Università degli Studi di Ferrara | DA Dipartimento Architettura Ferrara | Universiteti POLIS

A methodology on the treatment of the issue of Cultural heritage restoration in Tirana, period 1920-'40

BIM modeling, Seismic simulation and Theoretical interpretatios

Candidate: Nikolla Vesho

POLIS Supervisor: Dr. Merita Guri
DA Supervisor: Prof. Marco Zuppiroli

Cycle XXXIV

IDAUP

International Doctorate in Architecture and Urban Planning

Università degli Studi di Ferrara | IUSS

Nikolla Vesho

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UNIVERSITETI POLIS

INTERNATIONAL DOCTORATE
IN ARCHITECTURE AND URBAN PLANNING

Cycle XXXIV

IDAUP Coordinator Prof. Roberto Di Giulio

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Curriculum: Architecture / IDAUP, **Topic**: Cultural Heritage Restoration, Seismic analysis and Retrofitting, BIM Tools (Area – SSD: ICAR19)

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Topic: *Cultural Heritage Restoration, Seismic analysis and Retrofitting, BIM Tools*

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ABSTRACT IN ENGLISH

The history has left its mark on the Albanian culture and society, from the Roman Empire, Greek colonies, Turkish Empire, to the Balkan and World Wars. Indescribable are the traces and influence of Italian architects and designers between 1920 and 1940. The architecture of the center of Tirana, reflected mainly along the main boulevard that divides the city into two parts, is an undeniable proof of the symbiotic process that has always characterized the relationship between Italian and Albanian culture in all dimensions.

By researching and analyzing the materials found in the technical archive of Tirana, also, the Italian Luce Institute, specifically in the archives of L. Luiggi, G. Fiorini etc., it helps to better understand the Italian vision for Tirana. Today, these sketches and drawings serve as a point of reference for architects, engineers and restorers, as long as buildings need reconstruction or intervention.

After the Second World War, these buildings were perceived as signs of a foreign invasion, but over the last 30 years, superstitious ideologies have been replaced by a more peaceful evaluation process. Built during the 20-40s for other purposes, after liberation they took other functions, from universities, study centers, headquarters and ministry facilities, thus becoming an inseparable part of the day-to-day and historic part of the city, intertwined and in cooperation with each other. Now this historical-architectural heritage, that is shared among people, has helped to change the initial perception.

This cultural heritage buildings of Tirana's case provide structures and monuments of great value, since they are proof of historic forms of life and the history of modern societies, and show the existence of a tangible cultural identity. The architectural heritage adds character to its surroundings, is an integral part of the city, and is also a valuable tourism resource. Nowadays, architectural and cultural legacy are regarded as a perishable and valuable resource that must be protected and passed on to future generations. However, protective programs are not always as effective as they may be, owing to a lack of interest on the part of residents, professionals and an unfavorable socioeconomic climate.

Performance of cultural heritage buildings after earthquakes is the concern of people and many professionals from different disciplines . Although, everyone supports for protecting these architectural masterpieces from seismic threats, the predicted loss to their aesthetic values (as a result of additions and retrofitting processes) hinders a required decisive consensus on whether or not an action should be taken to save these national treasures. This could be due to a lack of agreement on how to value the added value of seismic risk reduction on the building as a result of structural strengthening compared to the damage values related to any particular seismic retrofit technique.

The age of these buildings is approaching 100 years, which makes us aware of the greatness of the designers of that period. In this regard, this study aims to define the principles and secrets of structural simplicity and to interpret theoretically their structural arguments. Plan and height configurations, the most useful structural elements of the period and the ability to withstand a large number of seismic events.
The strategic vision of the study is to develop a detailed methodology which can serve as a manual for addressing the issue of restoration, as well as addressing the issue of structural

analysis of cultural heritage with the principles and international charters on restoration. Theoretical analyzes and interpretations of the architectural solutions of the period will be developed. The main goal is to treat the complicated modeling of buildings of the past, using the building information modeling methodology as a tool that helps us improve the methods of evaluation and parametric interaction. Regarding the proposals for intervention, it will be attempted through this methodology, to create a controlled space monitored by experts, to prevent damage to architectural assets during restoration.

The study will be carried out through theoretical approaches initially and literature research, while later the methodology will take shape through the treatment of some cases of studies, which have not been previously studied in this specific context. The Albanian context has shown a lack of cooperation in a team of experts or governments have made this contribution even more fragile. To achieve this goal, the right atmosphere of cooperation between experts must be created, to consider their diverse perspectives. On the other hand, this research aims to raise awareness of Tirana's cultural heritage past by fostering a debate on cultural heritage and its future within a structured heritage framework. The study tends to stimulate the process of digitalization by creation of 3d models including BIM, in such a way as to create accessible database of materials, elements, combined architectural and structural models, database for additions and retrofitting’s.

Also, in this study will be targeted to overwhelm the curiosity of researchers, students, aspirants of doctoral studies or lovers of cultural heritage who want to know more about the architectural and engineering part of the main buildings that marked the 20th century architecture of Albania. Those buildings that surround us today define the spaces of our cities which still more tell us how we were, how to judge the past and above of all how we can project the future.

ABSTRACT IN ITALIAN

La storia ha lasciato il suo marchio nella società e la cultura albanese da le colonie Greche al Impero Romano dal Impero Ottomano alle guerre balcaniche fino alle guerre mondiali. Descrivibili sono le tracce e l'influenza lasciata dagli architetti Italiani tra il 1920 al 1940. L'Architettura del centro di Tirana, riflessa principalmente lungo il viale principale il quale decide la città in due parti e prova indelebile del processo simbiotico che ha caratterizzato le relazioni culturali tra Italia e Albania in tutte le dimensioni.

La ricerca e l'analisi dei materiali trovati al archivio del istituto Tecnico di Tirana e anche ne archivio del Istituto Luce, specificamente negli archivi del L. Luigi e G. Fiorini sono stati d'aiuto nel capire meglio la visione degli architetti Italiani per Tirana. Oggigiorno questi disegni servono come punto di riferimento per architetti, ingegneri e restauratori per quanto riguarda al bisogno di ricostruzione e intervento di manutenzione che questi edifici hanno. Dopo la seconda Guerra Mondiale questi edifici venivano percepiti come memoria e segno del invasione straniera, negli ultimi 30 anni queste ideologie e superstizioni furono rimpiazzate da un più pacifico processo evolutivo. Costruitesi tra gli anni 20-40 per altri scopi dopo la liberazione cambiarono destinazione d'uso trasformandosi in Università, centri di studi, sedi per Ministeri diventando così parte inseparabile per la vita di ogni giorno e entrando a far parte nella storia della citta, intersecandosi e comunicando tra di loro. Oggigiorno questo patrimonio Storico-culturale condivisa ha aiutato a cambiare la percezione iniziale. Questo patrimonio culturale di Tirana fornisce strutture di grande valore si come sono prova di storia e delle forme della vita e della storia moderna della società. Il patrimonio architettonico da un distintivo aspetto al contesto circostante a uno degli elementi essenziali della città e ancor più diventa una risorsa turistica. Oggigiorno questo patrimonio culturale architettonica viene riconosciuto come fragile e insostituibile, patrimonio che va preservata e trasmessa alle future generazioni. Comunque le politiche di protezione non sempre sono efficienti come lo dovrebbe essere alle quali si aggiunge un disinteresse cittadino e un clima socio-politica molto avversa.

La performanza degli edifici patrimonio culturale dopo i terremoti e una preoccupazione di tante figure professionali di diverse discipline. Anche se tutti predicono la salvaguardia di questo patrimonio culturale – architettonica dal rischio danneggiamento a causa dei terremoti, il prevedibile danneggio di questi valori estetici di questi edifici (causa le addizioni e processi di riqualificazione) viene ostacolato da una decisione consensuale sul bisogno di intervento o meno nel salvaguardare questi tesori. Questo deriva dalla mancanza di una solida base di principi, nel tenere conto dei fattori che incidono sulla riduzione del rischio sismico negli edifici, per il consolidamento della struttura e nel contempo il danneggiamento dei valori attribuiti a specifici tecniche di intervento. L'età di questi edifici si sta avvicinando ai 100° anni fatto che ci rende consapevoli della grandezza degli architetti di quel periodo. Riguardo a questo studio tenta di definire i principi e i segreti della semplicità strutturale e la reinterpretazione teorica degli argomenti strutturali. Le configurazioni in piano e altezza, degli elementi strutturali più usati nel periodo e l'abilita di sopportare a un ampio numero di eventi sismici.

La visione strategica di questo studio e di sviluppare una dettagliata metodologia la quale servirà come manuale di riferimento nel indirizzare sia problemi di restauro anche i problemi del analisi strutturale del patrimonio culturale con i principi delle carte internazionali sul restauro. Si svilupperanno analisi teoriche e interpretazioni delle soluzioni architettoniche del periodo. Lo scopo principale e di trattare il compilato modello degli edifici passato usando i BIM come

strumento di miglioramento dei metodi di valutazione e l'interazione parametrica. Al riguardo delle proposte d'intervento tramite questa metodologia sarà tentato di creare uno spazio controllato e monitorato da esperti, per prevenire danneggi agli assetti architettonici durante il restauro. Questo studio verrà eseguito inizialmente tramite un approccio teorico e studio della literatura mentre la metodologia prenderà forma tramite la considerazione dei casi studio i quali non sono stati precedentemente nello specifico contesto. Il contesto albanese a dimostrato una mancanza di cooperazione di gruppi di esperti o il governo ha fatto che questo contributo sia ancora più fragile. Per raggiungere questo risultato bisogna creare l'atmosfera giusta di cooperazione tra gli esperti considerando i punti di vista diversi. Da l'altra parte questa ricerca mira ad aumentare la consapevolezza riguardo al patrimonio culturale di Tirana tramite la creazione di un dibattito sul patrimonio culturale e il suo futuro al interno di una struttura di lavoro. Questo studio tramite la creazione e la modellazione BIM inclusa, tenta di simulare il processo di digitalizzazione in modo di creare un database di materiali, elementi, modelli combinati strutturali accessibili per futuri interventi di restauro.

Inoltre questo studio si cerca di suscitare la curiosità di ricercatori, studenti, aspiranti dottorandi di ricerca o semplicemente ammiratori del patrimonio culturale i quali vorranno sapere di più degli aspetti architettonici e ingegneristici degli edifici che hanno marchiato l'architettura del XX° secolo in Albania. Questi edifici che oggi definiscono lo spazio la quale oggi ci racconta di come eravamo, come possiamo valutare il passato e come possiamo progettare il futuro.

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Symbols and Abbreviations

- **Symbols**

E	modulus of elasticity;
G	the shear modulus;
v	Poisson's ratio;
V	shear force;
V_{Ed}	design shear force in a wall;
V_{Rd}	the design shear capacity;
M_{Ed}	design bending moment from the analysis for the seismic design situation;
M_{Rd}	the resisting bending moment;
f_b	normalized compressive strength of masonry units;
f_k	the characteristic compressive strength of masonry;
f_m	compressive strength of masonry mortar;
f_t	tensile strength of masonry;
f_{vd}	design shear strength of masonry;
f_{vk}	characteristic shear strength of masonry;
f_{xd}	design flexural strength of masonry having the plane of bending;
EI	stiffness;
σ	normal stress;
τ	tangential stress, shear stress;
ε	is the symbol of deformation (or relative deformation);
ε_{mu}	compressive boundary deformation of masonry;
d	displacement;
d_t	the target displacement of the Multi Degree of Freedom MDOF system (EN 1998-1: AnnexB B5);
d_m	the ultimate displacement of the Multi Degree of Freedom MDOF system (EN 1998-3: C.3.3 [2]);
γ_M	partial masonry resistance factor, according to the Eurocode standard;
γ	specific weight of materials;
Γ	the transformation factor into an idealized equivalent system with one degree of freedom, EN 1998-1 : Annex-B B2-(B.3);
Φ	the standard normal cumulative distribution function;
T	vibration period of a linear single degree of freedom system;
T_1	fundamental period of vibration of a building;
T_B	"the lower limit value of the period";
T_C	"the upper limit value of the period";
T_D	"the constant defining value of the upper limit of the period";
$S_{e(T)}$	elastic response spectrum;
$S_{d(T)}$	design spectrum;
T^*	the period of the idealized equivalent SDOF system;
d^*_m	the ultimate displacement of the idealized system (SDOF);
CF	confidence factor of the material;
γk	k-th modal participation coefficient of the construction;
α_g	design ground acceleration on type A ground;
α_{gR}	reference peak ground acceleration on type A ground;

g	acceleration of gravity;
S	soil factor;
q	behaviour factor;
η	damping corrector factor;
m^*	mass of the equivalent SDoF system;
ξ	viscous damping ratio (in percentage %);
C_{Mi}	center of mass;
C_{Ti}	center of torsion;
αNC	the seismic vulnerability index (Near Collapse) 3Muri software;
αDL	the seismic vulnerability index (Damage Limitation) 3Muri software;
αSD	the seismic vulnerability index (Significant Damage) 3Muri software;

- **Abbreviations**

FEM	the finite element method;
FEA	finite element analysis;
BIM	building information modeling;
H-BIM	heritage building information modeling;
DLS	damage Limit State;
ULS	ultimate limit state;
SLS	Serviceability Limit State;
CSM	Capacity Spectrum Method;
S.D.O.F	the single degree of freedom system;
M.D.O.F	the multi degree of freedom;
PGA	peak ground acceleration;
KTP	Albanian design technical conditions;
IGJEUM	Institute of Geosciences, Energy, Water and Environment;
AQTN	Central Technical Archive of Construction, Tirana;
EN 1996	Eurocode 6: Design of masonry structures;
EN 1998	Eurocode 8: Design of structures for earthquake resistance;
FRCM	Fiber Reinforced Cementitious Matrix;
FRP	Fibre-Reinforced Plastic;
CF	Confidence Factor;
MPa	Megapascal (unit of measurement);
kN	kilo Newton (unit of measurement);
kNm	kilo Newton * meter (unit of measurement);
URM	Unreinforced masonry;
RC	Reinforced Concrete;

Technical symbols, as well as other engineering abbreviations that are specific to paragraphs, sketches-images or special equations, are explained in detail in the relevant paragraph of the theoretical part

ABSTRACT

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Also, in this study will be targeted to overwhelm the curiosity of researchers, students, aspirants of doctoral studies or lovers of cultural heritage who want to know more about the architectural and engineering part of the main buildings that marked the 20th century architecture of Albania. Those buildings that surround us today define the spaces of our cities which still more tell us how we were, how to judge the past and above of all how we can project the future.

CHAPTER 1.

Introduction

1.1 Extended Introduction

This study will initially focus on the context of Tirana's cultural heritage buildings, designed during Italian influence at the period 1920-40s, literature and data collection, also analysis, which will be further compared with the European context, Italian architecture and with similar cases in content. Tirana represents a very special occasion, unique in terms of intertwining the Italian architectural design, combined with Albanian motives and details. This feature of this category of buildings has resulted from many political, economic and social factors of the time that radically changed the way of vision and architectural conception in the Albanian capital. It has been a long time since that period, now the urban-architectural and construction vision of modern Tirana is changing, but it still preserves the most valuable part of the assets and the beauty of the old architecture.

During the period 1920 to 1940, a group of Italian architects, or rather designers reviewed existing urban plans and proposed new and more efficient plans for Albanian cities. The Italian-style architectural heritage and its monumental structures designed during the 1920s in Albania possess precious architectural and cultural elements that must be preserved and promoted, and to achieve this, we can begin by first identifying and presenting them to the community, also a wider range of professional stakeholders and experts. Through the treatment of this study, some of these buildings have been identified and selected, the research focuses on buildings with institutional functions, highlighting their architectural qualities through analysis, investigations and modeling in addition to engineering performance. Through the cases of study on the typology of buildings the aim is to explain and know the design morphology, materials, architectural survey, data collection and BIM modeling. The data of this study will serve for future restoration interventions, in order to help re-evaluate the architectural and urban landscape.

Looking over Albania territories, many professionals are surprised by the big quantity and the quality of this architectural heritage for which have left traces among the best Italian architects and engineers of that period, each with their own skills and militancy in the movements of that time. These designers can be placed within a well-defined cultural "map" that reflects the great ideological aspirations of their country, “the spirit of the beginning of the twentieth century, Eclectism, Rationalism etc.”. The historical period considered is marked by a rich production of projects, sometimes realized, in some cases not, which have however produced a trace in the imagination of the citizens, often marking a drastic change in the way of "living in the city", closely linked to politics and to the ideology of power.

The current situation of these buildings today can be considered problematic in terms of urban performance. During this period in Tirana, an urban-plan is being implemented where it considers the vertical and horizontal expansion of the city, extending in three new rings. Approximately within 2030 the city it will extend to 4 rings. Also, the current city of about 1 million citizens anticipates a progressive increase in the coming years, this has given priority to the government for "expansion, urban planning and infrastructure". Referring to the buildings in the study we can say that they are also neglected in terms of structural performance aspect. These buildings, being positioned in the central axis, are also considered the assets of the city, so, have been constantly maintained to their façades in aesthetic terms, mainly in painting and plastering. There has never been an in-depth scientific study regarding their structural performance as well as seismic consolidation projects. Apart from this, no structural engineering studies have been carried out over the years, on the capacity and current state of their construction. Currently, there are no in-depth, accessible computer models with complete data on these buildings (with a time file) including their architectural or engineering point of view.

The main difficulty as well as dilemmas related to 3d models dealing with seismic rehabilitation of historical monuments is the dominance of ambiguous data but compelling values of the structure model that comes across with the transparency and ease of structural (or seismic) engineering techniques and technology in reducing seismic hazard risk on old buildings. The gap between these two different classes of problems is similar to the known gap between art and science and their reconciliation can be achieved only based on morals and theories.

The inherent value of architectural heritage buildings is indebted to their originality and authenticity, matured appearance and the charm of their designer impression. None of these values have a real substitute, or any solution in our contemporary life and any damage to these architectural assets cannot be authentically restored. This is, perhaps, the main reason for our nostalgic sentiments toward any change, modernization or restoration in these category of buildings. Accordingly, architects, engineers, archeologists, historians and those institution responsible for cultural-historical aspects of the society have developed a kind of sensitive attitude against any restoration strategy for these treasures. In many similar cases, this attitude has reached to a 0-tolerance level if restoration program for the building suggests strengthening the whole system beyond its authentic capacity . *In many literatures, "it's always argued that the great designers of the past" have accomplished creation of a "perfect building" and there is no need for strengthening of such structure for a long time. But it must be admitted that this argument does not serve the reality and our precious buildings need to be studied, investigated and simulated many unfavorable scenarios, seismic risks or beyond* .

Obviously, seismic rehabilitation in cultural heritage structures causes damage to the originality, impression and beauty of the building and should be done, only, if there is a real necessity, such as when structural stability is compromised. When these monuments are located in a region prone to earthquake hazards, the task of the researcher or architect is not to preserve the historical values of the building only at this time, but to extend these values to a longer time span. This can be accomplished in the most efficient way, only if very detailed numerical and graphic models are created, to enable many simulations, scenarios and scientific cooperation between disciplines . Actually the experts should try to rationalize the concept of historical values. In fact, there is a need to add another dimension to the concept of historical values, their life expectancy regarding the earthquake hazard risk in the Balkan region, carefully analyzing risk factors, reliability coefficients, but not only. Without ignoring the problems of the age of the structure, the degradation of materials or atmospheric conditions which directly affect the performance of structures. So, if historical values can survive longer "considering all the above risks" they should be considered more valuable through multidisciplinary modeling .

In this way, addressing the issue of scientific studies related to these buildings beyond the aesthetic or transitory threshold, including seismic or all risks may add to the historical values of the city and can increase efficiency of the issue of restoration . This requires weighing the current historical values together with that after the interventions strategy "when contemporary architectural values are reduced but their life expectancy improved". Such weighing procedure eventually leads us to a consensus on whether the interventions or seismic retrofit plan should be recommended or not according to each specific case. In general terms there must be a well-organized interaction between structural engineers, architects, archaeologists, and so on to take their views into the consideration "*regarding the damage tolerance*" and prepare not to stick to a predefined level of structural & seismic hazard risk for cultural heritage buildings. This is something difficult in theoretical and applied terms, but a methodological basis which can be advanced through computer modeling can minimize the current gap in this issue.

One of the aims of this topic is to assess the current performance of architectural heritage structures, based on the current scientific knowledge mainly of seismic discipline, summarized in literature, guides, codes and standards, through a conservative process of "research, architectural survey, site investigations, BIM-modeling and simulations", without neglecting the theories of restoration, the basic concepts of international restoration charters.

The primary purpose in dealing with this issue, closely related to the study of Cultural heritage Buildings in Albania is to raise the awareness at the academic level initially, starting with practical guidance to improve theoretical and applied methodology for conservation and restoration practice. It aims to assess the performance of these buildings, and also to evaluate and compare their seismic performance in their existing state even according to the requirements of Eurocodes.

Primary vision with announced objectives of the study is to develop a methodology which will help the process of research in the field of restoration in Albania to be improved. This will be made possible through an input-output system serves in the form of a manual in academic rank for addressing the issue of cultural heritage restoration, collaborating and combining with engineering fields, maintaining an immovable pillar of architectural principles and postulates in implementation.

Structural interventions on historical buildings, must be carried out with great care and sensitivity if important special features of the buildings and its essential historic character are to be properly safeguarded. In the first instance, it is therefore always advisable to do plenty of research and obtain the right advice.

Today there are a lot of solutions or intervention techniques on the market, that are well suited to the needs of reversibility and low invasiveness on existing buildings. These tangible contributions are the result of a lot of researches and technological innovation in the academic environment. Regarding this fact, the aim is to further advance this current research product, addressing specific cases such as Albania, conclusions which may contribute to the regional or global context.

Appropriate refurbishment of cultural heritage buildings and their structures is a crucial part of their conservation to ensure they have a safe and sustainable future. Improving the performance of buildings and protection of the historic environment through a careful and critical process, with more research activities and modeling, are therefore strong objectives.

In the elaboration of this thesis, three main cases are treated in detail, including a fourth case theoretically treated in the annexes. Starting with Municipality of Tirana building was dealt with, a historic masonry building from the early 1929s which during the first half of the 1990s underwent an expansion to accommodate other municipal offices; continuing with the analysis of the Complex of buildings of the Polytechnic University, a typical building of 1940, with the first application of the brick masonry mix system combined with RC moment frames; and closing the application phase with the University of the Arts building, a 1939 complex combined between 3 buildings, accompanied by some interesting structural solutions that will be addressed in detail in chapter 6.3. Meanwhile, in the annexes of the study, the fourth case of the building of the National Theater, which is demolished in 2020 to make way for a new multifunctional building, is treated in a concise manner with some findings.

The cases were treated in the framework of the architectural and engineering study, initially mentioning the architectural surveys accompanied by archival or field investigations, organizations of scientific works through academic courses of restoration, student workshops, data collection, engineering context with BIM models, equivalent models, parametric models related to Heritage content, experimental analysis phases and simulations for each possible scenario and finally concluding with some graphic products and recommendations which tend to contribute to the field of restoration.

Research-related issues on restoration and conservation has recently gained a lot of attention in many countries, including the great progress and achievements of architecture, executing preservation, protection, retrofitting, maintenance and restoration of immovable cultural heritage in a standardized way.

1.2 Aims and Objectives of the thesis

The purpose of the study is to address a detailed methodology which can serve as a manual for the issue of restoration, survey & digitization of archival projects, theoretical interpretations of the structure accompanied by simulations and collapse scenarios, as well as addressing the structural issue of cultural heritage with principles or restoration charters, to limit them to a controlled space, to prevent damage to architectural assets. This will be realized through theoretical interpretations initially and then by treating 3 cases of previously undocumented study (in this context).

To achieve this, one of the objectives is to have a well-organized interaction between structural engineers, architects, archaeologists, and so on to take their views into the consideration "regarding the damage tolerance" and prepare not to stick to a predefined level of seismic hazard risk for historical buildings . We emphasize that so far, the spirit of cooperation in Albania is fragile. Much more damage has been done in terms of cultural heritage and the stated objectives tend to reduce this distance between experts.

- One of the objectives of this topic is to assess the performance of buildings with historical value, based on the current scientific knowledge of seismic field, summarized in literature, guides, codes and standards, without neglecting the charm of their architecture, and the historical aspect.

- Interpretations and debate on construction techniques and technologies used by designers in the period 1920-40.

- One of the objectives related to the time context in which we face today, is related to the necessary process of digitization and creation of parametric models by applying BIM, in such a way as to create accessible files for other researchers, with a database of materials. , architectural elements, equivalent structural models intertwined with the architectural one, documentation of interventions or additions, time timeline of the building through modeling (authentic modeling in the design period and current).

- Another objective is the investigation of the structural arguments that have been taken into account in the design, the design codes, the physical-mechanical parameters of the materials, the seismic parameters and certain coefficients. Not forgetting the analysis on calculation reports.

- The issue of rehabilitation of cultural heritage buildings in Albania is an objective to raise the awareness, practical guidance to achieve good conservation and restoration practice. It aims to assess the seismic performance of these buildings, and also to evaluate and compare their performance in their existing state even according to the requirements of Eurocodes. This should be done through literature review and taking into account the principles and theories of restoration, mainly proclaimed by international restoration charters.

The issue of treatment of cultural heritage is complex and must be treated with special care, regarding the aesthetic and historical value. So far, many consolidation interventions, additions, or restorations have been performed on these objects which have left traces. Rapid and routine treatment, lack of diagnostics or the need for consolidation without a proper project, lack of opposition or conservative review has done significant damage to the Albanian cultural heritage.

- This makes us aim to review any restoration, addition or consolidation project, regarding the sensitivity of the restoration & conservation principles and not to allow erroneous interventions in such buildings. This objective requires specific recommendations and a very detailed methodology, on the steps that must be followed to address it. Theoretically this is addressed in the methodology section, where it is shown and graphically how it can be applied.

- One of the long-term objectives that this study aims to create is the inclusion or linking of restoration techniques in programs that apply BIM. This is currently being applied in some countries, mainly in terms of documentation, digitalization and virtual reality. But the issue of interference is not included in these applications. The purpose of this method is to prevent erroneous interventions, by being reversibly parameterized in programs that apply BIM. Wrong interventions can be corrected or made effective based on parametric recommendations that satisfy the principles of restoration (or international charters). This objective begins to be discussed and theoretically systematized in this study and remains open for later post study or collaborations between experts of the disciplines involved.

1.3 The research questions

- The question that will lead the research is whether the architectural restoration and the anti-seismic retrofit of these buildings can be the meeting point between the interests of architects, structural engineers, monuments restorers, government and residents of Tirana, mixing the charm of Italian architecture with the modern vision of Tirana for the future.

- It's always argued that great designers of the past have realized the perfect structural and architectural building. But, is enough this conservative view enough, in the actual reality, not to intervene with a genuine seismic retrofit in these buildings?

- What were the most popular typologies of Italian architecture during the period between the 1920s and the 1940s? What role does the structural and architectural typology of these buildings in the vision and priorities of modern urbanism apply?

- How to renovate the structure and increase the seismic performance of these complex typologies without affecting their aesthetics, which carries historical value? If the question is better re-formulated, the main problem appears in the fact, how to intervene in the object without damaging its aesthetics and architecture, how to integrate with additions made in different periods, and the most importantly "how to find a mathematical non-linear connection to link pre-conceived engineering f.e.m. simulations or collapse scenarios with restoration theories / principles?"

- How have these buildings evolved over the years, the architectural exterior aspect or different design modifications in function of their use and function?

- How can the issue of additions be addressed through interpretations of Brandi theories?

- Regarding the current dynamics of the city, in the framework of new constructions and towers near the cultural heritage objects, the question arises "what are the main challenges that form the key reasons for the preservation of existing heritage places"?

The following sub-questions were elaborated to provide guidance throughout the research trajectory:

- What are the phases of a genuine retrofitting project?
- What are the most common actors involved in the retrofitting project?
- How can the project management process be improved for more effective management in the operation and delivery of heritage building projects?

1.5 Methodology, stages and concept diagrams on the proposed system framework

The research started from the complete study of all archival materials and old or contemporary literature based on these objects. Sources have been works written in Albanian, Italian, articles of symposiums and conferences, writings of foreign authors, experts and scientific reports. In them, attention is focused on the architectural point of view combined with structural system interpretations in general and aspects of BIM modeling and simulations in each selected case in particular. The theoretical explanation followed and the methodological context of this study is done on some general theoretical stages as follows:

Phase 1 "Theoretical bases, principles and charters of restoration, engineering interpretations". This is a long phase covered throughout Chapters 2-5, which theoretically addresses all the architectural bases and principles of heritage restoration & conservation, Brandi C. theories, restoration cards and theoretical analysis on them. At this phase, specifically in chapter 3-4 are treated the basic theoretical engineering concepts on materials, masonry, and seismic engineering accompanied by the respective calculations and parameters. The evaluation on the design codes of the period, compared to the current codes and the Eurocodes are also treated.

Phase 2 "*Historical values identification and manifestation*". Initially, rehabilitation of historical building start with a qualitative appreciation related to the values of the structure and its materials. However, in the case of seismic retrofitting and rehabilitation process, these values should be quantified carefully in order to be able to continue the process. This phase will be realized with great care and by consulting step by step with experts in the fields of architecture, engineering and archeology, for preserving the architectural and historic values and impressions of the building. To have a simplified guideline . The process of recognizing historical values can not be done completely without being completed and with the context drawn in the second phase of architectural survey, but considering the cyclical interaction between the phases, more favorable conclusions emerge.

Phase 3 "*Architectural Survey, documentation, archival digitization, collection of material and model selection criteria*". This is one of the main phases of this study. This phase is briefly managed in theoretical aspects and then adapted to each case study analyzed in Chapter 6. Collection of visual documents and reports, photos, archival drawings, graphics, previous architectural surveys, additions and their projects or documentation, models and recent intervention projects.

These documents were provided on the basis of the central technical archive of Tirana, on-site architectural survey, interpretations and confrontations from literature, publications, books and scientific articles, and then systematized taking into account:

- Determining the date of taking the photo, sketch or survey;
- Verification, through direct viewing of the building, site architectural survey to investigate changes with the current situation or with other visual and archival documents;
- The process of orthogonal photography with a drone, or the use of a laser scanner and then the processing of these phases through photogrammetry;
- Placing in chronological order to enable the results in their historical evolution, whether or not there were changes or interventions in time, or whether there were pre-existing structures in the same place;
- Analyze and create the transition or timeline of the building;
- Digitization of archival drawings in cad format;

- 3d modeling of buildings (model of the authentic building at the time of design and the current model of each building), the emphasis is on BIM modeling;
- Analysis on the degradation of the facade material, problems with humidity, mold, fractures and cracks of the masonry panels.

Direct examination and interpretations of the work – reflections and analyzing typological details.
This inspection has been done several times and has been done documented through photos and sketches. Detailed analysis of additions over the years, why these additions were made and how they affect the performance of the structure. It is analyzed whether these additions are carried out in accordance with the principles of architectural restoration. During this observation will be documented:

- Distinctive construction and architectural phases through theoretical analysis;
- Status of the monument, the current architectural value of the building;
- Materials and physical-mechanical properties of materials used for construction, to better understand the building and the structural performance of buildings;
- Small details of the architecture and constructive details of the building and ways of working the material, in-depth analysis of facades;
- Additions, floors or side additions. Change, or not, of the compositional form of previous interventions in facades, reconstructions or different phases of construction;
- Investigations on the additions, the function of the additions and their documentation in the historical timeline of the building. Theoretical interpretations on the architectural style of the additions.

The selection criteria of buildings became related to the necessity to analyze and investigate on different typologies of this period. The objects themselves have their own features and interesting points to be analyzed and discussed. Based on the found materials and the analysis made to each building of the architectural typologies, it was decided that the study would focus on engineering analysis and seismic performance first, and then analyzing with the architectural context and some of the principles of architectural restoration. The building of the Municipality of Tirana with masonry structures were analyzed first and then the building of the Polytechnic University, and at the end the building of the University of Arts, which have more complex structures. These are discussed in detail and constitute the core of this study. The case of National Theater (demolished now[1]), is treated briefly in the annexes of this study.

An important part of this phase is the creation of bibliographic files, known as “A digital database about all the elements of the cultural heritage building”. During the reading of the relevant bibliographic files and archival reports found in projects, are created which are not based, as usual, on the data of a book but summarize, according to the typology. These bibliographic files contain data on the time of construction, writing references, materials parameters, calculation reports, what was written about it and how each author or designer comments on the typological work/project, compositional or constructive data and what original literature contribution the author brings, graphic data of the writing as architectural plans, altimeter sections, details or sketches.

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[1] The National Theater building complex was demolished in 2020 by the local authorities (on conclusions of the degraded structure and the needs for a new building with more space), to build a new contemporary building.

Regarding the methodology, it should be noted that in addition to theoretical and archival-collection work, this second phase will be carefully realized through the interaction of experts in the fields of architecture, engineering and planning, through the subject of "Cultural heritage restoration". So the coordination of academic experts and coordination of work with architecture and engineering classes at Polis University, with the course which is applied in the 4th year, is the basis for the development of the on-site research phase. The students worked on the guidance of the lecturers of the course to process the archival material and to make verifications or field survey processes near the selected buildings. The work has been strictly monitored and directed to bring out a good digital base of this phase. Furthermore the specific work of each group is explained specifically for each case in Chapter 6.

Phase 4 "*3D modeling, f.e.m. analysis, seismic simulations and investigation of possible collapse scenarios*"

In order to accomplish such a task, the design of three-dimensional finite element models and simulations must be an integral part of this research. The basic concept will be the conversion between the architectural model and the structural 3D model. Two types of model conversion are targeted. One is for linking architectural models and structural models together, another is for linking among structural analysis applications. The first model will represent building geometry and appearance representation while a structural model will include all structural elements involved in vertical and lateral load transferring. Through this BIM model, it pays attention to the details mainly on the facades, so we cannot overlook any detail in the 3D modelling, which should be as close to reality, representing the charm, beauty and even the damage that has been carried through the years. The second model is associated with the equivalent structural and analytical model to undergo seismic analysis. Care has been taken to investigate possible collapse scenarios through nonlinear static analysis, performance point, target displacement, and structure age calculation. This aspect has been treated to locate the most fragile parts of the structure, in order to identify these areas which will be subject to subsequent consolidations.

Phase 5 "*Proposals on rehabilitation and retrofitting strategy and critical review of restoration projects*". On heritage buildings, any attempt for strengthening the system is facing the possibility of damage to one of the values of the building. Therefore, a vigilant agenda for proposing rehabilitation plans for historical buildings should be adopted. Practically, this phase of the work should be based on the structural engineering visionary expertise in devising retrofitting techniques with damage tolerance constraints. Earthquake engineering knowledge is also required for evaluation the seismic hazard risk level for each rehabilitation technique. This parameter can be, later, converted to the seismic life expectancy of the structure. Another face of the problem is assessment of damage to the historical values of the building, attributed to each rehabilitation technique. This requires, at first, calculation of damage ratios in each historical aspects of the building. These ratios will be used in damage estimation and, consequently, evaluation of contemporary historical value of the building after the structural retrofitting. This important phase is closely related to the process of reverse project review, which is explained graphically in detail in (figure-2).

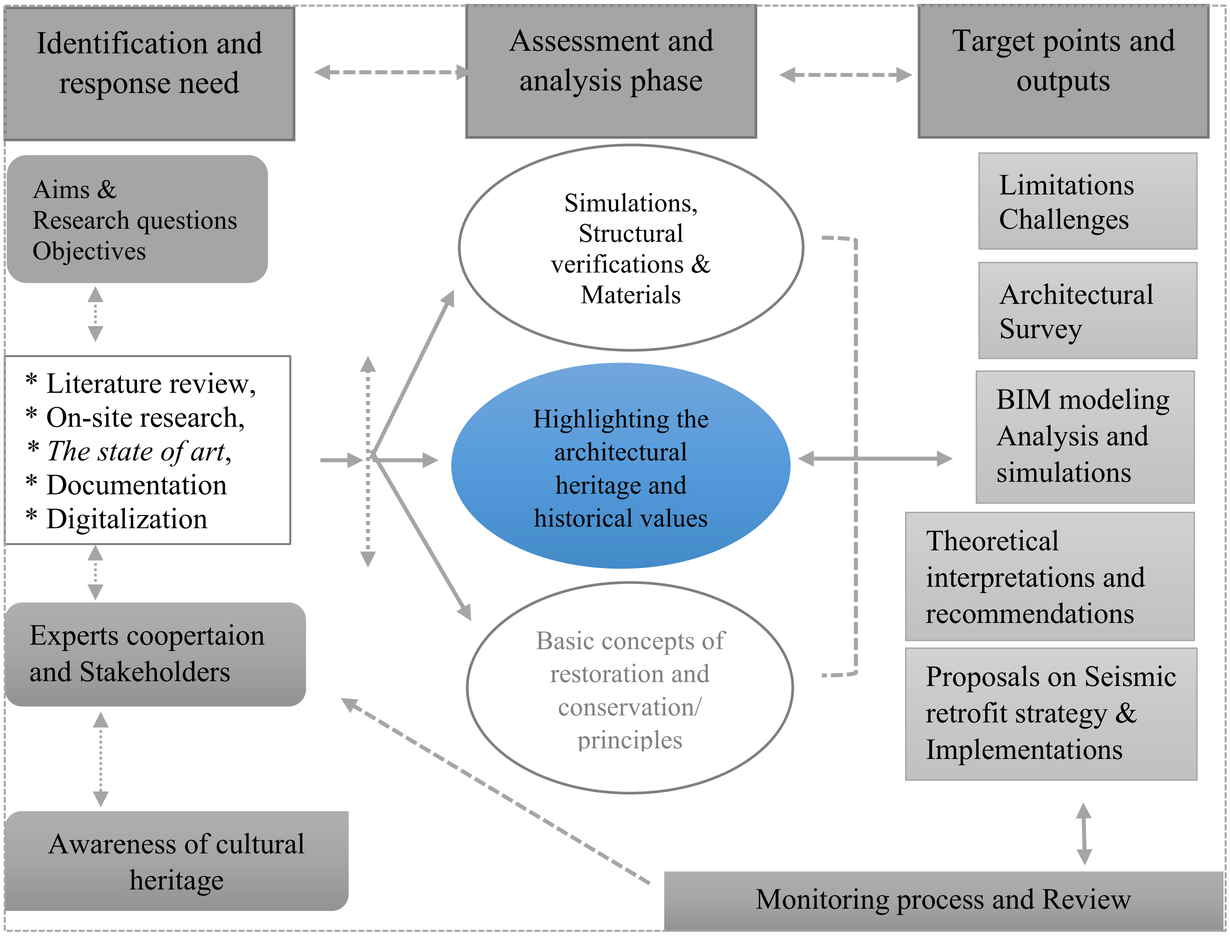
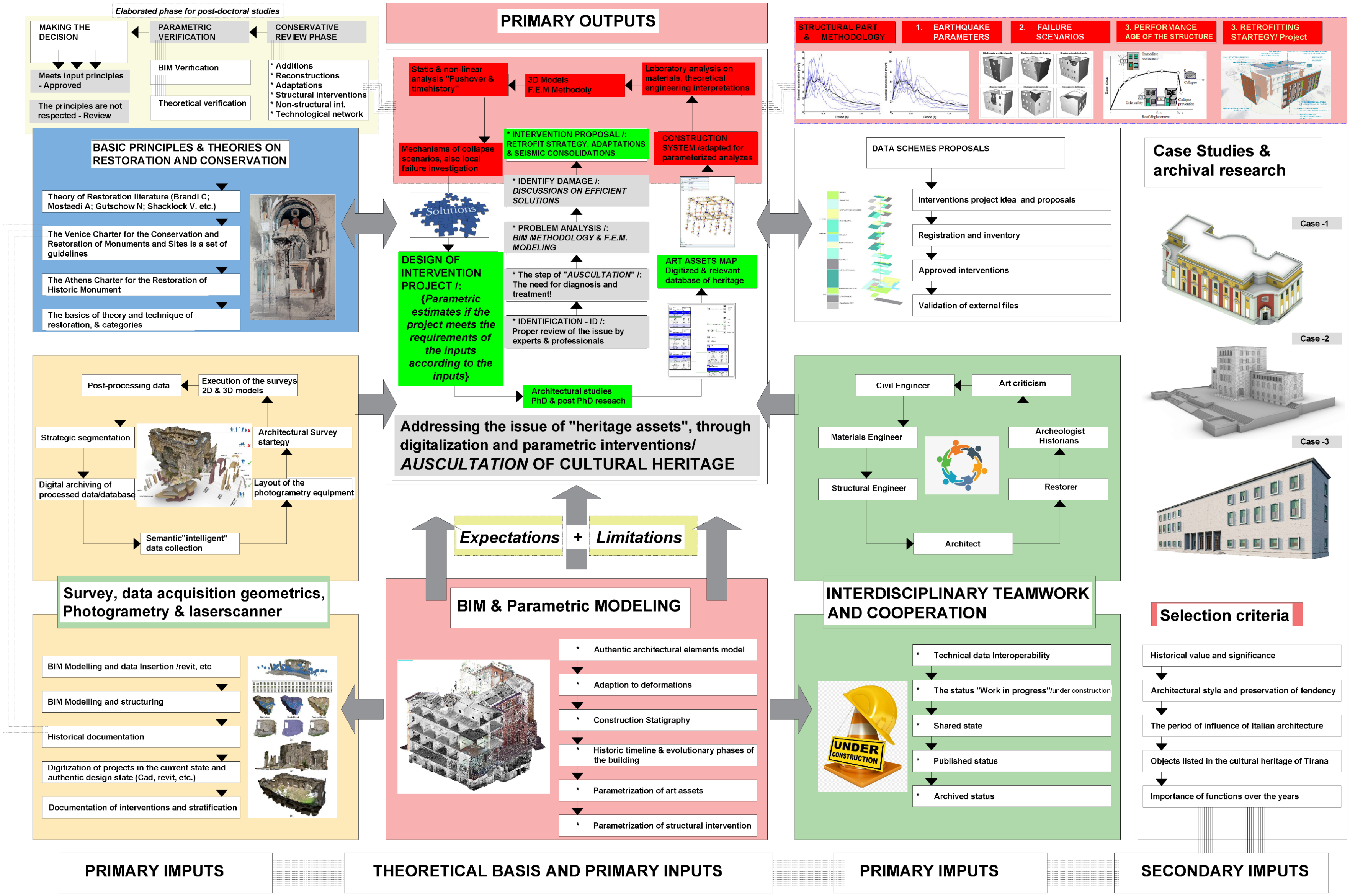


Figure 1. Initial framework of the study, Research stages and Management (source: author)

Above (figure 1) is shown a very general overview of the methodology proposed at the beginning of this study (specifically in the research proposal phase), where the work is based on 3 general pillars. The first phase includes Identification and response need, with all the processes mentioned above, such as literature review, on-site research, state of the art briefly, project documentation and archival digitalization. This phase includes experts cooperation, stakeholders and general awareness of cultural heritage. The second phase includes the whole process of theoretical assessment, the state of art, the review of the regional, international context, also reflections, theoretical interpretations and analysis. The third phase summarizes the entire phase of 3d modeling, analysis, simulations, BIM[2] involvement, recommendations and proposals on intervention strategies. Also this phase is indirectly related to critical reviews on the given proposals, linking the proposals with a theoretical basis and controlling the application of theoretical principles on the implementation projects. This phase is potentially reversible at the starting point and is cyclically related to phase 2 of the diagram. So it is an initial methodological diagram, which has laid out the theoretical basis of the research and is then completed and specified in the main diagram, which is presented in (figure 2).

[2] Building Information Modeling "b.i.m." is the methodology of digital transformation in the architecture, civil engineering, technology & overall construction industry.



Elaborated phase for post-doctoral studies
MAKING THE DECISION
PARAMETRIC VERIFICATION
CONSERVATIVE REVIEW PHASE
Meets input principles - Approved
The principles are not respected - Review
BIM Verification
Theoretical verification
* Additions
* Reconstructions
* Adaptations
* Structural interventions
* Non-structural int.
* Technological network
BASIC PRINCIPLES & THEORIES ON RESTORATION AND CONSERVATION
Theory of Restoration literature (Brandi C; Mostaedi A; Gutschow N; Shacklock V. etc.)
The Venice Charter for the Conservation and Restoration of Monuments and Sites is a set of guidelines
The Athens Charter for the Restoration of Historic Monument
The basics of theory and technique of restoration, & categories
Post-processing data
Execution of the surveys 2D & 3D models
Strategic segmentation
Architectural Survey startegy
Digital archiving of processed data/database
Layout of the photogrammetry equipment
Semantic"intelligent" data collection
Survey, data acquisition geometrics, Photogrammetry & laserscanner
BIM Modelling and data Insertion /revit, etc
BIM Modelling and structuring
Historical documentation
Digitization of projects in the current state and authentic design state (Cad, revit, etc.)
Documentation of interventions and stratification
PRIMARY OUTPUTS
Static & non-linear analysis "Pushover & timehistory"
3D Models F.E.M Methodoly
Laboratory analysis on materials, theoretical engineering interpretations
Mechanisms of collapse scenarios, also local failure investigation
* INTERVENTION PROPOSAL /: RETROFIT STRATEGY, ADAPTATIONS & SEISMIC CONSOLIDATIONS
CONSTRUCTION SYSTEM /adapted for parameterized analyzes
Solutions
* IDENTIFY DAMAGE /: DISCUSSIONS ON EFFICIENT SOLUTIONS
* PROBLEM ANALYSIS /: BIM METHODOLOGY & F.E.M. MODELING
DESIGN OF INTERVENTION PROJECT /: {Parametric estimates if the project meets the requirements of the inputs according to the inputs}
* The step of "AUSCULTATION" /: The need for diagnosis and treatment!
ART ASSETS MAP Digitized & relevant database of heritage
* IDENTIFICATION - ID /: Proper review of the issue by experts & professionals
Architectural studies PhD & post PhD reseach
Addressing the issue of "heritage assets", through digitalization and parametric interventions/ AUSCULTATION OF CULTURAL HERITAGE
Expectations + Limitations
BIM & Parametric MODELING
* Authentic architectural elements model
* Adaption to deformations
* Construction Statigraphy
* Historic timeline & evolutionary phases of the building
* Parametrization of art assets
* Parametrization of structural intervention
STRUCTURAL PART & METHODOLOGY
1. EARTHQUAKE PARAMETERS
2. FAILURE SCENARIOS
3. PERFORMANCE AGE OF THE STRUCTURE
3. RETROFITTING STARTEGY/ Project
DATA SCHEMES PROPOSALS
Interventions project idea and proposals
Registration and inventory
Approved interventions
Validation of external files
Civil Engineer
Art criticism
Materials Engineer
Archeologist Historians
Structural Engineer
Restorer
Architect
INTERDISCIPLINARY TEAMWORK AND COOPERATION
UNDER CONSTRUCTION
* Technical data Interoperability
* The status "Work in progress"/under construction
* Shared state
* Published status
* Archived status
Case Studies & archival research
Case -1
Case -2
Case -3
Selection criteria
Historical value and significance
Architectural style and preservation of tendency
The period of influence of Italian architecture
Objects listed in the cultural heritage of Tirana
Importance of functions over the years
PRIMARY IMPUTS
THEORETICAL BASIS AND PRIMARY INPUTS
PRIMARY IMPUTS
SECONDARY IMPUTS

Figure 2. Principal methodology and process applied for cultural heritage on this study, main inputs of theoretical concepts used and literature, research strategy, application, long-term strategy and expected outputs (source: author)

The methodology is presented on a cyclical basis with inputs and outputs (Figure 2). Basic inputs and theoretical framework is static and should be applied rigorously, while for the announced objectives and expectations of outputs is left free zone to interpret according to the specific case, while in this methodological diagram are proposed recommendations for other future post-research, to take this study to other dimensions. The initial idea for the creation of this matrix methodology was taken from the Nieto's study (Nieto-Julián, Lara, & Moyano, 2021), further this idea has been developed and updated according to the research of this topic. This theoretical-methodological diagram means that it acts as a basic method to control procedures, in which the results obtained at an early stage are re-incorporated back into the proposed BIM system in order to optimize the effectiveness of cultural heritage interventions.

Regarding this cyclical circulation diagram (Figure 2), the intended purposes, in addition to those discussed above, is to generate a digital platform or adapt to current platforms that apply BIM, which includes the database of cultural heritage objects in Albania in a digital information model. This is the first research phase integrated from the theoretical work, using an existing BIM structure. The system management in this study is focused on research, theoretical interpretation, preservation, consolidation, restoration and awareness for heritage dissemination; in addition, the proposed methodology is theoretically applied to 3 case studies of cultural heritage or architecture in Tirana.

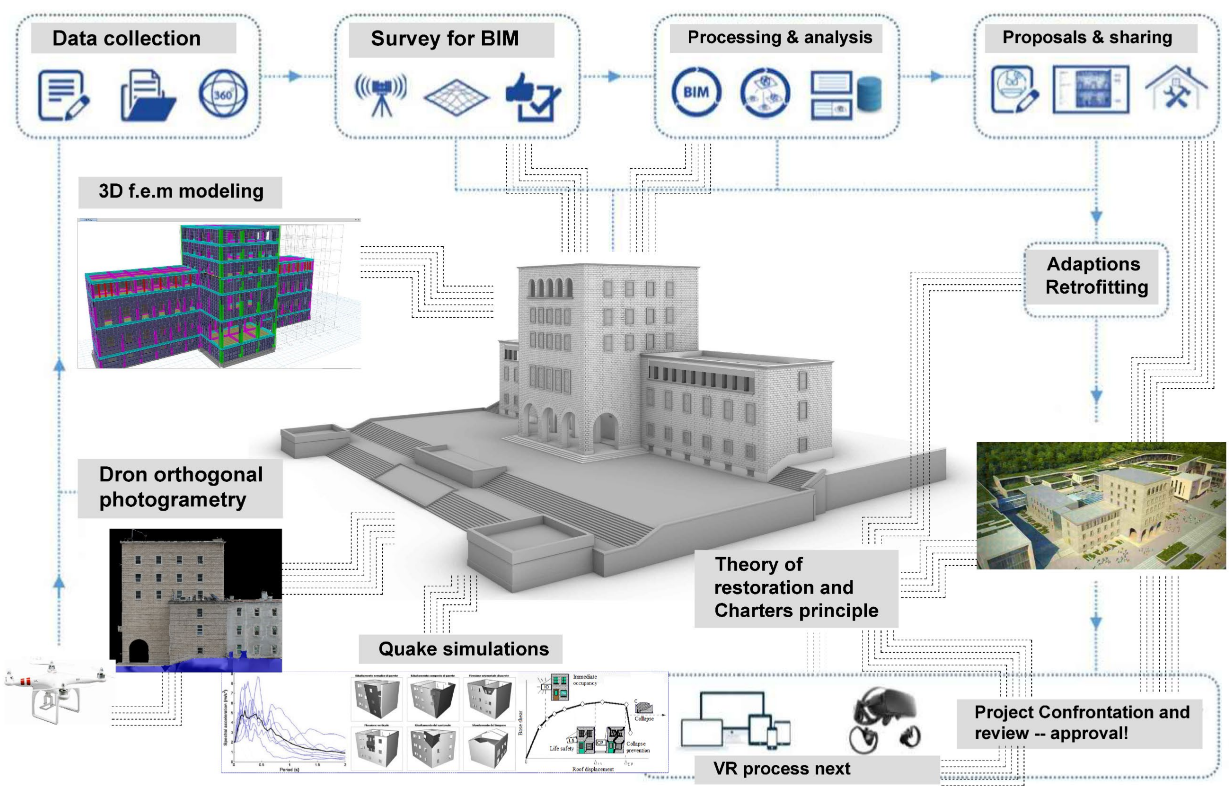


Figure 3. General diagram on the research method proposed in one of the cases selected for analysis of this study. (source: author)

Consideration of engineering simulations, study of types and parameters of earthquakes that may affect the performance of these objects, theoretical basis for the treatment and evaluation of structural performance, inclusion of engineering database in architectural modeling files, the connection of the theoretical basis of Eurocode as well as the comparison of engineering parameters after almost 1 decade, are an important part of the methodology treated in this study.

The methodology shown in these graphic diagrams aims to achieve the basic objectives announced above, such as archival digitization, modeling, simulation and analysis. The issuance of conclusions and proposals does not mean the closure of the research for the created system, but leaving the free path for post-doctoral studies or other research on the creation of the inclusion of these theoretical aspects specifically in current programs using BIM, interaction of parametric analysis referring to the interventions in cultural heritage, the creation of the virtual museum of these objects and many other aspects initiated in this study for the specific Albanian context.

1.6 Expected results

Regarding the expected results, Seismic analysis, simulations and architectural survey of selected buildings will be developed. In terms of engineering & seismic simulations a higher level of performance is considered, beyond the current level of "live safety" for the design and consolidation of structures. This means looking for a new level of performance for the detailed seismic analysis of these buildings, researching between live safety field and structural stability (near collapse) field. Also, we should base on the basic principle of restoration of buildings, "It should not interfere in architectural details, in the facade motives, but only on the structure or skeleton". Accurate and prudent implementation of this phase will be based on the application of innovative methods and technology of buildings repair and modernization.

1.6.2 Stakeholders

Concerning stakeholders there are 3 main groups. The first group consists of field experts, architects, engineers, archaeologists, restorers and historians. The second group includes administrators and actual users of these buildings, which is the government with all its units. Also this group includes landowners. And the last group includes residents of Tirana.

1.6.3 International interest in this research

The need for the existence of these assets of historic values is nowhere denied rather they are worth preserving. So, referring to these great values, this study is an added value for all studies in the Balkan region. These types of researches are full of values to the region, based on large wealth with old historical heritage that need to be repaired and updated.

1.7 Reasons to make this study and select this topic

Thousands of tourists and citizens who visit every year the central axis of Tirana, have different cultural backgrounds. They see buildings and works of architectural heritage, and often, unless they are architects or engineers, they manage to penetrate the style, elegance and architecture of these buildings. They have read about the city, the history, they go to visit it, they are in front of this part of the city heritage. In the multitude of problems of the city today, government and local policies, the transformation of the city into a metropolis, new constructions, reconstructions and additions have made professionals in the fields of engineering and architecture or others unable to penetrate, in true elegance and value of these objects, fail to perceive how they were and in what forms the original objects were, or even the urban planning of the surrounding area which has changed completely. They come out almost disappointed by the visit to the city. A tour guide or an application is not enough to make understandable the form that the architectural works of the city have had, mainly of the period 1920-1940.

In this way, almost all the architectural and historical value of the city is lost, and consequently our culture and national heritage. One aspect that would help a lot in the accurate study of these heritage objects, is their 3D-dimensional modeling digitally with engineering methods. structural analysis looking also at theories of architectural restoration or digital, virtual reconstruction.

Such cases are similar in the history of engineering but also of restoration architecture. 3D dimensions of architectural works of historical heritage or of the cities themselves. But to achieve such engineering models and architectural reconstructions requires a good historical and typological study of the buildings and the city itself, research on materials, facades and archival projects, the study of analogous cases and typologies in other countries, mainly Italy, but also the Balkan context. Only after it becomes complete and based on factual material and historical data, can we allow ourselves to reach formal deductions and engineering models for the shape of the buildings and for their structural condition today.

The other reason is related to the necessity to study the architectural aspect of the buildings, especially those that have been little studied, but keeping it related to the engineering context and structural performance, emphasizing that in previous studies the structural issue has not been addressed. these objects.

Thus, following this logical flow, we found the reason for an in-depth research and comparative work to study some key typologies built in Tirana by Italian designers, and to theoretically investigate the principles used in design and construction as well as the structural performance of objects. selected. Through this study we want to show that the typological architectural study, coupled with the engineering and seismic context should precede and become the basis for their 3d virtual modeling.

CHAPTER 2.

Research on Structural, Architectural and Urban typologies of the period 1920', Italian design models

2.1 General characteristics of unreinforced masonry buildings designed in the 1920s

The control of masonry buildings is of growing interest from the academic, professional and industrial world for the following reasons related to their diffusion and their response to external actions:

1) masonry constructions constitute a large part of the existing residential and historical-monumental building heritage;
2) some types of walls (for example stone walls or buildings with insufficient box-like behavior) have shown a high vulnerability to seismic actions;
3) some construction types (for example tower buildings) have shown a dangerous sensitivity to environmental vibrations, in particular those induced by vehicular traffic;
4) the materials constituting the wall textures and horizontals have often undergone irreversible alterations caused by the chemical-physical actions of the environment, made highly aggressive by pollution.

The pathologies manifested in the structural behavior, in particular in buildings of a historical-monumental nature, have on the one hand raised the question of safeguarding the heritage through political choices that are sometimes difficult to implement (for example the limitation of traffic in historic centers) and, on the other hand, given a considerable impulse to the research of investigation methodologies and to the development of experimental techniques aimed at the knowledge of the state of affairs that allows, as previously observed, to prepare the implementation tools for the restoration and / or construction consolidation.

The behavior of a building both from a structural and conservation point of view (durability) depends on two characteristics:

1) From the wall typology (Bufarini, D'Aria, & Giacchetti, 2009), with reference to which it is possible to make the following classification:

- brick masonry,
- well-squared stone masonry with regular courses,
- partially worked stone masonry and fairly regular courses,
- listed masonry,
- non-squared stone masonry with irregular courses,
- sack masonry;

2) The type of construction of the structural complex (Bufarini, D'Aria, & Giacchetti, 2009), with reference to which the following classification can be made:

- buildings entirely in masonry (with vaulted horizontals);
- buildings with continuous masonry walls and with wooden or iron floors;
- buildings with masonry walls and reinforced concrete floors and curbs;
- mixed structure buildings.

The setting up of the campaign of instrumental investigations aimed at diagnostic control is conditioned by the location of the building in question within the above classes, which in turn may require, in the preliminary phase, the use of special relief techniques. These techniques must aim to highlight the aspects that have the greatest influence on the performance capacity.

For buildings built in seismic areas, or in any case subject to dynamic actions, the degree of vulnerability depends on numerous factors (Bufarini, D'Aria, & Giacchetti, 2009):

- the shape in plan and the distribution of masses and stiffnesses in the height (structural system);
- the type of construction of the structural elements and the type of assembly;
- the quality of the binders often altered by physical-chemical degradation phenomena;
- the degree of clamping between walls;
- the type of connection between walls and horizontals;
- the presence or absence of pushing elements;
- the stiffness of the floors in their own floor;
- the global and local dynamic characteristics, linked not only to the masses but also to the overall rigidity and their relationship with the dynamic characteristics of external actions;
- the state of tension and the current geometric configuration, due to the statically acting loads.
- To these factors must be added those related to soil-structure interaction:
- lithology, hydrogeology, and geotechnical characteristics of the sediment soil;
- type of foundations and related tax rates.

To understand better the difficulties inherent in the diagnostic process oriented towards the design of seismic improvement and / or adaptation interventions, a real case is illustrated having as object of study a school building characterized by a great constructive complexity.

A wide campaign of endoscopic observations made it possible to find that the structure of the main building is made up of masonry walls which, almost entirely, were built with a "sacco" type[3].

In the walls of the first elevation (basement) the faces are sometimes both of solid brick with one head but more frequently of limestone with regular ashlars. The stone blocks are of a pink or white limestone nature with thicknesses ranging from 15 cm to 37 cm. In most of the cases investigated in the same wall, the internal and external facing are made with stone blocks of different colors. With regard to the masonry walls of the floors above ground, the facing are both made of solid bricks and have an almost constant thickness equal to 13 cm. The filling between the two linings of the "bag", whether they are in stone blocks or in bricks, is always made up of a sort of conglomerate of rounded aggregates of various sizes linked by a rather poor quality cement-based mortar.

In only one case, at least among those investigated, the masonry is compact with two heads made with bricks placed at the head.
Inside the type with double brick lining there is a sub-group of walls which also function as infill, which have an external facing in red perforated brick and an internal facing sometimes of solid bricks of yellow color, sometimes of square stone, sometimes of a mixture of stone and brick.

[3] "a sacco" masonry: with a thick inner wall and a thinner outer wall, where the gap was filled with stones and mortar. In this masonry (the so-called "a sacco" typology) it is possible to recognize stones with different height-length ratio of the external face (1:1; 1:1.5; 1:2).

In all cases the mortar joints are of variable thickness around 15 mm. The bedding mortar is always cement-based, characterized by poor consistency and sometimes tending to pulverize. To allow the creation of openings of considerable light, in some cases the internal walls have been removed and replaced locally with architraves having considerable spans. The disposition of the resistant walls is quite regular even if, especially the infill walls, they are characterized by the presence of numerous openings.

The horizontal elements are made up of brick-concrete floors with parallel ribs placed at a distance of 50 cm. The pitched roof is also made with the same type of floor. This floor rests on walls which, for some sections, have been made with double-headed UNI type perforated bricks. The building that have the big spaces with plan dimensions of approximately 27.54 x 13.10 m and a height of approximately 6.00 m. The connection between this building body and the main one takes place through a covered path made structurally independent by a technical but not seismic joint. The load-bearing structure consists of a perimeter masonry on which a roofing consisting of a brick-concrete floor is supported, carried not only by the transverse walls but also by three spatial beams in reinforced concrete, also arranged in the transverse direction. The connection between the beams and the underlying walls takes place by means of three pairs of pillars always in reinforced concrete. which transmit the loads to a continuous curb made on the top of the walls. The autopsy examination showed that all the main beams have, at the ends, capillary cutting cracks and, across the mid-section, flexural cracks.

From the surveys carried out, it is immediately clear that the supporting structure of the building has a multiplicity of structural types, however all attributable to that of “brick masonry with independent facings and filling of poor consistency” (Bufarini, D'Aria, & Giacchetti, 2009). The vestments were made with different techniques:

- solid brick masonry of predominantly yellow color and cement mortar;
- white limestone masonry with squared ashlars and cement mortar;
- pink limestone masonry with squared ashlars and cement mortar;
- mixed masonry of solid bricks and white or pink limestone with squared ashlars and cement mortar;
- chaotic matrix masonry with sporadic presence of brick blocks;
- semi-solid red brick masonry and cement-based mortar.

The overall thickness of the masonry walls is also highly variable in relation to that of the filling; in fact, the thickness of the vestments is always kept almost constant and equal to a head (about 13 cm). Since this type of investigation has been extended to a sufficiently large number of masonry, it seemed legitimate to attribute the same type of sack masonry to the walls not directly investigated.

Related to the building with big hall spaces, the masonry, have a thickness of about 44 cm clear of the plaster, is made with a “sacco” typology in which the external facing, having a total thickness of 26 cm, is made up of two linings 12 cm thick each, the first of semi-solid red bricks "facing" and the other, simply placed next to the first through the interposition of a 2 cm thick cement mortar plaster, made with solid bricks. The inner lining, on the other hand, is made up of perforated brick blocks. Regarding to the connections between orthogonal wall walls, the close visual examination showed that the clamping was carried out sporadically by crossing and overlapping a very limited number of elements (bricks and / or stone blocks) to a depth of a few centimeters. This generally results in an insufficient degree of mutual interlocking which makes the clamping of modest effectiveness. A careful autopsy investigation revealed that, on the contrary, the degree of connection between the masonry walls and the brick-concrete floors appears to be effective.

The endoscopic survey was followed by other determinations in situ and in the laboratory. Tests with a flat jack in a single configuration made it possible to evaluate the current state of tension of the masonry linings. Having obtained these values, the application of the flat jacks in double configuration allowed to determine the elastic parameters (Young's and Poisson's modulus) in an interval around the value of the current working stresses (for gravitational loads only) and of the tension in situation seismic. Finally, the on-site removal of sample bricks and mortar made it possible to directly determine the resistance to compression of the elements making up the masonry walls. All the information collected during the experimental investigation campaign, suitably processed, made it possible to fine-tune the structural calculation model aimed at the seismic verification in the current situation and, subsequently, to make design choices with the aim of adequately increasing the security level of the building.

In fact, having recognized that the weak points of the main building were substantially the poor effectiveness of the clamping between orthogonal wall walls and the sack type of the walls, it seemed technically correct to improve the situation, in both cases, by means of post stretched that could enhance or realize a structural solidarity.

The effect of the type of solidarity intervention on the walls was finally translated into an appropriate structural model in order to calculate the increase in resistance obtained.

2.2 Italian concept, building design and planning strategies for the Albanian cities

Based on the research carried out in the Albanian technical archives, also on the literature of the time and the current one, it can be said that the Italian designers contributed to the planning and construction of Albanian cities according to two main phases, linked to the Italian conquests of the country. The first phase, which runs from 1915 to 1939, brings the Italian architects and engineers employed in the technical offices of the various cities. Their contribution in Albania is extensive and ranges from design and construction implemention. of including aslo the infrastructural system, the drafting of the first Regulatory Plans of Tirana and the arrangement of city centers through the construction of representative buildings and architecture of great public interest.

The second period begins with the creation of the "Central design office for Construction and Urban Planning" for Albania, especially Tirana, from 1940 until 1943, at the time of capitulation of Italy. The interventions that have taken place in recent years are all to be traced back to the activity of this design-office which consisted in the control of public and private construction activities in Albania, in the drafting of new building design "especially institutional buildings of special importance but also villas or residences", city plans and urban planning regulations. As well as in the strengthening and control of all cities infrastructural systems, related an efficient development of the cities and territories adjacent to it. In addition, the work of this design-office was of a great double value, on the one hand a centralized political instrument for albanian territorial development while on the other hand it was a guarantor of design quality and architecture.

The design activity concerned the following works: "valuable projects in Tirana, turning the port of Durres into one of the largest in the region, port of Vlore and Porto Edda in Saranda at south, Shengjin port, new projects and urban plan for Berat and Elbasan, the organization of the central area of the Shkoder and Korça city. And finally the urban intervention of some small towns with strategic importance such as Milot and Permet. The italian designers of the central office in the preliminary phase of drafting the projects and plans followed a common practice for all cities, considering the variables due to the different contexts at second period. The project-startegy consisted of historical knowledge, the type of approach with the existing city plan and its connection with the new expansion. The historical study was focused on the re-evaluation of monumental cultural heritage and traditional characters, in particular for the oriental and ottoman ones that gave the cities an aesthetic aspect. The enhancement of the architectural and cultural heritage was the basis of the italian strategy.

The connection strategy between the new city and the existing one was subordinated not only to the road system or infrastructure, but also to the green bands spaces and in particular to a commercial or monumental directorate axis. In all coastal and portual cities, the policies already in place in Italy since the 1920s were applied for the enhancement of seaside tourism. Through promotions and financial incentives was promoted all types of accommodation services for an attractive increase. It has been ascertained that the italian designers considered cities to be living organisms, often resorting to the paradigm of the human body they were able to better manage and plan their development. This design philosophy began to be further applied in building complexes and villa projects which today are considered the basis of cultural heritage sites.

2.2.1 Tirana, the construction of a capital city. Birth and evolution of the Ottoman city

Based on the theoretical research, the Architect Marco Stigliano has summarized this article for the design of the Albanian capital, Tirana, as follows:

The Ottoman conquest of Albania, which began in the 14th century, found in Tirana an important crossroads between the main transport routes between East and West.

The transformation of Tirana from a village to a city dates back to the seventeenth century when various religious buildings began to be built, as part of the desire to convert the population from Christianity to Islam. An urban system with a "diffuse archipelago" was formed: a series of distinct urban nuclei, which probably referred to powerful local families, organically organized around the centrality of the mosque which became the element of social and political aggregation of the population .

The first urban nucleus of Tirana probably grew around the old Pasha Sulejman mosque (1614), at the center of the current conformation of the city, at the intersection of the main interregional transit arteries. Along with the mosque, other buildings were erected, including those of the feudal lords and their relatives, on the right bank of the river Lana. The second urban nucleus was created in the early 18th century around the Fire Mosque about 600 meters north-west of the first nucleus, where today Rruga Barrikadave intersects Rruga Fortuzi. The mosque was called "Beshiri mosque" after its builder. The third nucleus was built north-east of the first and the Zajmi mosque was erected there, at the intersection of Rruga Dibrès and Rruga Thanas Ziko. The fourth nucleus dates back to the time of the foundation of the Haxhi Ethem mosque, about 200 meters west of the old mosque.

In other neighboring areas, around the first nucleus, other agglomerations were born, always with a mosque as a fulcrum (Stèrmas 1840; Kokonozi and Bèrxolli in the 19th century; Karapici 1858; etc.). Each of these nuclei was born independently of the others, until, as they grew up, they had merged to form a spontaneous urban design in patches of leopard. Added to this was the feudal fragmentation of the land and the absence of a central administration.

The construction of the Sulejman Pasha mosque, the Baths, the Inn, the Oven and the Pasha Kapllan Tomb, historically and architecturally symbolize the birth of the city of Tirana1. All these buildings, except the last one, have been destroyed over time, especially during and after World War II. The most historicized current pre-existing structures of the Ottoman period, the Ethem Beu mosque and the Clock Tower, were built between 1794 and 1822.

The city in this period was recognizable in two distinct areas: a residential one, with low brick houses, very extensive without apparent limits with the countryside; the other denser represented by the bazaar, a real shopping center, destroyed and rebuilt several times. The latter insisted on an area of about two hectares along the road to Dibrës at the intersection with the main interregional roads; Demolished and rebuilt in 1905, it had the typical appearance of the Ottoman market, the narrow and winding streets were defined by single-storey buildings consisting of a shop and a back room with wooden roofs that protruded in a cantilevered way. protect from bad weather. In 1960 the bazaar was definitively demolished to make way for the Palace of Culture.

2.2.2 Identification and the performance of the cultural heritage in Tirana

Selected projects analyzed in this study, tackle the delicate problem of the transformation and integration of modern buildings, a practice that is now widespread in the Albanian capital, but perhaps not sufficiently debated: just think of the "style" extension of the Tirana town Municipality in 2004 , to projects for the Parliament house, to the expansion and functional adaptation of the Bank of Albania.

The buildings taken into consideration are the Placetenential Building, currently the ministerial complex and for which the current Town urban Plan provides for an expansion, the former Skanderbeg Circle, intended for demolition frequently, for which reuse is instead assumed as a "museum of city "in analogy to the function of "City Palace "foreseen in 1943, and the Ex. Hotel Dajti, whose possible adaptation (actually owned by the Bank of Albania), is verified while maintaining its hotel destination, a function entered in the collective memory that has assumed a value over time symbolic.

In these cases analyzed in this study, the extensions and additions are interpreted not as additions to parts of buildings, but as stylobates, podiums, wings, excavations, which relate the existing building to the open space and measure the surrounding void. The modeling and excavation of the bases allows you to create open but delimited spaces, conquering a condition of interiority and closure.

For example, in the project for the expansion of the Ex. Lieutenancy Building, a great emergence stands out on an excavated stylobate ground. Thus we work on a double register: the small scale of the city with enclosed spaces and the large scale of the new urban landscape, where the isolated volumes and the great void are no longer deaf towards each other, but enter into mutual tension. .
In their architectural definition these projects want to interpret and give shape to that double soul of Albanian architecture that appears clearly in the construction of traditional houses, where the use of the stone that roots the building on the ground and the use of wood coexist. or in any case light systems, which delimit the places of living.

2.3 General characteristics of existing masonry and rc structures, period 1940 in general

Nowadays, thanks to the requirements for the construction of building interventions, action has been taken almost everywhere on the durability of buildings; in fact almost all the buildings have undergone ordinary and extraordinary maintenance. However, this does not give any certainty in terms of the structural safety of the building itself; for this purpose much more in-depth investigations are needed into any architectural, structural, executive and material deficiencies.

The seismic behavior of the building is strongly conditioned by its regularity in plan and elevation. Its structural performance, especially at the ultimate limit state, however, depends on the strengths of the materials. It is therefore essential to have detailed information on the reference values of these mechanical characteristics. It is quite clear that this information must be sought on the individual building when it comes to assessing its vulnerability, however it is useful to have a large-scale picture of the size of the phenomenon of distribution of resistance on the building stock. Within the vast building stock, constructions with reinforced concrete structures play a special role because the problems of durability, linked to the temporal response of the materials, present themselves in a worrying way and their solution is generally technically difficult and economically very expensive. It is known that the durability of the reinforced concrete structure is linked to the quality of the concrete, ultimately to its resistance and to the relationship between it and the working tension and to the level of protection that the cement conglomerate is able to operate. on armor.

For this reason, it is very useful to understand, from a statistical point of view, what resistances can be expected on a building based on the time of construction of the same. It is known that in the case of normal distribution large errors have a small probability of occurring. The data processing was therefore preceded by a filtering procedure according to the criteria of rejection of the observations.

What has been observed in the generality of the most striking cases is that the serious architectural deficiencies have been accommodated by the structural designers without being put in place sufficient corrections to heal them or at least mitigate them. To these shortcomings were added structural shortcomings resulting from the lack of reference regulations and glaring shortcomings of an executive nature which are essentially due to:

- the mediocre mastery used for the construction of structural works and components defined as “non-structural”, ie infill walls, partitions, cladding;
- the mediocre and sometimes bad quality of the materials used for the construction as a whole;
- the lack of attention on the part of the construction management.

The main cause of the lesions on non-structural elements is to be found above all in the excessive deformability of the structure due to which the interpy displacement limits are largely exceeded. For a building to presumably respond correctly to an earthquake, it must be as simple, symmetrical, hyperstatic and regular as possible both in plan and elevation.

It is evident that it is not possible for existing buildings, and in particular those prior to the entry into force of the first seismic standard, to comply with the conditions of regularity; it is also true that some conditions are essential for a correct and necessary seismic response.

In particular, the simplicity of the geometry in plan is an essential condition, therefore all buildings that do not have this quality should be evaluated more carefully. It is also important that there are no significant planimetric deviations between the position of the elements of greater horizontal stiffness, such as structural or non-structural walls, stair groups, etc., and the distribution of the masses of the building which, otherwise, would give result in dangerous torsional effects.

The distribution of non-structural elements such as “non-cooperating” masonry infill panels also affect the overall behavior of the structure in the event of an earthquake. In fact, even if they are not considered in the calculation phase, the infill panels, until they collapse, contribute to the rigidity of the building and, consequently, the irregularity of their distribution in elevation leads to a concentration of efforts where these are less present and the formation of the so-called soft plane as in the case of the pilotis and the case of the garages plane. For the purposes of a good overall dissipative behavior, the inelastic deformations must be distributed in the largest possible number of flexible elements, in particular in the beams, while avoiding their occurrence in the less ductile elements, such as the columns, and in fragile resistant mechanisms. To obtain this result it is necessary to pay attention to the irregularities of the local connections between the structural elements such as wide beams on narrow column, misalignments of the beams with respect to the columns, etc., and also check that the arrangement of the reinforcements in the critical areas is correct, in particularly those near the connections between the structural elements such as for example nodes between beams and columns, the grafting of the beams in the stiffening walls, etc.

As with the geometric-architectural requirements, obviously, the regularity of the structural elements also contributes significantly to the correct seismic response of a building. It is therefore a good rule to have frames warped in the two main directions avoiding misalignments of the beam-pillar joints and beam-beam couplings. The experience, which is acquired from the direct observation of the damage produced by earthquakes, teaches us that the main structural factors, responsible for the seismic damage of reinforced concrete constructions, concern both the global behavior of the structures and some executive imperfections of a local. Statistical studies carried out in various countries on buildings with evident structural deterioration have shown that most of the damage occurs during the construction phase of the structures and is the result of human errors. Only 29% of structural damage is considered inevitable. More in detail, the results of these investigations can be summarized as follows:

- the damages are mainly produced in the execution phase;
- the human factor is largely responsible for one's own ignorance, neglect, underestimation of the consequences, errors.

The conclusions that can be drawn are essentially the following:

- the bad positioning of the reinforcements, the incorrect use of diameters and the consequent reduced thickness of the concrete cover is responsible for the cracking and subsequent fall of pieces of concrete due to the thrust due to the expansion of rust (spalling);
- incorrect tying of the brackets causes slippage during casting;
- the indiscriminate execution of important structural variants without authorization involves the upset of the static scheme;
- the impurities present in the badly washed aggregates are responsible for the reduced strength of the concrete;

- early stripping, before the concrete has reached the necessary strength, is responsible for injuries;
- the production of concrete on site, thus not resorting to the more controlled industrial one and with a correct mix-design, involves the presence of different classes of concrete;
- the incorrect compaction of the concrete leads to the segregation of the various constituents of the mixture and therefore to the creation of gravel nests;
- the addition of water in the concrete mixer at the time of casting creates an alteration of the water-cement ratio and therefore a reduction in the necessary resistance.

