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SUSTAINABILITY

Low-cost strategies for renovation of Residential Building Stock of the 70s-80s in Albania

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Cycle XXXIII

International Doctorate in Architecture and Urban Planning

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Aguljeln Marku

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Abstract

In the 21st century, the most used word was sustainability. That is because one of the main problems of our century is the climate change, which is caused mostly by the carbon emissions. On the other hand, the carbon emissions are cause by the use of energy. The reduce demand of the energy consumption Would impact in the climate change. The most part of the energy use comes from the buildings. the new buildings, because of the new European energy regulations, are very effective in their energy use. the main problem of using that energy efficiency comes from the existing buildings. according to the BPIE. existing buildings contain a huge potential in the energy savings. Therefore, it is a must in retrofitting these buildings regarding their energy use.

The focus of the thesis lies of finding different measures for a total renovation of the existing building stock. These measures can help improve the energy and the seismic performance. interventions will be done in the building insulation in the building technical then and also in the building masonry resisting wall. also, will be discussion about the possibilities of integrating the two types of retrofits. it must be mentioning this building, live a low-income population, therefore the retrofit measures must fulfil the minimum requirements, while being cost-effective. there are several retrofit measures that have been adopted another country and have been successful. yet, there are several difficulties and barriers in improving the energy and seismic perform answer of building. such can be the technical measures, ownership problems, government politics and mostly costs.

Retrofitting existing buildings is one of the realities of the European Union. the most part of these existing buildings are multi-family buildings. Before also the seismic improving performance is very important, since in an event of an earthquake it would cause a lot of Damages, including human lives.

Albanian is a third world country, therefore the main issue for the retrofit will be the economy aspect.

The vast majority of problems in housing stock, which is characterized by constructions which, among other things, do not meet expectations on energy performance and consequently those for the conditions of comfort. Seen in this direction, the quality of life and living standards leave enough to wish. Even after the 1990s, when the need for housing was quite high, the tradition of building cheaply and quickly continued, especially in large urban centers. However, the biggest problem remains the apartments built in the period 1945-1990 where, in addition to technology construction, the situation is further aggravated by their depreciation.

In Albania, as a country with high seismic risk, seismic design and assessment of structures is very important. In most cases, the seismic design situation is crucial in structural solution and in the dimensions of elements. In addition to designing new structures seismic assessment of existing structures is an ever- increasing need due to the existence of old structures built with design codes that reflect knowledge and accumulated experiences up to the time of their design and construction. It can be said that in compared to 30 - 40 years ago, the changes in design codes are significant.

Provisions of the Building Code, which provide adequate protection and safety of life during severe seismic events, regulate ant seismic technical conditions for buildings. A significant percentage of existing buildings are designed using earlier codes when seismic loads were at lower levels than what it currently is. During recent earthquakes, the behavior of masonry buildings, designed according to new seismic codes is satisfactory. Structures designed with previous codes have suffered severe damage due to insufficient capacity to cope with seismic load and limited ductility. Concerns about the suitability of old codes with new ones can be answered more accurately through input of new methods of analysis.

The main objective of this research is to evaluate the energy performance of masonry buildings in Albania pre 1990 and identification of opportunities and alternatives for rehabilitative intervention in them.

These interventions consist in increasing seismic and energy performance. Also, it will be studied the possibility of a sustainable intervention.

The building that will be used as a case study for analyses purpose are the social masonry buildings built in the communism era before the year 1980. Before this year, the design code used was the KTP-63. It had little knowledge for the seismic risk and design.
There have passed about 45 years since the building was builds. According to the European design codes (EC-8, 2004; NTC, 2008), the service life of the is in its end. Therefore, taking into account also the deficiency of the previous seismic codes in Albania, there is an immediate need for the study of the seismic performance and retrofitting.
In absence of the laboratory tests, the analysis will be done taking in consideration the mechanical properties of the material as in the time they were built, without considering the deterioration.
The analysis will be performed with ETABS software, and for the seismic performance will be used the KTP-89 spectre and EC-8 spectre (since Albania is trying to implement this code as a national standard). we will focus in these four types of reinforcement:
TRM, CFRP, Ferrocement and adding steel frames.
These solutions are given based on the possibilities of integration with the energy efficiency aspects. TRM, CFRP and ferrocement, in the phase of implementation in object, have the same methodology as the interventions on the building envelope, especially on the outside walls. Therefore, it can help to reduce the labour costs. Adding steel frames can help generate new shading system and also improving the facades.

Keywords: sustainability / renovation / seismic / energy efficiency / retrofit

Astratto

Nel 21° secolo, la parola più usata era sostenibilità. Questo perché uno dei principali problemi del nostro secolo è il cambiamento climatico, causato principalmente dalle emissioni di carbonio. D'altra parte, le emissioni di carbonio sono causate dall'uso di energia. La riduzione della domanda del consumo di energia avrebbe un impatto sul cambiamento climatico. La maggior parte del consumo di energia proviene dagli edifici. i nuovi edifici, a causa delle nuove normative energetiche europee, sono molto efficaci nel loro consumo energetico. il problema principale dell'utilizzo di tale efficienza energetica deriva dagli edifici esistenti. secondo il BPIE. gli edifici esistenti contengono un enorme potenziale di risparmio energetico. Pertanto, è un must nel retrofit di questi edifici per quanto riguarda il loro consumo energetico.

Il focus della tesi sta nel trovare diverse misure per una ristrutturazione totale del patrimonio edilizio esistente. Queste misure possono aiutare a migliorare le prestazioni energetiche e sismiche. gli interventi saranno quindi effettuati nell'isolamento edilizio, nell'edilizia tecnica quindi anche nella muratura dell'edificio resistente alle pareti. verranno inoltre discusse le possibilità di integrazione dei due tipi di retrofit. deve essere menzionato questo edificio, vive una popolazione a basso reddito, quindi le misure di adeguamento devono soddisfare i requisiti minimi, pur essendo convenienti. ci sono diverse misure di retrofit che sono state adottate in un altro paese e hanno avuto successo. tuttavia, ci sono diverse difficoltà e barriere nel migliorare la risposta energetica e sismica dell'edificio. tali possono essere le misure tecniche, i problemi di proprietà, le politiche di governo e soprattutto i costi.

Il retrofit di edifici esistenti è una delle realtà dell'Unione Europea. la maggior parte di questi edifici esistenti sono edifici plurifamiliari. Prima anche il miglioramento sismico delle prestazioni è molto importante, poiché in caso di terremoto causerebbe molti Danni, comprese vite umane.

L'albanese è un paese del terzo mondo, quindi il problema principale per il retrofit sarà l'aspetto economico.

La stragrande maggioranza dei problemi riguarda il patrimonio abitativo, che è caratterizzato da costruzioni che, tra l'altro, non soddisfano le aspettative sulle prestazioni energetiche e di conseguenza quelle sulle condizioni di comfort. Visti in questa direzione, la qualità della vita e il tenore di vita lasciano a desiderare. Anche dopo gli anni '90, quando il fabbisogno abitativo era piuttosto elevato, la tradizione di costruire in modo economico e veloce è proseguita, soprattutto nei grandi centri urbani. Tuttavia, il problema più grande rimangono gli appartamenti realizzati nel periodo 1945-1990 dove, oltre alla costruzione tecnologica, la situazione è ulteriormente aggravata dal loro deprezzamento.

In Albania, in quanto paese ad alto rischio sismico, la progettazione e la valutazione sismica delle strutture è molto importante. Nella maggior parte dei casi, la situazione progettuale sismica è determinante nella soluzione strutturale e nelle dimensioni degli elementi. Oltre alla progettazione di nuove strutture, la valutazione sismica delle strutture esistenti è un'esigenza sempre maggiore per l'esistenza di vecchie strutture costruite con codici di progettazione che riflettono le conoscenze e le esperienze accumulate fino al momento della loro progettazione e realizzazione. Si può affermare che rispetto a 30 - 40 anni fa, i cambiamenti nei codici di progettazione sono significativi.

Le disposizioni del Codice dell'edilizia, che garantiscono un'adeguata protezione e sicurezza della vita durante eventi sismici gravi, regolano le condizioni tecniche antisismiche degli edifici. Una percentuale significativa di

gli edifici esistenti sono progettati utilizzando codici precedenti quando i carichi sismici erano a livelli inferiori rispetto a quelli attuali. Durante i recenti terremoti, il comportamento degli edifici in muratura, progettati secondo

i nuovi codici sismici sono soddisfacenti. Le strutture progettate con le normative precedenti hanno subito gravi danni a causa dell'insufficiente capacità di far fronte al carico sismico e della limitata duttilità. Le preoccupazioni sull'adeguatezza dei vecchi codici con quelli nuovi possono essere risolte in modo più accurato attraverso l'introduzione di nuovi metodi di analisi.

L'obiettivo principale di questa ricerca è valutare la prestazione energetica degli edifici in muratura in Albania prima del 1990 e identificare opportunità e alternative di intervento riabilitativo in essi.

Tali interventi consistono nell'incremento delle prestazioni sismiche ed energetiche. Inoltre, sarà studiata la possibilità di un intervento sostenibile.

L'edificio che sarà utilizzato come caso di studio a scopo di analisi sono gli edifici in muratura sociale costruiti nell'era del comunismo prima dell'anno 1980. Prima di quest'anno, il codice di progettazione utilizzato era il KTP-63. Aveva poca conoscenza del rischio sismico e della progettazione.
Sono passati circa 45 anni dalla costruzione dell'edificio. Secondo i codici di progettazione europei (EC-8, 2004; NTC, 2008), la vita utile dell'apparecchio è giunta al termine. Pertanto, tenendo conto anche della carenza delle precedenti norme sismiche in Albania, si rende immediatamente necessario lo studio delle prestazioni sismiche e il retrofitting.
In assenza delle prove di laboratorio, l'analisi verrà effettuata tenendo in considerazione le proprietà meccaniche del materiale come all'epoca in cui è stato costruito, senza considerare il deterioramento.
L'analisi verrà eseguita con il software ETABS e per le prestazioni sismiche verranno utilizzati lo spettro KTP-89 e lo spettro EC-8 (poiché l'Albania sta cercando di implementare questo codice come standard nazionale). ci concentreremo su questi quattro tipi di rinforzo:
TRM, CFRP, Ferrocemento e aggiunta di telai in acciaio.
Queste soluzioni sono date in base alle possibilità di integrazione con gli aspetti di efficienza energetica. TRM, CFRP e ferrocemento, in fase di realizzazione in oggetto, hanno la stessa metodologia degli interventi sull'involucro edilizio, in particolare sui muri perimetrali. Pertanto, può aiutare a ridurre i costi di manodopera. L'aggiunta di telai in acciaio può aiutare a generare un nuovo sistema di ombreggiamento e anche a migliorare le facciate.

Parole chiave: sostenibilità / ristrutturazione / sismica / efficienza energetica / retrofit

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I consider it an honor and privilege that my scientific work, in addition to Polis University, also belongs to the University of Ferrara, Italy, a prestigious international scientific institution.

And last but not least, my gratitude goes to those without whom nothing would make sense to me, my two parents, and my sister. They taught me to be who I am. To be demanding, persistent, and systematic in one's knowledge methods. Of course, I also apologize for the little time I have probably put at their disposal, devoting in some cases, much more time to academic life and work for this doctorate.

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1. INTRODUCTION

In the 21st century, the most used word was sustainability. That is because one of the main problems of our century is the climate change, which is caused mostly by the carbon emissions. On the other hand, the carbon emissions are cause by the use of energy. The reduce demand of the energy consumption Would impact in the climate change. The most part of the energy use comes from the buildings. The new buildings, because of the new European energy regulations, are very effective in their energy use. the main problem of using that energy efficiency comes from the existing buildings. according to the BPIE. existing buildings contain a huge potential in the energy savings. Therefore, it is a must in retrofitting these buildings regarding their energy use.

The most of residential building here in Albania are built before 1990, in the communism era. They have been constructed for an extended period of time and have received no renovation. The most of residential building here in Albania are built before 1990, in the communism era. They have been built for a long time and have had no restoration. The majority of social buildings are in poor condition and lack energy efficiency, resulting in a substantial cost to the government budget as well as a risk to structural stability, taking into account structural degradation over time (as the 26th November earthquake showed).

Also there have been a lot of studies in seismic performance and structural stability. But it has never had a coordination between these two fields; energy efficiency and structural stability. So, the point of this study will be to improve the energy efficiency of these buildings and to study the effect of this improvement on the stability of the building. Which technology is the best solution regarding the energy efficiency for a building with specific conditions and if this technology has any major effect in their structural stability?

In order to know how far we can go in saving energy, we need to know the energy demand of the building. the primary source for the energy used in a buildings or heating, domestic hot water and cooling. These can serve as an indicator to estimate the primary energy use and that carbon emission. For the right efficiency retrofit we need to know the deficiency of a building envelope and its energy consume. By that we can provide packages to lower than you consume and by analyzing the costs, we can choose the cost-optimal solution for that type of building. The thesis will suggest with a wide analysis of the costs and benefits of the energy efficiency retrofitting of Albanian residential buildings.

But, as mentioned above, their structural stability may be at risk and by that it is important to study if the building will withstand another earthquake. Also, must be taken in consideration if the savings from the energy efficiency can cover up also for the seismic retrofit.

The thesis examines mechanisms that promote the mobilization of upgrading projects in existing building stock. This section discusses tools which their objective is to find appropriate insulation provisions at the building envelope (e.g., insulating materials of the external walls or roof, window renewal, or configuration of shielded window frames) or that seek to improve the efficiency or co2 emission of a building's active heating systems. Besides applying higher efficient types of technological and limiting heat transfer in the transmission system of a building or heating system, this also addresses the rising use of renewable energy sources for heating supply.

The most of measures apply towards both residential and nonresidential building. Both parts of buildings contain similar structural features (e.g., exterior walls, roof, and openings), regardless their variances in dimension, safety, and quality (for instance in terms of persistence and thermal insulation). Additionally, heating mechanism is quite similar. In an ideal situation, heating and hot water demand might be satisfied entirely through the use of waste heat that would've been dispersed.

The focus of the thesis lies of finding different measures for a total renovation of the existing building stock. These measures can help improve the energy and the seismic performance. Interventions will be done in the building insulation and also in the building masonry resisting wall. Also, will be discussion about the possibilities of integrating the two types of retrofits. It must be mentioning these buildings, lives a low-income population, therefore the retrofit measures must fulfill the minimum requirements, while being cost-effective. There are several retrofit measures that have been adopted another country and have been successful. Yet, there are several difficulties and barriers in improving the energy and seismic performance of a building. Such can be the technical measures, ownership problems, government policies and mostly costs.

Retrofitting existing buildings is one of the realities of the European Union. The most part of these existing buildings are multi-family buildings. Improving the seismic performance as soon as possible is very important, since in an event of an earthquake it would cause a lot of damages, including human lives. Albania is a third world country, therefore the main issue for the retrofit will be the economy aspect.

