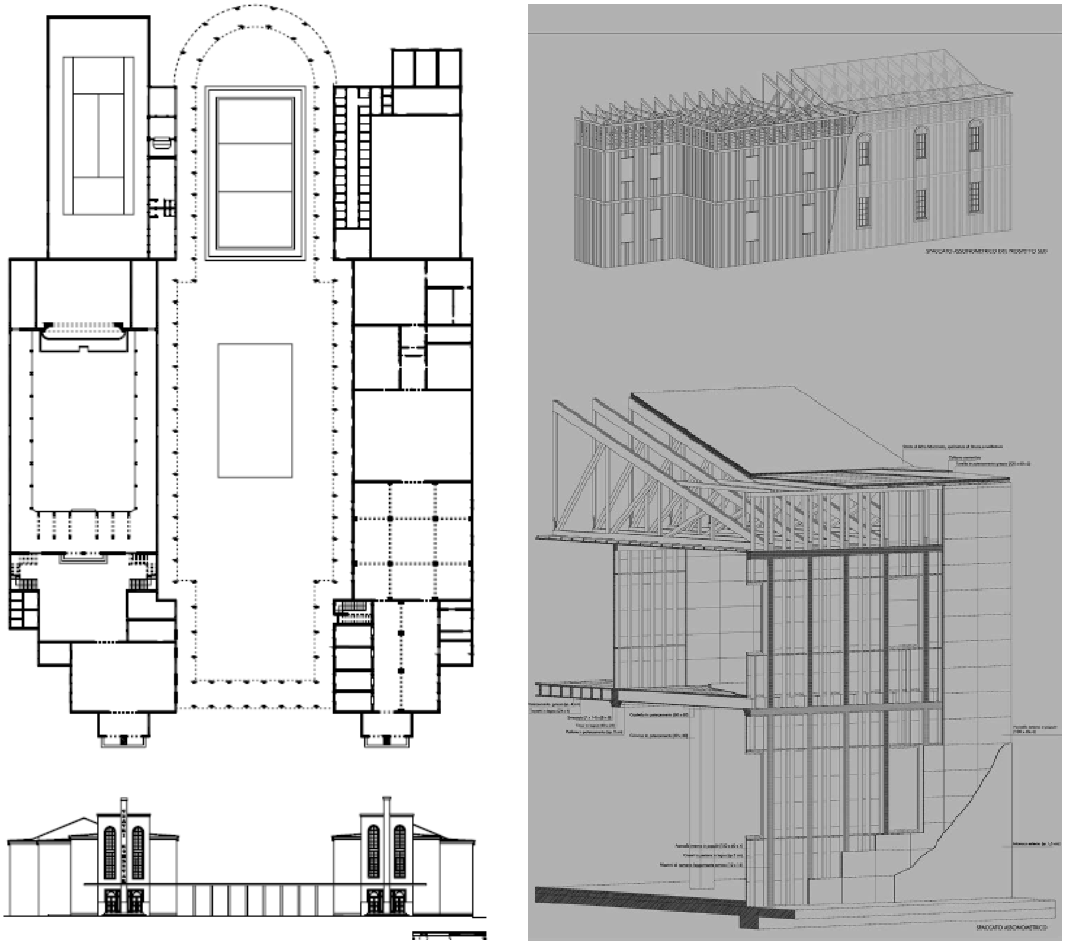

Figure 184. National theatre ground floor plan, main façade view and technical details of the structural project (Menghini , Pashako, & Stigliano , Modern Italian architecture for the cities of Albania, 2012)

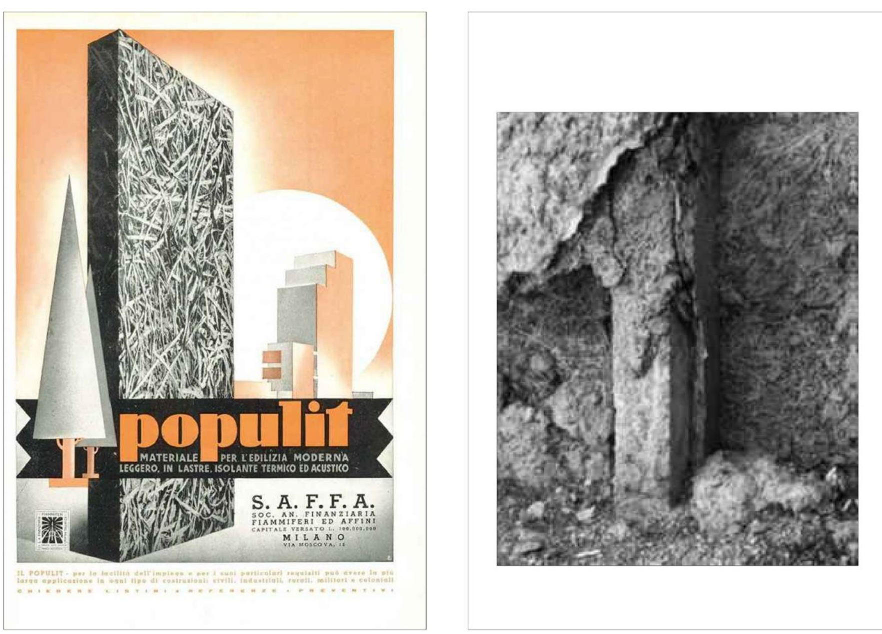

Figure 185. National theatre structural details and "populit panels" used on structural masonry (Ermanno Tunesi, 2019)

The wall openings are made between the concrete columns and consequently always have the same light-length. A collaborative role played by the wooden boards of the 3x15 cm section which reinforce the vertical structure and are disposable formwork for the pillars. The casting of concrete for the realization of the supporting pillars therefore took place between the wooden planks and the “populit slabs”, used as infill, as it appears from the traces still visible today.

This material, produced by “S.A.F.F.A. (*Società Anonima Finanziaria Fiammiferi e Affini*)” was an agglomeration of vegetable substances (poplar chipboard fiber, waste product from the factory of matches and seaweed) mixed with high-strength cement that allowed the creation of a resistant product, with good thermal and acoustic insulation. Today many of the original functions of the club have disappeared and the complex houses only a theater and its service spaces. The portico, consisting of cylindrical concrete pillars, which connected the various buildings to the demolished state and the entire complex has undergone many changes over the years: in fact, extensions and superfetation’s that have changed the volumes and the shape of the courtyard are recognizable. At the planning stage, the refurbishment of the complex was hypothesized: the right wing was destined for the City Museum of Tirana while the left wing chose to preserve the theater by annexing spaces to be used for classrooms, laboratories, services and exhibition spaces.

It was also chosen to demolish all the extensions and superfetation’s made over the years, safeguarding the original parts of the complex and creating a transversal volume between the two longitudinal bodies, a sort of fifth, with the function of connecting the various levels, accessible through a monumental staircase, below which there is a conference room.

The expansion was achieved through the iteration of wooden portals grafted onto a stone base and a continuous casing also made of wood. The full-height museum space, below which a large underground room develops, is divided into long galleries by means of a series of wall boxes containing niches and small exhibition areas.

The elevations of the museum extension, made up of movable panels to regulate, together with those of the roof, the entrance of the light, have large engraved or raised writings of futuristic ancestry, as if they were “graphic pages”, thus creating that fusion of architecture and visual arts typical of the years in which the building was born.

The ephemeral nature that had characterized the construction of the building is declined in light of new construction needs and technologies, accepting its appearance as a temporary pavilion and reinterpreting it as a large “exhibition machine”.

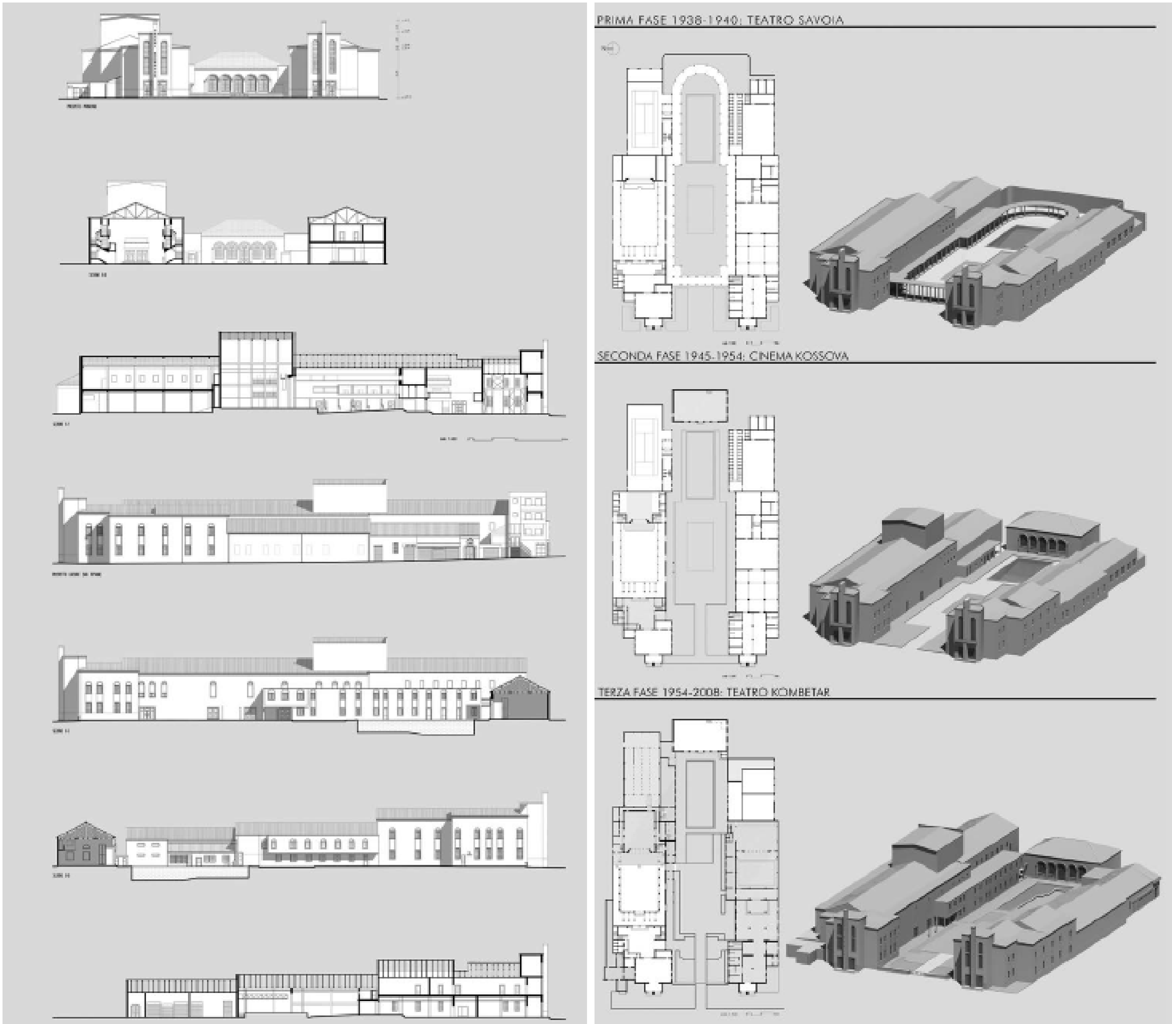

Figure 186. National theatre project details and building evaluation (Menghini, Pashako, & Stigliano, Architettura Moderna Italiana per le citta d'Albania, Modelli e interpretazioni, 2012)

This case study is focused on the context of Tirana's cultural heritage buildings, designed during the 1938-1939s. Tirana represents a special scientific occasion, unique in terms of researching Italian design mixed with Albanian layers over the years. This feature has resulted from many political, economic and social factors of the time that fundamentally changed the way of vision and architectural conception in our capital.

Every cultural heritage is inseparable from history as a witness of which it is, as well as from the place where it is located. Consequently, complete or partial interventions in a cultural heritage may not be permitted, except cases when the preservation of the heritage requires, or when this is justified by reasons of great national or international interest.

This study aims to analyze the restoration of these buildings, by means of seismic retrofit ways, preserving aesthetic and historical values. The main goal is to turn these buildings into full use of their previous function, increase their lifespan or value identification in our case.

The focus of this study is the identification of structural problems in these buildings, secondly 3d modeling, simulations, scenario-investigation and in-depth structural analysis.

In this work the peculiarities of the global response of old building are shown with the aid of a simplified physical 3d model, realized with SAP2000 software, able to reproduce earthquake damage to composite-masonry buildings and failure modes observed in experimental tests. The application of this methodology to Albanian composite-masonry typologies points out the difficulties related to existing buildings.

8.1.2 Theoretical interpretations of the case and methodology used

The historical and architectural heritage of Tirana is located along the main axis and the main boulevard of the city. A valuable part of this architectural heritage over time is losing the attention of citizens and the government, demolishing to build high towers. One of these heritage objects of Tirana is complex of the National theater buildings, which was just demolished by the government this june. The national theatre represents features of Italian architecture integrated with Albanian motives during the years. Italian architecture changed the image and history of Tirana, giving it a modern-style referring to the time was a building full of elegance and architectural harmony. Over the years this building changed its function several times. Also, small non-structural interventions have been made several times. (Menghini, Pashako, & Stigliano, Architettura Moderna Italiana per le citta d'Albania, Modelli e interpretazioni, 2012)

The relationship that the Italian architect built from time to time with the new geographic and cultural context was certainly a guide to his preparation and sensitivity. (Prifti, 2017)

The structural typology of the building of arch. F. Di Fausto, A. Brasini and G. Bosio consists of building types with retaining walls combined with columns in some cases. The thickness of the walls varies and is reduced by the height of the building, the foundations are of stone and can be considered continuous beams, between the floors there are thin concrete beams and the slabs types works as shells [37]. The facades of these buildings are carefully crafted with decorative details of traditional Albanian motives, accompanied by the charm of the Italian architecture. The preservation of historical buildings from damage due to earthquakes, also the need to make their structures stable and safe, especially for their historical value, became essential, also to restore forgiveness and attention to them.

Due to reasons such as age of building, interventions made by people, interventions by modifying the interior facilities of the buildings, or adding new parts, the old codes design methodology [38] of the time, these types of buildings are vulnerable to earthquakes (Mitrojorgji, 2015). It is therefore important to evaluate the seismic performance and the life of these buildings. So, based on this assessment, techniques must be developed to strengthen these buildings in order for them to resist potential earthquake damages and other challenges in the future. The buildings that will be part of this study doesn't have RC-columns and beams. Their main structure is based on the brick masonry URM typology. Therefore, they are more vulnerable to seismic action [39]

[37] Shell-type behavior: both in-plane membrane stiffness and out-of-plane plate bending stiffness are provided for the section. The Shell type will combine the rigidities from both Membrane and Plate.
[38] Albanian technical code and Italian design code (1920-1940)
[39] Shaking and seismic frequency activity.

As a traditional building, this typology can be found almost in all the central part of Tirana. Consequently, it may be subjected to different climatic conditions and may have suffered various degradations .

A common or a frequent approach is to treat all cultural heritage assets similarly, which results in a skewed list of priorities. On the other hand, it should be recognized that seismic risk varies from building to building or cultural heritage asset to cultural heritage asset. The widespread assumption that risk is low is frequently caused by erroneous observations: If a monument was built several hundred years ago and has remained relatively unscathed in recent years, this does not mean that the risk is low. There is evidence that a significant number of really ancient monuments collapsed during the recent quakes.

This perfectly acceptable sentence demonstrates the critical nature of correct architectural design and ongoing maintenance. While testing from previous earthquakes is well documented, structural safety can be attained only with the assurance of good design, continual maintenance, and testing.