In addition to these problems there are all those "small" interventions carried out by man after the construction of the building, such as the execution of holes in load-bearing structures for the passage of electric cables and / or hydraulic pipes and chamfer of the pillars to facilitate the passage of vehicles in the local garages.

Until a few years ago it was believed that a reinforced concrete structure was practically unalterable over time. Daily practice has shown that the reality is quite different as many reinforced concrete structures of the past have shown signs of decay, the causes of which are:

- descaling: it is a phenomenon due to fresh or slightly acid rainwater and produces an increase in porosity, creating more favorable conditions for the penetration of aggressive agents inside the structure and a loss of compressive strength. The cement, in contact with rainwater poor in salts, loses lime due to hydrolysis with a consequent increase in the size of the capillaries. The loss of mechanical strength, a consequence of the increased porosity, leads to a decrease in compressive strength around 1-2% for every 1% of the original content of hydrolysis lime removed by washing. A particular cracking method is attributable to the progressive decalcification: along the surfaces of reinforced structures, with wall reinforcements exposed to alternating dry and wet cycles, cracks open parallel to the direction of the reinforcements;

    sulphate attack: the destructive action of the cement paste is determined by the magnesium sulfate which, reacting with the calcium hydroxide present in the concrete, gives the gypsum product. This reaction takes place with an increase in volume of about 120%. The gypsum produced then reacts with the hydrated phases coming from the hydration of the tricalcium aluminate, forming ettringite. The increase in volume is approximately 370%. The sulphatic attack is manifested, therefore, through the swelling of parts of the structure and consequently determine its weakening;

    carbonation: carbonation is a neutralization process between the alkaline components present in the outer layers of the concrete surface and the acidic substances coming from the external environment. These acid substances are generally the carbon dioxide CO_2 contained in the air and in particular industrial atmospheres and the sulfur dioxide SO_3 contained in the rain. Certainly it is carbon dioxide that most determines the process considering its high concentration in the air (600-1000mg/m^3 of air). The aforementioned chemical reaction involves lowering the pH from the initial value of 13-14 to pH values <9. In this acidic environment, the solubility of the calcium carbonate present in the concrete increases both in the form of inert material and through the transformation of $Ca\,(OH)_2$. A chemical process is then triggered that leads to the formation of calcium bicarbonate, soluble in water, therefore easily removable by rain. The subsequent entry of water through the pores of the concrete therefore also involves the corrosion process of the reinforcements;

corrosion of reinforcement: corrosion of reinforcement is certainly the most important degradation process for the durability of a reinforced concrete structure. The corrosion of the steel of the reinforcements occurs through the electrochemical process of redox.

- The anode and cathode are supplied by the same armature, in fact along the same bar the areas coated with very adherent oxides (calamine) act as the cathode, the electrolytic solution is formed by water absorbed by capillarity and a soluble salt. The process takes place with constant subtraction of material from the anode and deposit of ferric hydrate (rust). Since the rust occupies a larger volume than the original steel, there is therefore cracking of the concrete and the exposure of new sections of reinforcement (spalling). Corrosion can also be induced by the action of aggressive substances (chlorides) present in the concrete as they are transported from the external environment. In the presence of water and oxygen, these substances affect the protective oxides of the reinforcements, even in non-carbonated concrete, (pitting), thus creating an anodic zone from where the electrochemical corrosion process develops;

- the alkali-aggregate reaction: after hydration, Portland cement is characterized by a high concentration of alkali (sodium and potassium salts) in the solution contained in the pores.

Currently, the alkali-aggregate reaction represents one of the most worrying forms of structural degradation for a variety of reasons but above all for the fact that it is unstoppable if not by avoiding the entry of water or water vapor into the pores. If some waterproofing or dehumidification measures (for example by means of impregnation based on silanes and / or siloxanes) can be carried out for elevated structures, the same measures are almost impossible to carry out for foundation structures. Depending on the degree of reactivity of the silica, the moisture content, the alkali content present in the cement and, finally, the environmental temperature, the phenomenon can occur relatively quickly (a few months) or even after several years.

CHAPTER 3.

Theory of Restoration and Architectural Interpretations

3.1 Theoretical summaries, elaborations and analysis on the principles of International Charters for Conservation and Restoration

The need to protect architectural monuments from destruction and alteration found its first interpreters "architects, engineers and other professionals" at the end of the eighteenth century, leading personalities such as William Morris and John Ruskin had an enormous influence on the theoretical elaboration of the discipline, but initially their voices remained highly isolated, with no massive impact.

In 1883, an important congress held in Venice brought together architects and engineers around a table to discuss restoration topics and find a point of mediation: after years of experimentation, some principles were laid down which should essentially be guaranteed, along with conservation. of monuments, even a correct reading of them.

The result was a complex and gradual elaboration of principles and recipes, later codified and included in a series of documents aimed at guiding interventions according to basic principles and postulates, so-called "the Restoration Charters". From the Athens Charter of 1931 to the "Krakow Charter" of 2000, the texts are reported to be preceded by a brief introductory note.

3.1.1 International conference of Athens, the charter of Athens 1931'

The first charter of the cultural heritage restoration and conservation was written in 1931 by the "International Conference of Architects" gathered in Athens, Greece. It is made up of 10 points that more than establish real principles, called recommendations, addressed to the governments of the States, summarized as follows:

- take care of their heritage and architectural protection;
- standardize legislation so that private interest does not prevail over public interest;
- to expand the study of art and architecture in order to teach and raise awareness of the population with love and respect for their architectural heritage.

If we analyze in the technical aspect, the "Charter of Athens" defends a kind of philological restoration, rejecting stylistic restoration, accepts the use of modern materials for consolidation, such as reinforced concrete , accepts only "anastylosis"[4] in the case of archaeological restoration. (Kadluczka & Cristinelli, 2015)

The Athens Conference, convinced that the preservation of the architectural and archaeological heritage of the cities is of interest to all States, which are the guardians of civilization, hopes that the States will mutually give a wider and concrete cooperation and contribution to favor the preservation of architectural and history monuments;

The Conference considers it highly desirable that the institutions and qualified groups of professionals, without prejudice to any international public law, be able to express their interest

[4] In architecture and archeology, anastylosis is the restoration technique with which the original pieces of a destroyed structure are put back together, element by element, in the same position, for example after a possible collapse.

in the protection of the cultural heritage in which civilization has found its highest expression. and who currently appear threatened. The conference intended the exposition (her general principles concerning the protection of cultural heritage) to avoid risks by establishing permanent maintenance to ensure the conservation of the buildings. In the event that a restoration appears essential following degradation or destruction, it recommends respecting the historical and artistic work of the past, without proscribing it architectural style of any epoch. Also, the conference recommends maintaining, whenever possible, the adaptation of heritage buildings which ensures their vital continuity, provided, however, that the new destination is such as to respect the historical and artistic character.

The Athens conference intended the exposition of the legislations whose purpose in the different nations is the protection of cultural heritage of historical, architectonic or scientific interest; and it unanimously approved the general tendency, which in this way preaches a collective right as opposed to the private interest.

The Athens charter emphasizes that the principles and techniques exhibited in particular communications are inspired by a common tendency, that is: To restore in place the original found elements (anastylosis); and new materials needed for this purpose must always be distinguishable. On the other hand, when the conservation of ruins revealed in an excavation is recognized as impossible, it will be advisable, rather than devoting them to destruction, to bury them again, after having taken precise architectural surveys. It is clear that the excavation technique and the conservation of the remains require close collaboration between the archaeologist, the architect and the engineer.

Architects, also engineers have intended various principles relating to the use of modern materials for the consolidation of ancient buildings; and they approve the judicious use of all the resources of modern technology and especially the use of reinforced concrete element. The conference also notes that in the conditions of new use of the monuments are increasingly threatened by external agents; and, while not being able to formulate general rules that adapt to the complexity of the specific cases.

The conference recommends respect, in the interventions of buildings, of the urban character and physiognomy of the city, especially the area close to the cultural heritage, for which the environment and the landscape should be the object of special care. The same respect should be paid to some picturesque views. The object of study may also be plantations and plant ornaments suitable for certain monuments to preserve the ancient character.

The Athens Conference, fully convinced that the best guarantee for the preservation of cultural heritage and works of art comes from the love and respect of the people, and given that these feelings can be greatly favored by the right actions in restoration.

3.1.2 Italian international charter for the conservation and restoration of monuments 1932'

In 1932, the High Council of Antiquities and Italian Fine Arts issued a "Restoration Charter", which may be the first official directive of the Italian state for restoration. On the same principle similar to the "Athens Charter", but with some additions and more specifications by Gustavo

Giovannoni, such as "scientific restoration". Giovannoni (1873-1947), Italian architect and civil engineer, was the first to suggest a methodology, in every aspect necessary to include all the most modern technologies to achieve the achievement of scientific restoration.

The Superior Council of Antiquities and Fine Arts in Italy, bringing its study on the rules and principles that should regulate, also improve the restoration of cultural heritage, which in Italy rises to the rank of a primary national issue and coming from the need to maintain and improve and more the indisputable primacy of restoration in this activity, consisting of science, art, architecture, engineering and advanced technology. A brief summary of the principles of this conference is summarized below:

- At the conference they were very convinced of the multiple and very serious responsibility involved in any restoration projects, ensuring the sustainability of the destroyed elements. Placing his hands on a complex of documents of history and art translated in stone, no less precious than those preserved in museums and archives, allowing numerous studies that may have brought unexpected new definitions in the history of architecture;

- Considering that in the restoration projects various criteria of different order must be united but not eliminated, even in part: that is, the historical reasons that do not want to cancel any of the phases through which the architectural heritage was composed, nor distorted its knowledge with additions that mislead scholars, nor disperse the material that analytical research brings to light;

- The Italian Conference and its founders believed that after more than thirty years of work on-site carried out entirely with great results and recommendations, a set of specific lessons and principles should be drawn from these results to validate and clarify a theory of restoration already established continuously in discussions of the Council and by most of the superintendents for Medieval and Modern Art; So, according to this theory controlled by practice, the essential principles will be given.

3.1.3 Analysis and notes on the context of the 1964 Venice Charter

World War II, considering the destruction of the European architectural heritage, brought to the fore the problem of architectural restoration. At this particular moment, the practice of restoration almost always extended, rebuilding what already existed, even at the risk of committing historic forgeries.

After the post-war reconstruction phase, architectural culture again questioned the exact restoration practices and at the Second International Congress of Monuments held in Venice from 25 to 31 May 1964, Architects and Technicians, created a new card. Italian scholars such as Roberto Pane, Pietro Gazzola and Cesare Brandi made a fundamental contribution to this "Venice Charter".

The scientific material consists of 16 articles, which admirably summarize the principles that can be considered immutable in the methodology of architectural restoration. This charter emphasizes above all the importance of the historical aspect of a building and introduces for the first time the concept of preservation of the urban environment that surrounds monumental buildings. Below is a very concise summary of the basic principles of this conference:

- Architectural monuments should be considered part of a larger ensemble;
- Not only great works of art but also the most modest works of the past, which have acquired cultural significance, are considered worthy of preservation;
- No new construction, demolition or modification that would alter the relationship of mass and color will be allowed;
- Each architectural monument is inseparable from its place and the environment in which it is located;
- All additions should be in contrast to the old one, be distinct from the old one and possibly be removable;
- The valuable contributions of all periods in the construction of an architectural monument must be respected, as the unity of style is not the goal of a restoration.

One of the most innovative aspects of the Venice conference was the specific point of view on the building, not only the aspect of the historical monument will be treated as a separate case, but the study will be extended, including the 'urban and landscape environment', which carries as much historical and aesthetic value as the monument itself. The context, like the monument, is an important evidence of a culture, of its development and of historical events that may have occurred in time.

The charter is summarized in general definitions on the notion of the monument and its values, and of the monumental complex as evidence of the culture of a civilization. Then it continues with the treatment of various topics such as: purpose, conservation, restoration, monumental complexes, archaeological excavations, documentation and publication.

Of more interest is the treatment of the issue of maintenance of works, in a regular and continuous manner, avoiding or moving as far as possible the restoration interventions. Also very important is the context of the new function that can be given to an object. The idea of a function close to the authentic one is replaced with that of giving a use with a new function which does not damage the values of the object, both during the adaptation phase and during its perforation.

Given 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 of 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.

3.2 The concept of restoration according to Cesare Brandi

In general, any intervention aiming at restoring the efficiency of a product of human effort is considered to be a restoration intervention. Therefore, there will be two types of restoration: one for industrial artefacts and another for works of art; however, while the former will come to be seen as a synonym for compensation or restoring the object to its original state, the latter will be distinguished qualitatively from the former in that the former will consist in the re-establishing of the product's functionality, whereas the latter, while such a re-establishing may be relevant in certain cases such as architecture, will be distinguished qualitatively from the former. (Brandi C. , 2005)

However, the unique product of human activity known as a work of art is described in this way due to the fact that it is recognized in the consciousness for the first time, and it is only after this recognition that it can be considered to be distinct from other products. This is a characteristic that is unique to a work of art in that one does not inquire into its essence, but rather it becomes a part of the world of life and thus enters the realm of individual experience rather than remaining isolated. It follows from this premise that any behavior toward a work of art, including restoration intervention, is contingent on whether or not the work of art has been recognized as a work of art in the first place. So, the quality and modality of the restoration intervention will also be closely linked to the recognition, and even the restoration phase, which a work of art may have in common with other products of human activity, will be considered merely an add-on phase in terms of the qualification that the intervention receives as a result of the fact that it is carried out on a work of art. From this point on, there is the opportunity to exclude restoration, as restoration of a work of art, from the common exception of restoration, and to articulate its concept not on the basis of the practical procedures in which it is carried out, but in relation to the work of art as such from which it receives its qualification, rather than on the basis of the practical procedures in which it is carried out. (Brandi C. , 2005)

Nonetheless, even though it is distinct from all other products of human activity, a work of art always retains the characteristic of being a product of human activity when compared to things of nature. It also poses two instances as a work of art and a product: the aesthetic instance, which is comprised of the fundamental fact of artistry for which the oeuvre is a work of art; and the historical instance, which reflects the emergence of the work as a human product at a specific time and location. Furthermore, the fact that it is presented to the recognition of a consciousness at a specific time and in a specific location lends the work of art a second historicity that is gradually transferred over time. It is at this point that the definition of restoration, specifically the restoration of a work of art, can be stated in the following terms: Restorative work is the methodological moment at which the work of art is recognized in its physical consistence, as well as in its twofold historical-aesthetic polarity, with the goal of transmitting it to posterity. (Brandi C. , 2005)

This definition shows that the imperative of restoration, like the general imperative of conservation (which, despite its name, presents itself as a preventive restoration), is primarily concerned with the material consistence in which the image manifests itself, rather than the image itself. Afterwards, the first and most fundamental axiom is presented: one can only restore the physical matter of a work of art. In contrast, the physical mechanisms that allow for image transmission are not in opposition to one another; rather, they are coextensive with one another: one does not have matter on one side and image on the other in order to transmit an image. While this coextensiveness may be a necessary part of the image, this coextensiveness cannot assert itself as being wholly intrinsic to the image. For example, the foundations of an architectural structure, or the board, canvas, or wall that serves as a support for a painting, are all examples of physical means that can be used as supports.

The intervention must be carried out in accordance with the requirements of the aesthetic instance if the conditions of the work of art reveal themselves to require, for its preservation, the sacrifice or replacement of a certain portion of the physical means with which it was extrinsicated. The historicity of the oeuvre, on the other hand, should not be underestimated; and this should be taken into consideration not only at the first historicity, which is that which was founded in the act of formulating the oeuvre, but also at the second historicity, which begins immediately after the act of formulating the oeuvre and extends all the way up to the moment and location at which the recognition occurs in the consciousness of the audience.

As a result, the dialectical nature of restoration, namely as the methodological moment of recognition of a work of art as such, results in the second restoration principle: restoration must aim to re-establish the potential unity of a work of art, to the extent that this is possible without creating an artistic or historical counterfeit and without erasing all trace of the work of art's passage through time.

By reading and browsing the theories of C. Brandi we can underline what he defines for restoration: "Restoration is the methodological moment of evaluation of the work of art in its physical content and in its dual polarity, aesthetic and historical, in order to convey its towards the future ". So he emphasizes the evaluation of the tangible visual appearance, as well as the temporal context, the extent of the architectural work in time with several stages.

From a careful reading of Brand's theories it is noted that there are limitations, his principles cannot be applied to any kind of architectural heritage property. His definition of restoration as the methodological moment of recognition of a work of art limits the field of study only to well-known works of art or architecture, leaving aside industrial products that are meant as services to cities. Restoration is thus an act of distinction - once the architectural or artistic value of the building is recognized, and at this point conservation becomes a cultural necessity. (Brandi C. , 2005)

3.2.1 Restoration principles and Terminology defined

Previous researchers' definitions of the concepts of conservation, restoration, preservation, and adaptation are summarized in the following section, along with terms and definitions.

Adaptation – A building's function, performance, and capacity are altered as a result of work performed on it (over and beyond maintenance). Adapting a space to accommodate a proposed compatible use. Modification is acceptable only when the adaptation has a minor impact on the cultural significance of a location, and adaptation should include the smallest amount of change to a significant fabric, which can only be achieved after considering all of the alternatives. Adaptation refers to making minor changes that are still reversible, as opposed to making significant changes that are less reversible . Adaptation is the process of transforming a building for a new purpose, and it may be the most effective method of preserving a historic structure. (Aplin, 2002)

Conservation - There are a lot of things that need to be done to keep a place culturally important. Maintenance: May include preservation, restoration, reconstruction, and adaptation, depending on the situation. Most of the time, it will be a combination of more than one of these. It's important to look after the natural and cultural significance of a place so that it doesn't lose that significance. This definition is summarized according to the concept of Alpin. (Aplin, 2002)

Preservation - Keep the structure of a building the same way it is now by slowing down the rate at which it breaks down. Slowing down the deterioration of an old building by using the right repairing methods. Preservation is "the act or process of taking steps to keep the existing shape, integrity, and materials of a historic property the same as they are now." Because some parts of the building are old and important, they should be kept in good condition even if they are damaged. Making sure that there isn't a lot of natural decay Preservation is similar to maintenance, but it requires a lot more work and programs to keep the fabric of the building in good condition and to protect it from damage. (Aplin, 2002)

Restoration - Back to how it was before: Getting rid of things that didn't belong there and replacing them with things that did, without adding any new materials. Returning the current structure of a building to what it was like in the past without using new materials . Restoration involves "*reinstating the physical and/or decorative condition of an old building to that of a particular date or event*". The process of getting the building back to how it was before. It is done this way so that original materials and techniques can be used, as well. (Brooker & Stone, 2004)

In the course of their lives, almost all heritage buildings will have these applications. In order to keep a building and its values for present and future generations and make it usable at the same time, all of these activities are done on heritage buildings.

3.2.2 Genesis of Cultural Heritage

The term "heritage", which comes from legal terminology, refers to anything that can be passed down from one generation to the next and the next and to the descendants of the original owners. This is one of the reasons that landscapes, buildings, and objects play a big role in the practical management of heritage, because these are things that the law recognizes as property and can be passed down through the generations. As a result, the term also implies that those who came before and those who come after have a strong connection. This means that they have a sense of responsibility and "trust." It's also true that law only exists as a mix of customs and judgments dating back to the beginning of legal memory in 1086. This means that law itself, like the heritage it describes, is based on what the ancestors did. (Avrami, Mason, & De La Torre, 2000)

Cultural heritage in general is a way to think about heritage that goes beyond the simple idea of it. Ideological elements, like physical ones, help inheritors get into their rightful places and be their true selves. In this case, inheritance is broadened to include these elements. An untrue dichotomy is one that separates ideologies, ideas and feelings from property in the legal sense of things like material goods and real estate. This is a wrong cut, though. People can't have social ideas without things like land, objects, food and bodies used for them, as well as places where they can show them off. No physical thing can be without its ideological information. This physicality is why cultural heritage needs a lot of people to run and maintain it, why it can be owned, and why no group can afford to keep all of its heritage in the way that it would like.

This analysis leads to the next important thing to talk about. Cultural heritage is thought of as an outside expression of who you are, and it works in a variety of ways and at different levels. It's a social fact, and like all social facts, it is both passive and active at the same time. It is passive because it is a place where things are chosen. Most things, no matter what kind, don't make it into the heritage zone. Its power comes from the fact that once certain elements are passed down, they have power. They have a life of their own that affects people's minds and, in turn, their choices. Heritage is a way for people to express their beliefs about themselves and their communities. These beliefs nest with other beliefs about self and community to make a whole that runs through all the ways politics, economics, and the use of resources affect us as individuals.

Heritage is the cultural authority of the past, as well as a way for people and businesses to show who they are. European modernism also has a lot to do with how people think and act. Heritage (in the sense being talked about here) is also a part of that. There were a lot of changes in the way people thought about things in Europe, especially in northwestern Europe between 1500 and 1750. This is about how people thought about things like history, the power of scientific reason, the rights of the individual, and how the law worked. Modernism and heritage both have their dark sides. When we choose and cultivate our heritage, we make distinctions between "us" and "them," and we can expect all the nationalistic and fascist horrors that can come from that. Like many modern ideas, the idea of heritage has spread around the world. We must keep in mind that these ideas are not native to most cultures and are not by any means the only or best way to build a relationship of identity on the cusp between the past and the present. (Avrami, Mason, & De La Torre, 2000)

3.3 Interpretations on Cesare Brandi theories, also on "Time concept", regarding the architectural heritage and restoration

By reading and browsing the theories of C. Brandi we can underline what he defines for restoration: "*Restoration is the methodological moment of evaluation of the work of art in its physical content and in its dual polarity, aesthetic and historical, in order to convey its towards* *the future*". So he emphasizes the evaluation of the visual appearance, which is tangible (in the case of buildings we can relate the Brandi's concept to the importance of the cultural heritage facades.), as well as the temporal context, the extent of the architectural work in time with several stages.

From a careful reading of Brand's theories it is noted that there are limitations, his principles cannot be applied to any kind of architectural heritage property. His definition of restoration as the methodological moment of recognition of a work of art limits the field of study only to well-known works of art or architecture, leaving aside industrial products that are meant as services to cities. Restoration is thus an act of distinction - once the architectural or artistic value of the building is recognized, and at this point conservation becomes a cultural necessity.

Reflecting on the theories of Cesare Brandi, to make some interpretations some paragraphs are detached as follows:

> *"Many lamentable and destructive errors have come about because of failures to investigate the material constituents of works of art for both appearance and structure. For example, there is a common misapprehension that unquarried marble is no different than marble that has been worked into a statue. (This could be called the 'illusion of immanence'). Whereas unquarried marble has only its physical makeup, the marble in a statue has undergone radical transformation to become the vehicle of an image. In doing so it has become a part of history thanks to the work of human hands. As a result, a chasm has opened up between its existence as calcium carbonate and its existence as an image. As an image, the marble of the statue has separated into appearance and structure, making structure subordinate to appearance".* (Brandi C. , 2005, p. 52)

Considering this, it has become part of history thanks to the work of human hands of creators or designers. As an image, the marble of the statue is divided into aesthetic appearance and structure, making the structure dependent on appearance.

According to Brandi theories, the creation of the work of art, in other words the process of design and creation was closely related to the artistic process, but also technical at the same time. From this logic derive the basic principles of restoration, the almost sacred respect for the original design, the authenticity, and the "raw material" considered as something irreplaceable for any kind of project. This concept brings visual and tangible recognition by all, of the conception of interventions and its repetition.

Another paragraph related more specifically with some kind of interventions on the work of art, is taken from Brand's book on the theory of restoration:

> *"Reconstruction, re-creation or replication have nothing to do with restoration proper. By their very nature, they go too far, and have legitimacy (if at all), only in the field of deliberate reproduction of the processes used in forming a work of art".* (Brandi C. , 2005)

> "*Nonetheless, it should be pointed out that even the worst reconstruction does, in fact, document human activity, albeit mistakenly, and that it is still part of human history. Therefore, it should not be removed - at the most it may be isolated. This position would*

seem unassailable historically, were it not for the fact that it leads to a conviction of non-authenticity or falsification for the entire work of art". (Brandi C. , 2005)

According to Cesare Brandi, the basic concepts of a good restoration have nothing to do with ordinary reconstruction or re-creation processes. But we can say that these processes can manage to document valuable objects, in their own way they manage to create a story or revive the history of the work of art. If through these processes the designer manages to create tangible moments and make the object part of human history, we can say that in some way he has succeeded, even though new debates open on historical forgeries and anti-authenticity.

Time concept according to Brandi's theories meets in the architectural heritage in three different moments:

1) The time of the realization of the work or project;
2) The time that passes between the end of the creation of the work and the moment in which our conscience recognizes the work of art as such (present);
3) The time of recognition by the conscience;

In which of the three times will the restoration work be legitimate? In the first? No because it would interfere with the creative moment (fantasy restoration), In the second? No, because it would tend to cancel the changes that occurred at that time in the idea of restoring the original state of the work (restoration restoration). In the third? Yes, because only in this way will he respect the time that has passed without trying to eliminate its traces.

> *"Any behavior towards the work of art, including the intervention of restoration, depends on whether or not the recognition of the work of art as a work of art occurs. Therefore, also the quality and modality of the restoration intervention will be closely linked with this recognition, and even the restoration phase, which eventually the work of art may have in common with other products of human activity".* (Brandi C. , 2005, p. 48)

Brandi's theoretical work progresses through a clear distinction between the aesthetic image and reality, a subject that was previously addressed by the Italian philosopher Benedetto Croce and taken up by Brandi in his growth of his theoretical work. Art historian Brandi was the one who first developed a theory of artistic creation, which he divided into two phases: the construction of the object created by the artist, to which he assigned symbolic values that distinguished it from what it was originally (its raw material), and second, the formulation of the image, which is the process by which a reality is created. He called this pure reality because it is distinct from the real world that surrounds us, or, to put it another way, it is an enhanced version of the real world. (Morera, 2019)

Regarding this distinction between the two periods of creative creation, we can clearly distinguish the notions of flagranza and astanza that are associated with the work of art in connection to this distinction. The first of them, flagranza, relates to the existential condition of art, specifically the consciousness of its bodily presence at the time it is observed by the observer. In the realm of restoration theory, it is associated with the theme of the composition of the work of art that is being restored. (Morera, 2019)

3.3.1 Restoration according to the historical instance

Each architectural heritage has its own historical value as a human product made in a certain time and in a certain place. With this in mind, the problem of conservation or removal of additions and renovations arises in the restoration. Two definitions are elaborated below:
Addition: a new testimony of human doing and therefore of history;
Refurbishment: intervention that intends to reshape the work, get in the way in the creative process to recast the old with the new.

For the historical instance, the preservation of only the addition is legitimate because the reconstruction that aims to create a false historical is not acceptable and therefore must be removed NB only when the reconstruction does not try to recast the old with the new and is therefore recognizable, it must be preserved in its historical value.

3.3.2 The restoration according to the aesthetic requirement

Each work of art has its own aesthetic value as an artistic product. Additions or remakes. What to do? Keep or remove? If the addition disfigures, distorts, obscures, partially removes the work of art from view, it must be removed by documenting the removal. Conflict of interest between the historical and the aesthetic instances: the aesthetic demand prevails since the essence of the work of art is its being such, its artistry, only later its being a historical testimony.

3.3.3 The space of the work of art

What is the space that must be protected from the restoration? The work of art has its own spatiality that fits into the space in which we live (the physical space of existence). The restoration must ensure that the work of art retains its spatiality Eg: respect the spatial conditions of an architecture or the possibility of perceiving an all-round sculpture from all sides

3.3.4 Preventive restoration

It means anything that aims to prevent the need for restoration. It is the first imperative of conservation and branches out into several investigation directions:
First directive: determine the conditions necessary for enjoyment of the work both as an image and as a historical monument;
Second directive: investigate the state of consistency of the matter;
Third directive: investigate environmental conditions, such as elements that can allow, threaten or make conservation precarious. As in actual restoration, advances in science are important in preventive restoration;

3.3.5 Theoretical analysis on the basic principles of restoration of the work of art

A creative process is completed when a piece of art is created and becomes a visible presence in the world as a result of the work's presence in human awareness. Restoration can then be considered, but it must always be done with the understanding that the artifact is a work of art, that is, that it is a unique product of human activity, as the foundation for any work done on it. This recognition will be critical in the rehabilitation process. From his first definition of restoration, published in 1948, Brandi distinguishes between two schools of thought: one is concerned with restoring efficiency to the common products of human activity, while the other is concerned with the actual restoration of special products, such as artistic objects. According to this definition, a piece of art may only be restored on the basis of the aesthetic approach taken to the work itself, which is not a matter of personal preference but is tied to the specificity of the art form in question. It is the piece of art that dictates the terms of the restoration, not the other way around.

As Brandi describes in his book Le due vies, the process of recognizing a work of art / architecture is comprised of the identification of the work as such by the observer (Brandi, 1966; Brandi, 1989). Instead of examining the piece of art from the perspective of the artist / architect or the observer, Brandi offers to study it from the following perspective:

- in and of itself, in its structure;
- when it is accepted into consciousness.

By considering the case of a historical structure, it is possible to see how it is not only made up of a particular amount of material, but also how each piece and the same spatial structural system are conditioned by an architectural concept. Thus, the structure in its material form symbolizes a physical phenomenon, but at the same time, the material serves the purpose of communicating the architectural concept to those who are looking at the building. As a result, the structure as a work of art is more than a physical occurrence; it also contains the aesthetic notion, which is immaterial (phenomenon which is not a phenomenon). The building's material matures with time, but it is only in the present that the aesthetic concept of the structure is understood by human mind. As a result, Brandi concludes, a piece of art exists in the present at all times. As a result, every time the job is planned, even in the case of its restoration, it is necessary to develop recognition on the part of the individual.

When considered in its entirety, a piece of art is more than the sum of its parts; all of the aspects work together to create the 'unity of the whole' according to the artist's or architect's concept and the unique way in which it was made. The tesserae of a mosaic are not art in and of themselves, nor is the ad hoc collection of such tesserae. Additionally, a work of art or architecture can only be 'what appears'; we cannot use an external model to reconstruct it into an ideal aesthetic scheme, as was frequently done in the eighteenth century. Rather than that, the whole reveals itself as an indivisible oneness that can theoretically continue to exist in its fragments even if the original is destroyed to ruins. Restorative work must be limited to the original unit and must be guided by the potential unity of the work of art, taking historical and aesthetic considerations into account.

The work of art has a dual polarity, consisting of two aesthetic and historical requirements or 'instances' that combine to produce a whole with the possibility for unity. Its historicity is inextricably linked to aesthetic values and their evolution over time. Both of these scenarios must be taken into account when determining whether to restore. This principle is summarized in a definition of fundamental restoration, which is followed by two complementing principles:

- Restoration constitutes the methodological moment of recognition of the work of art, in its physical consistency and in its double aesthetic and historical polarity, in view of its transmission to the future

- Only the material of the work of art is restored

- The restoration must aim at re-establishing the potential unity of the work of art, as long as this is possible without committing an artistic or historical forgery, and without erasing all traces of the passage of the work of art over time.

From the definition of a work of art, it appears that time and space constitute the formal conditions and "find themselves closely fused in the rhythm that establishes the form". Furthermore, time represents the phenomenological aspect in the work of art, divided into three specific phases that form its historical time:

- the duration of expression of the work of art while it's being formulated by the artist;

- the interval between the end of the creative process and the moment in which our conscience actualizes the work of art in itself;

- the moment of "electrocution of the work of art in the consciousness of the present".

Historically, a piece of art can be historicized at two distinct points in time: when it is concretized by the artist (for example, a palace erected in the sixteenth century) and when it is recognized by the conscience of an individual in the present. It is possible to find examples of the 'historical instance' in connection with various restoration instances of works of art. Even in the most extreme situation of a ruin that is no longer recognizable as a monument to human activity, restoration can be viewed as a process of consolidation and preservation of the current state of affairs. When a piece of art ceases to be a work of art and becomes a ruin, it can be difficult to determine when this has occurred. The only method to determine this is to determine whether or not the object has retained its potential oneness (for example, the medieval structures of S. Chiara in Naples). As a result, one should avoid attempting to restore the potential unity of the work to such an extent that it destroys its authenticity and so imposes a new, historically untrue reality that is superior to the ancient work in absolute terms.

The task of art history, according to Brandi, is to investigate - in temporal succession - the 'extra-temporal' moment, the internal dimension of time and rhythm; this is not to be confused with the history of 'time in time' relating to changes in taste and fashion, which "gathers in its flow the finished and unchanging work of art." Restoration is acceptable when it intervenes in the third phase, which covers both the present and the past, because one should not expect to be able to change the course of time or eliminate history. Additionally, the restoration must be characterized as a historical event, as a human action; it is an integral component of the process of passing the work of art into the future. Any other time for the restoration will result in arbitrary results because of the nature of the restoration. In the United States, for example, identifying the restoration with the moment of artistic creation will result in an imaginative restoration, which will be at odds with the concept of a work of art as a completed process. Stylistic or period restoration, as they are defined in the United States, will also result in an imaginative restoration.

Another pertinent subject is the work of art's interior spatiality in relation to the space represented by its physical surroundings. The architectural spatiality of a structure is not confined solely within its walls, but also in its relationship to the spatiality of the surrounding built environment. There are particular difficulties in historic districts, when alterations to the urban fabric alter the spatial conditions of certain historical monuments. The same issue applies to architectural remnants. Ruins are frequently interwoven into the environment, as in the example of English parks with medieval abbey ruins, and should be managed suitably in connection to this new artistic ensemble.

The demands of the twofold polarity, aesthetic and historical, should not be reconciled through a compromise, but rather through an adaptation inherent in the work of art itself whenever they appear to be at odds with one another. When you consider that the uniqueness of a work of art lies in the fact that it is a piece of art, the historical instance can be viewed as secondary in most cases. An aesthetic instance can justify the removal of modifications that obfuscate or upset the artistic picture of an object that has kept its potential unity while taking the precautionary measure of documenting the fact that they have been removed. In contrast, if these modifications have become iconographically cemented, their removal could result in the reconstruction of the object from the ground up, which is not the intended outcome of the restoration process. Because of this, anytime repressions are considered, the decision must be made on the basis of ideals that take both the aesthetic and historical contexts into account.

For his part, Brandi condemned a specific type of 'archaeological restoration' activity, in which the ruins were frequently treated solely from the standpoint of history. It is sometimes the case that even the ruins are the remains of works of art, and as such they must be submitted to the same type of critical examination. Alternatively, the ruins could be a component of another work of art; in this case, the unity of the second creation should be honored in the appropriate manner. For example, the rebuilding of a medieval mullioned window in a classical facade (a tendency that may be found in many European countries) can be difficult to justify on financial grounds.

Brandi asserted that the material, in connection to the aesthetic element of a work of art, can be defined in terms of two functions: one dealing to the 'structure' of the object, and the other relating to the 'appearance' of the object. Taking into consideration the artistic significance of these artefacts, emphasis will generally be given to those that are the most artistically significant. If a consolidation or reinforcing intervention is required for structural reasons, it must be restricted to the portion of the material that is used to construct the structure and not interfere with the look of the building. When restoring a historic structure, for example, the goal is to keep the building's architectural appearance intact as much as possible. Brandi's difference, on the other hand, should not be interpreted as implying that structure is of little significance; in particular, when it comes to ancient architecture, the original structural system must be viewed as a vital aspect for the entire meaning of the building itself. When it comes to archaeological significance, the structure can be even more important than its appearance in some circumstances, as it frequently holds vital archaeological information. The preservation of historic buildings is not solely concerned with the preservation of their facades, as many believe.

If you are analyzing the aesthetics of a piece of art, a historic building, or even an ancient monument that is partly in ruins, you can refer to the experience that Gestalt-Psychology, or the psychology of form, has collected in evaluating the weight. A visual representation of the various sorts of integration in relation to the existing original surfaces; fresh, hard, and showy additions can quickly draw the viewer's attention away from the old patinated originals. The repair will be necessary to accommodate the current reintegration into the historic structure and not the other way around. This is because the restoration's goal is to maintain rather than renovate a historical structure. Several approaches for the practical application of the theory to the restoration of paintings were established under Brandi's supervision, including precise criteria for the reintegration of gaps. Paul Philippot has investigated the extension of these criteria to ancient buildings and structures in ruins in his books and ICCROM talks (Philippot, 1976). Brandi established three guiding principles (Brandi, 1963: 45):

- integration must always be easily recognizable upon close inspection, even if from a distance it must not disturb the unity that is intended to be re-established;

- the material of which the image results is irreplaceable only where it constitutes the appearance and not the structure;

- the restorations must not prevent future interventions for the conservation of the work of art, but rather facilitate them.

In reference to previous restorations, Brandi mentions Hadrian's renovation of the Pantheon as an example of re-establishing the monument's concept, not of restoration. The principles underlying the Renaissance's 'restoration' of ancient statues (Apollo of the Belvedere, Laocoon) were fundamentally based on the concept of beauty, in accordance with Platonic philosophy; restorers spiritually connected the statues to their own time, 'in a historical presence,' as if translated into a new language. This is Brandi's reading of the Renaissance, not as a revival of antiquity, but as a new style that incorporates components and notions from the past into a new creative framework. Thorwaldsen, on the other hand, regarded classical antiquity as perfect and remote, and his completion of the Aegina sculptures' arms and legs was based on an incorrect interpretation of defined canons; he thus reproduced the missing parts using the artificial language of nineteenth-century neoclassicism. According to Brandi, nineteenth-century revivals aimed mostly at copying existing patterns rather than developing a new architectural vocabulary.

However, from a historical perspective, the additions can be viewed as the beginning of a new era in history, which, in the case of architecture, can be linked to the development and introduction of new functions. It is possible to justify the additions this manner, and the additions must, in principle, be retained. As a general rule, it is vital to appreciate the new unity that has been produced by creative interventions, particularly if it reflects a historical phase. Any removal must be justified, and a trace must be left on the monument itself; otherwise, the demolition might easily result in the distortion of history and the annihilation of the past itself. Constructions, on the other hand, have a different situation when they are designed to interfere with the creative process and eliminate the time lapse between the moment of creation and the moment of restoration. Brandi was opposed to the reconstruction of the bell tower of San Marco, believing that in this particular circumstance only a vertical element, rather than a complete reconstruction, was required.

The use of "copies, replicas, or reproductions" can be accepted for documentation purposes, and they are considered permissible only if the process does not cause damage to the original building, as is the case when casts are used. In spite of the fact that copies and counterfeits are created using similar methods, counterfeits are distinguished by the intent to deceive; this can be accomplished either by pretending to pass a replica as the original or by producing an object in the style of a bygone period and offering it to the market as an original of that period (Brandi, 1992: 368; and Jones, 1990). A badly designed restoration might distort the creative concept of a work by misinterpreting its proportions, surface treatments, or materials, a problem that is particularly prevalent in ancient sites.

Brandi summarized the most important elements of conservation in regard to works of art, including architecture and its branches, in his theories. He emphasized the uniqueness of each, as well as the importance of the historical-time crucial definition as the foundation for every restoration effort. Also emphasized by him was the significance of preserving historical authenticity. The theory explains the critical process that must take place whenever a modern restoration is planned, and in doing so, it helps to develop a sort of restoration language or basic-methodology, the application of which necessitates a mature historical grasp of the subject matter. Brandi's theories can be considered a paradigm in the formulation of restoration and conservation policies that is recognized throughout the international community. He has served as the primary direction in the educational and academic programs of numerous specialist degrees, faculties, and departments, as well as the international courses offered by the International Center for Conservation of Resources in Rome and in other parts of the world. As a starting point for the formation of the Venice Charter, as well as the production of additional declarations and directives for the conservation policy of cultural heritage, this idea has been used extensively. Brandi himself was involved in the development of a new directive for the administration of the Italian government in 1972, known as the International Restoration Charter (International Restoration Charter).

3.4 Analysis, reflection and browsing on the theories of Cesare Brandi

Cesare Brandi was a major influence on Italian conservation philosophy and practice. His conservation theory was inextricably linked to practice, since he proposed numerous rational rules for conservation and restoration methodology. Cesare Brandi (1906–1988) researched restoration theories in art and architecture in the early 1930s. Brandi asserted that restoring a 'piece of art' in general necessitates the identification of its unique aesthetic, historic, and 'claims' characteristics. He also placed a premium on aesthetics in order to re-establish the work's potential integrity in architecture . According to Rouhi's idea, Brandi established a critical restoration theory and expanded upon it by developing a framework for the meticulous restoration and conservation of historic buildings and structures. Brandi studied many types of restoration, ranging from "basic respect" to a "radical operation," and concluded that the uncertainty in restoration concepts resulted from this ambiguity. As stated by Matero (Matero, 2007), Brandi viewed restoration as primarily a critical effort, emphasizing the "reestablishment of the potential unity of the piece of art, to the extent that this is possible without causing an artistic or historical faux pas or erasing the passage of time entirely." Thus, from Brandi's perspective, restoration was the process of restoring a historic structure to its original state without introducing artificial things or even erasing evidence of degradation. According to "Schädler-Saub" (Schädler-Saub, 2008), Theoretically, Brandi characterized restoration and conservation as a methodology that begins with the identification of a piece of art and its physical condition within its aesthetic and historical context, while keeping in mind its future transmission. (Yazdani Mehr, 2019)

Jokilehto was convinced According to Brandi, because the construction material of a heritage building is the result of human labor, employing the same sort of material for restoration may produce "chemically the same substance" but would have a "different significance" Under these circumstances, restoration lost its original meaning and became historically and artistically fake. (Jokilehto J. , 2007) However, on the contrary to Jokilehto, Mimoso stated that Brandi believed that material could be sacrificed due to the importance of the aesthetic value of a cultural heritage building. Schädler-Saub (Schädler-Saub, 2008) believed that Brandi viewed material as an integral aspect of the aesthetic message sent by a work of art and that it is imperative to retain material that demonstrates the artist's process of creation.

Brandi viewed building as a "work of art" that could be restored with an artistic eye. Brandi continued by stating that restoration must be limited to the original structure and must be guided by the building's conceivable harmony in light of its aesthetic and historical features. Thus, Brandi prioritized historical and aesthetic aspects when restoring a historic structure. However, as stated by Matero (Matero, 2007), Aside from aesthetics, Brandi viewed functional performance as a factor in restoration, which differed depending on whether the work was classified as "industrial" or "art." As a result, Brandi's approach of restoration was based on the aesthetic, historical, and practical aspects of old structures, rather than on their structural integrity. In 1963, Brandi articulated three additional principles in regard to the restoration of a historic structure:

- Any architectural re-integration should be easily recognizable at close distance but, at the same time, it should not offend the unity that is being restored ;
- A part of material that directly results in the building’s image or architecture is irreplaceable since it forms the appearance and not the structure ;
- Any restoration should be carried out in way that it will not be an obstacle for necessary future structural interventions .

Brandi concentrated on a methodical restoration strategy that would allow for more restoration work. He believed that all restoration work must be done in a way that is respectful to the original structure, and hence must be distinguishable. Moreover, Brandi believes some materials cannot be replaced because of their significance in expressing the most important characteristics of a building. As a result, Brandi's restoration idea indicated the necessity of conservation as well. According to Brandi, the primary goal of conservation is to preserve a work of art. Several fundamental aspects for the preservation of historic buildings, according to Barassi, were emphasized by Brandi during his tenure:

- A conservator must not imitate an original architect’s design style or interpret the work subjectively, instead, a conservator designer must respect the time of creation of a work or project, and thus try to conserve a historic building based on its era “time”;
- It is important to prevent restoration interventions in the form of removing the original signs of decay on a cultural heritage building, which hide the real age of the building;
- Any conservation work on a cultural heritage building must be reversible ;
- A conservator architect must plan conservation based on the specific building needs and condition of the work. Thus, he must have knowledge about a historic building .

Brandi classified all conservation work into three categories: physical form and fabric, history, and context, all of which must remain recognizable after alteration . Thus, Brandi was concerned with "loss and compensation," which were regarded as critical issues in the conservation of art and architecture. According to Wong, Brandi's thesis was worldwide accepted when conservation regulations and UNESCO mandates were developed.

Brandi was a twentieth-century theorist who addressed the current trend of restoration and conservation. He placed a premium on aesthetic and historic qualities when it came to the repair and conservation of old structures. His thoughts and practices influenced the development of national and worldwide conservation strategies. (Yazdani Mehr, 2019)

3.5. Interpretations and theoretical analysis on the architectural principles of interventions. Consolidation of mortar from the architectural point of view

Consolidation procedures covering architectural tile schemes fall into two distinct materials skills base: consolidation of the mortar substrate and the ceramic itself. Consolidation of the mortar substrate is usually achieved by introducing a material homogeneous with the substrate itself in a liquid or semiliquid consistency which will bind the degraded or fragmented mortar, fill voids, and adhere to the adjacent surfaces, and in so doing, stabilize the degraded substrate which threatened the security of the ceramic layer. It also implies the use of a treatment method which will avoid the wholesale, and potentially damaging, lifting and removal of tiles in order to replace the original mortar substrate with the new one. (Oddy & Linstrum, 2005)

3.5.1 Degradation and consolidation of old mortar

The constituent ingredients of medieval lime mortar element are a mixture of lime, sand, and pozzolanic material in varied proportions and grades. They can decay due to a variety of circumstances, including water infiltration, frost action, impact damage, or chemical alteration. The outcome is frequently cracking, fissures and fractures, or spaces that allow loose or unseated tiles to become loose. If the underlying mortar is significantly deteriorated or damaged, valuable tiles become susceptible to damaged or worn edges, fractures, or, in the worst-case scenario, complete loss .

“Consolidation strives” to rejoin loose tiles and provide a stable base while retaining the medieval mortar's original appearance. Lifting or relocating loose tiles from their original placement is not a good idea, as it is rarely possible to reseat them exactly as before, unless the tiles have traveled sufficiently from their original location that lifting and resetting is beneficial. Due to the fact that no two medieval mortar mixes are identical, it is critical to conduct a few simple trials to develop a slurry mix of hydraulic lime and water, possibly with the addition of a small amount of fine sand, that will flow far enough beneath the tiles to fill voids and provide an adequate bond and set between mortar and tiles. Slurry is a viscous mixture that retains its fluidity. By use a slurry rather than the conventional firm mortar mix for pointing, the probability of the tiles becoming unseated throughout the procedure is reduced.

3.5.2 Causes of degradation in nineteenth and twentieth century mortars (Oddy & Linstrum, 2005)

The visual and auditory diagnostic of failing mortar in nineteenth- and twentieth-century tile schemes is quite similar to that of seventeenth and eighteenthcentury tile schemes; bulging surface planes and a hollow sound when tapped. The causes are considerably different; thermal shock is less frequent because the typically used glue, Portland cement, is resistant to thermal shock except in extreme circumstances such as fire damage. Normal fireside temperatures combined with continuous heating and cooling are most likely to result in tile loosening from the mortar bed (element joint).

Excessive volumes of water following flood damage frequently cause the mortar's adhesion qualities to fail while the grout structure remains intact, frequently resulting in a hole behind the tiles despite their continued attachment to one another. While the same problems might occur purely as a result of shifting load, when water infiltration is also present, the situation is typically aggravated. When mortar adhesion deteriorates in combination with external stress, such as footfall or vibration, or with continued settling or subsidence, the tile layer can suffer catastrophic failure in the form of fracturing or spalling around the tile edges, or even complete structural collapse, as illustrated in Figure 4 .

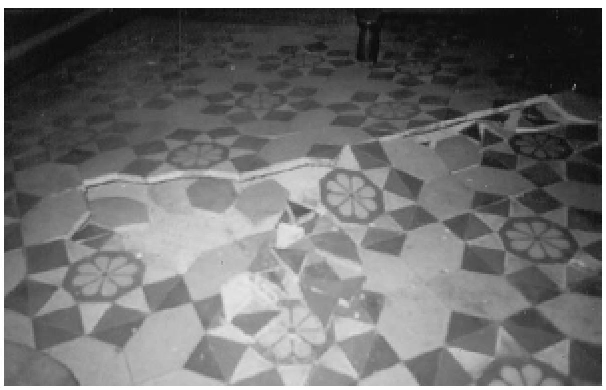


Figure 4. Complete collapse of a tiled floor after severe water penetration (Oddy & Linstrum, 2005)

3.5.3 Consolidation of nineteenth and twentieth century mortars

The main purpose of the consolidation procedure is to fill the spaces behind or underneath the tiles and to create a new adhesion between the tiles and the substrate without having to dismantle major portions of the entire scheme, which would cause unsettling, altering, and unnecessarily severe damage. While technically achievable without the removal of some tile material to allow for the injection of new slurry mix, which will bond all of the parts together, this is not always the case in practice. The removal of tile material without causing harm to surrounding material will be covered in greater detail later in this chapter, but there are certain apparent considerations to keep in mind when deciding which tiles to remove and which to leave in place.

They must be spaced and uncommon enough so that they do not cause more modifications to the overall scheme than are necessary, yet close enough so that the newly bonded sections are adjacent in spread; nonetheless, an efficient consolidation can be achieved even if some gaps in the bonding remain. Clearly, it is preferable to remove a broken tile rather than a perfect example if the option is available, and, again if the option is available, it is always preferable to forfeit undecorated tiles in colors and textures that are most easily copied rather than a flawless example.

There should be little structure in the cement-based slurry mix, which is normally one part Portland cement to four parts extremely fine sand. If the original mix contains lime, one part hydrated lime may be added to make up for the lack of structure. Following the customary thorough pre-wetting, the mix can be injected into the voids by narrow copper pipes that can be either gravity fed or manually pushed under pressure. Copper pipes are preferable to plastic tubes because they are hard yet may be curled into usable shapes, and one end of the tube can be flattened to reach as far into the voids as feasible. Copper pipes are more expensive than plastic tubes.

A very tedious procedure, feeding mortar slurry through narrow copper tubes is comparable to watching paint dry, according to some observers. Since it is impossible to feed down the pipes after the hardening process has begun, new mortar must be mixed on a regular basis, and it will easily harden inside the pipes, leaving them worthless; therefore, a plentiful supply of copper piping is required. Because there are no standard or readily available equipment for doing this duty, it is frequently left to the conservators to devise their own devices that are tailored to the specific scenario. A number of technical challenges can arise during the operation, including variations in the degree of prewetting, the component parts and ratios of the slurry mix, and whether or not to employ gravity or pressure to force the slurry mix down the tubes. The diameter and length of the tubes are also important factors in determining whether or not the exercise will be successful. The time and work involved in building test boxes, similar to those described for medieval mortar consolidation, in which to carry out trials to perfect the procedure for the specific area is well worth it if the alternative choice is to entirely lift and reset a whole scheme . (Oddy & Linstrum, 2005)

CHAPTER 4.

Engineering theoretical framework

4.1 Literature Review. Observations on Design Codes in the past and now, related to the Masonry Structures Design

Many researches, manuals, publications and books that deal with specific cases of masonry structures have been worked on as quite widespread objects, and in addition these have resulted in summaries of standards, normative and codes which define the principles of design, analysis and evaluation methods. Calculation models as well as the criteria which must be met both the elements in particular and the structure as a whole. Since masonry structures are seismically sensitive many of the works and codes deal precisely with their behavior in terms of ground movements.

Everything of this kind of research is based on experience of failures and collapsed structures after strong earthquakes, experimental reviews as well as accounting theories. Today there are a lot of theories and models studies which offer experimental and numerical results in the mentioned cases but also raise many dilemmas that some of them are very good for reinforced concrete frame cases but in regard to specific cases with small differences can differ up to 2-3 times from one another or from experiments.

This is a consequence of the great variety of constituent elements, construction methods, technological level, and at the same time shows the difficulties which accompany these structures. This in part also justifies why this area of accounts has lagged behind compared to reinforced concrete or steel structures.

During the work in certain cases the author underlines such cases when there is a difference between the authors or the norms. As in other fields in the last century, this field has been developed by the application of powerful computers and adequate application programs for this purpose. These are mainly based on finite element MEF methods which give fast and detailed results.

For the use of models with microstructure where the materials are elaborated with their real specifics and characteristics, a powerful computer or software and time for calculation are needed, therefore more often macrostructure models are used which, in addition to simplicity, offer satisfactory results.

Despite the fact that it is estimated that American standards for masonry such as FEMA (Federal Emergency Management Agency) are considered more advanced in the paper, the author compares his experimental results more with European Normative EN (Eurocodes) as more current as well as in some cases in the former Yugoslav and Greek standards. Just as well as the standards of Albania (Technical code of design) when it comes to recognizing the existing structures which must have been worked according to them.

4.1.1 European Standards, Eurocodes related to the study of masonry and mortar

The general principles of European codes and standards also apply to these parts, which despite the definition of the principle and unique methods, but for certain aspects allows and is preferred through National Local Annexes the acquisition of parameters obtained from experiments to approve specific values of local character.

Eurocode 6 respectively EN 1996-1-1: 2005 in its entirety elaborates the masonry structures, where in addition to the introductory part (field of application, symbols, references, terminology, etc.) deals with design principles, constituent materials, types of walls and connections, possible loads, stability, durability, state of use and boundary condition, execution, details, physics, etc.

Eurocode 8 which studies the seismic impact in its entirety in its chapter 9 defines the specifics of masonry and elements, ie the minimum conditions that must be met to be used for seismic areas. Standards are:

EN 771 - (1-6) elaborate masonry elements from different materials;
EN 772-1 methods of examining elements of compressive strength;
EN 998-1.2 elaborates the mortars;
EN 1052- examines the walls configuration and design etc.

When it comes to the application of e.g. reinforcements with concrete, cell or polymer fibers apply adequate standards to the used materials. These will be analysed and discussed more detailed and specifically in the case studies reviews in the following chapters of the study.

4.1.2 Observations on the current Albanian Code of Design and Implementation for masonry structures according to KTP-1978

This technical condition defines the method of calculating the wall section and the foundation section. For constructions in seismic regions, the technical instructions defined in KTP 2-78[5] are taken into account. These general guidelines were published in 1978. This technical code specifies the calculation of the wall and foundation section with limit state method of design.

Loads and their combinations are taken in accordance with the technical instructions, which are defined in KTP 6-78 (Determination of loads in civil and economic buildings). This code specifies all cases of masonry with bricks, stones, concrete block and concrete mix by stones, the mark and plasticity of the mortar, the thickness of the mortar joints and their leveling, the height of the row, the way of connection and the quality of construction .

The most important part of this code is shown below. First the calculation parameters of the wall are shown. Exactly the calculation resistance is the product resulting from the multiplication of the normalized resistance versus the homogeneity coefficient. It varies according to the tense condition of the element and the type of materials used to build the structural wall.

[5] Albanian National Design Code, KTP/2-78

Table 1. Compressive strengths for brick walls, with row height over 12cm (KTP-78)

No.	Brick grade [kg/cm^2]	Mortar grade [kg/cm^2]						
		100	75	50	25	15	4	0
1	150	22	20	18	15	13.5	12	8
2	100	18	17	15	13	11	9	6
3	75	15	14	13	11	9	7	5
4	50	-	11	10	9	7.5	6	3.5

Table 2. Compressive strengths for concrete block walls, with row height over 18cm (KTP-78)

No.	Concrete block grade [kg/cm^2]	Mortar grade [kg/cm^2]						
		100	75	50	25	15	4	0
1	100	20	18	17	16	14.5	13	9
2	75	16	15	14	13	11.5	10	7
3	50	12	11.5	11	10	9	8	5

Table 3. Compressive strengths for stone walls and foundations with kave stones (KTP-78)

No.	Stone grade [kg/cm^2]	Concrete grade [kg/cm^2]		
		100	75	50
1	Over 200	27	18	18
2	Less than 200	-	15	15

Table 4. Calculation resistances in central traction and shear (KTP-78)

No.	Stressed state	Mortar grade [kg/cm^2]			
		100	75	50	50
1	Axial tension:				
	Combined intermittent joints	1.6	1.1	0.5	0.2
	Continuous horizontal joints	0.8	0.5	0.3	0.1
2	Shear				
	Combined intermittent joints	1.6	1.1	0.5	0.2
	Continuous horizontal joints	2.4	1.6	0.8	0.4
3	Main Stress in tension	1.2	0.8	0.4	0.2

The following interpretations are the calculations for the modulus of elasticity:

- For calculating walls according to bearing capacity (resistance and static stability):
  $E = 0.5 * E_0$ (Eq. 1)
- To determine the deformation of the wall is used:
  $E = 0.8 * E_0$ (Eq. 2)

where: E_0 - initial modulus of wall elasticity, which for unreinforced walls is calculated by the formula:

$E_0 = \alpha * Rn$ (Eq. 3)

where: α - elastic characteristics of masonry and is obtained according to table 2.5

Rn - standardized resistance to central pressure of masonry

Table 5. Elastic characteristics of masonry, "α" (KTP-78)

No.	Wall type	Mortar grade [kg/cm^2]			
		100-50	25	4	0
1	Brick wall and concretee blocks	1000	750	500	350
2	Brick wall with vertical holes	2000	1500	1000	-
3	Brick wall with horizontal holes	1500	1000	750	-
4	Stone wall and concrete blocks	2000	1000	750	-

4.1.3 Masonry structures, a brief description

Represent the assembly of interconnected elements with certain mortar. The role of the element itself is the shaping of the wall as well as the acceptance of external influences, while the role of the mortar is the "homogenization" of these elements playing the role of the material which connects the elements and fills the spaces between them.

The constituent elements are intertwined so that together as a whole they create a stable structure usually in the form of vertical walls, vertical cylinders such as minarets, wells and chimneys, but with dedicated skill arches, bridges and curved coverings are formed - domes like cylindrical shells or even spherical.

4.1.4 The walls definition

They represent the elements - the vertical plates of the structure which are mainly loaded in its plane and that in compression. The interweaving of the walls at the base as well as its stiffening with mesquite tiles forms massive structures where the walls are retaining d.m.th. receive and forward external loads as well. But lately the bearing capacity of the structure is entrusted to reinforced concrete or even metal structures where the walls have a dividing character which are loaded only with their own weight and eventually by the wind.

Based on EN they are categorized into three groups:

- Unreinforced masonry;
- Masonry with reinforced steel elements;
- Reinforced walls.

Also characterized by the material:
- Filling elements;
- Retaining elements (retaining and divider).

Since the object of study of this paper is the bearing capacity of masonry structures under seismic impact, in the following we will concentrate on the walls with special emphasis on the walls of clay elements, as typical objects of special interest for our territories.

4.2 Impacts affecting the performance of structural walls

Due to the internal structure of the combination of elements and mortar, the walls as a whole present inhomogeneous and anisotropic tiles. They have good bearing capacity in their own plane while normal ones have relatively little resistance. For this reason masonry objects at the base, with the walls as elements are usually combined with each other at an angle of 90 o forming a stable structure.

In daily conditions they are usually loaded only with vertical loads - by the own weight of the structure, therefore even within it the state divided into pressure dominates even though there are elements of the three-axial state. In these cases it is assumed that horizontal loads e.g. winds that cause normal impact on the wall plane, ie bending have a relatively small impact and withstand the weight itself without causing high eccentric pressure.

According to EN norms, masonry structures as a whole are calculated based on the general principles and principles defined in EN 1990. For example the boundary condition of the structure are analyzed as well as the bearing capacity capacity of the element respectively the structure. In all cases the internal momentum must be greater than the external influences with which the structure is charged. Load analysis is done including partial safety factors as well as their combinations which are defined in EN 1991.

4.3 Materials and components of masonry structures

Masonry as a structure is mainly a combination of filler elements, and the joints between them "mortar", and sometimes other elements to increase the stability of the wall structure, such as wooden elements, reinforced belts, metal rod elements, polymer fibers. FRP etc.

4.3.1 Filling elements, masonry units

These are materials and elements, which in terms of shapes and dimensions are suitable for use and enable a combination in creating a structure with load-bearing masonry. They are found in nature or produced with a relatively simple and quite economical technology. They are considered as materials with massive geometric shapes, with high resistance against to atmospheric conditions and aggressiveness of the environment, they are refractory, aesthetic and ecological materials.

Regarding the physical-mechanical characteristics they usually possess good resistance to compression and are used for vertical retaining elements, such as retaining walls which accept and transmit vertical loads from the structure to the foundation. Materials can be natural stone, processed stone, various products from baked clay, concrete, calcium silicate, aerated concrete, etc.

In applications in the design of structures with natural stone, the main challenge is in finding suitable shapes and dimensions for their combination into a whole, as well as need large amounts of mortar, are very sensitive to horizontal "seismic action" ". At the same time, this complicates the account, ie the verification of stability for such structures. With the application of processed stones either only in the corners of the building or as a whole, the stability and functionality has been improved, while the needs for processing - stone carving have made the execution more difficult and have made it uneconomical for more comprehensive use.

With the application of elements of regular shapes, processed from baked clay the construction became easier, more economical as well as the structures gain in stability. Today in use we have a large variety of these elements with high mechanical quality as well as with different shapes and dimensions and also with different percentages of voids depending on the needs, ie destination.

With the development of production technologies, other elements were also advanced, such as elements under steam pressure - autoclaves made of calcium silicates, which are characterized by a more regular shape and good mechanical properties. Elements from aerated concrete can also be mentioned, which are characterized by regular shapes and low volumetric masses. Concrete elements with natural aggregates or even with recycled materials can also have frequent use.

The elements are grouped and evaluated with numerous standards and norms in this field where during the work the classifications according to EC 6 will be used, respectively EN 1996-1. Depending on the materials we use, we distinguish 6 groups of elements as well as the standards which specify the requirements for them:

- Elements from clay (baked) EN 771-1
- Elements of silicates EN 771-2
- Concrete elements EN 771-3
- Aerated concrete elements EN 771-4
- Elements of artificial stone EN 771-5
- Elements with natural stones EN 771-6

According to EN 1966-1 today the elements are divided into 4 groups depending on the basic materials and the percentage of voids.

4.4 Mechanical properties of structural unreinforced masonry elements

4.4.1 Compressive strength of the masonry materials

Compressive strength is the main mechanical property of the element which has a great impact on the compressive strength of the wall as a whole. It is examined in the prepared samples by placing them on uniaxial presses with the destructive method, depending on the direction in which it will be placed on the walls. It is still a challenge to evaluate the compressive strength in the laboratory and how much it corresponds to its bearing capacity inside the wall. The author Crisafuli emphasizes "the compressive strength of the element according to current standards does not represent its real uniaxial resistance due to the effect of stiffness of the tiled element during the examination" and the author complements it due to the ratio of dimensions and the effect of mortar.

Due to the non-flat surfaces one of the surface treatment methods should be foreseen such as abrasion, leveling with layers of plaster mortar, leveling with layers of cement mortar, leveling with layers of sulfur mixtures; these processes which cause an entanglement - cooperation between the plate and the element, preventing the free expansion that the element actually has. Element reviews are known which try to reduce this effect e.g. increasing the height of the element compared to the base (ratio: H/B up to 5 times), the use of "combs" special devices which allow lateral movement of the contact surface, the use of soft substrates such as corks, layers of fibers and wood, mediapan of different resistances and thicknesses, these layers have a coefficient of succession close to zero.

4.4.2 Tensile strength of unreinforced masonry

It also has its own importance especially when dealing with walls that are also subject to horizontal pressure. It is significantly smaller than the compressive strength and are linear quasi-instantaneous fractures. It can also be obtained through examination based on direct traction, but it is quite complicated - it requires special equipment and materials for the realization of traction, so with great reliability are used methods in bending (fracture module) or even in indirect traction - in cracks. These do not achieve the same results but a correlation can be established between them. There is also a tendency to find the correlation between tensile strength - usually that of bending and compressive strength, which according to different authors we have large differences

4.4.3 Modulus of elasticity and Poisson coefficient for masonry elements

The modulus of elasticity can result from the working diagram σ-ε of the element where it is defined as the tangent which passes through the point 0 and 1/3 of the compressive strength of the element. This diagram is relatively elastic in blocks while in bricks it shows a plasticity.

Experimental results show a distribution of results so we have distinct preferences. While in concrete elements it ranges from 3-12 GPa in clay elements it is approximately:

Eb = 300 f 'cb (Eq. 4)

According to Kirtsching:

Eb = 980 f ' cb 0.77 (MPa) (Eq. 5)

While the Poison coefficient according to Atkinson, McNary and Abrams ranges from 0.13-0.22 (without specified materials) while according to Ameny this value ranges from 0.07-0.14.

4.5 Mortar and binders

4.5.1 Types of mortars

The mortar serves for the connection, ie the adhesion between the elements of the masonry as well as for the filling of the spaces between them. In the beginning, mortars based on bituminous bases were used, mortars with lime binders, with hydrated lime, and lately, continuous mortars are usually used - cement, lime, aggregate, water and, if necessary, additives. As a bonding material it has an important role in the bearing capacity of the whole structure and especially when the shape of the wall fracture is made in the cut.

Based on the Eurocode-6 classification according to qualities and use we have the following types of mortar:

- Mortar for general use which uses only dense aggregates and has a joint width > 3 mm
- 1-3 mm thin layer mortar is designed-prefabricated to meet the specific requirements of the structure (eg adhesive of aerated concrete or silicate elements)
- Light mortar with volume mass <1500 kg / m^3 - where filling the aggregate is light as e.g. perlite, expanded clay, pumice, etc.

According to the production concept, mortars can be:

- Designed (according to cases and requirements)
- Ordinary (according to general descriptions) And according to the way of preparation:
- Pre-prepared
- Semi-prepared

The recipes are mainly prepared on the basis of experience as a mixture of cement, slaked lime and sand in volume ratios e.g. for mortar of general purpose. Powdered lime (hydrated) or even cement mortar can be used, which is actually categorized as M5.

Table 6. Orientation ratio by volume of mortar components for mortar brands

Mortar class	Average compressive strength	Approximate mixtures by volumes		
		Cement	Quenched lime	Aggregates in relation to connectors
M-2.5	2.5	1	1.25-2.5	2.25-3
M-5.0	5	1	0.50-1.25	2.25-3
M-10	10	1	0.25-0.50	2.25-3
M-12	12	1	0-0.25	3

In the table are the orientation values because the final quality of the mortar depends not only on the ratio but also on the quality of the ingredients themselves, e.g. grade of cement, generosity of lime as well as granulometric composition of sand. While the role of cement is in increasing the strength and durability of mortar, the role of lime is to improve workability, initial adhesion and absorption - water retention.

The role of the compressive strength of the mortar does not have a significant impact compared to the element itself, but in cases of impacts in tensile or even in some cases in cutting the role of the mortar increases.

The thickness of the joint itself has a significant impact, which is preferred to be as small as possible (Naom 1994) and the ratio of the thickness of the element compared to the thickness of the joint to be larger. The thickness of the mortar in the horizontal joints for clay elements is preferably 8-15 mm, and it is mandatory to fill the vertical joints (10 mm) with the exception of areas with low seismicity.

In cases of seismic when poor quality mortar has been used, it has led to the disintegration of the elements, therefore based on EC 8 are determined the minimum criteria for application of mortar in seismic areas:

$f_{m,\,min} \geq 5$ N/mm^2 for unreinforced masonry walls and;

$f_{m,\,min} \geq 10$ N/mm^2 for reinforced walls

These calculations and equations are summarized on the research and discussions conducted in the framework of field investigations, expert consultations and calculation reports found in the archives (AQTN).

4.5.2 Compressive strength of mortar

Presents the main quality of mortar. It depends on many factors such as the type and percentage of connectors or even connectors when there is more than one as well as the ratio between connectors. Much also depends on the filler (sand) and the granulometry and shape of the grains, mineralogical petrographic composition, the amount of water or water / binding factor, the method of preparation and placement in the work. Mortar evaluation is done through laboratory samples (chapter 6, section 6.1.5.1). In this case it should be noted that due to different maintenance conditions, paving in thin layers (8-15) mm, rapid absorption of water in the mortar from the elements in the walls {changing the ratio W/(C + G) }, inadequate maintenance and reinforcement due to the triaxial condition in which the mortar works inside the wall but not in the samples in the laboratory, etc. Mortar tested in the laboratory is not a reliable indicator of mortar on walls. According to the author Schubert, also (Cullufi pg, 23) the difference can be of the level 0.5-1.5.

4.5.3 Other mechanical resistances

Also other qualities of mortar such as tensile strength, shear strength, abrasion resistance, adhesion, are parameters that affect the behavior of the mortar and the wall as a whole. Adhesion and friction also depend a lot on the masonry element, so even today, in the case of micromodeling calculations, the mortar-element interface parameter is very important. As a porous material it is very sensitive to the effect of freezing - thawing so special care is given to this parameter.

Durability - the longevity of the mortar depends mainly on the petrographic mineralogical composition of the sand, binder, as well as the aggressiveness of the environment in which it is used, the composition of alkalo-silicates and soluble chlorides, which should be given importance to wet mortar. In many cases, special binders or various additives are applied - additives to improve certain qualities.

4.4.4 Modulus of Elasticity, Slide Modulus and Poisson Coefficient

Based on these parameters and their relationship with the analog parameters of the masonry element itself comes to the internal redistribution of partitions within the wall that must be taken into account in the case of models with microstructure. The modulus of elasticity results from the working diagram σ-ε as second module between 0 and 0.5 fm. According to Brown and Whitlock authors the initial module is 15-25% larger than the second one.

$Em = 1000*f'm$ (Eq. 6)

The slide modulus is calculated:

$G = 0.4*E$ (Eq. 7)

Whereas the Poisson coefficient ranges in a very wide range of (0.07-0.25) although for low-strength mortar - average values 0.15-0.250 are more realistic.

Adhesion, tensile strength, resistance to environmental aggressiveness are also parameters that must be analyzed for certain cases (EN 1015-1-19). In the case of micromodeling, adhesion represents the third parameter that is well considered - mortar interaction.

4.5 Concrete used for antiseismic elements in masonry

It is usually used to form reinforced belts or even to fill large holes inside the elements. In these cases they "tie - sting" the wall but in reality are not retaining. Must have the minimum class C12/15 and the maximum grain is conditioned by:

dmax> b min of hole / 5 or protective layer > 15 mm

Since a fluidity is required to fill the holes then additives such as plasticizers are used and those to reduce shrinkage. In the case of repairs, concrete (mortar) with microfiber is also used, such as. torkret concrete.

4.5.1 Reinforcement

It is used in reinforced walls to increase the bearing capacity of the wall with emphasis in the transverse direction as well as to increase the ductility of the wall as well as as anchors for the cooperation between the concrete frame and the wall. If the concrete belts are reinforced according to EC 2 as constructive reinforcement, and in specific cases the usually thin reinforcement Ø 6 or Ø8 can be placed in cooperation with the mortar in the horizontal joint or even in the case of joint reinforcement or specific products of truss shape are found or special stirrups.

4.6 Use of FRP Materials in masonry structures

Today, the use of polyester nets or microfibers that are fired directly into the mortar has started. Also, every day more and more glass fibers, carbon fibers or even aramid fibers are used, in combination with their resins. These are very current, especially when it comes to various adaptations in the structure.

4.7 Compressive strength of retaining walls (brick and mortar together)

Masonry structures show good behavior, usually when under the action of normal compressive forces on the horizontal joint of the mortar. Initially, for low force levels, the stress-strain dependence is linear. As the force increases, the bearing capacity of the wall behaves as non-linear and normal cracks begin to appear in the horizontal joint. Thus, the wall is divided into several vertical strips in the form of columns, until it loses stability and comes the point of collapse or panel destruction.

By the action of the compressive force the deformations in the mortar would naturally be greater than those of the filler elements. However, since we have friction between the mortar and the elements, then tensile stresses appear in the elements. At the same time the mortar, due to the reinforcement by biaxial action can withstand greater stresses in compression. This leads to the compressive force on the walls being limited by the tensile strength of the elements.

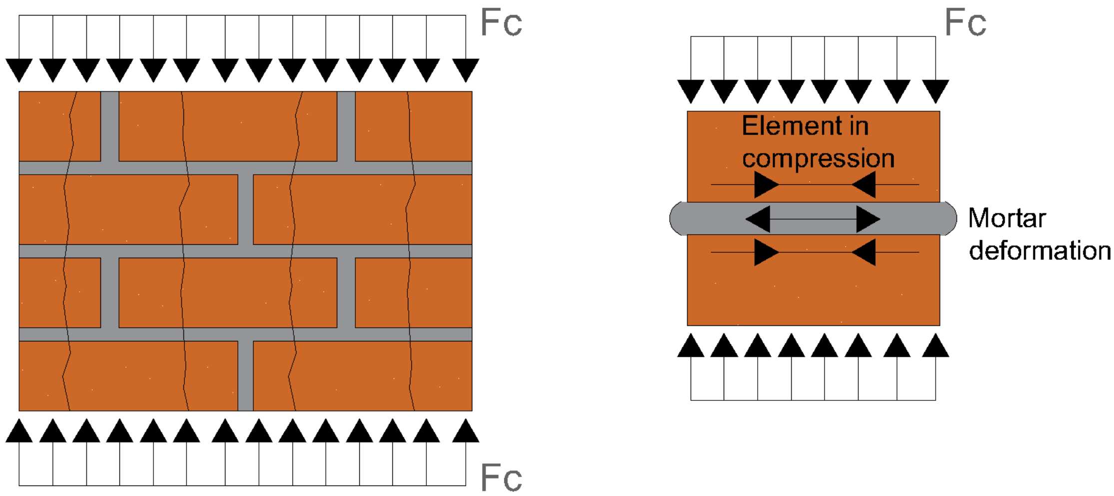


Figure 5. Cracks in normal elements in tensile stress and Tensile stress in elements including mortar deformation

The compressive strength of the walls is determined experimentally. When this is not possible, compressive strength is determined based on empirical expressions derived from experiments in different countries.

Secondary factors affecting the compressive strength of structural walls

There are two main factors that affect the resistance to wall pressure:

- Tensile strength of elements (gap elements are unfavorable in relation to this aspect)
- Compressive strength of mortar (greater resistance of mortar reduces lateral deformations).

But, there are other factors that affect the resistance to wall pressure. These factors are:

- Thickness of the mortar in the horizontal joint (recommended height 8-15mm);
- Wall construction, forms and methods of element connections;
- Total filling of joints or meeting directly and through interlocking scaling;
- The number of horizontal joints, elements with higher height are more favorable in this respect;
- Wall humidity - water absorption and water retention, etc.

4.7.1 Shear-slide resistance of the masonry

It is known from the engineering literature that the shear strength of walls depends on the level of axial force acting on the wall. However, two different hypotheses have been elaborated to model the mechanism of destruction in shear to plan walls. One of the hypotheses which has been accepted by Eurocode EC 6 for the determination of shear strength is based on the friction theory.

According to this theory the wall resistance under the action of shear forces is defined as the combination of shear strength when the shear force is zero and the additional resistance that comes as a result of the compressive stress acting normally in the shear plane, i.e. of friction between the mortar and the elements. In fact the shear strength is the combination of two different mechanisms, the bond strength and the friction resistance between the mortar and the filler elements.

4.7.2 Shear resistance for horizontal sliding, Review and reflection according to Italian literature and NTC-code

The collapse mechanism due to sliding shear occurs by breaking the rows of mortar between the blocks with consequent sliding between two portions of masonry. The shear strength of the masonry is evaluated using the Coulomb internal friction criterion which takes into account the compressive stress acting in the masonry. As the compression tension increases, the resistant shear stress will increase.

The resisting tension must be multiplied by the compressed portion of the masonry only, assuming a linear diagram of the compression tension.