1.1. Background

Like many other countries that have gone through or are still in the process, Albania is facing development challenges and the constant transformation of the economic, social, cultural and environmental context. The rapid pace of this transformation, confusion, lack of planning but spontaneous development as well as the difficulties encountered during a chaotic transition process, have created a development model oriented to the present and which does not guarantee in most cases, meeting the needs of future generations. Sustainable development with a well-studied strategy is today the basic and most important principle for a successful model, which would enable the continuity in time of the increasing effectiveness. Very little has been done in Albania so far for the energy performance of buildings and consequently the increase of efficiency and the possibility of good management of energy resources.

It began to build massively in Albania long after the establishment of democracy. This came from the huge shortages that were in the housing field, but unfortunately the technology left much to be desired. Lack of legislation as well as in most cases there were constructions without the opinion of specialists and this was especially in the suburbs of urban and rural areas. Only in recent years the construction technology advanced, especially thermal insulation, and the design of the building envelope has begun to receive attention. Only in 2002 there were the first sparks to take action on energy performance issues in buildings with the adoption of Law no. 8937, dated 12.09.2002 "On heat storage in buildings", which together with the bylaws adopted during 2003, makes it possible to sanction the minimum values of volume heat loss with transmission. Realistically and unfortunately the above-mentioned law and the relevant bylaws were never implemented, sometimes due to the difficulty of the calculation methodology and its control, but also because the construction market was unprepared for such a quality hop that would affect growth of construction costs. Although delayed, in Albania and especially in Tirana, there is an increase in demand and supply for buildings with thermal insulation, which is associated with an overall improvement in quality in the field of construction. In this regard, the private market has advanced greatly in the quality of construction, while the public sector continues to build at low-cost and without any special care for the energy performance.

The vast majority of housing stock, does not meet expectations on energy performance and consequently those for the conditions of comfort. Seen in this direction, the quality of life and living standards leave enough to wish. Even after the 1990s, when the need for housing was quite high, the tradition of building cheaply and quickly continued, especially in large urban centers. However, the biggest problem remains the apartments built in the period 1945-1990 where, in addition to technology construction, the situation is further aggravated by their deterioration.

One of the most important current problems in the housing stock is already the process of their energy rehabilitation, which has as its main barrier the economic impossibility of investment by residents and the lack of incentives from public structures. Also, the obstacle has come from the lack of successful practices and little information on measures that can be taken in existing buildings. We emphasize that in the stock of collective housing, the most problematic in relation to energy performance are the housing of the years 1970-1990. This is due to the technology of their construction, deterioration, lack of maintenance as well as socio-economic factors, etc.

From the world experience it has been proven that energy consumption in new buildings can be reduced by 30-50% using traditional technologies and without significantly increasing the cost of investment. In the case of rehabilitation of existing residential buildings, return periods of investment are longer and to make them effective, there are necessary state initiatives. Therefore, in order to support and achieve the result in this process, it is necessary to build a legal, financial and organizational framework.

The structural stability of the building stock, 70-80s, may be at risk, taking in consideration structure degradation over time; as the 26th November earthquake showed. We can find the best energy retrofit solutions for the buildings, but if the building can't withstand another earthquake, the investment will be in vain. It is needed to analyze the seismic performance of the buildings, and asses if it is feasible to do an energy retrofit. Also, must be taken in consideration if the savings from the energy efficiency can cover up also for the seismic retrofit.

The improvement of the energy efficiency in Albanian existing residential building stock would have a huge effect since this sector is responsible for the 30% of the country energy used (INSTAT, 2013). This stock is mostly built before the 90s in Albania and consist in masonry bearing walls. It should be noted that these buildings with built-in the same technology in all the part of Albania. The time that they were built it was no energy regulation codes nor effective seismic codes. Taking in consideration of this fact, and also so the time that have passed since they were built, in which they had suffered material deterioration, we can conclude that this type of buildings doesn't fulfill the current energy and structural codes. As other countries have already taken measures, Albania is still in the implementation phase. The energy retrofit will be done to according to The International Energy Agency, Annex 56 guidelines. The structural retrofit will be done according to EC-8 and FEMA 440. The integration of these two retrofits would lower the cost compared to the case if done separately. Since Albania is a candidate for the European Union, it must fulfill some requirements regarding the energy consumption according to the guidelines of the EPBD. Also, Albania has been subject to different earthquakes the last one being on November 2019, therefore it is a must, intervening immediately in these buildings.

Figure 1-1 Wall deterioration as a result of material degradation (Source: photo by author, Tiranë)

Until about the collapse of the communist regime in 1990, masonry has been used in Albania for household and public facilities due to its low cost. These types of structures are still being used today. The majority of buildings in Europe and Albania were constructed prior to the adoption of energy regulations, and as a result, they have low thermal comfort, low energy efficiency, and poor seismic performance. The existing building stock in Europe shows that about 40% were built before the 60s (Guri & Marku, 2018). In these periods there was a little knowledge about the about the earthquakes and the important use of energy. The fact they are responsible for about the 20% of the total energy consumption in Europe, highlights the largest energy saving potential (Simaku, 2011). Also, the energy retrofit would improve living conditions of the inhabitants by improving the thermal comfort and lowering the energy costs. For these buildings have already passed their service life of 50 years (NTC, 2018). They also don't fulfil the requirements of the new structural codes, as the loads taken in account, are two to three times higher than before. If we only would do the energy retrofit, the building would be at structural risk for the reasons mentioned above. As a part of Europe is earthquake prone, the energy retrofit would be of no beneficial in case of earthquake and serious structural damage. If we would do only the structural retrofit, the people would be living in in low condition and having high energy costs.

The only way to meet Europe's energy goals and seismic criteria is to renovate existing structures. As a result, renovations should increase energy efficiency, structural integrity, and environmental quality. For this purpose, this research focus is to find solutions that promote sustainable renewal all the existing piercings.
Another solution would be the demolition and the reconstruction of the buildings. This scenario is easy because new buildings would fulfill the new requirements; energy and structural. However, it would have a huge impact in the environment and it would be very expensive. Currently the two types of retrofits are being done separately, as they are extremely expensive. Therefore, the main objective of this study is to find low-cost solution for the total renovation of the residential existing buildings. The thesis aims to achieve high performance in safety and energy requirements and in economic sustainability.
The energy retrofit is easier to be implemented since it has economic recovery, by saving in in energy consumption, even though the payback period may last some years. The seismic retrofit tends to be more difficult to achieve since most people believe that earthquake would not occur in their lifetime, therefore interest doing such retrofit it is very low. But, in Albania there is a high sensitivity regarding the seismic events, since one of a high magnitude recently happened. The last earthquake on November 2019 had a catastrophic impact, resulting in life loses. This is the right time to raise the awareness regarding the structural retrofit. And in this scenario, we can do also the energy retrofit, as a possibility to improve the living condition and to save labouring costs.
Numerous buildings in Albania's existing building stock are at danger of inadequate seismic performance since no seismic design code was available or needed at the time they were created. The seismic design code utilized was in its infancy and contained weaknesses, or the quality of the original construction or environmental deterioration impaired the original design.

The importance of seismic design and analysis of structures in Albania, a country with a high seismic risk, cannot be overstated. In most cases, the seismic design situation is crucial in structural solution and in the dimensions of elements. In addition to designing new structures seismic assessment of existing structures is an ever-increasing need due to the existence of old structures built with design codes that reflect knowledge and accumulated experiences up to the time of their design and construction. It can be said that in compared to 30 - 40 years ago, the changes in design codes are significant.
Provisions of the Building Code, which provide adequate protection and safety of life during severe seismic events, regulate antiseismic technical conditions for buildings. A significant percentage of existing buildings are designed using earlier codes when seismic loads were at lower levels than what it currently is. During recent earthquakes, the behavior of masonry buildings, designed according to new seismic codes are satisfactory. Structures built to prior codes have sustained serious damage due to their inability to withstand earthquake loads and their restricted ductility. Concerns about the suitability of old codes with new ones can be answered more accurately through input of new methods of analysis (EC6-1, 2008).
Today, numerous attempts are being made to incorporate seismic evaluation methods for existing structures and their restoration into Design Codes; additionally, in some developed nations (the United States of America, Japan, and others), these "Assessment Codes" are incorporated into the legal framework for construction. Although developments in the field of design are substantial, in our country as well as in many European countries there is still no proper procedure or a special Code for the assessment of capacity and for the rehabilitation of existing buildings in seismic situations.
A high level of expertise in the field of structural engineering has been achieved in most European nations through the adoption of "Structural Eurocodes," which have been implemented into the design process. Already, these norms are a part of everyday design practice in Albania, and efforts to implement them have begun, both through official activities by the competent organizations and through individual initiatives by Albanian engineers themselves. Eurocode 8's seismic design of structures is more advanced than the one based on our country's Technical Design Conditions (KTP). KTP was last updated in 1989 with the acceptance of KTP-N.2-89, which was the most recent revision (Academy of Science, Ministry of Construction, 1989). Many existing structures, on the other hand, were created before to this year and were built in accordance with even older design regulations. Particularly relevant to this study are the structures that were planned in accordance with

the regulatory codes in effect at the time of construction beginning in 1963, such as KTP-63 and KTP-78.
One of the most difficult engineering challenges is the evaluation of seismic capability in both new and existing buildings, as well as the assessment of their response in the event of a ground motion. To attain this goal, nonlinear techniques in different country codes such as ATC-40 (1996), FEMA-356 (2000), FEMA-440 (2005), and EUROCODES 8 (1996), which have been developed during the last two decades, are used.
In nonlinear analysis, the structure's capacity can be predicted in the form of a capacity curve, which is then used to design the structure. Prevalence of masonry constructions especially in areas with high seismicity, in countries such as Italy, Turkey and Greece, has stressed out the need to expand knowledge, in order to assess the vulnerability of existing buildings with masonry (EC8-1, 2004).
Among the multitude of works of Civil Engineering, an important place is occupied by social buildings. The importance of maintaining their structural integrity closely related to ensuring the lives of inhabitants in the event of an earthquake. The actual age of these buildings makes it necessary to know and seismic capacity assessment and methodologies for their structural rehabilitation.

Referring to 2015, the final energy consumption in the building sector for heating services was 4.9 TWh, of which 54% are met by electricity, 37% by timber and 9% by liquefied gas (Simaku, 2020).
Referring to the "passive" action (left in the actual state), final energy consumption for thermal services in buildings is expected to increase by 17% during the period 2015 - 2030 and final consumption will reach 4.1 billion kWh in 2030. Following the trends of the market, it is assumed a rapid increase in electricity heating of existing housing. Therefore, during the period 2015 - 2030 the consumption of electricity will increase by approximately 2.2% / year, while the consumption of firewood and LPG will decrease by approximately 11% / year and 10% / year due to the intervention of the TAP project (Simaku, 2020).
Energy needs in existing buildings is predicted to decline despite an increase in thermal comfort due to passive improvements that are entirely dependent on consumer behavior and have no bearing on national energy efficiency policies. The renovation rate of the building is 2.8% / year and this happens from the investments of the residents themselves (Simaku, 2020).
If we refer to the current regulatory package, the engineering principle of the Albanian regulation, according to the legislative act published in the DCM, no. 38, 16/01/2003, is beyond any doubt, accurate and carefully studied. The regulation (Energy Code of the building) contains information which is sufficient to make the calculations of the insulation layer for new constructions after 2003. Recommendations in the regulation are also given to measure the power of the heater and to plan a thermal load for blocks and regions with different buildings and areas that will be subject to urbanization.

1.2. State of art

Nowadays, a significant amount of the world's architectural history suffers from challenges such as inadequate seismic performance and thermal limitations on a daily basis. It is estimated that the annual cost of repair and maintenance of existing structures in the European Union accounts for around 50 percent of the overall construction budget (Gkournelos, Bournas, & Triantafillou, 2019). The research for creative techniques to optimizing the repair and rehabilitation of the built heritage continues to be a top priority for scholars, practitioners, and decision-makers alike. Furthermore, it was determined that the existing building sector had the greatest potential for energy and CO2 savings in terms of both energy consumption and CO2 emissions reductions. (BPIE (Building Performance Institute Europe), 2011).
Enhancing the energy efficiency of buildings does not imply a reduction in the requirements of indoor thermal comfort; it is a demand for more efficient energy use in order to eliminate waste and the quantity of energy required to meet those requirements. In short “efficiency involves reduced energy consumption for acceptable levels of comfort, air quality and other occupancy requirements, including the energy used in manufacturing building materials and in construction” (Hui, 2002).

Assessing a building's energy efficiency is not a simple operation, as the facility's energy usage is the consequence of a complex relationship in between structure, the environment, and the tenant (Roaf, 2004).
The appropriate indicator for evaluating the energy performance of buildings should be capable of performing the following tasks: a) quantifying the energy demand of the buildings, displayed for example in terms of kWh/m2 per year; b) taking into account the primary energy consumed by the building; c) analyzing the energy life cycle; and d) restricting the amount of energy that can be supplied to the building (renewable and non-renewable) (Casals, 2006);
The high initial cost of energy-efficient equipment is widely regarded as the most significant economic impediment to the widespread adoption of such technology (Levine, Koomey, Price, Geller, & Nadal, 1995).
This is particularly true in poor countries, where the increased cost of energy efficiency technologies is expected to be recouped over a long period of time, rather than immediately (Koeppel & Ürge-Vorsatz, 2007).
When it comes to technology, technical limitations exist in developing nations where there has been a poor planning, knowledge, and information, as well as inadequate after-sales technical support services. (Balce & Zamora, 2000).
The design and layout of a structure are influenced by an energy efficient approach in a variety of ways, such as the orientation of the building or the use of limited window area, the materials used, and the construction. Architectural characteristics can have a substantial impact on user satisfaction (Thompsen, 2008). It is widely known that a building's appearance conveys information about its purpose and function, and that architectural features could have a direct impact on customer happiness. The question of whether the requirements for energy efficient buildings result in certain architectural manifestations, as well as how the aesthetics of sustainable buildings are viewed and influence user happiness, should therefore be of particular interest to architects and designers. How much of an impact does the aesthetics of energy-efficient design have on the users' perception of it, their ability to identify with it, and what part does the aesthetics of energy-efficient architecture play in their decision to live in an energy-efficient home?
Developing energy efficiency improvements is regarded to be a critical component of accomplishing these goals since it reduces energy use while without compromising societal wellbeing (Kenichi, Keigo, Fuminori, Junichiro, & Takashi, 2012).
The EPBD recommends that all Eu countries develop a method of analysis for determining the energy performance of residential buildings that considers at the very least thermal and insulation properties, heating, air conditioning, lighting equipment, the building's orientation, and indoor climatic conditions. (Poel, van Cruchten, & Balaras, 2007).
Without a doubt, when searching for the most energy-efficient solution that satisfies the requirement of energy and non-energy associated factors such as financial, legal, and social aspects, it is necessary to evaluate the complex system of relationships among all components of a structure and its environment (Ma, Cooper, Daly, & Ledo, 2012).