Finally, degradation of construction materials and damage caused by recent earthquakes are a concern, particularly when these were not restored adequately or at all. These factors may result in considerable losses in the seismic capacity of the building. Consideration should always be given to damage accumulation. The idea that old construction is synonymous with good construction is once again called into question by the inexorable march of time. With our case study shown below we estimate and evaluate the selected building to the action of seismic elastic spectrum [40] according the Euro code 8. According the methodology, it is used the static linear analysis [41] and the masonry of the building is modeled with nonlinear behavior [42].

8.1.3 Explanations and interpretations on the structural model used

The seismic risk class depends on one parameter: which takes into account the damage and refers to the cost of reconstruction of the building; taking into account the achievement of the limit state to ensure the safeguarding life of people inside the building, during an Earthquake (life safety level)[43]. The use of F.E.M. model[44] interpretation of the crack Pattern and their distribution.

The assessment of seismic performance of U.R.M. buildings[45] requires the identification of the collapse mechanisms and masonry local damages step by step activated by the synthetic earthquake (elastic demand spectrum) [46]. Referring the current practice in our region has been

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40 Elastic spectrum represents a series of synthetic equivalent earthquakes summarized in one.

41 A linear static analysis is an analysis where a linear relation holds between applied forces and displacements. In practice, this is applicable to structural problems where stresses remain in the linear elastic range of the used material.

42 Methodology for modelling the unreinforced masonry with nonlinearity characteristics for each layer of the wall on ETABS, a possibility to create the wall as close as possible to reality.

43 Second level mostly used for designing civil structures based on seismic performance levels [Eurocode 8]

44 The finite element method (FEM), is a numerical method for solving problems of engineering and mathematical physics

45 Unreinforced masonry building typology, without reinforced concrete frames.

46 Merging a number of strong short-period ground motions and long-period ground motions. From the merging of these accelerograms, an elastic specter is deduced.

taken into account only three first modes of failure, by studying the capacity curves of certain structural typologies, to get the right strategy for strengthening and updating the structure.

The modelling of the structure behavior and its safety assessment by mesh process (finite-elements) can highly benefit of the ETABS, which enables us to create layered walls, considering the non-linearity of each layer that represent materials data. (Vesho, Guri, & Marku, 2019)

The most important step is transformation and conversion of panels in piers and spandrels labeling [47]. The vertical panels working in compression are converted in the Piers (frame elements that work in compression), while the horizontal panels under the openings below are converted to the spandrels (beams in bending) (Pitilakis, Crowley, & Kaynia, 2014). The methodology for the analytical part was performed on modal analysis (CEN Eurocode 8, Eurocode 8: Design of structures for earthquake resistance Part 3: Strengthening and repair of buildings, 2003).

Investigation procedures: In general the necessity of monitoring and investigating the building integrity or the load carrying capacity of a unreinforced masonry building arises for several reasons including: assessment of the safety and stability of the structure before or after a seismic event, extension of the building and also the change of use, assessment of the effectiveness of repair innovative techniques applied to structures or different materials, and long-term monitoring of material parameters and structural performance. (Binda, Saisi, & Tiraboschi, June 2000)

8.1.4 Modal analysis "Structural evaluation and seismic performance of the National Theater, Tirana"

Below is presented the object to be analyzed, the National Theater building after interventions. The constructive-structural project with drawings and technical specifications for this building are taken from the technical archives of Tirana, to be analyzed and investigated later.

[47] pier = column, spandrel = beam. Both piers and spandrels are equivalent panels constructed of shell elements, showing the element way of work according the static concept.

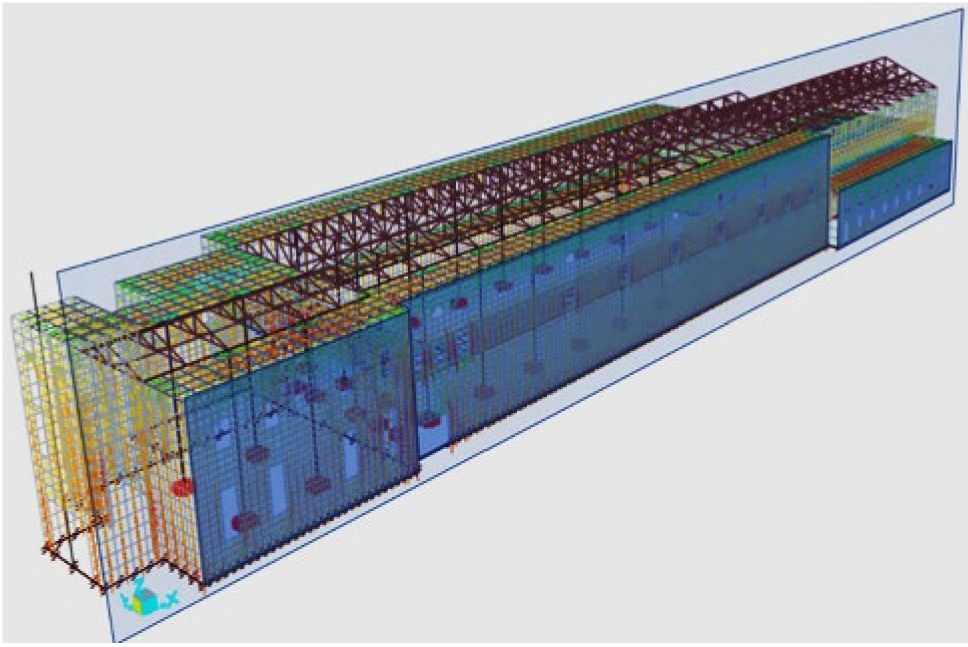


Figure 187. The National Theater finite elements structural model analyzed (SAP2000 V.22)

The typology of the existing building is a composite-masonry structure which consist of a mixture between wood and concrete with 2 different masonry thicknesses, 23cm at basement level and 20cm. The last thickness is mainly used as a separating wall between rooms and on the upper levels. (Menghini, Pashako, & Stigliano, Architettura Moderna Italiana per le citta d'Albania, Modelli e interpretazioni, 2012)

This kind of masonry structures have low masses and they respond well to seismic waves, but due to the interventions that have been occurred the masses have changed.

The building has been modeled in SAP2000 v22 and due to the lack of the program for masonry type of buildings the masonry has been modeled as a reinforced concrete wall with a decreased capacity.

Mechanical properties of masonry:

- Material property data — Masonry
- Directional symmetry type: — Isotropic
- Weight per unit volume: — 8 kN/m^3
- Mass per unit volume: — 256 kg/m^3

Material mechanical property data:

- Modulus of elasticity: — E=18608 MPa
- Shear Modulus: — G=7753 MPa
- Poisson's ratio: — u=0.2
- Coefficient of thermal expansion: — $A=10^{-5}$ 1/C

The masonry behavior is modeled as a linear shell-thin with a low compressive strength concrete. The importance is to see where the combination of the vertical stresses S1-1 and the horizontal stresses S2-2 would intersect and create additional stresses.

8.1.5 Seismic parameters

Eurocode 8 have a detailed specific way to calculate the seismic spectrum. In this case it depends on several factors: peak ground acceleration p.g.a, the category of the soil, the predicted magnitude (*in the case of Albania is used M > 5.5*) and the behavioral factor. This last one as a concept is comparable to the inverse of ductility. Given the studies, Albania has a variety of seismic peak ground acceleration from 0.15-0.31g. (CEN Eurocode 8, 2008) With the same reasoning as above, we choose the seismic acceleration that has greater surface in the seismic map. Eventually the selected parameters are:

- Soil category: C
- Spectral acceleration: ag/g = 0.27m/s^2
- Direction: Horizontal
- Behavioral factor: Damping factor: 5%

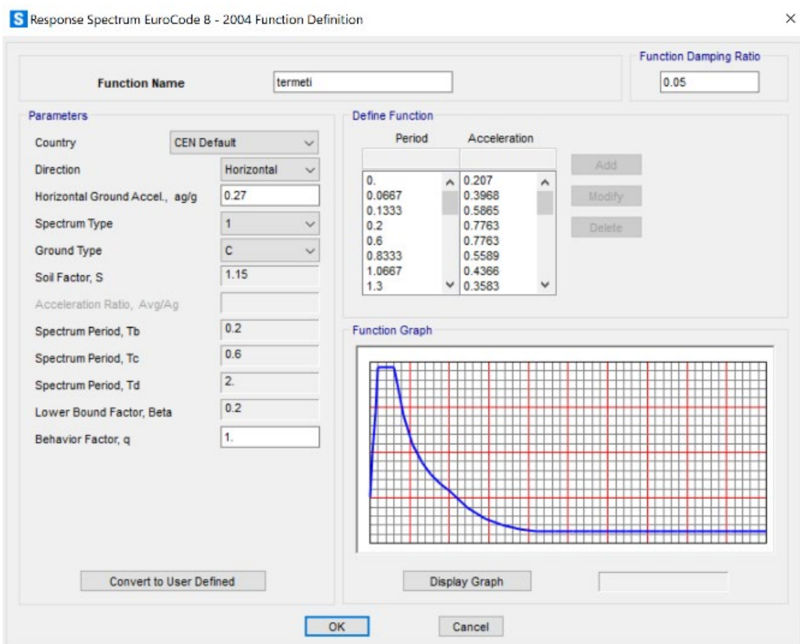


Figure 188. Elastic demand spectrum, referring Tirana ground parameters (SAP200 V22)

8.1.6 Seismic analysis and results obtained

Given the above explanation in methodology, historical heritage was primarily analyzed to define seismic parameters and their walls load carrying capacity.

Modal analysis was used also in this case to establish the structure's fundamental seismic "modal-shapes" and "natural frequencies" parameters of self-vibration during the earthquake. The goal of modal analysis is to determine the structure's maximum response in each of its significant modes, which are then summed appropriately. The structure was subjected to a modal analysis using a mixture of several modes of vibration in accordance with Eurocode methodology.

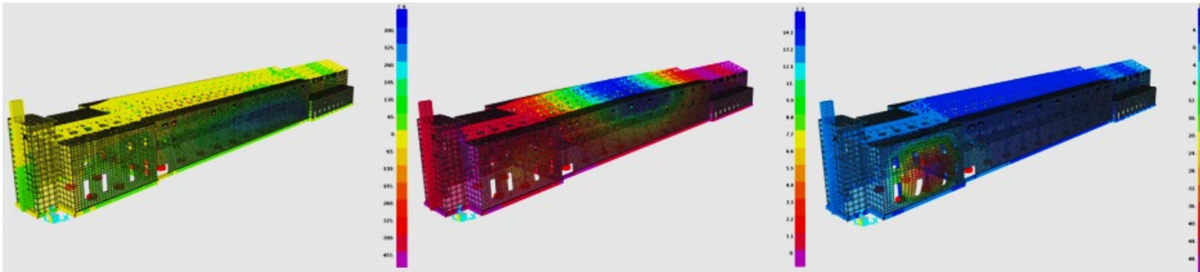


Figure 189. First 3 modes of vibration according to SAP2000 V22 for the case study

OutputCase	StepType Text	StepNum Unitless	Period Sec	Frequency Cyc/sec	CircFreq rad/sec	Eigenvalue rad2/sec2
MODAL	Mode	1	0.490144	2.04021740...	12.8190640...	164.328402...
MODAL	Mode	2	0.367381	2.72197177...	17.1026530...	292.500741...
MODAL	Mode	3	0.348863	2.86645507...	18.0104684...	324.376973...
MODAL	Mode	4	0.327664	3.05190840...	19.1757060...	367.707703...
MODAL	Mode	5	0.285879	3.49798084...	21.9784618...	483.052784...
MODAL	Mode	6	0.255425	3.91504389...	24.5989462...	605.108156...
MODAL	Mode	7	0.246978	4.04894648...	25.4402810...	647.207900...
MODAL	Mode	8	0.24152	4.14043852...	26.0151424...	676.787638...
MODAL	Mode	9	0.237891	4.20360048...	26.4120008...	697.593786...
MODAL	Mode	10	0.235172	4.25221222...	26.7174373...	713.821458...
MODAL	Mode	11	0.233253	4.28718464...	26.9371756...	725.611429...
MODAL	Mode	12	0.230605	4.33642688...	27.2465736...	742.375777...

Figure 190. Modal data, frequencies and seismic parameters, obtained from the technical report generated in the software (SAP2000 V22)

Modal parameters reffering the allowed period formula: [T]= 0.075 * $H_b^{\wedge\, 0.75}$ (CEN Eurocode 8, Eurocode 8: Design of structures for earthquake resistance -Part 1: General rules, seismic actions and rules for buildings, 2008)

First mode: T1=0.49 s > [T] Translation move on X-direction
First mode: T2=0.367 s Translation move on Y-direction and presence of torsion
Third mode: T3=0.348 s Torsion

The problematic part that needs to be studied critically is in the Y direction due to the fact that the structure is more flexible in that direction and it shows problematic displacement in the middle of the building. This phenomenon is problematic because it causes additional flex and in masonry buildings normally this causes serious problems.

To get more detailed information for the vertical and horizontal stresses the south part of the building has been mashed 50cm by 50cm.

On the south side there are 3 surfaces and each surface has been studied individually as follows:

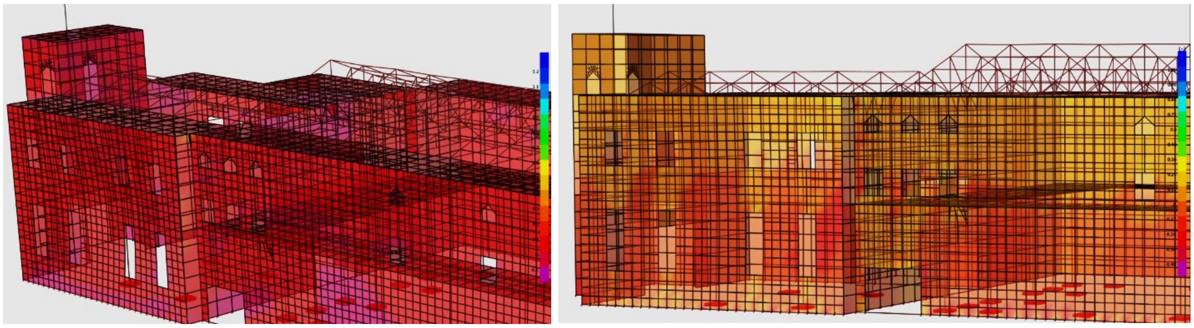


Figure 191. Main stresses distributed on the surfaces taken in the study (SAP2000 V22)

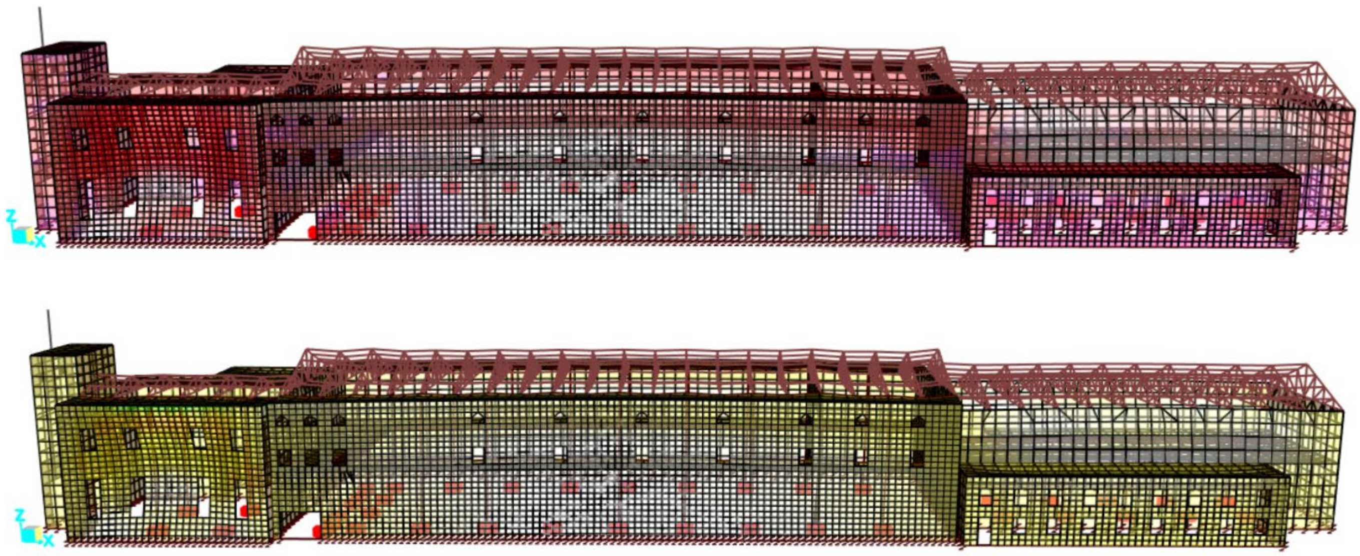


Figure 192. Distribution of stresses in the longitudinal I of the building, according to the two components σx and σy (SAP2000 V22)

The minimal stress amount occurs on the lower end of the building and the maximum on the upper part, the part where the roof lay. Beside the uniform stresses there is one concentrated stress on the upper left corner of the second surface. The maximal uniform stresses are between 1.2-1.6 N/mm^2 and the maximal concentrated stress is 4.2 N/mm^2 which is a way higher value than the 1.1 N/mm^2 which is the maximal stress allowed on masonry buildings. (CEN Eurocode 8, Eurocode 8: Design of structures for earthquake resistance -Part 1: General rules, seismic actions and rules for buildings, 2008) This kind of stress has been removed on the other corner due to the seismic gap that has been applied on the model.