$V_t = L' \cdot t \cdot f_{vd}$ (Eq. 8)

V_t = shear resistance for horizontal sliding;
L = compressed length of the masonry wall;
t = thickness of the masonry;
f_{vd} = resistant tangential tension of the masonry in the presence of compression.
The above formula is in the Italian code, specifically with number 7.8.3 - NTC2018

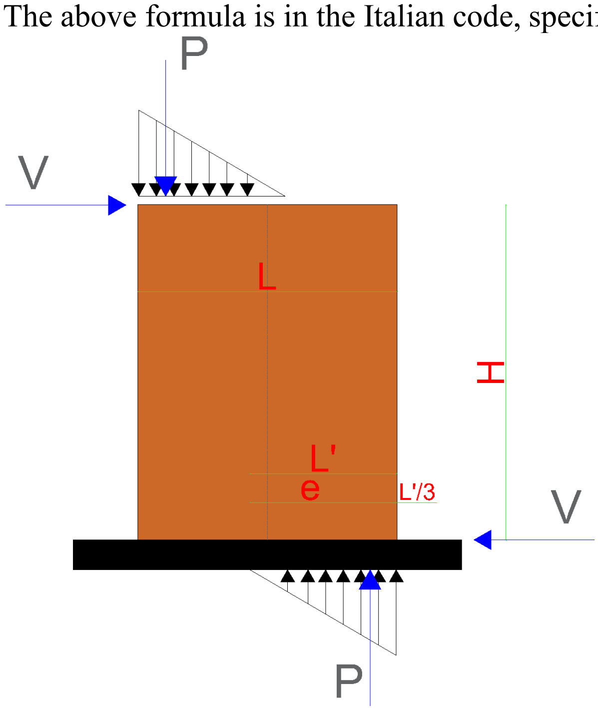


Figure 6. resistant shear - break by shear-sliding

L' - reactant base zone obtained, assuming a linear distribution of the compression stresses in the elastic phase, in the absence of tensile strength.

Characteristic resistance of masonry in shear:

$f_{vk} = f_{vk.0} + 0.4 * \sigma_n$ (internal attraction criterion – of Coulomb) (Eq. 9)

$f_{vk.0}$ – characteristic shear strength of masonry in the absence of axial stress;
σ_n – average normal voltage due to vertical static loads;
f_{vk} – characteristic resistance of masonry to shear in the presence of axial stress.

In case of decompression of the masonry, the compressed length L 'of the section is canceled and therefore the shear resistance due to horizontal sliding becomes zero.

4.8 Observations and interpretations on the experimental tests

The typical experimental tests performed on wall panels, macro-elements consisting of at least 3 panels of "bricks", are as follows:

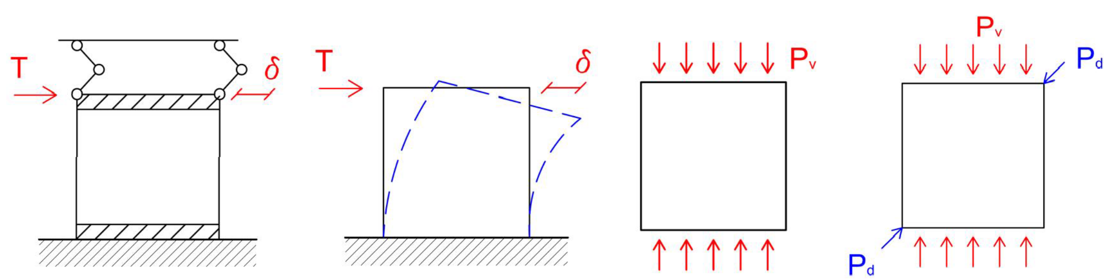


Figure 7. Pure shear test (faces remain parallel), shear and bending test, simple compression test, diagonal compression test

The four tests are to be understood as conventional as they originate rather complex and difficult to compare tension states in the panel. The diagonal compression test is usually taken as a basic test for the characterization of the shear characteristics of the masonry on the basis of its simplicity of execution and knowledge of the stress distribution inside the panel.

The simple compression test, on the other hand, highlights the behavior of the panel under vertical loads. To extend the results to a generic case of normal stress and shear on the panel, suitable resistance criteria are generally required, capable of capturing the response in all possible combinations.

4.8.1 The collapse mechanisms

The following are the possible breakdown mechanisms of the wall panel:

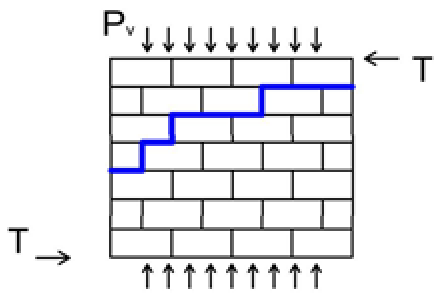


Figure 8. First shape of the collapse mechanism, sliding of joints

Sliding of joints. This breakage is common in strong brick masonry and relatively weak joints. It generally occurs if the value of the P_v component is limited.

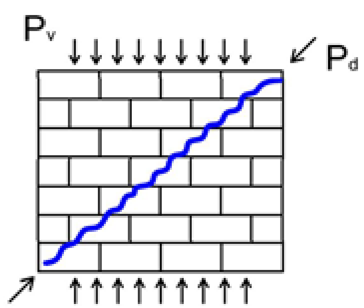


Figure 9. Second shape of the collapse mechanism, Cracking of blocks

This rupture is caused by the tensile failure of the block. Generally it involves the central part of the panel. The inclination α depends on the ratio between the vertical and horizontal components of the applied loads. Generally affects bricks perforated with the use of high-strength mortars.

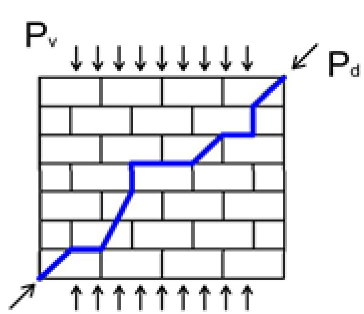


Figure 10. Third shape of the collapse mechanism, Combined mechanism

The crack generally follows the diagonal of the panel. It affects both the joint and the brick. It is a collapse that generally occurs when the mortar and brick have comparable strengths. It is a type of failure that generally affects the walls due to a wide variability of load combinations.

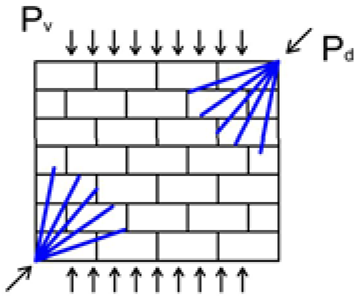


Figure 11. Third shape of the collapse mechanism, Crushing in the vicinity of the load devices

Crushing in the vicinity of the load devices - It is a localized breakage generally due to a reduced size of the load application devices.

4.8.2 Reviews and analyzes of masonry constituent materials

The quality required by the literature for the basic elements examined in Eurocode-6[6] or Eurocode-8[7] that deals with seismic conceptions, analysis of certain analogous standards, or other specific requirements, should be confirmed by laboratory or on-site examinations.

In order for the result to be truly representative, as adequate and reliable as possible for research and to have a crucial role, there is the number of material samples as well as the way of taking them, sampling which must be done professionally in no case with selection of elements or within a small quantity. It is normal that even for this there are many standards which define each application case and relevant detail which affects the results obtained.

Also special attention should be focused to the maintenance of samples as well as their preparation for examination, as well as the examination and analysis itself which should be carried out as provided by the relevant standards.

4.9 Information for structural assessment: knowledge levels according to Eurocode

In order to choose the right type of analysis and appropriate values of reliability factors related to knowledge levels, the following three levels are defined:

CL 1: Limited knowledge
CL 2: Normal knowledge
CL 3: Complete knowledge

Factors that determine the appropriate level of knowledge (eg class 1, class 2, or class 3) are:
Geometry: the geometric features of the structural system and some non-structural elements (eg filler masonry) can influence the reaction of the structure.

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[6] Eurocode 6 - Design of masonry structures - Part 1-1: General rules for reinforced and unreinforced masonry structures.
[7] Eurocode 8: Design of structures for earthquake resistance -. Part 1 : General rules, seismic actions and rules for buildings.

Details: these include the amount and details of reinforcement in the connection structure between the steel elements, the connection of the interstitial diaphragms to the structure resistant to lateral action, the connections and joining of the mortar to the masonry and the nature of each reinforced element in the masonry.

Materials: mechanical properties of materials and their composition.
Levels of knowledge manage to determine the appropriate method of analysis, as well as the accepted values of reliability factors (CF).

Table 7. knowledge levels according to Eurocode 8, part.3 (CEN Eurocode 8, Eurocode 8: Design of structures for earthquake resistance Part 3: Strengthening and repair of buildings, 2003)

Knowledge levels	Geometry	Details	Materials	Analysis	CF
Class 1	From original architectural drawings with simple visual controls or complete control.	From simulated design in accordance with previous practice and from a limited on-site inspection.	Values determined in accordance with design time standards and a certain amount of on-site test limits	LF-MRS	CFCL.1
Class 2		From the incomplete original drawings of the executive project with limited on-site inspection or with a more extensive inspection.	From the original project specifications with a limited amount of on-site tests or an extended amount of tests.	All	CFCL2
Class 3		From the original drawings of the executive project with a limited inspection or from a detailed on-site inspection.	From the original test report with a limited amount of on-site tests or from on-site detailed tests.	All	CFKL3

4.10 Recommendations for interventions on monumental heritage with a specialized and specific typology in seismic areas. Part of the state of art

4.10.1 Interpretations summarized from the recommendations issued in Italian case 1986

Numerous interventions in historical and architectural heritage located in seismic areas, carried out in recent years and still in progress, especially after devastating seismic events, as well as other seismic events less violent, but still harmful to buildings, often are characterized by considerable difficulties, related to different orders of factors:

- The lack of clarity in the technical regulations regarding the technical aspects of the interventions, worsened by the tendency to improperly apply technical standards , rules that have been written for ordinary buildings and not for monumental buildings with a specialized typology such as churches and palaces generally comprising large rooms, vaulted roofs, frescoed walls and horizontal elements or of precious materials;

- The conflict between the conservation and restoration needs on the one hand and the protection from seismic risk of construction and human lives on the other hand, with the related assumptions of responsibility that are attributed to the professionals involved in the interventions and to their colleagues working in the bodies control ;
- The lack of clarity, technical, technological and even conceptual or cultural, surrounding the use of modern materials in ancient constructions;
- The absence of a numerous calculation reports and verification F.E.M. models recognized as valid for special typologies, an absence that is too often filled in a completely improper way by the adoption (the models valid only within precise limits "example of the application of POR-type methods")[8]. (Tomazevic, The computer program POR, 1978);

Thus, the interventions on the monumental complexes have often been conceived as a static restructuring carried out with a series of massive interventions that take up the culture of new materials with largely extensive criteria, in particular of steel and reinforced concrete, thus developing a structural restoration strategy, which seeks to remodel the ancient factories according to the resistant patterns typical of modern materials. The results of this state of affairs very often translate into :

- unnecessarily "heavy" (if not sometimes counterproductive) interventions, which often distort the monument from the point of view of its identity and value ;
- Excessively expensive interventions, which are countered by non-interventions in other architectural organisms, due to the exhaustion of available funds;
- Security guarantees that are often completely illusory, as they are based on unreliable calculation models;
- Widespread inability, substantial and formal, to check the effectiveness of the interventions carried out (think of armed injections and injections of mortars or resins) ;

As an example of the phenomena mentioned above, some design positions that are as widespread as they are harmful are listed:

- Projects developed without any objective element (knowledge about the structure and the foundation soils; - systematic use of bored piles (small diameter micro-piles) almost always proved superfluous to a more careful geotechnical examination;
- Anchoring of massive structures with harmonic steel tie rods injected into the ground;
- Insertion of new structures to which the static function is completely entrusted, thus reserving only the function (the formal element) to the old structure;
- Insertion of different structural elements that perform static functions considered by the designer not compatible with the ancient organism; in this case, in addition to originating a hybrid mechanical behavior, particular uncertainties can be introduced due to the interaction of different structural schemes and materials ;
- Attempt to achieve, by means of interventions, a behavior that can be modeled with schemes typical of new buildings;

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8 A simple method for the seismic resistance analysis of plain masonry buildings has been developed in Ljubljana

- Unjustified use, with respect to the present crack pattern and the original structural conception of the monument, of "seams" and "injections";
- Unthinking use of new materials, especially with reference to durability and interaction with original materials.

With respect to the above situation, introduces a new implementation of the problem into the technical regulations for constructions in the seismic interventions on existing buildings, making it possible to operate in prevention rather than just repairs, as well as throughout the national territory; the main innovation is represented by the introduction of a double level of objectives achievable through structural interventions aimed at increasing the resistance of buildings to seismic actions; in fact, the following are identified:

- The adaptation interventions, defined as he as a set of works necessary to make the building capable of resisting project actions equivalent to those envisaged for new constructions ;
- Improvement interventions defined as a set of works aimed at achieving a greater degree of safety against seismic actions without substantially modifying the overall behavior of the building ;

The conceptual distinction between the two types of intervention mentioned, although not directly referring to monumental buildings pursuant to article 16 of law 64/74, has significant importance with regard to the objectives that must be based on an intervention on the monumental heritage.

By their nature, interventions on the monumental heritage are not included in any of these cases: the obligation to adapt is in fact triggered in the presence of interventions that can be configured as elevations, extensions, building renovations and in any case such (substantially modifying the static and dynamic of the building organism.

It can therefore be said that, in light of the provisions for ordinary construction, the objective of the interventions on the monumental heritage as regards safety and seismic actions, is comparable to improvement. In this perspective, it can be concluded that the interventions on the monumental heritage must be characterized by an increase in safety against seismic actions without, however, the problem of respecting the formal checks in relation to the seismic actions of the project envisaged for the new buildings.

Therefore, pending the definition of specific technical standards for monumental heritage, to which the National Committee for the Prevention of Cultural Heritage from Seismic Risk is called upon to make a proactive contribution, a line of behavior based on the systematic recourse to interventions of improvement and on a conduct of design operations that has directed regard to the cultural value of the building considered and which implies:

- Particular attention to the original materials and magisterium's, as well as to subsequent transformations;
- A careful reconstruction of the seismic history of the building, with particular attention to any repairs following past seismic events;
- A rigorous and systematic interdisciplinary approach in all the design phases, with particular reference to the architectural, historical, geotechnical, structural, plant

engineering contributions (if applicable): The use of techniques and materials as close as possible to the originals, with a severe interdisciplinary critical examination of any interventions that differ from the aforementioned. Ultimately: in the presence of an "ordinary pathology or damage" of the monument and in the absence of the constraints referred to in theoretical restoration manuals. of the aforementioned Decree, the choice of widespread conservation must be made which, combined with the above mentioned regulatory concept of improvement, allows to achieve the objective of seismic risk prevention.

The operations to be carried out will be, by way of example, of the following type:

- Coordinated interventions on the connections, especially if compromised by previous earthquakes or lack of maintenance;
- Verification and repair of the horizontals (roofs, floors, arches, vaults, platbands) with mainly traditional procedures (partial replacement of only the degraded wooden elements, restoration of the tension of chains and spanners, stiffening of the planks with a second nailed planking, placing new tie rods at low voltage operating floors, partial reintegration of arches or platbands, etc.;
- Verification and repair of vertical or sub-vertical cracks with traditional procedures in order to restore the continuity of the masonry structure, even without excessive stiffening;
- Skiving of the joints, topping up and restoration with traditional mortar of the plasters where they existed and have fallen, to reintegrate the bearing capacity of the masonry structure, with attention to any decorated plasters.

It can be observed that the examples now outlined are largely configured as maintenance interventions, aimed at mitigating degradation and restoring the building to its original capacity for resistance, or improvements, aimed at increasing the aforementioned capacities without upsetting the own resistant schemes; only in the presence of one "Extraordinary pathology" due to defects of origin in the structural conception, or to a very accentuated state of decay, or to considerable damage, the need arises for a more complex evaluation; this need also arises when large-scale interventions are configured such as those envisaged within the finalized projects.

In order to pursue the aforementioned objectives, the completeness of the analysis and project documents is of fundamental importance, as the result of a methodology organized in operational phases strictly connected to each other through the coordination of the expert in architectural restoration, so that the lack of a or more phases can only lead to the non-acceptability of the final proposal represented by the project. Therefore, the project documents must as a rule be at least the following:

- A critical historical study on the complex to be restored which identifies all the transformations that have occurred over time and illustrates them in a specific graph;
- A study of the seismic history of the site; - an accurate plano-altimetric survey of the complex, including the foundation structures;
- A detailed critical survey that reports the data acquired by crossing them with data obtainable through the use of diagnostic tools;

- A detailed analysis of the loads with the designer identifying all the load-bearing elements, including the foundations, through which a rational structural scheme is identified; - a metric and photographic survey of the failures found;
- A description of the constitution of the subsoil and of the stability conditions of the surrounding area; - a report that identifies the causes and extent of the failures; this report should indicate, if and to what extent, the failures have damaged the load-bearing elements of the structure;
- An report on the structural materials present with an assessment of their state of conservation, supported where possible by experimental investigations;
- The qualitative and quantitative project of the planned interventions, indicating the reasons that suggest them and the increases in resistance that are presumed to accompany them;
- In the graphic basis of the project, all the interventions (consolidations, plants, etc.) which by their nature involve substitutions or alterations of the original material and surface of the artifact must also be highlighted, in such a way as to make the extent of transformations consequent to the 'intervention.

It is essential that the testing itself is not limited to examining the so-called technical aspects, but rather addresses the intervention as a whole.

CHAPTER 5.

Seismic, Technical Observations on Parameters, Estimates and Methodology

5.1.0 Seismic risk assessment

All the technical conditions developed in different countries of the world, are designed in order to achieve three main objectives: firstly to avoid losses in human life, secondly to limit as much as possible the damage to ordinary buildings and thirdly to buildings of special importance to remain in the operational phase. In this chapter will be made a brief presentation of seismic risk in Albania and the changes that the latter has had over the years along with all regulations built to ensure structures from seismic risk.

5.1.1. Seismic risk in Albania

The seismicity of a certain region is determined by the size of earthquakes (magnitude, intensity, seismic moment, other dynamic parameters) as well as the frequency of their recurrence (period or frequency of their occurrence). Albania is part of the alpine-Mediterranean seismic belt, which includes the contact area between the lithosphere plates of Africa and Eurasia, which extends from the Azores to the eastern border of the Mediterranean basin. The most active part is the Aegean Sea and the surrounding region. In this region (33-43ºV, 18-30ºL), which is characterized by the fall of an earthquake with $M_s \geq 6.5$ with almost annual frequency, are: Greece, Albania, Montenegro, Macedonia, Southern Bulgaria and Western Turkey.

Albania is characterized by the activity of intense micro-earthquakes ($1.0 < M \leq 3.0$), small earthquakes ($3.0 < M \leq 5.0$) and medium ($5.0 < M \leq 7.0$) and only rarely by events with large earthquakes ($M > 7.0$). During the twentieth century, about 7% of the energy of shallow earthquakes was produced from autochthonous and aloktone5 seismic sources for the territory of Albania. The activity between the Adria Mountains and the Albanides is the main beneficiary of the seismic activity.

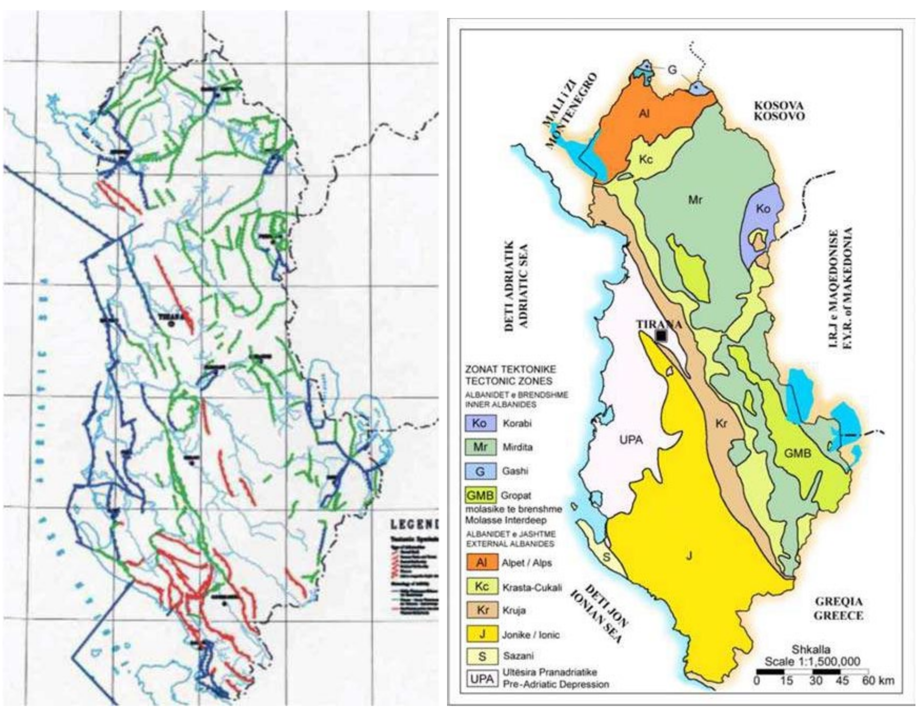


Figure 12. Map of tectonic faults on the left, tectonic map of Albania on the right (IGJEUM)

The old seismic map of Albania dates back to 1952 as a product of the work done by engineers and geologists of the Institute of Sciences and the Ministry of Construction of that period. Since then, the work for the most accurate seismic risk assessment of the land in our country has continued with numerous publications until now. The seismic zoning map that is still in force according to the technical design conditions dates back to 1979 (presented in figure.13).

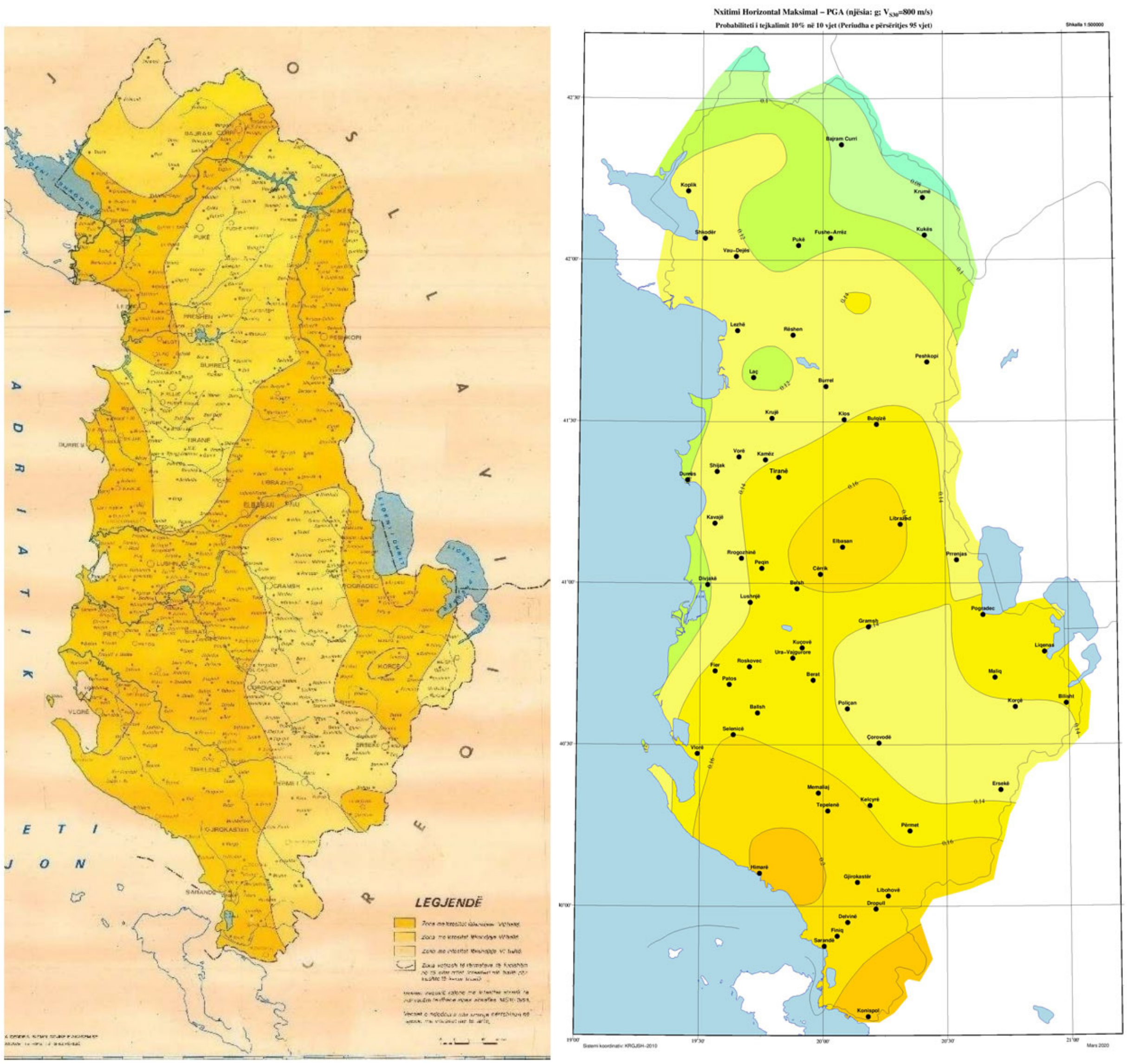


Figure 13. (a) Map of the current design code for seismic zoning of Albania, year 1979, (b) New seismic map, related to peak ground acceleration PGA recurrence period 95 years, return period 95 years, probability of exceeding 10%, Summarized and re-worked by the Institute of Geosciences (IGJEUM)

In another perspective the way design codes over the years have taken seismic operations into account has changed. Although the use of "elastic design spectra" for seismic analysis has existed in earlier design procedures in our country, the values and parameters have been much lower compared to today. In figures below are presented in the same coordinate system the spectra of KTP-N.2-78 (according to the seismic zoning map of 1963), KTP-N.2-1989 (according to the seismic map of 1978) and Eurocode 8, EN 1998-1 (according to the 2004 seismic map, which is not in force). The increase in the values of the spectral accelerations of different periods of the night is noticeable. If we compare today's seismic demand (for an area with ag = 0.25g) with that of 1978 for an area with intensity VIII front, we notice a large increase in spectral acceleration taken into account for low (stiff) buildings . If we refer to the Tirana area, this difference can go up to 10 times, as many studies today give ag values up to 0.25g, while the intensity on the map was "7-balle" in 1979 and "6-balle[9]" in map of 1963.

Taking into account the conservative view of the Eurocode for the Balkan area, and the impact of the November 2019 earthquake, engineers and specialists are drafting and updating the new map of seismic zoning of Albania.

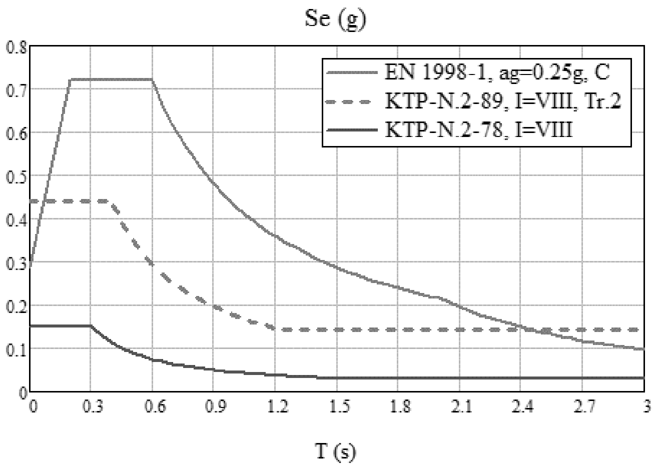


Figure 14. Comparison of elastic response spectra based on the seismic requirements of KTP-N.2-78, KTP-N.2-89 dhe EN 1998-1

5.1.2. Seismic action referring to current studies and methods according to Eurocode

In accordance with the two basic requirements of anti-seismic design, for ordinary buildings, seismic loading is taken as a function of two main moments or events of the life of an object:

- Design earthquake, for which the structure is calculated and detailed to meet the failure condition;
- Service earthquake, for which the structure is calculated and detailed to meet the damage limitation condition;

A design earthquake is an earthquake with a probability of occurrence once in 475 years, or an earthquake for which there is a 10% probability (probability) in 50 years of overcoming the level of damage to the failure structure of the structure. A service earthquake is an earthquake with a return period of once in 95 years, or an earthquake for which there is a 10% probability (probability) of occurring in 10 years.

[9] Balle – unit of measurement for seismic intensity of the area according to the Richter scale in the Albanian technical code

Seismic analysis for DCM[10] and DCH[11] is done with design spectra[12], which are dependent on the local ground conditions, the maximum ground acceleration obtained from the seismic maps (Figure.9). They are the same for both the non-demolition claim and the damage limitation claim. Horizontal seismic action is described by two orthogonal components (S_{dx}, S_{dy}), considered as independent and given through the same reaction spectrum .

$$0 \leq T \leq T_B : S_d(T) = a_g * S * [\frac{2}{3} + \frac{T}{T_B} * \left(\frac{2.5}{q} - \frac{2}{3}\right)] \qquad \text{(Eq. 10)}$$

$$T_B \leq T \leq T_C : S_d(T) = a_g * S * \frac{2.5}{q} \qquad \text{(Eq. 11)}$$

$$T_C \leq T \leq T_D : S_d(T) = \{ a_g * S * \frac{2.5}{q} * \left[\frac{T_C * T_D}{T}\right]$$
$$\{ \geq \beta * a_g \qquad \text{(Eq. 12)}$$

$$T_D \leq T \leq 4s : S_d(T) = \{ a_g * S * \frac{2.5}{q} * \left[\frac{T_C * T_D}{T^2}\right]$$
$$\{ \geq \beta * a_g \qquad \text{(Eq. 13)}$$

$S_d(T)$ - design spectrum
T - the period of oscillation of a system with a degree of freedom
a_g - The maximum ground acceleration, which also takes into account the safety factor, is taken from seismic maps.
TB - the lower limit of the period in the constant part of the spectrum
TC - the upper limit of the period in the constant part of the spectrum
TD - the value of the period where the displacement acceleration spectrum, the displacements are constant
S - factor that takes into account the ground
q - behavioral factor
β - lower limit value of the horizontal projection spectrum

Parameters S, TB, TC, TD are taken in tabular form and are in function of local land conditions. In EN 1998 Part 1, Section 3.2 more information can be found on how to classify land categories and the corresponding values of these parameters. In the Table.8 gives the values of the parameters used to construct the elastic spectrum[13] with 5% quenching traced in Figure.15.

[10] DCM - Ductility Class Medium for structural design according to Eurocode
[11] DCH - Ductility Class High for structural design according to Eurocode
[12] A response spectrum is a jagged plot of peak response of all possible SDOF(single degree of freedom) systems, and hence is a description of a particular ground motion
[13] The elastic spectrum with 5% quenching is expressed is obtained from expressions 3.10-3.13 but by replacing the behavior factor with 1. More data can be obtained in Section 3.2.2.2 of EN 1998 Part 1

Table 8. Elastic spectrum parameters according to EN1998-1 for categories of lines Type 1: A,B,C,D,E

a_g/g	Spectrum type	Ground type	S	T_B (s)	T_C (s)	T_D (s)
0.22	1	A	1.0	0.15	0.4	2.0
		B	1.2	0.15	0.5	2.0
		C	1.15	0.20	0.6	2.0
		D	1.35	0.20	0.8	2.0
		E	1.4	0.15	0.5	2.0

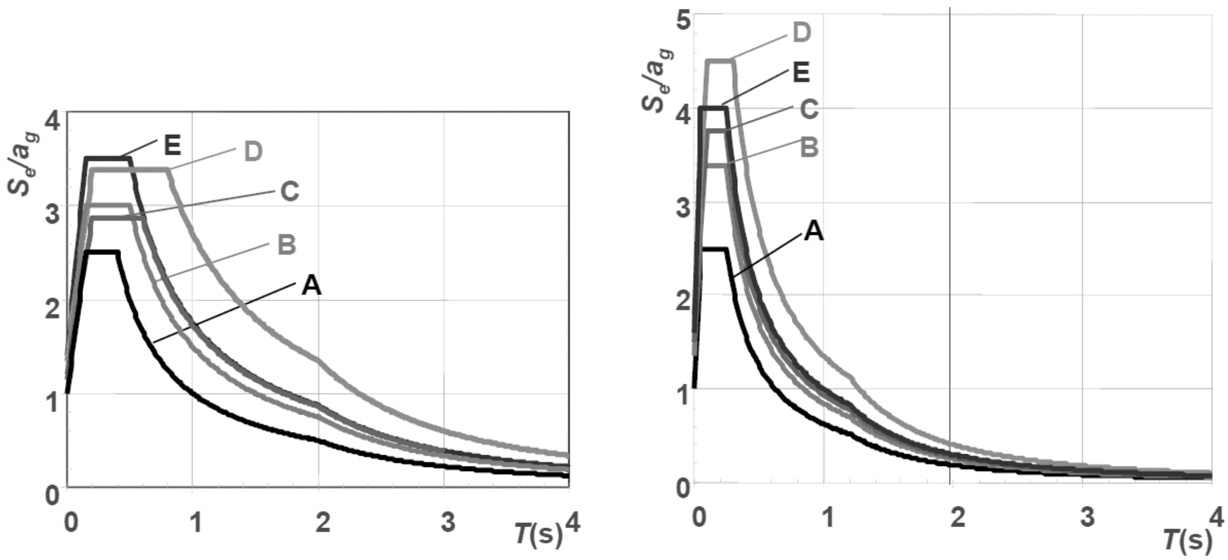


Figure 15. Recommended elastic response spectra according to Eurocode-8

The vertical component of seismic action is given analogously to the horizontal component, depending on the type of spectrum. The effects of the vertical component should be considered in the case where the vertical component of the maximum ground acceleration is greater than 0.25g. More about the shape and parameters used to evaluate the vertical component of seismic action can be found in Section 3.2.2.3 of EN 1998-1.

5.1.3. Seismic loads combination

According to EN 1990, for each of the load schemes, the design value of the actions and forces (Ed) is determined by the combination of those loads that are considered to occur at the same time. Thus for permanent and temporary loads we have (the first combination of loads):

Ed = E { $\gamma_{G.j}$ G_{kj}; $\gamma_{Q.1}$, $Q_{k.1.}$; $\gamma_{Q.j}$. $\psi_{0.j}$ $Q_{k.j.}$ } $j\geq1$; $i\geq1$ (Eq. 14)

E_d - the value of the design foci
$G_{k,j}$ - permanent loads

$Q_{k,1}$ - temporary predominant load
$Q_{k,j}$ - temporary loads
A_{Ed} - seismic load
γG - partial coefficient of permanent loads
γQ - partial coefficient of temporary loads
ψ_0 - temporary load combination factor for the first load combination
ψ_2 - temporary load combination factor for seismic load combination

5.2. Two significant Earthquakes that have influenced structures and architecture in Albania, to be considered for the study

"Earthquake of April 15, 1979", area between the city of Shkodra and Ulcinj

One of the most significant and damaging seismic events in the region of Albania was the strong earthquake of April 15, 1979. Among various engineering works in Albania, the earthquake also hit new buildings with brick masonry supporting structure, or of reinforced concrete built in accordance with the design conditions of the time (KTP-1963). This includes 5-storey buildings with unreinforced masonry Structures, which according to KTP-1963" should not show seismic problems.

One of the most affected cities was Shkodra, where in a considerable number of typical masonry buildings, typical diagonal damages and cracks were formed, but also masonry out of plan. Especially the two and three-story buildings, also the private villas in the region suffered corner damage and roof damage. These effects have appeared on the upper floors where the wall displacements are greater while the pressure stress that could serve as opposition is at a lower value .

5.2.1 Analysis and assessments on strong seismic events and the Earthquake of November 26, 2021 in Albania

The diagram below shows a summary of parameters and data on the accelerations of the 5 strongest seismic events captured by the Institute of Seismology in Albania, including the moderate seismic event of 2019. In the left part of the diagrams are given evaluation parameters of a seismic event, specifically "earthquake acceleration, quake velocity, ground displacement, arias intensity and housner intensity". While the diagram summarized on the right contains in the form of diagrams the comparisons of the 5 strongest seismic events recorded in the Albanian territory since 1978. Above on the right is the diagram "amplitude-frequency oscillation", while on the bottom right, is the summary of elastic-spectrum process of these seismic events, specifically "spectral acceleration-periods". This summary gives us a more complete information of the seismic risks of the Albanian land and the risk of these buildings for the future.

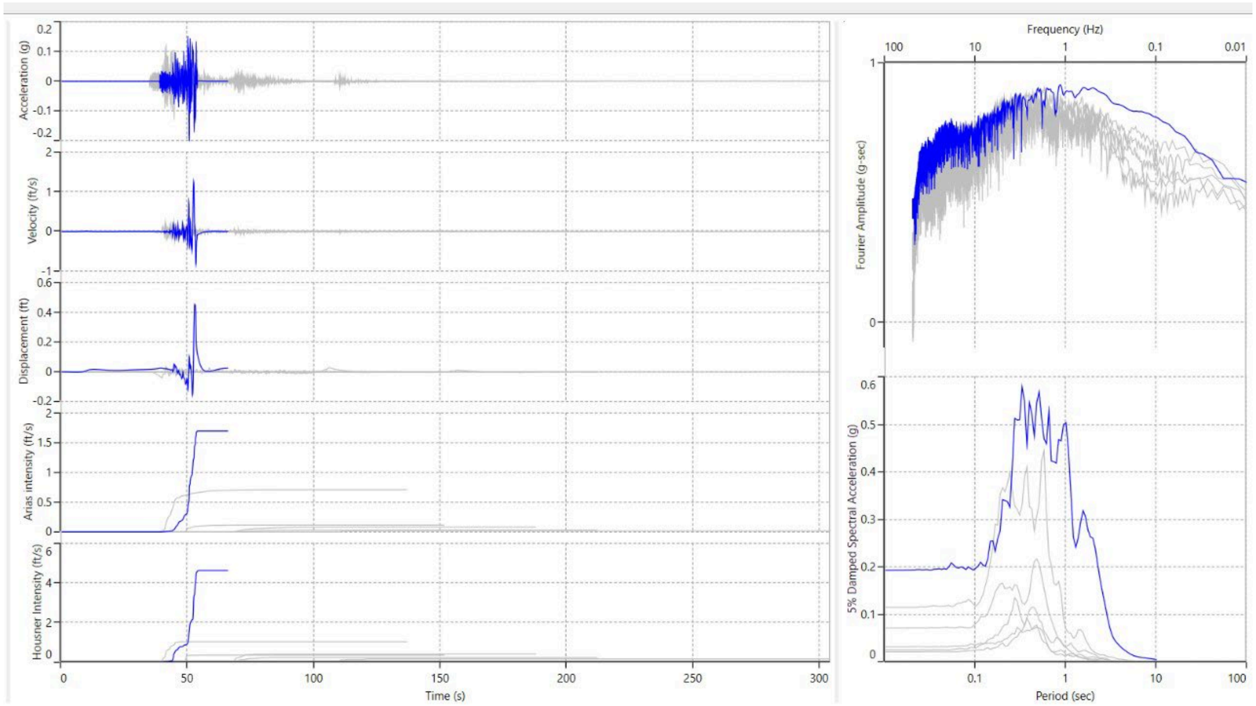


Figure 16. Summary diagram developed by the institute of seismology, after the seismic events of 2019 (Source: IGJEUM)

Regarding the 6.4 Mw earthquake that occurred near the Durrës area, which is positioned near the west coast of Albania in the Adriatic Sea, can be considered small compared to the design earthquake parameters, which is currently used in technical design conditions of Albania, however caused a quantity large damage to buildings, structural damage, collapse and non-reparable structural damages, as well as damage to non-structural elements, mainly partition walls and perimeter "infills". Fifty-one people died, about 3,000 were injured and between 5,000 and 14,000 people were left homeless after this seismic event.

5.2.2 Details of the seismic event of November 26, 2019 in Albania

The strong earthquake with a magnitude of 6.4 Mw in Albania, occurred exactly two months after the other two earthquakes considered moderate. The quake event started at 03:56 in the morning of November 26, 2019, emphasizing in addition to the damages mentioned above, causing severely damaged over two thousand buildings in the cities of Durres, Tirana and the surrounding area. The epicenter was reported below the Adriatic coast, 7 km north of the coastal city of Durres and about 30 km west of Tirana, the capital of Albania. (Figure.17)

Figure 17. Quake M6.4 affected area and the lines distribution of shakes intensity (Charleson & Vesho, 2020)

Based on archival research and review of a group of studies in this field, detailed information was found on the intensity of earthquakes, the geology of the basement and the effects of soft soil ground in the affected region of Durres-Tirana, also, the types of building structures and the extent of geotechnical liquefaction (Lekkas 2019). The authors of the seismic engineering field have also identified that Tirana and Durres are located in a seismically active area, near the tectonic fault of the Adriatic and above the continental fault, which passes between Durres-Tirana and has been almost completely destroyed by earthquakes, at least seven times before. in 177 BC, years 334 or 345 AC, 506, 1273, 1279, 1869 and 1870. Also, as mentioned above, a moderate event "earthquake with Mw 5.6", in the same vicinity on September 21, 2019, damaged about 500 buildings in the Tirana-Durres area.

This study had the opportunity to gather useful data on these events, as it went through these events a good phase of field research. Another report, also of a preliminary nature, contains information on the history of local building codes and construction and design approaches, the occurrence of aftershocks in a given period and the seismic performance of building types, including schools, hospitals, cultural heritage buildings and civil houses (Alam 2019).

Regarding the characteristics of earthquake oscillations, so far only two response spectra are available (Figure below), (Geo.edu.al, 2020). They were taken from two accelerations recorded in Tirana, 30 km from Durrës and then processed and summarized in a diagram. Unfortunately, an accelerometer in Durrës stopped recording after 15 seconds of oscillation, after problems with electricity, but the 'reconstructed' spectra are fortunately ready to be analyzed, and to be put to use seismic simulations. Due to its smaller epicenter distance and greater amplification from the soft soils of this area, the Durrës spectrum exhibits higher spectral accelerations and over a longer period interval. The duration of the strong shakes in Tirana was approximately 40 seconds, about four times longer than the most considered moderate earthquake with Mw 5.6 of September 2019.

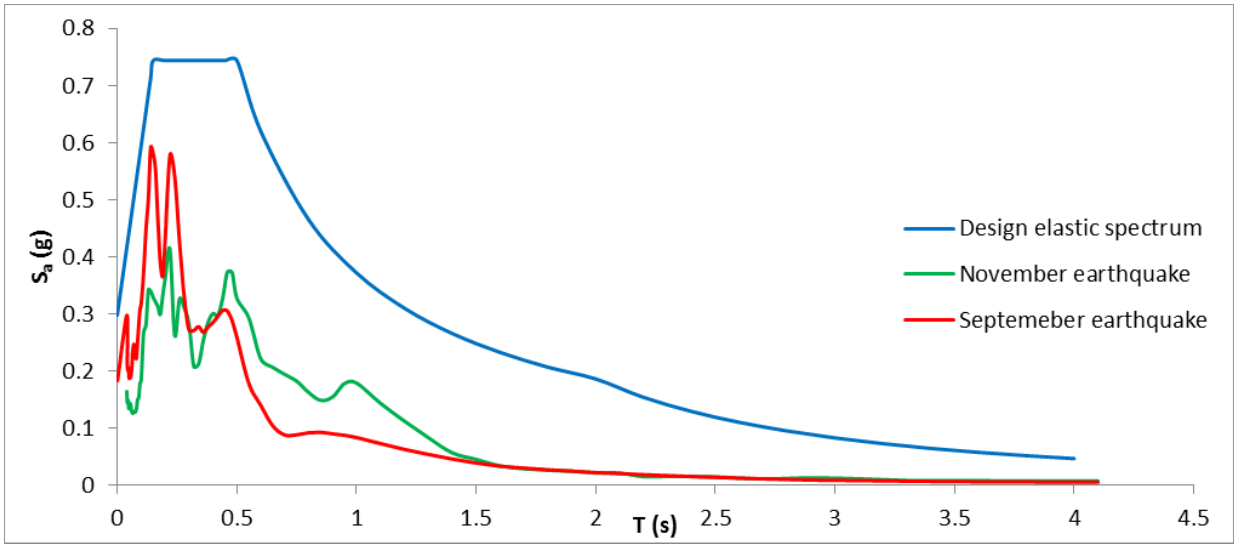


Figure 18. Two response spectra from Tirana re-worked and compared to the current design code elastic spectrum (Charleson & Vesho, 2020)

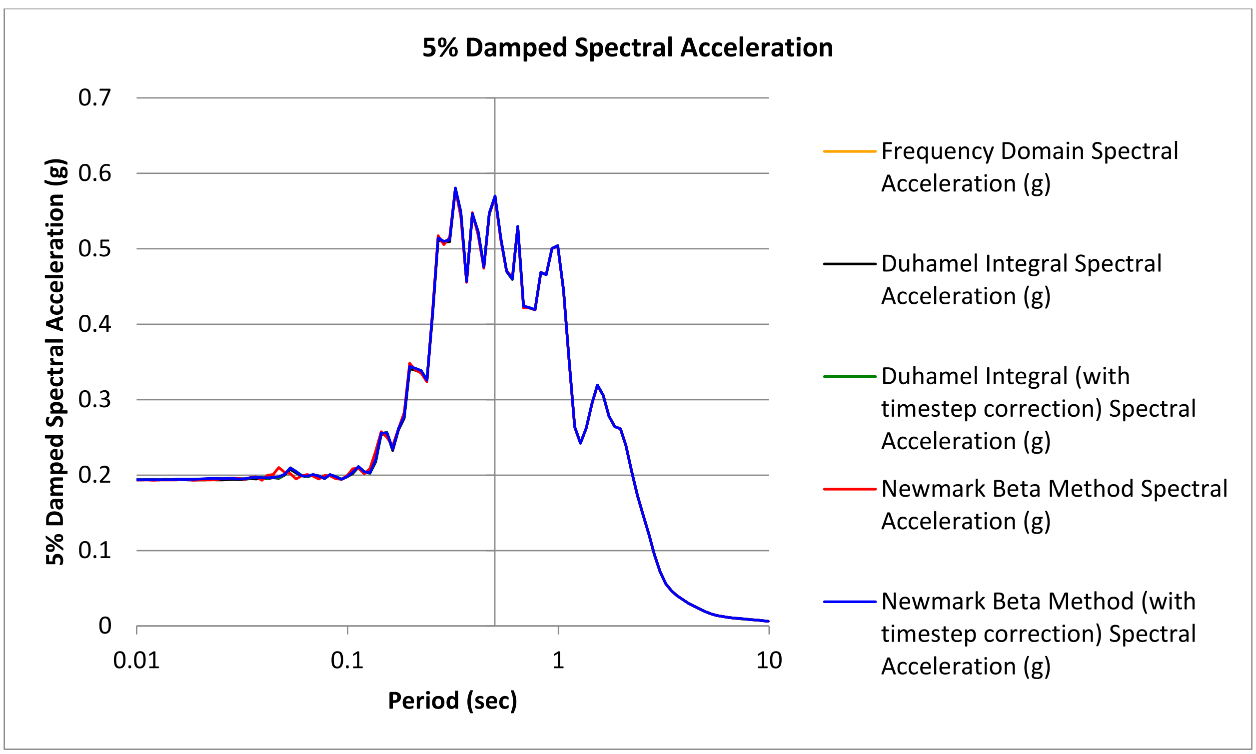


Figure 19. Data related to M.6.4 Durres earthquake spectra, 5% damped spectral acceleration – period (Source: IGJEUM/ Graphically processed by author)

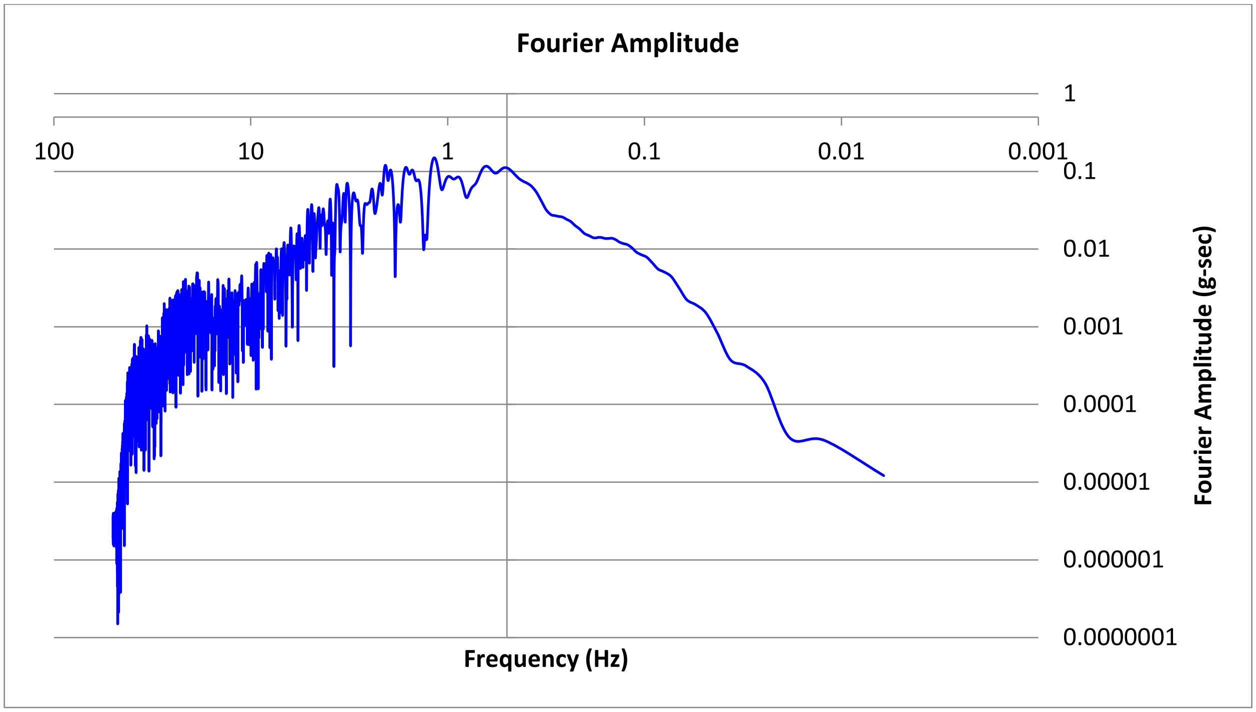


Figure 20. Data related to M.6.4 Durres earthquake fourier amlitude based on frequency and amplitude (Source: IGJEUM)

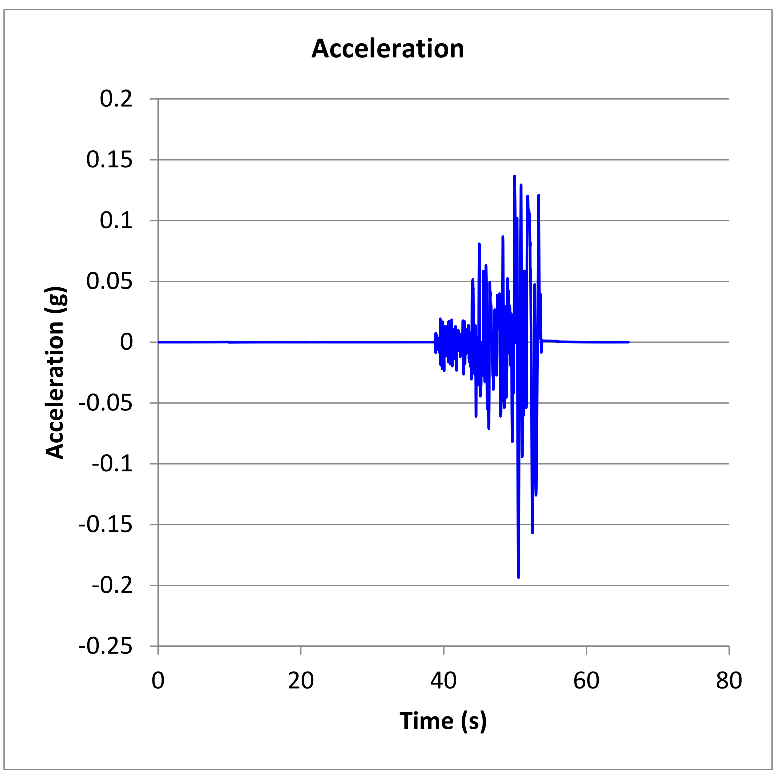


Figure 21. Data related to M.6.4 Durres earthquake acceleration recorded (Source: IGJEUM)

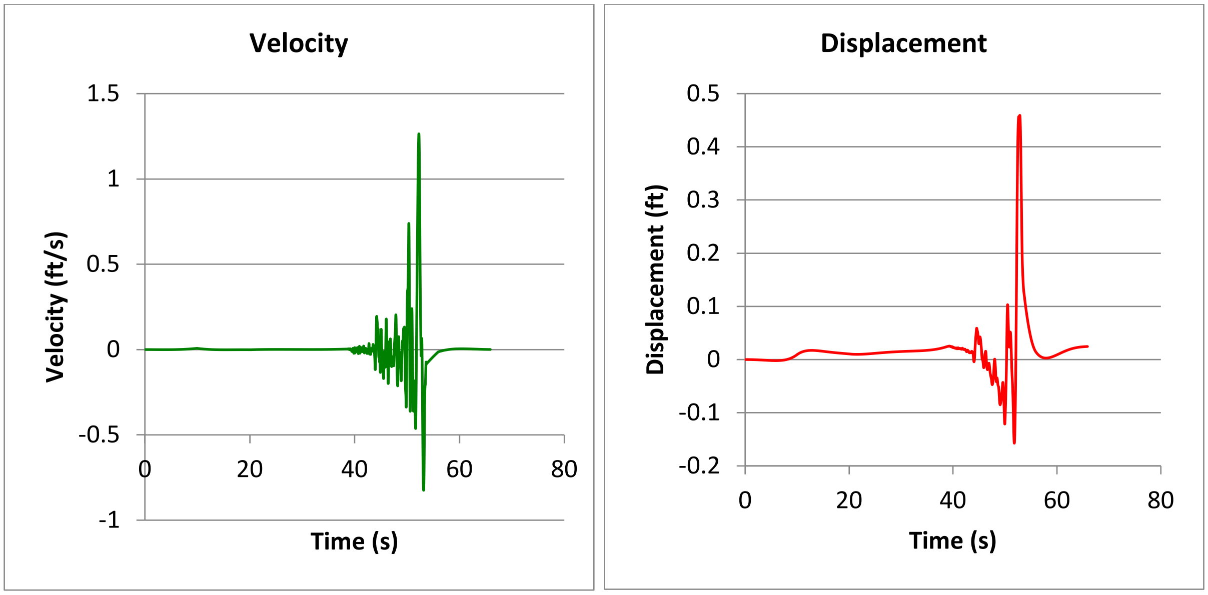


Figure 22. Data related to M.6.4 Durres earthquake Velocity and Displacement recorded (IGJEUM)

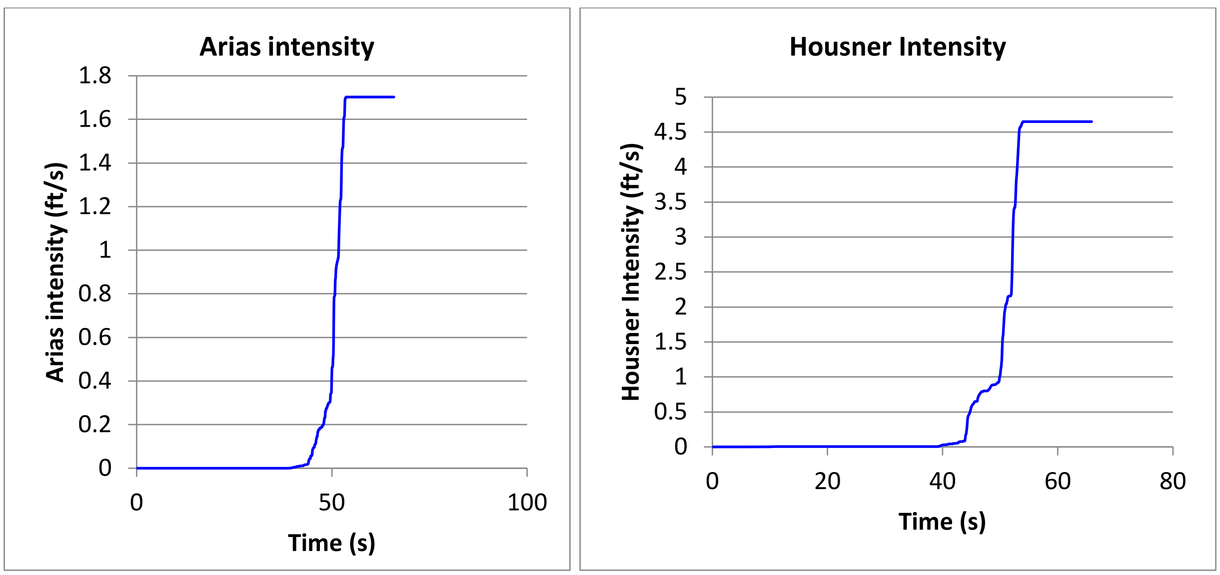


Figure 23. Data related to M.6.4 Durres earthquake Velocity and Displacement recorded (IGJEUM)

5.3.0 Theoretical interpretations on the impact of earthquakes and seismic risk on masonry structures, regarding the practice of design codes in Albania

An earthquake is a vibration of the basement under foundation, which conveys these to the object and causes displacement, velocity and acceleration in the object under consideration.

Masonry buildings occupy a significant place in Albanian construction. They were built in different time periods from 1900-1990. These typologies, designed before the 1990s constitute most of the residential buildings, which are designed in accordance with the technical design codes [KTP - 63, 1963, KTP - 78, 1978; KTP - 89, 1989], and after the 1990s consist of 2 or 3 floors, which were built mainly by private investors for residential purposes. Also these typologies of buildings are used as institutions, historic objects or businesses. Most of these structures are built based on traditional construction techniques, codes of neighboring countries "Italian, Greek, also the Russian code", some of them without genuine engineering projects based on design codes.

5.3.1 Seismic risks affecting the safety of masonry buildings

Seismic activity in countries like Albania is one of the main risks for buildings , this was shown also by the earthquake of November 2019. It is proven that seismic events are the main factor that affects the dimensioning of structural elements sections, therefore should be given an importance of great design and retrofit of these structures. Seismicity is represented by the elastic design spectrum, that according to the Albanian standard KTP - N2-89, which is still in force, many structures with masonry are designed. To build these spectra diagrams, such parameters have been used to represent the seismic risk in most of the territory of Albania .

In the current post-earthquake situation of 2019, the main structural damages of this typology are from seismic horizontal loads. For a structure to resist this force, it is necessary to have ductile behavior to absorb and extinguish seismic energy. In reinforced concrete buildings this ductility is gained by steel bars. Related to masonry structures we do not have proper ductile elements, so they are more vulnerable at this kind of seismic risk. They are capable of withstanding low, medium and moderate earthquakes due to the great stiffness of the large working section. Also their global ductility is ensured by the gradual detachment near the mortar joints with the bricks, in the most stressed areas.

The old Albanian design codes do not provide sufficient measures for the seismic safety of these buildings. This situation becomes even more serious when we consider the degradation over the years, additions, functional adaptations and structural interventions. For these reasons these structures do not agree the utilization requirements and the new Design Codes. It is about "Eurocodes", specifically part-6, which reflects a high level of knowledge in the field of Structural Engineering with masonry design, or Eurocode part-8 which deals specifically with the part of seismic engineering, retrofit interventions and relevant parameters.

Seismic design of structures according to Eurocodes, summarized in Eurocode 8 is more advanced compared to the code based on the Technical Design Conditions (KTP) of Albania. The last update of KTPs was made in 1989 with the approval of KTP - N.2-89 (Academy of Sciences, Ministry of Construction, 1989). On the other hand, many existing buildings were realized before this year, based on even older design codes, considering also uses of Russian and Italian codes. Structures designed with previous codes have suffered severe damage due to insufficient capacity to withstand seismic load and limited ductility . In the post-2019 period, the situation is being analyzed and work is being done through the associations of engineers to include the procedures of seismic evaluation of the existing structures and their rehabilitation in the Design Code, moreover, some aspects of the more advanced codes are being analyzed like the "Performance levels of the buildings according to ATC-40[14], FEMA-440[15] and FEMA-356[16]".

14 Seismic evaluation and retrofit of concrete buildings
15 Improvement of Nonlinear Static Seismic Analysis Procedures
16 Prestandard and. Commentary for the Seismic Rehabilitation of. Buildings

One of the most important challenges for designers remains the assessment of the seismic capacity of existing buildings, seismic performance and the assessment of their response under a strong ground motion.

Consideration of nonlinear procedures in country codes, such as "ATC - 40, 1996; FEMA - 356, 2000; FEMA - 440, 2005; N2-Method, 1996[17]; Eurocode 8.3[18]", which have been widely developed over the decades last, are the approaches to achieve this target. Using nonlinear analysis, it is possible to predict the capacity of the structure more accurately and realistically through the shape of the capacity curve. These results should be used to notify the competent authorities of the risk of a strong earthquake expected in the future.

5.3.2 Seismic events and movements of the basement

Seismic force is caused by the movement of the ground due to the earthquake, which is a movement in all directions but in calculation this movement, and consequently the seismic force, is taken in three directions: two horizontal and one vertical. In this way, for each element of a building structure, the calculated value of the factor that arises due to the action of the earthquake, the maximum value is taken from them:

$$S_{eq} = S_{eq,x} + \lambda S_{eq,y} + \lambda S_{eq,z}$$
$$S_{eq} = \lambda S_{eq,x} + S_{eq,y} + \lambda S_{eq,z}$$
$$S_{eq} = \lambda S_{eq,x} + \lambda S_{eq,y} + S_{eq,z} \qquad \text{(Eq. 15)}$$

$S_{eq,x}$, $S_{eq,y}$ - are the values of the factor arising from the calculation of the construction separately to the horizontal components of the ground;
$S_{eq,z}$ - the value of the factor resulting from the calculation of the seismic vertical component.

5.3.3 Combination of loads

Seismic loads are treated as separate loads and are included in the calculation of structures and foundations of engineering projects according to the specific combination of loads. In this study the load coefficients considered under consideration based on the design code are given in Table.9:

Table 9. Combination values related to load types

Load types	Specific combination coefficient values
Seismic loads	1.0
Dead loads	0.9
Live loads with long action	0.8
Temporary loads with short action	0.4

In the design and calculation phase of structures against seismic actions, the following parameters is not taken into account:

[17] A relatively simple nonlinear method for the seismic performance evaluation of structures
[18] Assessment and retrofitting of buildings

• Wind loads;
• Climatic temperature estimates;
• Dynamic actions caused by specific machinery or machines;
• Braking forces caused by the movement of cranes;
• Horizontal loads caused by the movement of suspended masses in the cable;
• Reductions (eruptions) of foundations.

We can emphasize that these parameters above can be analyzed through various unfavorable combinations suggested by Eurocode, technical design code of Albania or Italian code.

5.4. Calculation methods

The design and calculation of building structures and engineering projects against seismic actions is performed through:

- Seismic modal analysis with the response spectrum method (seismic loads are accepted as equivalent static loads and applied at the site of concentrated masses) [19];
- Use of direct dynamic analysis (This is done through the integration of equations of motion of the structure), choosing computational accelerograms, based on studies of seismicity of the construction site and its geomorphological and geotechnical features[20].

These calculation methods should be interpreted and analyzed in the Albanian design context in the period 1920-1940. Theoretically, a general research should be done on the beginning of anti-seismic design and construction technology in Albania. We can distinguish three periods of anti-seismic projections in Albania:

- Before 1963 when seismic requirements were very low or absent at all;
- Period from 1963 to 1990 with low seismic requirements;
- Period after 1990 where seismic requirements are based on KTP-N.2-1989, which based on what we said above, despite being more developed than the previous codes, again they can be considered insufficient for the level of risk seismic in our country.

So, we can say that at the time these buildings were designed and implemented, in Albania they were designed taking not into account advanced seismic aspects or simply not based on code. But normally they have withstood the test of time and have successfully passed many strong and moderate seismic events and happenings. This leads us to analyze that Italian designers have used good principles of anti-seismic design, carefully studying the configuration of buildings, regularity in plan and height, as well as equal distribution of masses.

5.4.1 The equivalent frame Method

For newly built structures, or for structures where the floor strips are not very rigid, an "elastic" check must be carried out, assimilating the wall to a framed system. The method involves a

[19] Modal analysis is the study of the dynamic parameters of systems in the frequency domain aspect.
[20] The direct steady-state dynamic analysis procedure can consider a perturbation procedure, where the solution is obtained by linearization about the current base state. For the calculation of the base the structure may exhibit material properties and geometrical nonlinear behavior as well as contact non-linearities.

macro-element modeling of masonry buildings: a flat model if we consider only one wall, three-dimensional if we consider the entire building.

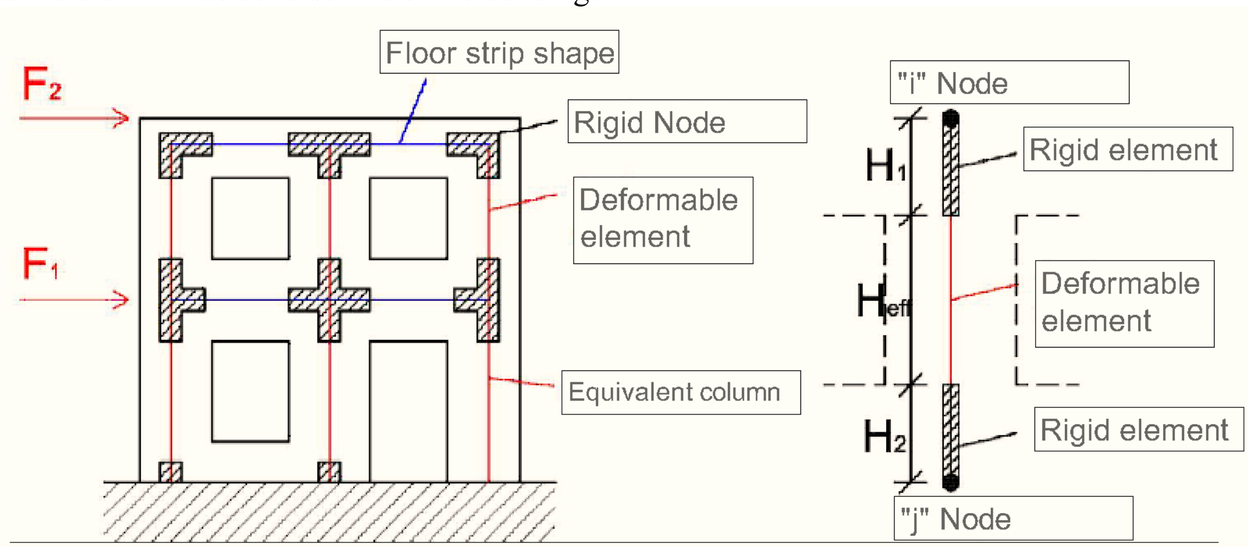


Figure 24. Equivalent frame method model and elements

In this numerical-physical representation the structure is schematized as an equivalent frame, consisting of:

- vertical axis elements: ordinary or reinforced masonry panels, pillars or partitions in reinforced concrete;
- elements with horizontal axis: coupling beams, floor strips, reinforced concrete curbs.

This schematization is acceptable if the geometry of the walls and the distribution of the openings presented there are characterized by a certain regularity, in particular as regards the alignment of the openings. Each frame element, with vertical or horizontal development, can be represented as a "one-dimensional" element by means of its main barycentric axis and is delimited by nodes usually positioned at the intersections of this with the barycentric axes of the elements to which that element is connected. The introduction of infinitely rigid sections (rigid offsets), of suitable dimensions at the ends of the elements (columns, curb and / or strips), allows to model the reduced deformability of the masonry fields delimited by the openings in the wall (structural nodes).

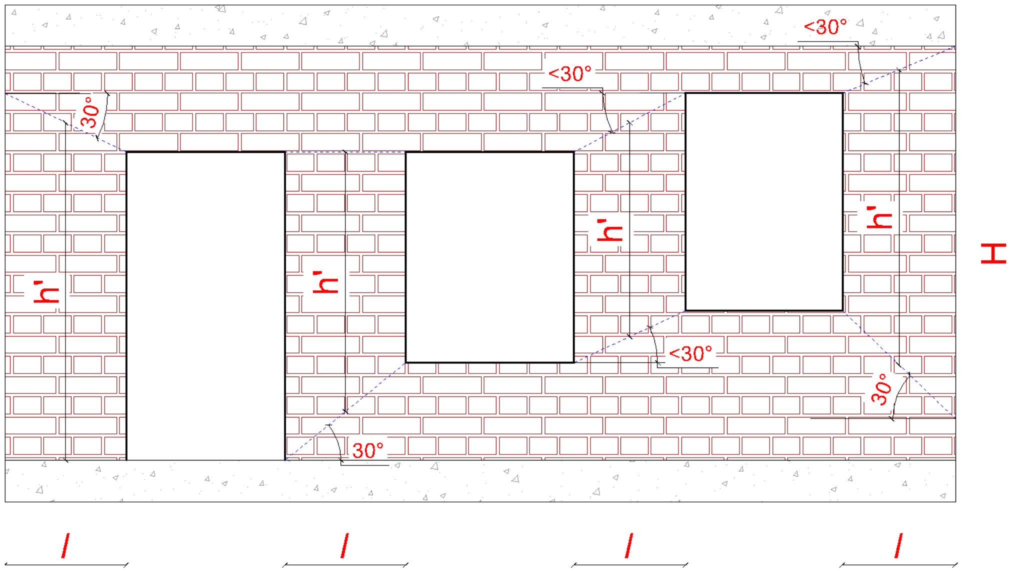


Figure 25. Experimental model with openings (Dolce, 1989/ Graphically processed by author)

The height of the deformable part, or effective height of the H_{eff}, must be defined in such a way as to roughly take into account the deformability of the masonry in the knot areas; it can be evaluated on the basis of the following relationship, as a function of the geometric dimensions of the panel and of the openings (Dolce, 1989):

$$H_{eff} = h + \frac{1*(H-h`)}{3*h`} \leq H \qquad \text{(Eq. 16)}$$

L - is the length of the panel;
H - Net length of the height of the cross;
h' - is a conventional height parameter defined on the basis of the cases shown in the figure

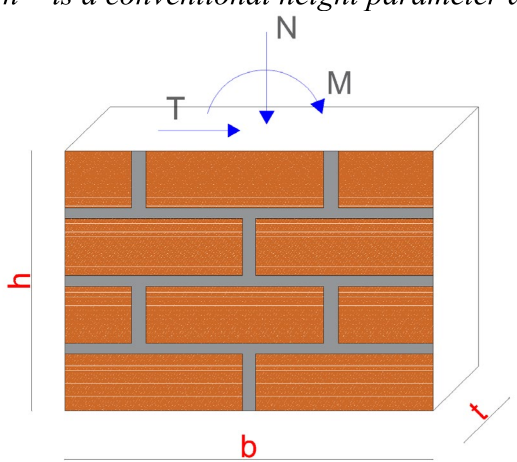


Figure 26. The panel under the action of static actions N,T,M

Once the elastic analysis has been carried out on the spatial framed system of the structure, subject to a distribution of horizontal forces (seismic or wind), each masonry pillar is subject to N, M, T actions. In addition to the checks on the masonry walls, the floor strips must also be checked.

5.4.2 Masonry calculation models and typologies

It is a well-known fact that structures with structural masonry were used and applied tens of centuries ago, the problem of mathematical modeling is still a major problem even today. Whereas if we do a research on materials such as concrete, steel and reinforcement which have been used in construction for only a century, there are formulas and models which with high precision calculate and predict the physico-mechanical behavior of reinforced concrete or steel structures.

The main problems in the configuration of the masonry model, are in the great variety of filler elements of the masonry, mortar and brand of mortar which is used, as well as the used construction techniques, as well as the technological level of production and construction. Therefore, the bearing capacity of the masonry depends on the qualities of the element / stone, mortar and the cooperation of these two elements.

Even the structure of masonry as a whole, as the assembly of elements in the individual aspect, presents a non-homogeneous and anisotropic structure, which makes it difficult to calculate and of course the conception of the physical model.

The two general modeling approaches: "micro-modeling and macro-modeling"

In the scientific literature, the problem of modeling masonry buildings is faced by following two different approaches, known as micro-modeling and macro-modeling.

In micro-modeling, a description is made of the individual materials making up the masonry, blocks and mortar joints, using different constitutive models. Usually this approach is pursued using the finite element method. By its nature, this technique is able to describe heterogeneous structural systems with complex geometry, but it requires such a high number of degrees of freedom in defining the model that micro-modeling is practically inapplicable in the study of real structural systems. Its use is almost exclusively limited to the validation of simplified modeling techniques.

In macro-modeling, it is not necessary to describe the constitutive bonds of the single component materials but macro-elements are used that are able to grasp the global behavior of entire structural portions such as masonry walls, lintels and node panels. The single macro-element must therefore describe all the possible inelastic mechanisms typical of masonry walls making use of a few constitutive parameters and a reduced number of degrees of freedom. This approach makes it possible to drastically simplify the description of buildings and to contain the calculation times necessary for the structural analysis. On the other hand, however, it presents the difficulty of being able to formulate an analytical model capable of taking into account all aspects of the non-linear behavior of an entire portion of a masonry building through a single structural element.

Mainly mathematical and numerical models are divided into two groups:

- "Macro-model" – models where the wall is considered as homogeneous
- "Micro-model" – are those models, where the wall panel is examined as a combination of elements (brick/stone), mortar, as well as the adhesion between them. The second

method is more accurate but requires software as well as powerful hardware, which are greatly complicated and loaded with increasing the size of the structure and this happens after the mesh configuration.

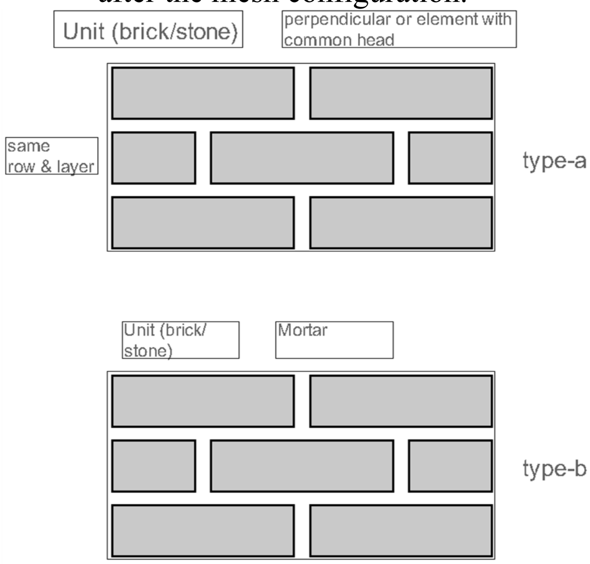


Figure 27. Type-a & b of computational models of micro-modeling and macro-modeling

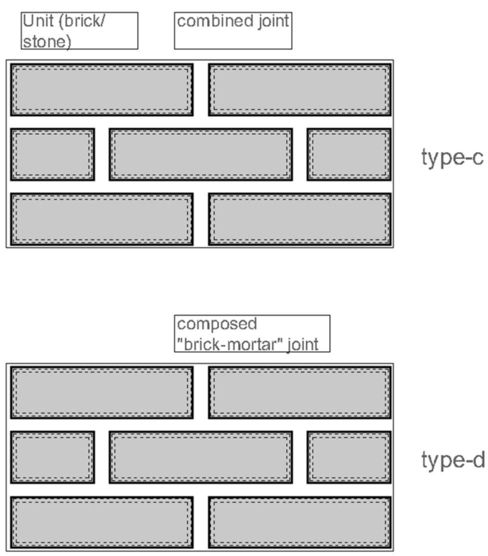


Figure 28. Type-c & d of computational models of micro-modeling and macro-modeling

Despite this, the macrostructure-based models, with the approximations made, show acceptable and logical results for many cases in engineering practice.

Necessary parameters for macrostructure are obtained either on the basis of experimental results or even by micromodeling of a relative area.
Types of general models to be adopted in softwares for masonry structures. The possible models are as follows below:

- Shell: the masonry structural elements are discretized using the finite element technique and modeled as elastic two-dimensional shells. This modeling can only be used to perform elastic analyzes while obviously it is not suitable for conducting push-over analyzes;

- Members: the structural system is modeled using the equivalent frame SAM method[21]. A non-linear structural model is thus obtained to be used for push-over analyzes;
- Macro-elements: the entire structural masonry system is initially discretized through a mesh of the type used in the finite element method. Each single element of the mesh is then modeled as a macro-element. A non-linear model of the structural system is thus obtained on which to conduct push-over analyzes.