Following the most recent earthquakes to hit Albanian territory, it was determined that masonry buildings' low seismic resilience resulted in severe loss and destruction. (Durres earthquake of November 26th,2019). For their part, low energy performance of buildings, which leads to increased energy consumption, is responsible for 40% of total EU final energy consumption, according to the EU Energy Efficiency Directive. In this circumstance, it is undeniable that a significant portion of Albania's building stock requires extensive renovation, both in terms of seismic and energy efficiency, in order to meet current standards. It wasn't until the last decade that seismic and energy retrofitting were regarded to be independent goals that needed to be accomplished separately. Although various studies on seismic retrofitting (Calvi G. , 2013), (Babatunde, 2017) or energy retrofitting (Salvalai, Sesana, & Iannaccone, 2017), (Ma, Cooper, Daly, & Ledo, 2012) have been published in the literature, it has only been in the last few years that researchers' attention has been drawn to the integration of the two domains. A seismic retrofit does not, in fact, increase the thermal comfort of occupants, and an energy retrofit alone does not result in a reduction in seismic risks, and the energy retrofit alone may be compromised in the event of an earthquake. Despite this, a number of obstacles stand in the way of widespread implementation of integrated retrofit measures (La Greca & Margani, 2018): These obstacles are divided into four categories: There are several types of obstacles to overcome: (I) technical barriers (e.g., the impossibility and/or lack of effectiveness of regular retrofit workarounds, hence the need for regulations simplicity); (ii) economic obstacles (e.g., increased retrofitting expenses, the "split-incentive"/"landlord-tenant dilemma," and a lack of willingness or tax breaks); and (iii) impediments imposed by organizations (e.g., the necessity for temporary relocation of residents and/or activities, the required of compromise is in the case of residential ownership, and the time required to get building permits); (iv) cultural/social differences (limited information and expertise, as well as a lack of appropriate policy measures to encourage renovation initiatives).

When it comes to masonry buildings, the design of energy-saving and structural retrofit interventions are typically two independent projects; integrated approaches are extremely rare. Solutions that address these factors can lower overall renovation expenses while simultaneously improving overall building performance. Massive modifications on the exterior, on the other hand, must be carefully planned in order to increase either earthquake and energetic performance while also reducing environmental impact on the local area.

In recent years, a lot of studies have investigated into energy conservation as well as structural aspects of buildings. Diverse strategies, extending from holistic approaches (Vieites, Vassileva, & Arias, 2015), to dynamic analysis of various buildings (Kramer, Maas, Martens, van Schijndel, & Schellen, 2015), to concrete solutions, including the use of a thermal, vegetal-based, insulating plaster have been implemented (Zagorskas, et al., 2014). Mannella et al. (Mannella, De Vita, & Sabino, 2017) studied an innovative multidisciplinary method, which they describe as follows: On the basis of preliminary historical study, structural diagnostics, and in-situ studies, they developed a reproducible approach for improving the performance of historic buildings, which might be replicated. Using this multidisciplinary approach to building structural and energy diagnosis, we were able to develop a model that can predict the structural stability of a building as well as its energy usage. A combined approach to earthquake vulnerability and energy efficiency analyses was provided by Calvi et al. (Calvi, Sousa, & Ruggeri, 2016). Using an in-depth cost–benefit assessment of the reinforcing methods, Marques et al. (Marques, Lamego, Lourenço, & Sousa, 2018) were able to compare the financial benefit achieved by minimizing earthquake damage to that incurred by the repair.

In the case of more concentrated retrofitting owing to substantial thermal and seismic problems, a global approach to the design/evaluation of the combined intervention is necessary. This is due to the fact that evaluating simply one component of the structure may not be reflective of the whole performance outcome. The double skin solution (D'Angola, Manfredi, Masi, & Mecca, 2019) , for example, has structural consequences that may be evaluated through a global building analysis, such as variations in load bearing capacity, as well as variations in absorption capacity. Because of the various modifications that have been generated throughout the building envelope, likewise imperative can be made for the energy efficiency evaluation. If the mixed thermal-seismic performances of the retrofitted structure are to be evaluated, it is typically done so by emphasizing a global metric that is indicative of the entire improved efficiency of the retrofitted building over its life span (thermal, seismic, sustainability efficiency) (Caruso, Pinho, Bianchi, Cavalieri, & Lemmo, 2020).

Composite materials, particularly textile reinforcing mortars (TRM), can allow for integrative retrofit. Using thermal mortars glass - reinforced fiber textiles, for instance, can improve the mechanical qualities of masonry walls or infills while dramatically reducing their thermal conductivity (Borri, et al., 2016) - may be an option for combined retrofitting. In a similar manner, the use of plasters for structural and energy efficiency improvements has recently been suggested (Coppola, et al., 2019). It has been demonstrated that combining TRM with thermal insulation materials is more beneficial from a strengthening standpoint (Triantafillou, Karlos, Kefalou, & Argyropoulou, 2017). Bournas (Bournas D. , 2018) determined the economic viability of this mixed TRM and thermal insulation solution by comparing the expected annual losses in terms of seismic losses with the expected annual expenditures in terms of electricity. It has been demonstrated that when contemplating a mixed retrofit, a considerable reduction in payback duration can be realized.

Albanian context

The majority of Albania's current structures are old structures that are getting towards the end of their "design" life. In the case of the existing unreinforced masonry (URM) building stock, unsustainability and serious environmental deterioration of structural and non-structural elements usually result in the partial or complete destruction of structures, even in the absence of a significant load or other unusual event. The structural vulnerability plays a key role in this context, particularly because the well-established engineering practices that are currently used to reduce age - associated or hazard-induced damage (e.g., environmental damage, or against seismic risks) were not yet mandatory or even well-known enough to be applied during the design phase. An analogous set of issues may be derived for the topic of energy efficiency in regard to the energy performance of existing URM structures.

Following the earthquake in Durres, Albania, in 2019, the significant seismic vulnerability of existing buildings has once again been put in the spotlight of the debate. Furthermore, the vast bulk of Albania's building stock was constructed before the country's first seismic regulations were adopted in 1979, and in a region that is totally characterized by moderate to high levels of seismic risk. The majority of URM structures were constructed in accordance with the available experience and construction practices at the time of construction. Furthermore, most of them have been designed and constructed prior to the implementation of any codes or measures for earthquake forces. As a result, URM structures require strengthening in order to meet current minimum standards and technical expertise of URM.

The first regulations targeting thermal performance requirements were established in 2002, though their influence was modest. With the addition of new structures, the reduction in energy use continued to be stable throughout 2012 and into 2013. Therefore, the Albanian building stock features reduced seismic capacity as well as poor energy efficiency, necessitating the use of integrated retrofit interventions methodologies in order to maximize the available resources. As a result of this, an integrative method for the seismic and energy retrofit of an unreinforced masonry (URM) structure was developed.

Because pre-1990 buildings in Albania frequently do not meet or exceed the minimum standards stipulated by regulatory requirements, they are in desperate need of an energy requalification process. Furthermore, the majority of the time, the provisions that have been established do not adhere to an integral design approach, according to which diverse components, including as architectural, energy, and structural, must be addressed with each other in order to achieve a whole structure renovation.

1.3. Objectives and research questions

It is typically more cost-effective to retrofit an existing structure rather than to construct a new facility in some cases. Given that buildings consume large quantities of energy, especially for heating and cooling, and that existing structures make up the biggest section of the building sector, it is critical to implement energy saving retrofits to reduce energy usage and the expense of heating, cooling, in order to significantly reduce energy consumption and costs.

Before embarking on what may prove to be a significant financial commitment in the retrofitting of existing buildings for energy and sustainability upgrades, it is critical to assess if the investment is worthwhile in context of current building's overall condition. Is the structure of the building in good condition? Is it necessary to make seismic upgrades in order to comply with contemporary standards and regional construction practices?

The objective should be to produce a high-performance building throughout the planning stage by utilizing an integrated, whole-building design process. For instance, the integrated project team may identify a single design strategy capable of addressing various design objectives. This results in the building being less expensive to operate, increasing in value, lasting longer, and contributing to a better, healthier, and more comfortable environment for people to live and work in. By incorporating sustainability measures into significant renovations and retrofits of existing structures, you may minimize operating costs and environmental impact while increasing the adaptation, longevity, and resilience of the facility.

The term "renovation" refers to the process of "restoring to a decent state of repair." In other words, crumbling structures or badly kept residences are occasionally regarded to be in disrepair. To restore a house or structure is to bring it back to life after it has fallen into decay.
Renovations can frequently be modest, enhancing the current structure or home. Alternatively, they can be extreme, similar to a remodel. Bear in mind that rehabilitation construction frequently refers to "restoring" or "repairing" an existing structure, rather than replacing the old with the new.

The main objective of this research is to evaluate the energy performance of masonry buildings in Albania pre 1980s and identification of opportunities and alternatives for rehabilitative intervention in them.
These interventions consist in increasing seismic and energy performance. Also, it will be studied the possibility of a sustainable intervention.

The main questions on which the research is based are presented as follows:

- What retrofit choices and package deals are available for each representative building type?
- What is the energy performance of residential buildings in Albania?
- What seismic performance have the masonry buildings in Albania?
- What are the low-cost techniques that fulfil the minimum requirements?
- How can we bring these two kinds of retrofits as close as the rules of the European Union?
- Is any connection between seismic retrofit and energy retrofit?
- Propose the most suitable technologies for both retrofits, for Albania.

1.4. Research boundaries

There are actually a few barriers for the Albanian case that can affect this research study. The main barrier in Albania is informality. It isn't any research study, the last one was done in 2013, that show how many buildings are in Albania, or how many people still live in this building. The market of materials is an informal one. There aren't official labour costs for the novel technologies and materials for energy and structural retrofit. This can affect the evaluation for the cost-effective techniques. Regarding the energy code that isn't that any work on implementing it. Also, there are many uncertainties regarding the energy targets. Old buildings data such as architecture and structural design blueprints are very hard to find. In order to do a full evaluation of energy and seismic performance, it is important to know the design project. In aspect of structural design, the construction code is not updating since 1989. Informally, the Albanian engineers use the new Eurocodes.
One important other barrier is the absence of the laboratory tests. The reasons may be because they're expensive and lack on appropriate technical appliances for most of the needed tests. Therefore, it is not taking consideration the material deterioration. Analyses are done like the building is still in the actual state that it was build.
Workmanship for the implementation of the new techniques can be a step back in choosing an appropriate technique. Also, the Albanian government hasn't any programs or policies regarding that renovation of the existing buildings. It is important to say that most of these buildings, the inhabitants have done interventions, structurally and energetically.

1.5. Methodology

It extends on previous research by considering the advantages of integrated energy and seismic retrofitting at the building stock, and applying it to the masonry building typology in Albania. A sample of existing structures dating from before the 1980s (the first seismic code in Albania was established in 1979; KTP-79) were chosen, and the objective for energy and seismic upgrading has been determined based on average building characteristics from the perspectives of thermal and structural performance. In order to achieve the energy and structural performance targets after retrofitting, an innovative retrofit scheme integrating thermal insulation and advanced composite materials for the building envelope is implemented. The energy consumption of the buildings, as well as their seismic stability, are measured before and after retrofitting.

Making use of current knowledge and expertise for both aspects of the construction assessment and improvement as a reference point, the current research seeks to develop a proposition for an innovative strategy that incorporates the two interventions in order to optimize the economical and technological effectiveness of the two practices as part of a complete methodology.
While the implementation of performance-based notions has been demonstrated in the specific example of earthquake engineering through the use of a decision support tool, less consideration has been devoted to existing structures in terms of their seismic vulnerability and energy efficiency equivalents.
The abovementioned situations underscore the importance of conducting a sensitivity analysis that will allow for the consideration of potential advantages deriving from an integrated approach that includes management of disaster risks and climate adaption, among other things.
For the proposed integrated renovation technique to be more eco-efficient, it is necessary to rethink the traditional design methodologies used in the construction industry. The concept of Life Cycle Thinking, which is typically used to promote sustainable development alone, is implemented here just to promote safety and resilience as well, with the goal of maximizing performance while reducing the environmental impact and costs all through the building's life cycle, as is the case today (Figure 1-2). In order to achieve this, the effective participation of various experts should be envisaged from the outset of the design process in order to establish the interdisciplinary aims of the intervention from the outset.

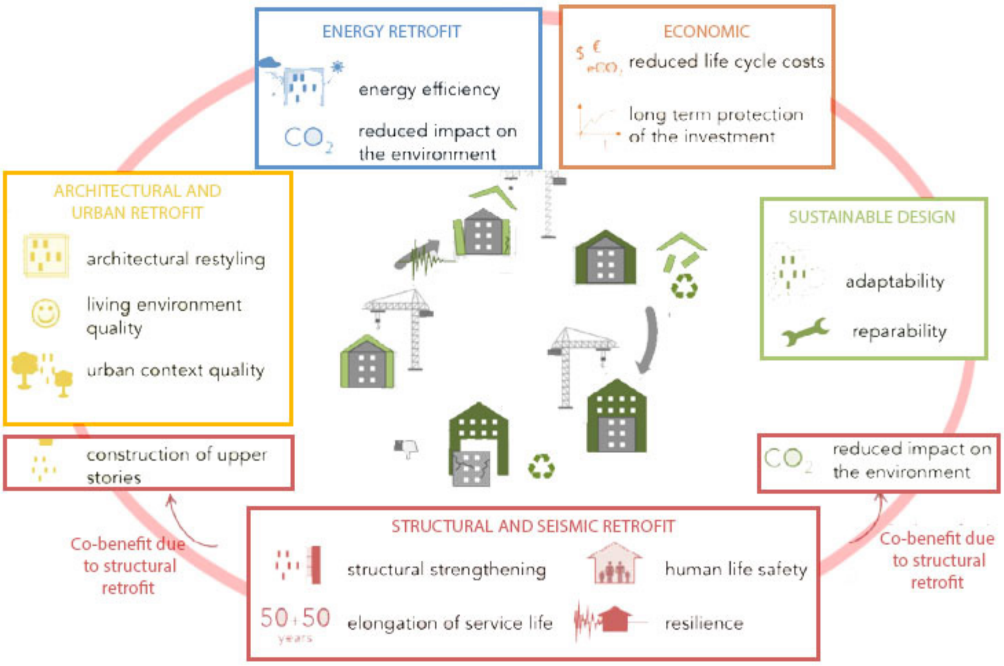


Figure 1-2 Sustainable and Resilient Life Cycle design

The methodology is divided into three major steps:
Step 1 - the improvement of building energy retrofit is carried out by considering a large number of possible and suitable combinations of retrofit options as one of a set of ERMs and deciding, at the end of this phase, the most appropriate configuration as the result of a cost-optimal analysis. It is a complicated topic that necessitates the consideration of a wide range of ERM packages in the effective design of an energy retrofit project. Clearly, the optimal solution is influenced by a variety of elements, including the preferences and requirements of the stakeholders, and also the context in which the structure is placed, particularly in terms of weather conditions. The energy retrofit of a building is handled in this study using a multi-stage optimization method, which is described in detail below.
Step 2 - Evaluation of seismic behaviour and retrofitting opportunities: Given that the present building is seismically active, this stage accounts for the future expenses associated with a loss in the structural performance of the building. A detailed analysis of the seismically caused damages and the resulting economic expenditure required to restore the damaged elements is provided for the

current building "as built" over the course of its entire lifetime. The lifecycle cost (LCC) analysis of a facility or building is a basic engineering tool that may be used to estimate the initial and future expenses associated with a facility or building over the course of its full lifecycle. When it comes to structural behavior, several hazardous events that occur over the operational lifecycle of a structure (such as earthquakes, floods, and other natural disasters) might have an impact on the structural stability of the structure. As a result, the decrease in structural capacity as a result of hazard-induced damage may need the implementation of an appropriate economic expenditure to replace the damaged components.
The process is divided into three steps, which are as follows:

- structure analysis: the engineering demand parameters are the outputs of this stage.
- damage analysis: this stage produces the damage assessment; and
- retrofit analysis: the outcome is the retrofit measures

Step 3 - Integration of energy and structural aspects: cost-effective ERMs are linked to the appropriate engineering requirement specifications and element performance of the current structure. In detail, the ERMs' operation is contingent upon the extent of seismic damage to the non-structural elements to which they have been applied (e.g., walls, windows, etc.). This step tries to simulate the interactions between various energy retrofit measures (ERMs) and the building structure. A sound plan begins with an examination of the building's location from both energy and structural perspectives. Moreover, the geographical location of the site has a direct effect on the energy retrofit design target; but at the other hand, the structural performance of the building is closely correlated with the amount of natural hazard in that location. Within this limitation, physical and technical linkages between structural and energy retrofitting techniques should be identified. The study pays special attention to any problems that prevent the ERMs installed on existing buildings from operating properly as a result of earthquake induced damage.