8.1.7 Summarized conclusions and recommendations

This study focuses on historical heritage masonry structures situated in Tirana, located in a seismically active zone. The objective was to analyze damage mechanisms and seismic vulnerability of the selected building. First a brief description of structural features and architectural characteristics of Italian typology was presented. This is followed by modelling one of the most typical building of this period to visualize structural response behind seismic events. A F.E.M 3D model was prepared in order to show behavior of the structure and its probable local and global weaknesses under seismic actions . The modal analysis is applied to predict the most possible damages and seismic vulnerability in weak zones of the structure under expected seismic intensity .

The static and modal analysis results have revealed that the critical section for the selected building is the transition zone between the section changes on the X direction and this is due to the lack of the seismic gap because the building length overpasses the 100m and there should be two seismic gaps on the geometric-section changes. This kind of stresses creates structural stability problems and it might be considered as one of the firs interventions that should have been done to the building.

The addition of the new interventions and the new additions might have increased the weight of the building and the period might have changed, making it even higher and more problematic.

8.2 APPENDIX B “Technical engineering and architectural diagrams” – CASE I

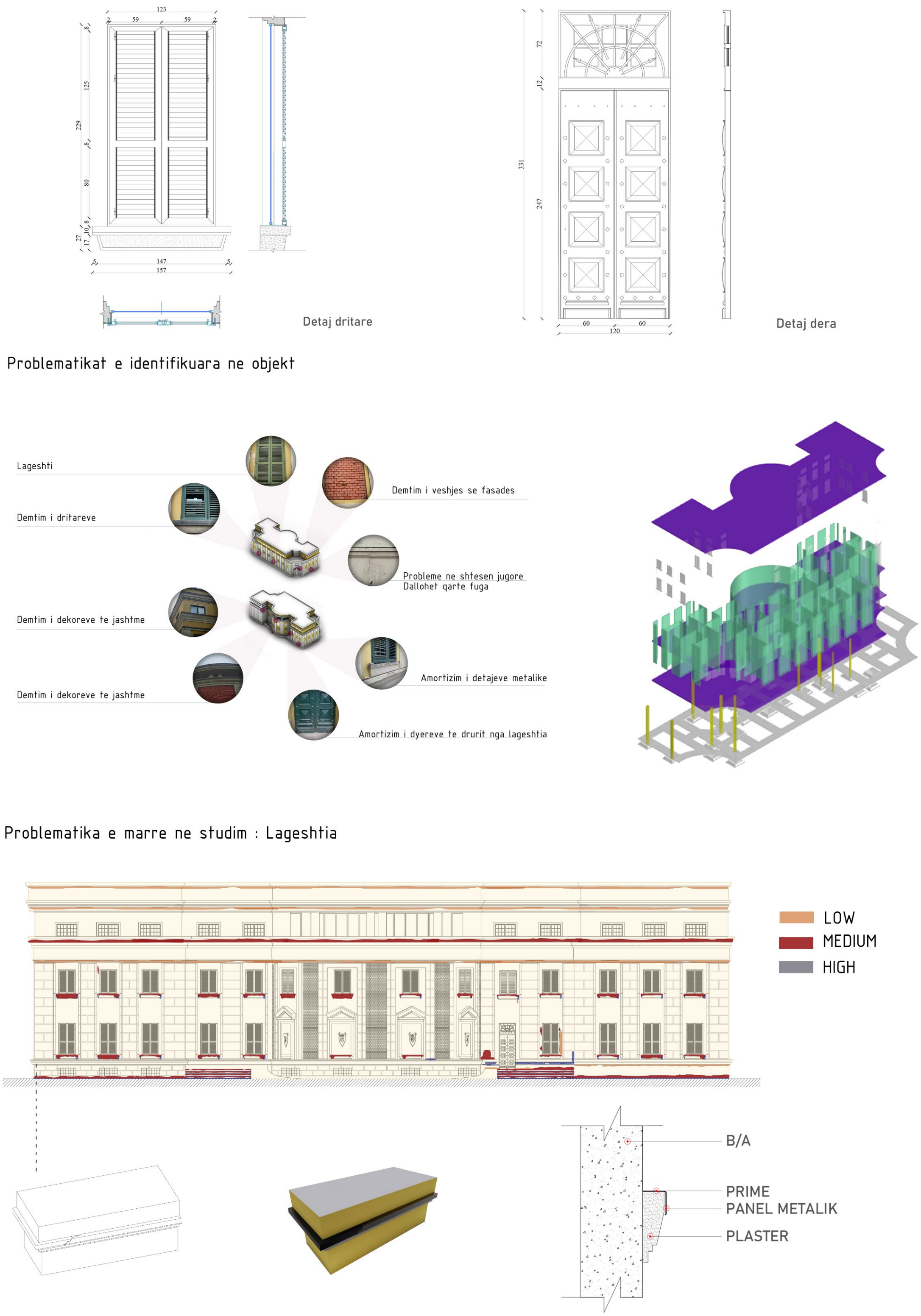


Figure 193. Architectural survey, in the framework of data processing related to the BIM model

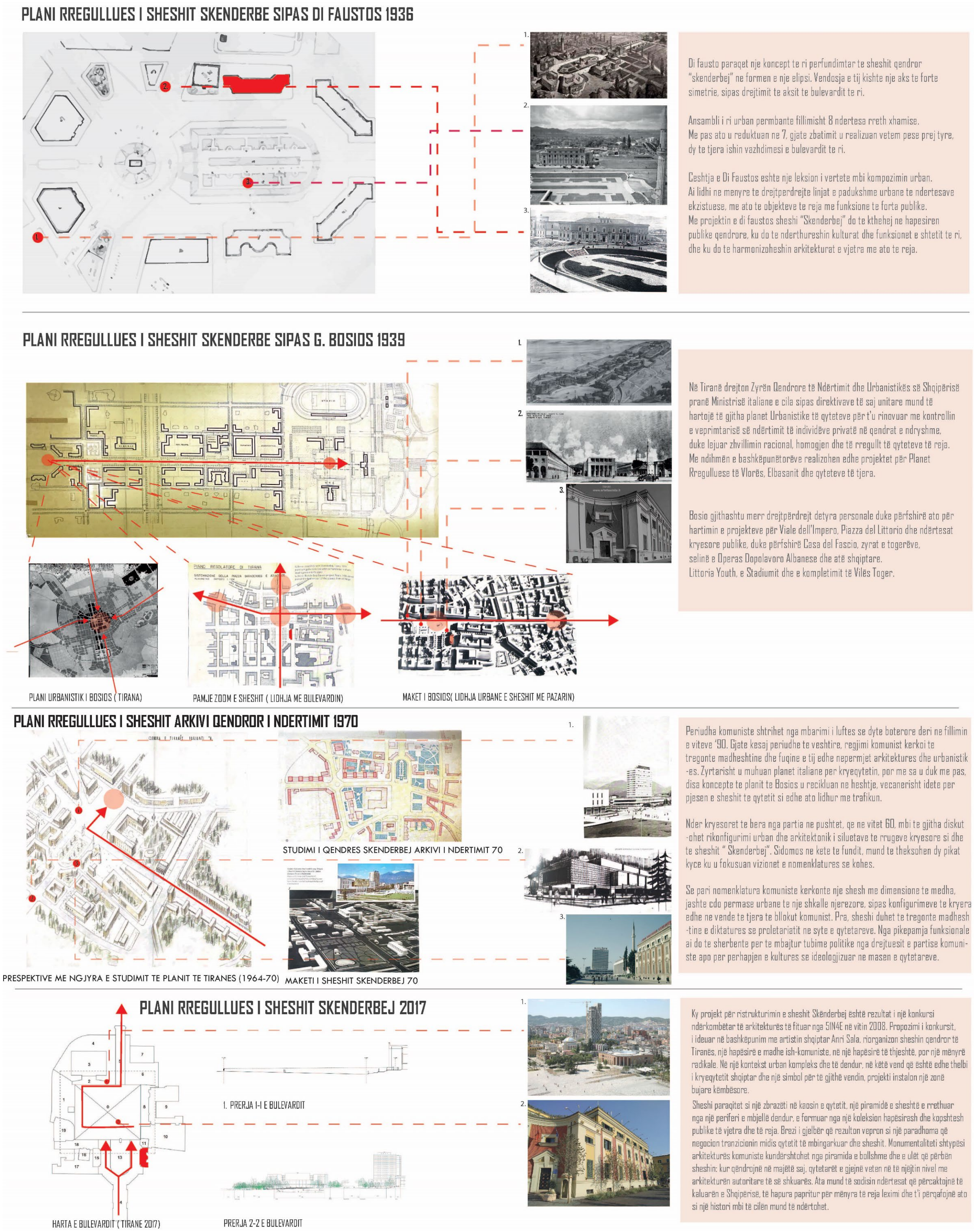


Figure 194. Diagram related to the analysis of urban planning of the area between periods

Materials summarized from simulations on investigations of possible collapse scenarios, selected from areas which have exhibited significant fragility in seismic performance. Simulated models according to the local theoretical mechanisms of collapse (worked in 3Muri software):

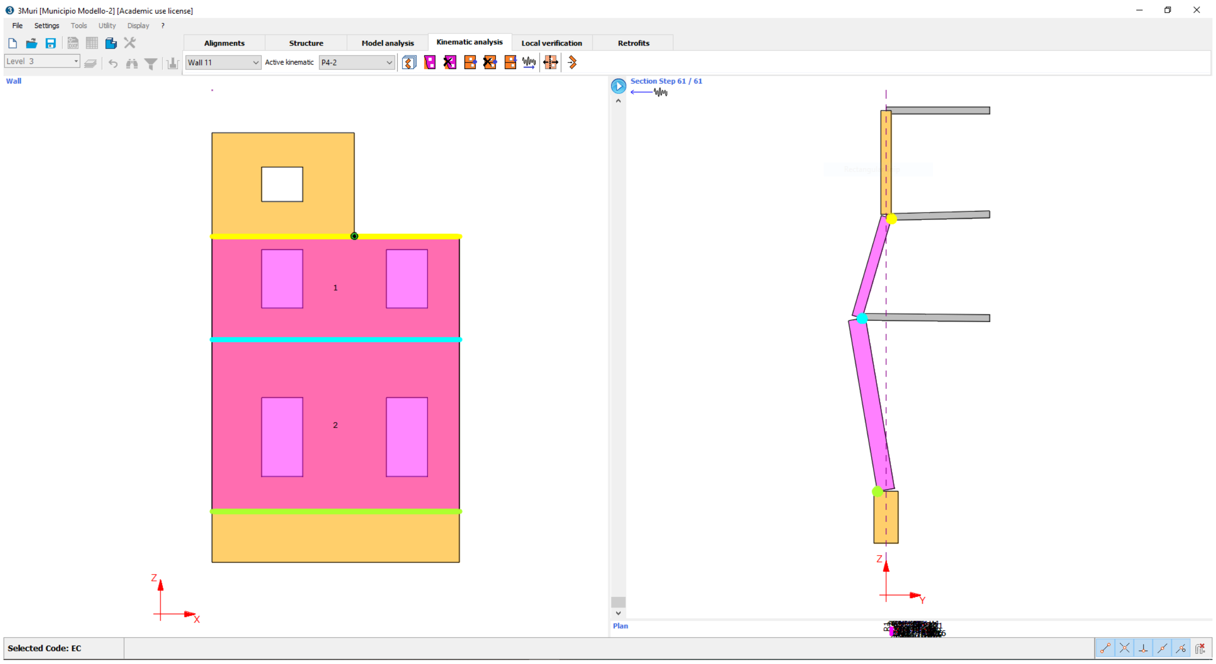


Figure 195. Simulations of local failure mechanisms, analyzed position "northern side facade"

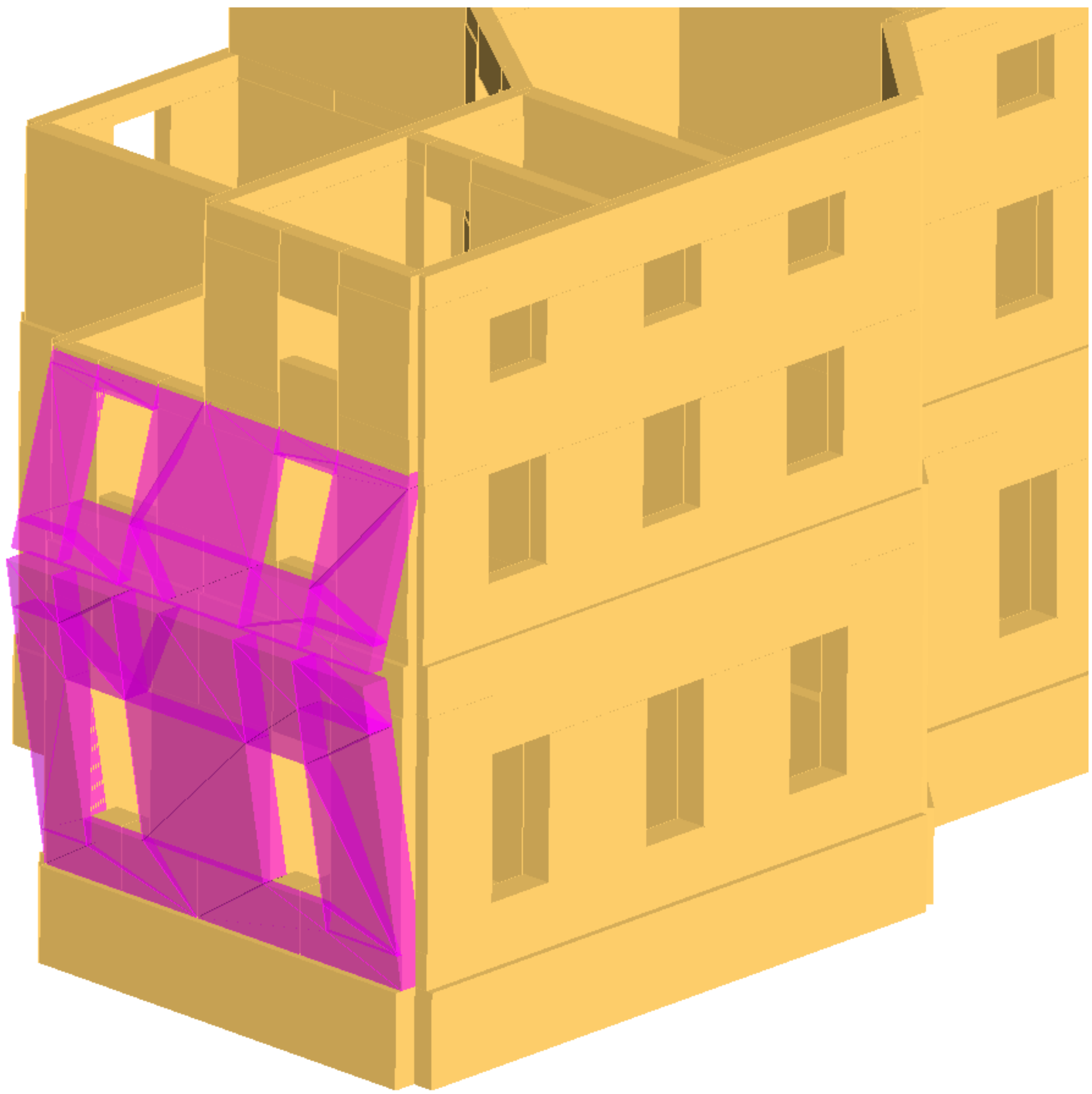


Figure 196. Simulations of local failure mechanisms, northern side façade. 3D view in the context of possible collapse scenarios