5.4.3 The definition of "Resistant mechanism" of a shear (or bracing) wall

The model presented and explained above, considered with equivalent elements can be further elaborated, giving the way of work of each element in particular. The following are defined:

- *strut panels* between two windows, which work floor by floor in parallel;
- floor strip/shape - the continuous strip between the upper and lower windows of each floor, icluding all horizontal elements.

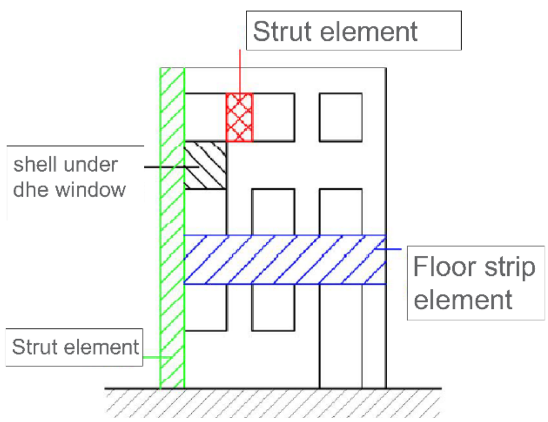


Figure 29. The model that represent the resistant mechanism of shear

If the shear wall has a sufficiently rigid floor strip, such as to guarantee the parallel functioning of the masonry elements, it is possible to identify at each level a resistant mechanism in which the elementary cell is the inter-floor. In these hypotheses, analyzing the single "cell" it can generally be observed that the collapse occurs due to the rupture of the Strutt panel with a mechanism characterized by the formation of plastic hinges in them.

[21] The Successive Approximation Model (SAM) is a simplified Model designed specifically to elicit feedback and build different working and calculating models

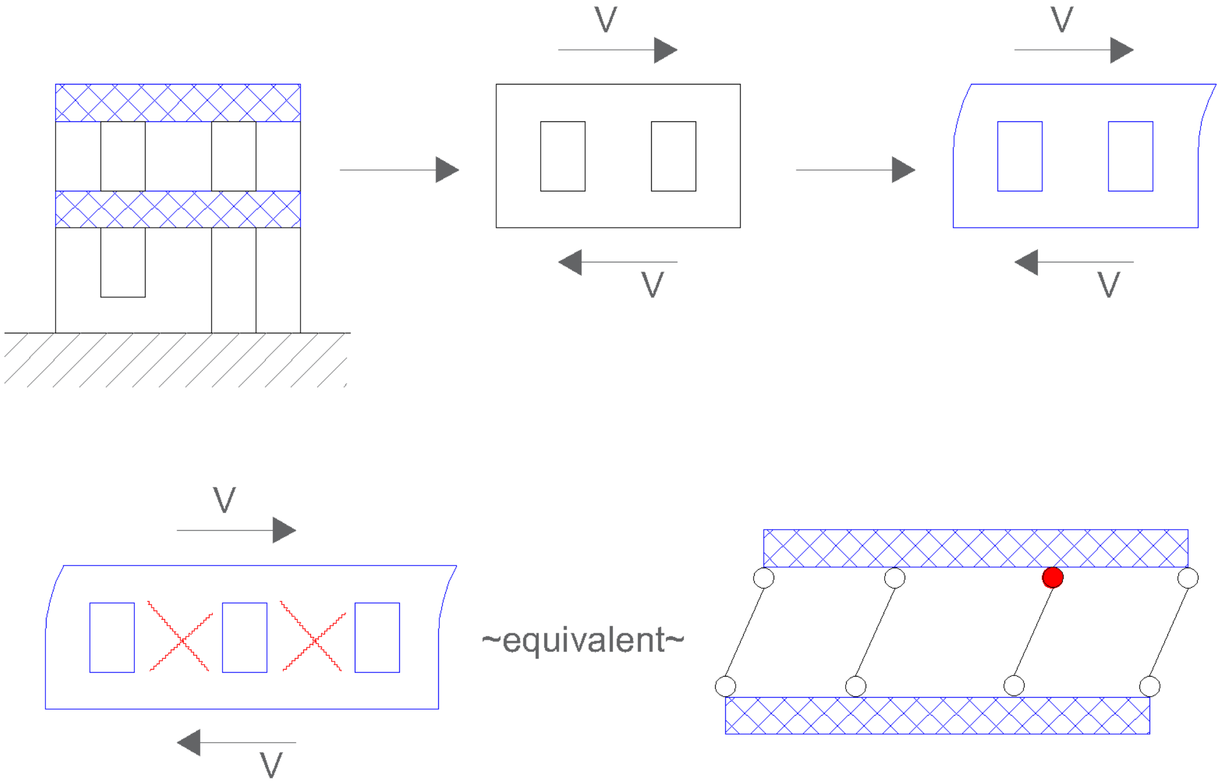


Figure 30. The stages that the resistance model goes through until deformation, and how it is conceived in static aspects

In this case, each Strutt panel is subjected to a stress state (shear stress) comparable to that reproduced in a diagonal test, therefore the criteria seen above can be applied. The collapse of the wall is reached when the first Strutt wall is broken.

5.4.4 Technical behaviors of unreinforced masonry structures

Unreinforced masonry structures normally consist on massive foundations, unreinforced walls, orthogonal piers and timber slab or thin concrete slab, working as a diaphragms, connected to walls with structural diaphragm. Unreinforced masonry walls are typically stiff structural elements, also can be categorized at the in plane and out of plane panels depending on the directions of earthquake motion events regarding to the plane axis of the walls. Wall panels oriented parallel to the motion direction of the earthquakes are known in plane panels, and panels perpendicular to in plane walls are defined as the out of plane walls.

Unreinforced masonry has been shown during the time to perform poorly behind the earthquakes events. There are some number of common details and technical aspects of unreinforced masonry constructions that have been identified as the deficient ones. The common mechanisms of collapse or failure are mainly sub-divided into two categories as below:

- In plane panels – Masonry wall panels subjected to in plane horizontal kind of loads may fail in one, two or three different ways. First by sliding horizontally, second in flexure, or third in shear stress. The mode of failure is influenced by many factors such as wall ratio aspects, axial compressions stress different levels, wall boundary conditions, physico-mechanical parameters and the strength properties of the materials used in the wall panel construction. These types of failure are shown diagrammatically in the figure below.

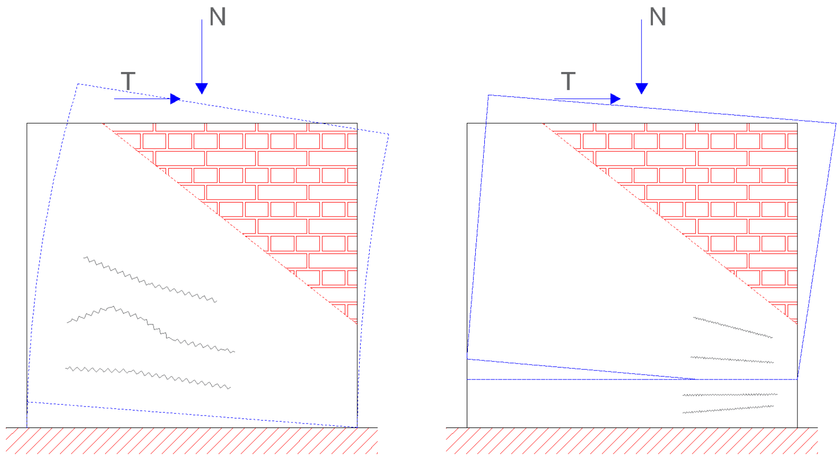


Figure 31. Failure shapes regarding in plane loaded masonry panel, first panel in flexure and second panel in rocking

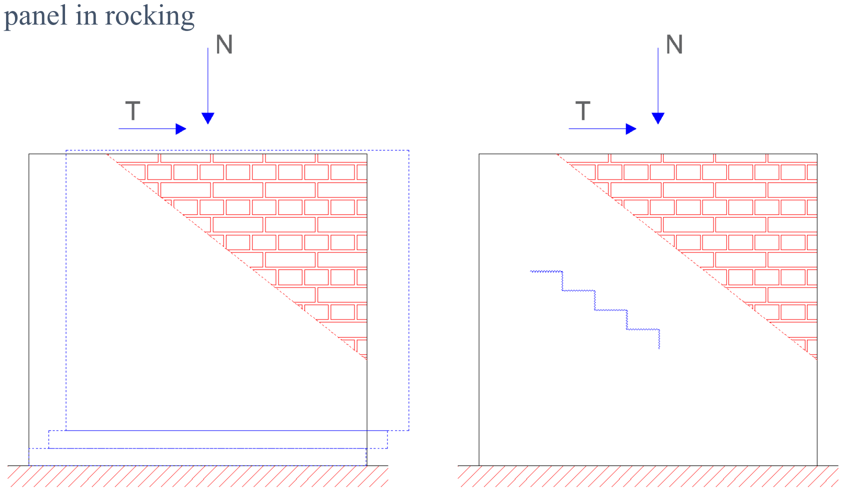


Figure 32. Failure shapes regarding in plane loaded panel, first in Sliding & second in diagonal shear stress

- Out of plane mechanisms – These kind of mechanisms occur mainly with out of plane kinematics of one or more wall panels of the selected unreinforced masonry structure causing the loss of its own original structural configuration at the expense of large seismic events excitation. The arising of out of plane failure or collapse mechanisms, mainly resulted according to bad connection between the wall panels of the façade and the orthogonal panels .

Based on the failure or collapse mechanism of masonry walls, the common failure modes of unreinforced masonry structures ca be summarized as follow below:

- Story shear mechanisms related to upper storeys;
- Story shear mechanisms related to lower storeys;
- Whole wall panel overturning;
- Partially wall panel overturning;
- Gable wall panel overturning;

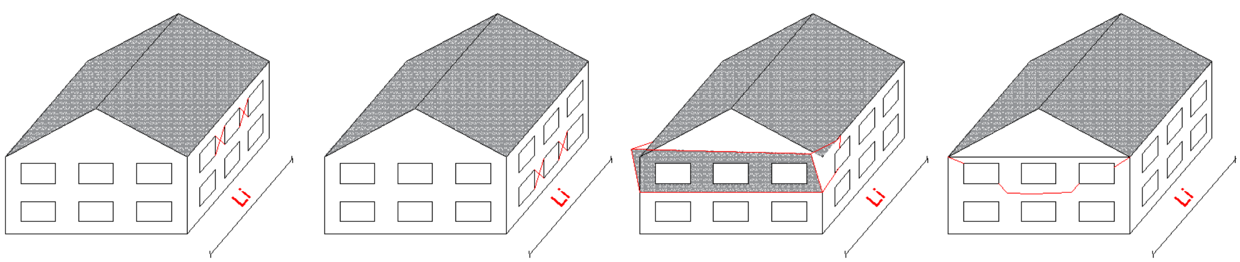
- Vertically instability of wall panel.

The story shear-mechanisms related to upper storeys – This kind of failure mechanisms as shown in the figure below is normally caused according to variations in the resistance system at the upper floors, for example variations in the wall thickness or the presence of poor quality masonry panel. This kind of failure mechanisms is also caused by the presence of heavy rigid roofs.

Story shear mechanisms related to lower storeys – This kind of failure mechanism that is showed also in the figure below with diagonal shear cracks of in plane panels positioned at the lower storeys. This is mainly caused by the small resistance area in 1 or 2 directions for example for high percentage of openings in the façade or small thickness of the walls panel located at lower storeys of the structure.

The whole wall panel overturning – This kind of failure mechanisms is mainly caused by lack of connections between orthogonal walls panel or ties elements or ring beams as will be shown at the figure below. This is also caused an resulted by large distance between walls panel and the thrusting roof panel at the top accompanied with lack of connection between wall and roof.

Partial wall overturning – This kind of failure mechanisms is mainly caused by the following "reasons large distance between panels", thrusting roof and lack of connections between wall and roof panel, also high percentage of the openings creating potential regions and areas for cracks and deformations on the panel.



(a). (b). (c). (d).

Figure 33. (a) Failure mechanism of Storey shear located on Upper storey, (b) Failure mechaninsm related to Storey shear, (c) the failure mechanisms of whole wall overturning, (d) the failure mechanisms related to partial wall overturning.

The Gable wall overturning type – This kind of failure mechanisms consists on overturning of the gable wall as shown in the figure below and is generally caused by the presence of heavy roofs with pushing in transversal elements into the gable walls panel. Another reason could be in good connections between the orthogonal walls panel, but the lack of connections or the ties element or the ring beams of the building in the top.

The vertical instability of wall panel - This kind of mechanism is mainly caused by the presence of ring beams in breach of the masonry to the double wall thickness as shown in Fig. below. Also the contributing factors could be in very poor quality of masonry panel and presence of intermediate heavy floors with very poor embedment to the wall panels.

According to studies is reported that the out of plane mechanisms (complete failure and partial failure wall panel overturning's, gable wall overturning's failure, vertical instability failure) can happen more frequently related to the high level of global damage aspects of the structures than the in plane collapse mechanisms including storey shears stress. Also, better vulnerability assessments proper cares and in site researches are needed for out of plane analyzing and strengthening of unreinforced masonry walls.

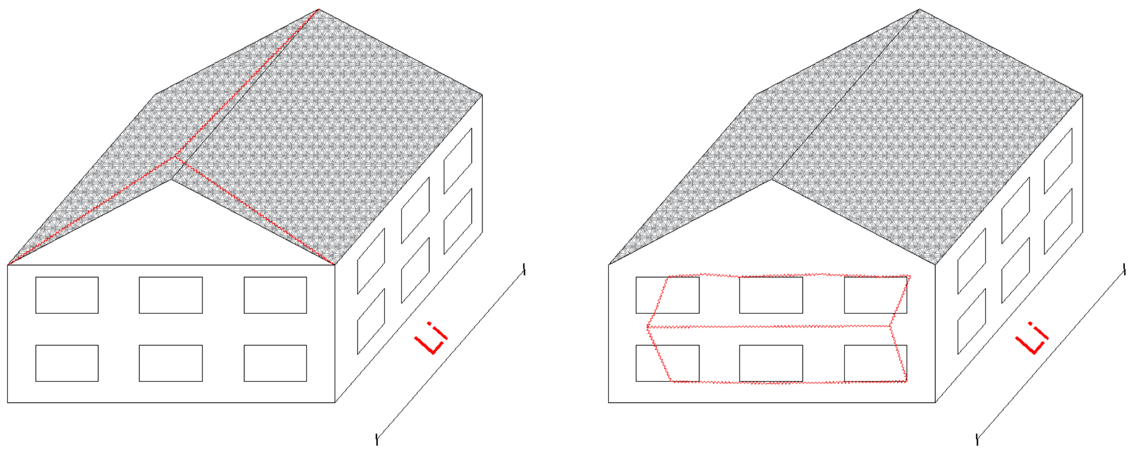


Figure 34. Gable wall overturning failure mechanisms and the Vertical instability failure mechanisms of the wall.

5.4.5 Theoretical Interpretations on Pushover Nonlinear static procedures

After creating the computational model in the software, we perform nonlinear static analysis (Pushover). Although the Pushover and Time History analysis is based on this method, the purpose of this Restoration topic is limited to in-depth aspects of seismic engineering and does not attempt to describe it theoretically, and will therefore be limited to a few general aspects. like below:

Pushover analysis of a structure, is a nonlinear static analysis under the constant action of vertical loads, and almost static horizontal loads that gradually increase until the destruction of the structure. The calculation model includes not only the detailing of the dimensions and properties of the structural and non-structural elements as in the paragraph above, but also defines the permanent and temporary vertical loads as well as the almost static horizontal load. The latter, which represents seismic action, increases gradually and is taken concentrated at floor level. From this analysis, we obtain the Pushover curve which expresses the dependence of the shear force on the structure, with the displacement at its apex. This gives us the opportunity to judge the load for which the collapse occurs as well as the level of ductility possessed by the structure.

5.4.6 Determining the performance point of the structure related to nonlinear procedure

To interpret the results obtained from non-linear pushover analyzes, the Capacity Spectrum Method is commonly used. This method uses the intersection of the global force-based displacement curve at the top, as well as the response spectrum, representing the spectral demand for earthquakes, to estimate the maximum displacement demand of the structure or to give its performance point.

After obtaining the capacity curve for the multi-degree system from nonlinear static analysis, the procedure followed to determine the performance point[22] for a seismic demand level is somewhat different from the conventional methods widely known in the literature and involves the following steps:

- Transformation of the Pushover curve into ADRS format, i.e. obtaining the capacity curve;
- Idealization of the capacity curve;
- Discretizing the idealized capacity curve and defining a suitable system with a degree of freedom for inelastic spectrum analysis;
- Inelastic spectrum calculation;
- Determining the point of performance.

[22] The Performance Point, which represents the state of maximum inelastic capacity of the structure, is found through the cross point of the Capacity Spectrum and Demand Spectrum for a given damping ratio.

CHAPTER 6.

Case Studies – Experimental Part

6.1. CASE 1 - General overview of the Municipality of Tirana building, part of Cultural Heritage. *Architectural identification, survey process and structural evaluation*

The Skanderbeg square complex consisted of three pairs of buildings, designed between 1929 and 1932 by the Roman rooftop architect Florestano Di Fausto & Gherardo Bosio. Initially, the project for the square included four other buildings on the north side, forming a circular exedra, however only one was built, the old Town Hall, which was demolished in the 1960s to make way for the National Museum. Next to the Ethem Beu mosque stood the Ministry of Economy and Education, opposite the Ministry of Foreign Affairs and Presidency.

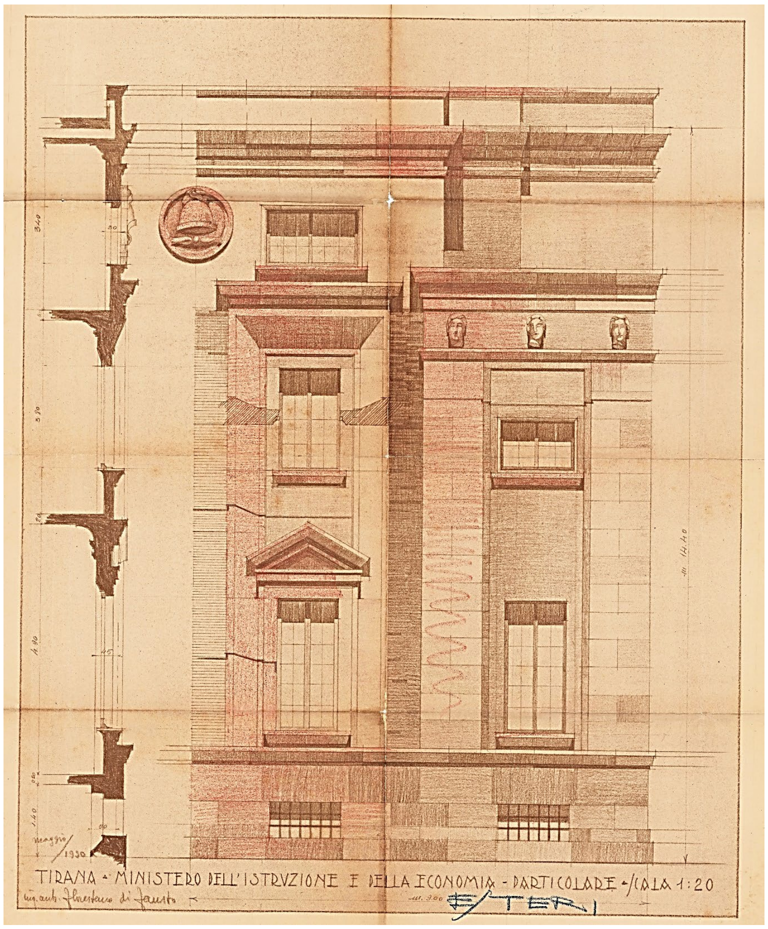


Figure 35. Municipality of Tirana original drawings of F. Di Fausto 29' project-idea (Source: AQTN)

These twin buildings had a "C" shape geometry with the entrances at an angle, connected by circular exedras. All the lift systems were positioned on the diagonal axes passing through the entrances, preserving a perfect symmetry of the plan. The load-bearing structure was of a mixed type: reinforced concrete frame and load-bearing masonry, a constructive solution that allowed for large rooms with free light, such as the ballroom on the rear side of the square, and at the same time to preserve the characters of the typical massiveness of the masonry, present on the entire external curtain of the building. The main facade of the wall surface is very rich, the numerous layers of the wall surface treated with different materials (stone, brick and plaster) accentuate the vertical sections of the façade, marked by stone columns between, which the openings are framed .

It's a formal repertoire that favors the wall surfaces on which loggias are recessed or from which volumes project, in which the compositional operations focus on the theme of the complex rhythm of the façade .

The buildings that housed the Ministry of Public Works and the Ministry of the Interior closed off Skanderbeg square, on the south side, inclined at 45 ° with respect to the monumental axis, these buildings served as scenographic backdrops to frame the monumental axis that was lost on the horizon. The buildings had many decorative details, stylish arch-beams around the windows and valuable architectural sculptures on their facades. Normally giving the Italian architectural style of the period 1919-1938.

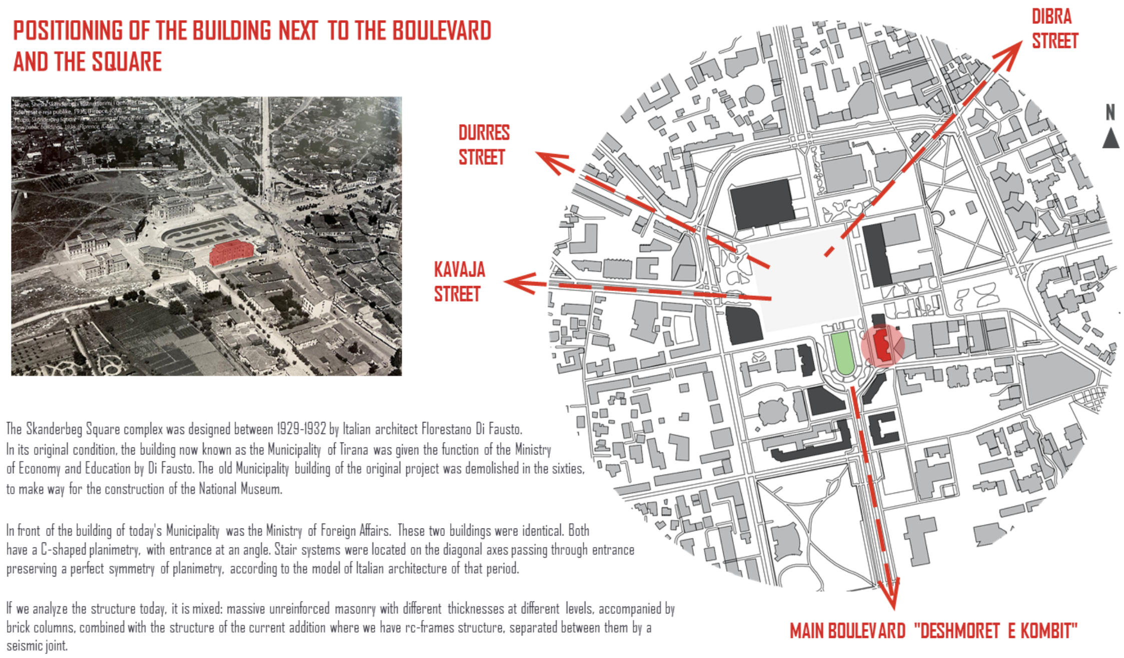


Figure 36. On the left, an old archive photo which shows the works on the construction of the Di Fausto building near Skenderbej Square, on the right an identification scheme of cultural heritage objects near the center.

Even this pair of twin buildings, like the whole complex of the square, were designed by Florestano Di Fausto between 1929 and 1932 and built by the Staccioli company, with which the architect had already worked in the Dodecanese. The architectural plastic of the façade is particularly articulated, on the bottom plane of the masonry the different scores, progressively projecting, stand out, framing the windows, the moldings that frame squares that could also have been enriched by pictorial cycles, the contained overhangs of the balconies, the shelves in cement stone, the teeth and the different profiles of the frames, but also the ashlars of the base part with respect to the joints and so on. In the full-bodied tones of the plasters, the light creates those chiaroscuro effects that distinguish the designs of Italian architects from those of Northern Europe. The buildings were perfectly symmetrical, with the monumental entrance on the central axis and then a longitudinal body concluded with a 45 ° rotation of the last part, in such a way as to manage the funnel of the square in connection with the other buildings.

These two buildings have also undergone changes over the years, both of a distributive type and of elevation and expansion, in particular the addition of a floor has made the central tripartite rooftop disappear.

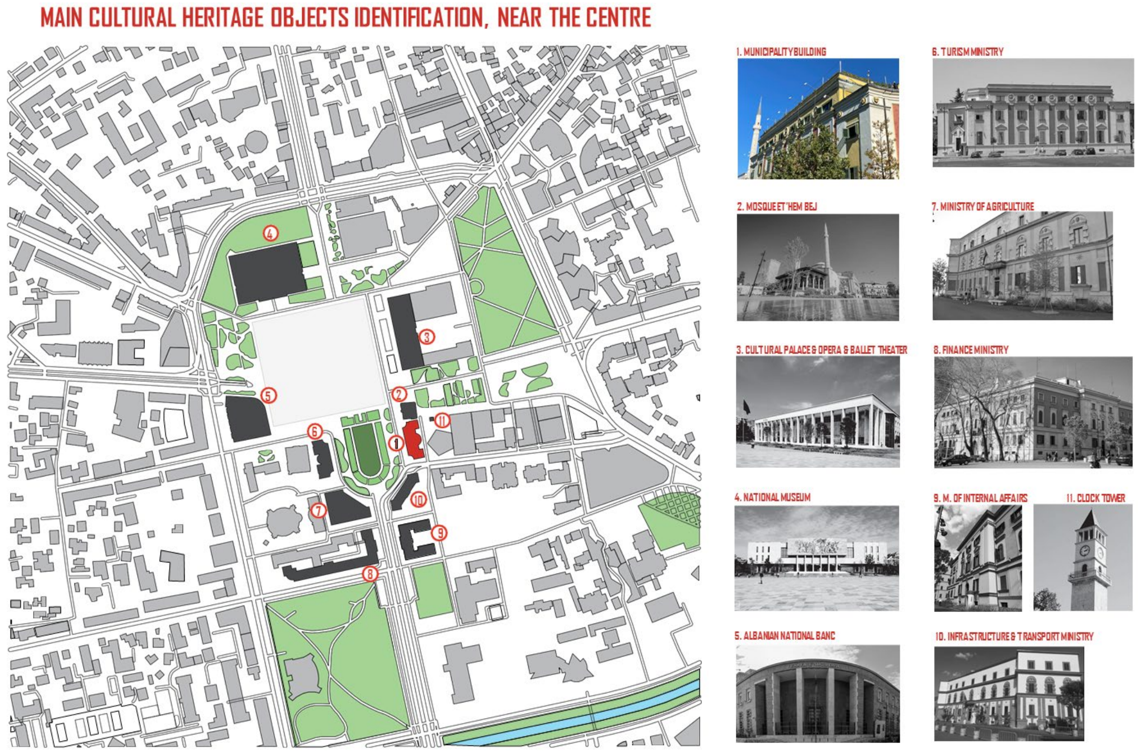


Figure 37. An identification diagram of cultural heritage objects near the center combined by photo collage for each monument

It should be mentioned and underlined that the structural intervention of 2004 and the addition in the back of the structure, may be the one that has left the most traces in the body of the building designed by Di Fausto. To show in more detail graphically and geometrically, what the transition, or transformation, was like before and after this period, at the end, in the study annexes there is a timeline with all the drawing sheets of the project step by step summarized.

6.1.1 Collection of data

The knowledge of the building for which an investigation and analysis is planned is the first operation to be performed.

The immediately visible and detectable information are those of a geometric nature and those relating to the surfaces. To these must be added the historical and documentary information, including those transmitted orally, and, deepening more and more, the knowledge of materials and their physico-mechanical parameters, textures, masonry equipment, mortar parameters, historical evolution and the state of conservation, just to name a few aspects. All these data subsequently require a contextual and coordinated examination, so that the hypotheses for the research and analysis are the result of an organic operation that does not leave out any of the available data, not even the apparently most irrelevant ones.

6.1.2. Architectural syrvey process and monitoring on-site

The research on-site was organised during the accademic year 2020-2021, led by the academic staff of the Cultural Heritage Restoration course, also included students of Architecture and Civil Engineering, fourth year, as a cooperation between Polis University, institute of cultural heritage and PhD program. The field work consisted of comparing the planimetry of the archival project with the real building of the Tirana Municipality today. The object was photographed with a drone from different angles and positions, to have a set of orthogonal photos for the photogrammetry process. Looking very carefully at the differences found between the current building today and the archival project according to the idea of Florestano di Fausto, such as a different number of doors and windows, the position of the decorative elements on the façade, changes in geometric shapes, changes in the positions of the interior walls, etc. Laser measurements were performed to give the proper dimensions that the building has today. In this report from the research on-site, the objects are presented and compared, coming up with some findings, such as noting the geometric differences in plan and height, between the real project and the cuts taken in the archives that we had available, some detailed photos , and some interesting issues to be analyzed were noticed.

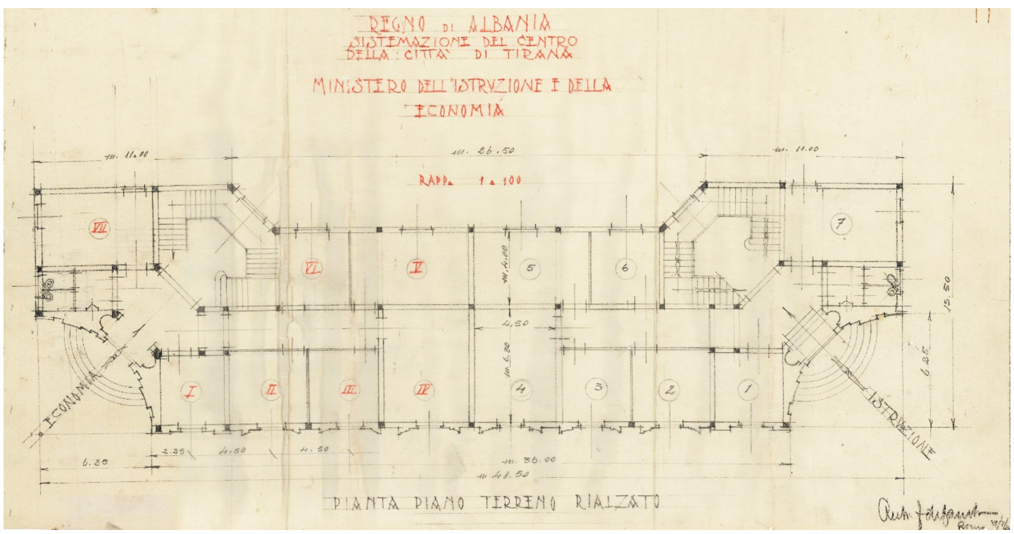


Figure 38. Basement floor according to F. Di Fausto idea, 1929 project-idea (Source: AQTN)

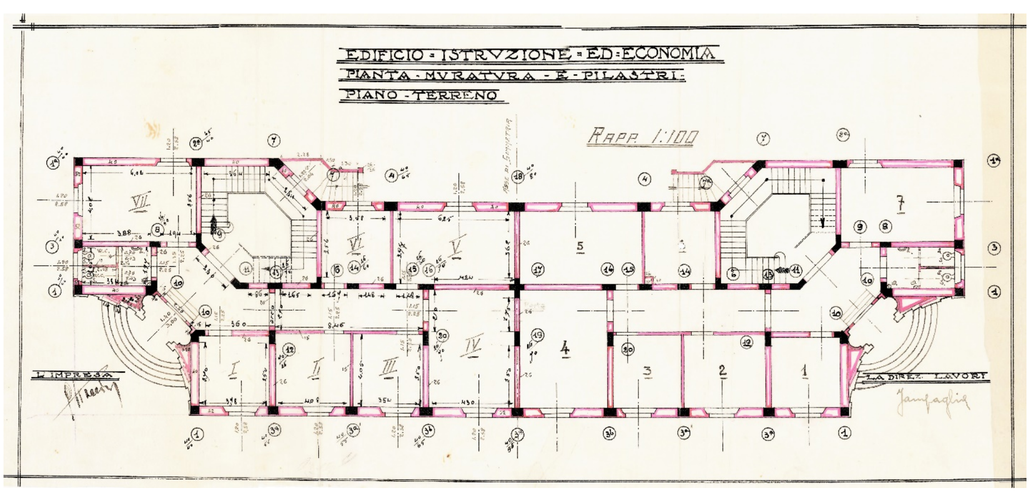
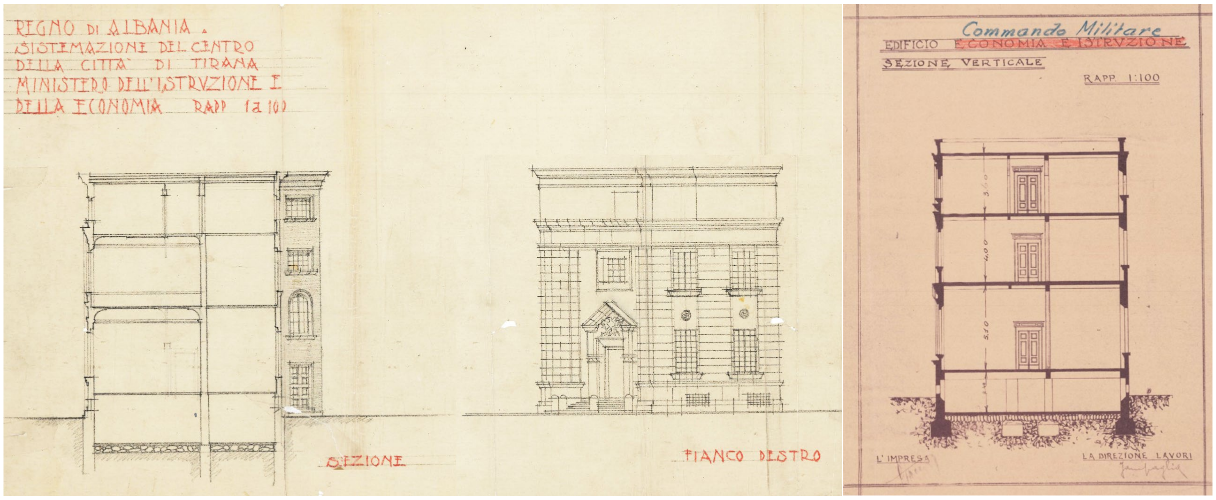


Figure 39. Ground floor according to F. Di Fausto idea, 1929 project-idea (Source: AQTN)



(a) (b) (c)

Figure 40. (a), (b) Section cut and the south façade behind, from the “F. De Fausto projcet idea 1929”, (c) Section cut from the implementing project 1941 (Source: AQTN)

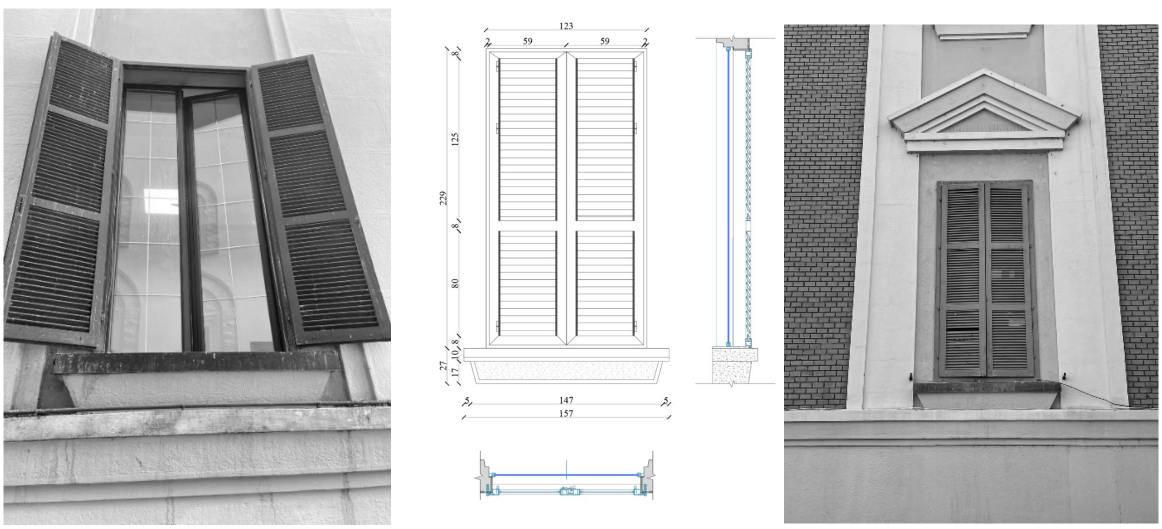


Figure 41. Architectural survey of two typical windos on the main façade, digitalization process

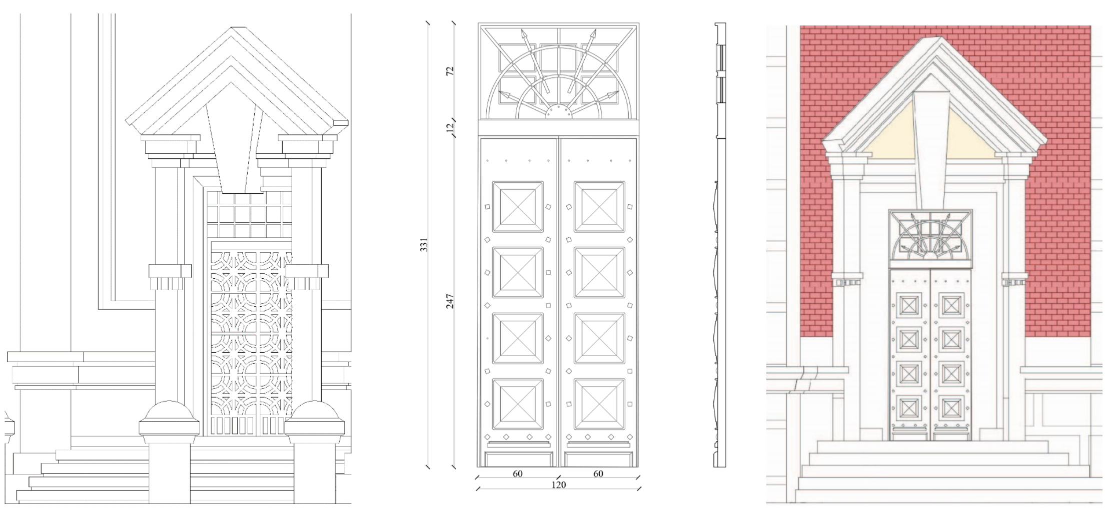


Figure 42. Architectural survey of the two main doors of the main façade, digitalization process

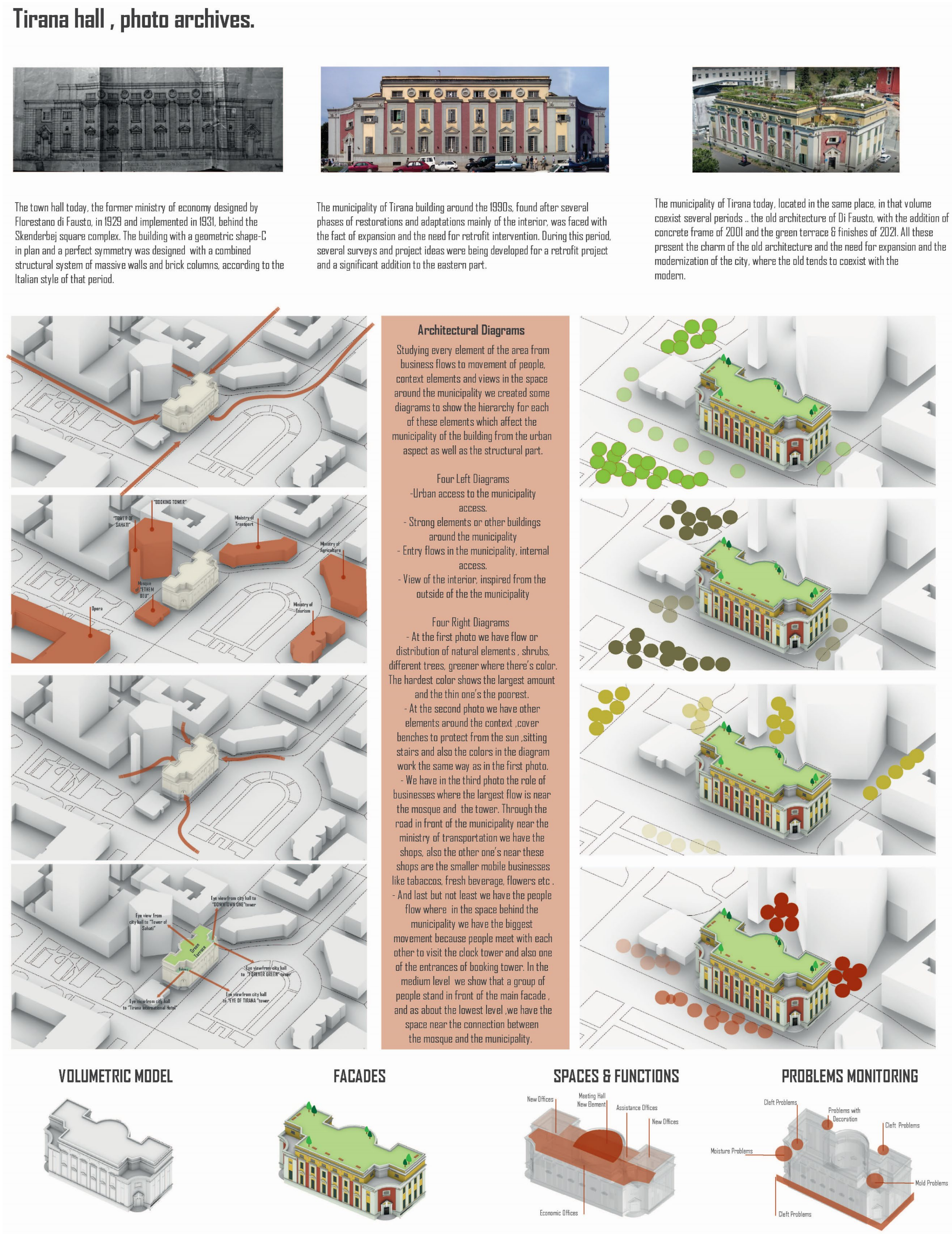


Figure 43. Municipality of Tirana analytics and architectural diagrams (credits D. Gjuraj & A. Kapaj)

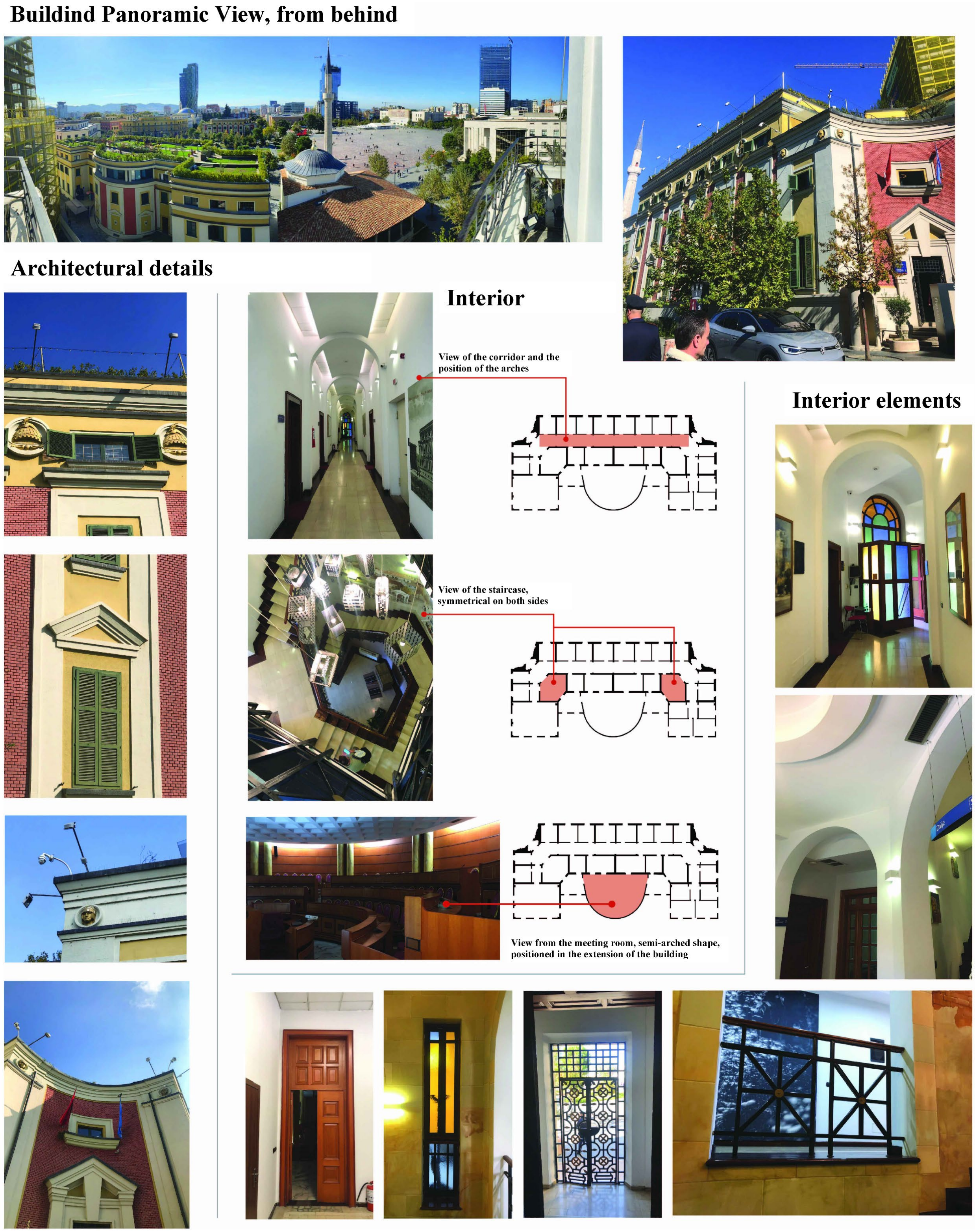


Figure 44. Summary and collage of photos from outside and inside the building, part of the survey process (credits: D. Gjuraj & A. Kapaj)

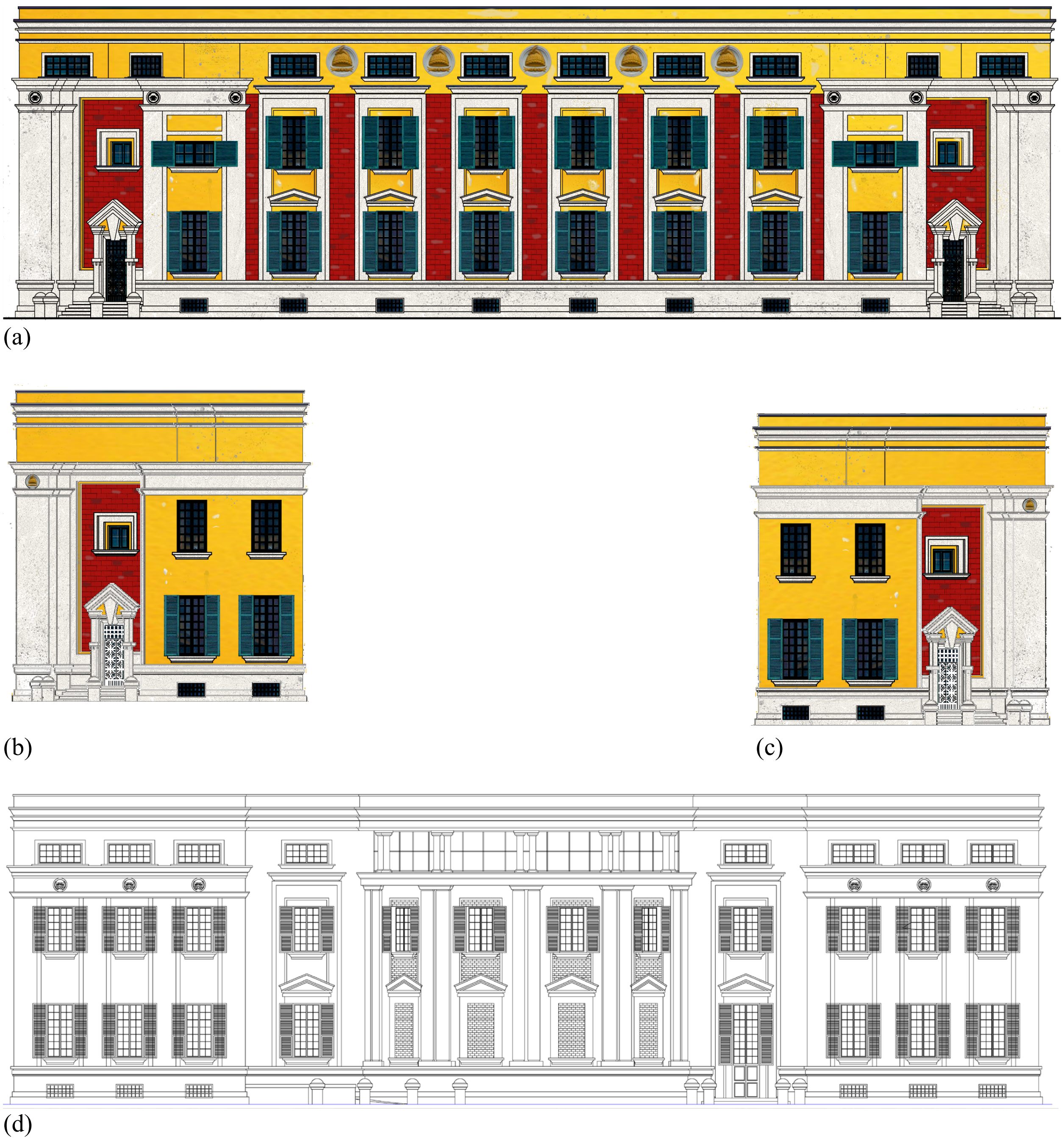


Figure 45. The process of architectural surveying, (a) main façade west side; (b) south side façade; (c) north side façade; (d) behind façade view, positioned in addition

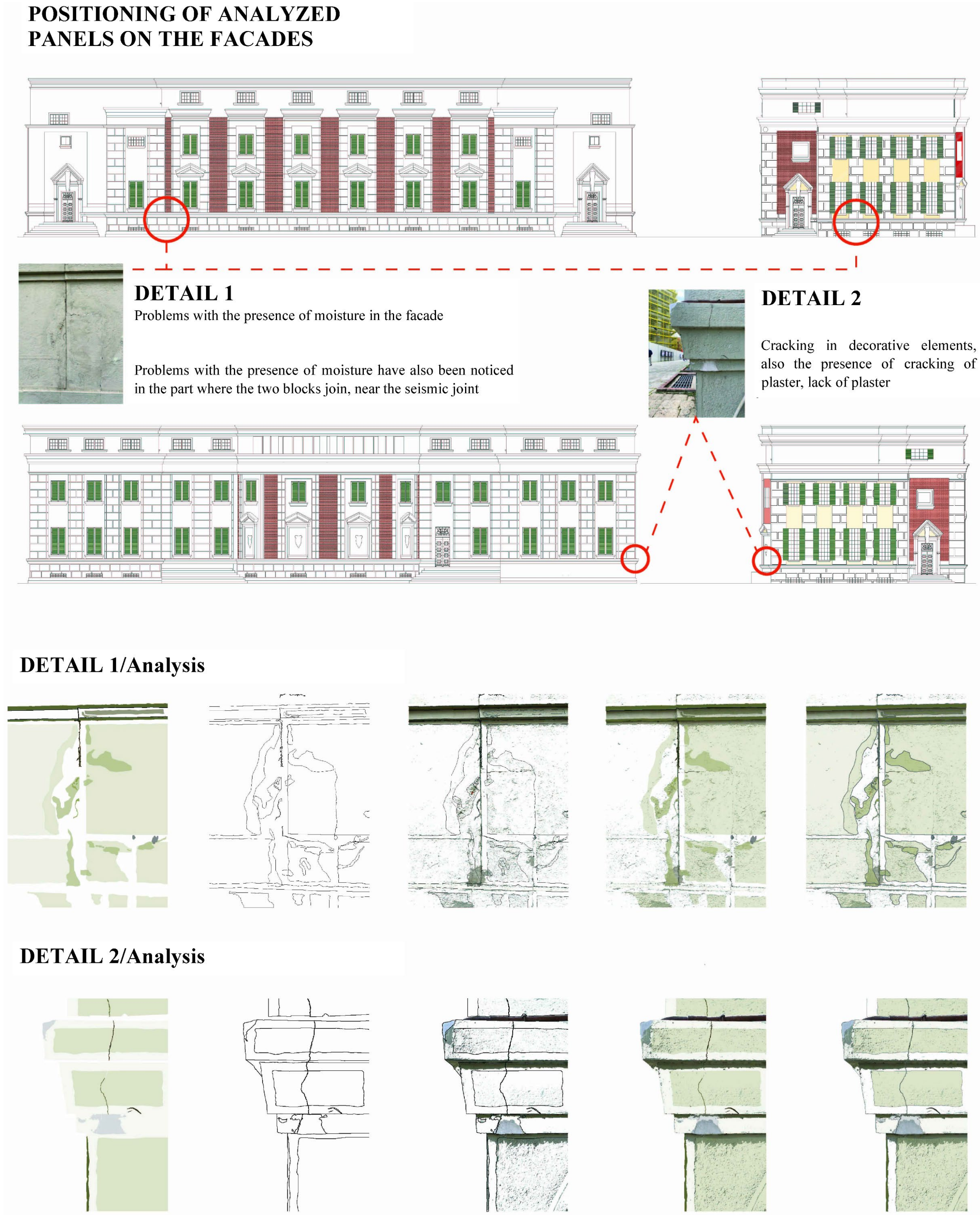
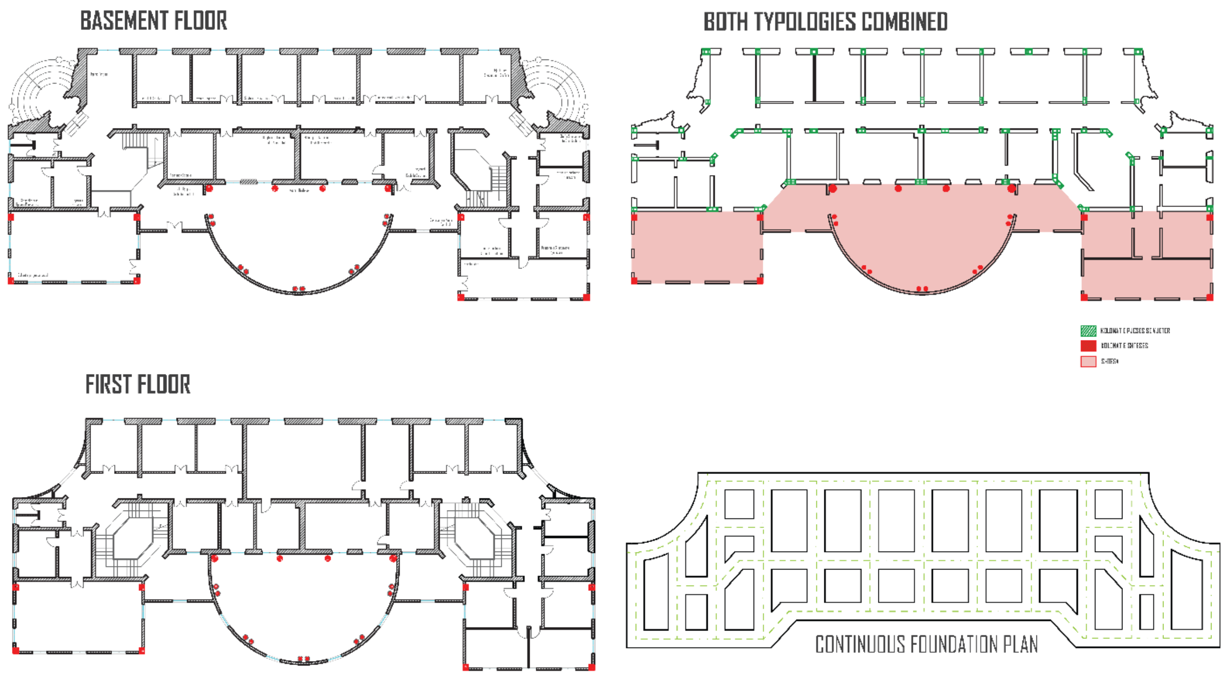
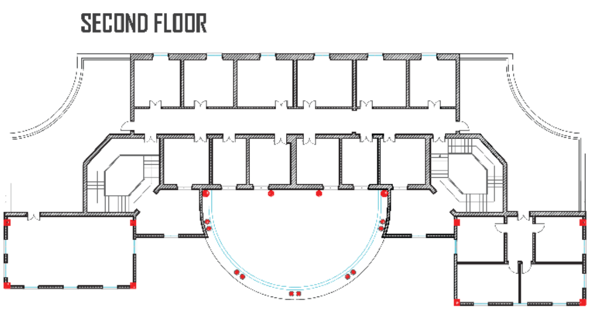


Figure 46. The process of architectural surveying, monitoring and analysis on facade maintenance issues (credits D. Gjuraj & A. Kapaj)





The original and authentic building is a 3-storey building with a structure of unreinforced stone masonry and a basement floor with a continuous stone foundation.

In the following years an addition was built, which is a structure rc frame, also three floors coinciding with those originals. One thing that is noticed in this object is the difference of levels between the floors. On the first floor we find the height of the floor 4.87m, the other floors continue with 3.75m and with a small decrease on the top floor 3.45m.

Also this building is characterized by Italian architecture, with an almost perfect symmetry except for a small difference in the part of the addition. This fact helps a lot in the way this structure reacts to seismic oscillations in a positive way.

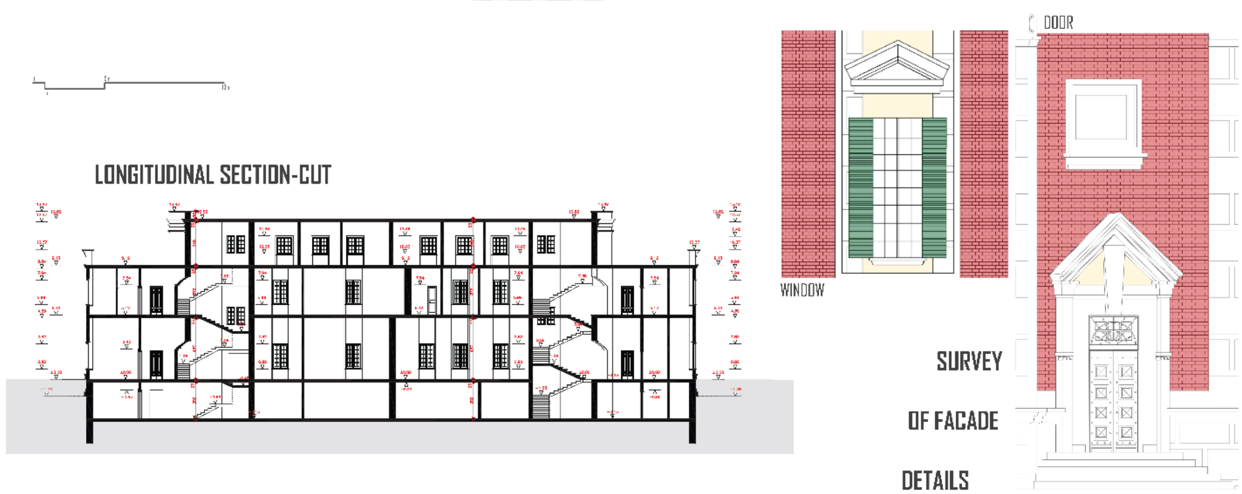


Figure 47 Parts of architectural survey process, all plans, main section cut, raports between two different typologies of structures in plan, foundation plan combined by architectural details analysed

6.1.3 Structural evaluation, methodology and Analysis

At the structural and architectural scale, the study provided a systematic collection of relevant data on the building techniques, brick materials and finish, state of conservation and seismic restoration. Interest was focused on the four main technical elements of these buildings, as walls, ground floor slab, wooden doors and windows. Meanwhile, in 2001 a partial restoration of the building was made, also a new structure was added in the back of the existing building. The typology of the new building is RC frame systems [23] and was connected to the old building on the joints of floor dividers, exactly with the slabs. Between the two objects there is a narrow space to allow the structures to work separately.

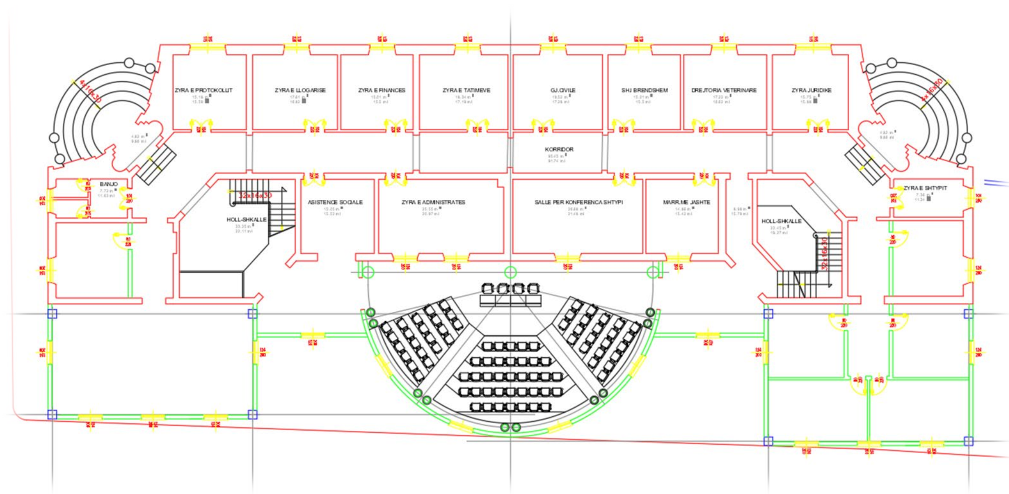


Figure 48. Municipality of Tirana, Updated ground floor plan after restoration (Dhimgjini, Katundi, & Paci, March, 2001)

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 for safeguarding life (life safety level) [24].

6.1.4 Use of F.E.M. interpretation of the crack Pattern and their distribution

The assessment of seismic performance of URM buildings [25] requires the identification of the collapse mechanisms and masonry local damages step by step activated by the synthetic earthquake (elastic demand spectrum) [26]. Referring the current practice in our region has been 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 behaviour and its safety assessment by mesh process and f.e.m[27] model (finite-elements-method), can highly benefit of the ETABS, which enables us to create

[23] Reinforced concrete (RC) frames consist of horizontal elements (beams) and vertical elements (columns) connected by rigid joints.

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

[25] Unreinforced masonry building typology, without reinforced concrete frames.

[26] 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.

[27] F.e.m. - The finite element method is an important method for numerically solving differential equations arising in seismic engineering and mathematical/numerical modeling.

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 [28]. 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 parameters followed for the seismic analysis are taken referring to the Eurocode. (Eurocode 8, Part.1, 2004)

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)

6.1.5. Structural evaluation and seismic performance of the building

Below is presented the object to be analyzed, the municipality of Tirana building after interventions. The constructive project and technical specifications for this building are taken from the technical archives of Tirana. While the data regarding the addition of the building in 2001, we are based on the respective drawings of the architectural and structural project. (Dhimgjini, Katundi, & Paci, March, 2001)

The structural typology is a masonry structure accompanied by rc columns, typology widely used in that period. Are evidenced four different masonry thicknesses, 60cm at basement level, 52cm, 34cm, and 17cm. The last thickness is mainly used as a separating wall between rooms.

Figure 49. Case study 1 updated model after interventions (Dhimgjini, Katundi, & Paci, March, 2001)

28 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.

Stone masonry structures have large masses due to heavy construction materials. Dead loads consist of the fixed weight of structural members and the weight of any permanent fixtures attached to the structure (superimposed loads). Dead loads always remain on the structure and affect the structure throughout its lifetime .

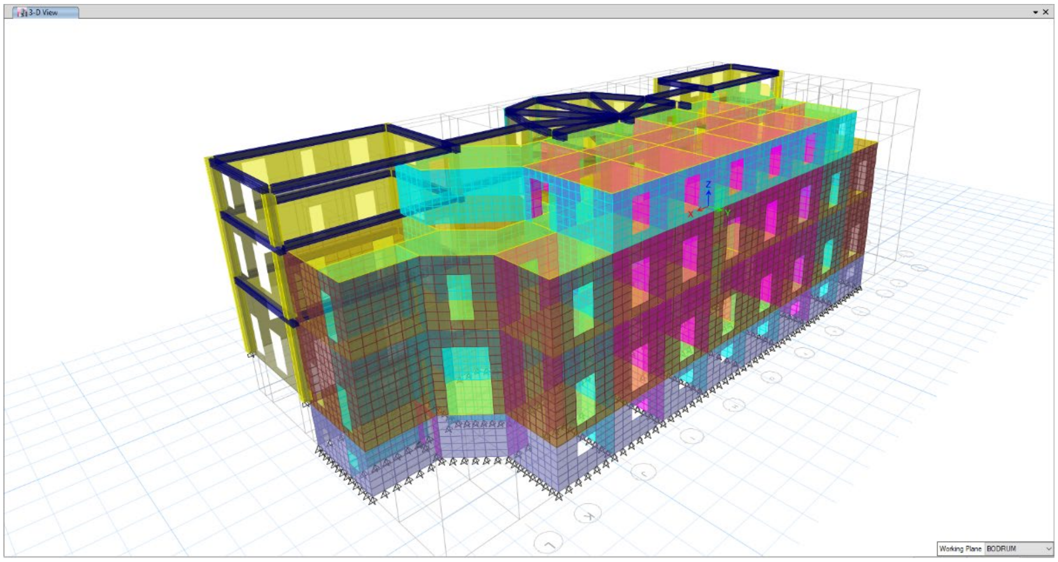


Figure 50. The municipality building, worked on ETABs v16.2.0 (June 21, 2019)

6.1.5.1 Materials, mechanical properties after performing laboratory tests on materials

For all case studies treated in this study, laboratory tests were performed, conducted on site by the company "Altea & GeoStudio 2000" for the generation of data and mechanical characteristics of materials. In the case of the town hall the focus was on taking and conducting tests on the brick and mortar material. The procedure performed starting from sampling the material in the structure, performing the relevant tests and obtaining the test results will be summarized in this section below. Other aspects of the laboratory tests will be summarized in the relevant study annexes.

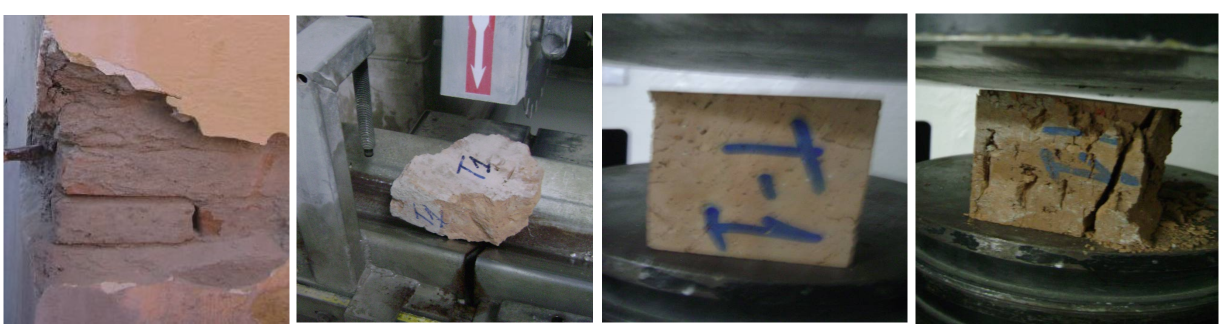


Figure 51. (a) Photo taken while sampling red brick on a perimeter wall panel, inside the basement; (b) sample of red brick preparing for laboratory test, (c) Sample of red brick during the laboratory test in printing, (d) Sample of red brick after completion of the test in compression, at the point of destruction (Altea & geostudio, 2019)

Figure 52. (a) Photo taken while sampling white brick on a perimeter wall, the eastern part from behind; (b) sample of white brick taken on the north façade wall, (c) Sample of white brick during the laboratory test in printing, (d) Sample of white brick after completion of the test in compression, at the point of destruction (Altea & geostudio, 2019)

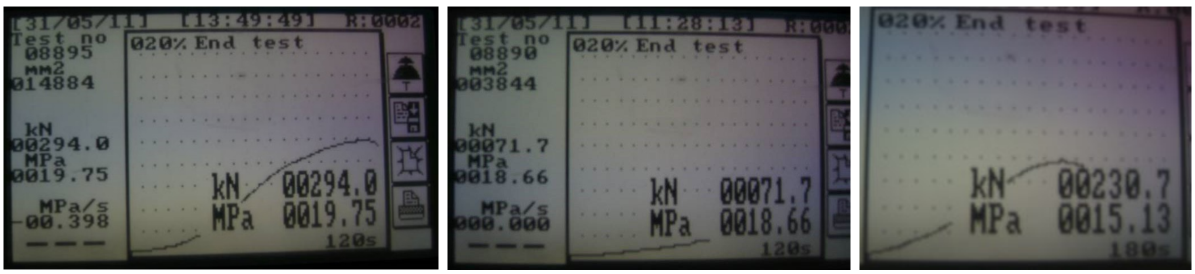


Figure 53. (a) The result of the red brick digimax test for the compression test; (b) + (c) the results of white brick samples (Altea & geostudio, 2019)

Figure 54. (a) sample of mortar during the compression test, (b) sample of mortar after completion of the test, point of collapse, (c) test result in digimax (Altea & geostudio, 2019)

Bricks - full red bricks or white silicates are not crushed. From the tests performed the results obtained are acceptable as they have given good compressive strength. No decompositions have been found.

Mortar - From the tests performed, mortar has good physical-mechanical properties. Mortar consists of river sand and cement. In those parts where the walls have been plastered (which are partial) it is advisable to re-plaster them.

Table 10. Table with mechanical parameters of masonry materials after performing laboratory tests, specifically tests in compression of cubic samples of red brick and silicate-white (Altea & geostudio, 2019)

Materials / Laboratory test					
Nr.	**Parameter**	**Value**	**Unit**	**Type of test performed**	**Figure**
1	Compressive strength – digimax	19.75	Mpa	*Compression test results for the red brick cubic sample-1*	
2	Failure load	294	kN		
1	Compressive strength – direct	18.66	Mpa	*Compression test results for the white brick cubic sample-1*	
2	Failure load	71.7	kN		
1	Compressive strength – direct	15.13	Mpa	*Compression test results for the white brick cubic sample-2*	
2	Failure load	230	kN		
1	Elastic modulus E (The Young's Modulus)	15837	MPa		
2	Shear modulus G	1811	MPa		
3	Poisson's ratio υ	0.15			

Material parameters on ETABS are set to the current state, referring to the laboratory results performed above (table 10), and reviewing the physico-mechanical parameters according to the literature.

The masonry behavior is modeled by two different layers accompanied by stress and strain characteristics (Tomazevic, Damage as a Measure for Earthquake Resistant Design of Masonry Structures, Slovenian Experience, 2007). The layers represent the vertical stresses $S_{1\text{-}1}$, $S_{2\text{-}2}$ horizontal stresses and shear stresses S12. It is very important to predict the best possible stress-strain graph for each direction (Baballeku, 2014).

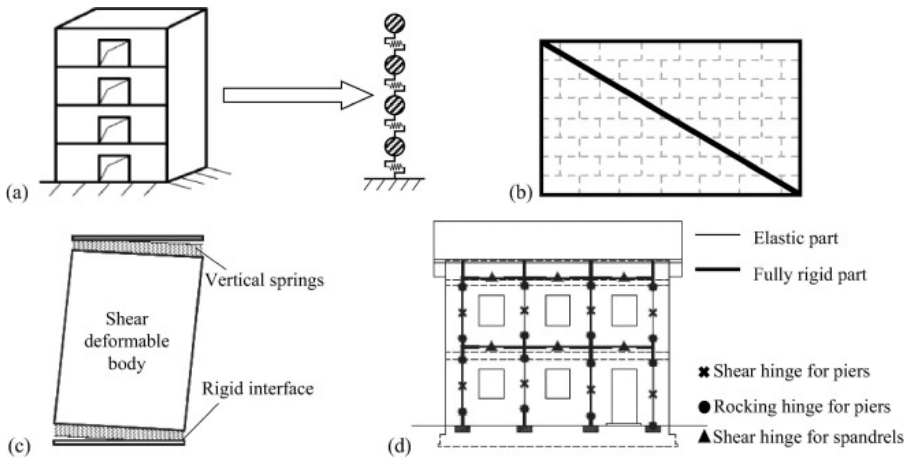


Figure 55. A unified model for the seismic analysis of brick masonry structures (Xu, Gentilini, Ju, Wu, & Zhao, 2018)

The nonlinear analysis Pushover, methodology is able to define capacity curves with performance point, the shear resistance and collapse mechanisms. It is able to combine different mechanisms for global seismic performance analyses of buildings with sufficient regularity and limited height, and take into account the type of connection among the structural elements.

6.1.6 The concept of the foundations

The foundation is continuous, with stone masonry, on two levels. The first level is in the depth of -2.7m and the second in the level ±0.00. The foundation is realized using two models: Theoretical model according to Timoshenko and Euler; and the physical model, understanding the case study.

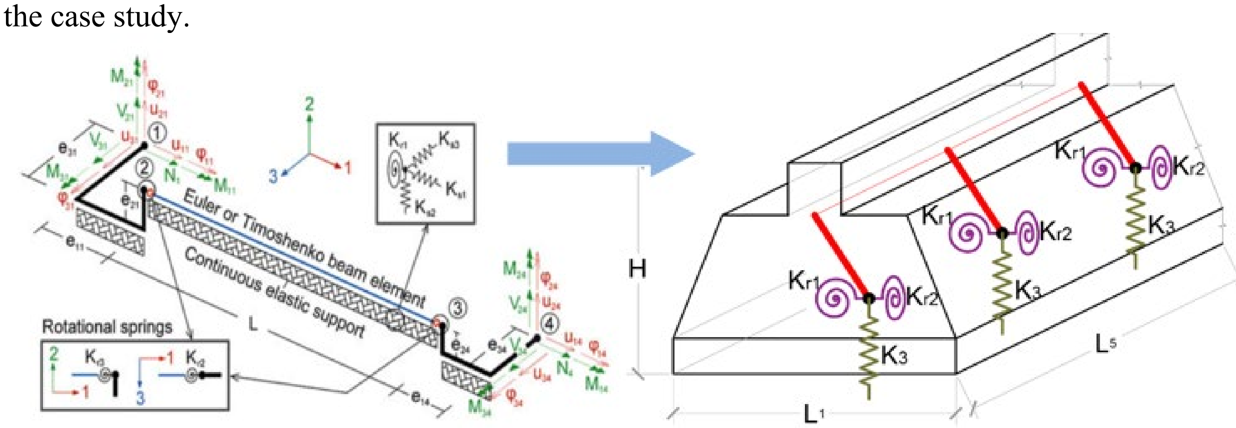


Figure 56. Theoretical model referring Timoshenko and Euler (left), the case study physical model (right) (Vesho, Guri, Marku 2019)

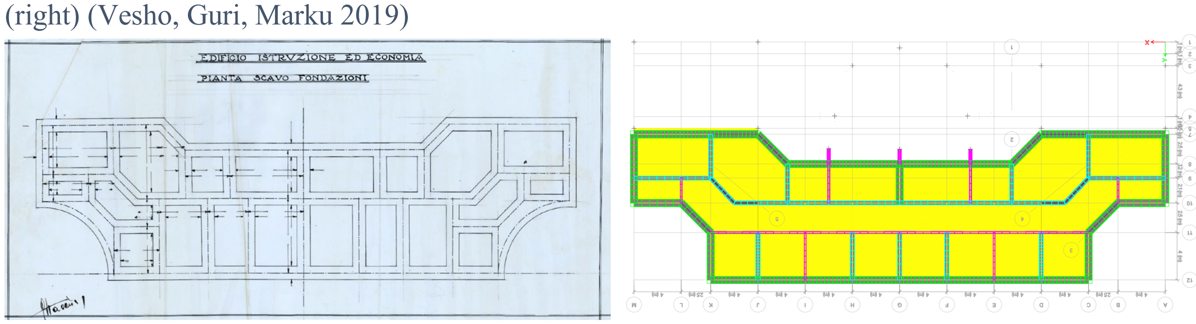


Figure 57. Foundation structural plan of the Di Fausto implementing project 1941 (source: Archive)

6.1.7 Seismic Parameters

Since the objective of this research is to evaluate the seismic performance of the building and improve it, we have to show below the elastic response spectrum[29] parameters (CEN Eurocode 8, Eurocode 8: Design of structures for earthquake resistance -Part 1: General rules, seismic actions and rules for buildings, 2008).