The study's age groupings are pre-1979. This time period was chosen due to the establishment of code provisions. In general, no considerable consideration was given to seismic design level prior to 1979, with minor seismic design standards in the late 1960s and early 1970s.

1.5.1. Methodology for energy efficiency analysis

With the establishment of the International Energy Agency (IEA) in 1974, as part of the Organization for Economic Cooperation and Development (OECD), the goal of implementing an international energy policy became a reality. In order to promote international cooperation among the 29 IEA participating nations and to strengthen energy security, the International Energy Agency (IEA) conducts energy research, development, and demonstration in the areas of energy efficiency and renewable energy sources, among other things.
The International Energy Agency (IEA) has established a comprehensive portfolio of Technology Collaboration Programs in order to better coordinate international energy research and development (R&D) operations. The aim of the Energy Efficiency and Conservation Center (EBC) is to promote the integration of energy-efficient and conserving processes and technologies into clean, low-emission, and environmentally sustainable buildings and communities through fostering innovation and research. EBC is a program of the United Nations Development Programme (UNDP).
It is the goal of the International Energy Agency's Energy Buildings Consortium (IEA-EBC) research and development (R&D) techniques to utilize technical potential for energy savings in the construction industry and to eliminate technological challenges to the market share of new energy efficiency measures. The research and development approaches apply to domestic, retail, hey will have an influence on the building sector in five key areas for research & development purposes:
– Incorporated planning and design of buildings
– Building energy systems
– Building envelope
– Building energy use

- *Objectives*

Energy is an essential factor for the prospective of the society and will be such also for the near future. Considerable development is ongoing regarding the type and the quantity of energy

consumed. Some of the main strategies are the transformation of the energy system to renewable energy sources, reduction of energy use and increase of energy efficiency.
In developed countries, the building sector plays an important role in the reduction of energy use. The main part of the energy policies of these countries is focused in new buildings, but the poor energy performance of some existing buildings made is necessary to retrofit these buildings in energy terms.
Existing buildings have a large potential on reducing the energy use and increasing the energy efficiency. It is the main objective of the thesis to raise awareness about the energy related to energy renovation.
We can cut carbon emissions into the atmosphere by reducing the energy consumption of existing buildings or increasing the proportion of renewable energy in the energy mix. By renovating an existing structure rather than constructing a new one, the consumption of resources is lowered, and the quantity of waste produced is reduced.
Existing buildings contain a substantial amount of potential for energy savings (BPIE (Building Performance Institute Europe), 2011), but it has proven difficult to completely realize this potential. The methodology established in this dissertation is aimed at obtaining the optimal balance among energy efficient technologies and the use of renewable energy in order to obtain cost-effective alternatives that result in the greatest possible reductions in both energy consumption and carbon emissions.

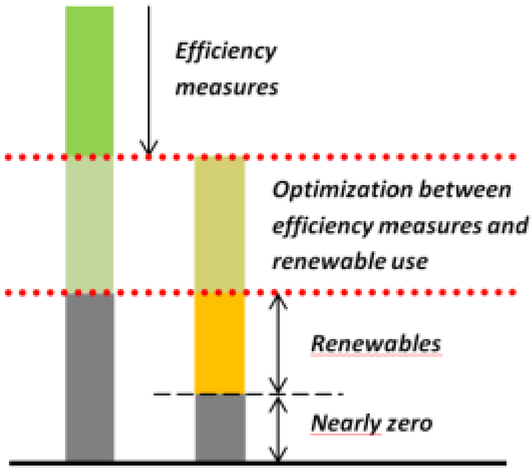


Figure 1-3 Potential in saving energy (Source: BPIE,2011)

- *Change of mind-set towards building renovation*

When doing energy retrofit in existing buildings, there are quite a few obstacles such as high investments costs, lack of information of the real condition of building and long payback periods. Also in some occasions, the ones that pay for the retrofit are not those who benefit from it.
Therefore, it is very important that policy makers, technical experts and building proprietors to find solution to these obstacles for the energy retrofits.
Sometimes, when retrofitting, the most cost-effective option is a package of measures that reduce the energy use and measures that take in account the renewable energy. So, it is important to know how much can we go with efficiency measures, starting from the least expensive, and how far can we use the renewable energy sources, taking in account the local context (International Energy Agency, 2017).
In the case of existing buildings, because of the high costs and long payback period, it can be observed that measures that improve in large amount the energy performance are often missed. Therefore, it is important to know the range of efficiency measures and the disposition of renewable sources to achieve the best building energy performance at the absolute lowest cost (less expenditure, lower long - term costs, less building intervention, less user disruption).

National policies (and legal requirements)

Taking into account the previous retrofits and available technologies, the energy consumption in existing building can be reduced to 30-80% during the building life cycle.

Improvements in the energy performance of the existing building stock are critical in Europe, not just to reach the EU's 2020 goals (European Commission, 2010), but also to satisfy the longer-term goals of a climate policy, as outlined in the Low Carbon Economy Roadmap 2050 (BPIE (Building Performance Institute Europe), 2011).
The EU Energy Performance of Buildings Directive (EPBD) is the main policy framework regarding the energy use in new and existing buildings. It was made know first in 2002 and gives recommendations for the implementation of the energy performance in buildings. It sets common target for the energy performance in EU states. In 2010 and 2018 the Directive was recast with more recommendations, including the implement of the "Nearly Zero Energy Building" and "cost-optimal solutions."

Setting targets for building renovation
A two-step method to improving energy performance is outlined in the directive. To begin, cost-effective techniques must be undertaken to attain a level of efficiency that is at least equivalent to the cost-optimal package of measures. Following that, more energy efficiency measures or the inclusion of renewable energy sources will be necessary to achieve zero or nearly zero energy buildings.
Regarding current structures, it is necessary to investigate in further depth whether the priorities outlined in the two-step approach remain appropriate in terms of overall cost-effectiveness. In fact, for the time being, stepwise renovation techniques are popular, and they frequently encourage the selection of steps to increase the use of renewable energy sources before any other measure (International Energy Agency, 2017).

- *A new approach*

In compliance with the EPBD, the need for the reduce of the energy consumption and therefore the reduction of carbon emissions in building sector, requires a new approach to optimize the energy performance, carbon emission and the whole renovation process in a cost-effective way (International Energy Agency, 2017).
Regarding the renovation of the existing buildings, there some issues that need to be developed. Since the building are long lasting structures, the investments need long-term strategies considering a life-cycle approach (International Energy Agency, 2017). The energy consumption needs a target depending on the local context. The renovations have additional benefits, except energy savings, also carbon emission reduce and increased user comfort etc...

Life cycle analysis in policies
In accordance with the Paris Agreement, in order to reduce carbon emissions, it is critical to concentrate not only on the energy performance of new buildings, but also on the energy performance of existing buildings. Optimizing the energy performance of an existing building not just to significantly reduces energy consumption and CO2 emissions, but it also helps to cut expenditures by lowering operating expenses.
The evaluation of the cost-effectiveness of energy efficiency measures is carried out using a cost-benefit analysis that incorporates a number of different methodologies. A straightforward way is the simple payback method (International Energy Agency, 2017), in which the payback period is defined as the amount of time required to recoup the cost of a capital expenditure. The simple payback method considers only the recovery of the initial cost and ignores any subsequent advantages, resulting in the cheapest option being the most preferable one in this case. It takes into account the expenses of capital expenditure, energy consumption, and operation and maintenance at the conclusion of the time period under consideration. This too simplified study results in the loss of an opportunity to improve the energy performance of the buildings in a more effective manner.

Co-benefits
When doing the energy retrofit of existing building stock, there are other benefits to the building and their inhabitants, other than improving the energy performance. These must be taken into account in policy design, otherwise could result in suboptimal investments. Also, the energy technicians focus

more on energy related effect for instance, energy use and cost, and tend to not consider other benefits of building renovations (International Energy Agency, 2017). This implies that in order to increase the influence of non-energy benefits in the decision making, it is important to spread the information of these co-benefits as well as the interdisciplinary cooperation.
Also, the co-benefits at the building level like increased thermal comfort, improved aesthetic, etc., should be taken into account for the energy retrofit. The building renovation can increase the value of the building depending on the reduced cost of the energy bills but other non-energy related benefits such as increasing the life-cycle of the buildings.
The contribution of these benefits is difficult to be added into a traditional analysis since they can't be measured accurately or to be quantify (International Energy Agency, 2017).

- *Renovation strategies for existing buildings*

Cost-optimate vs cost-effective

It's critical to understand the distinction between cost effectiveness and cost optimization in order to make informed decisions. When taking into account the energy measures that are most cost-effective (in comparison to a reference example), the most cost-effective solution is the one that has the lowest total life cycle costs. For the sake of this example, we will consider measures made that would have been necessary "anyway" in order to restore functionality to the building for another life cycle while not boosting its energy performance (International Energy Agency, 2017).
The benefits of energy retrofits show off in the long-term perspective so we must not focus on measures with short payback time (they can be less effective for the building life cycle) and not compare only the investment costs.
When it comes to renovating existing structures, the most cost-effective techniques do not always result in the best level of energy efficiency. To accomplish the local-level targets, it is necessary to increase the cost of energy retrofit measures over the cost-optimal level while maintaining their cost-effectiveness and effectiveness. These notions are illustrated in Figure 1-4.

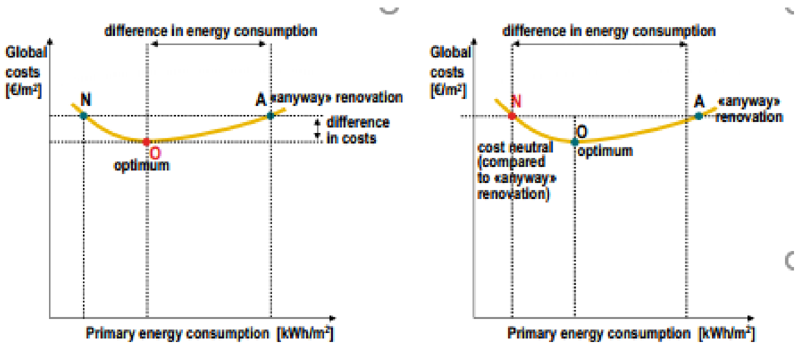


Figure 1-4 Reduction in main energy use in comparison to the reference situation "A" (before refurbishment). Optimal cost-saving renovation option (O). "N" signifies the most cost-effective renovation option. (Source: BPIE,2010)

Which components of the building must be refurbished?

The building elements that contribute to the energy performance of the building can be divided in three main categories (International Energy Agency, 2017):
- passive element; are the elements of the building enveloper like wall, roofs, windows that influence the energy needs of the building. Also, can be included to this category the elements with relation to solar gain via storage or shading devices.
- technical systems; are the systems that cove the energy demand of the building and its inhabitants. Such systems can be for heating, cooling, ventilation or domestic hot water.
- energy source; is used by the technical systems in order to work. It can be from fossil fuels or from renewable sources.
In the existing buildings case, a huge number of factors can influence in choosing the measures that technically and economically feasible for a specific building. The identification of the cost-effective measures to achieve the energy consumption targets for existing building is far more complex than for the new ones. It is critical to develop suitable synergies between the ways listed above in order to accomplish significant reduction of energy consumption in existing buildings in a much more

effective way. Flexibility is required in order to give renovation schemes a chance to succeed and enable the transition of the building stock to one that consumes less energy and emits almost no emissions.

Approach and strategy

It is well established that when performing an energy retrofit, it is mire cost effective to improve all parts of the building envelope rather than just a few of them. For instance, increasing the insulation layer of a wall from 10 to 25 cm often results in much less energy savings than keeping the wall insulation at 10 cm and adding a 12 cm layer of insulation to the roof (International Energy Agency, 2017). It is well established that when performing an energy retrofit, it is more cost effective to improve all parts of the building envelope rather than just a few of them. For instance, increasing the insulation layer of a wall from 10 to 25 cm often results in much less energy savings than keeping the wall insulation at 12 cm and adding a 12 cm layer of insulation to the roof [38]. To avoid missing chances, it is critical to establish ambitious energy saving targets when renovating a facility. When it comes to upgrading the heating system, it's a good time to consider renewable sources of energy. This is a good opportunity to combine the energy improvement measures with the renewable energy and the overall retrofit would be more cost-effective since the heating system would take into account the lower energy use. By taking into account the lower energy use the heating systems would be of lower capacity and therefore cheaper.

Although if energy targets can be met entirely by renewable energy, there seem to be various reasons to implement energy efficient technologies when building upgrades, as they can assure the building envelope has an adequate thermal quality and can boost thermal comfort.

When implementing energy efficiency measures, it is suggested to combine them with renewable energy sources to maximize cost effectiveness. Reduced energy consumption as a result of energy efficiency measures enables the heating system's capacity to be reduced, which boosts cost-effectiveness.

How far to renovate

Reducing the energy use in building and switching to renewable sources had proven to be very cost-effective not only in improving the energy performance of a buildings, but also helping in achieving the carbon emission reduction goals (75% to 90% in year 2050, if compared to 1990 levels, as determined by the EC (BPIE (Building Performance Institute Europe), 2011)).

It is advisable, when renovating a building, to take into account the buildings are long lasting structures (International Energy Agency, 2017). By such, it is important to do a life cycles analysis, which can show measures the are cost-effective, instead of the traditional analysis that are focused in measures with the shortest payback time, which may be more attractive at first.

The findings of a life cycle cost analysis for several potential refurbishment scenarios are depicted in Figure 1-5. It establishes a link between energy consumption and worldwide costs. The reference case is the "anyway" renovation, which restores the building's functioning but does not improve its energy efficiency. The lowest point on the diagram represents the most cost-effective scenario (figure 1-5). Between the cost-optima and reference scenarios, all refurbishment options are rated cost effective. To meet the energy performance targets established, situations far beyond cost-optimal level must be prioritized because they are nearer to zero energy while being cost-effective.