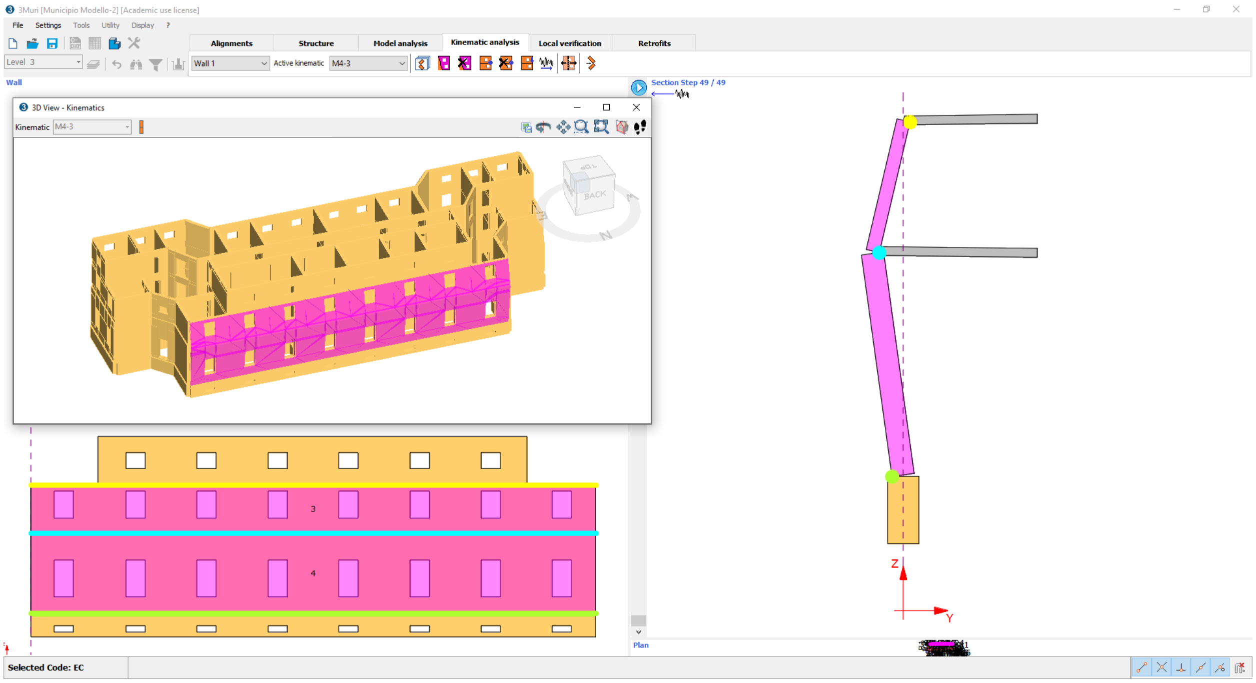


Figure 197. Simulations of local failure mechanisms main western facade, combined diagrams in the framework of possible collapse scenarios

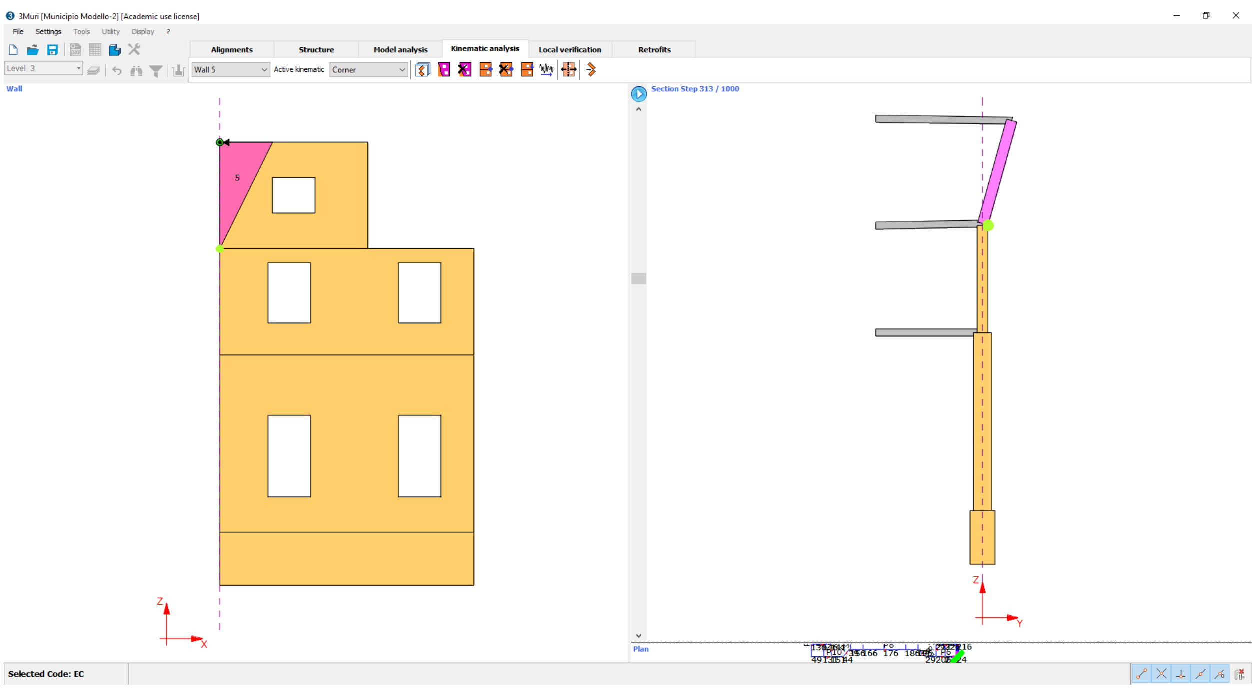


Figure 198. Simulations of local failure mechanisms north side facade, second typology of possible collapse scenarios

8.3 APPENDIX C “Technical engineering and architectural diagrams” – CASE II

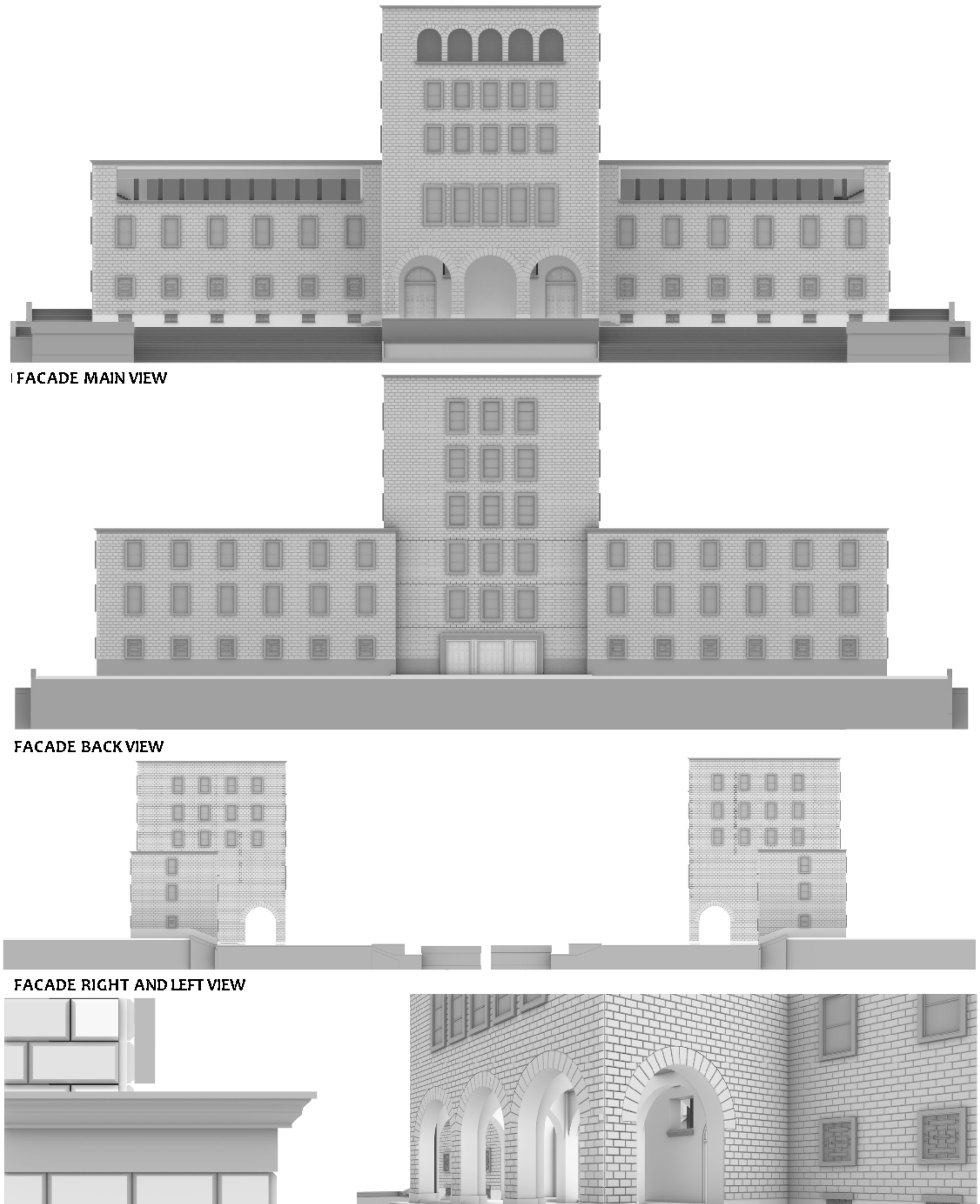


Figure 199. Architectural survey, main facades reworked for digitalization process (Credits R. Qose, A. Abdullaj)

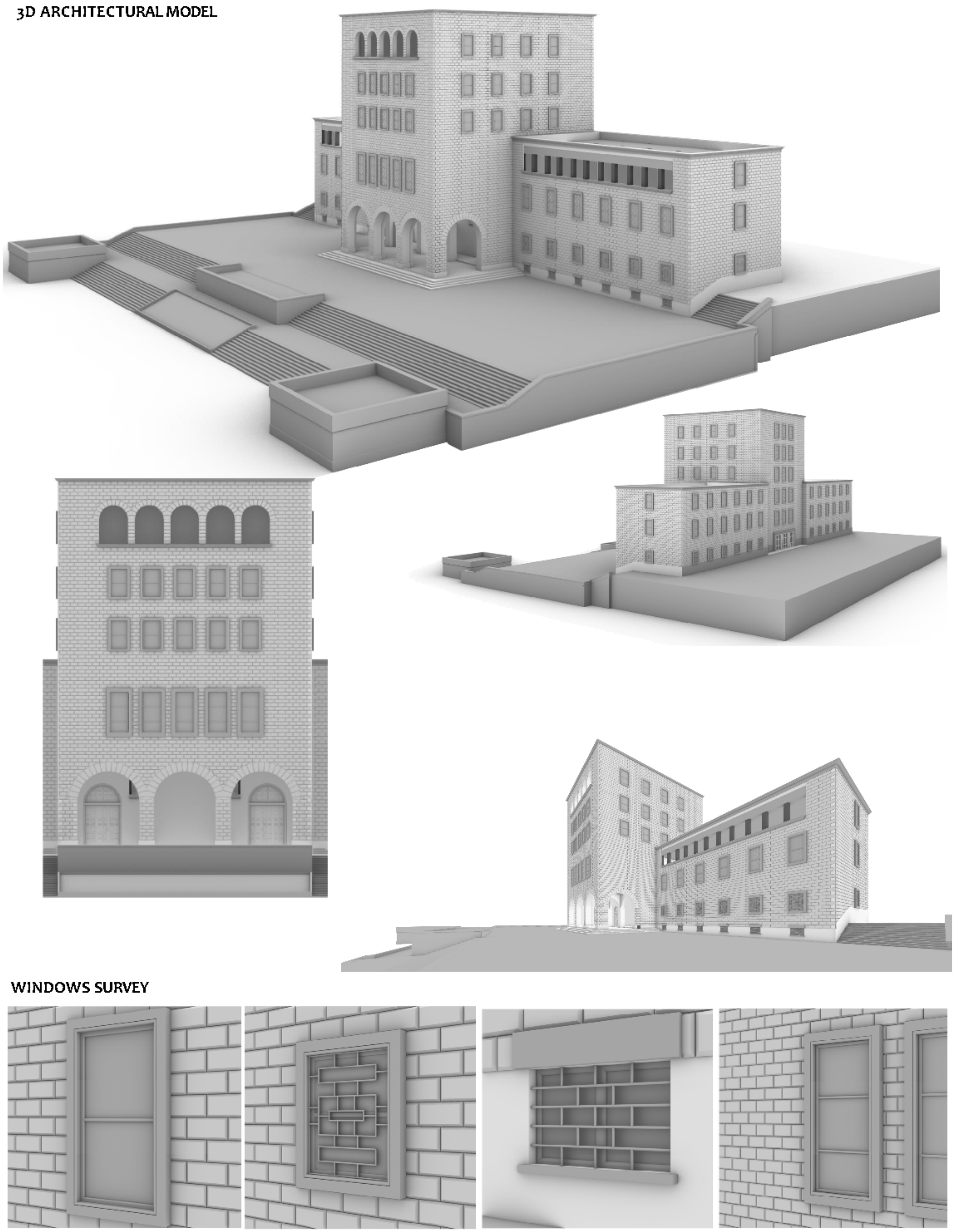


Figure 200. Architectural survey, pieces from the BIM model & details reworked on Rhino v.07, part 1 (Credits: R. Qose, A. Abdullaj)