Eurocode 8 have a detailed specific way to calculate the seismic spectrum. In this case it depends on several factors: peak ground acceleration PGA[30], the category of the soil, the predicted magnitude (*in the case of our country is 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 0.15-0.3g. (CEN Eurocode 8, Eurocode 8: Design of structures for earthquake resistance -Part 1: General rules, seismic actions and rules for buildings, 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: B*
- *Spectral acceleration: ag/g = 0.3m/s*^{2}
- *Direction: Horizontal*
- *Behavioral factor: 2.6 (the spectrum is elastic)*
- *Damping factor: 5%*

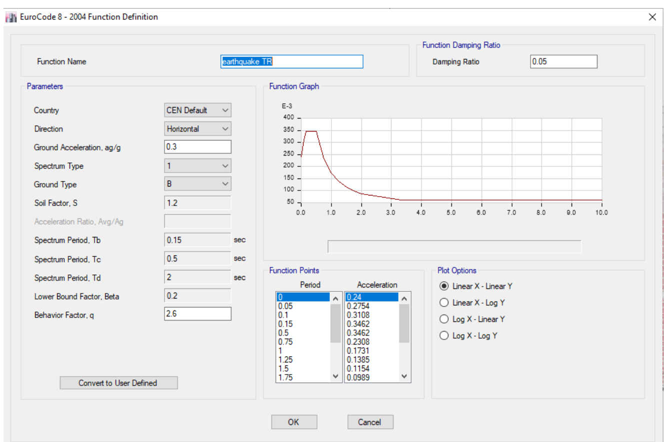


Figure 58. Elastic demand spectrum, referring Tirana ground parameters (ETABS, 2019)

Given the above explanation in methodology, historical heritage was primarily analyzed to define seismic parameters and their walls load carrying capacity. Modal analysis was conducted in order to determine fundamental mode shapes and natural frequencies of the structure during free vibration. The purpose of modal analysis is to obtain the maximum response of the structure in each of its important modes, which are then summed up in an appropriate manner. Modal analysis of the structure included different modes of vibrations in combination .

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[29] A response spectrum is a plot of the peak or steady-state response (ground acceleration) of a series of oscillators or earthquakes of varying natural frequency, that are forced into motion by the same base vibration.

[30] is equal to the maximum ground acceleration that occurred during earthquake shaking at a location. PGA is equal to the amplitude of the largest absolute acceleration recorded on an accelerogram at a site during a particular earthquake

6.1.8 Seismic analysis results and modal parameters

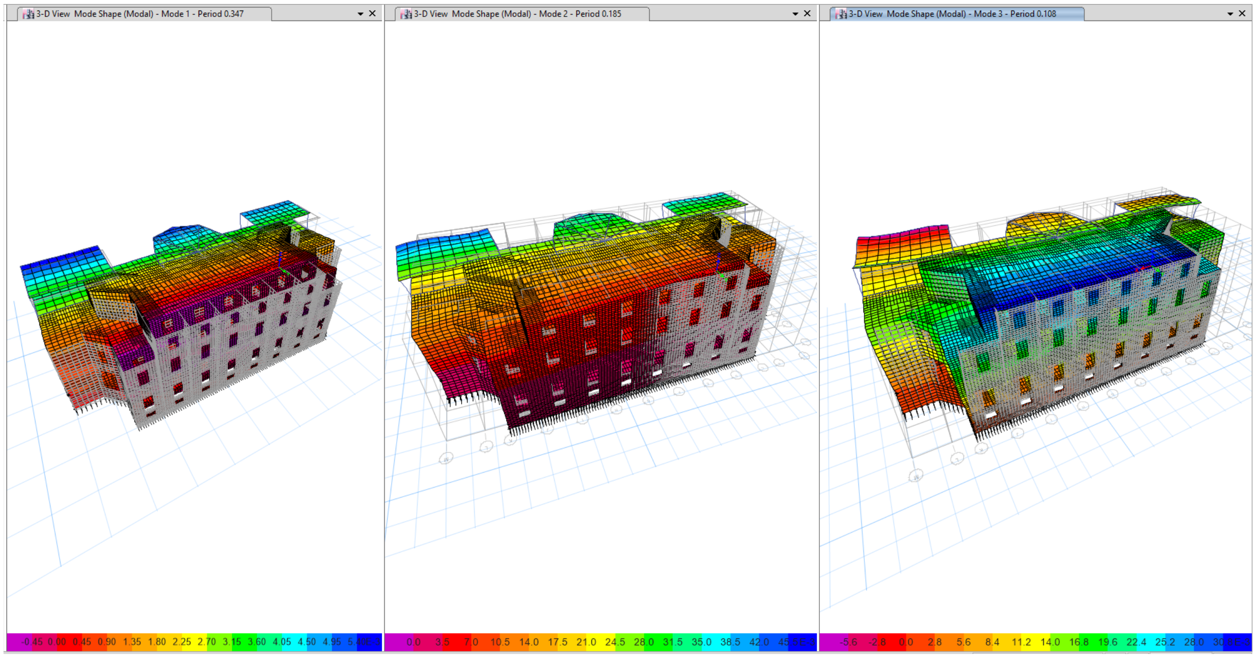


Figure 59. The first 3 modes of vibrations according the modal analysis (CEN Eurocode 8, Eurocode 8: Design of structures for earthquake resistance -Part 1: General rules, seismic actions and rules for buildings, 2008) (ETABS, 2019)

Table 11. Modal participating mass ratios and periods (ETABS, 2019)

Case	Mode	Period sec	UX	UY	SumUX	SumUY	RX	RY	SumRX	SumRY
Modal	1	0.347	0.0046	0.7411	0.0046	0.7411	0.3605	0.0025	0.3605	0.0025
Modal	2	0.185	0.3388	0.0181	0.3434	0.7591	0.0172	0.1851	0.3777	0.1876
Modal	3	0.108	0.4508	0.0005	0.7942	0.7596	0.0052	0.1528	0.3829	0.3405
Modal	4	0.085	1.1274	0.0003	0.7942	0.7598	0.0001	0.0041	0.383	0.3446
Modal	5	0.07	0.002	0.0003	0.7962	0.7602	0.0006	0.0114	0.3836	0.356
Modal	6	0.063	0.0011	0.0127	0.7974	0.7728	0.0316	0.0017	0.4152	0.3577
Modal	7	0.051	0.006	0.0015	0.8033	0.7744	0.0071	0.0223	0.4223	0.38
Modal	8	0.049	0.0001	0.0815	0.8035	0.8559	0.2134	0.0002	0.6356	0.3802
Modal	9	0.044	0.0298	0.0002	0.8332	0.8561	0.0001	0.0914	0.6357	0.4715
Modal	10	0.037	0.0011	0.0048	0.8343	0.8608	0.0116	0.0042	0.6473	0.4757
Modal	11	0.037	0.0001	0.0009	0.8344	0.8617	0.0027	0.0023	0.6499	0.478
Modal	12	0.036	0.0181	0.0006	0.8525	0.8623	0.0048	0.0847	0.6547	0.5627

Allowed period calculation: [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: T_1=0.347s > [T] Translation move on Y-direction
First mode: T_2=0.185s Translation move on X-dir. and the presence of torsion
Third mode: T_3=0.179s Pure torsion

We can mention in advance that the most problematic part founded above in modal parameters is a considerable torsion of the structure in global plane in the second mode of vibration. This phenomenon is problematic for masonry structures in general and also in our case can bring additional problems in the joining part between two buildings.

6.1.9. Local stresses and strain distribution in main facades

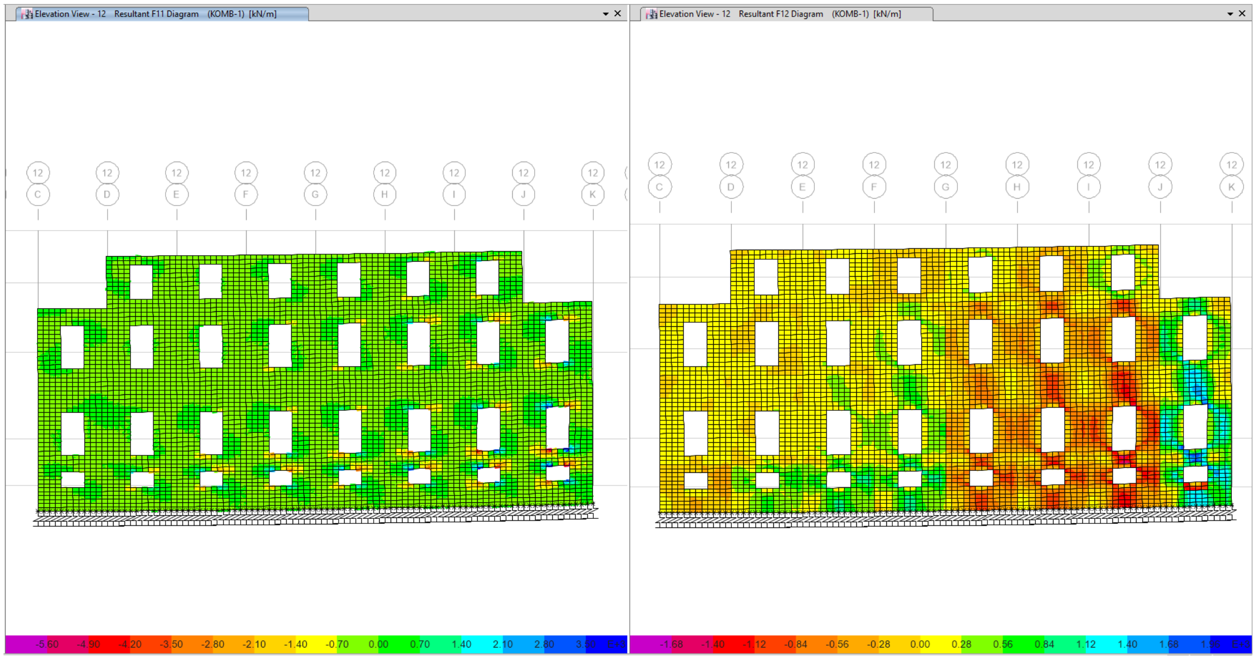


Figure 60. Resultant Shell forces on main facade, f1-1 and f2-2 (ETABS, 2019)

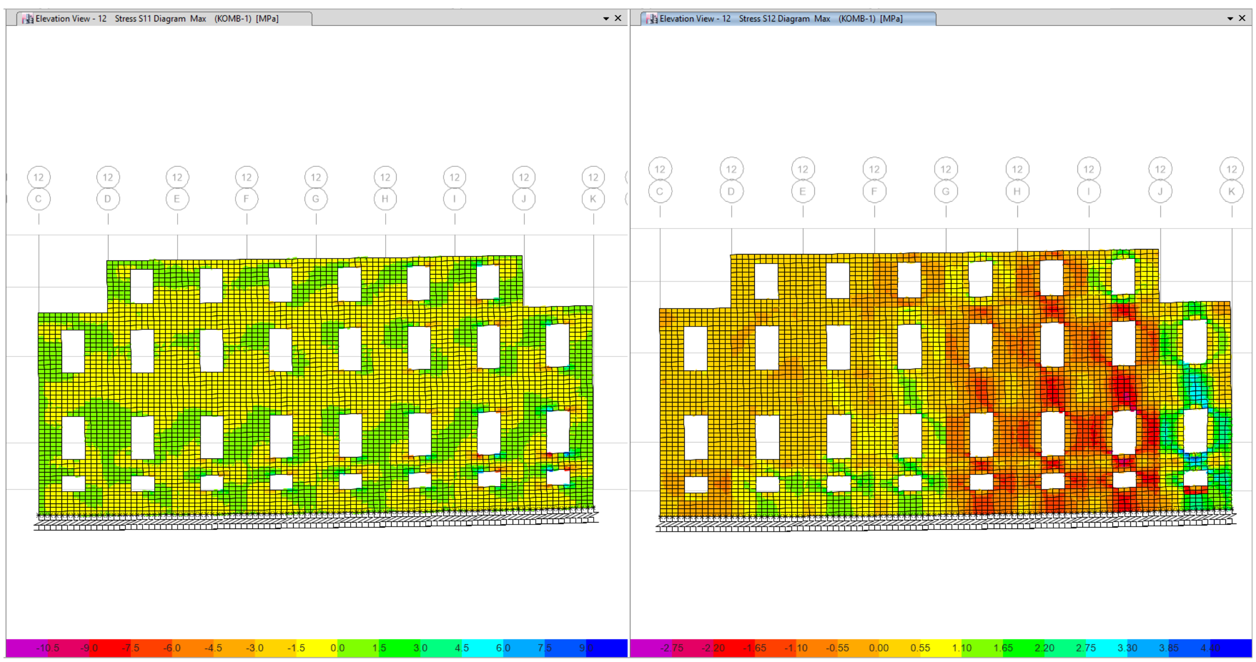


Figure 61. Resultant shell stresses S1-1 and S2-2 on the main facade (ETABS, 2019)

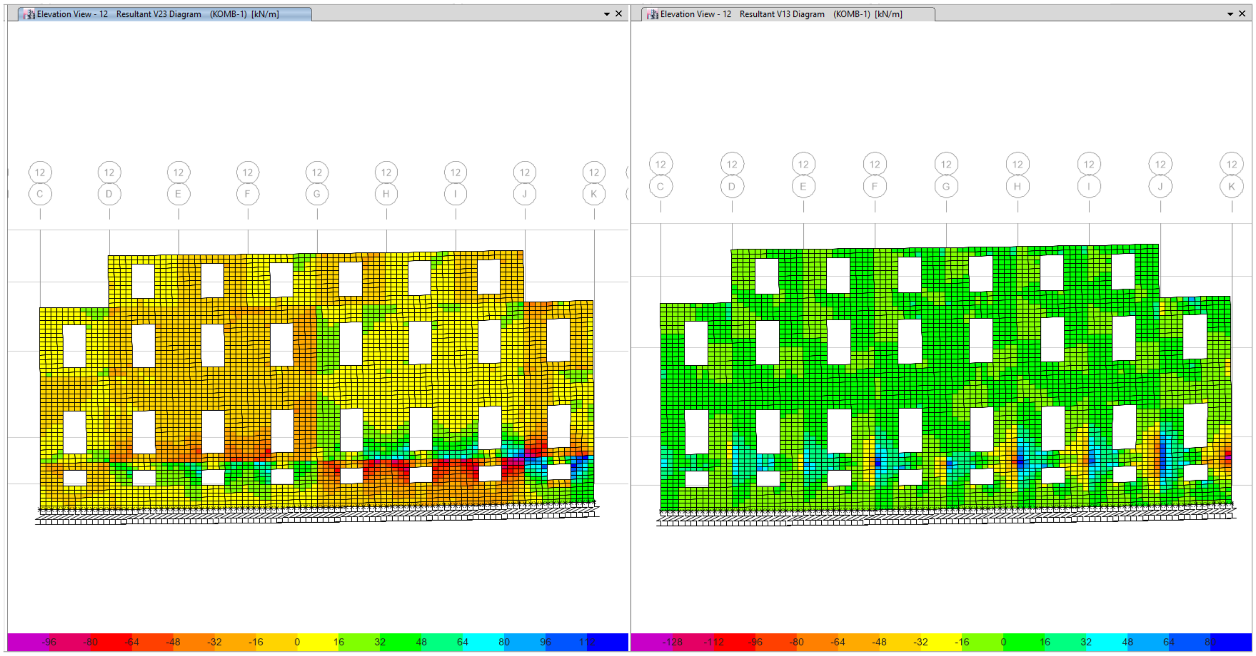


Figure 62. Shear force distributed on 2 directions, V1-3 and V2-3 (ETABS, 2019)

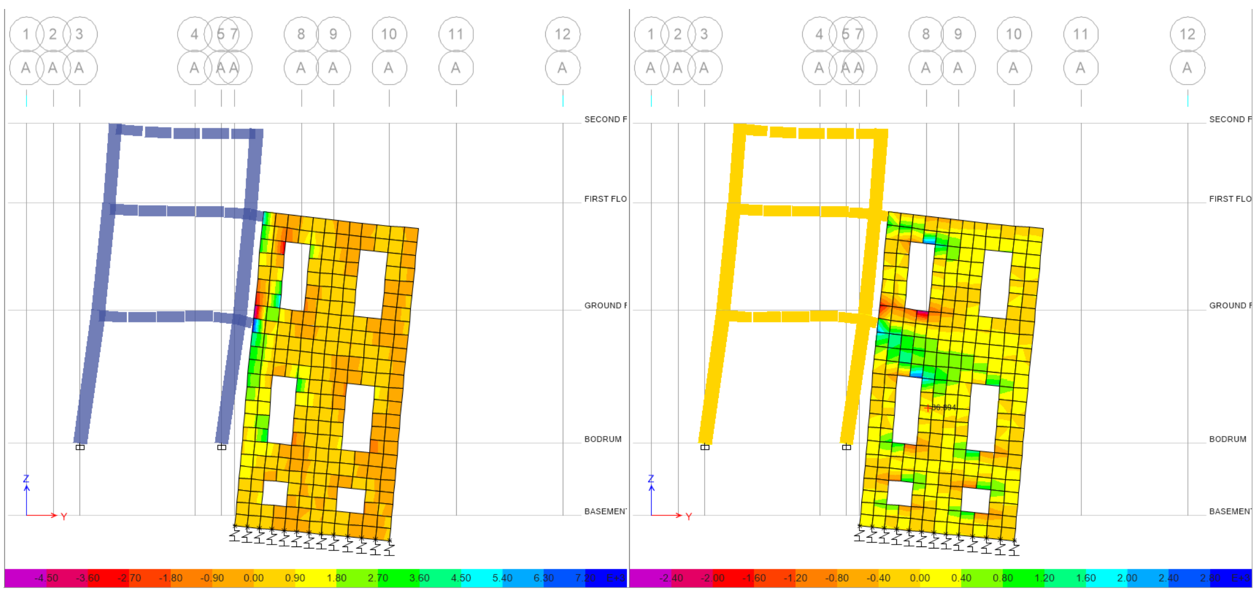


Figure 63. Resultant shell stresses in the area when the new frame system is linked with existing wall (ETABS, 2019)

The minimum principal stresses amount to about 7.13 MPa and they occur in the transition zone between the ground floor and the upper floor (figure 63). Maximum principal stresses amount to about 9.67 MPa and they occur above the top of the ground floor and at the first floor wall panels . Maximal displacement according combination 1 is 38.3mm on X-direction and 59.8mm on Y-direction. Is noticed that the structure has problems with the displacement and the creation of plastic hinges on the joints in the areas where the beams merge with walls, exactly in the meeting point between the new structure and the old part. There are also problems in the area when basement wall with 60cm width merge with foundation.

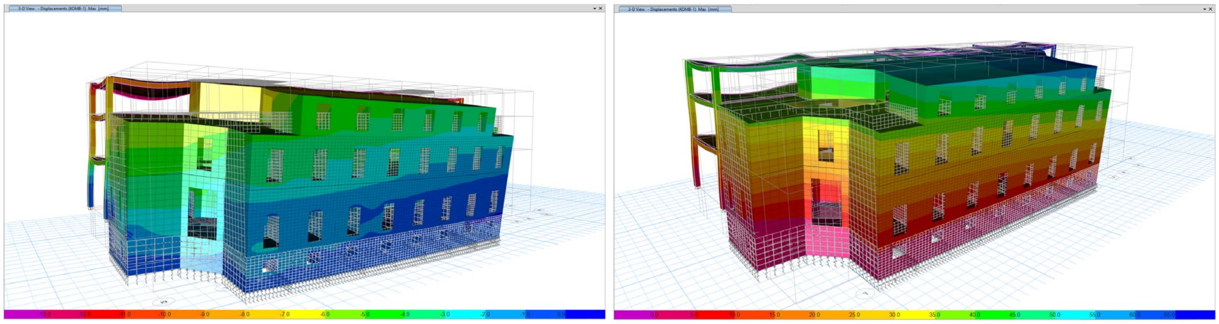


Figure 64. Seismic Displacements according to Combination 1, Δx-x and Δy-y (ETABS, v.2019)

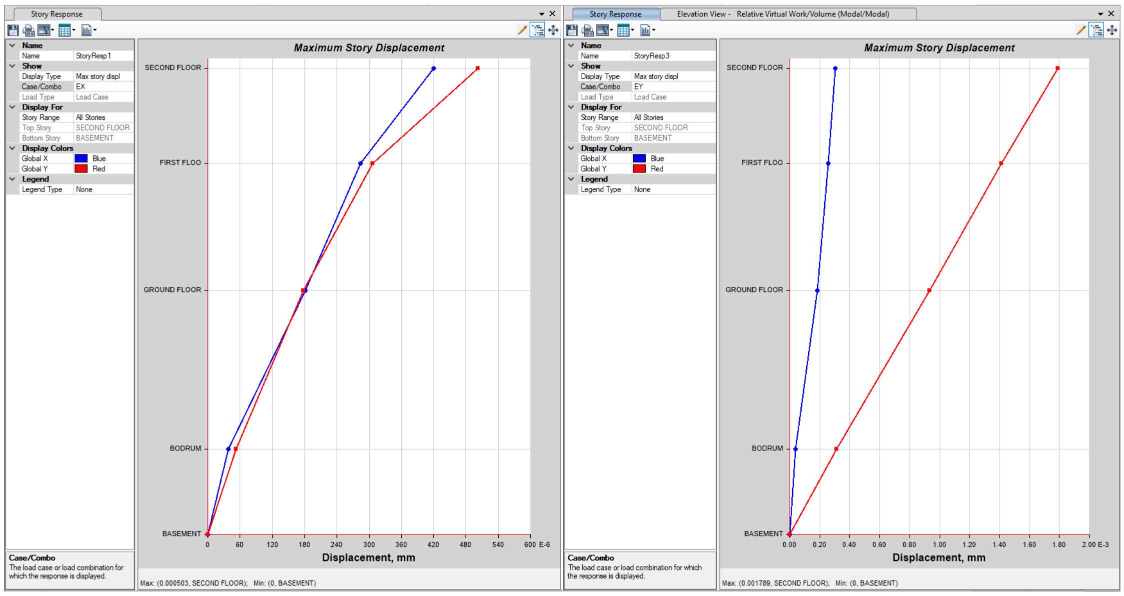


Figure 65. Maximum story displacements according to seismic actions in two directions E-x, E-y (ETABS, v.2019)

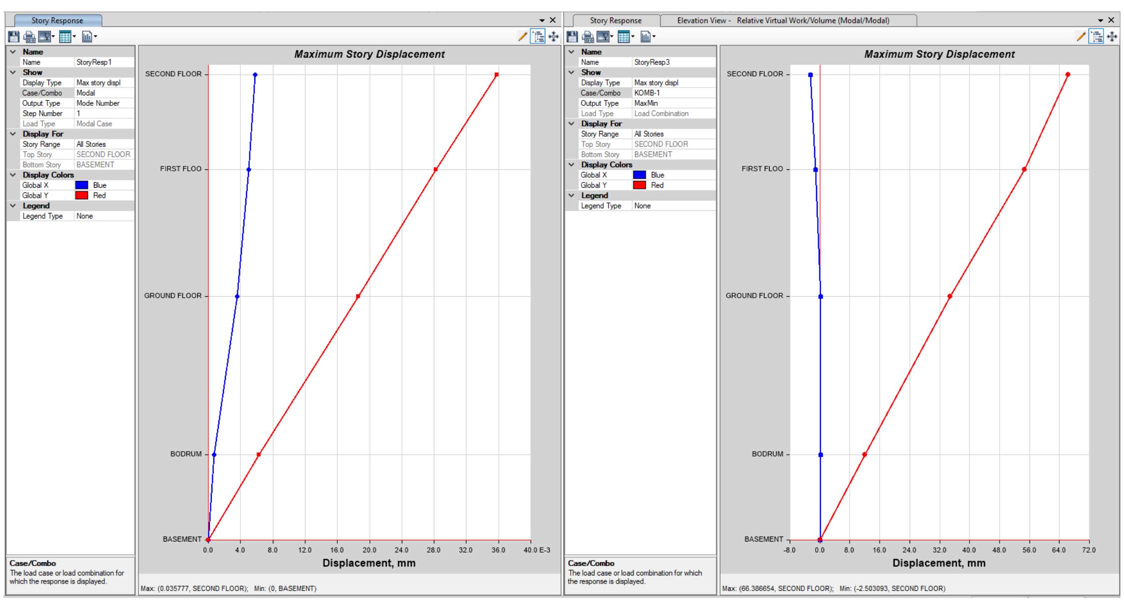


Figure 66. Comparison between Modal and combination 1 of Maximum story displacements (ETABS, v.2019)

Regarding displacement of the structure, an investigation has been done at the storeys level, to specifically analyze the reaction of the old structure in relation to the new structure. At this stage the analysis was done by simulating the model in Etabs according to the combination-1, considered as the most unfavorable. This combination includes seismic action in the orthogonal direction in relation to the building, specifically direction X, then combined with "dead loads" with a coefficient of 1.0*D.L and "live loads" with a coefficient of 0.3*L.L, also, showed in the modeling parameters above. From investigating and reviewing displacement values we have these values. The maximum size of displacements according to the combination-1 in the most fragile direction of the building, captures the maximum value of 6.48mm, while the values of maximum displacements according to the modal analysis in the most fragile direction of the building geometry reach the value 0.36mm. Normally there are large differences in displacements obtained from the most fragile combination compared to the static linear analysis results.

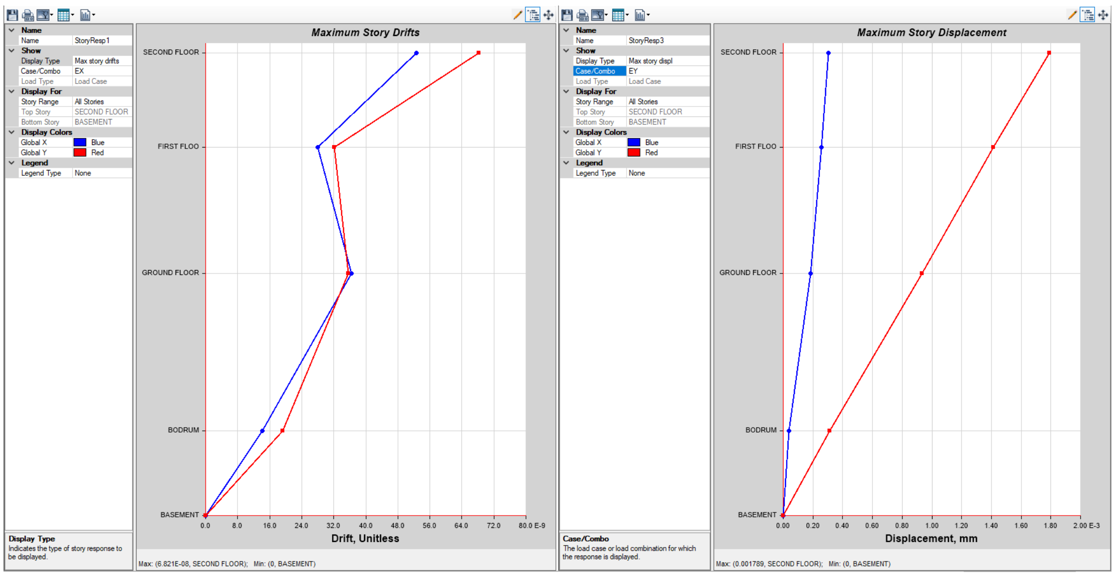


Figure 67. Story drifts comparison between seismic E-x and E-y direction (ETABS, v2019)

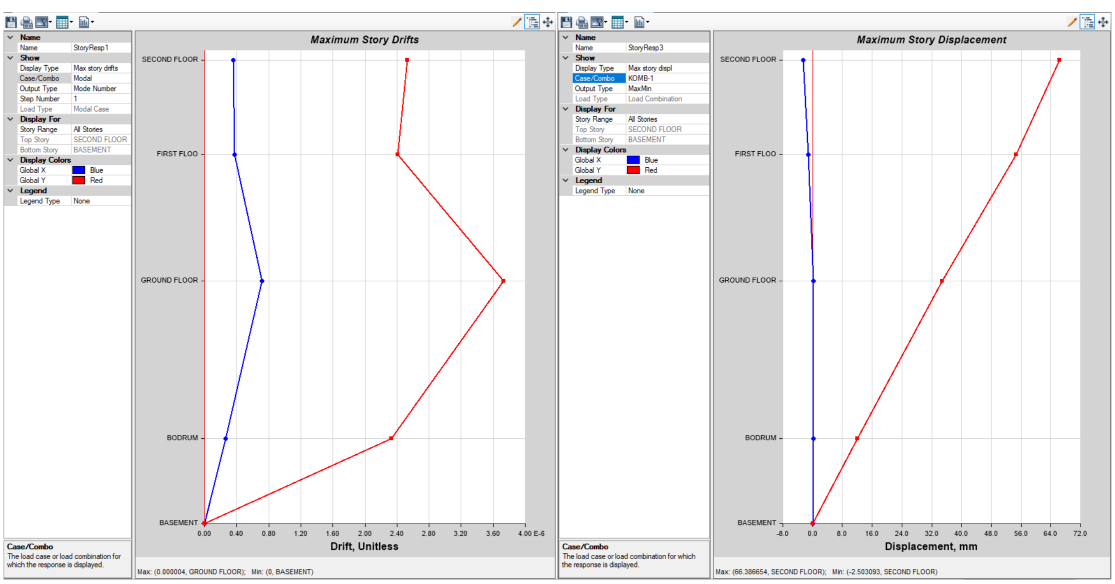


Figure 68. Story drifts comparison between modal analysis and combination-1 (ETABS, v2019)

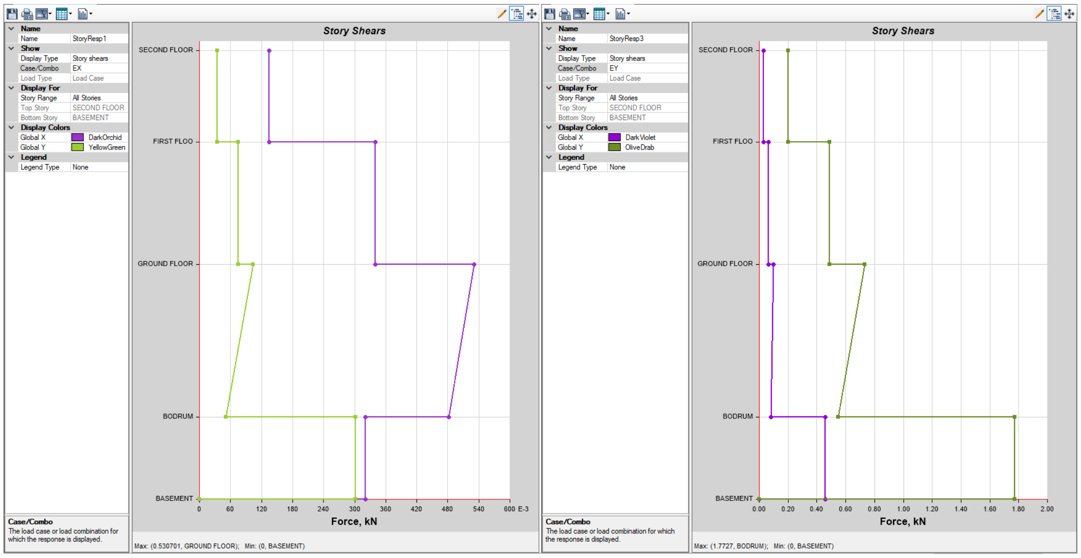


Figure 69. Story shear force distribution against seismic actions Ex-x and Ey-y (ETABS, v2019)

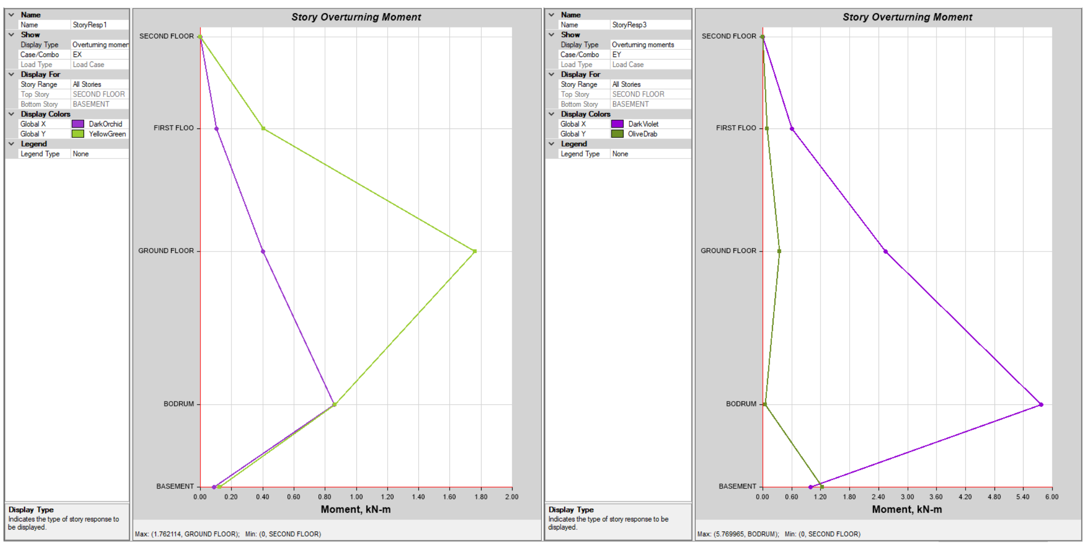


Figure 70. Story shear force distribution against seismic actions Ex-x and Ey-y (ETABS, v2019)

Making an interpretation of the diagrams above is analyzed the static reaction of the structure for this case, more specifically the diagram of the distribution of shear forces in the local analysis and the diagram of local moments, the second one taking into account the reaction of addition which has moment frames structure . The diagrams are taken under the influence of seismic actions and more specifically the action against the two directions x and y. From the shear-force diagrams we see that the greatest impact has the direction x where the values of shear stresses are about 80% higher compared to the direction y, this related to the configuration of the building in the plan. While there is a significant overrun and change of the diagram in the level-0 plan. This explains and reflects the change of volumes of the two buildings in that plan-level, analyzing that the addition starts from ground level 0 and continues to the terrace, while the existing building is embedded in the ground up to level -2.85, i.e. the basement floor, without considering the depths of the foundations of the two blocks. Referring to the moment diagrams, the parameters consist within the allowed values and can be considered insignificant, due to the volume of the existing building which is massive structural masonry with considerable width.

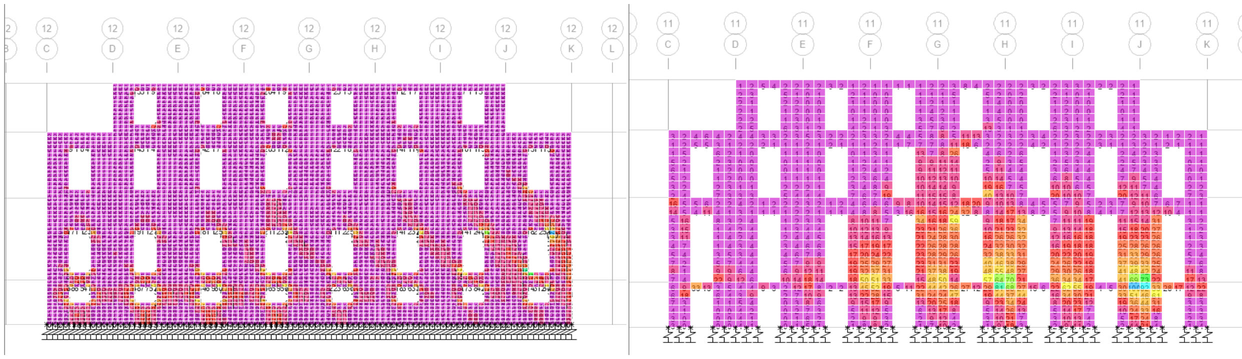


Figure 71. Virtual relative energy/work related to the main façade, related to comb-1 (ETABS, v.2019)

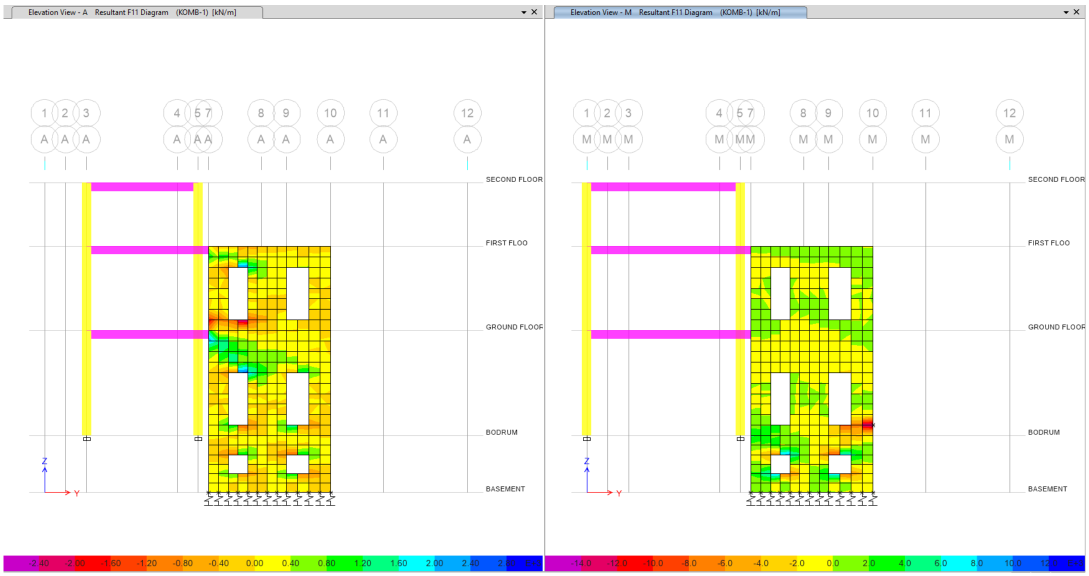


Figure 72. Distribution of the resultiant seismic force F1-1 in 2 front facades, related to comb-1 (ETABS, v.2019)

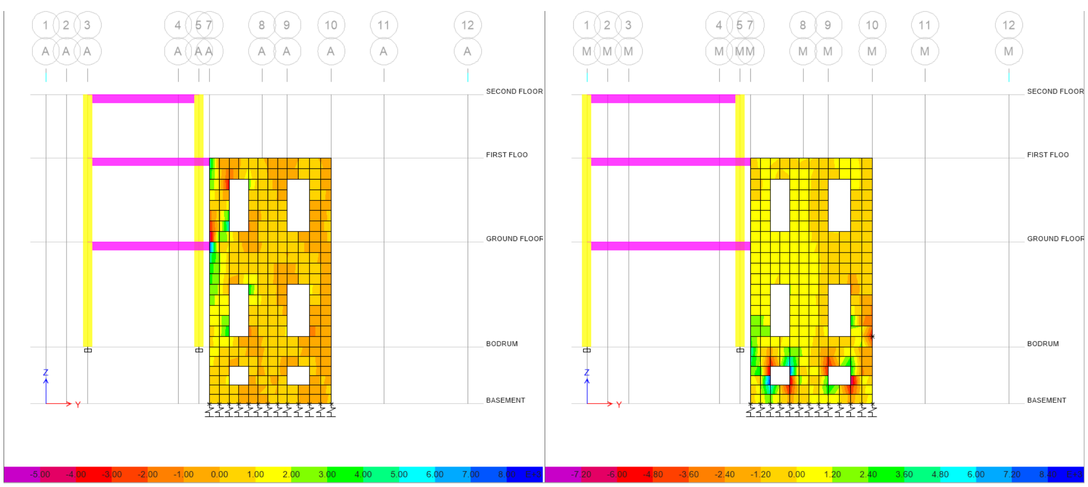


Figure 73. Distribution of the resultiant seismic force F2-2 in the two front facades, related to comb-1 (ETABS, v.2019)

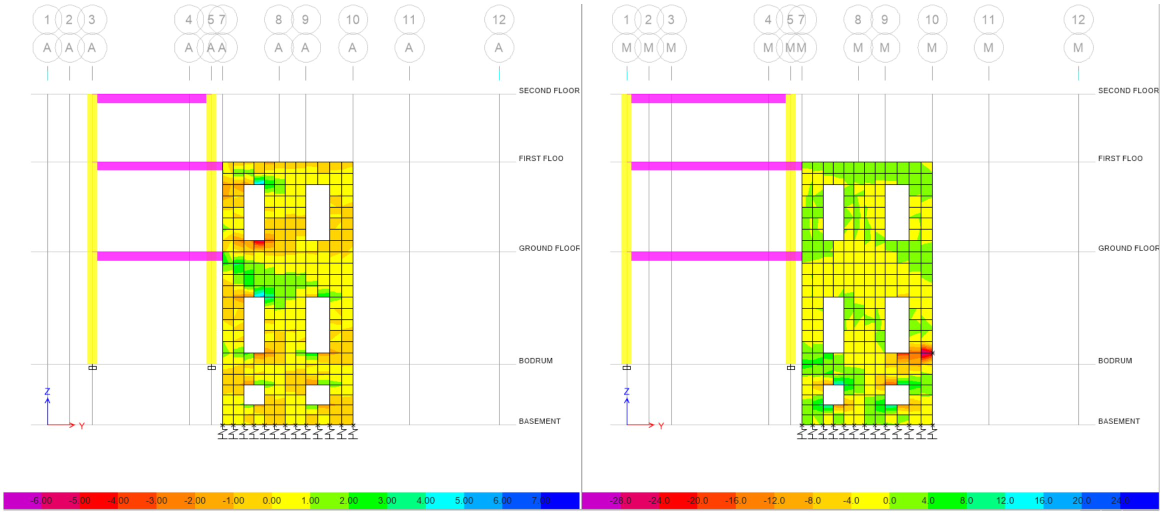


Figure 74. Distribution of the stress σ-x in the two front facades, related to comb-1 (ETABS, v.2019)

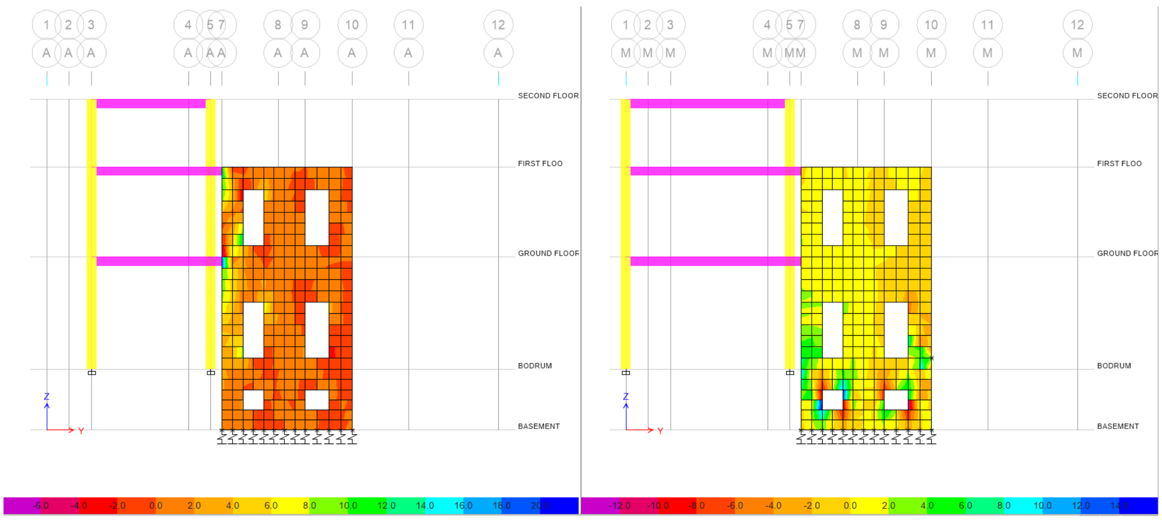


Figure 75. Distribution of the stress σ-y in the two front facades, related to comb-1 (ETABS, v.2019)

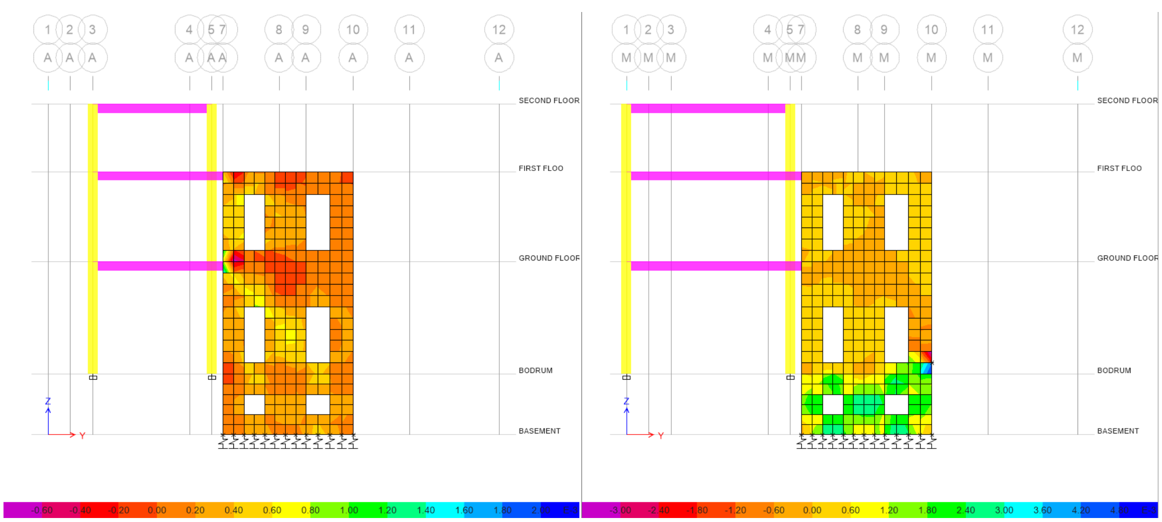


Figure 76. Distribution of the Strain ε1-2 in the two front facades, related to comb-1 (ETABS, v.2019)

6.1.10. The second phase of BIM modeling through “3muri software”, static nonlinear analysis and investigations into possible collapse scenarios

Following the seismic analysis (performed in etabs software), for the above case study, it was judged to perform further seismic verifications in the framework of non-linear analysis through 3Muri software, which specializes in analyzing these types of structures . In this theoretical framework it is attempted to obtain further information about the object, and also to increase the degree of structural investigation. Global "nonlinear pushover" analyzes were performed, and then attempts were made to investigate some of the possible local mechanisms of collapse. So, for the evaluation of local effects of the panels, the use of calculation models relating to the isolated fragile parts of the structure is allowed at this analysis stage.

There has always been a tendency to reduce and equivalent the masonry structural system to a homogeneous and isotropic material, to exploit the technical knowledge of theory of structures or building sciences. This schematization allows to evaluate the stress and deformation state and corelate similarly to what happens for reinforced concrete frames or steel structures.

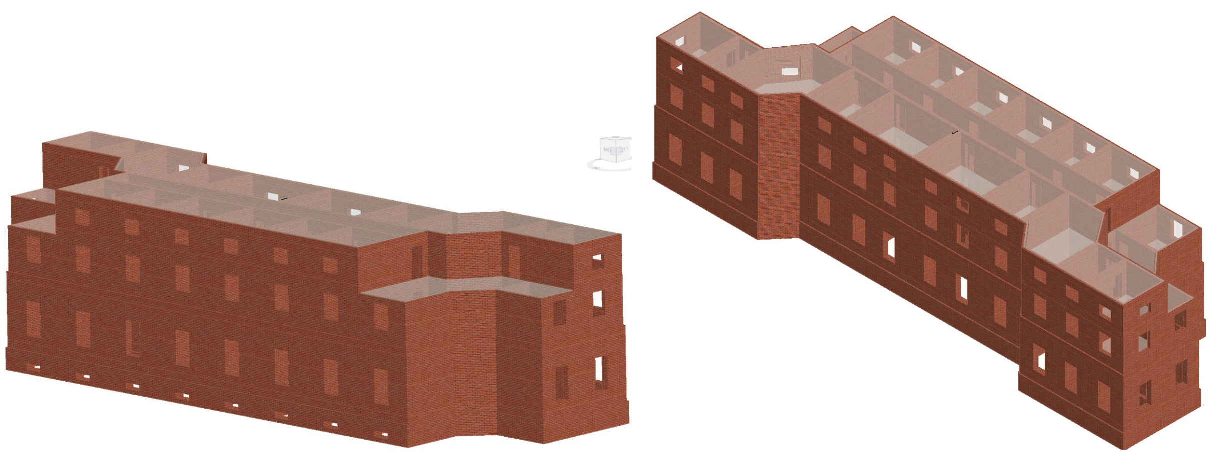


Figure 77. Axonometric model of the building, created in 3Muri v.13 software. Geometric modeling, creation of volumetrics and data entry of materials

As one of the basic interconnections of BIM modeling, a finite element treatment "F.E.M. method" would be valuable, also desirable, with which to schematize each individual brick unit and the reciprocal constraints, however this operation would involve an enormous computational burden, also, an extremely random relationships. By adopting 3-dimensional finite elements models, it is possible to obtain an exhaustive modeling for any type of existing construction and, in particular, for those made entirely of unreinforced masonry, with simple rigid ribbed slab, which can thus be analyzed in their entirety in this chapter.

The 3-muri calculation model is the numerical parameterization of the global behavior of the structure, respecting the constitutive bond and cooperation of the material parameters or data. The most frequent cause of errors in structural design is the difficulty to identify calculation models that are effectively representative of structure real behavior.

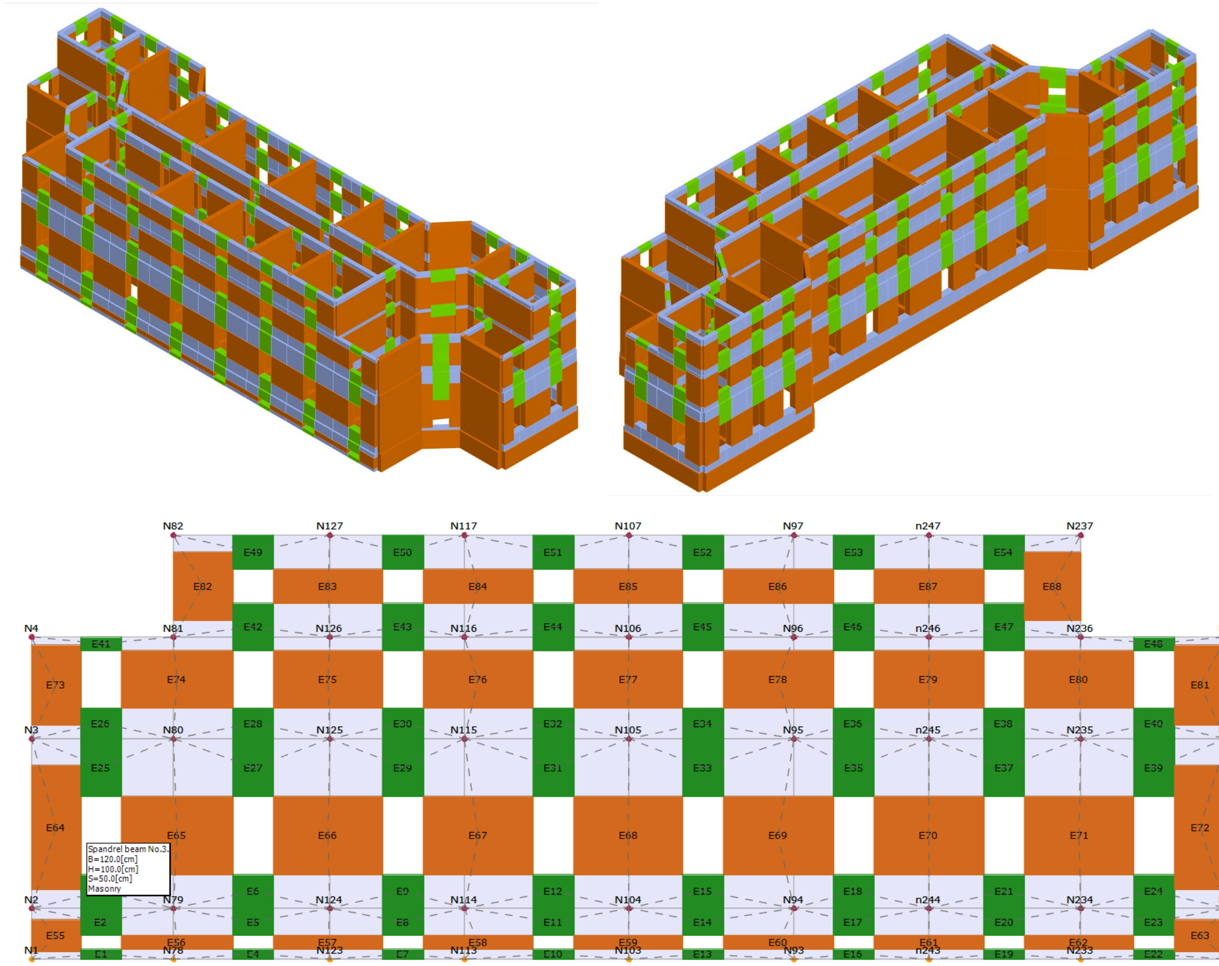
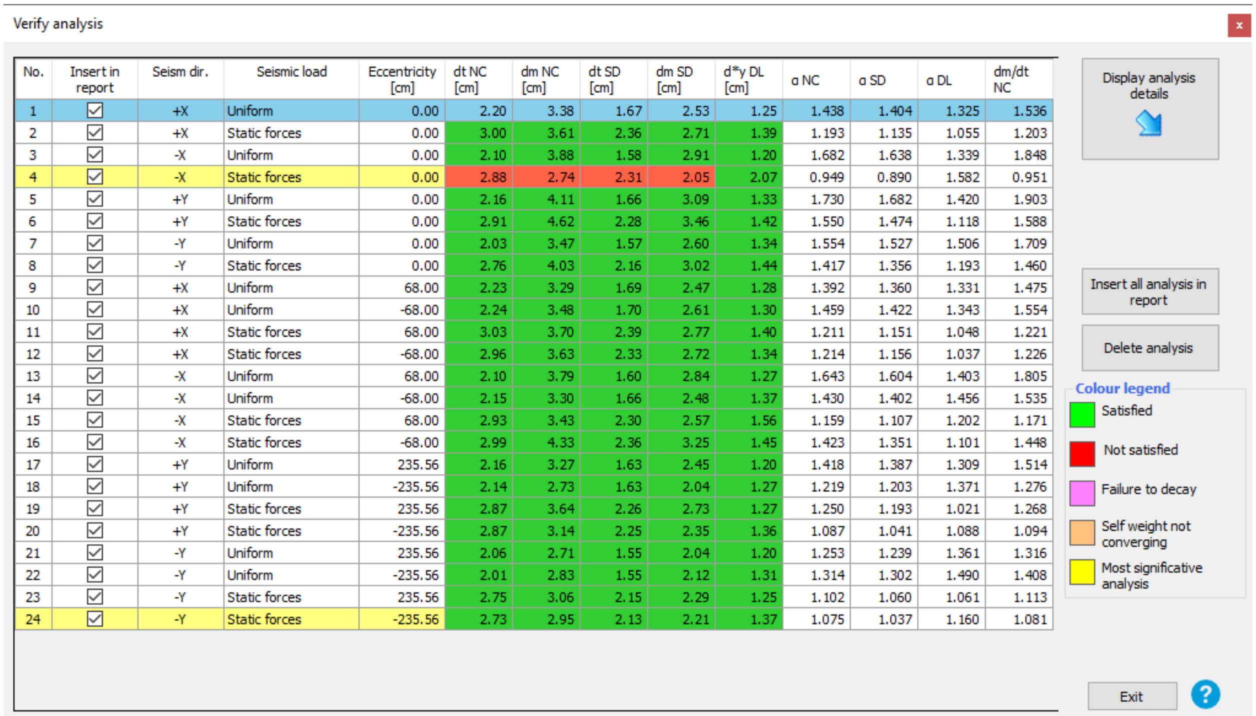


Figure 78. Computational model generated in 3Muri showing three of the component elements, piers spandrels and rigid nodes. The model presented in the axonometric version and the calculation model of the main facade in the western position of the building

Following the introductory explanation above, the 3Muri model and concept, always starting from the basic concept of equivalent frame model, rigorously addresses the bending mechanism considering the effective redistribution of the compressions to the partialization and discretization of the section, also to the achievement of the maximum compressive strength of the panel, while describing the "shear mechanism" according to the bond effect.

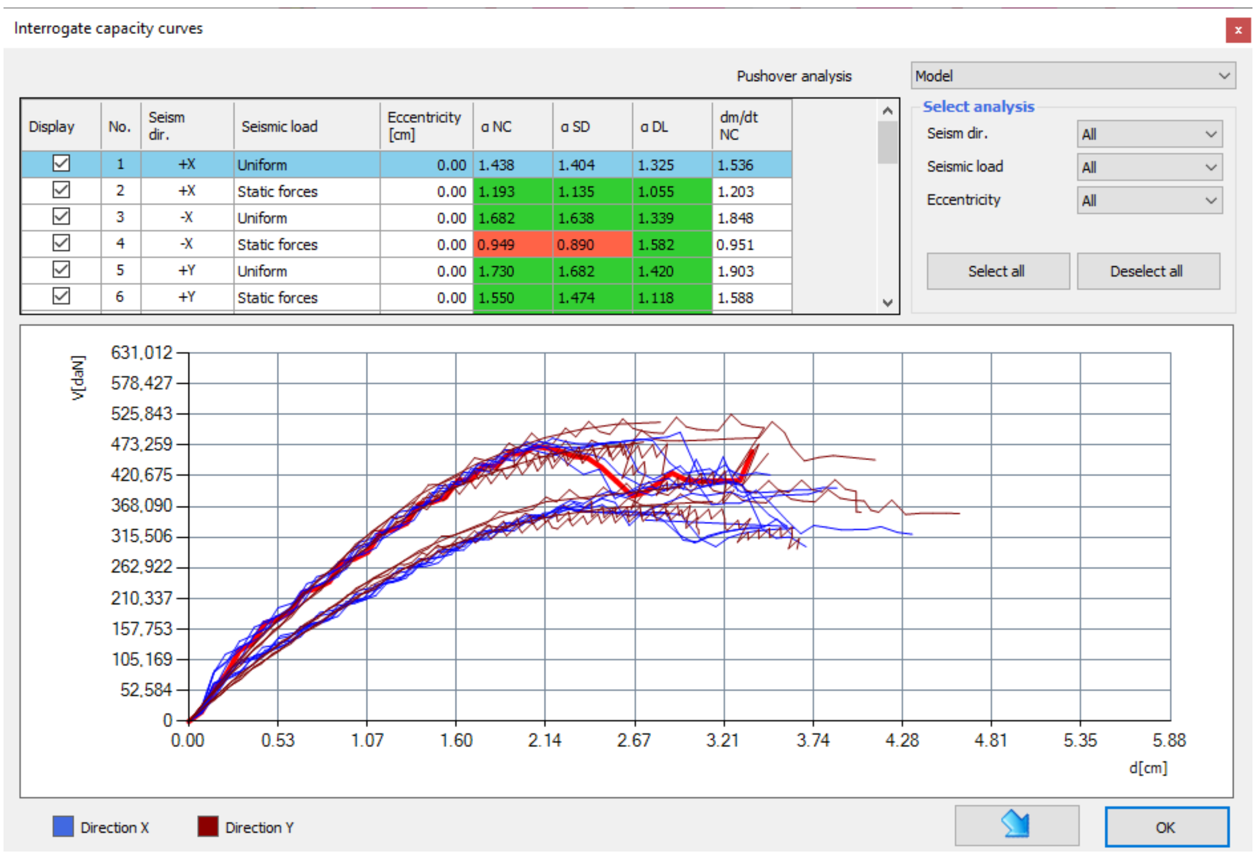
Structural masses and stiffnesses are distributed over all 3 dimensional model of degrees of freedom. The connection nodes and joints, belonging to a single wall panel, maintain their "degrees of freedom" in the local reference plane, while the nodes belonging to several walls connected in axonometric projection, must necessarily have the "degrees of freedom" in the global reference of the structure, considered "three-dimensional nodes".



Verify analysis

No.	Insert in report	Seism dir.	Seismic load	Eccentricity [cm]	dt NC [cm]	dm NC [cm]	dt SD [cm]	dm SD [cm]	d*y DL [cm]	α NC	α SD	α DL	dm/dt NC
1	☑	+X	Uniform	0.00	2.20	3.38	1.67	2.53	1.25	1.438	1.404	1.325	1.536
2	☑	+X	Static forces	0.00	3.00	3.61	2.36	2.71	1.39	1.193	1.135	1.055	1.203
3	☑	-X	Uniform	0.00	2.10	3.88	1.58	2.91	1.20	1.682	1.638	1.339	1.848
4	☑	-X	Static forces	0.00	2.88	2.74	2.31	2.05	2.07	0.949	0.890	1.582	0.951
5	☑	+Y	Uniform	0.00	2.16	4.11	1.66	3.09	1.33	1.730	1.682	1.420	1.903
6	☑	+Y	Static forces	0.00	2.91	4.62	2.28	3.46	1.42	1.550	1.474	1.118	1.588
7	☑	-Y	Uniform	0.00	2.03	3.47	1.57	2.60	1.34	1.554	1.527	1.506	1.709
8	☑	-Y	Static forces	0.00	2.76	4.03	2.16	3.02	1.44	1.417	1.356	1.193	1.460
9	☑	+X	Uniform	68.00	2.23	3.29	1.69	2.47	1.28	1.392	1.360	1.331	1.475
10	☑	+X	Uniform	-68.00	2.24	3.48	1.70	2.61	1.30	1.459	1.422	1.343	1.554
11	☑	+X	Static forces	68.00	3.03	3.70	2.39	2.77	1.40	1.211	1.151	1.048	1.221
12	☑	+X	Static forces	-68.00	2.96	3.63	2.33	2.72	1.34	1.214	1.156	1.037	1.226
13	☑	-X	Uniform	68.00	2.10	3.79	1.60	2.84	1.27	1.643	1.604	1.403	1.805
14	☑	-X	Uniform	-68.00	2.15	3.30	1.66	2.48	1.37	1.430	1.402	1.456	1.535
15	☑	-X	Static forces	68.00	2.93	3.43	2.30	2.57	1.56	1.159	1.107	1.202	1.171
16	☑	-X	Static forces	-68.00	2.99	4.33	2.36	3.25	1.45	1.423	1.351	1.101	1.448
17	☑	+Y	Uniform	235.56	2.16	3.27	1.63	2.45	1.20	1.418	1.387	1.309	1.514
18	☑	+Y	Uniform	-235.56	2.14	2.73	1.63	2.04	1.27	1.219	1.203	1.371	1.276
19	☑	+Y	Static forces	235.56	2.87	3.64	2.26	2.73	1.27	1.250	1.193	1.021	1.268
20	☑	+Y	Static forces	-235.56	2.87	3.14	2.25	2.35	1.36	1.087	1.041	1.088	1.094
21	☑	-Y	Uniform	235.56	2.06	2.71	1.55	2.04	1.20	1.253	1.239	1.361	1.316
22	☑	-Y	Uniform	-235.56	2.01	2.83	1.55	2.12	1.31	1.314	1.302	1.490	1.408
23	☑	-Y	Static forces	235.56	2.75	3.06	2.15	2.29	1.25	1.102	1.060	1.061	1.113
24	☑	-Y	Static forces	-235.56	2.73	2.95	2.13	2.21	1.37	1.075	1.037	1.160	1.081

Figure 79. Image of the summary table of the number of analyzes performed in the framework of pushover analysis in 3Muri-v.13



Interrogate capacity curves

Display	No.	Seism dir.	Seismic load	Eccentricity [cm]	α NC	α SD	α DL	dm/dt NC
☑	1	+X	Uniform	0.00	1.438	1.404	1.325	1.536
☑	2	+X	Static forces	0.00	1.193	1.135	1.055	1.203
☑	3	-X	Uniform	0.00	1.682	1.638	1.339	1.848
☑	4	-X	Static forces	0.00	0.949	0.890	1.582	0.951
☑	5	+Y	Uniform	0.00	1.730	1.682	1.420	1.903
☑	6	+Y	Static forces	0.00	1.550	1.474	1.118	1.588

Figure 80. Summary diagram of structure capacity curves according to 24 nonlinear analyzes according to the combination of 2 seismic directions

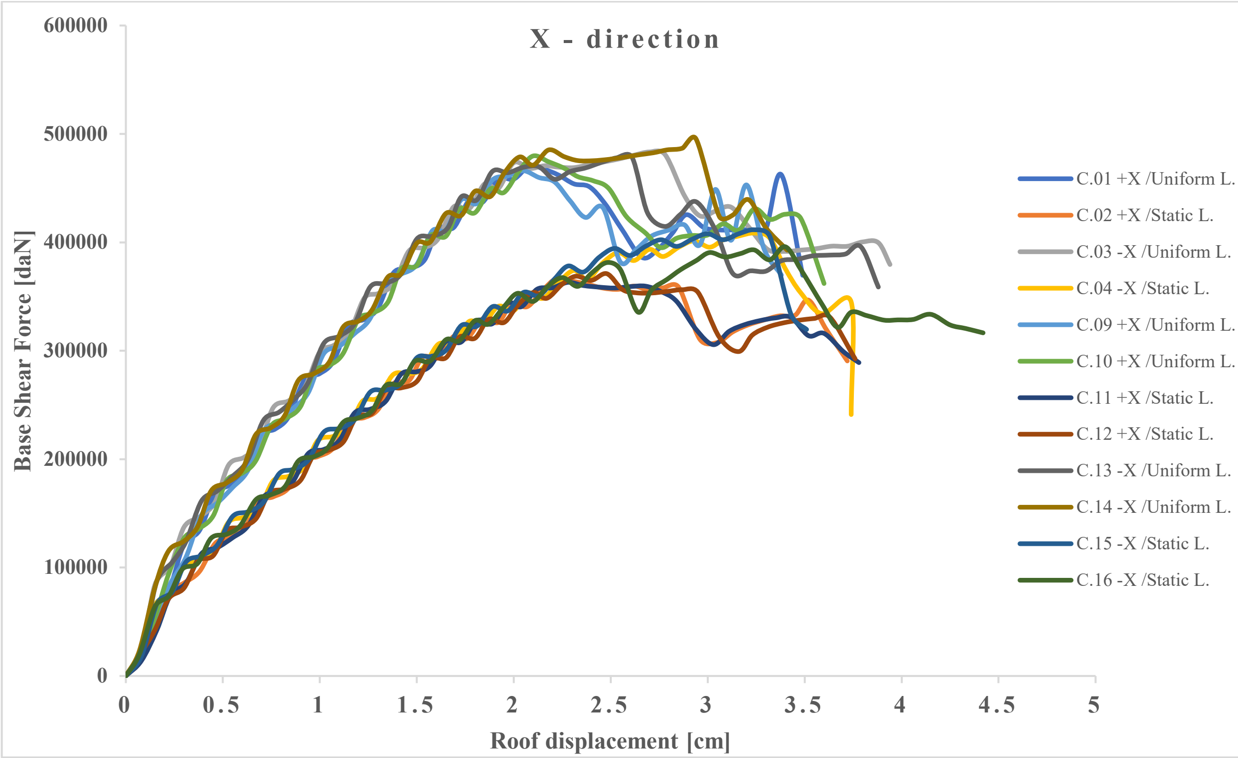


Figure 81. +X and -X direction combined capacity diagrams, processed from 3Muri numerical data

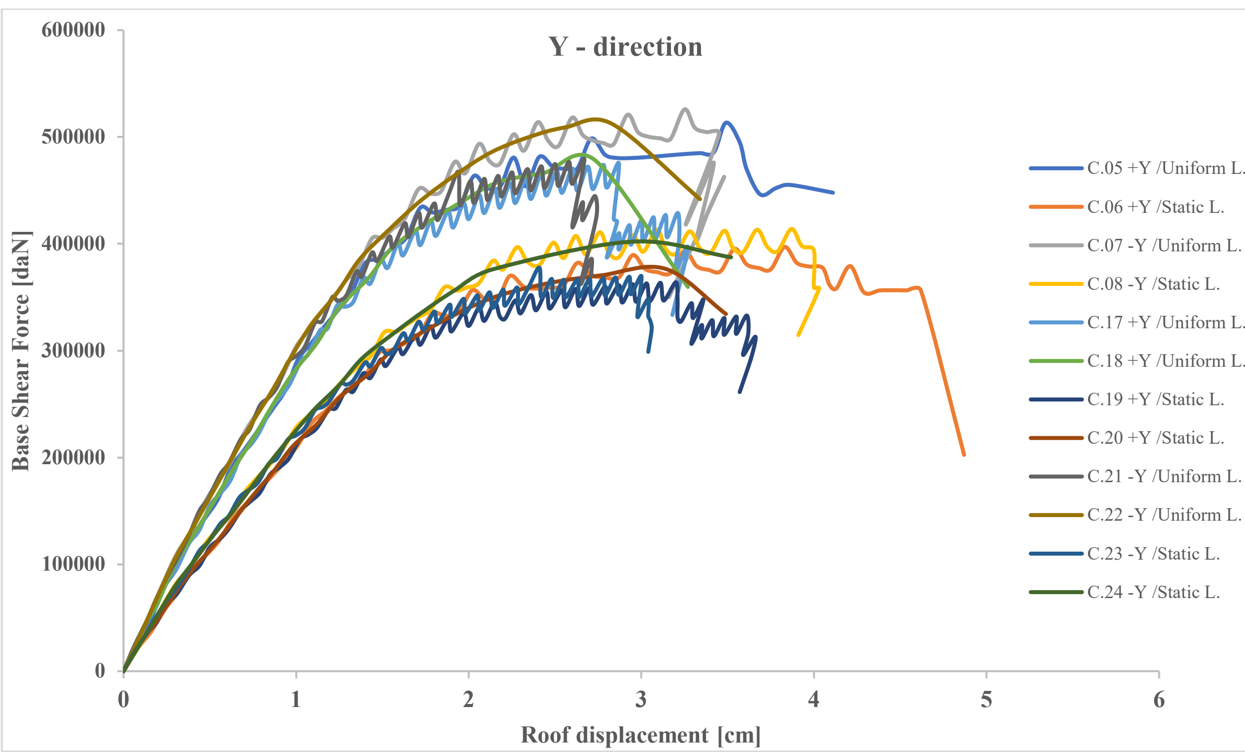
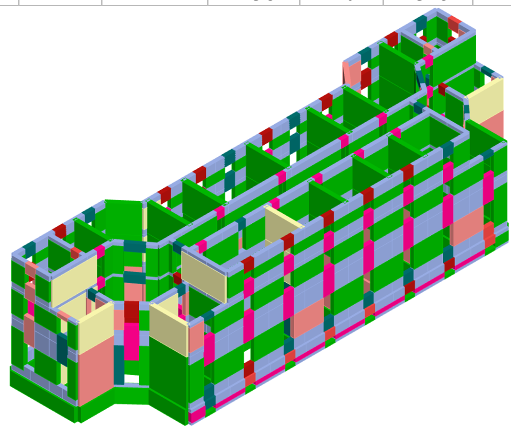
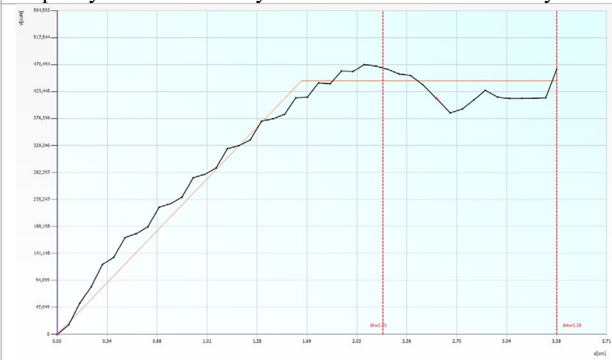


Figure 82. +Y and -Y direction combined capacity diagrams, processed from 3Muri numerical data

Table 12. Summary table of results obtained, after performing nonlinear analyzes on 3Muri v.13 software

No	Seism dir.	Seismic load	α NC	α SD	α DL	dm/dt NC	Capacity Curve
1	+X	Uniform	1.438	1.404	1.325	1.536	Capacity curve 01 / Analysis no.01 / +X dir./Eccentricity 0cm

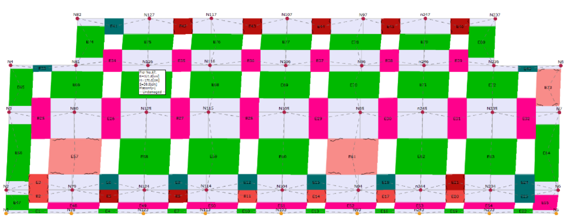


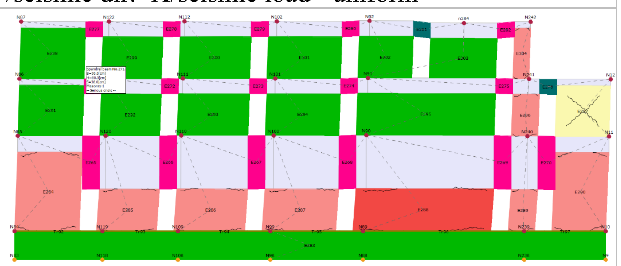


dt=2.20cm [NC]	dm=3.38cm [NC]	T*=0.465s

Analysis-01/Mechanism P.1 /Main façade masonry /seismic dir.+X/seismic load =uniform

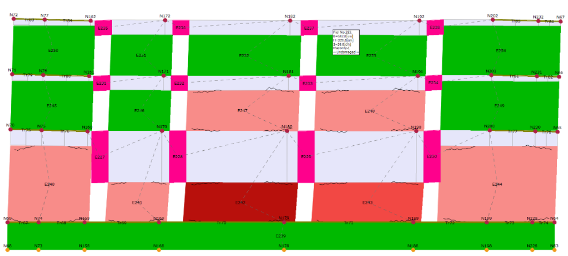
Analysis-01/Mechanism P.17 /Internal hall masonry /seismic dir.+X/seismic load =uniform

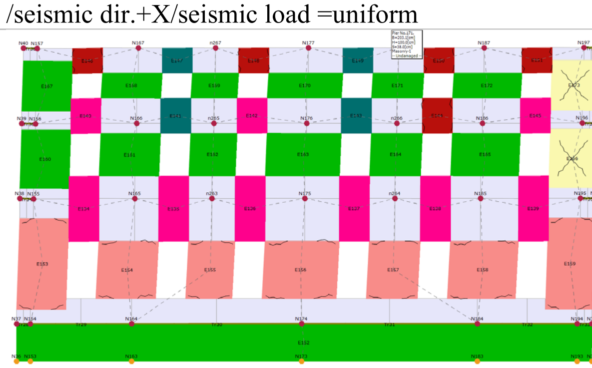




Analysis-01/Mechanism P.15 /2nd Internal hall masonry /seismic dir.+X/seismic load =uniform