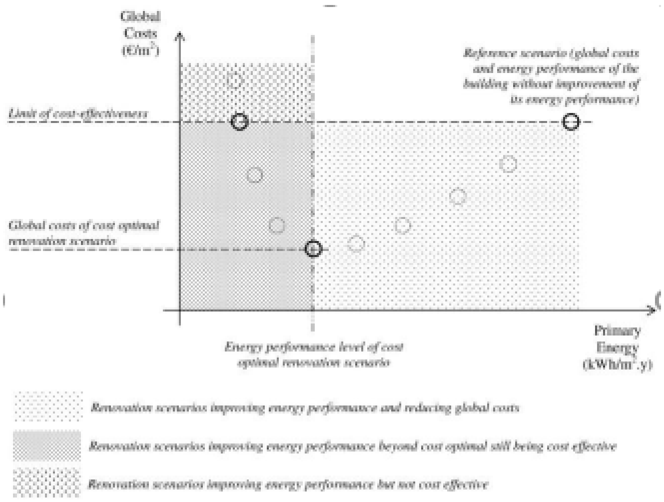


Figure 1-5 Cost-optimal solution (Source: International Energy Agency, 2017))

With all of the major eventualities depicted above, the anyhow scenario should not be the default. Whenever a budget is small, the cost-optimal solution may be the best option. When the aim is the nZEB level, however, a situation must be chosen that extends further than the cost-optimal solution while being cost effective. Regardless of the reason for the repairs, if to refurbish or enhance living circumstances, the older the structure, the more costly the renovations required to meet contemporary standards of comfort. Each sort of intervention increases the building's worth. However, the building's value is defined by the willing to spend for the use of the rebuilt structure (International Energy Agency, 2017). Numerous energy-related retrofit measures improve criteria including indoor thermal comfort, indoor environmental quality, natural light comfort, and building image, all of which raise readiness to invest for such restoration.

Energy use and cost reductions

In the existing buildings, because of the lack of maintenance, is possible to have a poor energy performance which leads in increasing the energy consumption. In residential buildings energy is used mainly for domestic hot water, heating, cooling and other appliances, while heating has the largest share of the energy consumed. Being not totally sealed, a building has lot of heat losses and gains. The properties of windows and shading systems are important in the magnitude of the heat losses and heat gains. Due to the substantial area in contact with the external environment, the roof and external walls have a significant effect on heat losses and gains. Additionally, some technical systems may be inefficient, resulting in energy waste.

Thus, in addition to resolving physical issues with the structure, a restoration that enhances the insulation and energy performance of the envelope also minimizes losses and maximizes gains.

Cost reduction

When the energy performance is improved, it is possible to recover the investments through the savings from the energy bills. To find out which renovation scenarios is cost-efficient, it is necessary to compare them with the “anyway” renovation (International Energy Agency, 2017), a reference case where there are no energy improvements but the initial quality levels are restored. This evaluation should take primary energy use into account as well as worldwide costs. The energy retrofit measures can lead to other benefit such improved aesthetics, thermal and acoustic comfort etc. which will lead to an increase value of the buildings.

“Anyway” renovation

This term refers to renovation scenario in which the building's functionality is restored or maintained. These kinds of interventions are not intended to increase the building's energy performance. ‘Anyway’ measures can be defined as “a set of actions, products and services necessary to guarantee the regular, safe and legal functioning of buildings, as well as aesthetics, technological and modernizing evolutions that societal changes require of them" (figure 1-6) (Ott, Jakob, Bolliger, Kallio, & von Grünigen, 2014:).

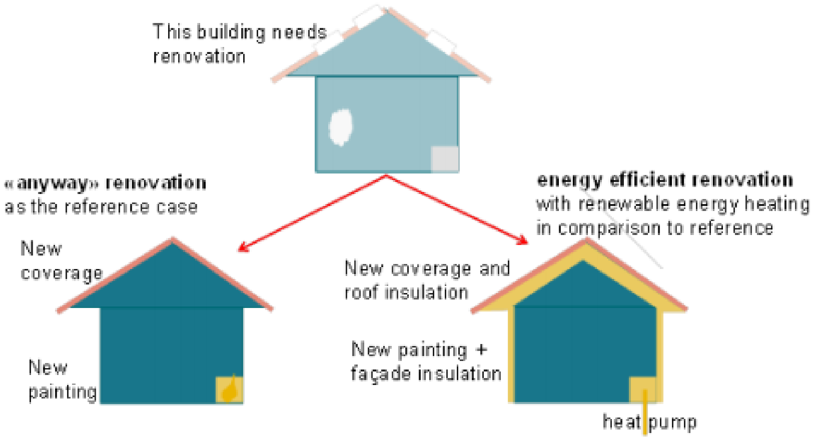


Figure 1-6 «Anyway renovation» vs. «energy related renovation» in the case of a building refurbishment required for functional or structural reasons. (Source: International Energy Agency, 2017))

For example, if exterior wall needs to be repaired, as "anyway" measures, the costs would include scaffolding, workmanship, new materials, lifting methods and other additional costs. If we would do energy retrofit, the wall would require to be insulated and the work would be approximately the same. If energy renovation is not done at a time when other renovations need to be carried anyway, energy retrofit would be less cost-effective, and it may take 30-40 years until that opportunity reappears. The "anyway" renovation, even if it doesn't have the purpose of improving the energy efficiency, can nevertheless lead to a significant reduction in energy consumption when compared to the pre-renovation state.

Renovations that are energy efficient and the potential for renewable energy deployment

Each structure is unique. There is no one-size-fits-all retrofit strategy. The energy remodeling process is influenced by a variety of elements, including location, climate, materials, design, and other qualities. Nonetheless, when a structure requires restoration, it is an excellent opportunity to enhance its energy performance as well. The optimal strategy is to implement measures that reduce energy consumption to goal levels by optimizing the thermal performance of building components. These advancements in interactions with renewable energy sources enable the use of smaller systems, hence lowering non-renewable energy consumption and co2 emissions more effectively. Renewable energy systems can be integrated into existing heating and hot water systems, or they can be used to completely replace them. These systems may include solar thermal panels for household hot water or heating, as well as solar photovoltaic (PV) panels for self-consumption of energy.

What and how… to renovate?

The elements that influence in the energy performance of the building can be divided into three main groups: passive elements (building envelope), active elements (technical systems) and energy supply. The passive and active elements are crucial for the energy use of the buildings. The renewable sources can help to achieve further targets to get close to nZEB.

Assessment (building + "anyway" renovation)

A building's energy performance must be evaluated prior to any energy retrofitting work being carried out on it. This can be accomplished by energy audits or through the use of energy performance certificates (EPC). This document contains information on the energy performance of the building as well as information on the influence of each element on the building's overall performance in

terms of energy consumption. These certificates enable buyers, property owners, and end users to compare the energy performance of a number of different buildings.
Energy audits can be used to examine a facility's energy consumption and suggest potential retrofit actions that can be performed to increase the energy efficiency of the building. Based on the structure's size and architecture, among other factors, this procedure predicts the amount of heat it loses. It is possible to estimate the energy expenses of a building by combining the data collected and other factors such as the type of energy used for heating, energy delivery costs, and environmental impact.

Building renovation options (envelope and technical systems)
Because of financial constraints, renovation scenarios often do not include measures for both the envelope and the technical systems. For example, we can change the technical system without improving the building envelope because does not need renovation yet. To improve the energy efficiency, it is important to renovate all elements of the envelope, since each element has e different influence in the cost-effectiveness of the renovation. In order not to miss opportunities it is important to choose ambitious energy renovation levels. The replacement if the technical systems is a good opportunity to combine with the insulation of the envelope and switching to renewable sources. This will help to reduce the energy needs and so allows downsized systems. Interactions between renewable energy sources and envelope improvements are critical for cost-effective solutions.

Period of reference for the renovated building
The energy analysis (LCA) is done on the basis of a reference period. The reference study period, for existing buildings can be the period from a renovation to the next one (30 years) or from the renovation to the end of the building's service life (50 years) (International Energy Agency, 2017).
The further we increase a building's energy performance; the less energy renovation will be required in the future. Additionally, it is difficult to foresee which materials could be used in the future to substitute energy-related construction components.
To avoid results being misinterpreted, the reference period of study should be equivalent to or greater than the operational life of the energy-related building elements evaluated. As a result, it is recommended that a reference of 50 years be used. If a different era of reference is utilized, it should be calculated and reported.

1.5.2. Methodology for seismic analysis

- *Problems of modeling masonry behavior*

Masonry is a material consisting of masonry units (such as bricks, blocks, stones) and mortar. Mortar, being the bonding material represents an essential role in the behavior of masonry as a whole. For Computer analysis, we can distinguish two major of masonry modeling techniques, respectively micro and macro modeling (Lourenço, 1996).
An in-depth analysis of masonry through the so-called "micromodeling" requires that the bricks, mortar and the interface between them, are modeled in detail. Such techniques of create large computer models that take a long time to build, calculated and processed.
In contrast, the "macromodeling" technique is considered to be the most effective for practical calculations achieving a balance between the time required for computer calculations and the accuracy of results. With satisfactory speed (computer time), this technique presents acceptable results.
Through the procedure known as "homogenization" it becomes possible that the three components (masonry unit, mortar and their interface) to be merged into a single unit for calculation purposes. The two-dimensional element obtained (detached representative unit in figure 1-7), can be conceived in different sizes.

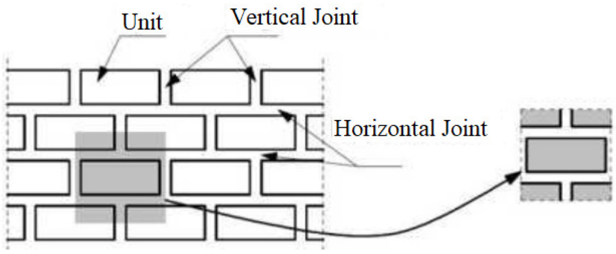


Figure 1-7 Homogenization procedure (Source: Lourenco, 1996)

The representative unit can be considered as orthotropic, with different properties according to three directions. The orthotropic behavior of the masonry corresponds to reality. It arises as a consequence of the technique of its construction, given here the different geometry of the bricks according to the different directions and their connection with the mortar. Representing these properties by numerical values requires that the values of stresses, deformations, and other characteristics to be determined according to the three main directions. Also, the relationship between these characteristics needs to be defined.

A significant engineering difficulty is determining the seismic capacity of new and existing buildings, as well as their response to ground movement. Procedures that are nonlinear in distinct nation codes ATC-40, developed in 1996; FEMA-356, 2000; FEMA-440, 2005; N2 Method, developed in 1996; and Eurocode, established over the last twenty years, are all approaches to this objective. It is possible to anticipate the structure's performance using nonlinear analysis in the form of a capacity curve.

Masonry modeling has long been also a challenge for researchers. This is because of its complex behavior of dissimilar properties in the different directions. The most favorable direction of work, is naturally the vertical one that serves for holding vertical static loads. Alternating placement of bricks at heights makes the best use of the bricks shearing capacity. It does not happen that way in horizontal direction. The bearing capacity depends only on the cohesive bond between the brick and mortar, which is several times is smaller than the bearing capacity in vertical compression. Even smaller are the tensile stresses from bending at on and outside plan of the wall. Fortunately, in most cases the bending is not sensitive due to the considerable stiffness of these structures. The main dangers for these structures are earthquakes. The risk of earthquake remains the highest disadvantage because it can lead the structure to collapse in a few seconds. As a result, it is endangered the lives of the occupants of the buildings. The bearing capacity of masonry that directly oppose seismic forces, is the shear strength.

Given the behavior of masonry as a rigid element that works on vertical compression and horizontal shear, many authors have tried to model it in different ways. Computer modeling with finite elements gives us three possibilities for masonry: i) with linear elements, ii) with planar elements, iii) with three dimensional elements. Some authors have used linear elements (Belmouden & Lestuzzi, 2009), giving such stiffness to represent the working conditions of the masonry. Of course, to achieve this it was worked with smaller models in laboratories. Based on the results of tests, have modeled in finite element programs with proper coefficients, that make it possible to match the results of the computer analysis with laboratory tests. Then with those modeling parameters they analyzed the real structures.

Less commonly used is the technique with finite plane elements. This is due to complexity in modeling the degrees of freedom. ETABS software with finite elements, gives us unlimited modeling possibilities with plan elements. We will use the method implemented in previous studies (Muhidin & B) which uses nonlinear behavioral plan of elements.

The three-dimensional finite element technique is less usable due to the considerable time required for modeling and analysis of structure. Three-dimensional element modeling has only been studied for limited masonry dimensions and not for three dimensional structures. Scholars who have used this model have divided the wall into bricks and have used their nonlinear behavior for each direction.

Nonlinear modeling of masonry in ETABS

Calculations will be carried out on the computer using the finite element software ETABS. To simulate the masonry, a shell element with nonlinear behavior layers will be used. The layers will depict the masonry's features in axial compression and shear (Bilgin and Korini, 2012) (Bilgin & and Korini, 2012).
In ETABS the plan element has three or four nodes and in elastic analysis has rigidity in its own and out of plane, both in bending and in compression-tension and shear. This type of element can be homogeneous or layered. Masonry is not homogeneous or isotropic, therefore this type will not be used in the following chapters.
The layered shell element allows to specify any number of layers according to width direction, each with an independent position, thickness, behavior, and material, from one to the other. Material behavior may be nonlinear. Unlike the homogeneous "shell", the degree of freedom of torsion in its own plan is not used, and should not be considered in bearing capacity. These rotations perpendicular to the plane of the element, are fixed to prevent its instability. For bending, it is used a Mindlin / Reissner formulation (Mindlin, 1951) (Reissner, 1945) which always involves cross-sectional deformations. Out of plane displacements are consistent with the displacements in the plan. "Shell" layers usually present complete behaviors both in the plan and outside it, but the degrees of freedom can also be modeled divided into layers (figure 1-8).