ARCHITECTURAL DETAILS

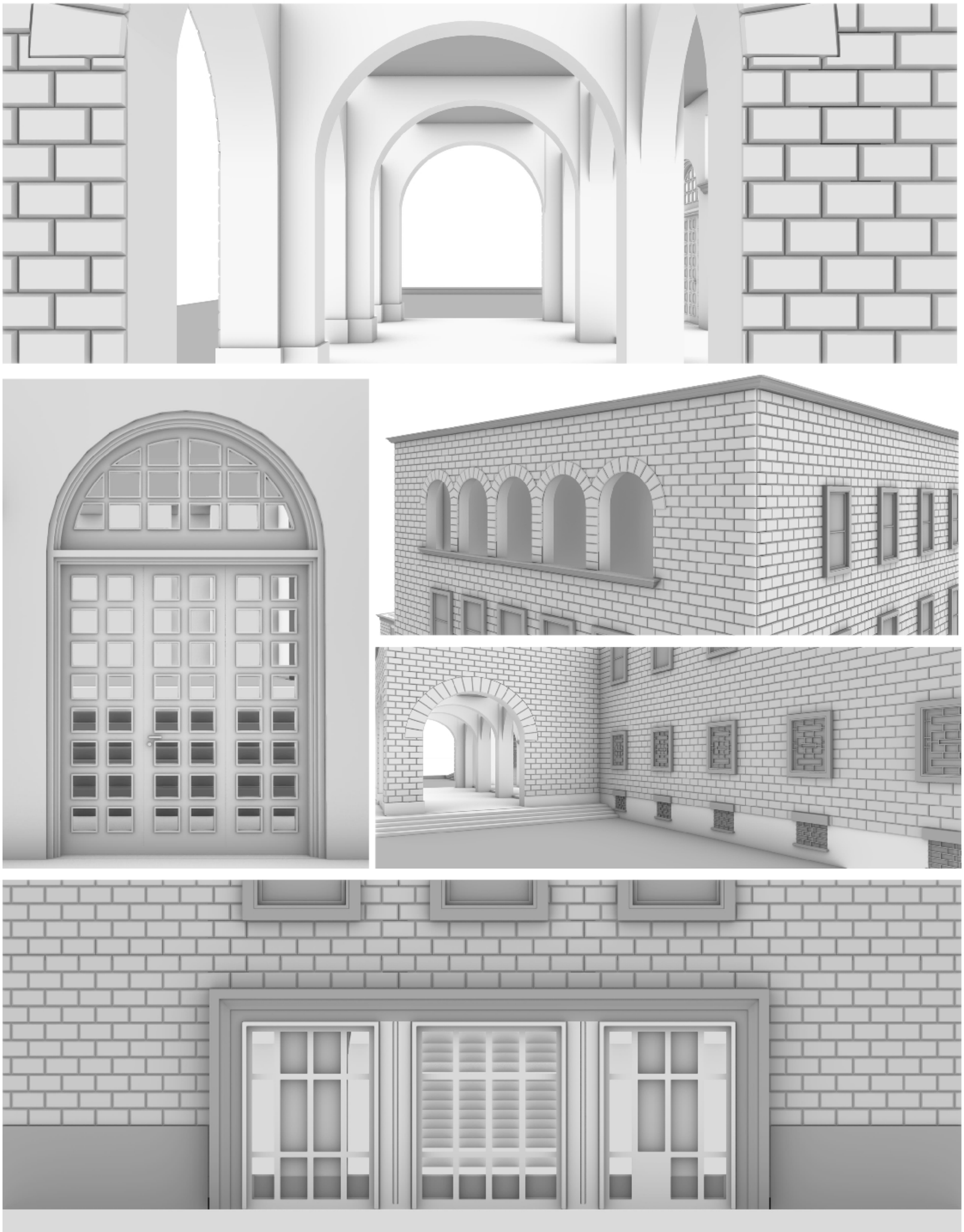


Figure 201. Architectural survey, 3D model & details reworked on Rhino v.07, part 2 (Credits: R. Qose, A. Abdullaj)

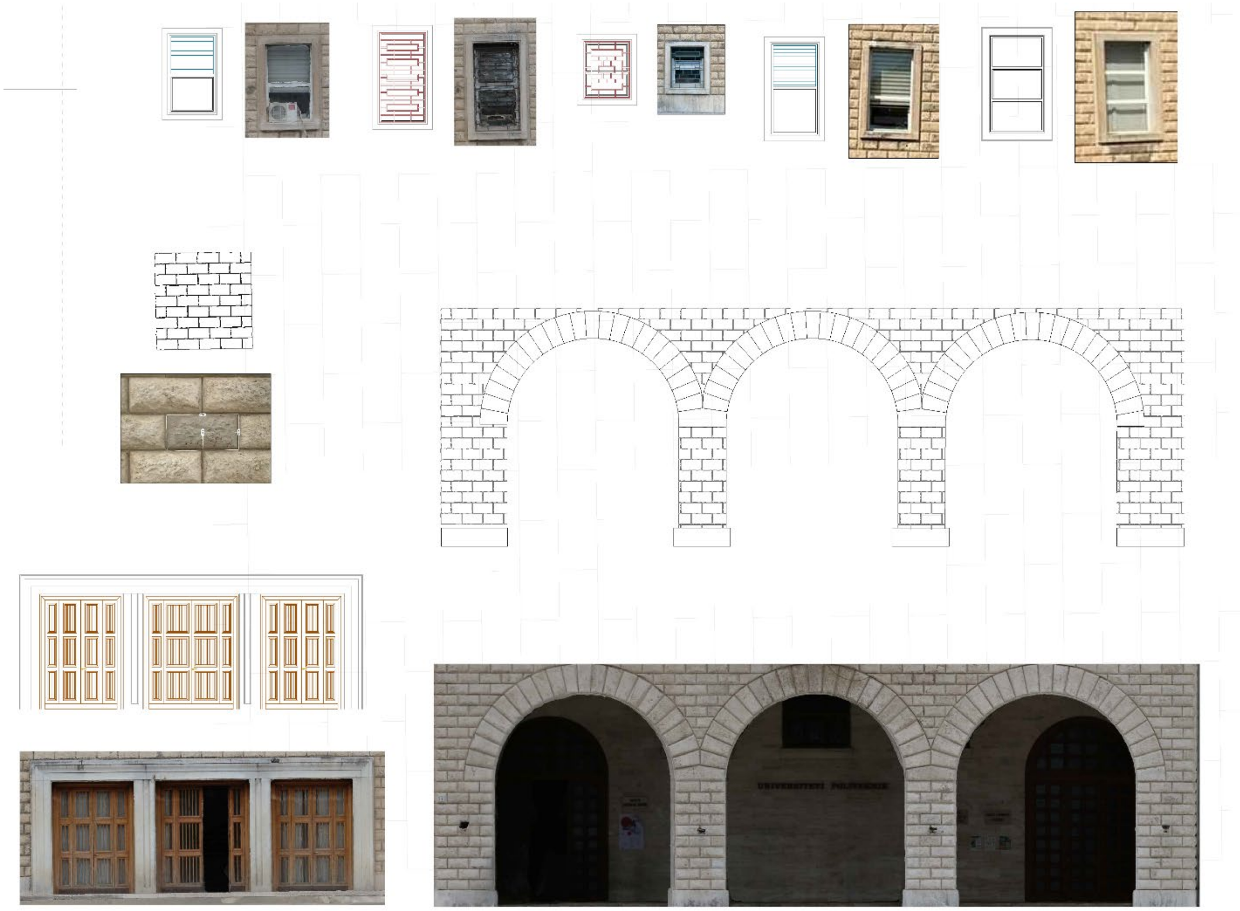


Figure 202. Architectural survey of windows, doors and arches

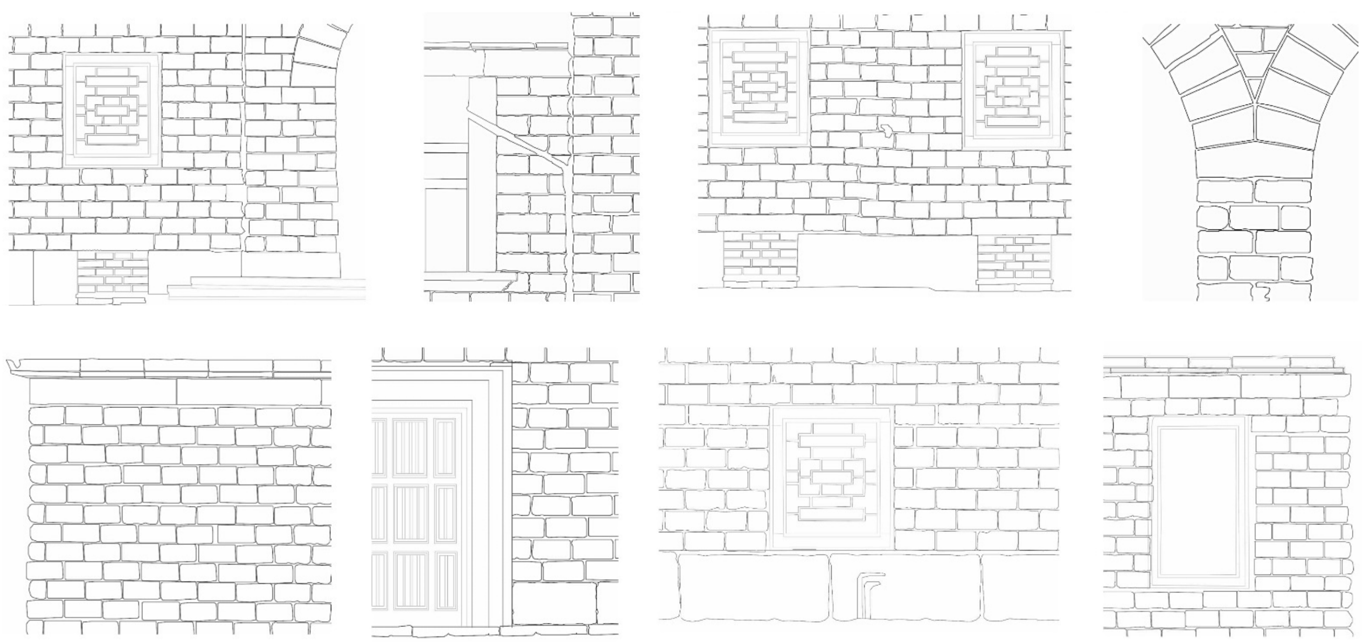


Figure 203. Careful sketching in detail stone by stone, mortar joints, façade elements and details

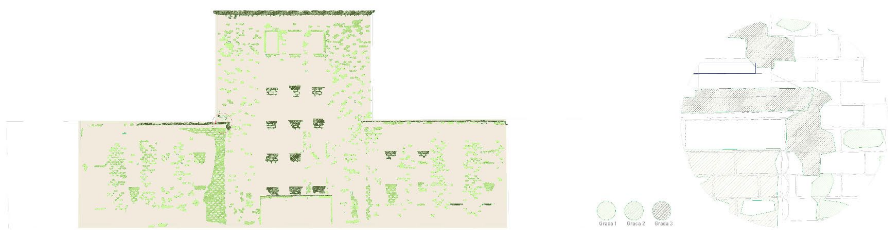
FACADE - SOUTH VIEW

Analysis of pathologies in facade masonry

The south façade is the one with which students have more contact with, as it overlooks the courtyard.
However, this facade shows a series of problems such as:
-cracking and damage, a part comes as a result of the earthquake of 26.11.2019, as well as interventions (eg drilling for the passage of air conditioner pipes) which have damaged the characteristic stones of the facade.
-humidity accumulated over the years
-parasitic elements, such as air conditioners, antennas, etc., which have damaged the image of the facade.

DOOR AND WINDOSW DETAILS

1. **Humidity**



2. **Cracks in marble and plaster**

3. **Degrading elements and Parasitic vegetation**

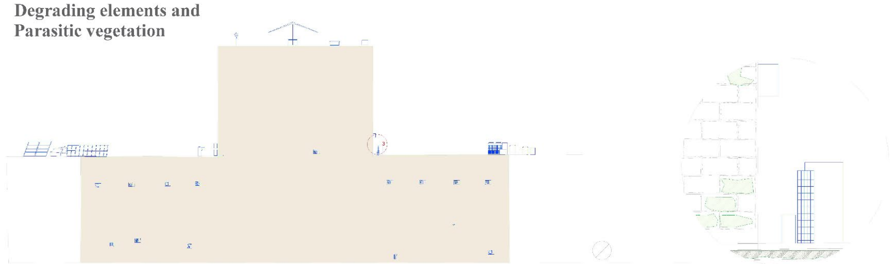


Figure 204. Analysis and investigation of the current condition of facades, pathologies and degradation; left survey of architectural elements

Figure 205. Architectural survey of the facade in the framework of the investigation of pathologies, cracks distribution and fractures

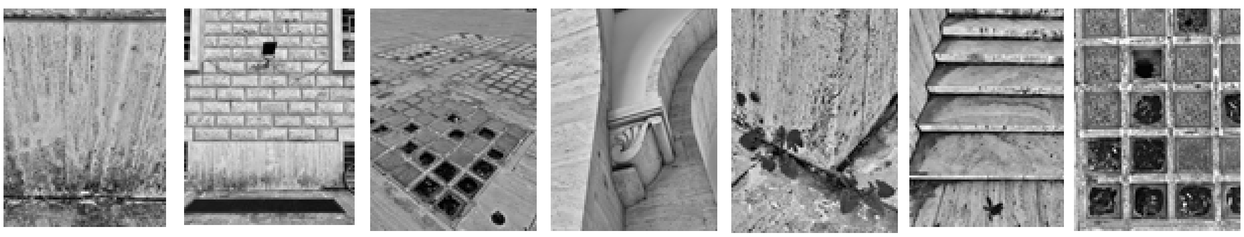


Figure 206. Collage of photos showing the current state and degradation of the material into different elements

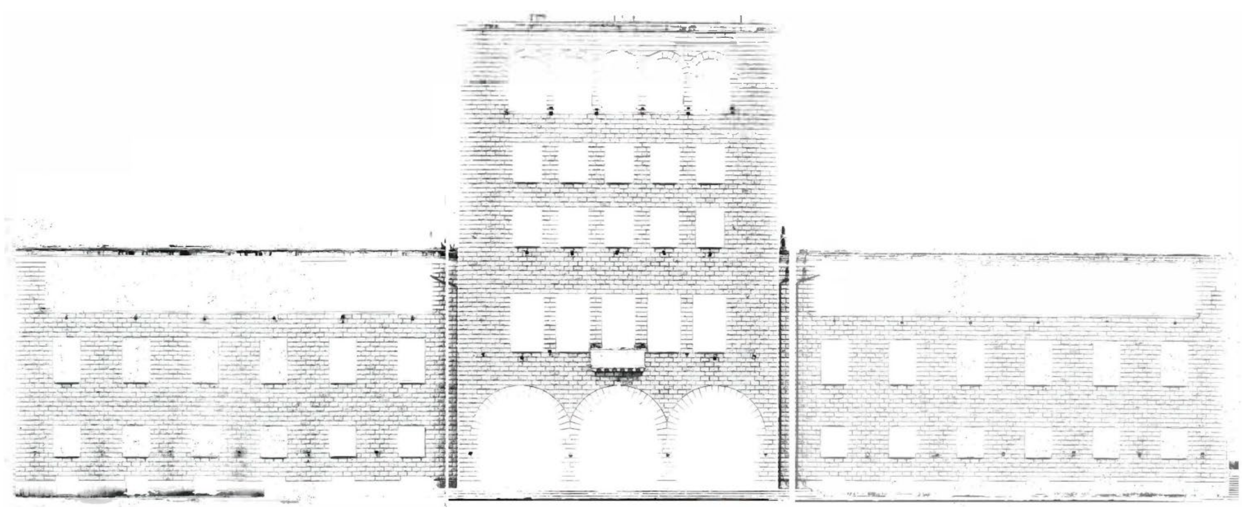


Figure 207. Processed diagram, based on laboratory data, showing the mold content in the main facade tiles