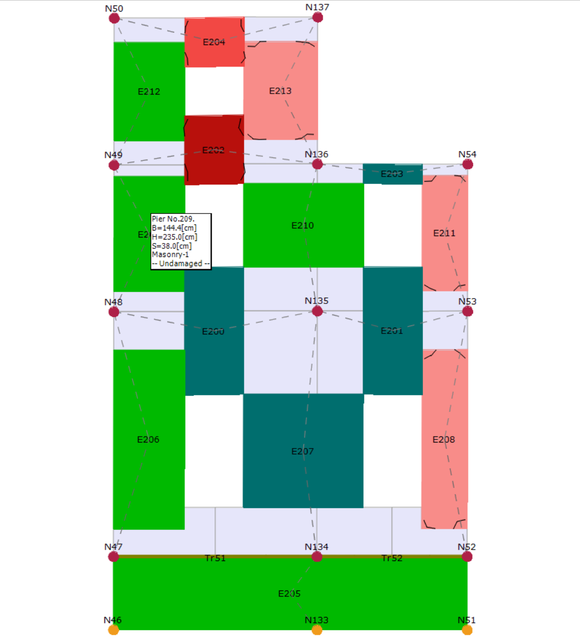
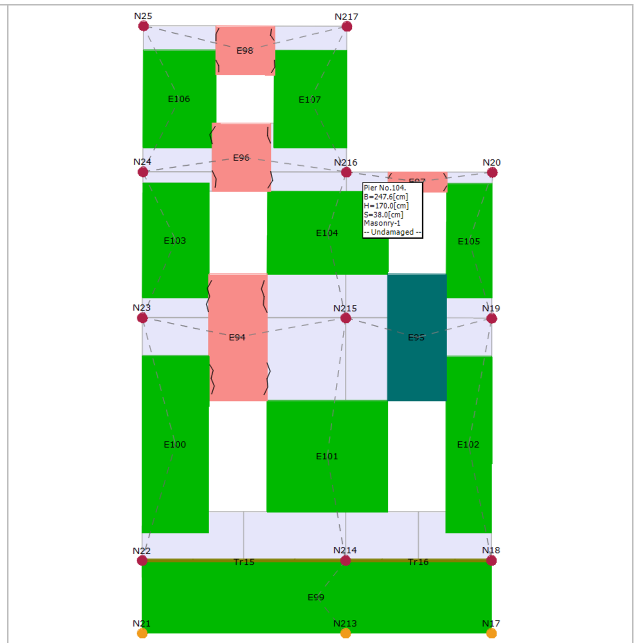
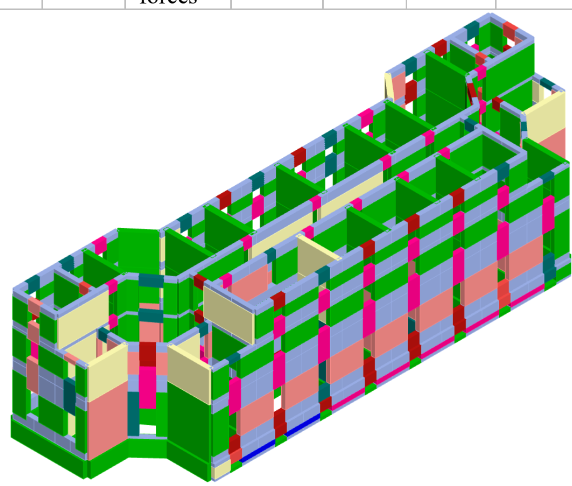
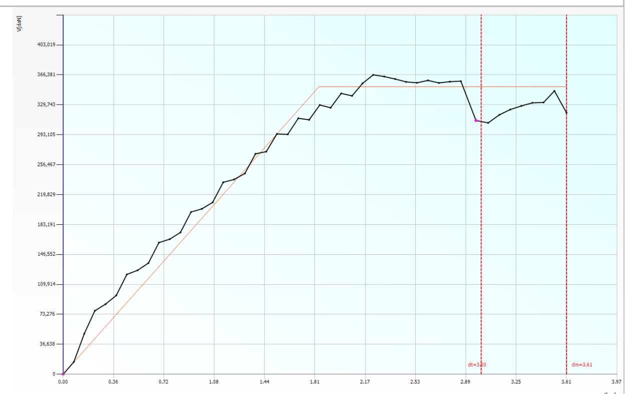
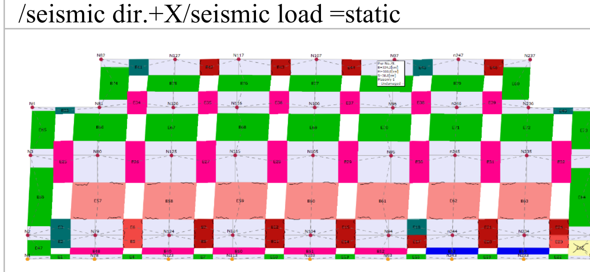
Analysis-01/Mechanism P.08 /Back façade masonry /seismic dir.+X/seismic load =uniform

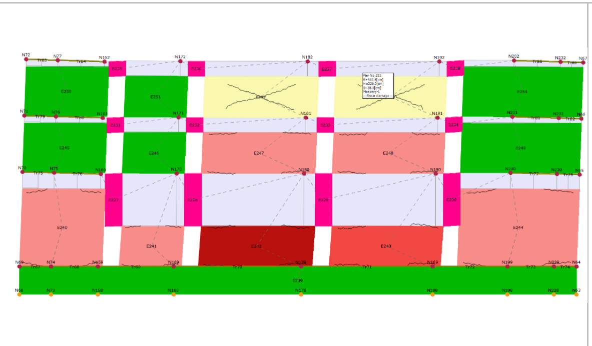




Analysis-01/Mechanism P.11 /South side façade masonry /seismic dir.+X/seismic load =uniform

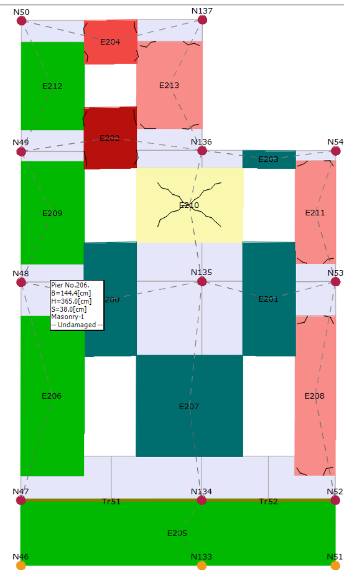
Analysis-01/Mechanism P.05 /North side façade masonry /seismic dir.+X/seismic load =uniform

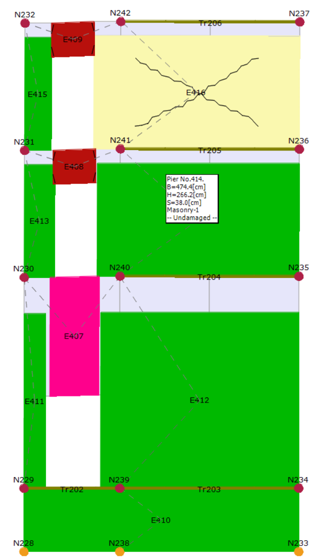
<table>
<tr><td colspan="7"></td><td colspan="3"></td></tr>
<tr><td>No</td><td>Seism dir.</td><td>Seismic load</td><td>α NC</td><td>α SD</td><td>α DL</td><td>dm/dt NC</td><td colspan="3">Capacity Curve</td></tr>
<tr><td>2</td><td>+X</td><td>Static forces</td><td>1.193</td><td>1.135</td><td>1.055</td><td>1.203</td><td colspan="3">Capacity curve 02 / Analysis no.02 / +X dir./Eccentricity 0cm</td></tr>
<tr><td colspan="7" rowspan="2"></td><td colspan="3"></td></tr>
<tr><td>dt=3.00cm [NC]</td><td>dm=3.61cm [NC]</td><td>T*=0.549s</td></tr>
<tr><td colspan="7">Analysis-02/Mechanism P.1 /Main façade masonry /seismic dir.+X/seismic load =static</td><td colspan="3">Analysis-02/Mechanism P.17 /Internal hall masonry /seismic dir.+X/seismic load =static</td></tr>
<tr><td colspan="7"></td><td colspan="3"></td></tr>
<tr><td colspan="7">Analysis-02/Mechanism P.15 /2nd Internal hall masonry /seismic dir.+X/seismic load =static</td><td colspan="3">Analysis-02/Mechanism P.08 /Back façade masonry /seismic dir.+X/seismic load =static</td></tr>
</table>



Analysis-02/Mechanism P.11 /South side façade masonry /seismic dir.+X/seismic load =static

Analysis-02/Mechanism P.34 /Internal masonry /seismic dir.+X/seismic load =static

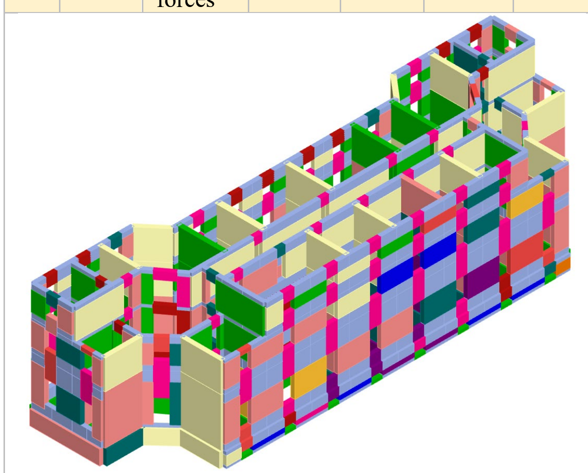


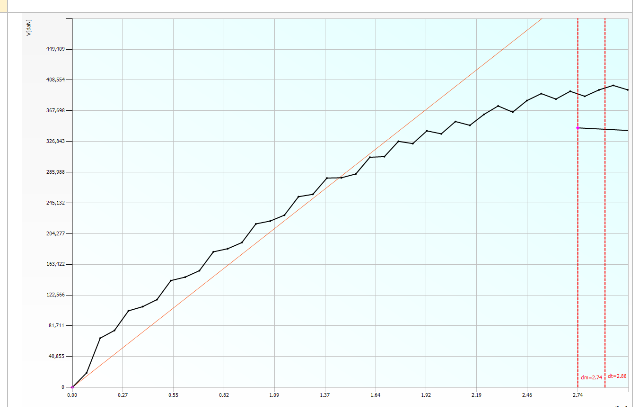


No	Seism dir.	Seismic load	α NC	α SD	α DL	dm/dt NC
4	-X	Static forces	0.949	0.890	1.582	0.951

Capacity Curve

Capacity curve 04 / Analysis no.04 / -X dir./Eccenticity 0cm

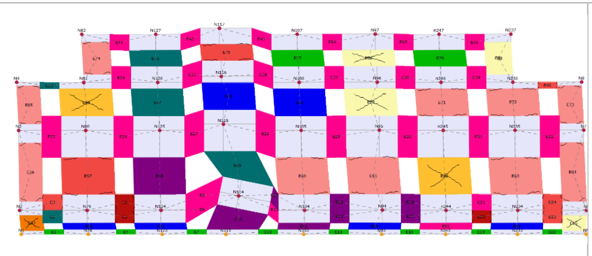




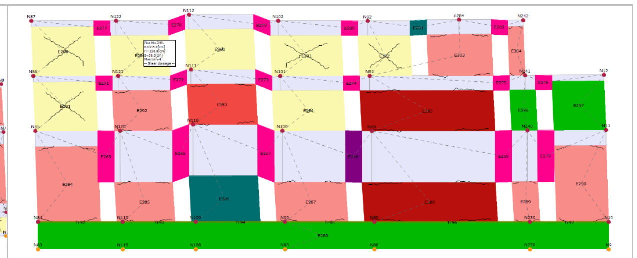
dt=2.88cm [NC]	dm=2.74cm [NC]	T*=0.548s
Not satisfied verification		

Analysis-04/Mechanism P.1 /Main façade masonry /seismic dir.-X/seismic load =static

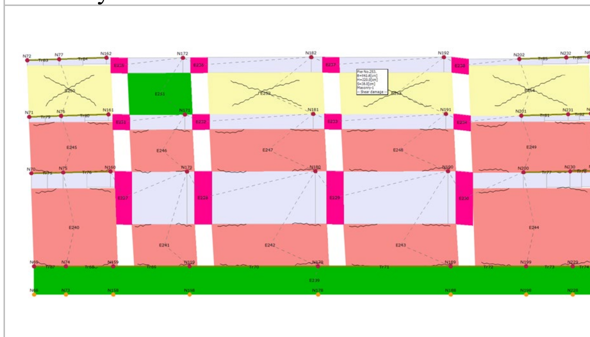
Analysis-04/Mechanism P.17 /Internal hall masonry /seismic dir.-X/seismic load =static



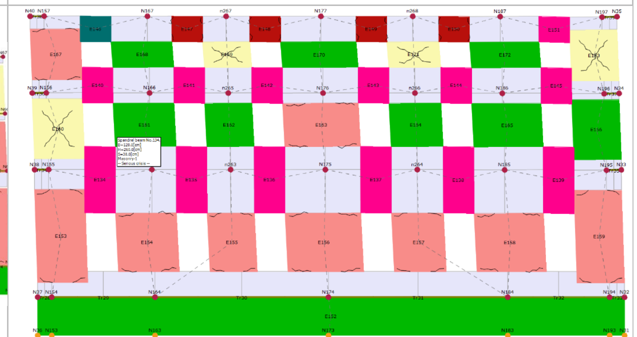
Analysis-04/Mechanism P.15 /2nd Internal hall masonry /seismic dir.-X/seismic load =static



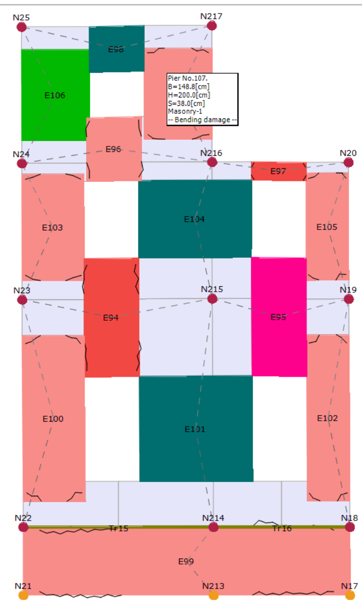
Analysis-04/Mechanism P.08 /Back façade masonry /seismic dir.-X/seismic load =static



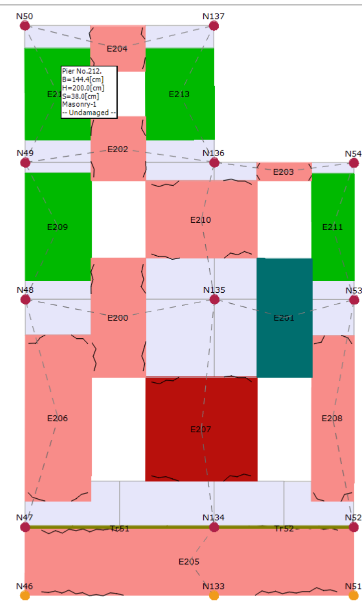
Analysis-04/Mechanism P.05 /North side façade masonry /seismic dir.-X/seismic load =static



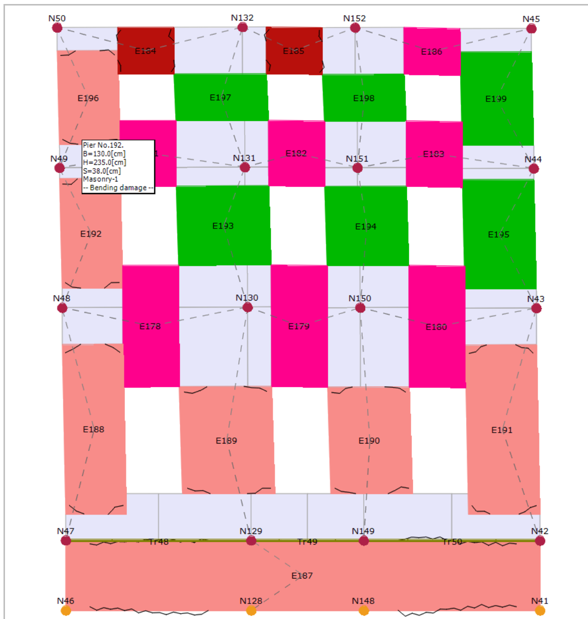
Analysis-04/Mechanism P.11 /South side façade masonry /seismic dir.-X/seismic load =static



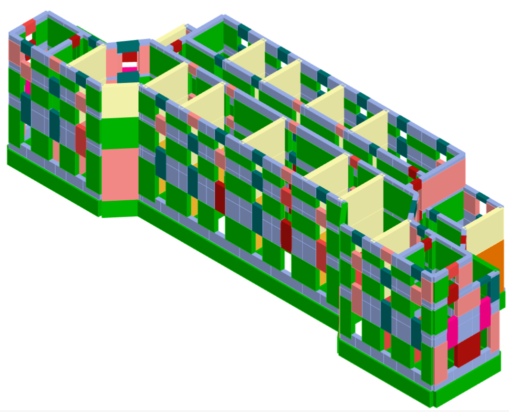
Analysis-04/Mechanism P.10 /S.Perimetral masonry /seismic dir.-X/seismic load =static

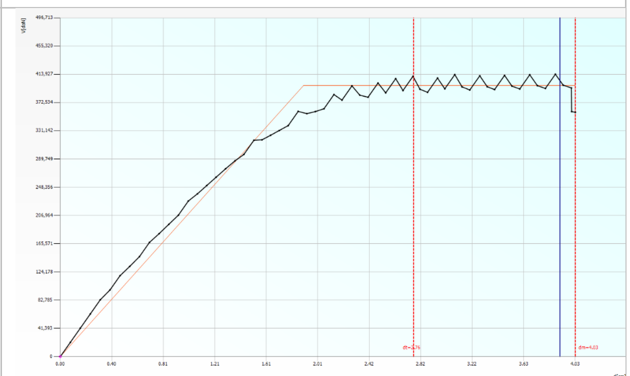


Analysis-04/Mechanism P.06 /N.Perimetral masonry /seismic dir.-X/seismic load =static



No	Seism dir.	Seismic load	α NC	α SD	α DL	dm/dt NC	Capacity Curve
8	-Y	Static forces	1.317	1.256	1.093	1.460	Capacity curve 08 / Analysis no.08 / -Y dir./Eccenticity 0cm

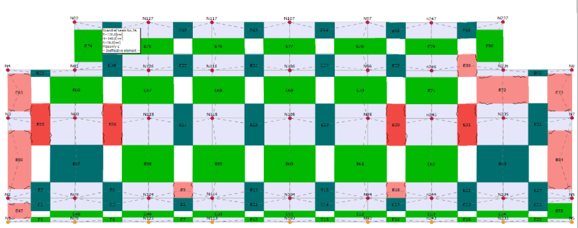


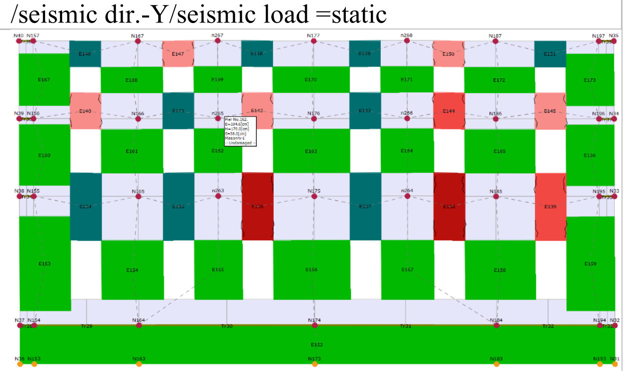


dt=2.76cm [NC]	dm=4.03cm [NC]	T*=0.525s

Analysis-08/Mechanism P.1 /Main façade masonry /seismic dir.-Y/seismic load =static

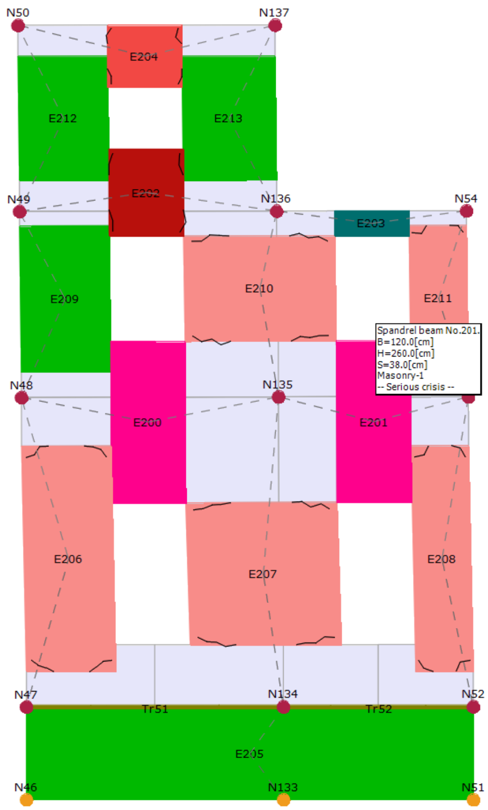
Analysis-08/Mechanism P.17 /Internal hall masonry /seismic dir.-Y/seismic load =static



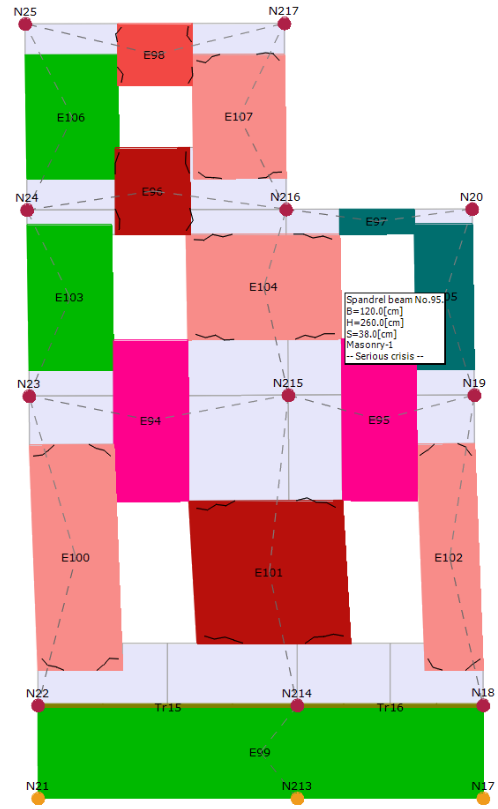


Analysis-08/Mechanism P.11 /South side façade masonry /seismic dir.-Y/seismic load =static

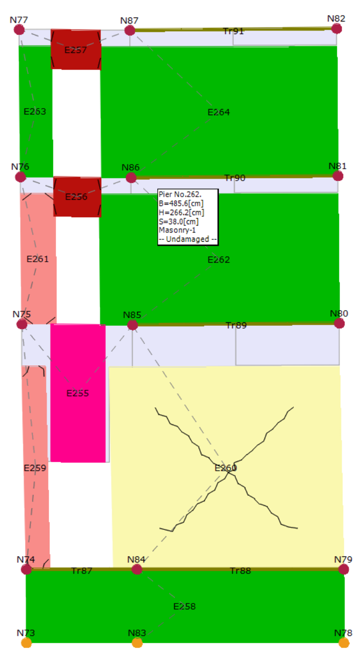
Analysis-08/Mechanism P.05 / North side façade masonry /seismic dir.-Y/seismic load =static

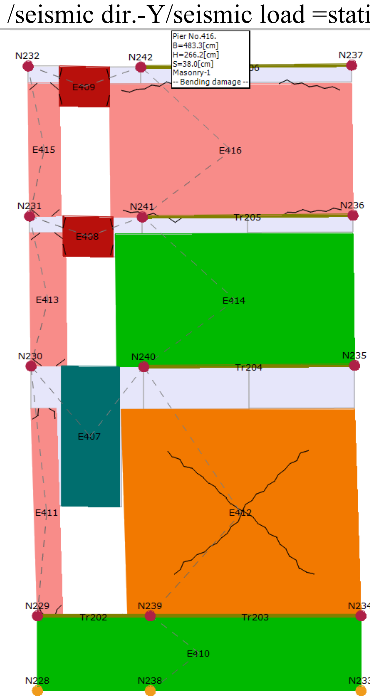


Analysis-08/Mechanism P.16 /Internal masonry /seismic dir.-Y/seismic load =static

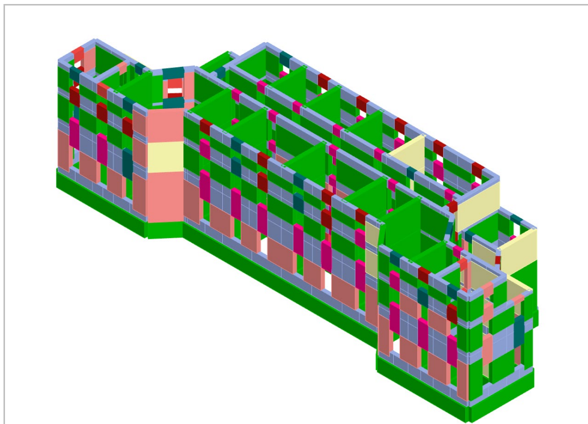


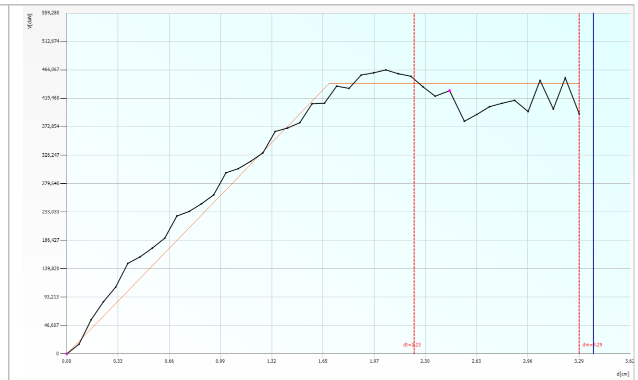
Analysis-08/Mechanism P.34 /Internal masonry /seismic dir.-Y/seismic load =static





No	Seism dir.	Seismic load	α NC	α SD	α DL	dm/dt NC	Capacity Curve
9	+X	Uniform	1.392	1.360	1.331	1.475	Capacity curve 09 / Analysis no.09 / +X dir./Eccenticity 68cm

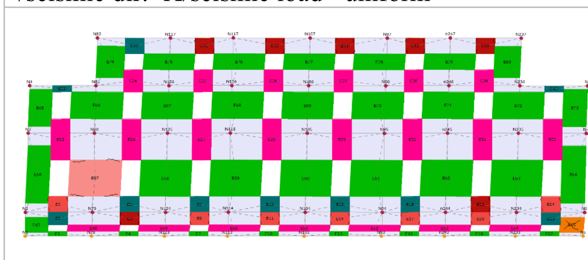




dt=2.23cm [NC] | dm=3.29cm [NC] | T*=0.469s

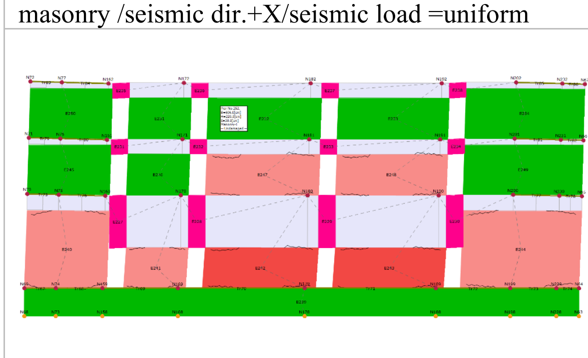
Analysis-09/Mechanism P.1 /Main façade masonry /seismic dir.+X/seismic load =uniform

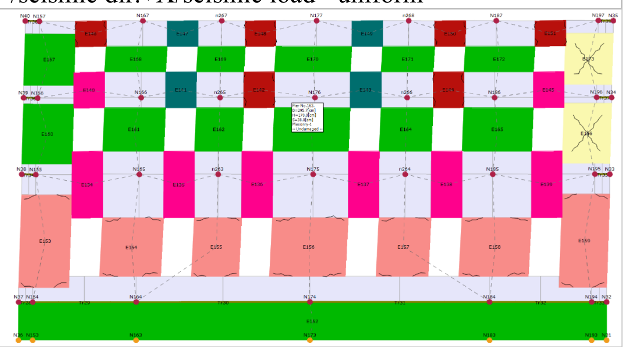
Analysis-09/Mechanism P.17 /Internal hall masonry /seismic dir.+X/seismic load =uniform



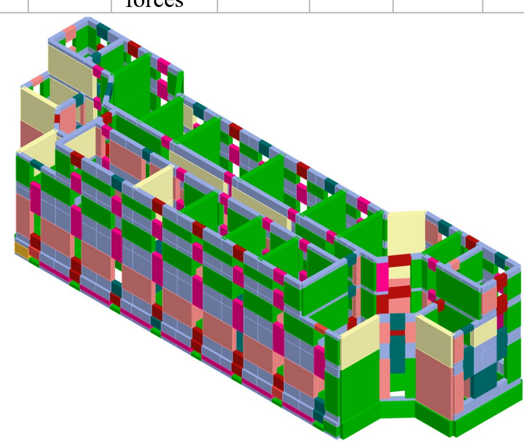
Analysis-09/Mechanism P.15 /2nd Internal hall masonry /seismic dir.+X/seismic load =uniform

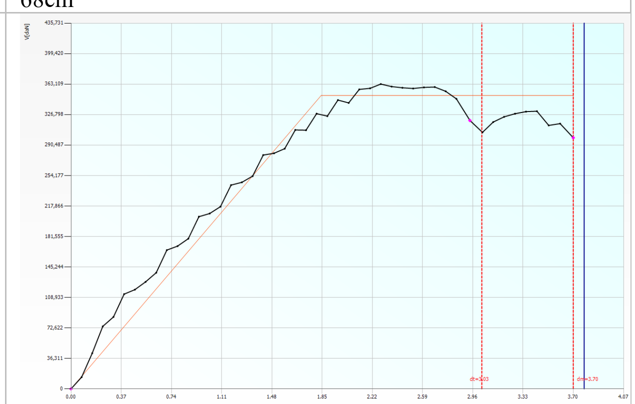
Analysis-09/Mechanism P.08 /Back façade masonry /seismic dir.+X/seismic load =uniform





No	Seism dir.	Seismic load	α NC	α SD	α DL	dm/dt NC	Capacity Curve
11	+X	Static forces	1.211	1.151	1.048	1.221	Capacity curve 11 / Analysis no.11 / +X dir./Eccenticity 68cm

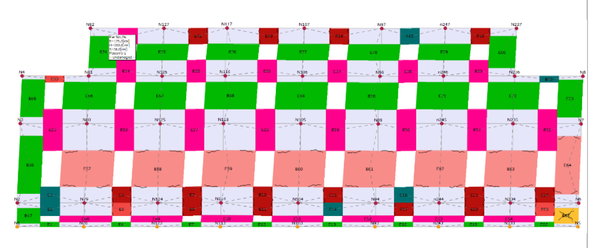




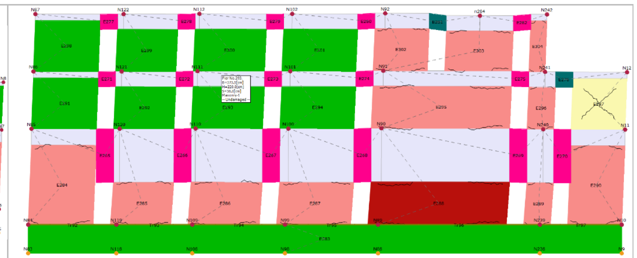
dt=3.03cm [NC] | dm=3.70cm [NC] | T*=0.552s

Analysis-11/Mechanism P.1 /Main façade masonry /seismic dir.-X/seismic load =static

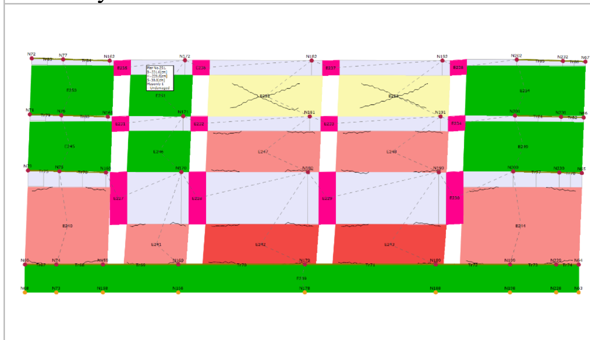
Analysis-11/Mechanism P.17 /Internal hall masonry /seismic dir.-X/seismic load =static

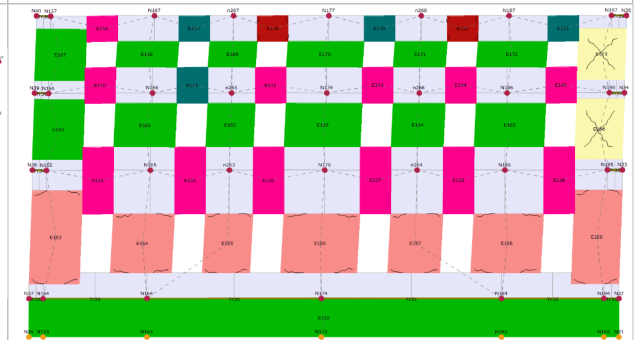


Analysis-11/Mechanism P.15 /2nd Internal hall masonry /seismic dir.-X/seismic load =static

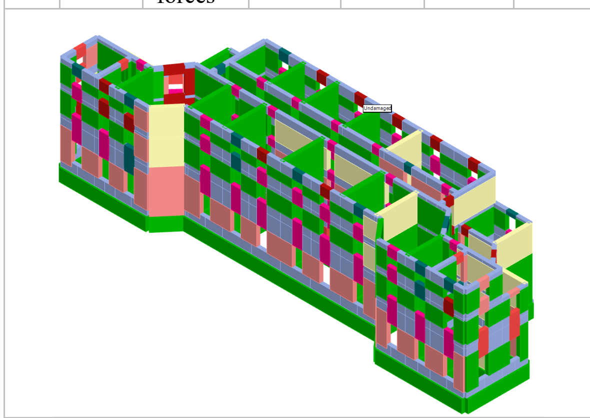


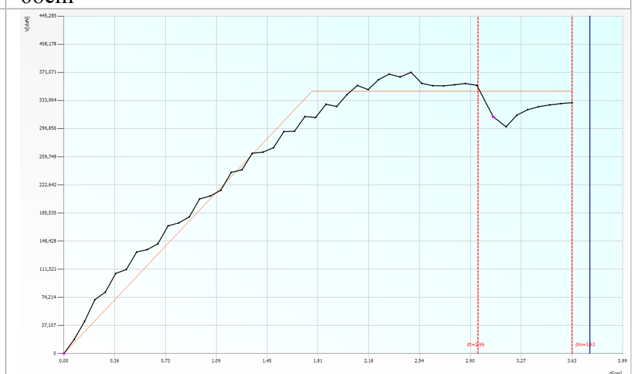
Analysis-11/Mechanism P.08 /Back façade masonry /seismic dir.-X/seismic load =static





No	Seism dir.	Seismic load	α NC	α SD	α DL	dm/dt NC	Capacity Curve
12	+X	Static forces	1.214	1.156	1.037	1.226	Capacity curve 12 / Analysis no.12 / +X dir./Eccenticity 68cm

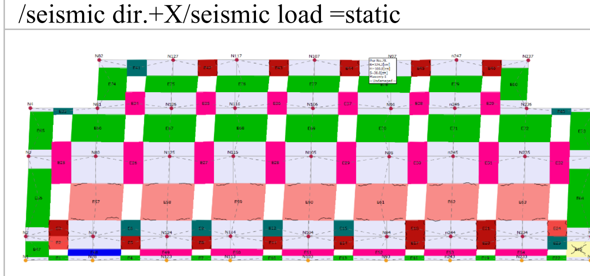




dt=3.03cm [NC]	dm=3.70cm [NC]	T*=0.552s

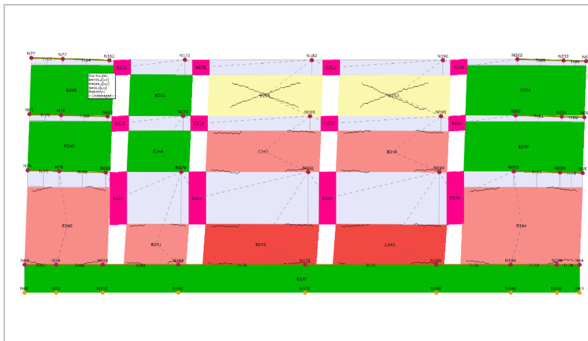
Analysis-12/Mechanism P.1 /Main façade masonry /seismic dir.+X/seismic load =static

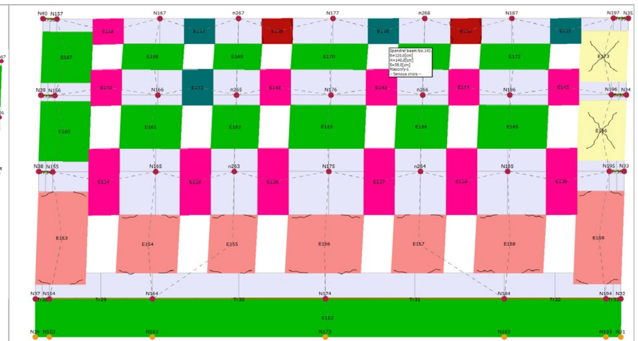
Analysis-12/Mechanism P.17 /Internal hall masonry /seismic dir.+X/seismic load =static



Analysis-12/Mechanism P.15 /2nd Internal hall masonry /seismic dir.+X/seismic load =static

Analysis-12/Mechanism P.08 /Back façade masonry /seismic dir.+X/seismic load =static





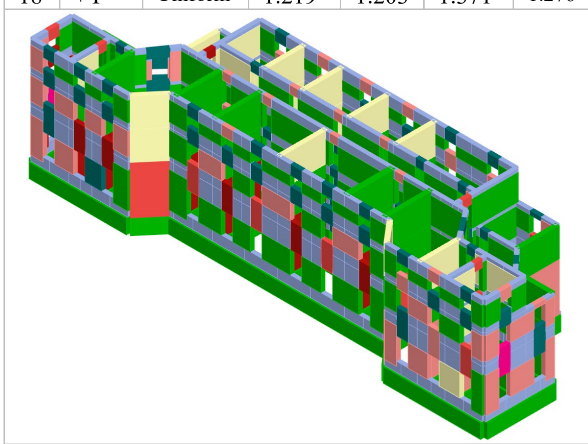
No	Seism dir.	Seismic load	α NC	α SD	α DL	dm/dt NC
13	-X	Uniform	1.643	1.604	1.403	1.805
14	-X	Uniform	1.430	1.402	1.456	1.535
15	-X	Static forces	1.159	1.107	1.202	1.171
16	-X	Static forces	1.423	1.351	1.101	1.448
17	+Y	Uniform	1.418	1.387	1.309	1.514

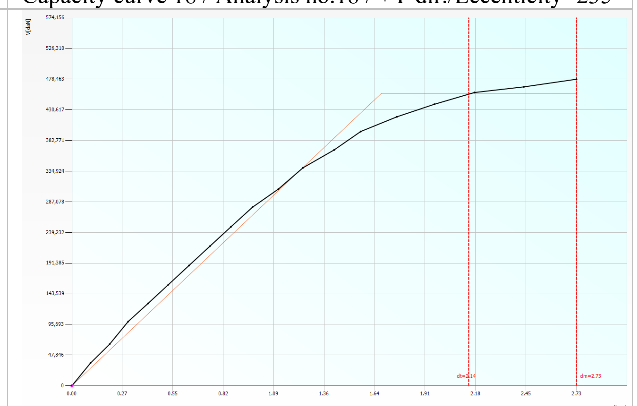
Capacity Curve

No	Seism dir.	Seismic load	α NC	α SD	α DL	dm/dt NC
18	+Y	Uniform	1.219	1.203	1.371	1.276

Capacity Curve

Capacity curve 18 / Analysis no.18 / +Y dir./Eccentiricity -235

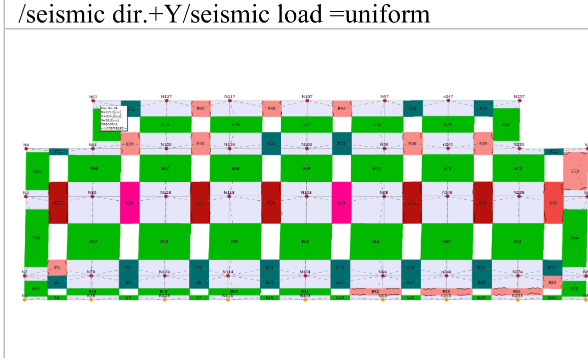


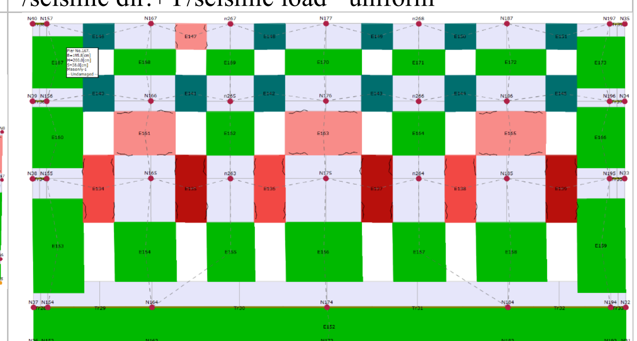


dt=2.14cm [NC] dm=2.73cm [NC] T*=0.460s

Analysis-18/Mechanism P.1 /Main façade masonry /seismic dir.+Y/seismic load =uniform

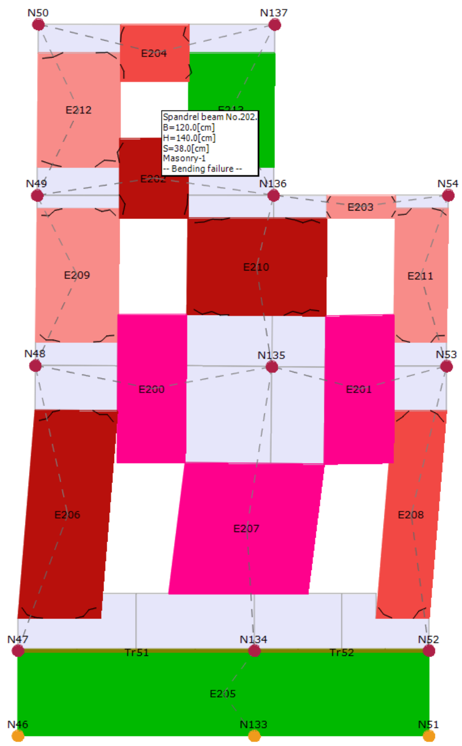
Analysis-18/Mechanism P.08 /Back façade masonry /seismic dir.+Y/seismic load =uniform

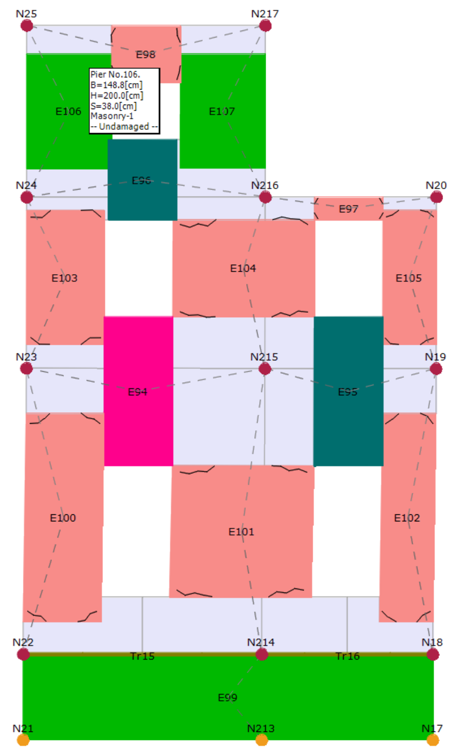




Analysis-18/Mechanism P.11 /South façade masonry /seismic dir.+Y/seismic load =uniform

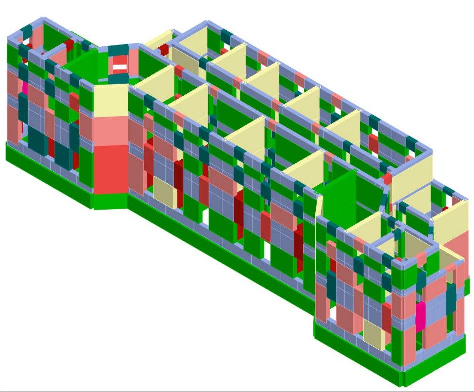
Analysis-18/Mechanism P.05 /North façade masonry /seismic dir.+Y/seismic load =uniform

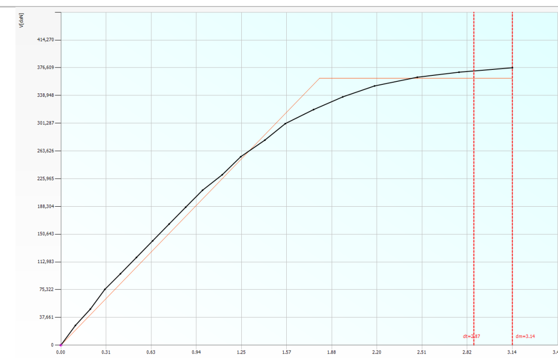




No	Seism dir.	Seismic load	α NC	α SD	α DL	dm/dt NC	Capacity Curve
19	+Y	Static forces	1.250	1.193	1.021	1.268	

No	Seism dir.	Seismic load	α NC	α SD	α DL	dm/dt NC	Capacity Curve
20	+Y	Static forces	1.087	1.041	1.088	1.094	Capacity curve 20 / Analysis no.20 / +Y dir./Eccenticity -235

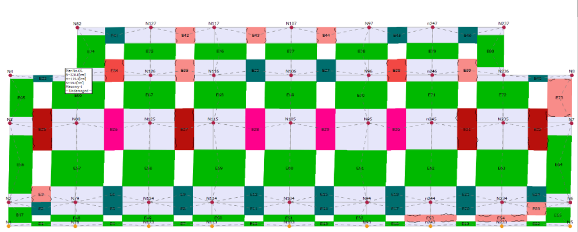


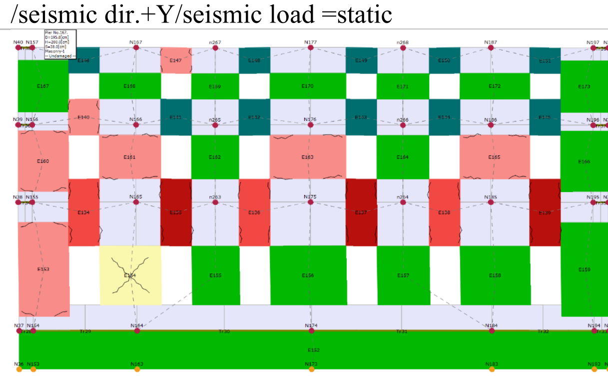


dt=2.87cm [NC]	dm=3.14cm [NC]	T*=0.535s

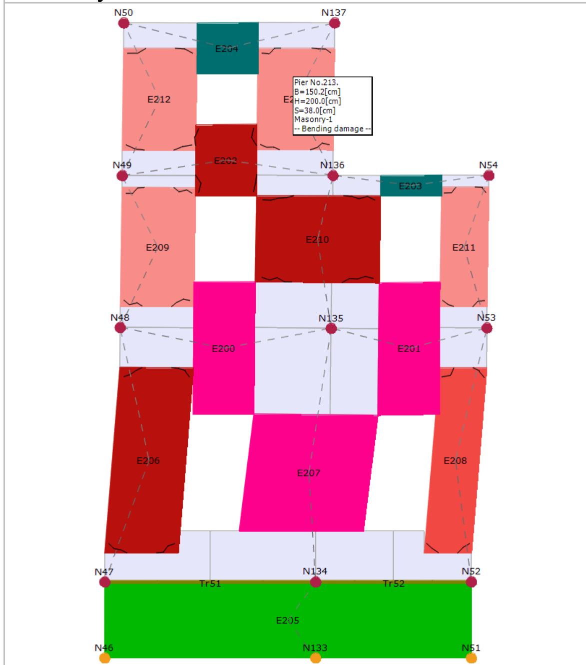
Analysis-20/Mechanism P.1 /Main façade masonry /seismic dir.+Y/seismic load =static

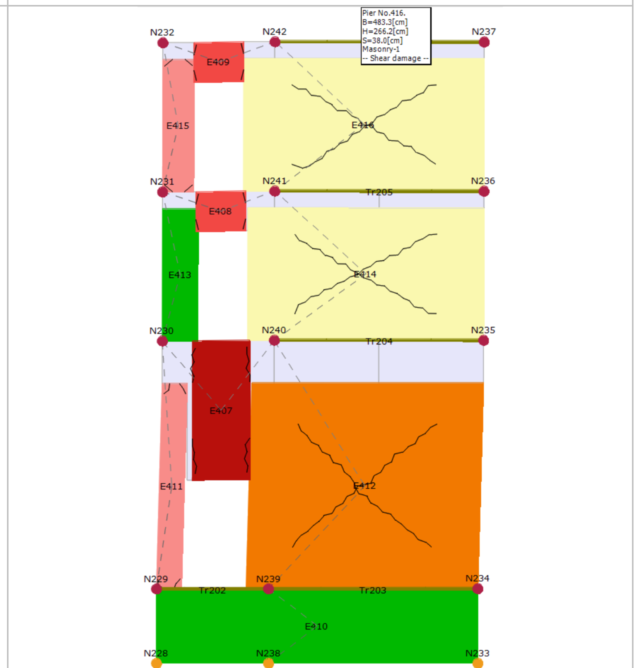
Analysis-20/Mechanism P.08 /Back façade masonry /seismic dir.+Y/seismic load =static





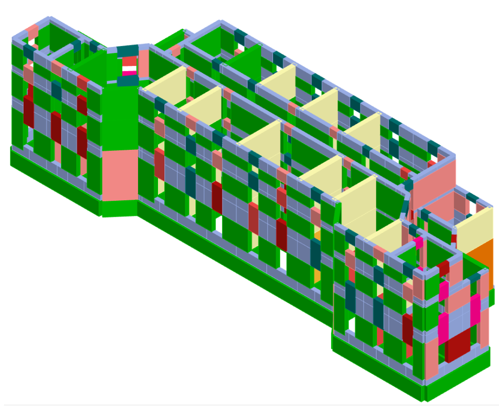
Analysis-20/Mechanism P.11 /South façade masonry /seismic dir.+Y/seismic load =static	Analysis-20/Mechanism P.34 /Internal masonry /seismic dir.+Y/seismic load =static

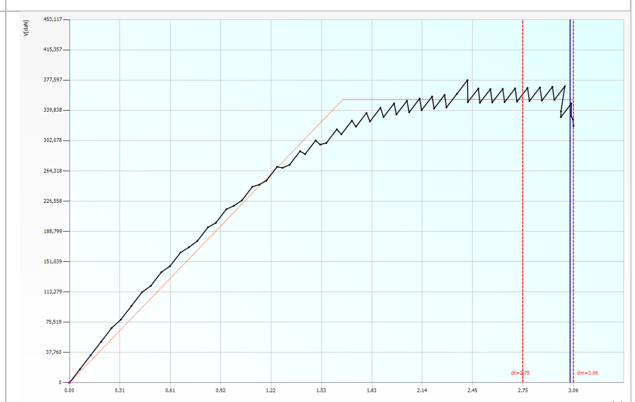




No	Seism dir.	Seismic load	α NC	α SD	α DL	dm/dt NC	Capacity Curve
21	-Y	Uniform	1.253	1.239	1.361	1.316	
22	-Y	Uniform	1.314	1.302	1.490	1.408	

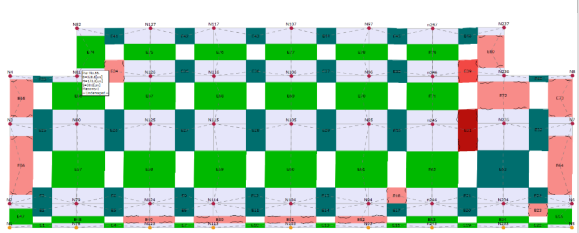
No	Seism dir.	Seismic load	α NC	α SD	α DL	dm/dt NC	Capacity Curve
23	-Y	Static forces	1.102	1.060	1.061	1.113	Capacity curve 23 / Analysis no.23 / -Y dir./Eccentricity +235

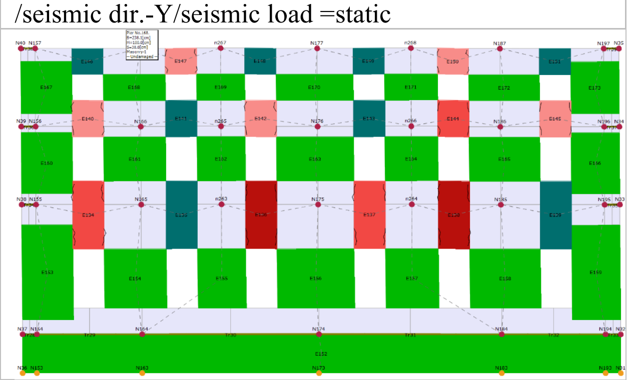




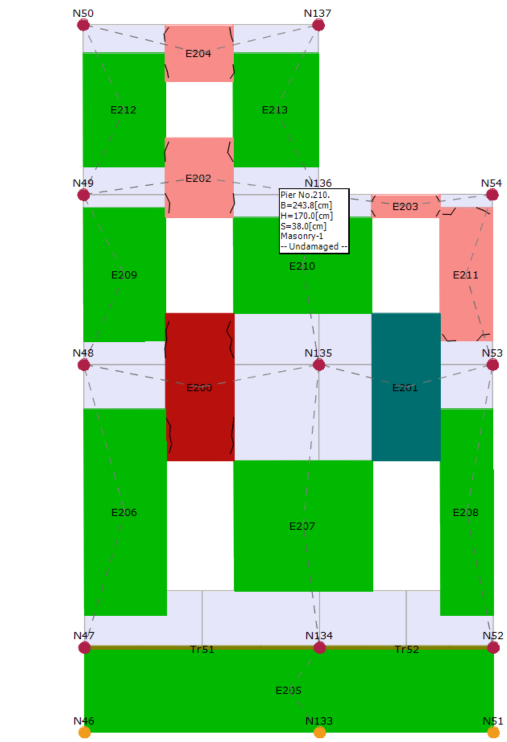
dt=2.75cm [NC]	dm=3.06cm [NC]	T*=0.520s

Analysis-23/Mechanism P.1 /Main façade masonry /seismic dir.-Y/seismic load =static	Analysis-23/Mechanism P.08 /Back façade masonry /seismic dir.-Y/seismic load =static

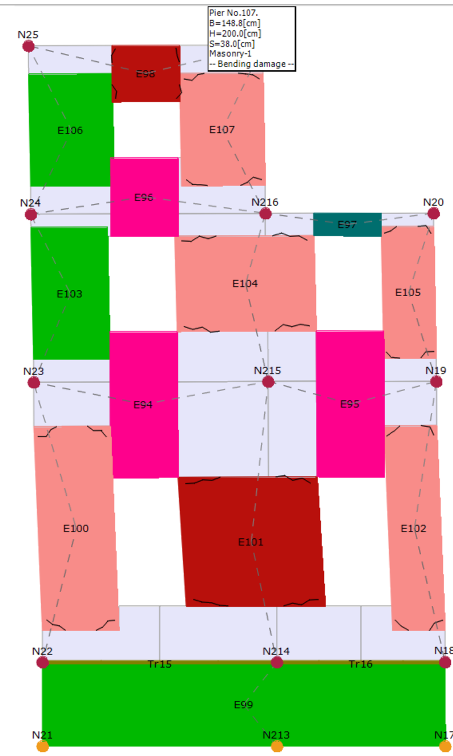




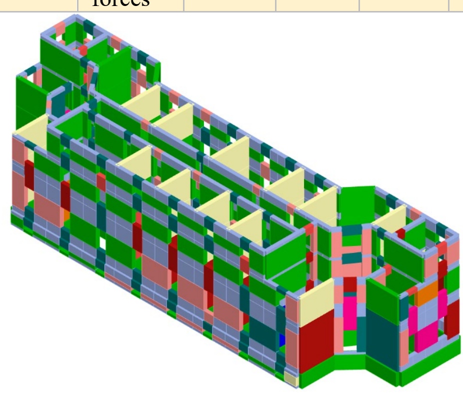
Analysis-23/Mechanism P.11 /South façade masonry /seismic dir.-Y/seismic load =static

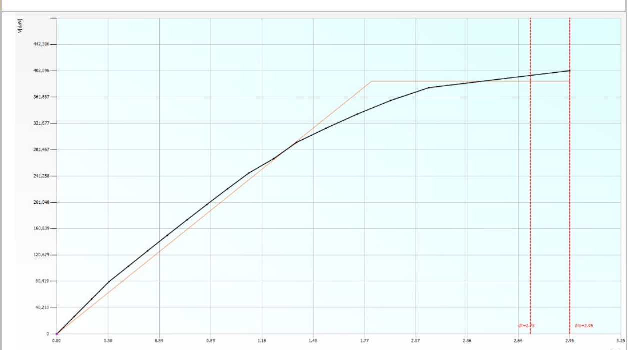


Analysis-23/Mechanism P.05 /North façade masonry /seismic dir.-Y/seismic load =static



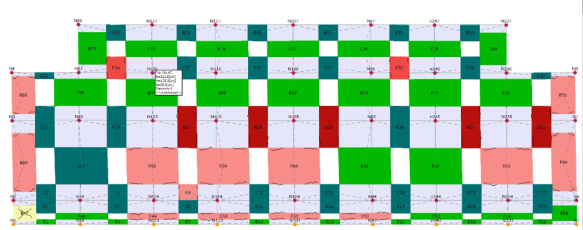
No	Seism dir.	Seismic load	α NC	α SD	α DL	dm/dt NC	Capacity Curve
24	-Y	Static forces	1.065	1.047	1.106	1.081	Capacity curve 24 / Analysis no.24 / -Y dir./Eccenticity -235



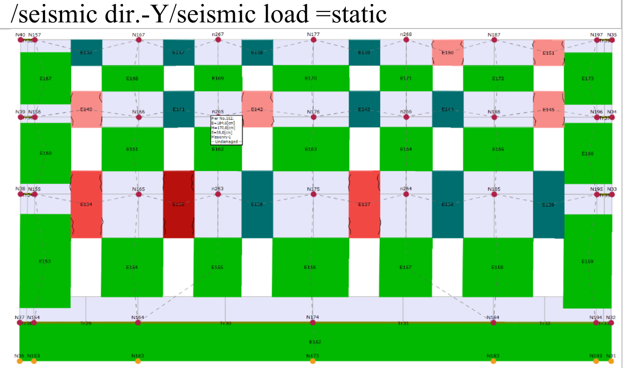


dt=2.73cm [NC]	dm=2.95cm [NC]	T*=0.520s

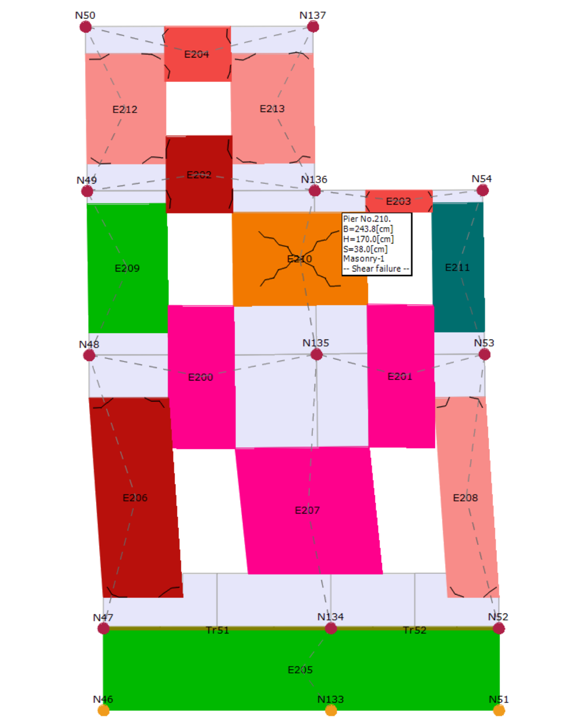
Analysis-24/Mechanism P.1 /Main façade masonry /seismic dir.-Y/seismic load =static



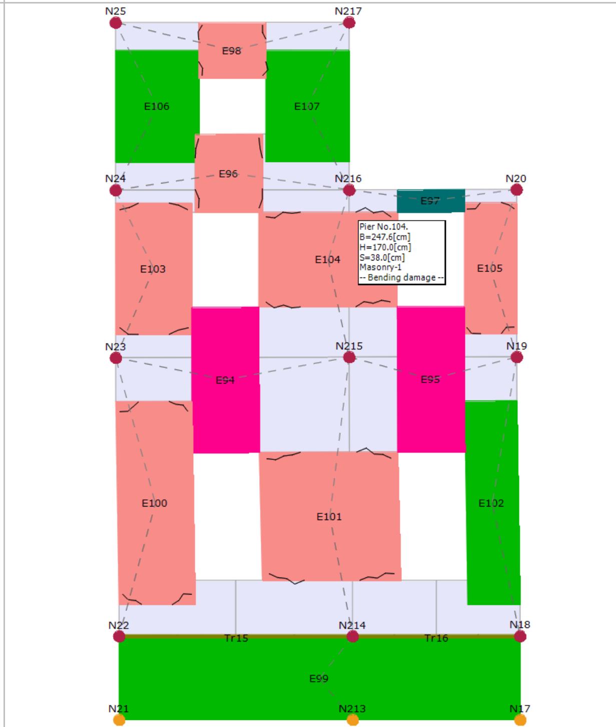
Analysis-24/Mechanism P.08 /Back façade masonry /seismic dir.-Y/seismic load =static



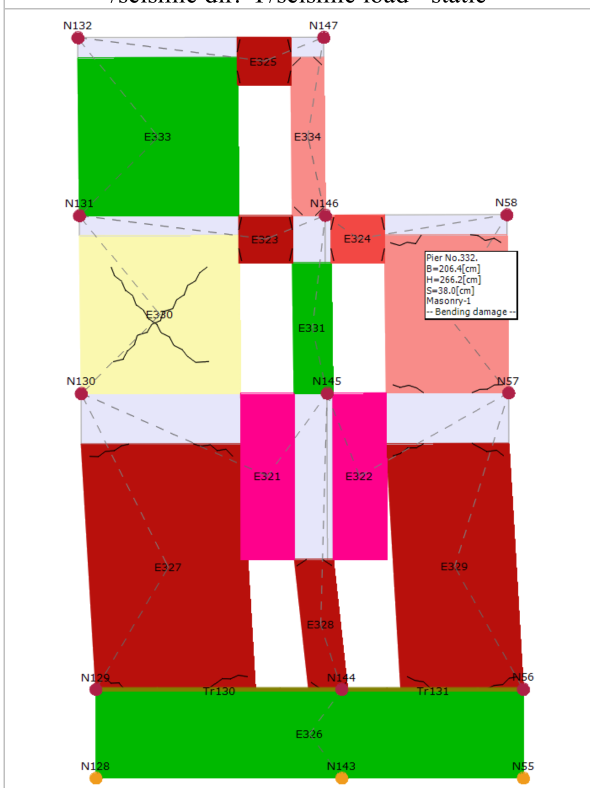
Analysis-24/Mechanism P.11 /South façade masonry /seismic dir.-Y/seismic load =static



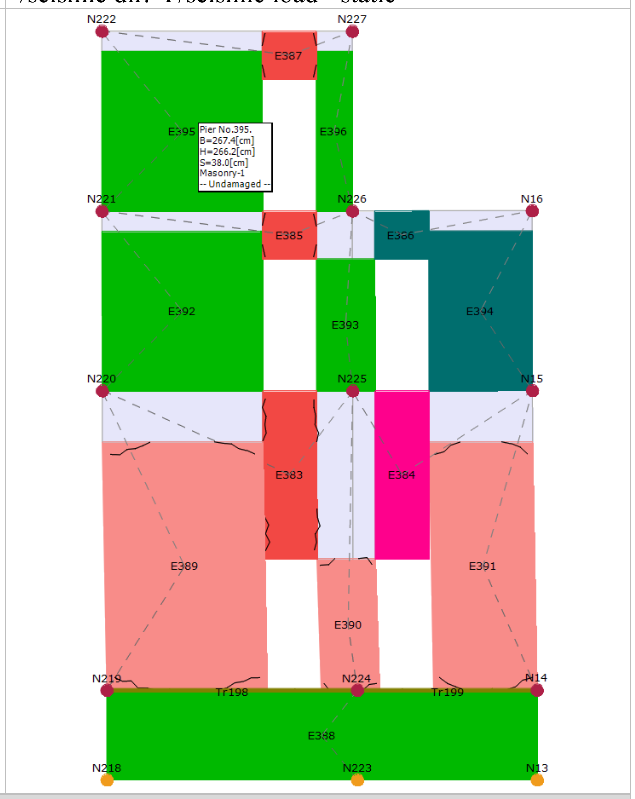
Analysis-24/Mechanism P.05 /North façade masonry /seismic dir.-Y/seismic load =static



Analysis-24/Mechanism P.22 /Internal masonry /seismic dir.-Y/seismic load =static



Analysis-24/Mechanism P.32 /Internal masonry /seismic dir.-Y/seismic load =static



6.1.10.1 Analysis of an effective consolidation strategy, making assessments, without compromising architectural values and with relevant simulations

From the analyzes performed in 3Muri software, although the building reacts well enough from a global perspective and shows a satisfactory structural performance, from careful investigations, some areas considered weak and fragile were identified. Thus, according to the list generated by the program in table.12 on the verifications performed in the framework of nonlinear analysis, it must be accepted that the structure shows a satisfactory performance in 3Muri software. It successfully passes 22 complete analyzes showing an vulnerability index $\alpha > 1$ according to the software evaluation method related to the evaluation parameters of the Eurocode standard. Meanwhile in the analysis no.04 of the seismic load "static force", the direction of the shock -X, the parameters are not satisfied with the performance of the structure, so it fails, although the values are relatively close to the evaluation index 1. Meanwhile in the analysis no.24 of seismic load "static forces", direction -Y again the structure reacts poorly and shows fragility by not satisfying the parameters required to be verified, where the index is very close to the value 1, we can rely on an in-depth interpretation.

So referring to these 2 analyzes, we are interested in conducting further investigations on the capacity and performance of the most endangered masonry. Meanwhile, the respective mechanisms of these panels and their respective parameters are summarized in table.12 discussed in the paragraph above. Re-emphasizing that the thesis does not attempt to provide solutions or details of reinforcement projects, this will not limit us to simulate panels with some reinforcement techniques, in the framework of BIM modeling and extracting as many structural parameters and recommendations, to increase the efficiency of modeling. So at this stage what will be proven is the testing and simulation of selected panels with some minimal intervention techniques, which aim to provide effective solutions to address the structural issue of masonry, increasing their performance, in objects of this category, without directly affecting the architectural aesthetics of the building.

Referring to the no.04 analysis of pushover simulations, two masonry panels were selected to be simulated in the software. It is about the panel no.01 of the masonry that corresponds to the main facade positioned in the western direction of the building, this is one of the panels that reacts poorly and shows fragility at this stage. Also in the same analysis is selected panel no.03 of the internal masonry of the building near the longitudinal hall, this panel shows some areas where the wall fails and creates local collapse mechanisms, which risk the performance of the structure.

In addition to these panels in analysis no.24 as mentioned above, 2 other masonry panels were selected for analysis. Since the direction of seismic forces in this analysis comes in the direction -Y, the selected panels are oriented according to the transverse direction, namely panel no.25 which corresponds to the southern side facade of the building, and the second panel is no.16 which corresponds to a partial internal wall partially on the first two floors and a perimeter side wall on the second floor level, also this panel shows fragility and local collapse mechanisms which should be treated with care especially in the proposals for rehabilitation interventions.

Regarding the situation presented in the above panels after performing the second phase of simulations, which shows the mechanisms of collapse of 2 of the most fragile facades, the following has been advanced with an intervention strategy in the framework of seismic retrofit. The proposals are conceived in such a way that they do not affect the aesthetics of the respective facades, but at the same time significantly increase the seismic performance of the wall. The "FRCM type of reinforcement" method is recommended, where this reinforcing layer is added to the masonry panel in its inner part. Specifically the selected material is "GeoSteel G1200, Kerakoll" with the following data and features:

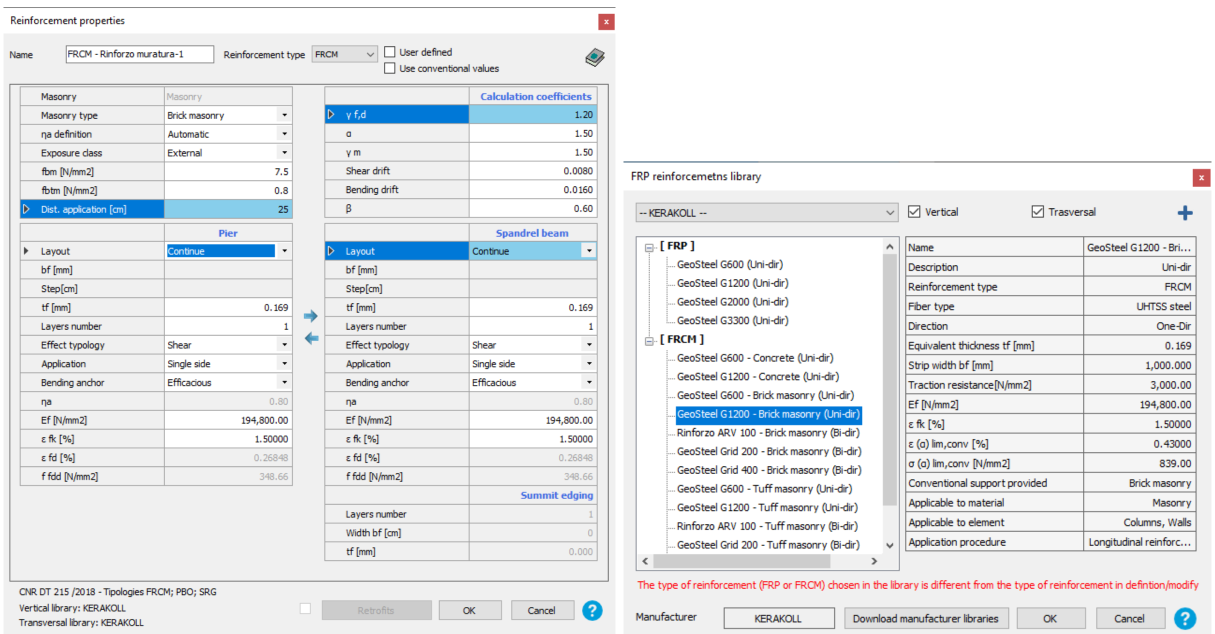


Figure 83. Physico-mechanical parameters and characteristics of the recommended reinforcement layer "Geosteel g1200", according to the database used in 3Muri software

Table 13. Technical data according to Kerakoll quality standard (Kerakoll, 2021)

Frabric-data Trefolo 3x2 ottenuto unendo fra loro 5 filamenti, di cui 3 rettilinei e 2 in avvolgimento con elevato angolo di torsione		
area effettiva di un trefolo 3x2 (5 fili)	$A_{trefolo}$	0,538 mm^2
n° trefoli/cm		3,14 trefoli/cm
massa (comprensivo di termosaldatura)		≈ 1200 g/m^2
carico di rottura a trazione di un trefolo		> 1500 N
resistenza a trazione del nastro, valore caratteristico	σ_{nastro}	> 3000 MPa
resistenza a trazione per unità di larghezza		> 4,72 kN/cm
modulo di elasticità normale del nastro	E_{nastro}	> 190 GPa
deformazione a rottura del nastro, valore caratteristico	ε_{nastro}	> 1,5%
spessore equivalente	tf	≈ 0,169 mm

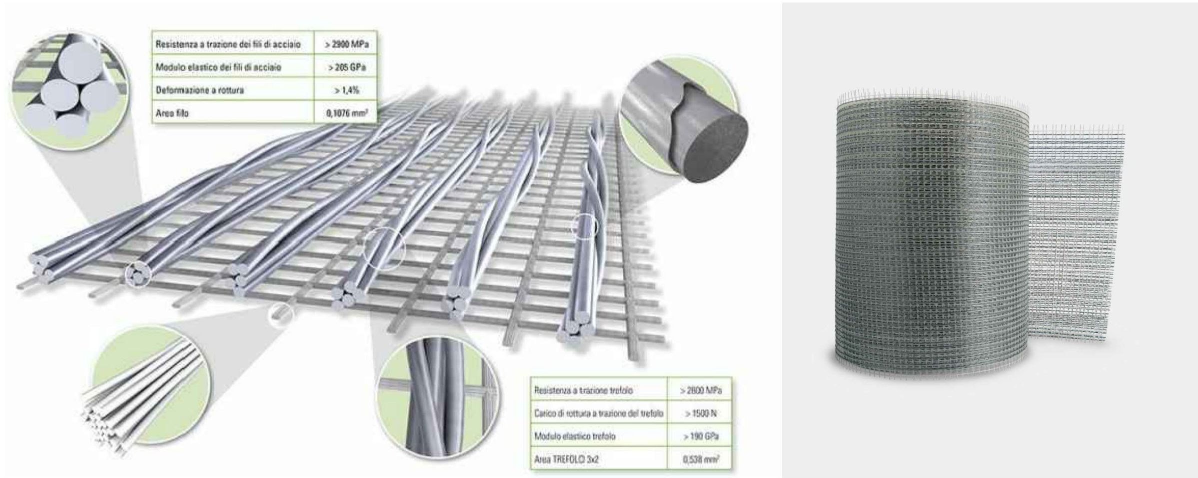
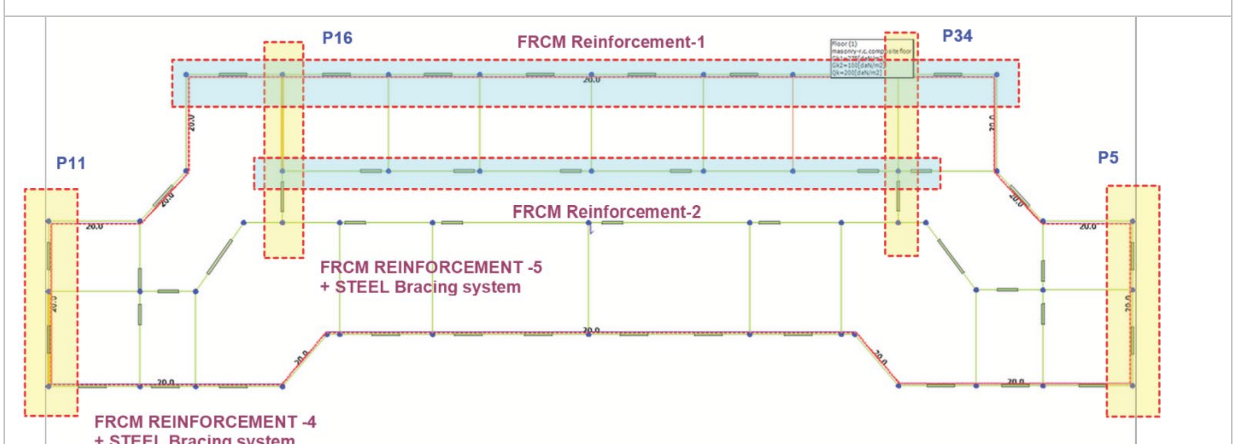
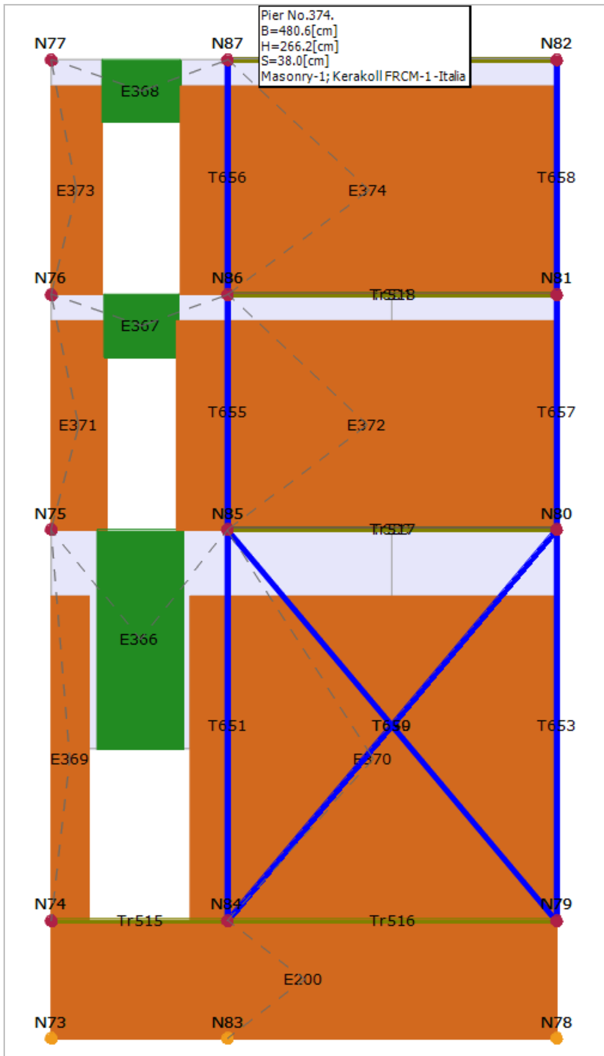


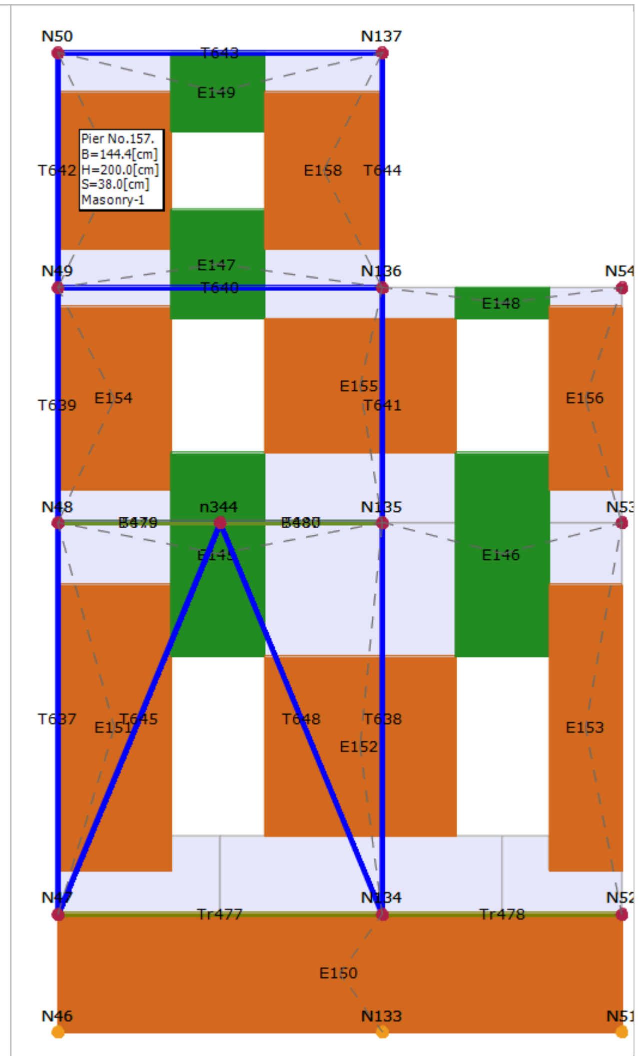
Figure 84. Image of the component assembly of the material FRCM GeoSteel G1200, (Kerakoll, 2021)

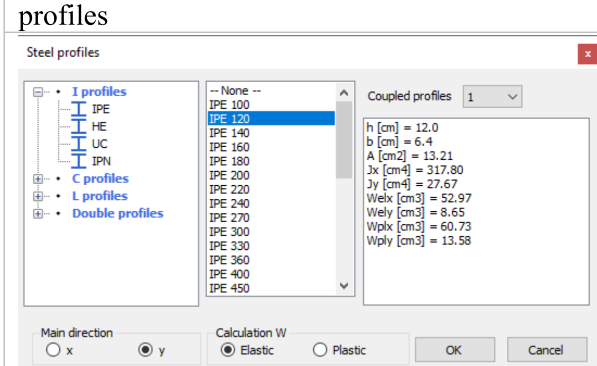
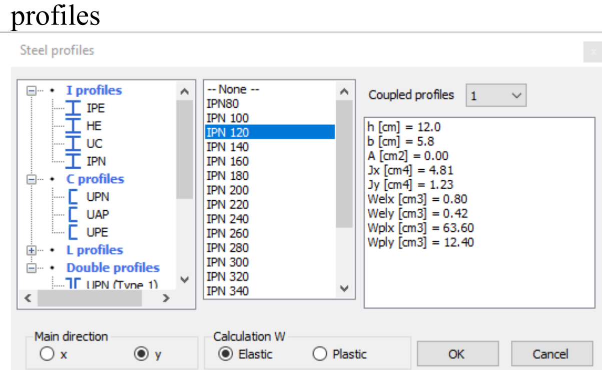
The placement of the reinforcing layer presented above will be applied on the inside of the facade masonry, will be fixed with the existing masonry and will perform in normal environmental conditions. Reinforcement applications in transverse masonry are placed on both sides of the building to maintain the sense of symmetrical distribution of masses and rigidities. The application of FRCM from karakol products was applied for 2 longitudinal panels ascertained by analysis no.04 according to the direction + X. After simulations this type of application is not enough to avoid failures in the 2 transverse panels according to the -Y direction. In these panels, in addition to FRCM applications, steel-bracing systems have also been applied, which enable a significant increase in performance. Their configuration is applied in simple logic according to the openings located in the masonry (doors, windows,), and necessarily their application in the interior of the masonry panels of the facades.