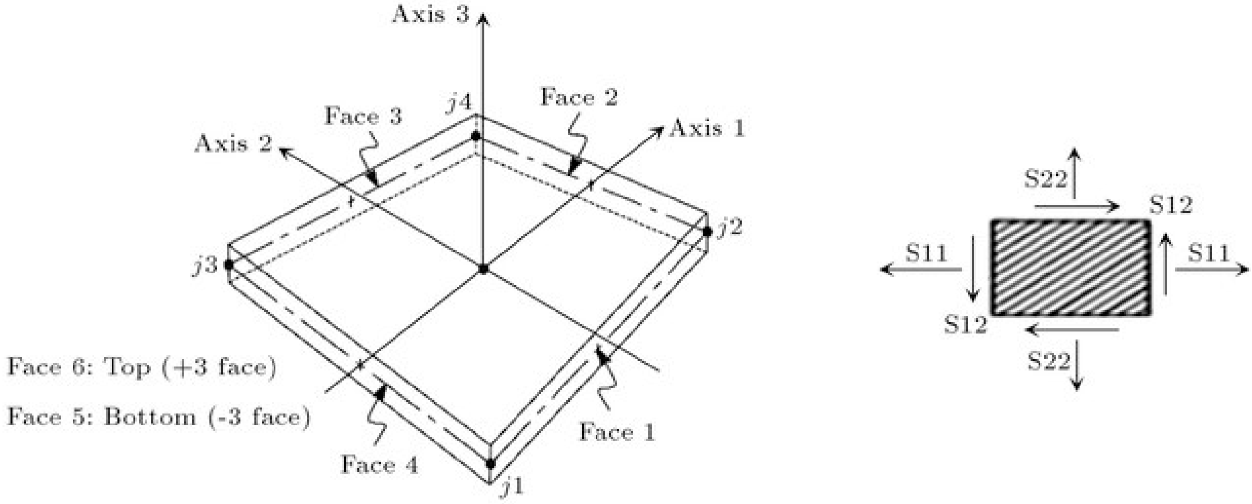


Figure 1-8 The plan element with 4 nodes and stresses in plan (Source: Guri, 2016)

In this research, nonlinear analysis will be used in conjunction with elements of the "Shell" type. Two separate stresses-strain graphs will be used to model the behavior of the masonry.
They will symbolize the vertical stress S11, the horizontal stress S22, and the shear stress S12. These behaviors are also the most important characteristics of the brickwork material. It is critical to accurately estimate the stresses-strain graph in each direction to the greatest extent possible. The goal of this study is to investigate masonry strengthening; as a result, earlier investigations will have prepared the visuals for this study (Bilgin & and Korini, 2012). Below we present details of them.

Stresses-strain graphs for directions S11 and S22 (Kaushik, 2007).
This behavior is well defined by researchers like Kaushik in 2007 (Kaushik, 2007) based on many laboratory tests.

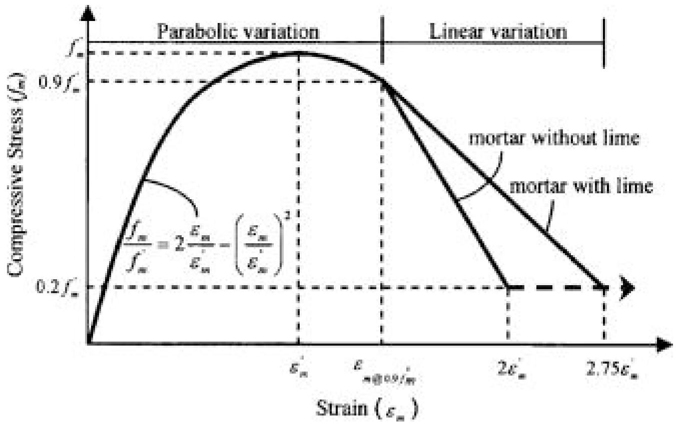


Figure 1-9 Stresses-strain graphs for directions S11 and S22 (Source: Kaushik, 2007)

It should be noted that tensile strength is not taken into account according to Eurocode 6. For the purpose of calculations, a straight line with zero value on the other side of graphic will be used.

Stresses-strain graph for shear S12 (Kaushik, 2007).
This curve depicts the nonlinear behavior of a masonry element up to the point of destruction in the horizontal direction. When masonry is exposed to horizontal ground shaking (earthquake), the horizontal resistance force is described in the literature as being represented by the cohesiveness and roughness between the bricks and mortar. This strength is the Mohr-Columbus shear stresses:

$$\tau = c + \sigma tg\varphi \qquad \text{Eq 1.1}$$

This equation expresses the vertical strain as " σ " and the friction between the elements as" $tg\varphi$”. The fact that cohesiveness must be destroyed in order for sliding friction to be activated should not be underestimated. The equation expresses a relationship between the behavior of vertical stresses and the behavior of friction. This kind of interdependence is not possible to realize for a nonlinear plan element in ETABS. For this is calculated an ideal bilinear curve, where in the plasticity zone, the value of the bearing shear stresses is as the cohesion between mortar and brick. This approximation is acceptable even when compares the model in ETABS with that of 3Muri (masonry calculator) in previous studies (Bilgin & and Korini, 2012).
The nonlinear analysis in ETABS will be performed after static loads are placed in vertical direction which will also be nonlinear in themselves. This to approximate as much as possible real behavior of the building. In reality, it is predicted that the collapse of the building happens from the seismic shear force which acts in the two main directions of the building.
Pushover analysis will be performed on the model, which pushes the object step by step straight to collapse. For this a certain push pattern is used for each floor. It can be life created by horizontal forces or a form of modal vibrations.
In general, the first modal forms define the seismic impact quite well, therefore in our case we will consider them.
The stressed condition of the masonry will only be with stresses within the plan as was discussed above. Schematic static loading and "pushover" cause the stressed states as in the picture:

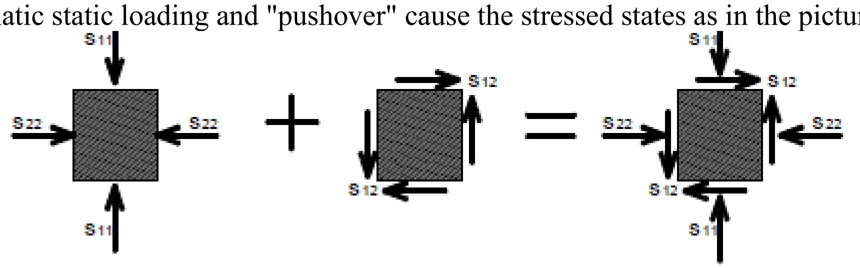


Figure 1-10 Stressed states caused by schematic static loading and pushover (Source: Guri, 2016)

- *Nonlinear analysis*

To perform a nonlinear analysis, it is necessary to determine the nonlinear behavior of the structure. This can be done by defining nodes with nonlinear behavior or materials with nonlinear behavior. In the case of masonry which modeled with planar elements, the use of nonlinear materials is more favorable. These materials are modeled by the corresponding stresses-strain graphs which are presented above.

Calculation of the capacity curve

For the calculation of the masonry building in the program ETBAS will be used nonlinear pushover analysis. In this type of analysis, the building is subjected to a horizontal loading until destruction. The pattern of destruction is determined by the purpose of analysis. This model may consist of one or several horizontal force or by displacement of modal shapes. Low-rise buildings, such as those with masonry in Albania, during the action of seismic forces vibrate mainly according to the first modal forms (Guri, 2016). Given that with pushover analysis we will evaluate their seismic performance, it is reasonable to use the first modal forms as loading models (figure 1-11). The program calculates step by step the shear force in the foundation against of a point displacement on the roof of the building. These data are presented graphically and establish the building capacity curve for that loading model (figure 1-12).

Bearing masonry buildings are far more fragile than r.c. buildings under the action of seismic forces. This is because they do not contain ductile elements as steel. However, they are capable of resisting after the elastic phase if the structure is regular in plan and height. This ductility that appears in the capacity curve (horizontal part), is explained by the successive detachment of the bricks from the mortar. This occurs mainly in a diagonal form, near open zones such as window doors.

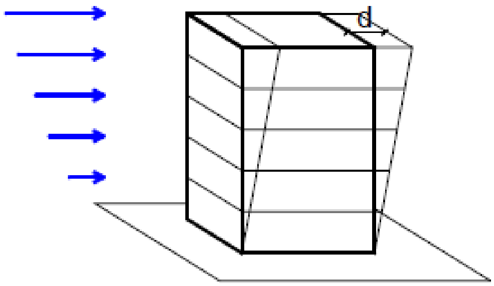


Figure 1-11 Pushover analysis

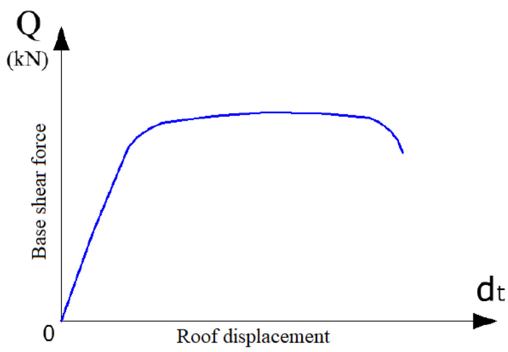


Figure 1-12 Building capacity curve

Determining service states

By service states we mean a limit point on the capacity curve which is used to classify building damage. These limit states are a function of the type of construction and the material with which they are built. A building with reinforced concrete frames system reacts differently from a masonry building. The latter has stiffened behavior and is fragile. Limit states of the masonry building depends on the regularity in its plan, on the quantity and the density of openings (doors, windows) and the thickness of the walls.

Researcher Calvi (Calvi G. , 1999) has proposed assigning service states in function of relative displacement between floors (interstorey drifts). Relative displacement is directly related to shear stress from the seismic force absorbed by each floor. Given that the destruction of the building comes from this shear force, it is convenient to use these limit service states for all cases of masonry buildings. So, in the following calculations will use these limits.
Calvi (Calvi G. , 1999) set three limits for service states as follows:
LS2 – "Minor structural damage and / or moderate non-structural damage; building can be used after the earthquake, without the need for significant reinforcement or repair of structural elements. The suggested limit of relative displacement is 0.1%".
LS3 – "Major structural damage and major non-structural damage. The building can not be used after earthquake without significant repair. However, repair and reinforcement are feasible. The suggested limit of relative displacement is 0.3%".
LS4 – "Complete collapse; repair of the building is neither possible nor economically reasonable. The structure will have to collapse after the earthquake. Beyond this limit state is expected complete collapse with risk to human. The suggested limit of relative displacement is 0.5%".
Below we are schematically presenting the limit states according to Calvi (Calvi G. , 1999). Not every building has all three in the performance curve conditions. This is because it can be destroyed before it reaches LS4 or LS3. It depends on the configuration of the load bearing walls and of the cracks as stated above.

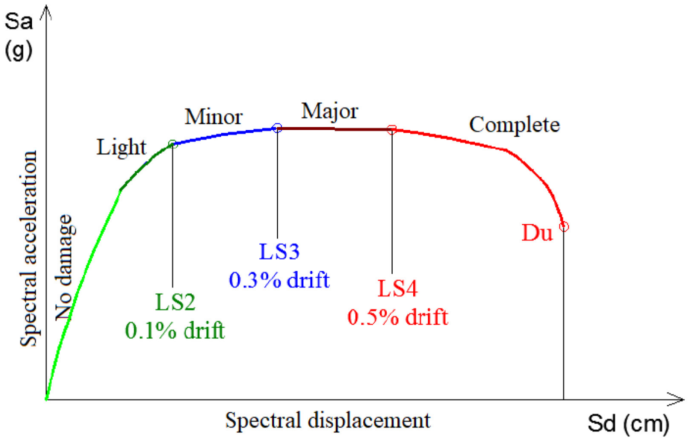


Figure 1-13 Service states

As demonstrated by the fact that lower loss proportions, that are commonly linked to operational damage states (when a facility is considered completely or nearly fully operational), are linked to lower seismic levels of intensity which are more likely to be surpassed, and a far more severe damage state is predicted to be affiliated with both a greater loss ratio and a lower annual probability.
Conversion of the capacity curve into Capacity Spectrum in ADRS format according to ATC40 (ATC40 Applied Technology Council, 1996)
To perform nonlinear analysis and determine the performance point of building for a seismic spectrum, it is necessary to follow a few steps. The first step is the conversion of seismic spectrum to ADRS format. The ADRS graph has on the horizontal and vertical axes respectively the spectral displacement Sd and the modified spectral acceleration Sa. To perform this conversion, it is necessary to calculate the factors of following:

$$PF_1 = \frac{\sum_i^N (w_i \varphi_{i1})/g}{\sum_i^N (w_i \varphi^2_{i1})/g}$$

$$\alpha_1 = \frac{\left[\sum_i^N (w_i \varphi_{i1})/g\right]^2}{\left[\sum_i^N w_i/g\right]\left[\sum_i^N w_i \varphi^2_{i1}/g\right]} \qquad \text{Eqs 1.2-1.6}$$

$$S_\alpha = \frac{V/W}{\alpha_1}$$

$$S_d = \frac{u_{roof}}{PF_1 \varphi_{roof,1}}$$

Conversion of seismic spectrum in ADRS format according to ATC40

Seismic spectrum conversion to ADRS format is performed by modifying the values of horizontal axis (period) in spectral displacement Sd. Vertical axis values Sa do not change. The modification is performed according to the following formula:

$$S_d = \frac{1}{4\pi^2} \cdot S_a \cdot T^2 \qquad (4.17)$$

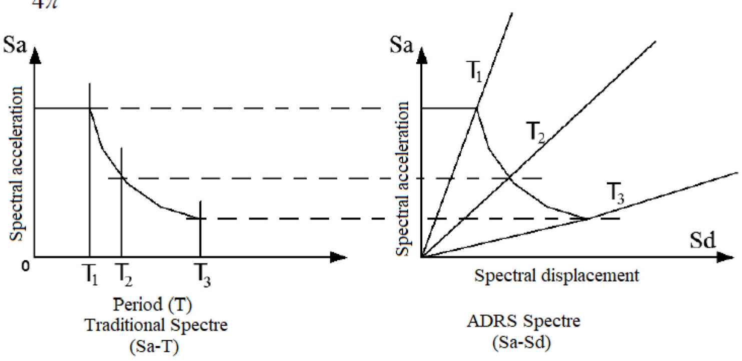


Figure 1-14 Seismic spectrum conversion to ADRS format (Source: ATC40)

Determining the structure's performance point in accordance with FEMA440 (Applied Technology Council (ATC-55 Project), 2005)

There are several procedures to determine the performance point of a building in world literature. We have chosen the improved “Equivalent Linearization” procedure, found in the document FEMA 440. This document is drafted and corrected based on the experimental tests of the authors. The following steps describe procedure B in Chapter 6 of FEMA 440 (Applied Technology Council (ATC-55 Project), 2005).

a) Initially the seismic spectrum and the capacity spectrum are constructed in a common graph. An initial performance point is assumed to serve as a starting point for procedure.

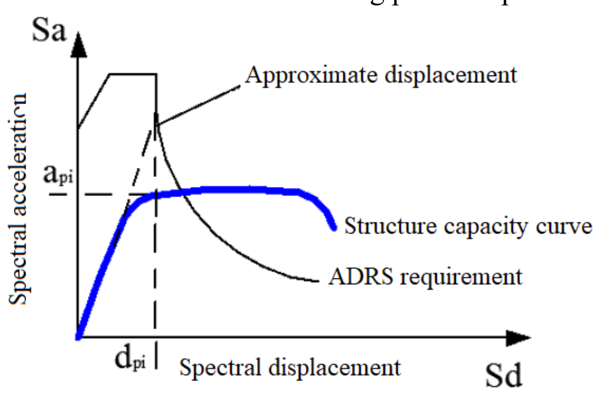


Figure 1-15 Evaluation of the FEMA440 performance point (Source: FEMA440)

b) A bilinear graph is then constructed on the capacity spectrum in such a way that the areas between the graph and the spectrum are approximately equal. Then they are defined α, μ as follows.