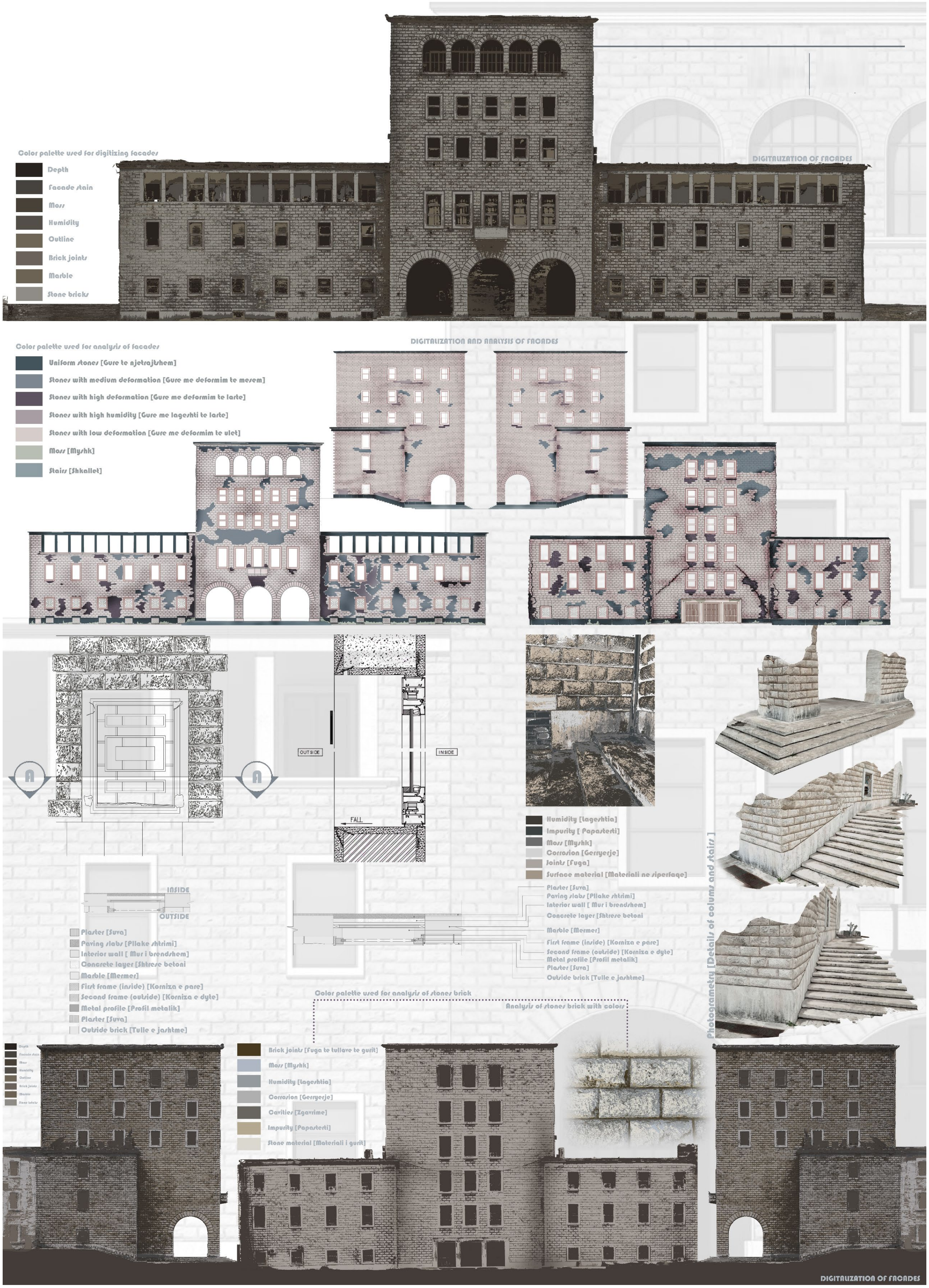


Figure 208. Material degradation analysis and photogrammetric processing of facades, in the framework of Bim modeling (credits S. Agalliu, B. Ndoja)

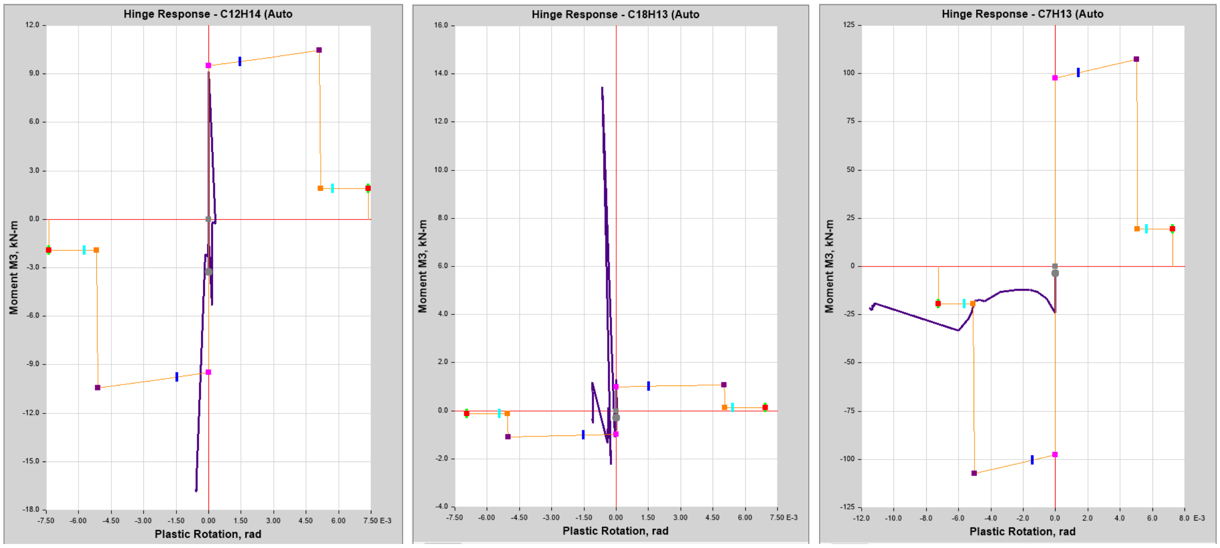


Figure 209. Column C12H14, C18H13 nad C7H13 hinge response diagrams, according to push-Y load

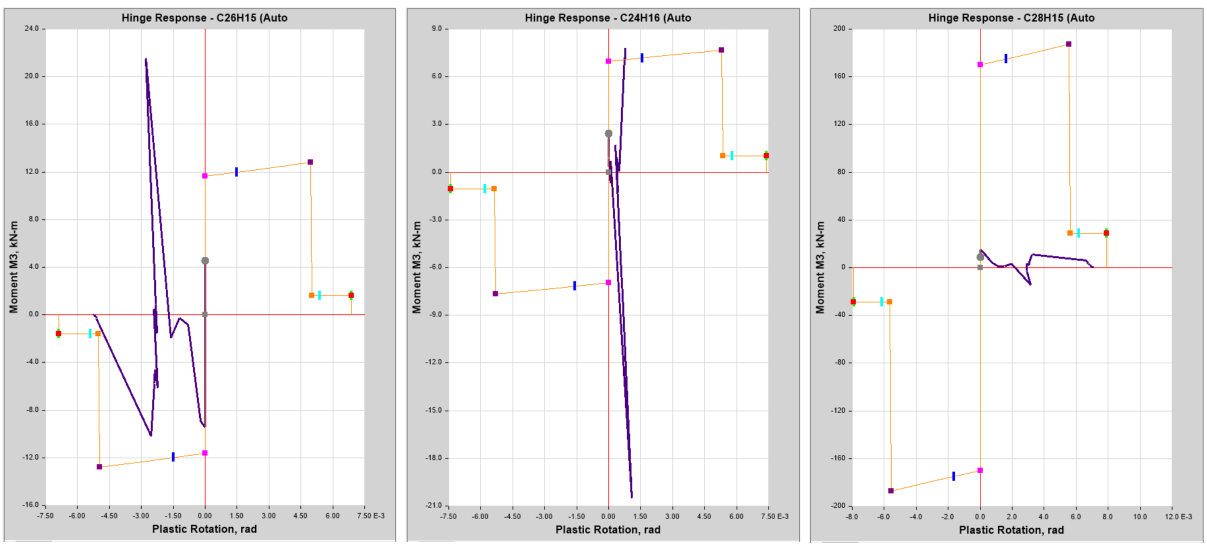


Figure 210. Column C25H15, C24H16 nad C28H15 hinge response diagrams, according to push-Y load

Summary of materials from local simulations, in the framework of the investigation of possible collapse scenarios, carried out in areas with significant structural fragility. Analysis performed according to the local theoretical mechanisms of the collapse (worked in 3Muri software):

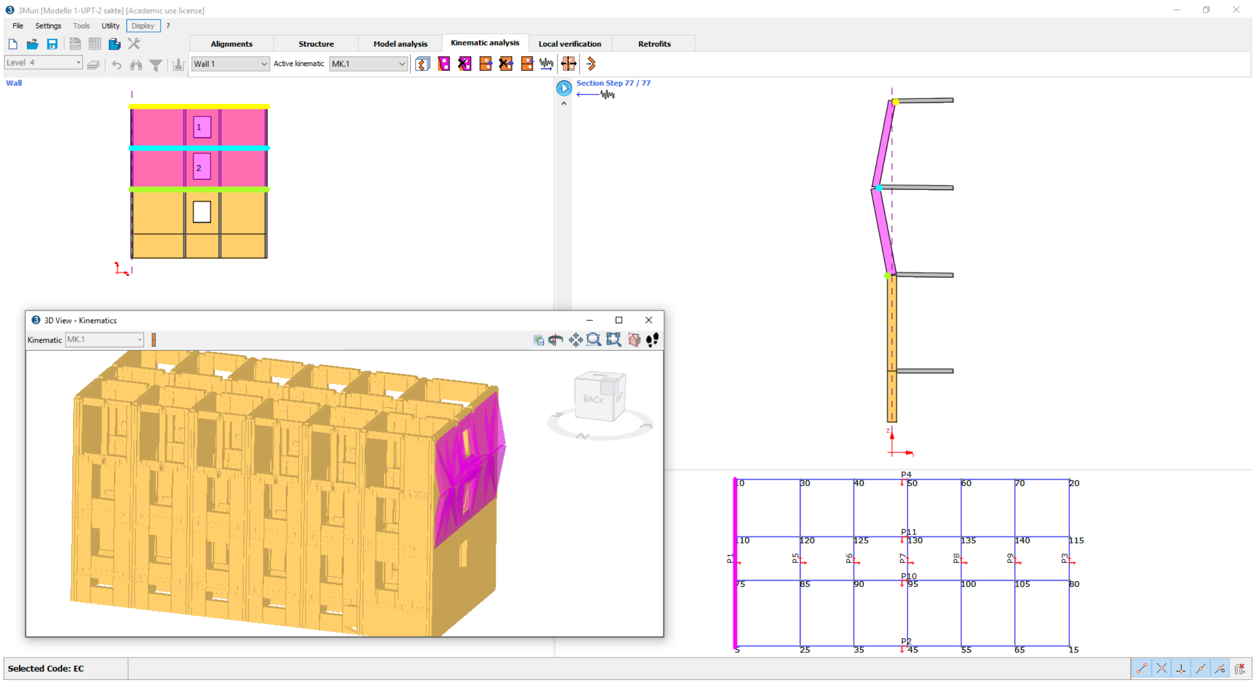


Figure 211. The first simulation in the framework of the investigation of local mechanisms of perimeter side panels, the scenario of possible mechanisms

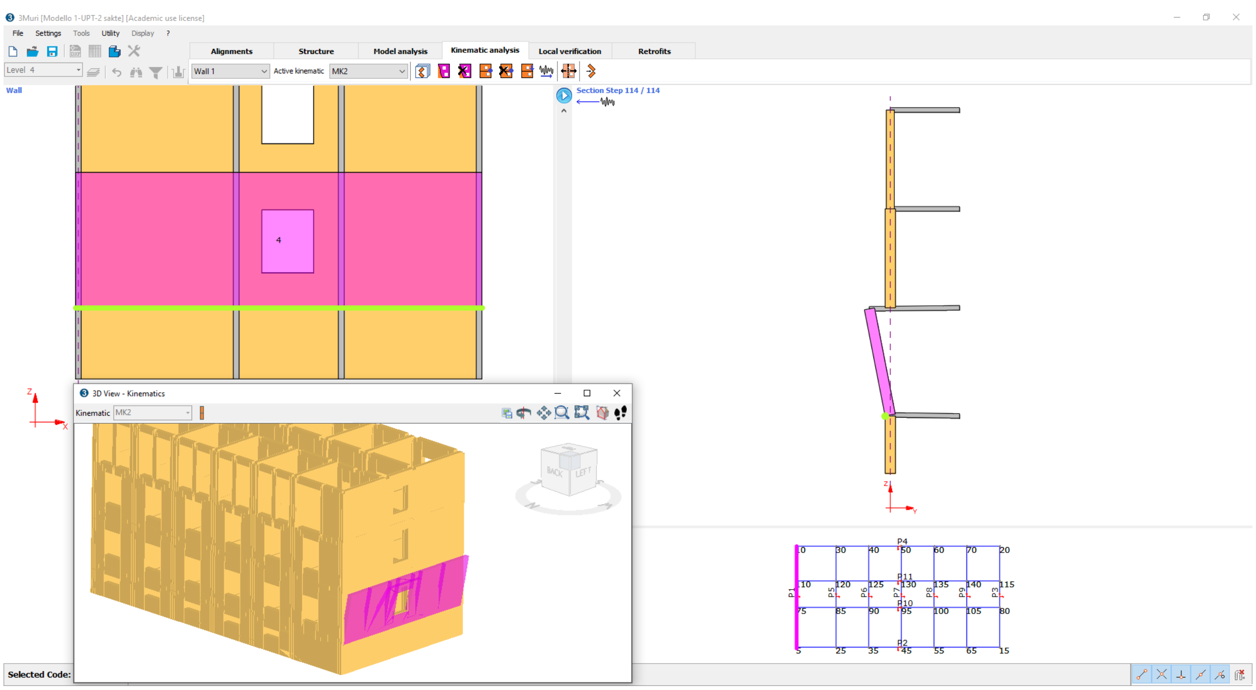


Figure 212. The second simulation in the framework of the investigation of local masonry mechanisms related to the ground floor masonry, the scenario of possible local mechanisms