Table 14. Configurations used for reinforcements, presented in the plan and facade

<table>
<tr><td colspan="2">* Positioning of the panels where the intervention was applied,
** Data on their geometric configuration</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td colspan="2">
</td></tr>
<tr><td>Bracing system application and configuration in panel no.16 of the internal masonry</td><td>Bracing system application and configuration in panel no.11 of the façade masonry</td></tr>
</table>



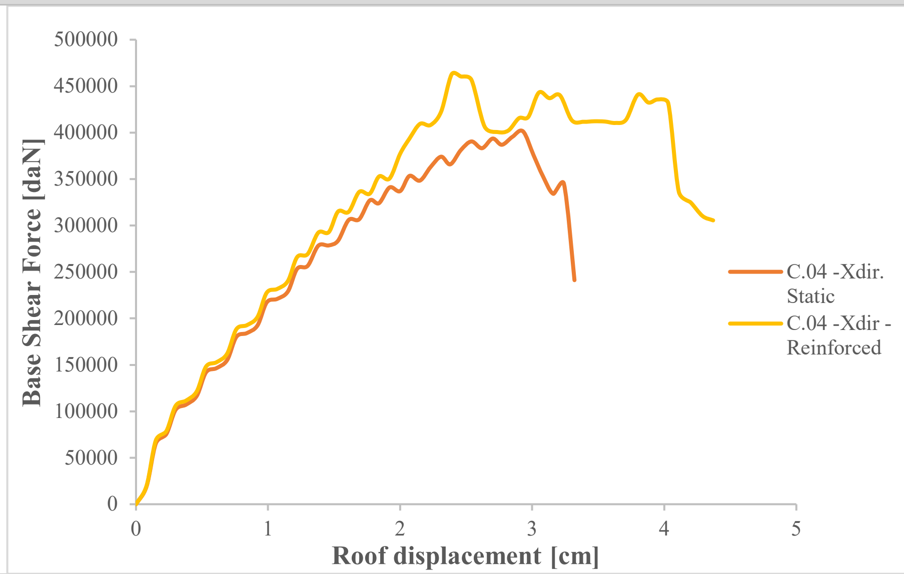


Numerical data and technical parameters of profiles	Numerical data and technical parameters of profiles
	

As for the results obtained after performing the software simulations, they are summarized in a tabular way below, giving the possibility of relevant comparisons between models, local mechanisms and key numerical parameters.

Table 15. Summary table of results obtained after reinforced building simulations

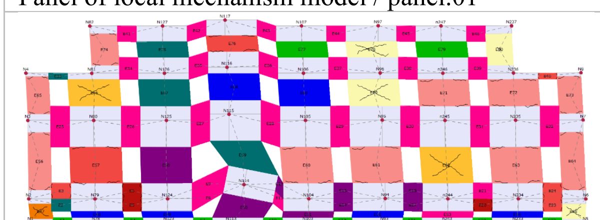
Case [1], Summary diagrams of the analysis no.04 +Xdir./static. The capacity before and after the intervention in the masonry of longitudinal (south-north) facades, processed with 3Muri data



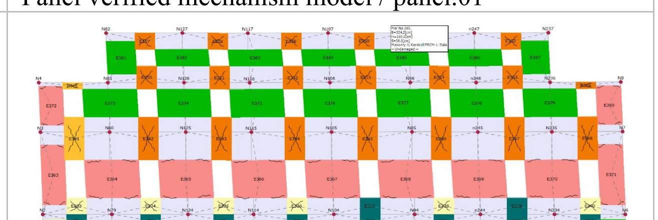
Comparisons

Before application Analysis no.04 +X /Static load/panel no.01							**After** reinforcement application Analysis no.04 +X/Static load/panel no.01						
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
04	+X	Static forces	0.949	0.890	1.582	0.951	**04**	+X	Static forces	1.471	1.403	1.221	1.511
dt=2.88cm [NC]		dm=2.74cm [NC]		T*=0.548s			dt=2.84cm [NC]		dm=4.29cm [NC]		T*=0.506s		

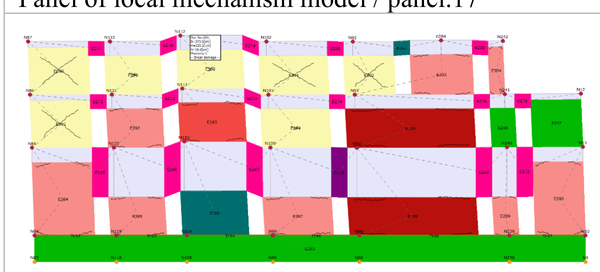
Panel of local mechanism model / panel.01



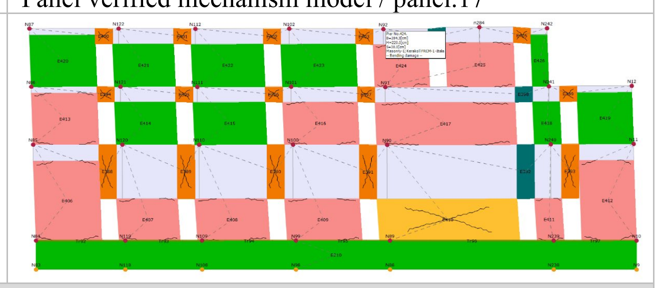
Panel verified mechanism model / panel.01



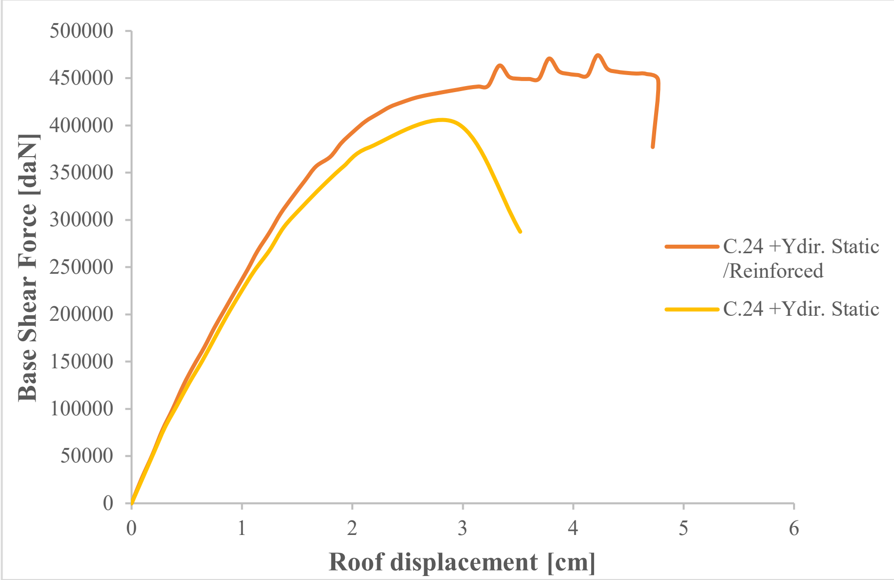
Panel of local mechanism model / panel.17



Panel verified mechanism model / panel.17

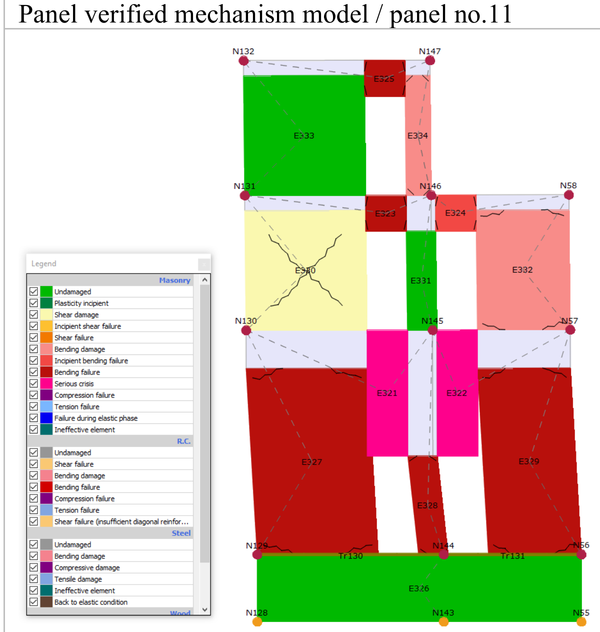


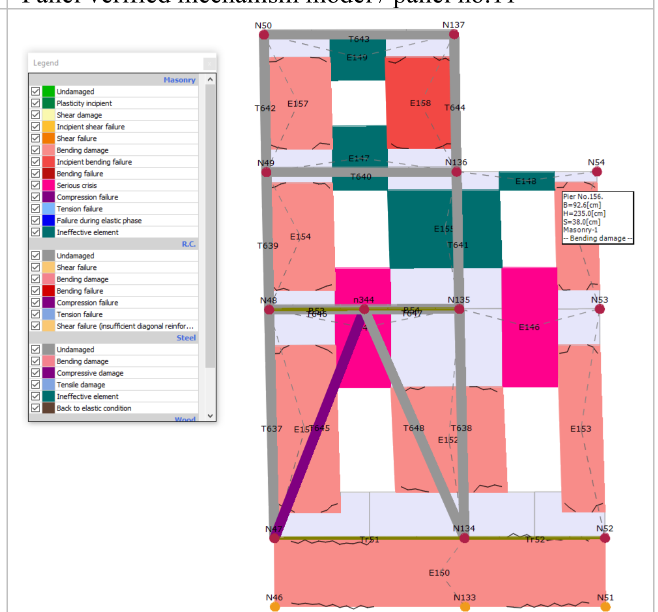
Case [2], Summary diagrams of the analysis no.24 -Ydir./static. The capacity before and after the intervention in the transverse masonry, processed with 3Muri data



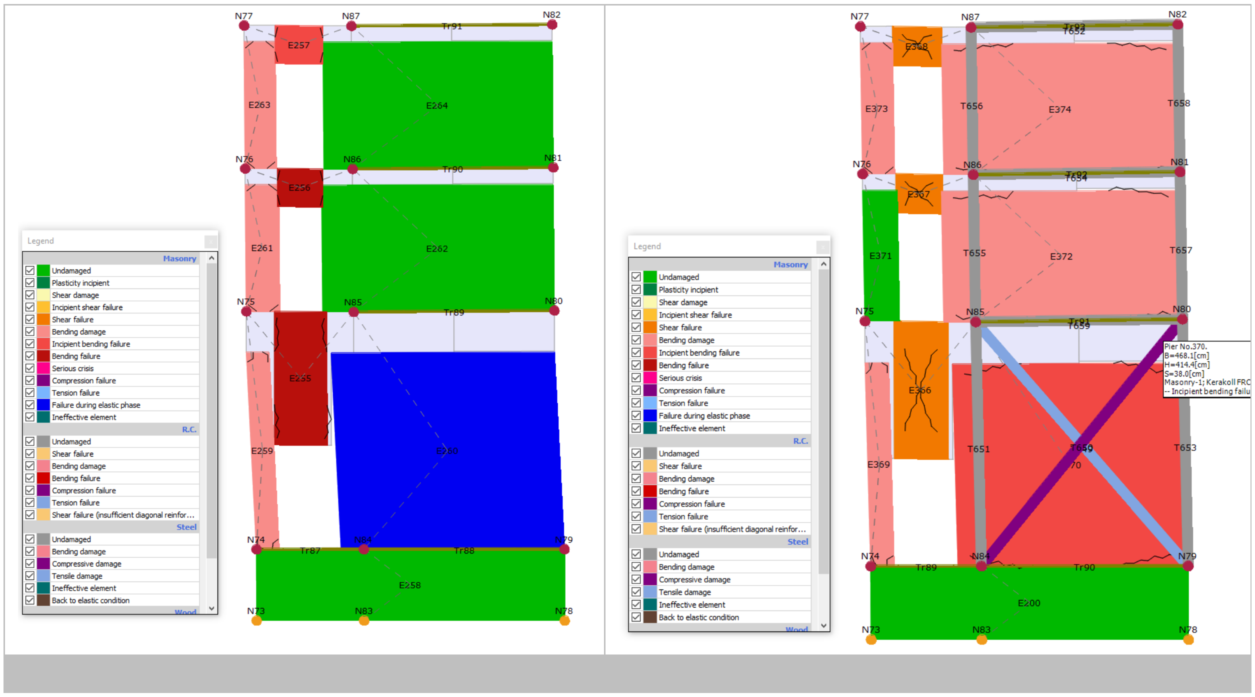
Comparisons

Before application / seismic parameters Analysis no.24 -Y/Static load							**After** reinforcement application / seismic parameters Analysis no.24 -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
24	-Y	Static forces	1.075	1.037	1.160	1.081	**24**	-Y	Static forces	1.741	1.671	1.671	1.842
dt=2.73cm [NC]	dm=2.95cm[NC]	T*=0.520s					dt=2.59cm [NC]	dm=4.77cm[NC]	T*=0.466s				
Panel verified mechanism model / panel no.11							Panel verified mechanism model / panel no.11						





Panel verified mechanism model / panel no.16	Panel verified mechanism model / panel no.16



6.1.10 Summarized conclusions for case one

In this paragraph there will be a discussion on the results obtained for this case study, i.e. a section with preliminary conclusions. As mentioned earlier, this study focuses on historical heritage masonry structures situated in Tirana, located in a seismically active zone. One of the objectives 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 3D model was prepared in order to show behaviour of the structure and its probable local and global weaknesses under seismic actions. The modal analysis is applied to predict 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 ground floor and first floor, also the area where the old building is connected with the extension new structure. The most critical stresses calculated during the static analysis occurred at the connection joints between old structure with another typology and the new frame building, also where the basement is linked with the upper structure and slabs. Results show that the node interaction between the supports and the walls plays an important role in the dynamic behaviour of the structure. It may be considered as risky in terms of creating structural stability problems. The results also show that structural problems and damage to these houses generally occur in the critical stress parts, and these results prove accuracy of the numerical approach, by verifying the problems that were identified on site.

The addition of the new structure has positively influenced on reducing the period of vibrations and the bending momentum in global aspect, but on the other hand increases the shear force on the base. Increases stresses on the facades of the building which were problematic even earlier and also promotes an increase in carvings and cracks on the façade. Most visual and more pronounced is the damage of the old building in the area where it joins the new object. This is evident from the seismic performance analyzed above in the ETABS. These findings show a significant reduction in the seismic performance of the building, judging the structure of two different types of construction.

Regarding this case study, an in-depth investigation has been done, regarding the architectural aspects and those of the restoration of the cultural heritage. This case study is part of the objects of cultural heritage of Tirana, listed in category B. It is protected by law and in this category of objects cannot be made excessive interventions, especially in the facade, where some of the decorative elements are fanatically preserved, and in in the same way the Italian architectural style. In these typologies, interventions or reinforcements can be made only when the potential structural hazard is presented and in cases when its static stability can be questioned.

Regarding my analysis and the methodology followed, referring to the field findings and dealing with the archival project, or other scientific studies related to this building, during the years in this object many structural and non-structural interventions have been made. So, the building has gone through a varied large transition. We can mention interventions that have affected the building, its shape and its architecture, such as:

- Partial and complete reconstructions including finishes;
- Floor additions on the terrace of the existing building, not following the existing architectural plan;
- Side additions in the eastern part, which can be considered the most extreme and recent structural intervention made to the building, also its architecture;
- Changes in the size of the windows in the two front facades;
- Change in the number of windows in the facade;
- Replacement of decorative elements of the period 1941;
- Plastering and painting of the facade in 4 different periods;
- Application of seismic joint between the two blocks, the existing one and the 2001 addition;
- Re-positioning of internal partition walls,
- Moving walls and re-configuring internal floor plans, at least 3 times;
- Door openings in interior walls;
- Demolition of structural walls, in the part which is in contact with the addition of 2001;
- Frequent interventions in the floor layers on the existing slabs;
- Installation of consolidating elements, which can be seen on the facade;
- Significant structural interventions in the basement floor of the building;
- Partial consolidation interventions and retrofitting in the foundations of the building;
- Total energy retrofit of the building;
- Re-conception of the infrastructure around the building.

One of the most sensational interventions and that has left visible marks on the body of the building is the addition of 2001. In this period, Tirana was in a phase of development and transition, after coming out of the long dictatorial period. There was a lot of dynamics in the development of the city, and there was no attention to buildings with architectural-historical values. The building had the status of a cultural monument, but in the period in question there was no conservative legislation on such interventions. Thus, regarding the need of the building for expansion, it was decided to make a significant structural addition to the back of the existing building, specifically in the position of the eastern facade. The geometry and plan evidencing of this structural addition was shown above in figure.48 where the contour of the additional architectural plan is distinguished in green line.

The structure of the addition consists of "moment-frame" elements, i.e. beam-column system positioned and oriented in one direction, while they are connected with secondary beams in the other direction. The expansion of the building continues uniformly in the 2 front facades, respectively for the ground floor and the first floor, with a volume reduction on the second floor. In the back is realized a considerable space to create a meeting / conference room for the needs of the municipality, regarding the positioning in the plan of geometry we are dealing with a semi-cylindrical shape in the middle, limited by two more advanced blocks of the extension of the two front facades. The structure of the addition, it is worth noting that there is another static behavior and dynamic reaction, compared to the masonry structure of the existing building. These aspects are explained above in the seismic response analysis of the building complex. The solution of the structural engineer made that a seismic joint with a thickness of 12cm was placed between the two objects, and this solution was effective in order not to influence the different reactions of the two types of structural systems. However, even this part was clarified above in the conclusions of the modal analysis. The foundations of the additive structure are monolithic footings connected with connecting beams in two directions to have uniformity of reactions, foundation sagging and foundation reductions. The seismic joint continues from the terrace to the foundation between the two buildings.

From the architectural point of view and within the theories of restoration, we have two different structural typologies fused into one, but at the same time we have 2 blocks which have a completely different history from each other. There are big time differences between them. The old building of 1941 carries in itself many values and history. There is the hand of the architect F. Di Fausto, his project-idea and the Italian architectural style of the period of the beginning of the XIX century.

The building today has reached its 80th anniversary and its aesthetics is an identifying and reference object for the city. Now with a slightly newer volume of the addition, they coexist in a building with the same name "Tirana municipality". If we make a connection with the theories of restoration and the Venice Charter for Restoration, in this object there are some aspects that are in conflict. The addition made in 2001, is not considered addition in the full sense, there is no visible separation of objects, the addition is not well documented with all phases of intervention, the addition is not visible and does not show the time difference between objects. Perhaps for many restorers, historians or architecture critics, this addition tends to go against restoration theories and make a historical fake, disguised as an extension of F. Di Fausto's authentic building. For any citizen who can see the building for the first time cannot distinguish the difference between the periods of objects. Perhaps this is not a problem for many professionals in the field, and can be considered an effective intervention and in line with the development of the building for the requirements of the institution. This will normally remain an open topic as long as there is no genuine debate in Tirana on the values and architectural richness of the many buildings that are part of the cultural heritage.

In conclusion of this part, to connect once again with the structural aspect, the building performs well, has reacted well to the moderate earthquakes of 2019 and results in a satisfactory structural and seismic performance. But this does not mean that the building may be able to withstand a new 50-year transition, with city dynamics, atmospheric disturbances and future seismic events. A new research question arises, "*How to renew the structural performance of these complex structural typologies, which carry architectural values in themselves?*". If the question is better re-formulated, the main problem appears in the fact, how to intervene in the object without damaging its aesthetics and architecture, how to integrate with additions made in different periods, and the most importantly "*how to find a mathematical non-linear connection to link pre-conceived engineering F.E.M. simulations or collapse scenarios with restoration theories / principles?*". This has been one of the dilemmas initially, and the impetus later to launch and conduct this study.

There are many studies and literatures dealing with the methodology and techniques of structural consolidation of old masonry buildings, traditional classical methods, modern and advanced methods which are briefly mentioned in the chapter "the state of art". *However, this study does not provide technical details or engineering solutions for the application of structural interventions in such buildings.*

In this study, *an attempt is made to establish a real connection between consolidation, retrofitting and interventions according to some basic principles of restoration. So the creation of a matrix, where any typology of intervention or structural retrofitting, to be automatically linked parametrically with the relevant theory of restoration, mainly basic principles of restoration charters*. Not being afraid of contrast between the new building/addition/partition against the old existing building; the time difference between the old and the new one should be clearly shown; to intervene for structural consolidation without affecting the aesthetics / architecture, until the static stability of the building is endangered; if the addition increases the static performance of the structure and solves the problem of the new function can be applied; etc. *This theoretical matrix can be applicable in many current software's that use the BIM methodology (building information modelling), where through some algorithms, some interventions will automatically blocked to be applied if the required principle is not respected*. This theory simply means dissatisfaction with the above elements. *To have the option of parametric recommendations in interventions*, just as parametric design is applied in the generation of forms, this can also be applied to the techniques of interventions and their form/shape in existing objects. It is also recommended to install a monitoring system with sensors, and a robotic system to control the performance of each building without limit, would help the progress and maintenance of heritage values in time.

6.1.10.1 Discussions on the results obtained from the simulations in 3Muri

Usually the knowledge level represents a critical phase for the definition of reliable structural 3d models of cultural heritage buildings.

Exactly for this aspect, different numerical models should be used. The proposed analyzes show a possible approach to investigating the seismic capacity and performance of an old heritage masonry building, considering two different levels of accuracy: the first is a global model based on a simplified seismic approach, and the second is based on the application of a classical pushover analysis, with nonlinear characteristics with a 3D macro-element model.

Thus after performing the modal analysis, the nonlinear static analysis was performed through the 3MURI software to obtain the capacity curves and to have clarity on their collapse mechanisms. The case study dealt with here emphasizes that, even in a fairly simple construction, with regular geometry and symmetric distribution of stiffness, many special aspects can be found after a detailed and careful investigation, divided into two phases, those field and experimental modeling.

The basis of these pushover analyzes in 3Muri, was the performance of seismic safety controls of the building verified in the ultimate limit state ULS, according to the Eurocode standard. As interpreted in depth in paragraph 6.1.10.1, after performing the simulations, it was noticed that the seismic controls among 24, only 2 of them were not satisfied referring to the vulnerability indexes α (combined according to 3 levels), obtained from software. In step no.04 -Xdir. vulnerability index values <0 were found, but close to the limit values. In this analysis dt (the target displacement of the MDOF system) dm (the ultimate displacement of the MDOF system), in numerical values dt = 2.10cm compared to dm = 3.88cm, with a ratio dm / dt = 1.85. Vulnerability index α (NC) = 0.949, while α (SD) = 0.890. No analysis no.24 -Ydir. low values of the vulnerability index and dt <dm were found, specifically dt = 2.73cm compared to dm = 2.95cm, with a ratio dm / dt = 1.08. But, even if we carefully investigate the other steps, local elements of masonry can be found which are fragile to be considered. From the investigations of each step, a considerable number of local collapse mechanisms have been identified, which are summarized in table.12 accompanied by numerical data, combined with the corresponding graphical mechanisms generated by 3Muri.

In relation to these data summarized above, some specific interventions for seismic improvement of the structure were foreseen. First, the reinforcement of the masonry was considered, through an intervention with FRCM Geosteel g1200 by increasing the mechanical properties of the existing masonry, to eliminate the mechanisms found in “step 04 -Xdir”. and to increase the seismic safety factor of buildings.

This simple intervention in terms, proved effective from the first attempt, and this is shown in paragraph 6.1.10.1 by the results summarized there. The application was made in the inner part of the masonry, specifically in 3 longitudinal panels, oriented in the X-direction of the building in plan. We emphasize that the intervention does not affect the aesthetics of the facade of the building, part of the cultural heritage.

Later, the intervention in the transverse panels of the masonry Y-dir. was simulated, after interpreting the results from “analysis no.24 -Ydir”. The focus was on intervening to improve the mechanical properties of the masonry, through the reinforcing layer with FRCM Geosteel g1200. The intervention in this case was not enough to eliminate all the mechanisms of collapse and was followed by a second intervention, the establishment of several steel-bracing systems, the relevant data of which are summarized in table 15 of paragraph 6.1.10.1. This double intervention provided a significant increase in masonry performance in terms of strength and rigidity.

If we make comparisons with modal analysis we have changes in values also in terms of vibration periods. In nonlinear pushover analyzes we have higher values of vibration periods. This difference is also affected by not considering the addition of the building in 3Muri software. However, there are aspects that show a higher care for performance, found after the analysis in 3Muri. Useful information which will enrich the BIM model targeted in the initial objectives with numerous structural data.

6.2 CASE II - General overview of the "Casa del Fascio", Polytechnic University of Tirana

Architectural identification, survey process and structural evaluation

The building of the Casa del Fascio was designed by Gherardo Bosio between 1939 and 1940. The conception of the architectural complex of the Littorio as an urban theater, surrounded by mighty tiers of travertine on the sides, which assumes the building of the Casa del Fascio as an artificial scenographic element placed in front of the natural scenography of the hill, lit up in the citizen the awareness of feeling part integral to urban representation.

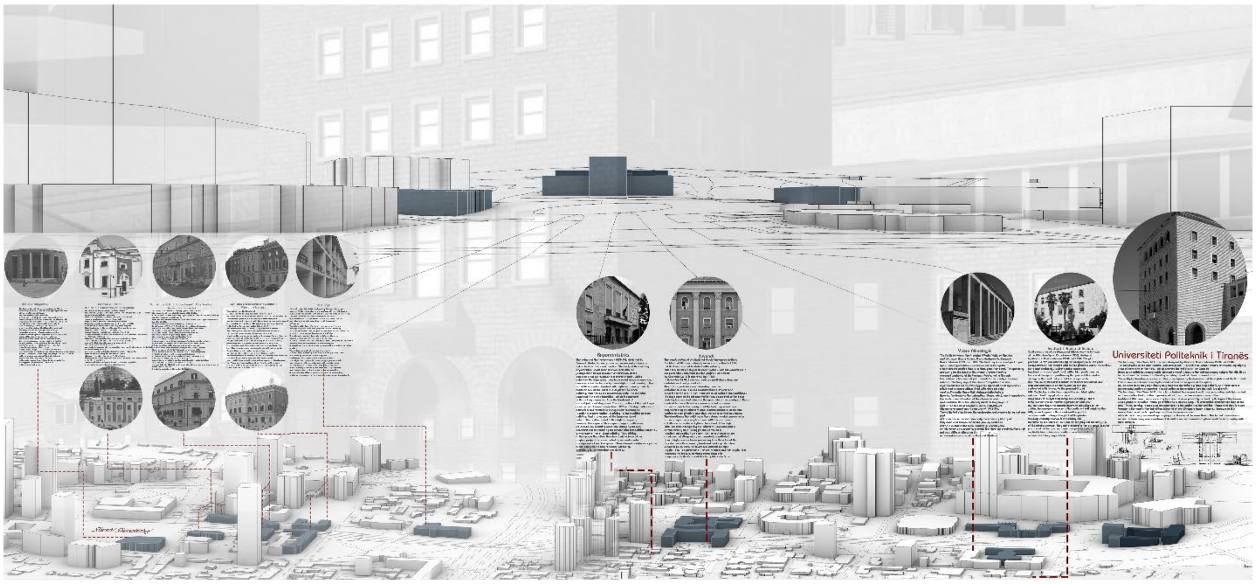


Figure 85. Casa del Fascio position and relations with other cultural heritage at the boulevard (Credits: S. Agalliu)

The multiple altimetric movements of the ground given by the terraces and the stylobate of the Casa del Fascio, on the one hand create multiple points of view of the space of the square, on the other organically hold together the buildings that construct it, as if there were a monumental podium excavated waiting for the architectures that will rise above it. The building of the Casa del Fascio, characterized by compact ashlar parallelepipeds intersected with each other that give the impression of a fortress, evokes reminiscences of the traditional Albanian tower according to some, but more likely inspired by the type of the Florentine Renaissance palace, although revisited in a modern key . This creation becomes the icon of the New Tirana, being re-proposed the same year in the project for the Albanian pavilion at the Fiera del Levante in Bari and at the Triennial Exhibition of the Terre d'Oltremare in Naples. For this reason, the almost unchanged re-proposal of its form in the project of the government square in Gondar by Bosio becomes curious.

This formal coincidence shakes many of its author's considerations on the character of places and on the relationship with local cultures. The uniform treatment of the ashlar overcomes the traditional vertical stratification of the facade in the basement-elevation-conclusion, giving the building an almost metaphysical purity. The temple of the new Albania lives a condition of formal abstractness compared to the other buildings of the Littorio complex, a similarity of sensations that is felt in the relationship to the EUR-Roma with the Palazzo della Civiltà, different forms but recurring characters: purity of volumes, symmetry, massiveness, elevated position, seriality, uniformity of materials .

The building had been built with a reinforced concrete structure buffered by solid brick masonry, the windows framed by a concrete frame were covered with white Carrara marble, the same podium covered in travertine was built with a reinforced concrete structure at the inside which there were some underground rooms.

Today the building houses the Rectorate of the Polytechnic of Tirana, the extensions on the back are shortly after the construction of ‘1939.

6.2.1 Architectural Survey and structural on-site investigation

Also in this case the same methodology was followed, the procedure explained in Chapter V, after the analysis of case study-1. The first phase was the on-site study, where through the organization of "Cultural Heritage Restoration and Conservation" subject, with students of architecture and Civil engineering classes, under the guidance of academic staff, the process of architectural survey was successfully completed, with more care throughout a five week period.

The processes that were followed in this survey phase are "Orthogonal photography with many cloud points of the facades of the building, processing according to the method of photogrammetry, drone photography, sketches and drawings of architectural elements, processing of elements in Photoshop, documentation and digitalization of the archival project in AutoCAD, investigation of interventions in the building over the years, investigation on additions and new blocks, investigation on material degradation, moisture in the masonry, opening and cracking of marble panels on the facade, possible damage to the masonry and the concrete frame actual state, the presence of moss and stone mold, parasitic vegetation, structural retrofit interventions, the impact of technological networks and installations on the building, the infrastructure around the building and the connection with the center, the urban planning of the area and the dynamics of urban development of the area, the function of the building and auditorium spaces, etc”. All these processes are treated in a concise way in this study, also a part of the material are found in the annexes of the thesis.

The feedback received from the students research and works was at satisfactory levels, meanwhile through this process, and the methodology used in this study, has been attempted very carefully to encourage the students, a culture on the works of architectural survey and in-depth study of the “Restoration of Cultural Heritage”. Using a well-structured source of professionals at this stage, a combination of experiences was made between Civil engineers and architects, opening a genuine scientific debate within the audience, regarding the values of Cultural heritage objects, and how they should be treated in it. the future.

The process of orthogonal photography and processing with the method of photogrammetry: As explained above, in the first phase of the architectural survey, the 4 facades of the building were worked in great detail through the processing of orthogonal photos, with the technique of photogrammetry. Below is shown the result of this on-site important work process.

Figure 86. Image processed with photogrammetry of the main facade of the building

Figure 87. Image processed with photogrammeter of the facade from behind

Figure 88. Photogrammetrically processed images of the side facades

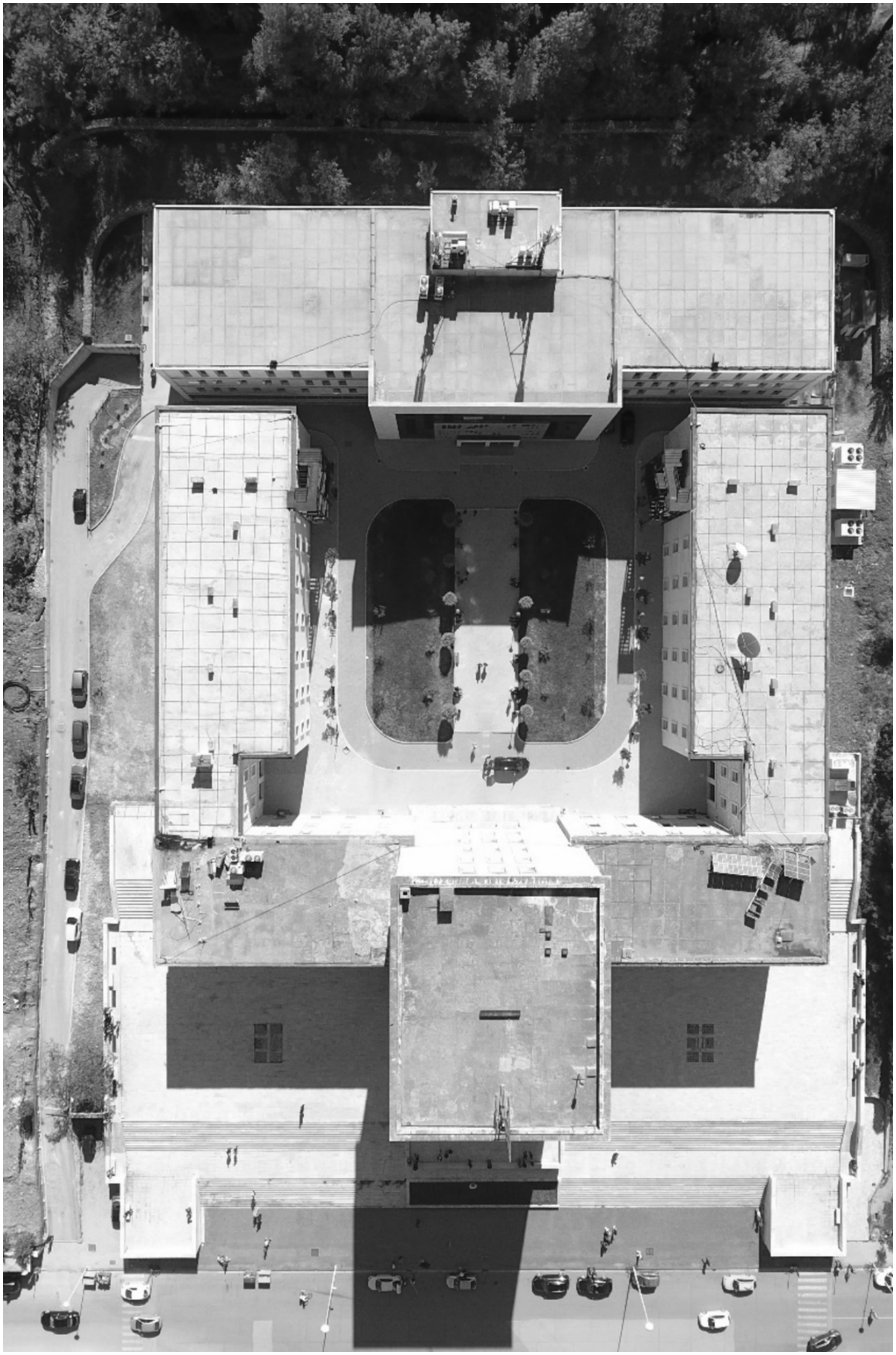


Figure 89. First aeral photo, showing the volumetric blocks, made by drone (credits: M. Begeja)

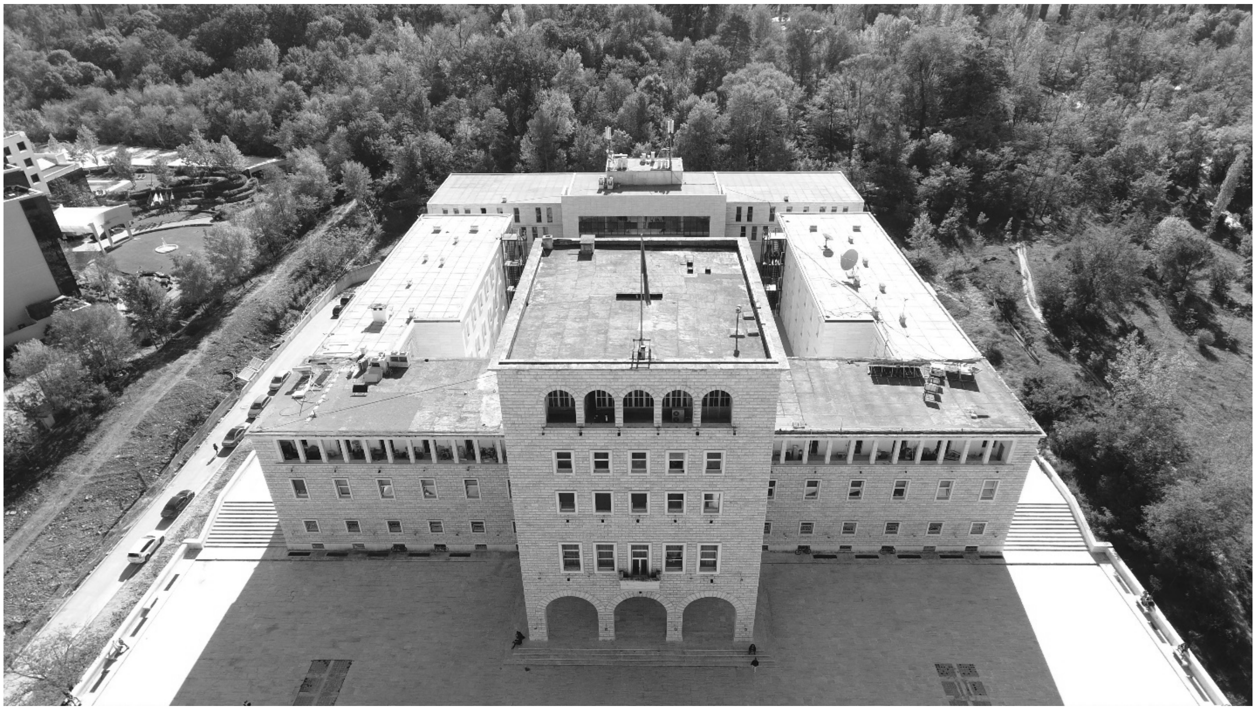


Figure 90. Second aerial photo made by drone (credits M. Begeja)

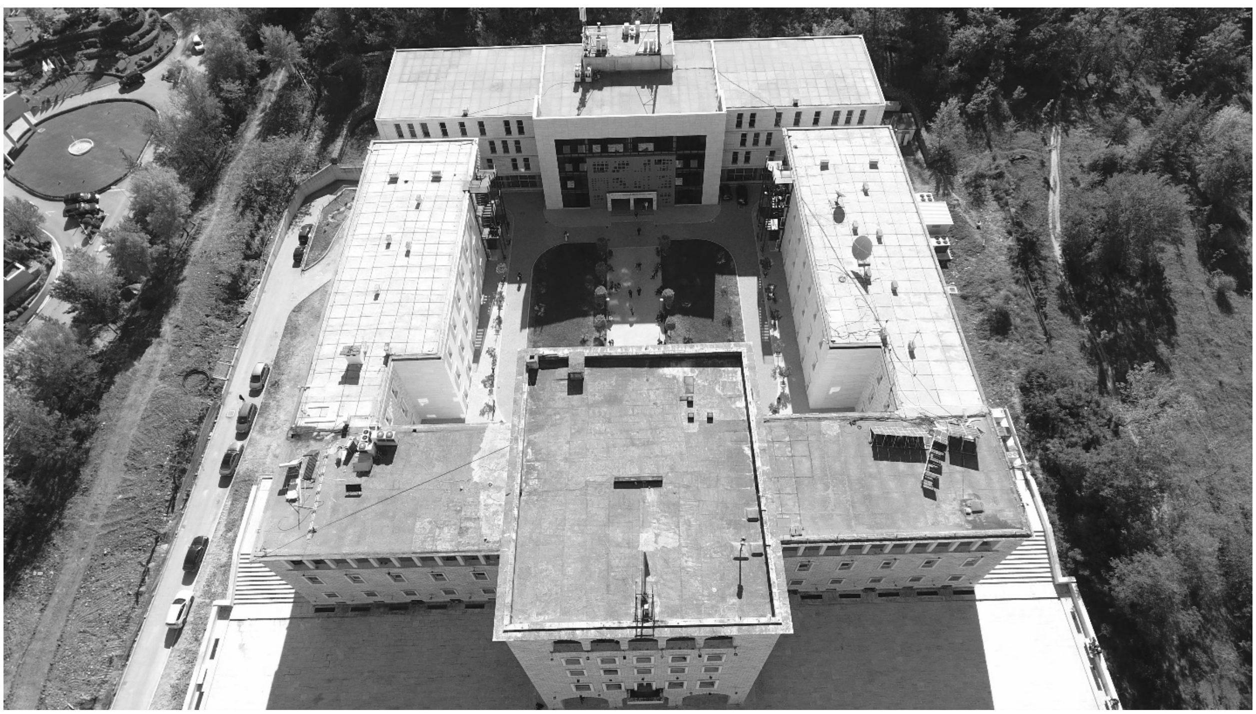


Figure 91. Third aerial photo made by drone (Credits M. Begeja)

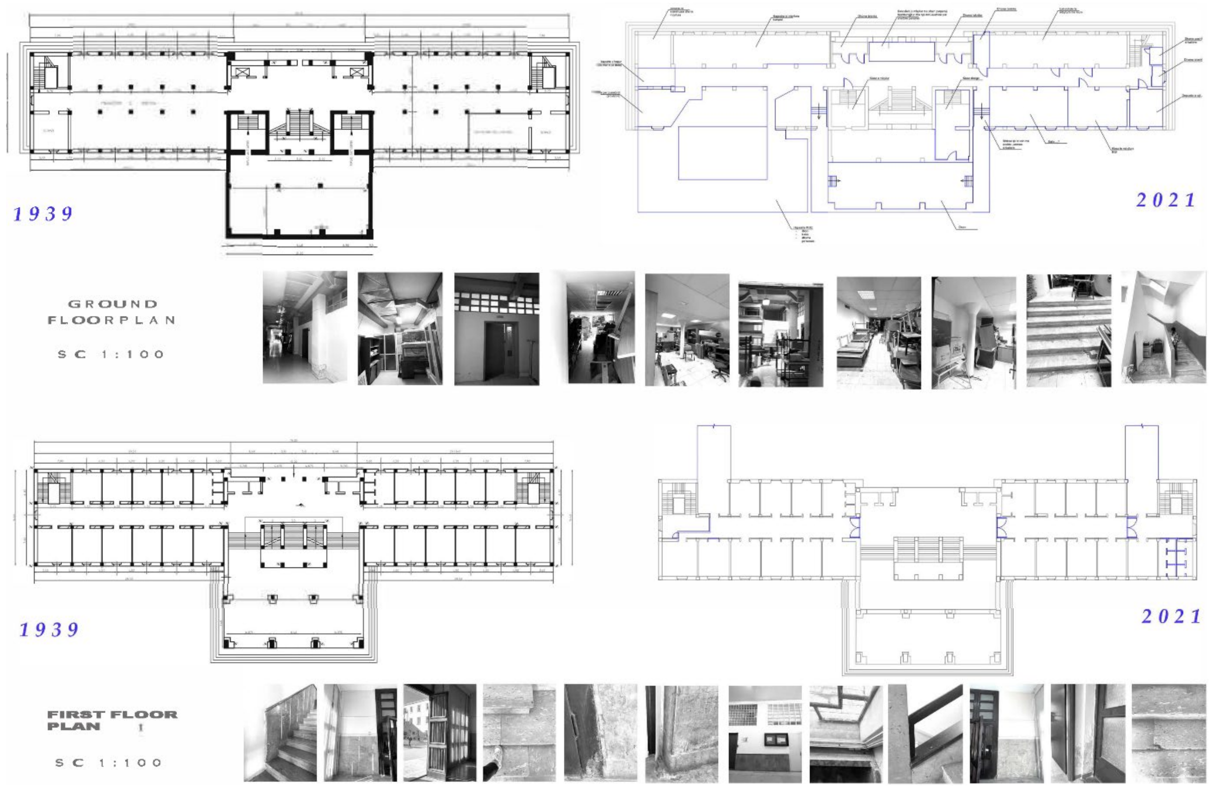


Figure 92. Archival project digitalization and comparisons with the actual survey, ground floor (credits: H. Nika; M. Lleshi; M. Begeja)

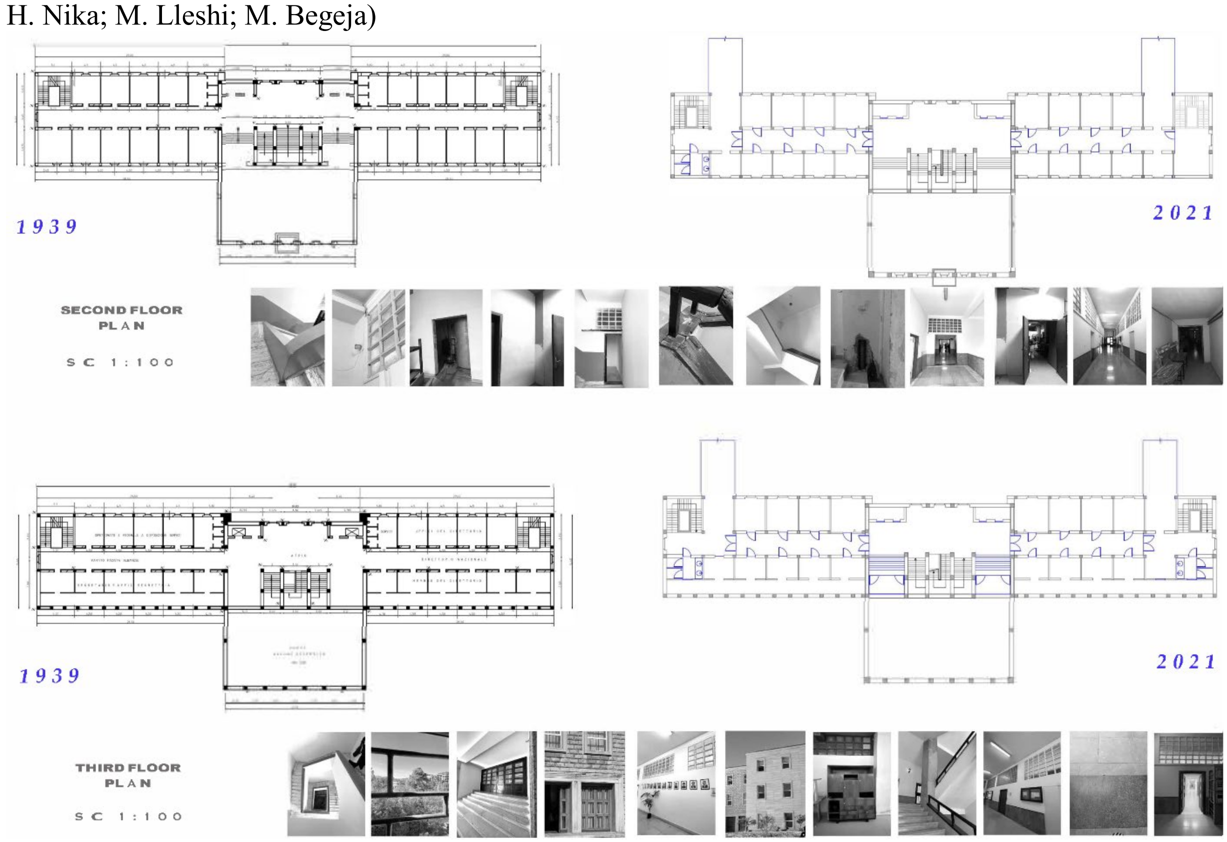


Figure 93. Archival project digitalization and comparisons with the actual survey, ground floor (credits: H. Nika; M. Lleshi; M. Begeja)

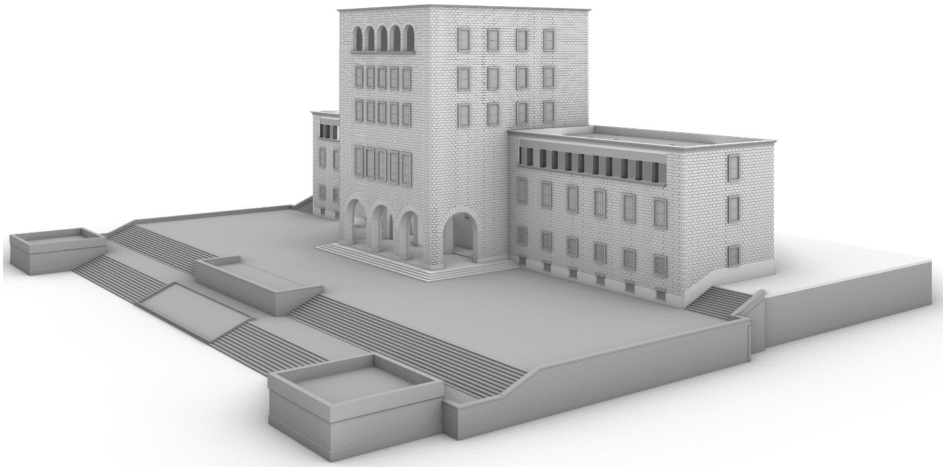


Figure 94. 3D Architectural model reworked in rhino v.07 after the survey process (Credits: R. Qose)

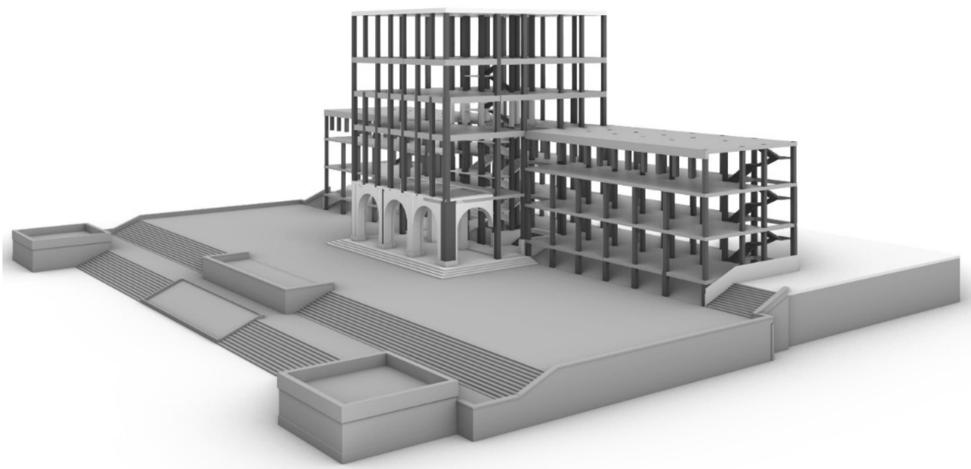


Figure 95. 3D structural model reworked in rhino v.07 after the survey process (Credits: R. Qose)

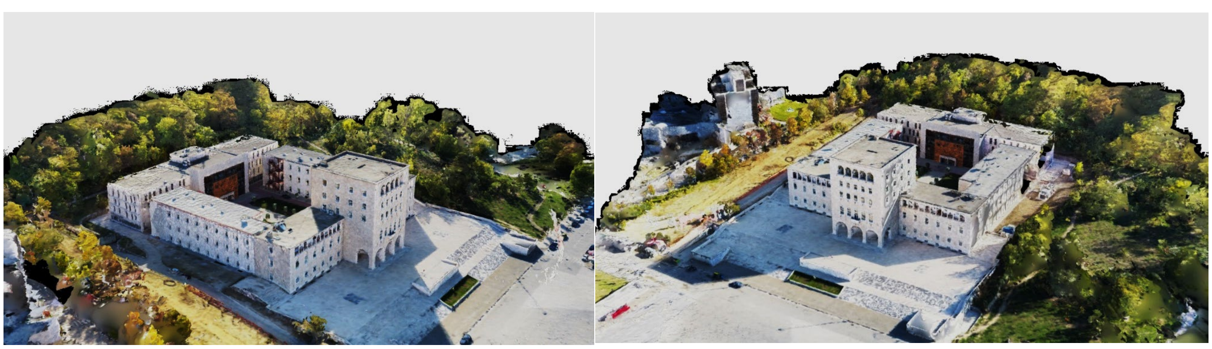


Figure 96. 3D photogrammetric model, processed after the on-site survey phase, in the framework of BIM modeling

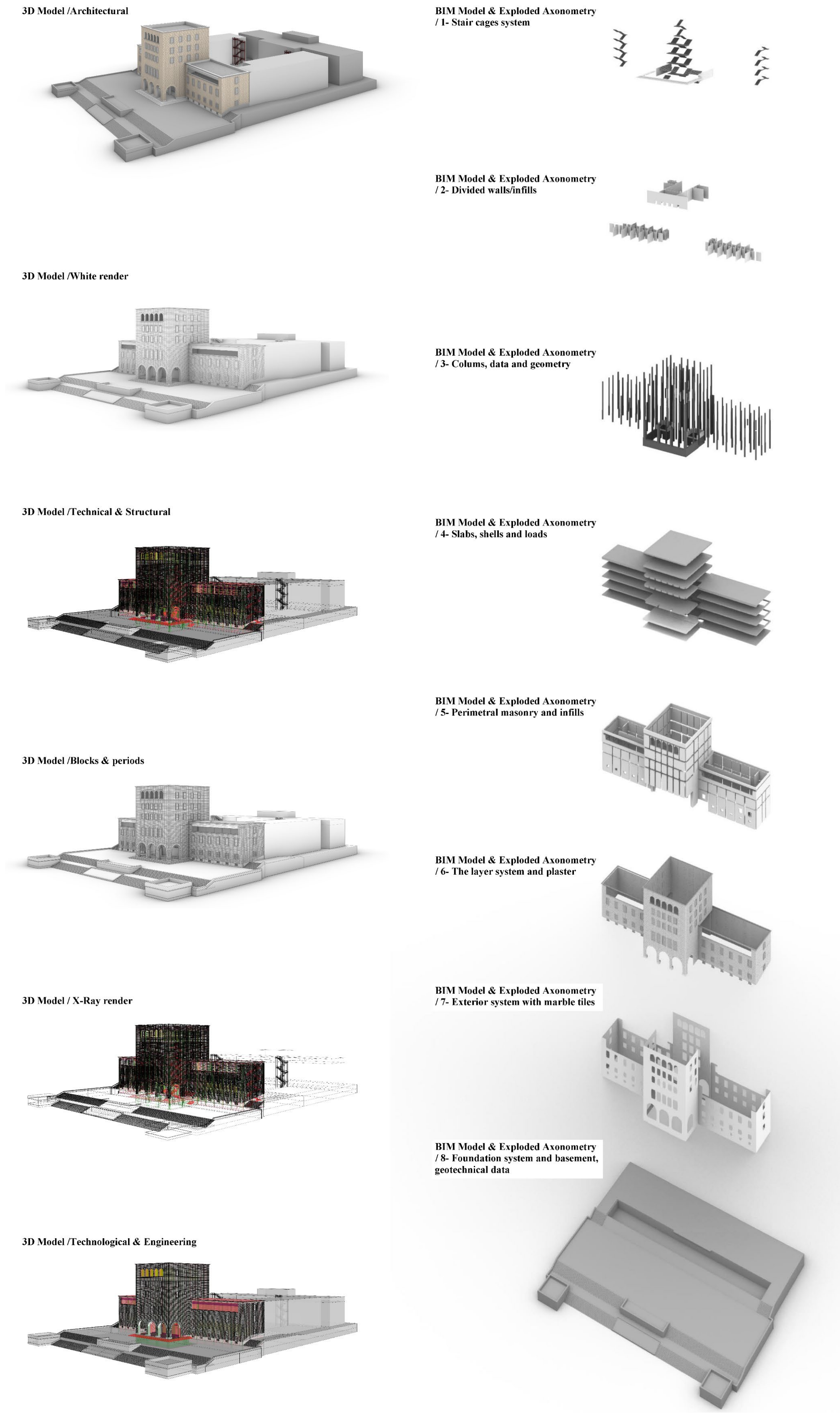


Figure 97. BIM Model concept through 3D exploded axonometry models

6.2.3.1 Theoretical interpretations, stratification and analysis methodology

The case study selected as part of this study, is one of the blocks of the building of the Polytechnic University of Tirana “Casa Del Facio-Tirana”, conceived by the Italian architect Gherardo Bosio, as an integral part of what we know today as "Mother Teresa Square". The reasons for selecting this building are primarily related to structural regularity, plan and height. So, it is not an object with complicated geometric features, and its use can also serve to pass in general for the type of structures rc frames with massive masonry presence, known as "rc frames with infills", designed and built without criteria of seismic risk protection. Also from the time of design until today, the destination of use of this object, as a cultural and educational unit, belongs to the buildings of special importance, which makes it suitable for the objectives of the thesis, related to the analysis and restoration of cultural heritage.

6.2.3.2 Technical description of the second case study “Casa Del Fascio-Tirana”

The authentic building with the famous grid-shaped facades of the Polytechnic University, built in the late 1930s, consists of three parts, separated by seismic joints. The two side parts are symmetrical to each other against the central axis of the building and structurally the same. The central part, which has even greater height, is analyzed in the general plan up to the level of modal analysis, while the following is analyzed in specifically only one of the side blocks.

The structure of one of the side blocks of the building consists of four floors, one of which can be considered partly underground. The type of constructive system is ram reinforced concrete plans combined with infills. But as a typical building of the '30s, designed by Studio Ferrobeton in Rome, in accordance with the Italian style of construction of that time, the perimeter walls are complete and with several layers, the effect of which on the static and seismic behavior of the structure , is very influential and considerable. On the other hand, the partition walls inside the building are thin with a thickness of 10 cm and with perforated brick, which are destroyed very quickly and also the interior partition walls do not extend to the level of the mezzanine and consequently their effects on the global behavior of the structure. , are negligible and are not taken into account in seismic and non-linear analysis.

6.2.3.3 Theoretical interpretations of the perimetral masonry, as an essential element in the structural performance of the building.

Based on the original project obtained in the technical archive, the investigation of photos of the time of construction, as well as the data recorded during the intervention for the realization of the southern additions of the structure (in the '70s), "perimeter walls", consist of three layers, two layers of side bricks (12cm thick), and between a layer of low-grade concrete 26cm thick. These layers are taken independently because brick and concrete by the way of construction (brick layers were built after concreting), and the findings on site do not seem to be related to each other. In the structural intervention mentioned above, the wall between the E and F axes in frame 4 of the structure was removed in order to connect the existing structure with the South addition.

The total thickness of the perimeter wall throughout the height of the structure is 50cm. The constructive system of the moment frame type consists of a network of columns with sections which vary in plan and height of the structure, while the cross sections of the beams, referring to the original designs, are two. The slab is made of reinforced concrete, as a lightweight filling sole (brick) with a total height of 25 cm, where 5 cm belong to the sole and the rest is composed of waffle beams 7 cm wide and with (reinforcement 2ϕ10) at the bottom and without reinforcement at the top as well as bricks.

The service load for which this slab has been calculated, according to the original projects is 350 daN/m^2.

6.2.4 The Calculaton model

The structural model is worked through the finite element method in Etabs v.19 software. The structure is modeled with elements of the moment frame type, combined with the walls which in the role of "infills" play a determining role in the seismic reaction of the building. In this way, in accordance with the recommendations of the structural program used, the masonry block is modeled as a two-dimensional element of the type "layered nonlinear shell", or nonlinear surface element, with two layers, concrete and masonry. Within the characteristics of the wall layer is considered a common volumetric weight between brick and mortar, which have a linear fixture interaction between each other.

The connection of the structural elements with the ground, for the columns is a solid connection (all six degrees of freedom are blocked), while for the walls, their connection at the base is considered a fixed hinge, because the masonry is supported on the foundation beams, and in addition to the contact there is no reinforcement to provide the inlay type connection of these two structural elements.

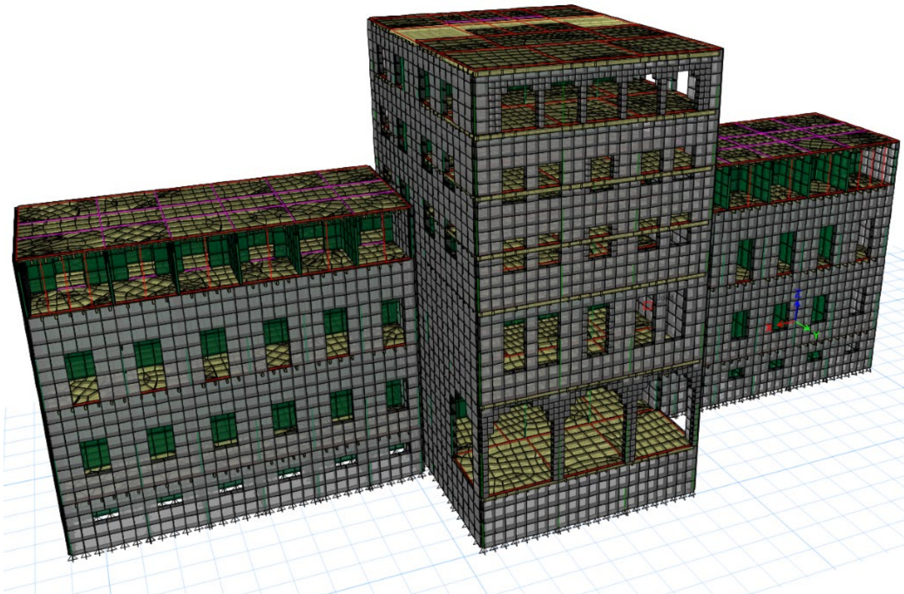


Figure 98. The Casa del Fascio finite elements model analyzed on ETABS v.19 software

The model selected for the Analysis is the real three-dimensional model. In this model, structural elements such as beams and columns are presented as linear type elements, which are easily modeled in any structural program. While the design of partition masonry presents a considerable difficulty, as they consist of bricks or blocks which vary in specific weight, strength as well as depend very much on the quality of their construction. In this topic, it is suggested that the partition masonry be modeled in the form of an equivalent beam, which is in fact the most used in various structural analyzes. While the other walls, without bricks and mortar in the composition, are modeled in the form of nonlinear layered elements with nonlinear characteristics for all three components.

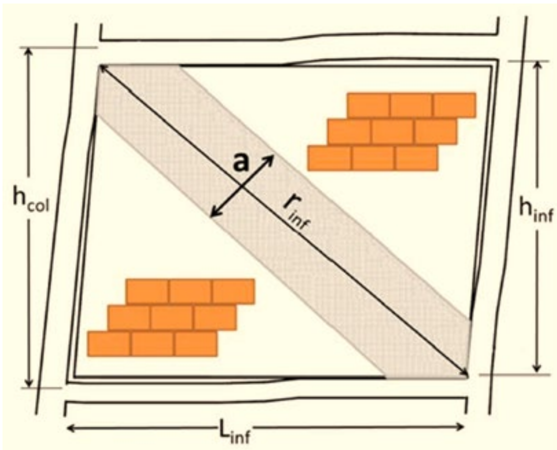


Figure 99. Theoretical representation of the equivalent strut of infills (based on the recommendations received from ASCE / SEI 41-06[31])

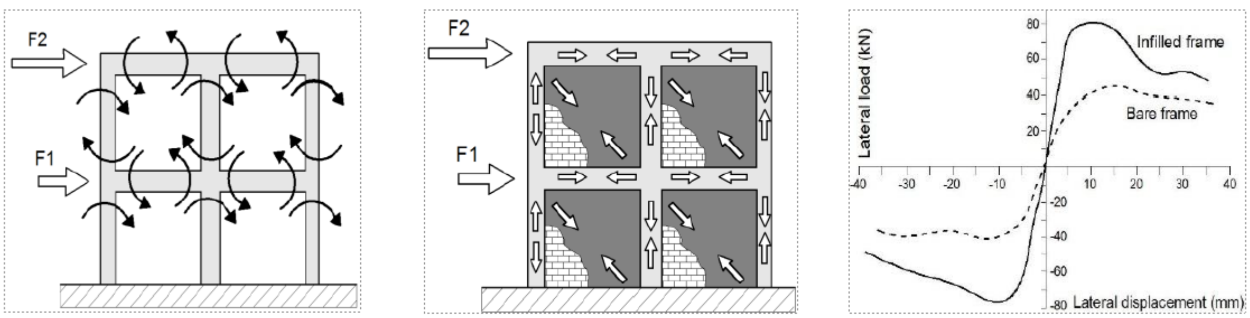


Figure 100. Behaviour of rc frames under lateral loads scenarios, first - bare frame (flexible moment frame), primary or predominance rc bare frame performance under the loads; second - the RC frame + infills, primary and predominant the truss action, the diagram shows the comparison between the experimental cyclic response of a rc-frame without infill vs combined one [source: (Tarque & Leandro, 2015)]

Above, in the figure.88 are summarized graphically the reactions of the basic frames, initially when considered "flexible RC frame", in this case the walls are simply infills geometrically and considered non-structural, while in the second case is shown the reaction of the RC frames which in cooperation with the structural infills perform in a combined manner and to show their characteristics is extracted graphically the comparisons between the capacities of the two typologies.

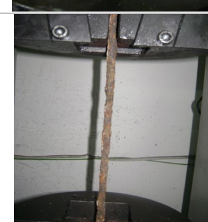
6.2.5 Characteristics and data of Materials, investigation on static calculations

Basic data on the materials and geometric dimensions of the structural elements are taken from the original projects and also from visual findings and investigations in the building.

[31] American Society of Civil Engineers. Seismic Rehabilitation of Existing Buildings

As we addressed the issue of materials in paragraph 6.1 in the first case study, also in this case laboratory tests were performed on-site through the assistance of the company "Altea & GeoStudio 2000", to extract the current mechanical data of the materials. In the case of the Polytechnic University the focus is on performing tests on concrete material, steel reinforcement and bricks. The procedure consists of taking a sample of the material in columns, beams, slabs and walls. Followed by the phase of preparing samples in the laboratory, performing the relevant tests and obtaining the test results, which will be summarized in this section below. Cylindrical concrete samples were taken from 3 different columns and tested in compression, steel samples were taken in 1 of the columns and tested to tensile strength, while cubic brick samples were taken in a perimeter basement wall which was tested with compression test.

Table 16. Table of mechanical data of laboratory tests, developed for this case study (Altea & geostudio, 2019)

Material	Class/grade	Resistance (MPa)	Failure load (kN)	Type of test performed	Sample image
Concrete	250 *up to* 350 kg/cm^2	16.81	72.3	*Compression test results for cylindrical concrete sample -1*	
Concrete	250 *up to* 350 kg/cm^2	28.23	121.4	*Compression test results for cylindrical concrete sample - 2*	
Steel	Ç-3*	177.7		*Tensile Test of Steel Rebar used, sample-1 of mild steel reinforcement*	
White brick		16.7	258.7	*Compression test results for cubic white brick sample - 1*	
* From on-site investigations, the steel used in reinforcement is “mild steel rebar”					

Calcoli Statici

I presenti calcoli statici sono condotti in conformità delle vigenti prescrizioni ministeriali, per la costruzione delle opere in cemento armato

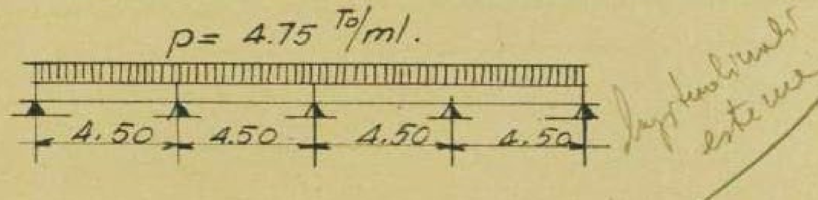
Le massime sollecitazioni ammese sono:

Beton a 450 kg. a flessione $\sigma_{be} = 50$ kg/cmq.

" " " " a compressione $\sigma_{be} = 40$ " "

Ferro $\sigma_{fe} = 1600 \div 1800$ kg/cmq.

Piattabande esterne tra i pilastri 17÷23 , 38÷44 -



Carichi

solaio	= 1.68 To/ml.
muro di riempimento	= 2,08 "
rivestimento di pietra	= 0,61 "
peso proprio	= 0.38 "
	4,75 To/ml.

luce di calcolo 4,50 ml.

$$M = \frac{1}{12}\, 4.75 \cdot 4.50^2 = 7.90 \text{ tm.}$$

$$h' = 0,43 \sqrt{\frac{7.90 \cdot 10^5}{60}} = 48.50 \text{ cm.} \quad h = 50 \text{ cm}$$

$$C_e = 0.0015 \qquad \omega_{fe} = 0,0015 \cdot 60 \cdot 114 = 10.20 \text{ cmq.} \equiv 5\phi 16$$

$$\sigma_{be} = 52 \text{ kg/cmq.} \quad \sigma_{fe} = 1700 \text{ kg/cmq.}$$

Figure 101. Static calculations applied in the design of the structure (more specifically, the introduction of the calculation methodology; calculation of bending moment, and dimensioning of the beam section at frames 2 and 3), (Source: AQTN)

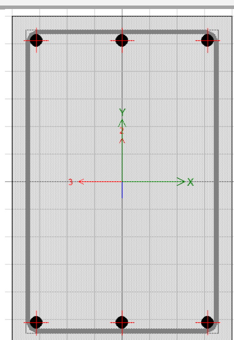
Regarding the table.11 during the autumn of 2020, all possible samples of the materials were taken on-site and then tested in the Laboratory. During the process, special care was taken not to damage the structure and structural elements of the constituent blocks of the Polytechnic University of Tirana building. Also, the samples are treated in the laboratory according to relevant standards. The standards that have been used to perform laboratory tests are:

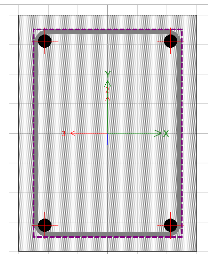
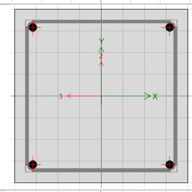
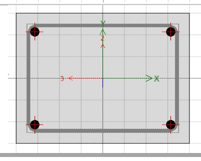
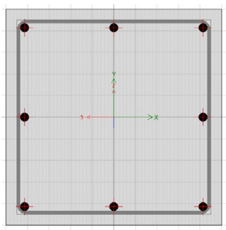
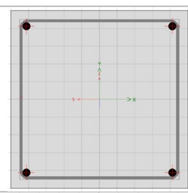
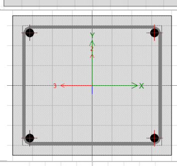
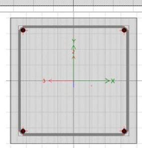
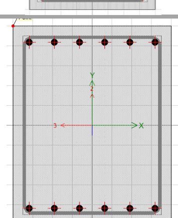
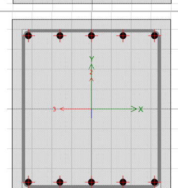
- *For reinforcement samples:* *UNI EN 10002 & 1065*
- *For concrete samples:* *EN 12390 - 3/01*
- *For mortar samples:* *EN 1015 - 11: 2001*
- *For brick samples:* *ASTM C 67 - 09*

Regarding the parameters obtained after the tests performed, we can briefly comment on some of the conclusions of the report prepared by studio Altea. Referring to the main material in this building, which is Concrete, has resulted in relatively good quality, which reaches the mark 250 to 350 kg/cm^2. From the concrete samples, it was concluded that it was prepared with selected aggregates. In special parts of the building there are degraded parts and with small cracks mainly in the cover, this is more evident in the elements of the basement level. According to the laboratory engineers, they add that one of the reasons for such findings is the presence of moisture and carbon dioxide released from the boiler of the facility. Also problems related to the maintenance and insulation of concrete.