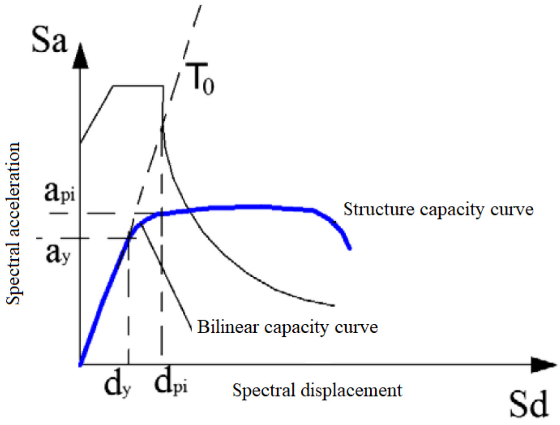


Figure 1-16 Bilinear graph according to FEMA440 (Source: FEMA440)

$$\alpha = \frac{a_{pi} - a_y}{d_{pi} - d_y} \frac{d_y}{a_y}$$

$$\mu = \frac{d_{pi}}{d_y}$$

Eqs 1.6,1.7

c) B_{eff} and T_{eff} are then calculated. There are some alternatives to calculate them in function of ductility type. Given that the case of masonry is special, it is reasonable to use the general equation. This equation depends on the ductility μ and initial period T_o. Since masonry has limited ductility, we will

$$\beta_{eff} = 4.9(\mu - 1)^2 - 1.1(\mu - 1)^3 + \beta_0$$

$$T_{eff} = \left[0.2(\mu - 1)^2 - 0.038(\mu - 1)^3 + 1\right] T_0$$

Eqs 1.8-1-10

$$B(\beta_{eff}) = \frac{4}{5.6 - \ln(\beta_{eff}\,\%)}$$

use the equation valid for ductility $1 < \mu < 4$.

e) Then multiply by the coefficient M, the reduced spectrum ADRS (βeff) found above, to obtain the MADRS spectrum. Spectrum intersection MADRS with capacity spectrum gives us a potential performance point.

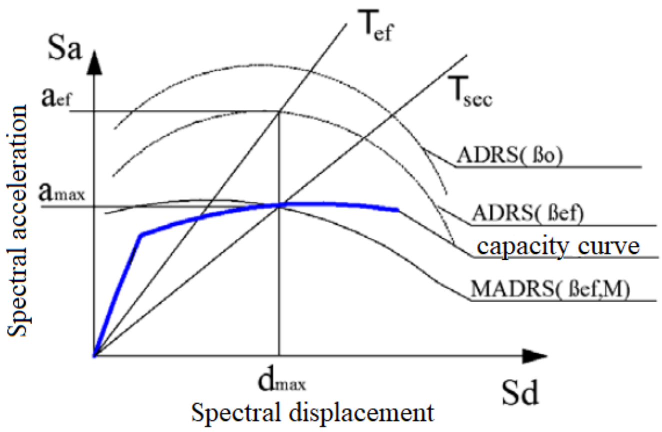


Figure 1-17 MADRS spectre (Source: FEMA440)

f) Finally, the ductility of the obtained performance point is compared with the ductility assumed at the beginning of the proceedings. If the difference is acceptable (e.g., less than 5%) then the point found is the performance point of the building. If these differences in ductility are by greater than 5%, we repeat the procedure with different initial assumptions until the condition is met.

2. RESEARCH TRACK

2.1. *Building and Energy*

In the year 1970 was the fuel energy crisis. The year where the first energy regulations for buildings started to emerge, in order to lower than energy consumption because of the high cost of fuel (United Nations Economic Commission for Europe, 2013). The first country to use a national program were the United States of America. For the first time they were target to achieve and energy consumption to be reduced on a national level. The European countries started to implement laws and regulation on a national level with Germany taking the lead (United Nations Economic Commission for Europe, 2013). The laws were mainly for the reduce of the energy consumption by improving the thermal insulation and the efficiency of the heating system. Nowadays the European Union has directive and regulation regarding the energy efficiency. European Union considers the climate change important issue and therefore has taken measures on reducing the energy consumption in order to reduce the carbon emissions (European Commission, 2010). The directive the guidelines regarding the improvement of the energy efficiency are as below:

- Energy Performance of Buildings Directive (EPBD, 2002/91/EC) and the EPBD recast (2010/31/EC),
- Renewable Energy Directive (RED, 2009/28/EC)
- Energy Service Directive (ESD, 2006/32/EC) and the new Energy Efficiency Directive (EED, 2012/27/EU)
- Eco-design Directive (2005/32/EC) and it's recast (2009/125/EC)
- Energy Labelling Directive (1992/75/EWG) and it's recast (2010/30/EU)

- *European legislative framework*

Since 1990, the development of PEN in Europe has been a priority and is generally related to the development of building materials and construction techniques while providing health security and especially energy saving. The motivation for this process has been the growing economic which has minimized costs and increased the competitiveness of building insulation materials (United Nations Economic Commission for Europe, 2013). In this context, rules and standards have been developed, where the evolution of building materials related to thermal characteristics has determined the way to increase the quality of life with cost-effective in relation to the energy consumed in buildings.
One of the determining factors of typology in buildings has been their geometric shape, which is directly related to heat transfer according to the elements that make up the enclosure such as: roof, exterior walls, windows, doors and floors, which depend on the time when they were produced and set, as well as by heat transfer (United Nations Economic Commission for Europe, 2013). But, also, no less important is the technical system of the building, especially the heating system which has always been the element that has undergone constant renovation due to technology.
In conclusion, PEN correlates with many parameters, among which the main ones are:

1. Year of construction,
2. The size and placement of the building in relation to others,
3. Type and age of the power supply system,
4. The fact how much the building has been subjected to energy saving measures and whether it has been evaluated from the point of view of energy consumption

The principles of energy valuation of all stocks in European buildings with a common indicator has enabled the reduction of efforts to estimate energy consumption and compare it with each of the EU countries. For this, the term "building typology" refers to a description of the stock according to criteria recognized by EU countries which have been decided to become known after 2000 in order to unify the various experiences coming from member countries of the EU. This has made it possible to create a unique opportunity to assess energy consumption for heating and hot water in residential and public buildings in order to develop a strategy to increase energy efficiency in the residential sector.

- *2010/31/EU Directive*

For the European Union to be in compliance with the Kyoto Protocol, the European Parliament enacted Directive 2010/31/EU, which contains guidelines on the energy performance of buildings, which was approved by the Council of Ministers in December 2010.
In the United States, the building sector accounts for approximately 40% of overall energy consumption, and with the expansion of this sector, the total energy consumption will increase (European Commission, 2010). Because of this, it is necessary to implement an effective, rational, and sustainable energy usage strategy in buildings, which also will result in a reduction in energy usage as well as greenhouse emissions.
It is not enough not only to reduce the energy consumption, but also the usage of renewable sources for energy must be increased. Climate conditions, indoor environment, and cost-effectiveness should all be considered when determining energy retrofit methods. These retrofit actions should have no adverse effect on the building's accessibility, structural stability, or function.
The methodology chosen for the energy performance may vary in national and local levels. Therefore, in addition to thermal characteristics, should be taken in account other factors such as heating installation, energy renewable sources, passive heating and cooling, natural light, air-conditioning, shading and building layout (European Commission, 2010). The methodology used must cover all the annual performance of the building and must meet the European standards.
The states should establish a minimum standard for the energy performance of buildings, that must be better energy efficient than the most cost-effective alternative available to them. The most cost-effective solution is one that achieve a balance between the amount of money invested and the amount of money saved on energy expenditures throughout the course of the building's existence. The minimum energy performance standards should be tailored to the climate in which they are implemented.
The energy retrofit methods implemented in the buildings will result in a reduction in both energy usage and CO2 emissions. Member States shall adopt a nationwide plan to boost the number of practically zero-energy buildings and to support green technology for the development of energy-efficient materials and systems in new and refurbished buildings in order to make this practicable.
The Energy Performance Certificate (EPC) can be a useful tool for promoting energy efficiency. It is necessary for these certificates to include information regarding a building's energy efficiency. Information on energy consumption for heating and cooling, as well as information on primary energy consumption and carbon dioxide emissions, will be provided through the energy performance certificate.
The strategies that focus on the thermal performance of buildings during the summer period should have the priority (European Commission, 2010). Therefore, must focus on measures such as shading, passive cooling and sufficient thermal capacity, thus the measures that avoid overheating.
In order to promote energy efficiency improvements in buildings, this Directive takes a number of elements into consideration, including external circumstances, as well as relevant guidelines and cost-effectiveness, among others. The standards outlined in this document are really the bare minimum. For example, the approach for assessing energy retrofitting of buildings, implementation of basic standards for existing structures, application of basic requirements for building elements, including part of the building envelope, national policies for expanding the number of energy retrofitted structures, energy certification of structures, and so on are all covered by this Directive.
The minimum energy performance requirements for buildings must be closer to cost-optimal levels (European Commission, 2010). These standards should take into account the internal climate circumstances, the local climate conditions, the function of the building, and the age of the building. Minimum standards must be evaluated and revised at least once every five years in order to keep pace with technological advancements in the construction industry.
It is necessary to compare the results of calculations with the minimal energy performance requirements now in effect with the results of studies with cost-optimal levels of energy performance. If the minimum energy efficiency standards in force are not considerably less energy efficient than cost-optimal levels of energy performance requirements, then the minimum energy performance criteria in force should be eliminated.
When existing buildings have extensive renovations, the energy performance of the building should be improved in order for the facility to satisfy minimal energy performance standards. It is necessary to apply such requirements to the newly renovated structure. Technology, functionality, and economic feasibility are all important considerations in this remodeling.

It is proposed that national programs be developed in order to increase the number of almost zero-energy buildings on the market. These national designs can contain a variety of standards that vary depending on the type of building being constructed.
The national plans shall include:
The concept of practically zero-energy buildings, taking into consideration locally and nationally conditions, as well as a quantitative indicator of primary energy use given in kWh/m2 per year The primary energy components that are used to calculate the primary energy consumption may be based on regional or national yearly averages.
Information on regulations and economic incentives to encourage the construction of practically zero-energy buildings, such as the use of renewable energy sources in new construction and large renovations of existing structures
The energy performance certificate should show the energy performance of a building and reference values in energy performance so the proprietors or inhabitants of the building can compare and assess its energy performance. The certificate shall include the percentage of energy from renewable sources and should give an estimate for the cost-benefits over its economic lifecycle. Other data on related topics for example, energy audits may likewise be given.
Single-family dwelling certification might be based on the evaluation of another comparable building with equivalent characteristics and a comparable energy usage. The energy performance certificate must be reestablished every 10 years or less (European Commission, 2010).
The countries will require that, when structures are built, sold or rented, the energy performance certificate or a copy.
The energy performance of a building is defined by the measured or actual annual energy consumption to meet the different needs associated with its classic use. This includes the heating and cooling energy required to maintain the building's designed temperature, as well as household hot water requirements. The approach for assessing a building's energy efficiency must be based on European standards and must adhere to Union regulations.
The framework for comparative methods facilitates Member Countries to ascertain the energy efficiency in buildings and their financial implications, and to utilize them to determine the most cost-effective level of energy performance. It must take into account the exterior climate, investment expenses, the type of building, as well as maintenance and running costs (including energy costs and savings). The methods used should be consistent with applicable European standards.
The comparative methodology framework necessitates that we identify reference buildings that are defined by their functioning and geographic location and are typical of them, specify the energy efficient technologies that will be evaluated for reference buildings, identify the energy requirements of reference buildings, analyze the cost of energy efficiency retrofits made to reference buildings across their economic lifespan
The cost-effectiveness of various levels of minimum energy performance criteria is determined by evaluating the expenses of energy efficiency measures throughout their estimated economic lifespan. This enables the determination of energy performance requirements at the most cost-effective level.

- *Commission delegated regulation (EU) no 244/2012*

In supplement of Directive 31/10 is Commission delegated regulation (EU) no 244/2012 which overviews the cost-optimal framework methodology.
States are responsible for setting minimum energy requirements for buildings in order to achieve cost-effective levels (Commission Delegated Regulation (EU) No 244/2012 of 16 January 2012 supplementing Directive 2010/31/EU of the European Parliament and of the Council). It is left to Member Nations to determine if the nationwide standard used as the final result of cost-optimal calculations is macroeconomic or exclusively monetary in nature. National minimum energy performance standards should not be less than 15% less efficient than the cost-optimal outcome of the calculation used as the national benchmark (Commission Delegated Regulation (EU) No 244/2012 of 16 January 2012 supplementing Directive 2010/31/EU of the European Parliament and of the Council). The cost-optimal level of performance may be within the range of performance levels with a positive cost-benefit analysis over the lifecycle.

To tailor the comparative technique framework to national conditions, states should determine the expected economic lifecycle of a building, the suitable cost of energy carriers, products, systems, maintenance, operational, and labor costs, and the energy price.
The financial lifespan of a building has a limited effect on the calculating period because it is determined or perhaps by the restoration cycle of a building, which is the time period following a major restoration.
The step suggested for the cost-optimal methodology framework are as below:

Establishment of reference buildings
The Eu Members will establish reference buildings for the following building types: single-family homes, apartment blocks and residential housing, and office spaces.
At least one reference building will be identified for each building classification for new facilities and at least two for existing structures undergoing massive energy renovation (Commission Delegated Regulation (EU) No 244/2012 of 16 January 2012 supplementing Directive 2010/31/EU of the European Parliament and of the Council). Reference structures can be established based on building categories (for example, those determined by area, age, cost structure, material properties, or climate region) that take into account the national building stock's features.
Furthermore, the states will determine the most cost-effective levels of performance for building components put in existing structures. When establishing standards, the most cost-effective criteria should take into account the relationship of that building component to the entire reference building.

Identify energy efficiency measures, renewable energy measures, and/or package and versions of such measures for each reference building.
For both new and existing buildings, energy efficiency measures will be used to determine all parameters for the calculation that affect energy performance, including those for high-efficiency systems, such as district energy supply systems and different options, as specified in Article 6 of Directive 2010/31/EU.
Efficiency retrofits that are recognized for use in the computation of cost-optimal criteria will include steps that are critical to meeting the bare minimum in terms of energy consumption. Directive 2010/31/EU specifies that Member States must implement measures to meet the minimum energy performance standards for practically zero-energy buildings for both new and existing structures, as specified in Article 9 of the Directive. According to the CEN standard 15251 on indoor air quality or comparable national standards, the selected energy efficiency measures must be compatible with the levels of air quality and indoor comfort required by the building.
Calculation of the primary energy demand
Members States will determine the energy effectiveness of initiatives by calculating, or by calculating first the energy required for heating and cooling on a nationally determined floor space, or both. The energy required for space heating, cooling, ventilation, and hot water is calculated in conjunction with these. Energy performance findings will be given in square meters of useful floor space of a reference building and will be based on primary energy consumption in order to achieve the most cost-effective computation possible.
Calculation of the global cost of each reference building in terms of net present value
the categories of costs are listed as below:
Upfront investment costs; ongoing operating expenses. Costs associated with the replacement of construction components on a regular basis
Costs associated with energy. The total cost of energy, which includes the price of energy,
The monetary value of greenhouse gas emissions. The CO_2 operational expenses arising from greenhouse gas emissions, expressed in tones of CO_2 equivalent over the calculation period, must be reflected in the calculation.
Calculation of the energy performance level that is most cost effective for each reference building
Member States shall examine the worldwide cost findings for several vitality energy saving measures based on green technologies, as well as variants of those measures, for each reference building (Commission Delegated Regulation (EU) No 244/2012 of 16 January 2012 supplementing Directive 2010/31/EU of the European Parliament and of the Council). When the outcome of cost-optimal estimations yields equal worldwide costs for different amounts of energy performance, it is recommended to compare the needs resulting in reduced primary energy consumption to the existing

minimum energy efficiency requirements. Upon determining whether a macroeconomic or financial method can be used to develop nationwide reference average values of the measured cost-optimal energy levels for all reference buildings, average values of the measured cost-optimal energy levels for all reference buildings will be defined to allow for comparison with average values of existing energy performance criteria for similar reference buildings (Commission Delegated Regulation (EU) No 244/2012 of 16 January 2012 supplementing Directive 2010/31/EU of the European Parliament and of the Council). This allows for the estimation of the energy performance gap between current energy performance requirements and calculated cost-optimal levels.