8.4 APPENDIX D "Technical engineering and architectural diagrams" – CASE III

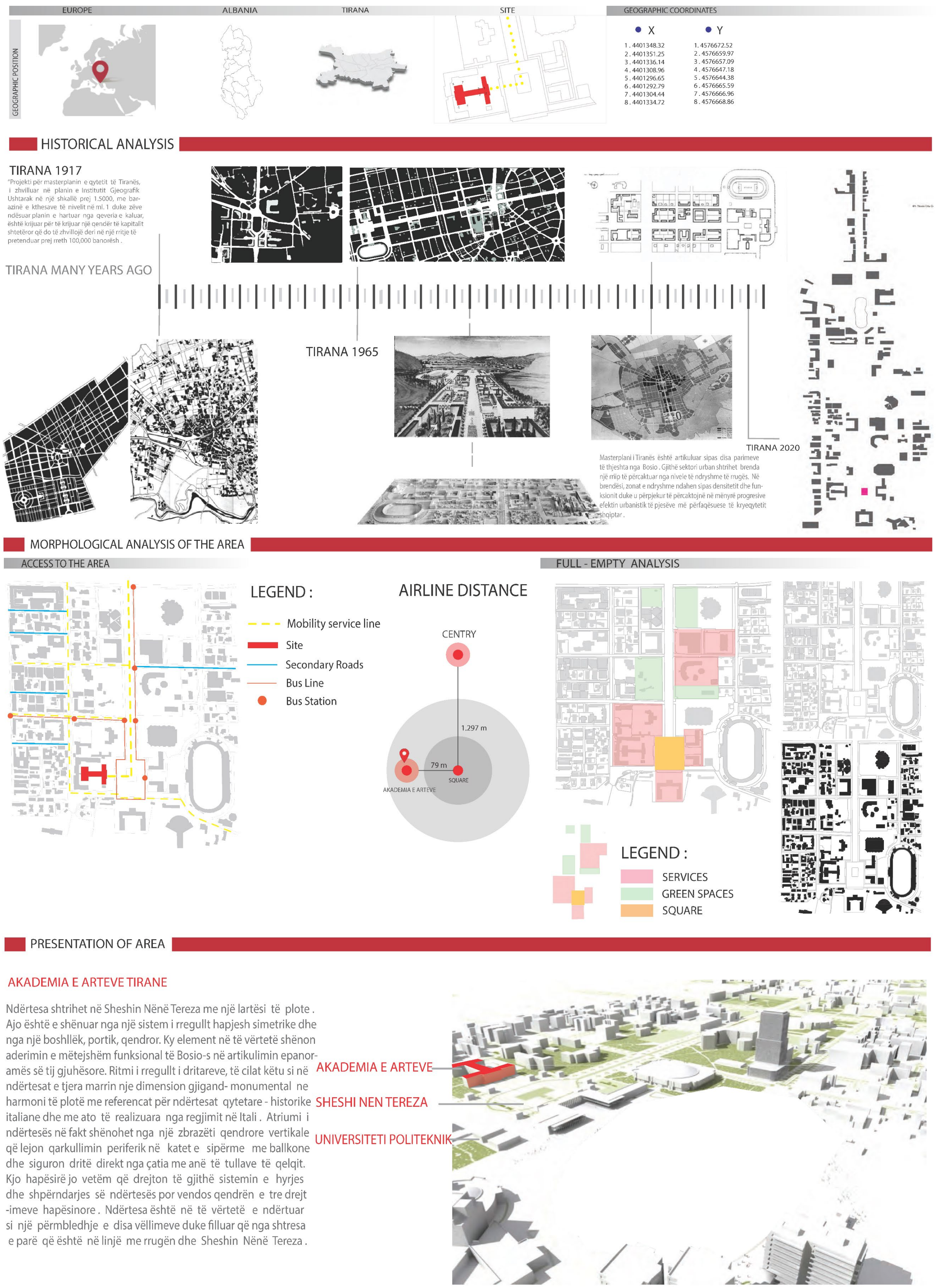


Figure 213. Analysis on the urban planning of the area between 2 periods, project identification

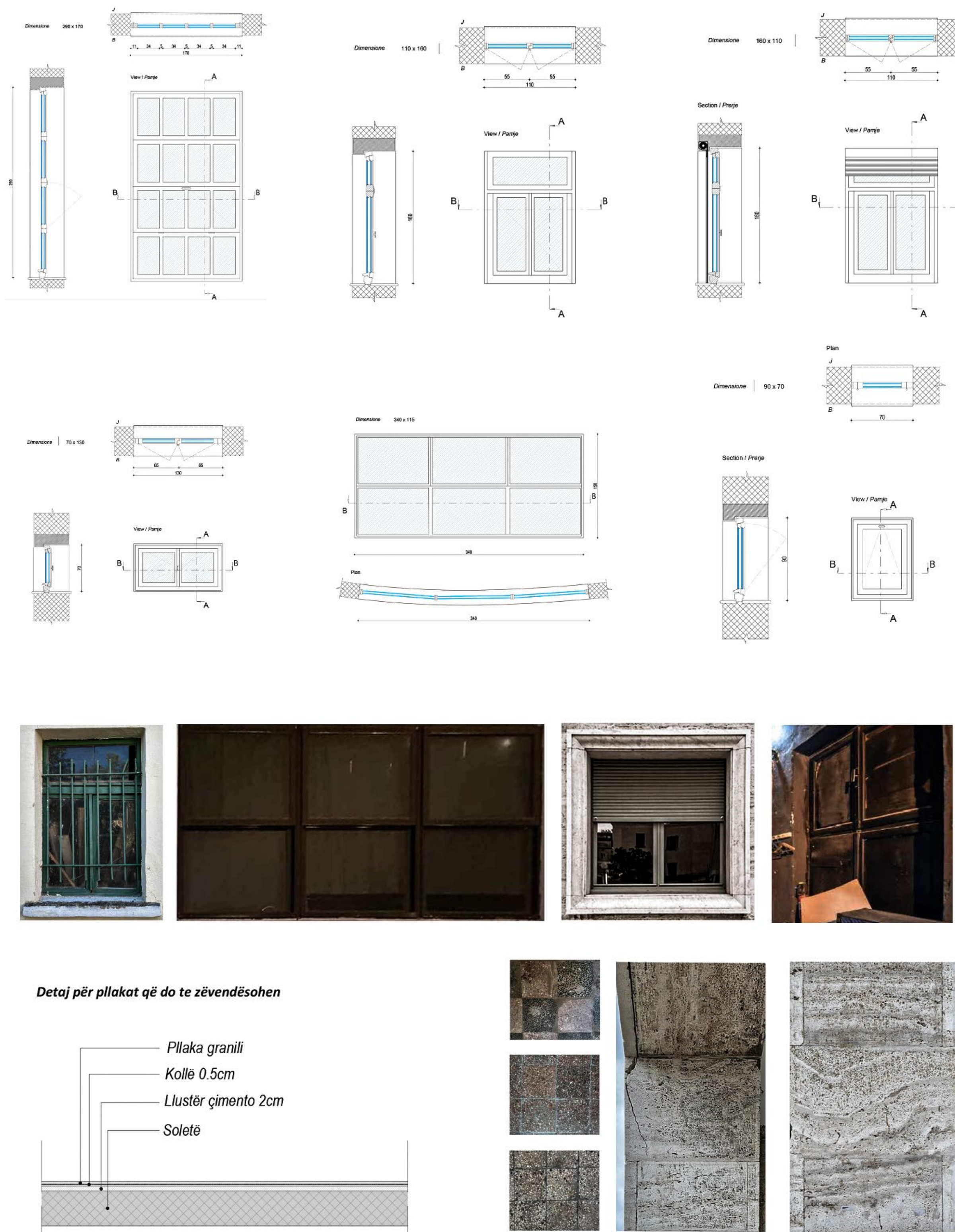


Figure 214. Architectural survey process, sketches of interior elements "windows" and constituent elements

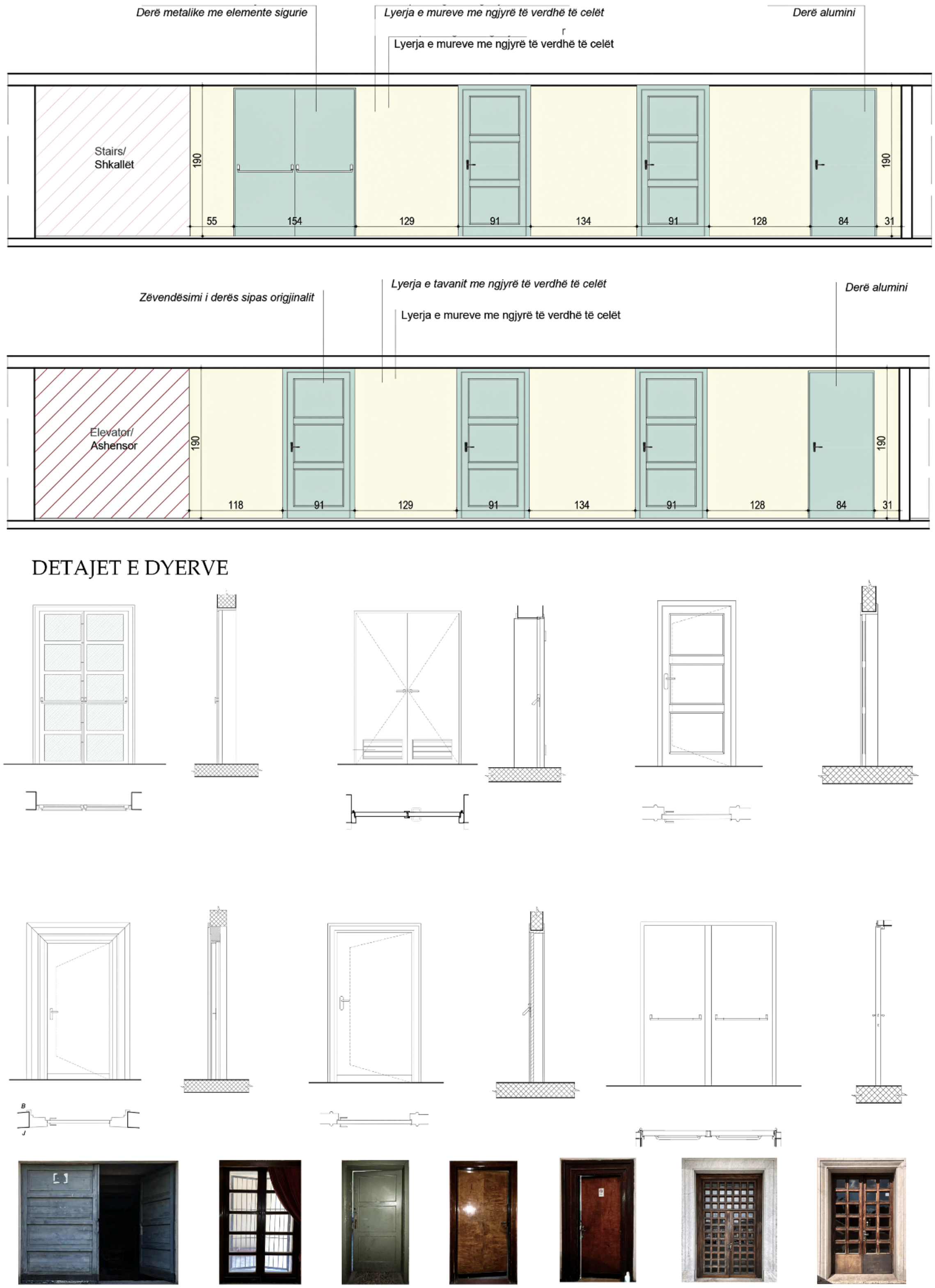
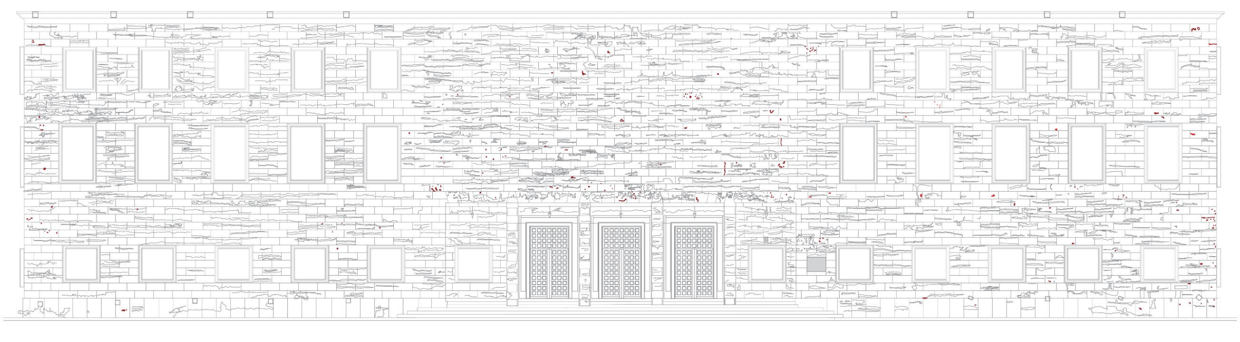
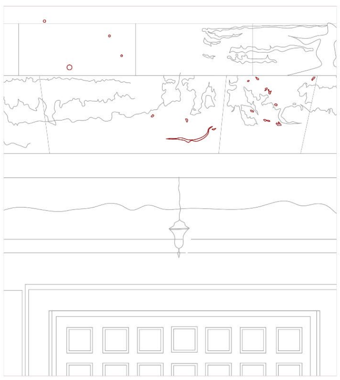
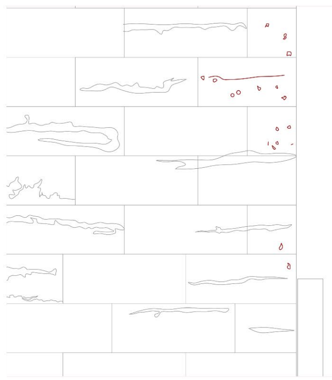


Figure 215. Architectural survey process, sketches of interior elements "doors" and constituent elements

Distribution of cracks and fractures in marble



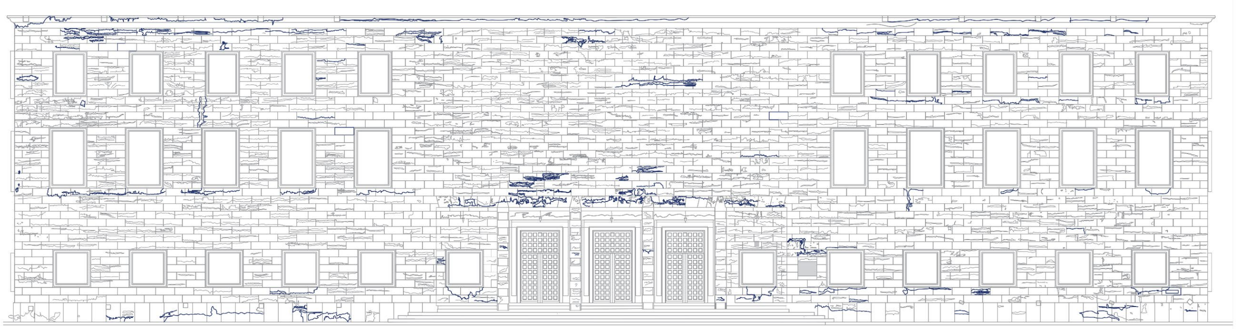


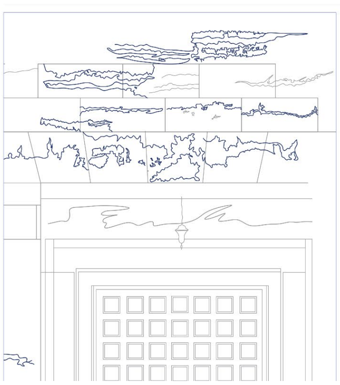


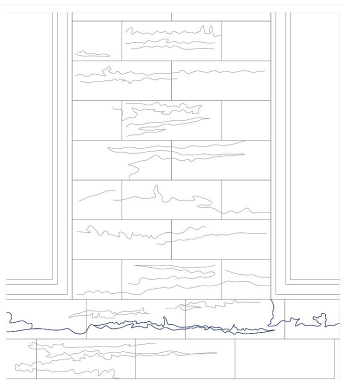
Hapat te cilat merren dhe ndiqen per te bere nje rilevm persa i perket Fasades per rikonstruktim dhe restaurim

Arkivi dhe dokumentacioni projektues dhe teknik janë duke u studiuar.
Është duke u bërë matja e fasadës së objektit.
Përcaktohet skema strukturore e ndërtesës.
Identifikohen deformime dhe vendbanime të mundshme.
Janë vendosur lokacione të mundshme për autopsi dhe marrjen e mostrave.
Është kryer një studim instrumental i detajuar dhe i plotë i strukturave dhe lidhjeve.
Identifikohen karakteristikat e forcës së materialeve dhe struktura mbështetëse e ndërtesës, si dhe identifikohen defektet e mundshme.
Nëse është e nevojshme, themeli dhe baza ekzaminohen.
Bëhen llogaritjet e verifikimit të elementeve mbajtëse të strukturave të ndërtesës.
Kryerja e punimeve gjeodezike.
Besueshmëria e strukturave mbështetëse mund të vlerësohet.
Dizajn grafik i materialeve për inspektimin e fasadës së ndërtesës
Zhvillimi i rekomandimeve të përgjithësuara për eliminimin e defekteve të zbuluara.
Rezultati i kësaj pune është përgatitja e një konkluzion teknik për gjendjen e fasadës së ndërtesës dhe mundësinë e rikonstruksionit të saj.