Whereas, regarding the geometric shapes data and the relevant specifications for the frame elements, below is a tabular summary of all the elements of the frame "columns and beams", which describes in detail the types, position and reductions by floors, the dimensions of the sections, the data of the fittings, as well as their sketches worked in the model in etabs.

Table 17. Summary table of cross sections of columns and beams, as well as specification of reinforcement (drawings are worked on etabs)

Elements data		Reinforcement and bars sketch	Section dimensions		Longitudinal bars		Stirrups data		
Type	Location		b (cm)	h (cm)	Φ	As (cm^2)	Φ	s (cm)	n
Perimetral columns	Basement		40	60	6 Φ 22	22.74	Φ 6	25	2

	Ground Floor		40	50	4 Φ 22	15.2	Φ 6	25	2
	First Floor		40	40	4 Φ 18	10.17	Φ 6	25	2
	Second Floor		40	30	4 Φ 14	6.51	Φ 6	25	2
Internal columns	Basement		55	55	8 Φ 20	25.12	Φ 6	25	2
	Ground Floor		45	45	4 Φ 22	15.2	Φ 6	25	2
	First Floor		40	35	4 Φ 20	12.56	Φ 6	25	2
	Second Floor		30	30	4 Φ 14	6.51	Φ 6	25	2
Beams	P (perimetral)		40	50	6 Φ 16	12.05	Φ 6	25	2
	B (internal)		40	45	5 Φ 16	10.05	Φ 6	25	2

6.2.6 Seismic analysis and Results

Given the above explanation in methodology, historical heritage was initially analyzed to define seismic parameters and the structural performance. Modal analysis was conducted in order to determine fundamental mode shapes and natural frequencies of the structure during free vibration. The purpose of seismic analysis is to analyse the maximum response of the structure in each of its important modes of vibrations, which are then summed up in an appropriate manner view. Modal analysis of the structure included different modes of vibrations in combination according to the theory.

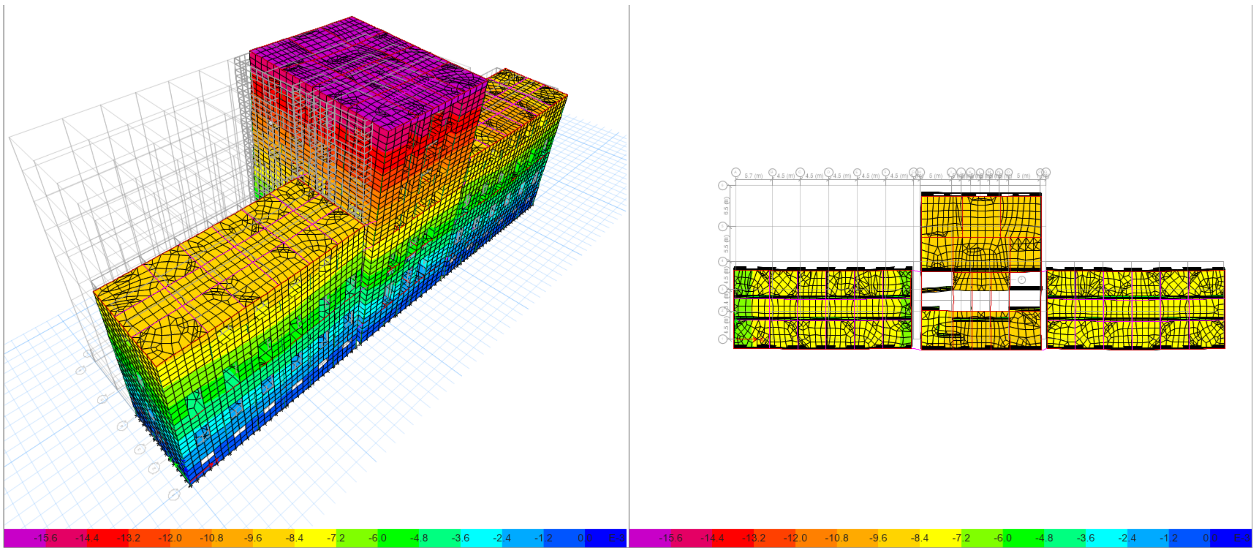


Figure 102. First mode of vibration considering the whole complex (Etabs v.19)

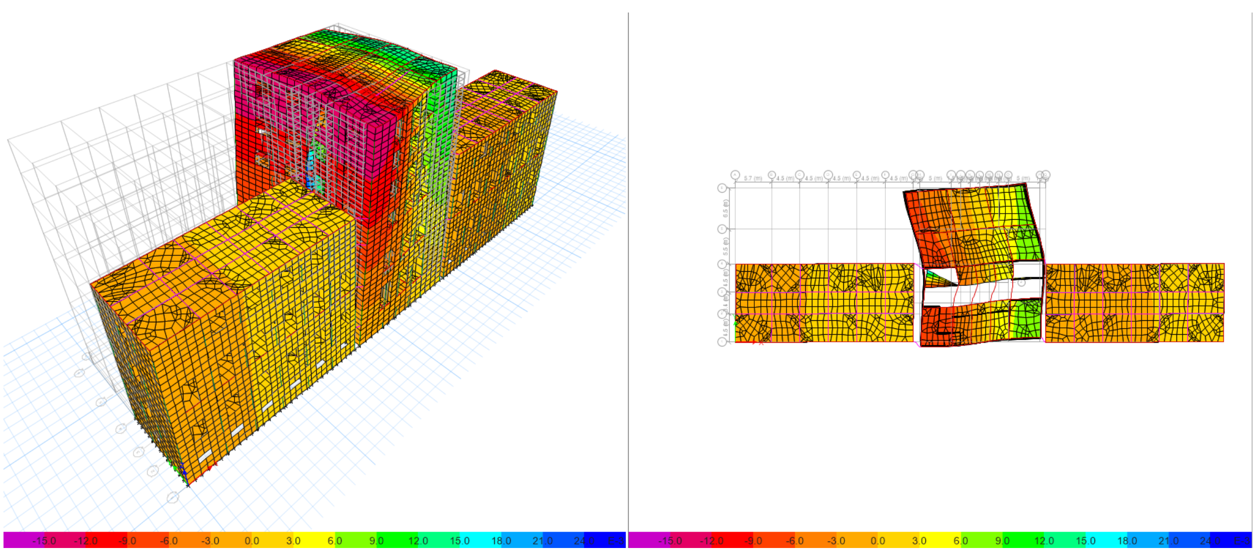


Figure 103. Second mode of vibration considering the whole complex (Etabs v.19)

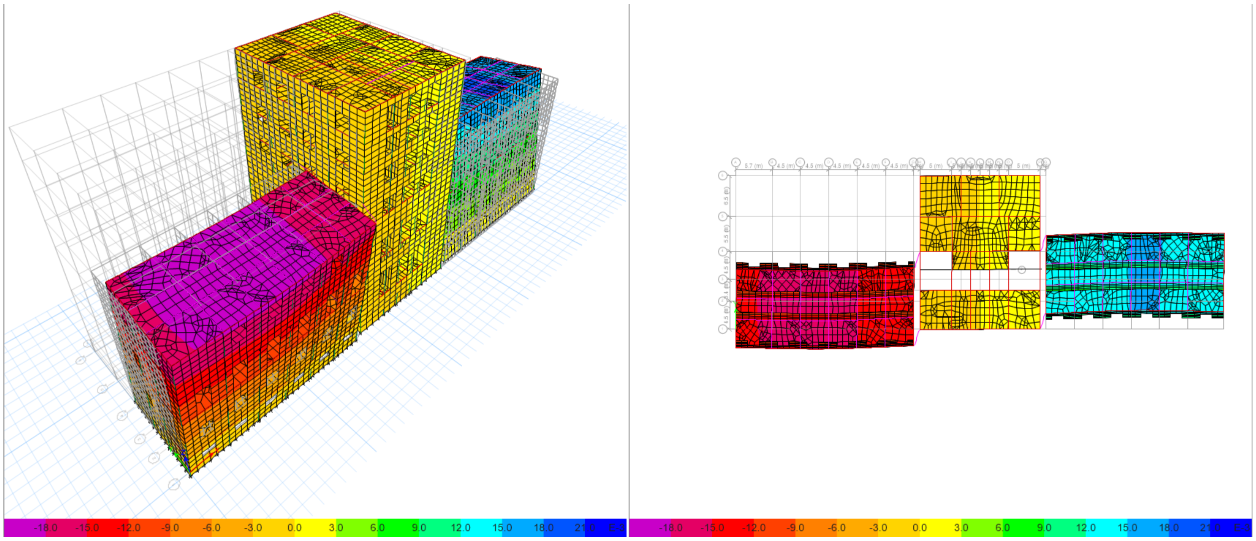


Figure 104. Third mode of vibration considering the whole complex (Etabs v.19)

As mentioned above in the methodology, to interpret the results of the modal analysis and to discuss the periods of self-vibrations, only the western block of the complex has been separated from the Etabs building for analysis. This block currently belongs to the building of the Faculty of Electrical Engineering. As it was pointed out, the Bosio building is divided into 3 blocks with seismic joints, and precisely for this fact the parameters of one of the blocks have been analyzed. A second reason why one of the blocks has been analyzed at this stage is the detailing and intensification of the finite elements, the density of the mesh, to increase the accuracy of the results and to make the model lighter in the software.

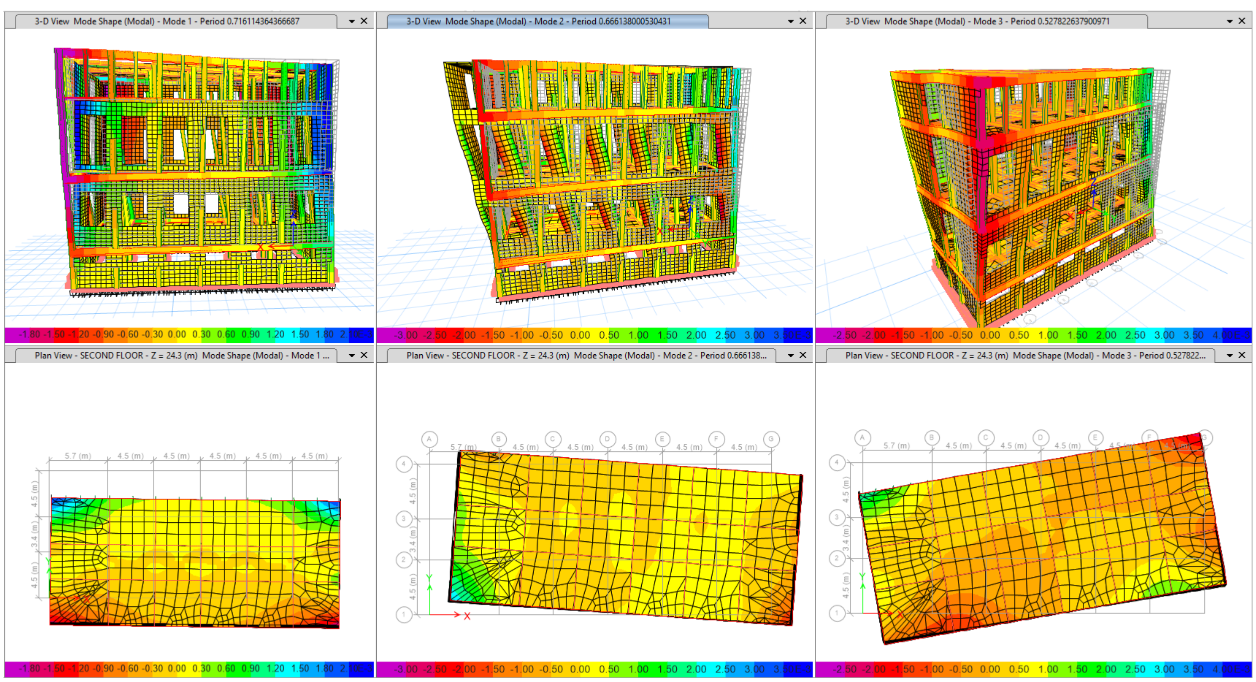


Figure 105. First 3 combined modes of vibration according to ETABS.v19 for the case study

Table 18. Modal data, frequencies and seismic parameters (ETABS v.19)

Case	Mode	Period sec	Frequency cyc/sec	CircFreq rad/sec	Eigenvalue rad2/sec2
Modal	1	0.716	1.396	8.774	76.983
Modal	2	0.666	1.501	9.4323	88.9675
Modal	3	0.528	1.895	11.904	141.7045
Modal	4	0.233	4.293	26.972	727.49
Modal	5	0.231	4.322	27.1585	737.5854
Modal	6	0.179	5.602	35.1984	1238.924
Modal	7	0.139	7.183	45.1309	2036.7998
Modal	8	0.125	7.987	50.1827	2518.3077
Modal	9	0.112	8.929	56.1026	3147.5005
Modal	10	0.108	9.26	58.1843	3385.4168
Modal	11	0.106	9.417	59.1676	3500.8084
Modal	12	0.088	11.405	71.6566	5134.6679

Table 19. Modal Participating Mass Ratios and period (ETABS v.19)

Case	Mode	Period sec	UX	UY	SumUX	SumUY	RX	RY	SumRX	SumRY
Modal	1	0.716	0.0013	0.7579	0.0013	0.7579	0.493	0.0009	0.493	0.0009
Modal	2	0.666	0.6345	0.0025	0.6358	0.7604	0.0016	0.448	0.4945	0.4489
Modal	3	0.528	0.1055	0.0007	0.7413	0.7611	0.0003	0.0689	0.4949	0.5178
Modal	4	0.233	1.994E-05	0.1145	0.7413	0.8756	0.3034	3.378E-05	0.7983	0.5178
Modal	5	0.231	0.0963	5.858E-06	0.8376	0.8756	4.667E-05	0.2061	0.7984	0.7239
Modal	6	0.179	0.0118	4.209E-06	0.8495	0.8756	3.995E-06	0.0375	0.7984	0.7615
Modal	7	0.139	2.955E-06	0.1232	0.8495	0.9989	0.191	5.578E-06	0.9894	0.7615
Modal	8	0.125	0.1225	2.219E-05	0.9719	0.9989	1.209E-05	0.179	0.9894	0.9405
Modal	9	0.112	0.0018	0	0.9737	0.9989	0	0.0189	0.9894	0.9594
Modal	10	0.108	0.0262	2.207E-05	0.9999	0.9989	2.487E-06	0.0389	0.9894	0.9983
Modal	11	0.106	1.829E-06	0.0002	0.9999	0.9991	0.0088	0	0.9983	0.9983
Modal	12	0.088	4.733E-05	0	0.9999	0.9991	7.316E-07	0.0016	0.9983	0.9999

Pre-conclusions reffering the 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: T_1=0.716 s > [T] Translation move on X-direction
First mode: T_2=0.666 s Translation move on Y-direction and torsion presence
Third mode: T_3=0.528 s Pure torsion

Regarding the interpretation of the modal analysis, it is worth noting the presence of torsion and rotation in the planimetry of the object, since the second mode of self-oscillation of the structure. Also some aspects that need to be looked at carefully in terms of block displacement, which will be commented on in the conclusions of the following model.

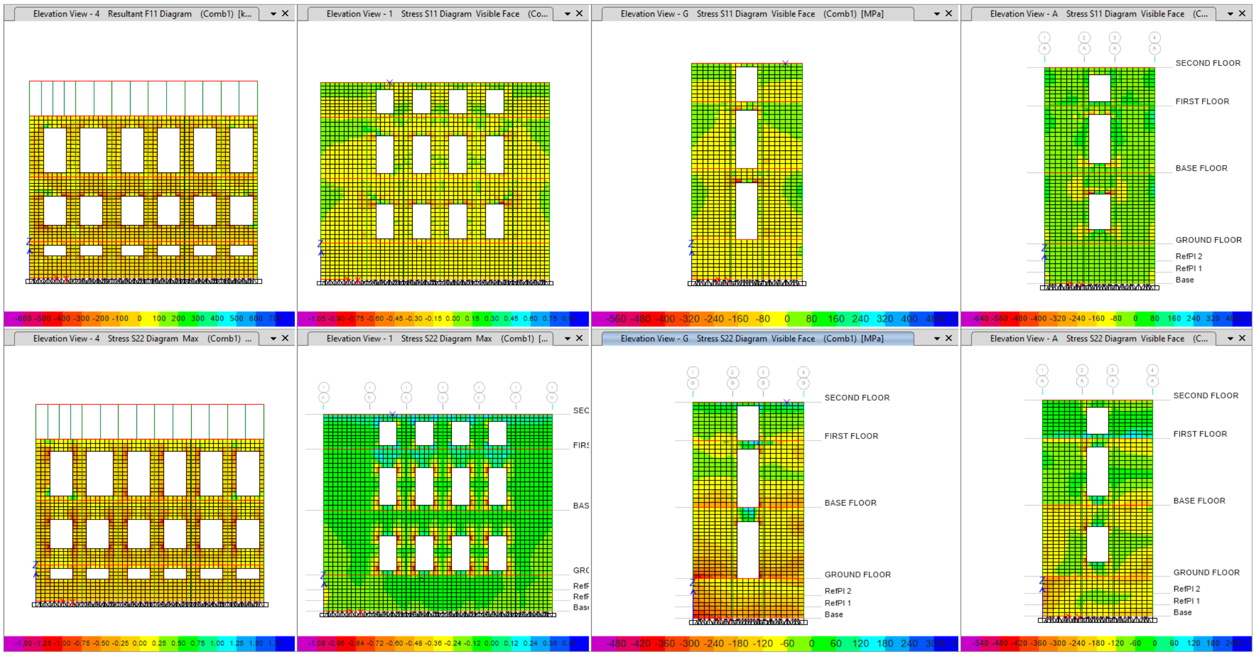


Figure 106. Masonry stress-starin diagrams in the main façade related to the seismic combo (Etabs v.19)

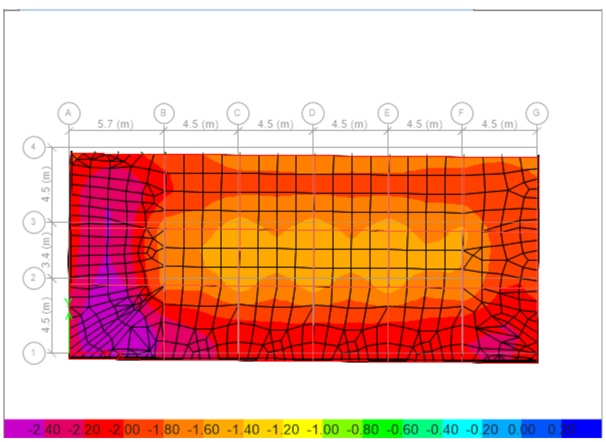


Figure 107. Displacement on the roof, obtained in the framework of static loads (ETABS v.19)

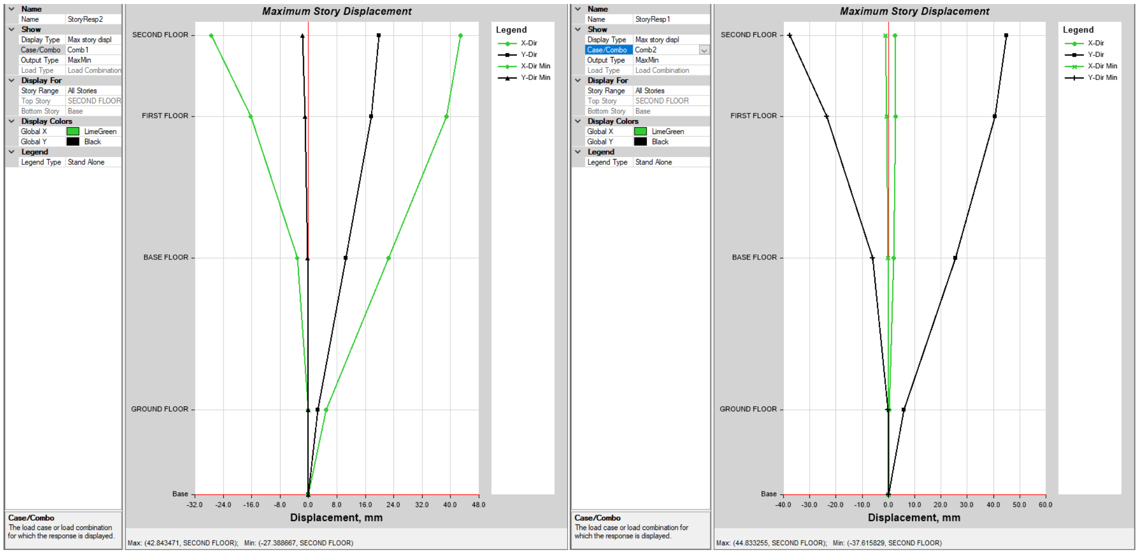


Figure 108. Maximum story Displacement of the building related to seismic combinations (Etabs v.19)

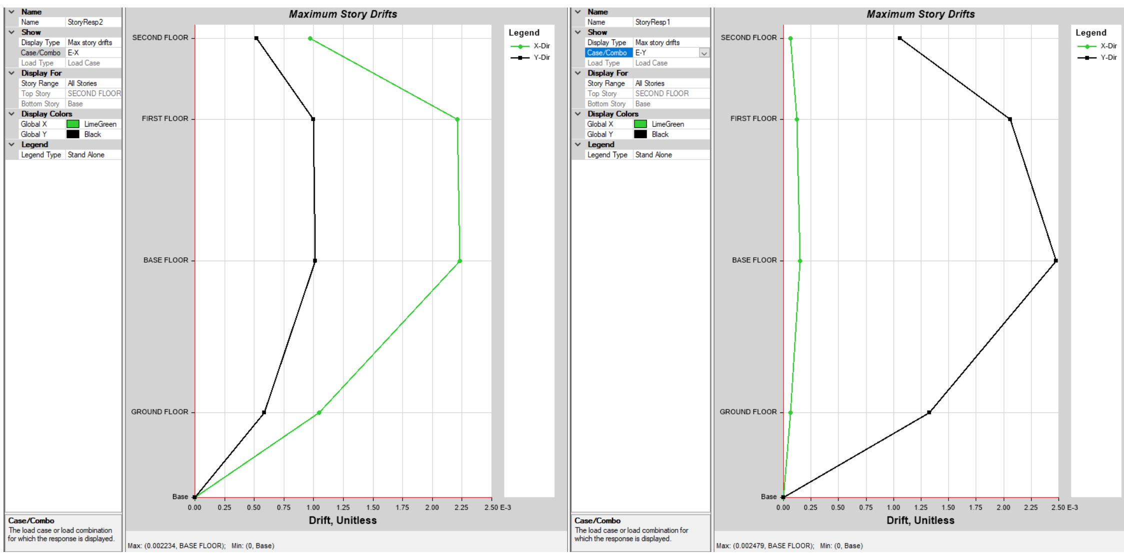


Figure 109. Maximum story drifts related to seismic actions x-y (Etabs v.19)

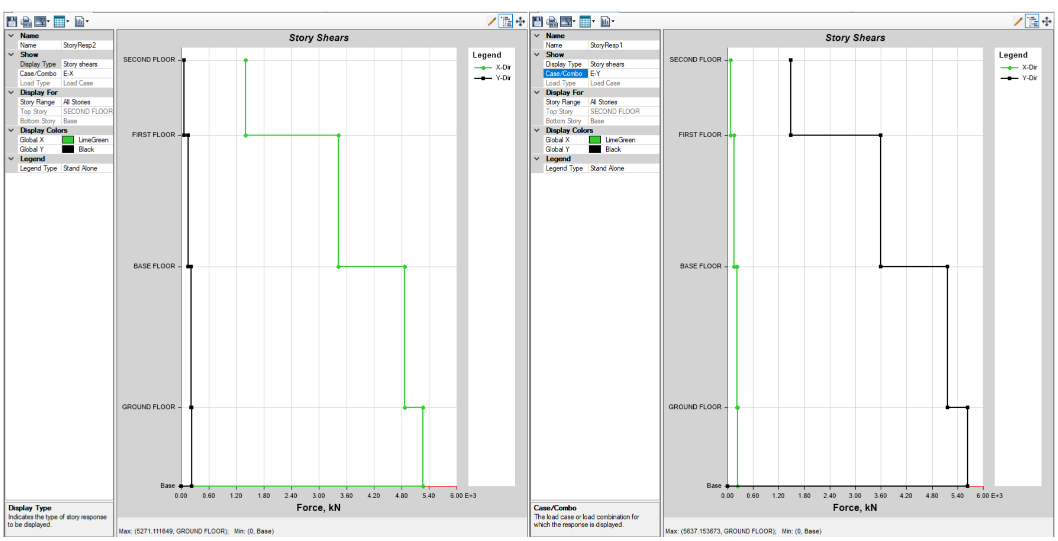


Figure 110. Story shear local force related to seismic actions x-y (Etabs v.19)

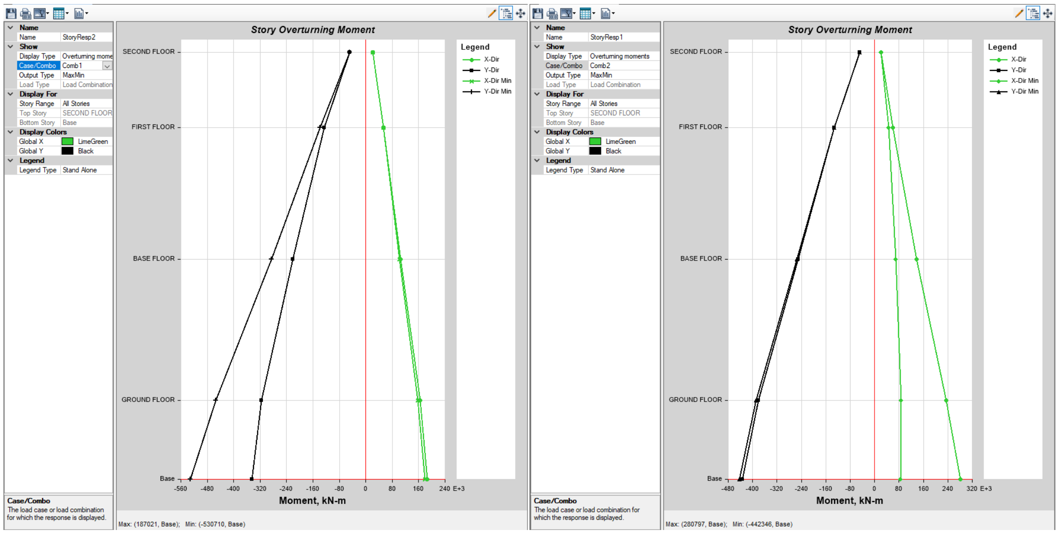


Figure 111. Story overturning moment of the building related to seismic combinations (Etabs v.19)

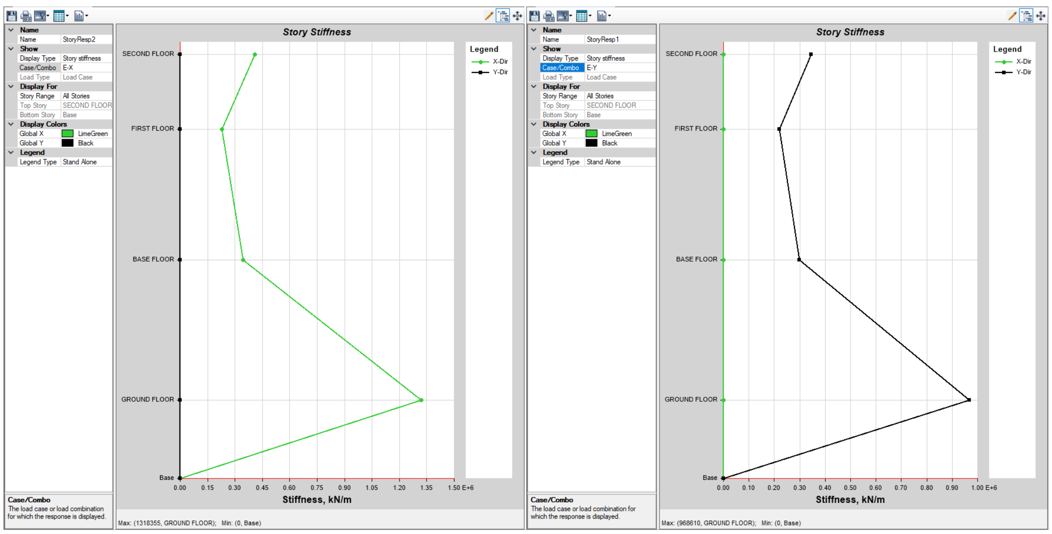


Figure 112. Story stiffness related to seismic actions x-y (Etabs v.19)

6.2.7 Non-linear analysis and the theoretical concept of the model

The nonlinear analysis of the second case study is performed through ETABS v.19.1. The nonlinear properties for frame elements, first columns are assumed to be a plastic hinge P.M2.M3 and beams component as a plastic hinge represented by bending moment M3 respectively. The axial force P for columns, also, shear force V for beams is considered through a simple combination according to Eurocode recommendation of dead and live loads "D+0.3*L", the same combination used in modal analysis.

The wall considered as infills, but also active in its supporting role, and absorbers of shear forces, is modeled through non-linear characteristics according to the non-linear layered wall model, specifically with two layers. The first combined layer predicts the stress state in compression and tension, keeping the normal vertical and horizontal stresses active. The second layer of the panel considers the mechanism of collapse from the crack according to the diagonal stresses. (Baballeku, 2014)

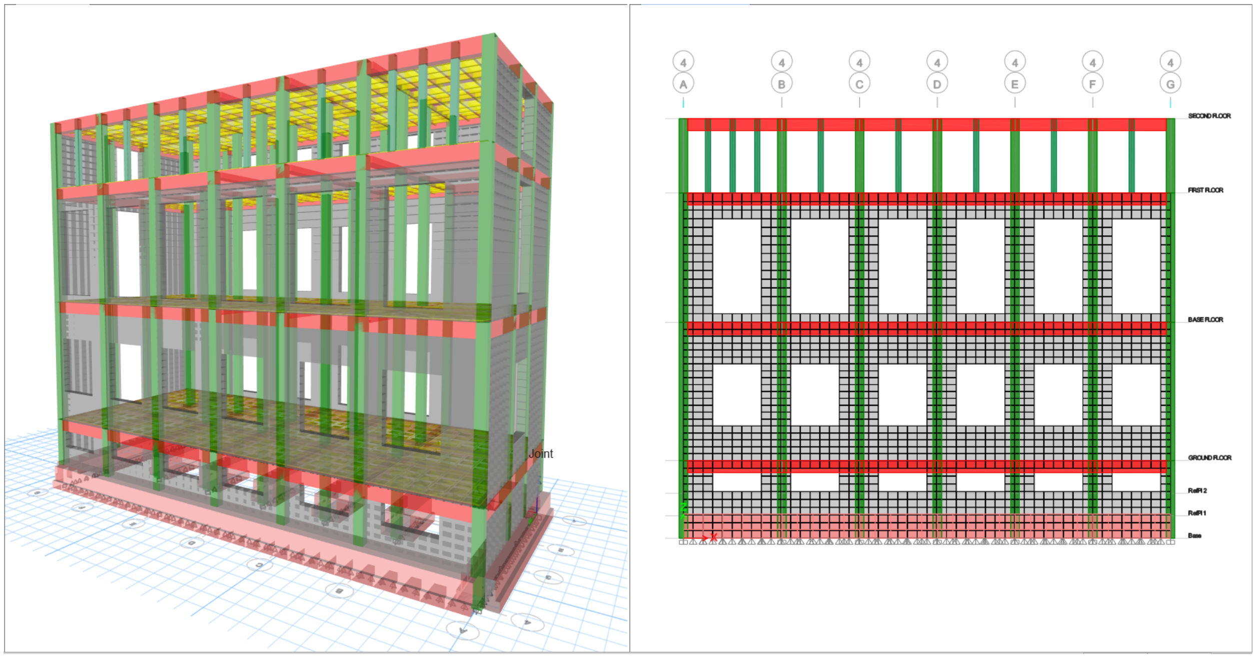


Figure 113. f.e.m. 3d model of the structure prepared for nonlinear analysis

The mathematical/numerical model must guarantee numerical accuracy in accordance with the experimental results of analogous cases and in the literature. This model should be able to predict and simulate the collapse mechanisms needed to represent as accurately as possible the behavior of the material and structure in each situation.

The static nonlinear analysis "pushover" is carried in both directions of seismic action Push-x and Push-y. The pushover curves for the case study in x-directions, step by step scenarios of plastic hinge creation, mechanisms and hinge response are shown below respectively.

Regarding the gradual loading modeling "Push-x and Push-y" this procedure has been followed: Load case data is selected “non-linear static”, the mass of the structure is also activated at these loads. Load type “acceleration” according to Ux direction for Push-x and according to Uy direction for Push-y, load scale factor = 1. Load application control “displacement control”. In control displacement is used load to a monitored displacement magnitude of 300mm. Monitored displacement is used the upper floor roof. Related to results saved for nonlinear static case is selected the minimum number of saved states = 10 steps, and maximum number of saved states =100steps.

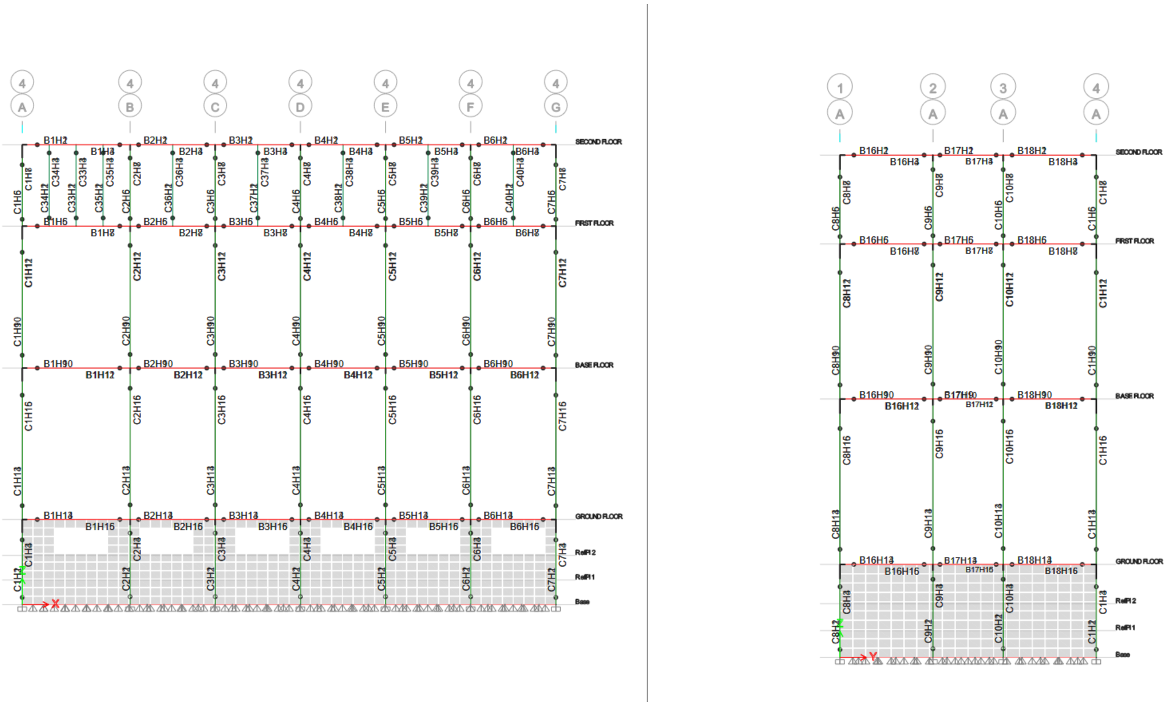


Figure 114. Graphical representation of the modeling of possible plastic hinges before performing the analysis, as well as their positioning towards the edges. Specifically the appearance of hinges in the sections on the C and A axis

The modeling of possible plastic hinges, presented above in (Fig.82) is realized through the option "auto hinge assessment data". The hinge type and their numerical parameters in general are taken from the tables: "ASCE 41-13 with EC-8 2005, Part 3 acceptance criteria"[32]. Regarding RC beams, the technical parameters of their hinges are obtained according to the tables" 10-7 of EC-8.3 (Tab.10-7 concrete beams in flexure/item 1), degree of freedom only M-3 for beams, horizontal loads applied in both directions "Push-x and push-y", deformation controlled hinge load capacity is chosen "drops load after Point E". Type of hinges "auto-M3" with relative distance to clear length, specifically 0.1 and 0.9 near the joints. Referring to the modeling of the hinges on the columns, the technical parameters are taken according to tables 10-8 of EC-8 for RC columns. Degree of freedom is selected P-M2-M3. Concrete column failure condition is selected "condition II - flexure/shear", horizontal loads applied "Push-x and push-y". Type of column hinges "auto-P-M2-M3" with the same relative distance to clear length, 0.1 and 0.9 at the column joints.

[32] ASCE standard ASCE/SEI 41-13 "American Society of Civil Engineers". Seismic evaluation & retrofit of existing buildings

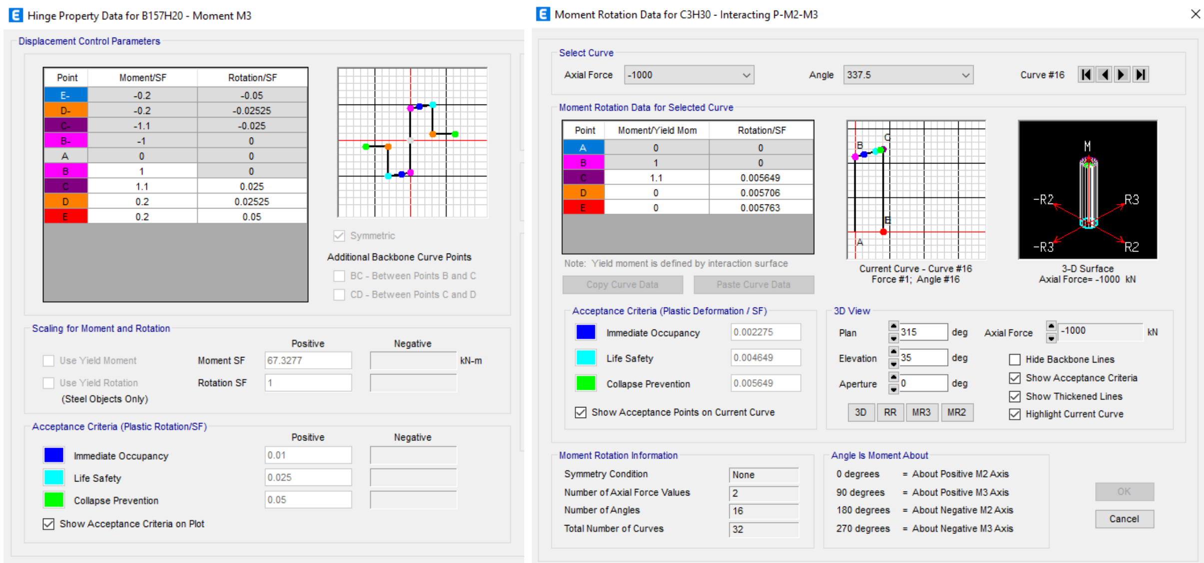


Figure 115. Hinge property data for a selected beam on the left, and for a selected column in the right, specifically the displacement control parameters, acceptance criteria (plastic rotation/sf) related to performance levels. General parameters and theoretical behavior of hinges on beams and columns

6.2.8. Results obtained after performing nonlinear analysis

The results used in this section are conceived in 3 main aspects “a- study of the mechanism of global collapse of the structure, b- capacity curves V-Δ and the procedure to find the performance points according to Sa-Sd in the ADRS-format[33], c-local analysis of Plastic hinge response in some of the selected plastic hinges". The transformation of the capacity curve into the ADRS format is done through modal displacements and floor masses, using the EC-8 (Annex B) procedure and reviewing methodology proposed by Rossetto (Rossetto & Elnashai, 2005).

The theoretical selection of the capacity curve idealization model greatly affects the accuracy of the performance point. In this study, the idealization / bilinearization procedure will be based on the principle of equal surfaces or their equivalence. The idealized capacity curve intersects the real V-Δ capacity curve by creating areas with surfaces below and above the real curve, which have equal surfaces, which means that the equivalent energy of the two curves must be equal. The shape of the bi-linearized curve is closely related to the type of structure and the shape of the V-Δ capacity curve. To increase the accuracy of the performance point determination, the idealized capacity curve is discretized with a certain number of points before and after the yielding limit point, which are used as analysis points. Each of these points is characterized by an Sd_i spectral displacement, Sa_i spectral acceleration, a corresponding T_i period, as well as by the ductility defined as the Sd_i spectral displacement ratio at that point with the spectral displacement of the Sd_y yielding boundary (displacement ductility).

The analyzed results are based especially on the y-direction according to the push-y load and the fragility of the structure in this regard regarding the geometry in the plan.

[33] Acceleration Displacement Response Spectrum format

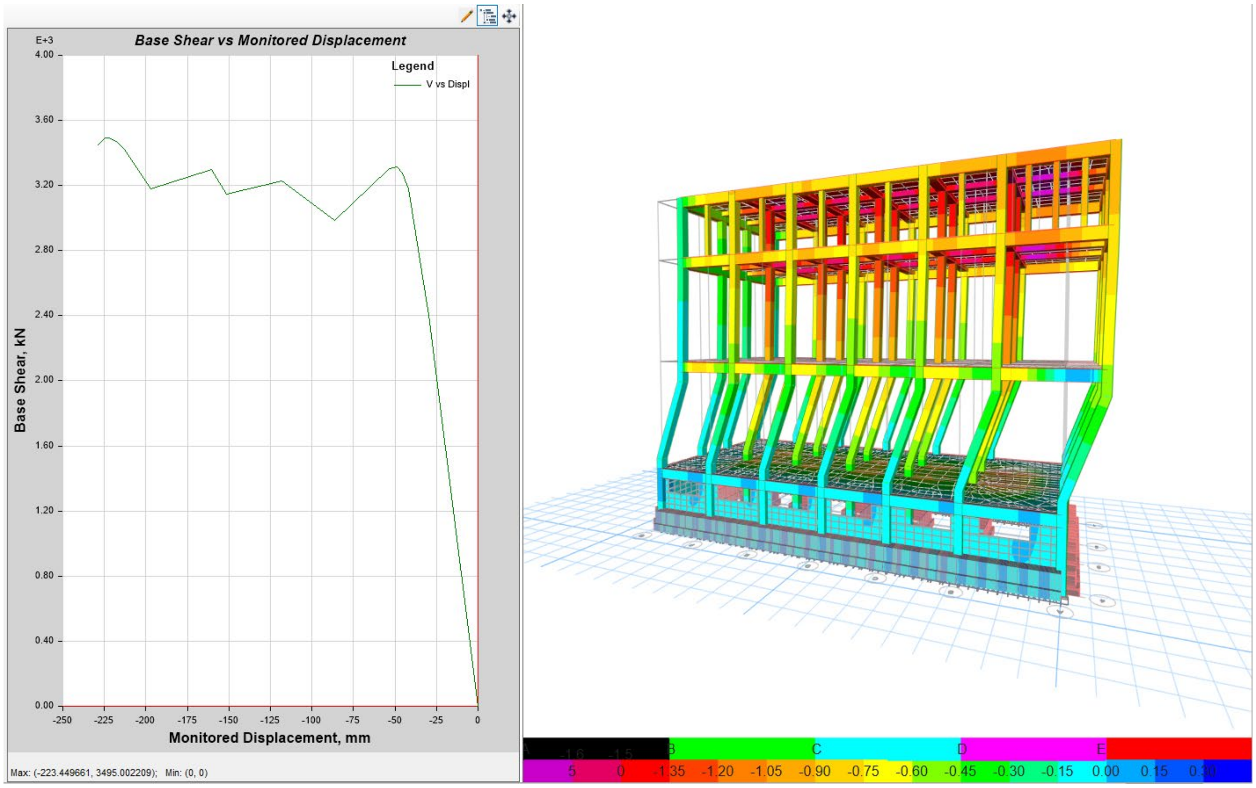


Figure 116. Generation of capacity curve in V-Δ format according to push-x load, captured in etabs.v19

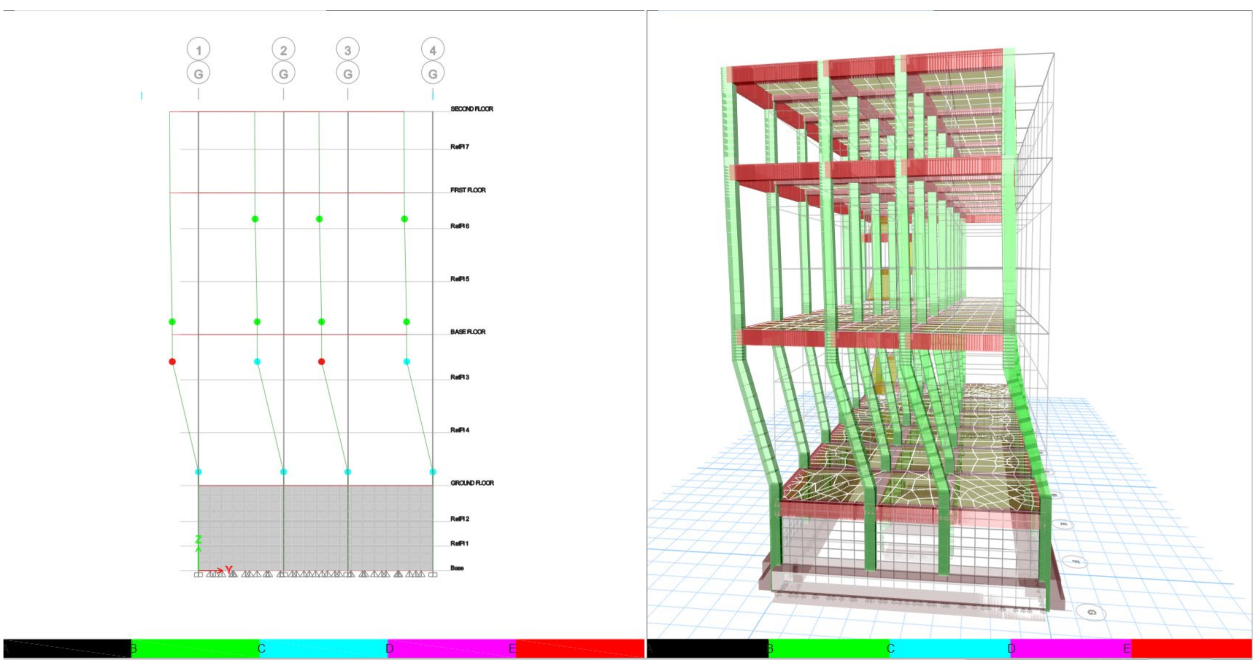


Figure 117. Appearance of plastic hinges in step-20, axis-G, push-y loading in nonlinear analysis

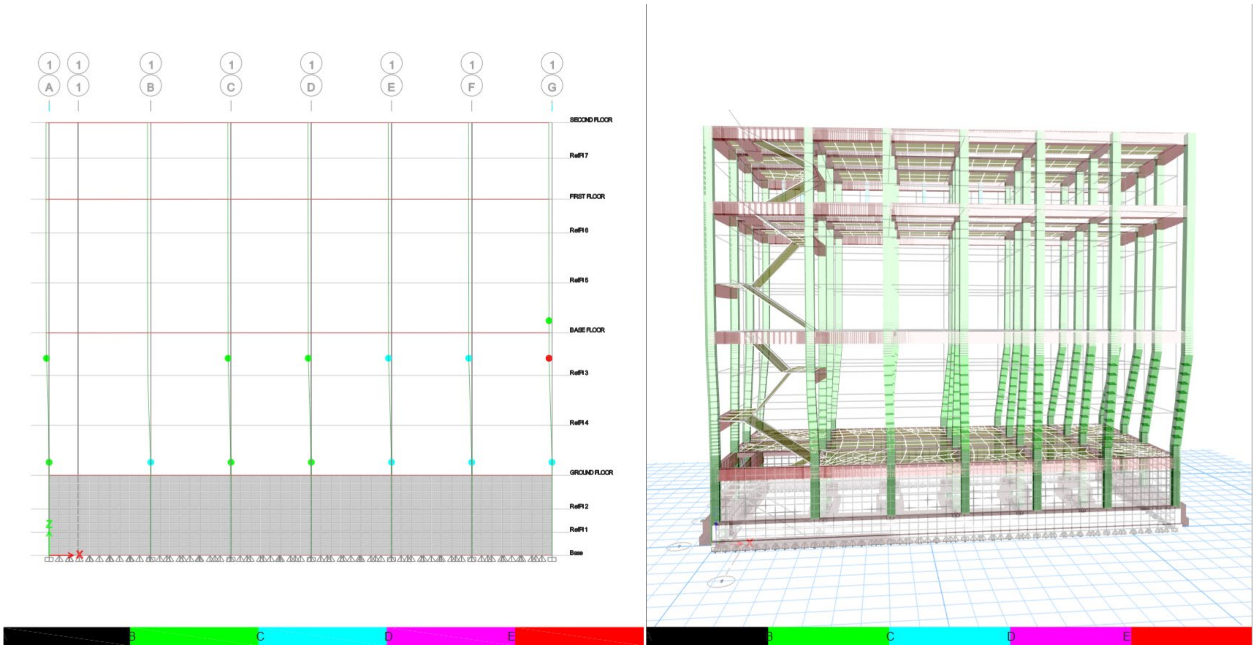


Figure 118. Appearance of plastic hinges in step-20, Axis-1, push-y loading in nonlinear analysis

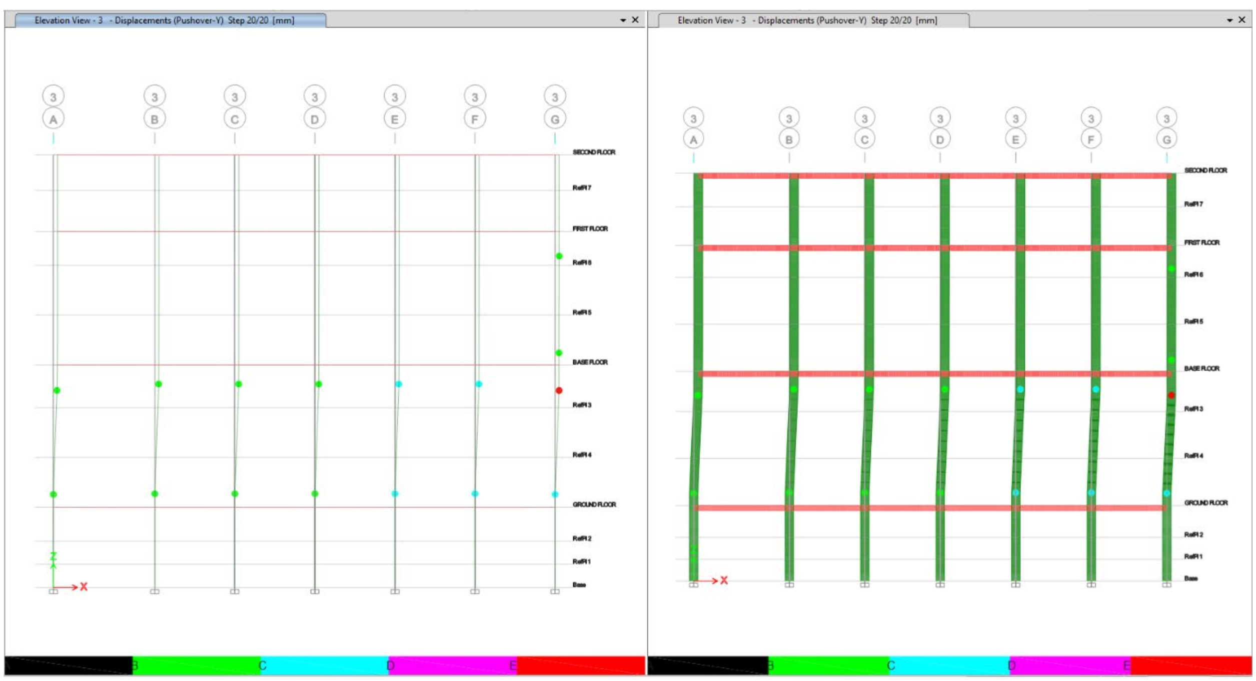


Figure 119. Appearance of plastic hinges in step-20, Axis-3, push-y loading in nonlinear analysis

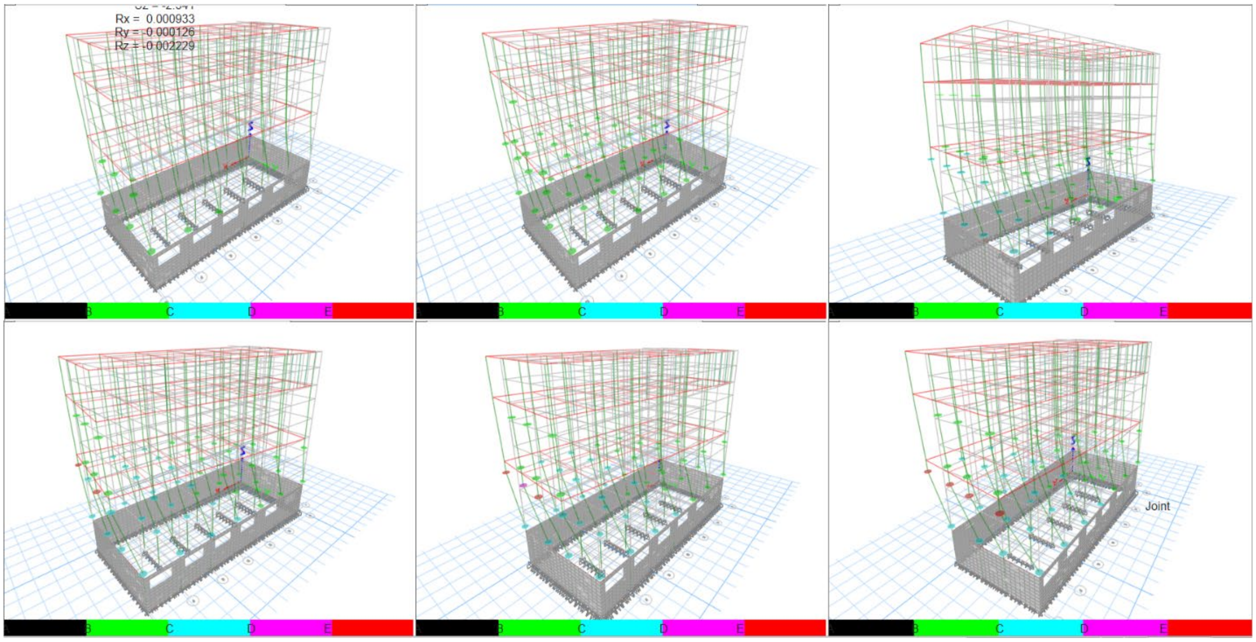


Figure 120. Combination of basic steps according to push-y loading and investigations into possible scenarios of collapse mechanisms

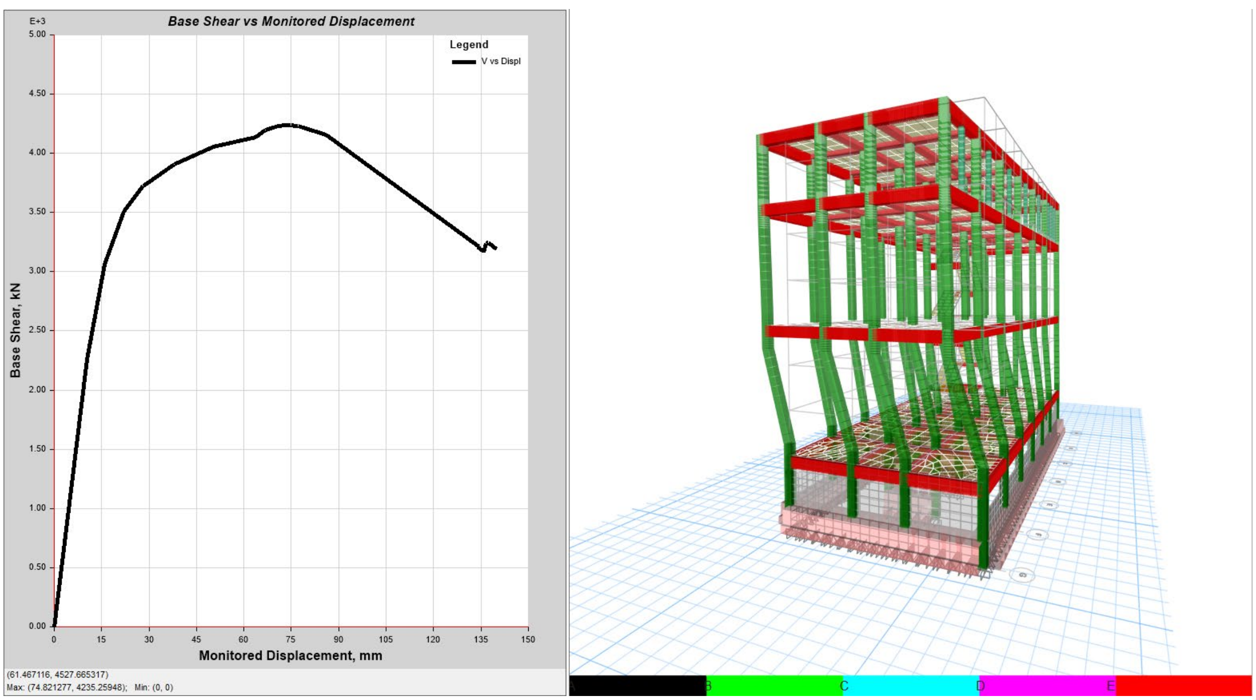


Figure 121. Generation of capacity curve in V-Δ format according to push-Y load, captured in etabs.v19

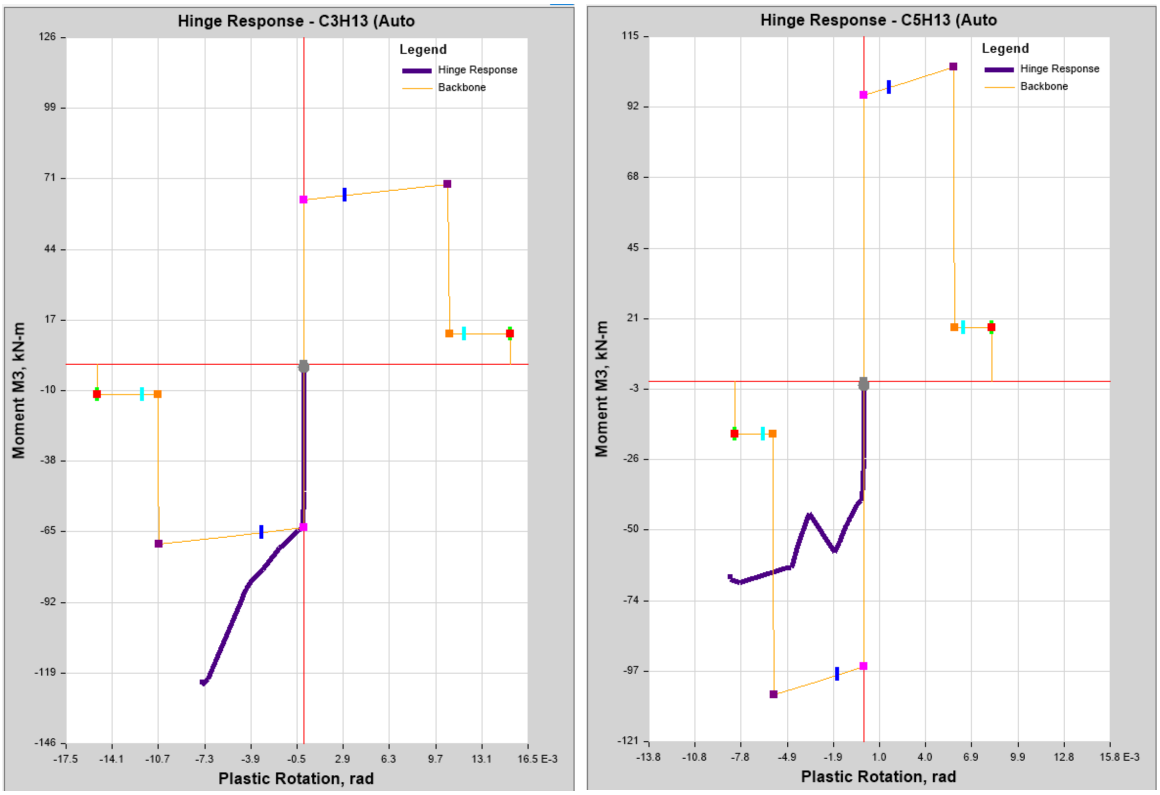


Figure 122. Column C3H13 and C5H13 hinge response diagrams, according to push-Y load

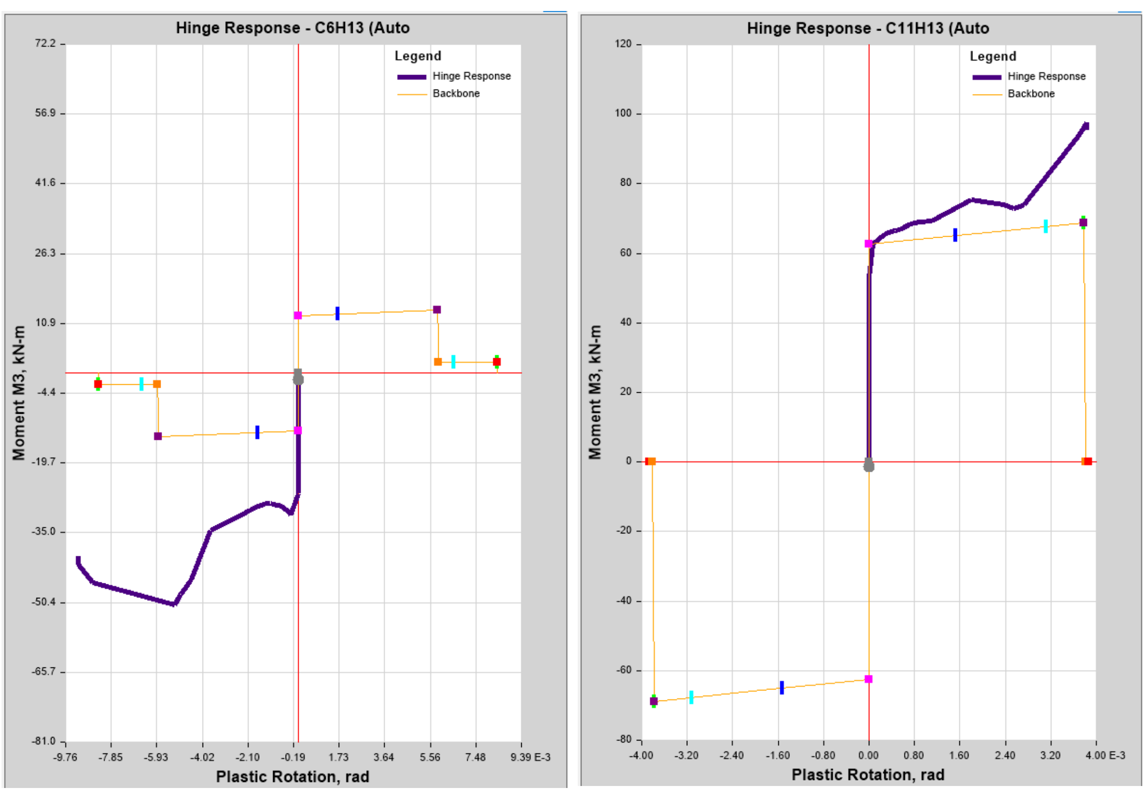


Figure 123. Column C6H13 and C11H13 hinge response diagrams, according to push-Y load

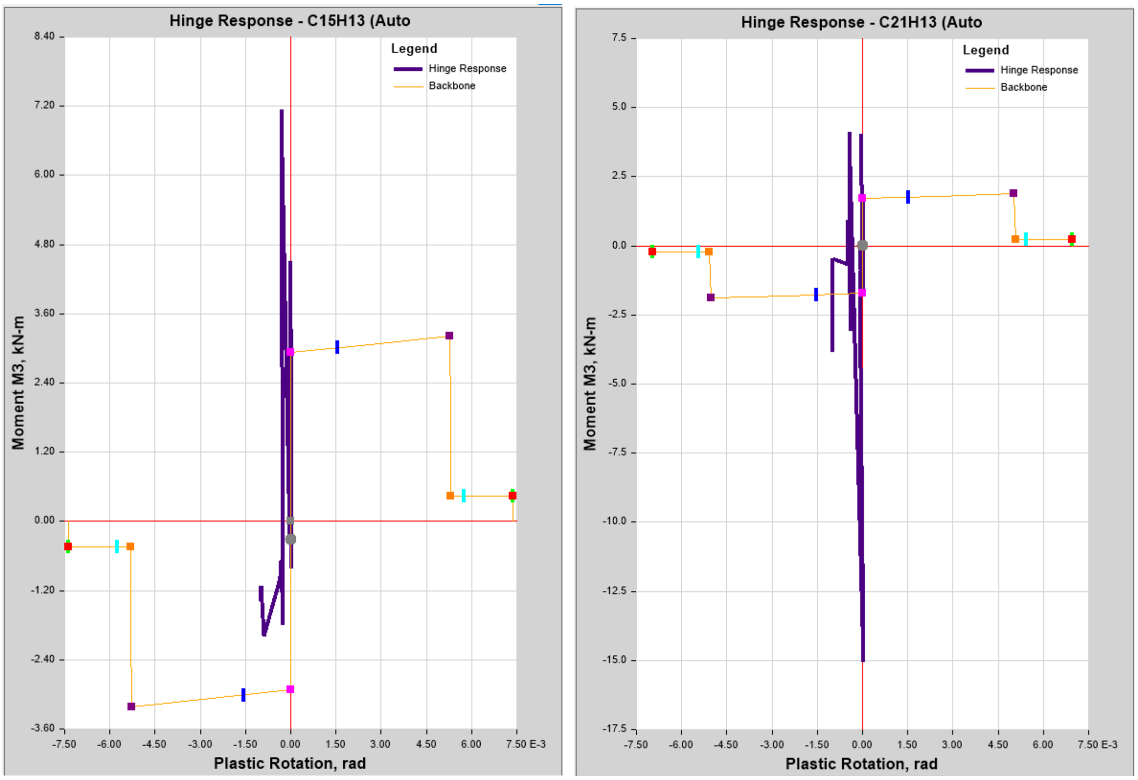


Figure 124. Column C15H13 and C21H13 hinge response diagrams, according to push-Y load

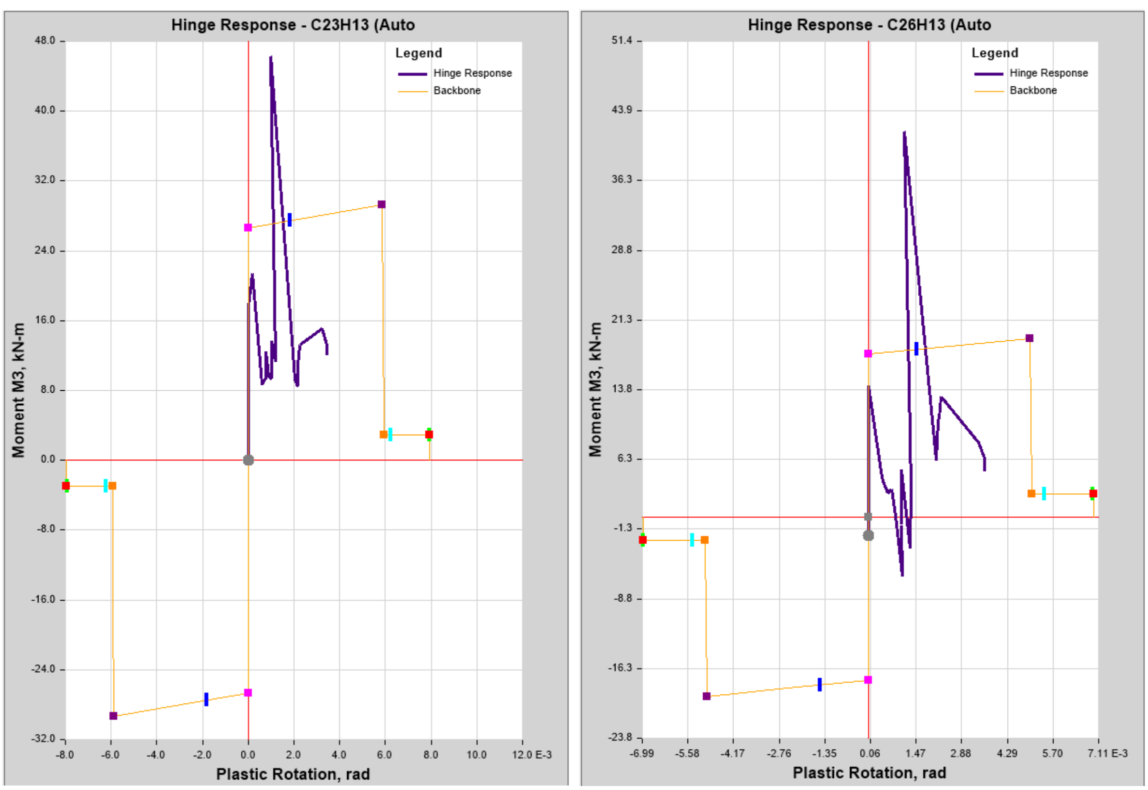


Figure 125. Column C23H13 and C26H13 hinge response diagrams, according to push-Y load

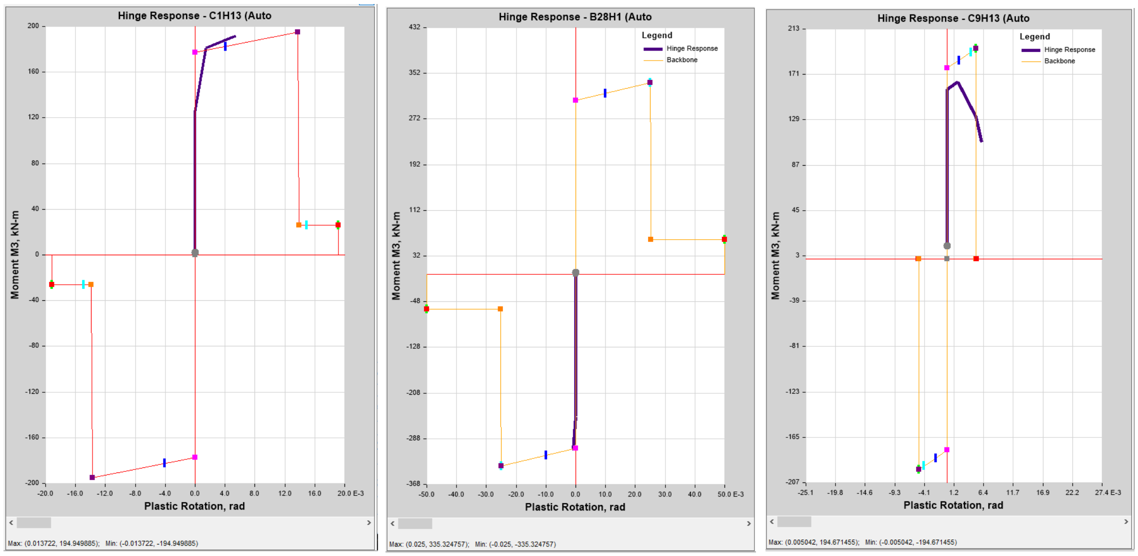


Figure 126. Hinge response diagrams selected from nonlinear analysis, according to push-x load (column C1H13, C9H13 hinge and beam B28H1 hinge response)

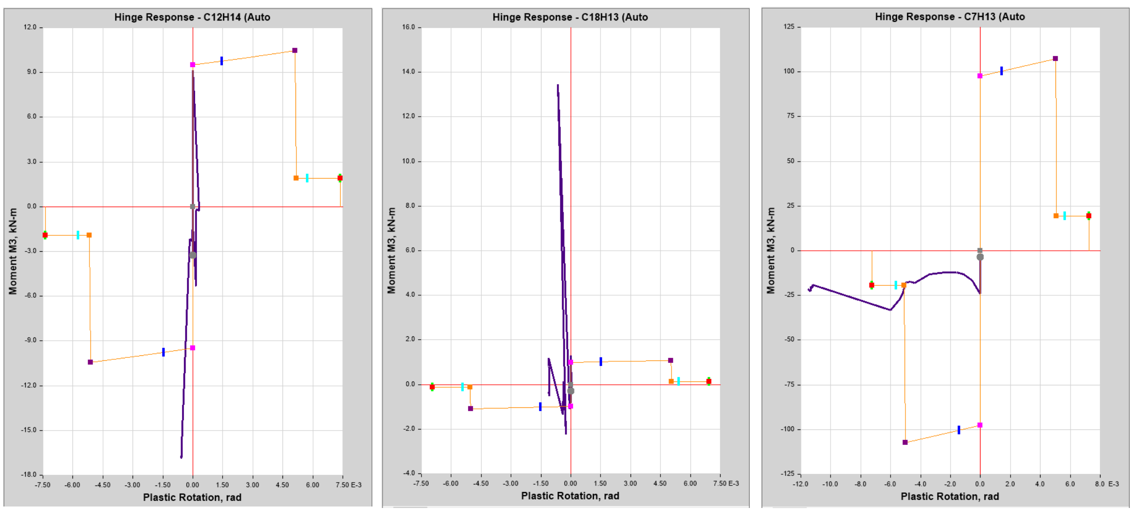


Figure 127. Column C12H14, C18H13 nad C7H13 hinge response diagrams, according to push-Y load

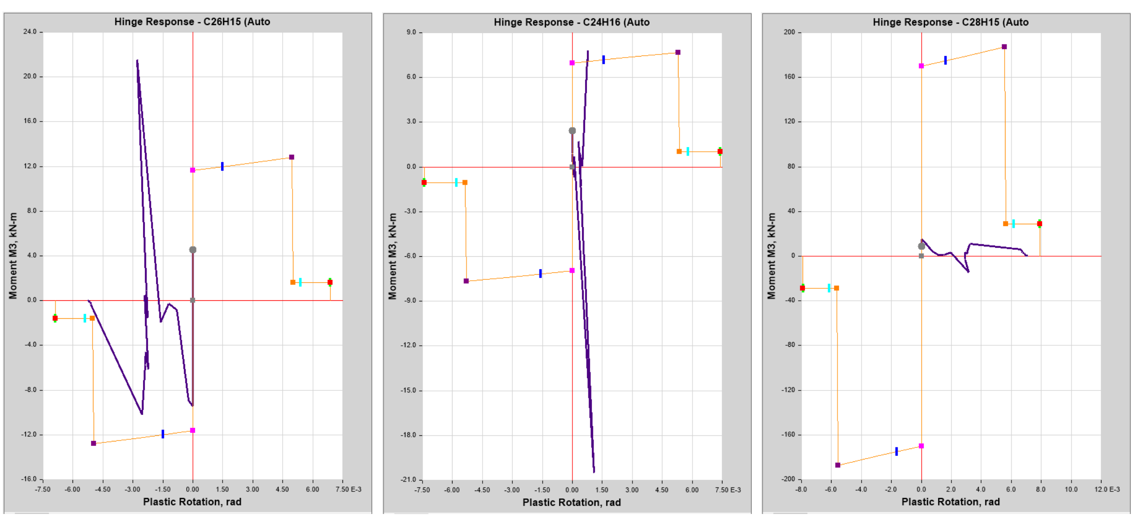


Figure 128. Column C25H15, C24H16 nad C28H15 hinge response diagrams, according to push-Y load