Distribution and moisture content in the facade







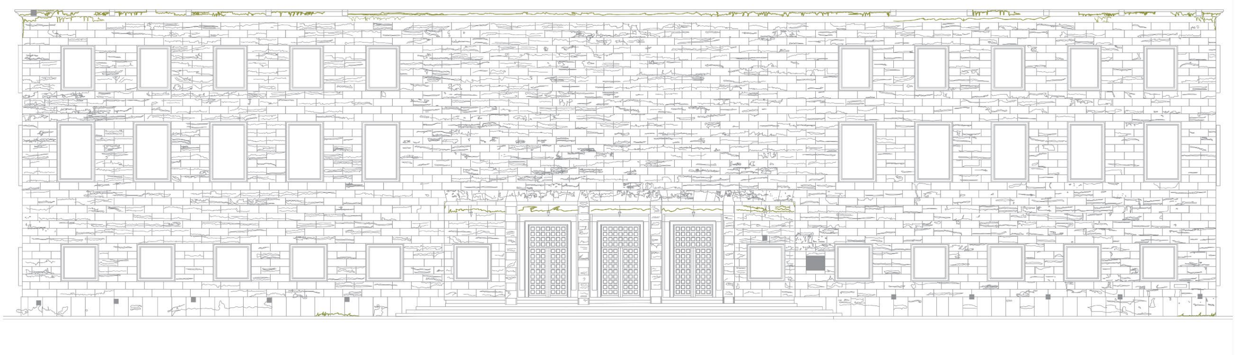
Burimet e lagështisë në ndetese

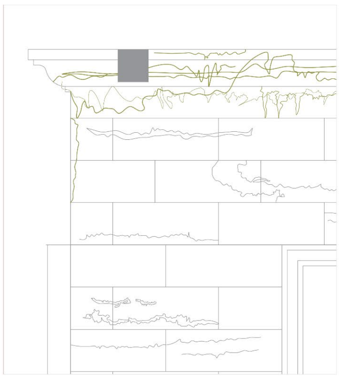
reshjet atmosferike: shiu, bora e shkrirë, kondensimi mund të hyjë në apartament përmes një çati që rrjedh, përmes poreve të mureve dhe shtresave të pambyllura (veçanërisht nëse era, mbingarkesa e papërshtatshme e çatisë ose kullimi i dëmtuar vazhdimisht drejtojnë reshjet në mur);
ujë i ndenjur në ndertese : pajisje hidraulike që rrjedhin, pishina, sauna, akuariume, përfshirë ato të vendosura në dyshemenë më poshtë, të njëjtin efekt jep një banjë me telefon ose një dush për një kohë të gjatë;
efekt serë nga ajrimi i dobët i dritareve (kondensimi grumbullohet në xhami), bollëk bimët e brendshme, veçanërisht nëse kanë nevojë për lotim të bollshëm;
frymëmarrja e njerëzve, kafshëve, bimëve gjithashtu rrit lagështinë - zakonisht ky faktor nuk është i dukshëm, megjithatë, në dhoma të mbyllura dhe / ose të ajrosura dobët do të jetë i dukshëm.

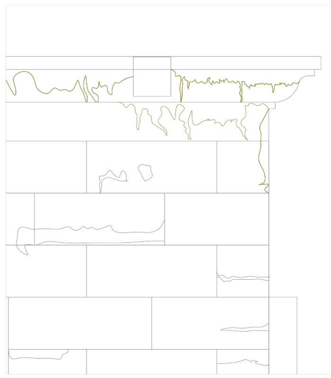
Një tjetër shkak i lagështisë është instalimi i pahijshëm i një dritareje me xham të dyfishtë. Nëse myku shfaqet në shpatet e dritares, duhet t'i rreshtoni ato dhe të shkumëzoni përsëri lojëra elektronike. Për të mos lejuar vendosjen e kondensimit në gotë, mos i rrënoni pragjet e dritares. Kjo ndërhyn në qarkullimin normal të ajrit të ngrohtë. Sills shumë të mëdha në dritare çojnë në të njëjtat pasoja. Për ta rregulluar këtë, duhet të shponi vrima në to.

Figure 216. Analysis of the main facade against fractures in marble and moisture content

Distribution of mold on the main Facade







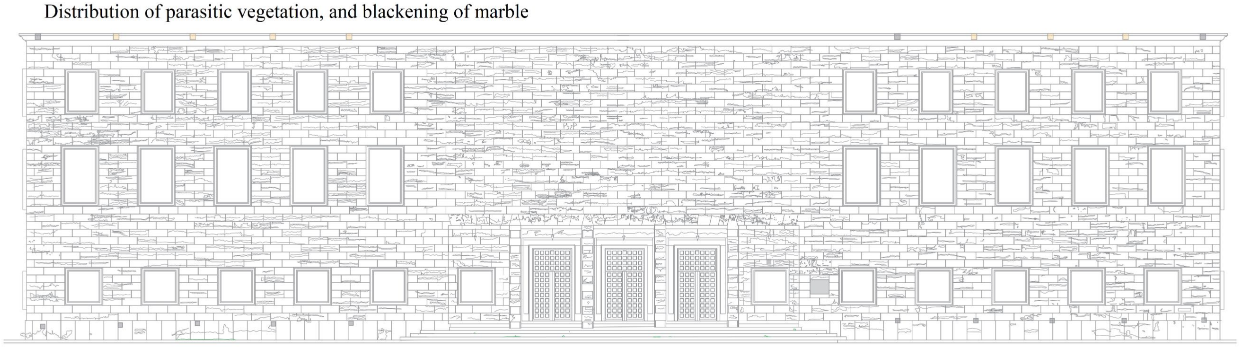
Asnjë korrigjim e kurim nuk mund të sjellë ndonjë rezultat të kënaqshëm, nëse nuk sqarohet dhe mënjanohet, apo së paku neutralizohet, shkaku i një lagështie të tepruar. Një ndër shkaqet më të shpeshta janë muret e jashtme të keqizoluara.

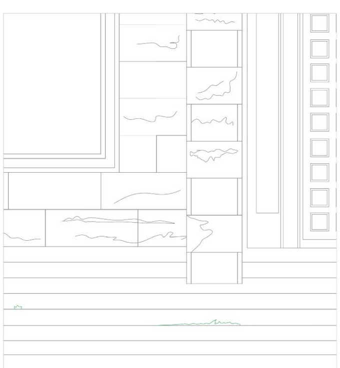
Gjatë stinëve të ftohta të vitit, ato ftohen dhe prandaj mbeten të njoma. Si rezultat vjen zhvillimi i mykut në muret e jashtme si dhe në skajet e tyre. Temperatura e ulët e dhomës, vetëm sa e përkeqëson këtë situatë jo të favorshme.

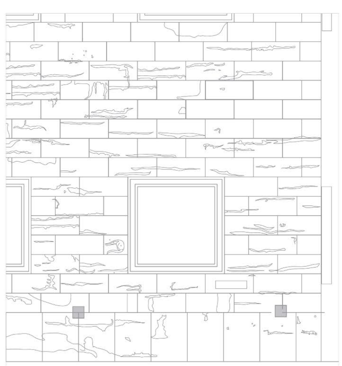
Megjithatë, edhe në kushte optimale shfaqet mjaft lagështi
kur ne bëjmë dush, banjë apo gatuajmë. Në qoftë se ajo lagështi vazhdon për një kohë të gjatë dhe nuk zhduket plotësisht, atëherë do të formohet myku dhe fillimisht në vende të ftohta si dritare, korniza dritaresh dhe në muret e jashtme. Nuk janë gjithmonë fajtorë banorët për ajrosje të pamjaftueshme: shkak për një ajrosje të pamjaftueshme
mund të jetë edhe ndonjë aspirator me defekt, ventilator i ndotur i sobës, dritare shumë të vogla, apo dritaret që hapen vetëm në mënyrë të pjerrët.

Ndodhë shumë rrallë që uji nga jashtë të depërtojë në ndërtesë duke bërë që të shkaktohen
dëme të shpeshta dhe kërcënuese të lagështisë. Shkaktarë mund të jenë edhe shiu i furishëm, plasaritjet, mbulimi i dëmtuar i kulmit, kullimi i pamjaftueshëm, rrjedhja e gypave apo lagështia e tepruar e tokës

Distribution of parasitic vegetation, and blackening of marble







Ndërtesat dhe monumentet historike mund të preken nga një shumëllojshmëri e gjerë e 'rritjes biologjike' duke filluar nga rrënjët e pemëve të pjekura që përbëjnë pjesë të një peizazhi të projektuar ose natyror deri te mikroorganizmat që mund të gjenden në sipërfaqet e jashtme dhe të brendshme të materialeve të ndërtimit. . Jo të gjitha këto janë të dëmshme.

Pasi rrënjët e një bime zbulojnë një çarje mikroskopike në beton, ato futen me forcë në pllakë. Edhe barërat e këqija dhe fidanët e vegjël kanë fuqinë të zhvendosin betonin duke përdorur energjinë potenciale nga rritja e rrënjëve. Me kalimin e kohës, rritja e vazhdueshme e bimës mund të plasaritet, thyejë ose shtrëngojë betonin përreth - në këtë moment ju mund të shihni bimën të shpërthejë në sipërfaqe.

Ndriçimi i duhur mund të përmirësojë performancën e detyrës, të përmirësojë pamjen e një zone ose të ketë efekte pozitive psikologjike te banorët. Ndriçimi i brendshëm zakonisht realizohet duke përdorur pajisje ndriçimi dhe është një pjesë kyçe e dizajnit të brendshëm. Ndriçimi mund të jetë gjithashtu një komponent i brendshëm i projekteve të peizazhit.

Figure 217. Analyzes on the condition of the masonry, the distribution of mold, parasitic vegetation and blackening of marble

Even in this case, materials were collected from local simulations to investigate possible collapse scenarios, only for areas with significant fragility. (3Muri software):

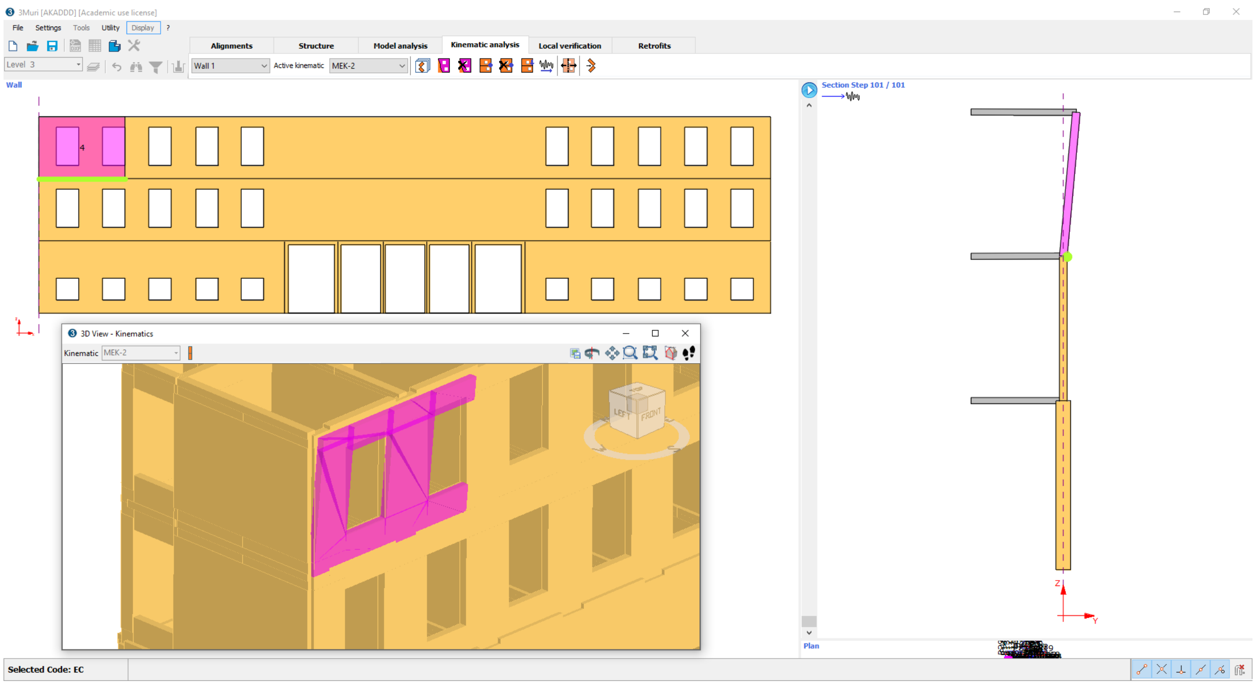


Figure 218. Simulations in the framework of the local mechanisms investigations, mechanism one

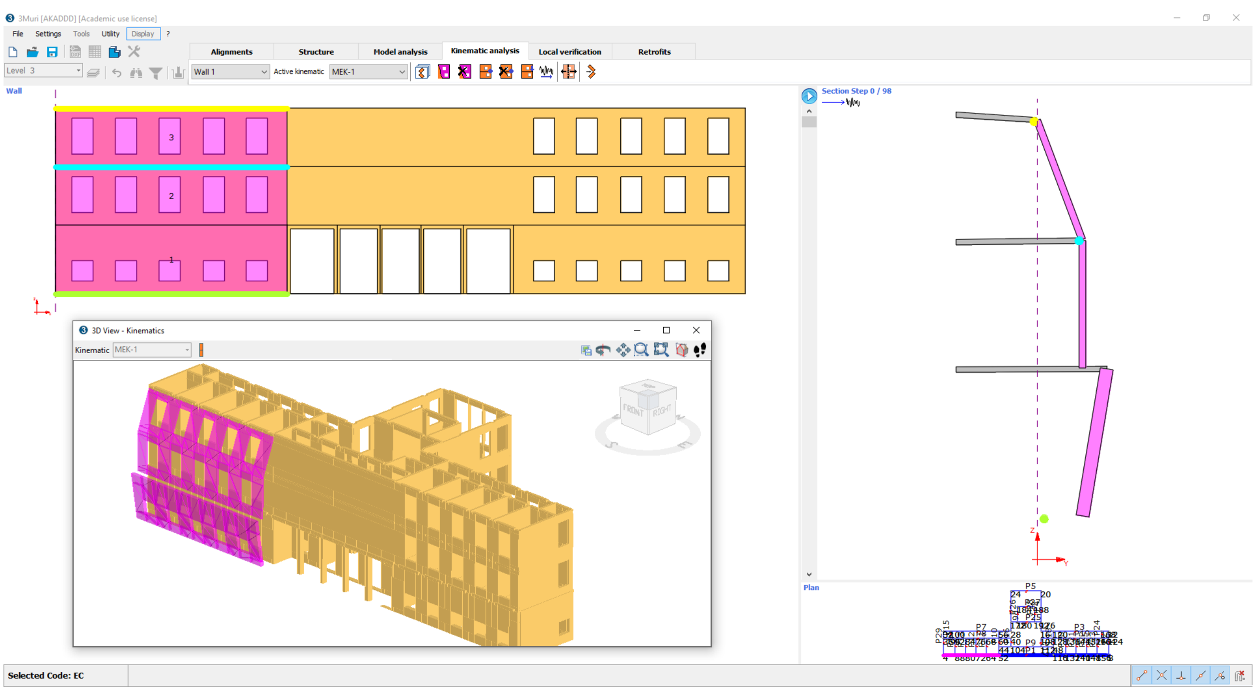


Figure 219. Simulations in the framework of the local mechanisms investigations, mechanism two