2.1.1. The impact on European buildings

Germany

The first edition of the national typology of residential construction was produced in 1990 on the basis of energy audit reports and was used to estimate the energy efficiency potential of buildings during scenario analysis. The construction typology was revised on a regular basis to reflect new advances (e.g., new energy conservation rules) and was initially used as a model for the building stock in various studies (IWU, 2003). The current edition includes 44 different types of residential structures that are classed according to their construction year and size. It describes the buildings' present state of repair. Building data are documented in and include the following:

- Basic information about the structure (floor area, number of units, etc.), the areas of structural elements (walls, roofs, ground floors, and windows), and the U-values of structural elements.
- Energy performance and saving potentials which are documented in the form of a two-page report.
- In addition to the measures needed to improve EP a report of energy analysis and advice from national regulations is known
- Proposals for the use of a number of funding programs and software for applications as a set of exemplary constructions.
- Energy class and generating a certificate.

Greece

Prior to 2008, Greece lacked comprehensive monitoring of its building stock. After the ratification of Law 3661 / 19.05.2008 on the National Adaptation of the EPBD Directive, the new Energy Performance Regulation of Buildings - KENAK (KYA 5825 / 09.04.2010), and the release of national technical guidelines (TOTEE) and tools scheduled in mid-2010 [58].

Data on Hellenic residential structures were gathered from a variety of sources (National Registration of Hellenic Statistical Services of constructions 1990-2000 and published literature). The endeavor resulted in the design of the appropriate number and size of buildings for:

a. Structures (e.g., residential and non-residential buildings (offices/commercial, hospitals, hotels, and schools))

b. Date of construction (i.e., three typologies based on the year of construction: prior to 1980 (when the national regulation of thermal insulation took effect), 1980-2001 (when the code's implementation was gradually changed), and predictions to 2010)

c. Four distinct climate zones (A, B, C, D - discretization based on the number of days of the heating rate in accordance with the draft National Regulation on the implementation of the EPBD).

d. Similarly, a map of specific annual operational consumption of electricity and heat has been achieved for different categories.

Additionally, a classification of the two types of residential buildings stated before was achievable based on their thermal properties and installed heating systems during three distinct construction periods, namely before 1980, 1980–2001, and 2002–2010.

Slovenia

Several attempts have been made in the past to compile construction typologies. To begin, there was a research conducted in the mid-1990s. The study examined how much energy is consumed by structures. Then there are construction typologies for statistical analysis and another for CO2 scenarios. It later reduced to just two types of construction (single family home and apartment

construction) and required numerous years of construction classes corresponding to various levels of energy efficiency.
The present condition of the residential building was analyzed (as part of the project for Energy Conservation of Existing Residential Buildings), and the structure was separated into distinct architectural designs. Additional stock buildings for each form of construction are considered on a regular basis. Since 1991, the population census served as the foundation. Then, only structures constructed after 1980 were included in the analysis. The year 1980 relates to the national standard, which imposes tougher requirements on the thermal characteristics of building components and energy-efficient construction. 18 construction typologies were identified as in need of energy efficient rehabilitation, and each was assigned a renovation plan. The renovation plan considered mainly the winding of the construction. The variations in energy consumption between these two scenarios correlate to the energy savings calculated on a national scale.

Italy
Until 2010, no formal construction typology was offered in Italy on a national scale. Italy has made scientific advances in this area in specific places. Regarding the typology of construction in Italy, the following points can be made regarding the building stock:
- a high proportion of historic buildings; - a low rate of renovation; - a widespread lack of inspections for compliance with energy-related building regulations; - significant climatic differences between regions; - distinct construction traditions (heavy construction in the south, wood construction in the alpine areas); - widely dispersed U values and heating systems; - disparities in construction age and level of insulation.
Several studies have been undertaken that can provide important data on the typology of buildings connected to energy valuation, based on significant national trends and data sources for the development of construction typology:
a. investigations undertaken by POLITO DENER as part of a series of research initiatives aimed at characterizing and evaluating the energy performance of existing Italian buildings.
b. established national research studies and standards that provide information on building construction and heat supply systems in the Italian building stock, as well as energy conservation strategies. (For example, in the 1980s, studies undertaken primarily by the National Energy Agency focused at describing the typology of construction stocks);
c. national statistical data on the building stock, including detailed data from the National Institute of Statistics (ISTAT) and CRESME (Economic, Social, and Market Center Sector in the Construction Sector); d. information on construction typologies and technical systems obtained from regional construction associations; e. data sets on energy certification compiled by local energy agencies and consulting firms.
f. Statistical statistics are published in the ENEA's (National Energy Agency) "Energy and Environment Report 2006" (June 2007) (ENEA, 2007)
Typical exterior walls are summarized in the Italian standard UNI / TS 11300-part 1 (national annex to EN ISO 13790). Specifically, 19 typical constructions are discussed. The following parameters are shown for each of them:
• layers (materials, thickness, density, and thermal conductivity); • location of construction; and • age of the structure.

Conclusions
Combining seismic and energy retrofitting, can be a huge cost for the investors. Therefore political initiatives are needed to encourage this investment. A good example is Italy, where the government propose reduce taxes for those who do one or both retrofits. USA uses tax reifies for energy retrofits. However, this can be not a good solution for the low-income population that are not taxpayers. Netherlands uses loans in order to cover retrofit costs. With these initiatives, the payback period may

be 10 to 11 years. Italy uses seismic certificate that show that seismic performance of building. This, like the energy certificate, is used to raise the value of the property.
Most of the Slovak building stock, before the 1980, a time when were no energy regulation. The new politics set the targets to 45% of reduce energy demand. The actors are the Homeowners Association, which collect a fund paid by the owners building for maintenance and repairs. For the energy retrofitted buildings is issued a certificate. In Estonia, to be within the guidelines of the European regulation, is used energy certificate. These certificates are mandatory in order to sell buy or rent a house. Also, as they serve as the Consumer Protection, there is the information about the energy performance of a building. In Bulgaria most of the buildings are from the communist era. This sector is characterized with low energy efficiency. In order to cope with the high energy consumption, Bulgarian government create the fund that could lend money for the energy retrofit and offer technical assistance. After the energy retrofit, the savings where 720 euros per house.
Renovating existing structures would make a significant contribution to the betterment of numerous critical facets of our society and daily lives. Currently, the EU's very low energy rehabilitation speeds are unable to generate sufficient energy savings, which must at least double in the near future if the EU is to attain carbon neutrality by 2050. Enhancing the energy efficiency of buildings would improve citizens' living standards and benefit a diverse variety of financial sectors. Considering the interconnectedness of EU economies, closing the divide between some areas is a vital requirement for ensuring Europe's growth is harmonic, balanced, and sustainable.
Significant progress has been achieved in recent years through the Energy Performance of Buildings Directive (EPBD) and the Energy Efficiency Directive (EED) (EED). Nowadays, new structures consume less than half the energy that structures constructed 30 years ago did. However, because about 80% of today's buildings will remain in operation in 2050 and 75% of this stock is inefficient in terms of energy use, the European Green Deal (EGD) anticipates implementing the 'Renovation Wave' project in this sector, as outlined in the 2020 Commission Work Programme. The EGD's objective is to turn the EU into a just and successful society with a modern, resource-efficient, and competitive economy that decouples economic growth from resource use.
Why is increasing building energy efficiency a win-win situation?
While repair of existing structures is not a panacea, it would significantly contribute to the improvement of a number of critical components of our society. The environment (i.e. climate change, local pollution, and resource use), the economy (i.e. sustainable growth, industry competitiveness, and job opportunities), energy infrastructure (i.e. energy security and reliance), and human wellbeing (i.e. energy poverty, health, and living conditions) are the primary concerns.
By limiting global warming to far below 2°C, the Paris Agreement established a worldwide framework for avoiding severe climate change. The EU building stock is Europe's greatest single energy consumer, accounting for 40% of energy consumption and 36% of EU greenhouse gas emissions. Due to this particular weight, energy efficient buildings are critical to achieving a global environmental solution. Additionally, fine particle emissions (PM2.5 and PM10) from fuel burning for heat and transportation are concentrated primarily in cities.
Construction accounts for 9% of EU GDP and almost 15 million direct and indirect jobs. Nearly the entirety of the value chain is based in Europe. Specialized construction activities, such as renovations and energy retrofits, employ nearly two-thirds of all construction workers.
Energy retrofits of existing buildings contribute to energy import reductions, which increased from little more than 44% of gross available energy in 1990 to 55.1 percent in 2017. The building stock has a significant impact on gas imports, and retrofitting 2% of the EU's building stock annually (together with some electrification of heat demand) will result in a 25% reduction in estimated peak monthly gas consumption in buildings by 20401.
Building renovations help citizens and businesses save money on operating costs. Vulnerable individuals in Europe are disproportionately affected by inefficiency in the built environment and growing energy costs. Over 50 million families in the EU are expected to be in energy poverty as a result of inefficient buildings and equipment, high energy costs, low household incomes, and unique household demands.

2.1.2. *Analyze the elements of the building envelope*

Building envelope has the function of enclosure in the building, considered as a shell. Such element functions as a threshold between the interior and outdoor environment, between private and public. The building envelope includes several spatial elements such as external walls, floors, roof, ceiling, windows and doors (figure 2-1). All of these components are indicators for the amount of energy required for the building for thermal comfort. However, the loss of energy is depended by several factors, which include climate of the context, construction technique, longevity of the building, building typology, users' behavior and location of the building.

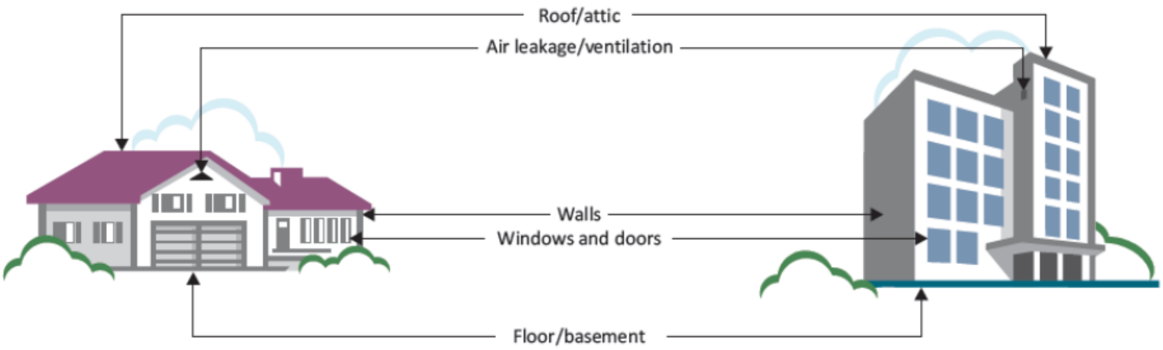


Figure 2-1 Building Envelope components (Source: IEA 2013)

There has been a significant improvement in the code requirements of the building envelope, an improvement in performance which is still in progress throughout years. As a result, there is increasing request for developing new materials which provide thermal insulation and low transmittance values, which is differently known as U-value (table 2-1). This value is the quantity of heat transmitted in a structure, whether it is made of a homogeneous substance or a composite, divided by the temperature differential across the structure. Watts per square meter per Kelvin (W/m2K) is the unit of measurement. Such U-value must be as low as possible to have a good insulation of the structure and is defined also by the standards of the insulation and the method, which should be as fit as possible to avoid gaps and cold bridges, in order to avoid high levels of thermal transmittance (Sadineni, Madala, & Boehm, 2005). The term "thermal transmittance" refers to the heat loss caused by conductivity, diffusion, and radioactivity

Table 2-1 Standard U-values (in W/m^2 K) (Source: John G, 2005)

Envelope element	1995 Standart U-values (W/m^2 K)	2000 Standard U-values(W/m^2 K)	Percentage reduction in U-value (%)
Walls	0.45	0.35	22
Roofs	0.25	0.16	36
Floors	0.45	25	44
Windows	3.3	2.2	33

- *Walls*

The main element in the building envelope is the external wall, by which it is provided thermal and acoustic comfort in a building, but along with such performance it is necessary to have aesthetic consideration which may have its indication in the context where the building is positioned. The thermal resistance of the wall (R-value) indicates the level of energy consumption. The proportion of wall to total exterior sector is high in tall structures. The market-available center-of-cavity and transparent wall R-values take thermal comfort into account.

High structures most of the time were constructed by providing energy conservation through thermal mass, without considering insulation, which is very important and is found in many technical solutions and variety of materials that can help the aesthetics of the building at the same time.

- *Fenestration (windows and doors)*

The functions of windows and doors are various, which is providing access inside the spaces or from outdoor environment to the interior of the building, providing source of natural light, providing thermal comfort naturally from daylight. Before specifying windows in a building, it is necessary to consider the climate situation of the context, by considering heating and cooling for maximizing the performance of energy balance, or energy gain. Energy gain in some regions can be provided by glazed window system paired with well-insulated window systems and seasonal-impact-adjustable architectural shading (Cazes, 2017).

Countries of cold climate are developing several solution considering increasing high-performance windows, mostly triple-glazed windows. Nevertheless, these achievements are not found in other markets of other countries (Interconnection, 2013). Most of the windows sold in many countries are usually single-glazed with poor insulated frames. These have U-values of approximately 4.6-5.5 W/m^2K.

Because of this, it is crucial to obtain the evolution of cold-climate country window solutions in other locations in order to improve the energy performance of buildings throughout Europe. Even existing buildings can benefit from installing insulation to their windows as part of this endeavor. When it comes to energy-efficient retrofitting of existing structures, triple-glazed windows have a lot of potential to penetrate the European market, especially when it comes to light-energy refurbishment projects. (IEA, 2013).

- *Roofs*

The roof contributes much to the performance of the building envelope. Being under the indication of solar radiation and being exposed from external climate factors defines the level of comfort inside the buildings. The most problematic aspect of the roof remains the large amount of loss or gain of heat, especially in public buildings, which are larger in surface. This decrease in the U-value over time demonstrates the critical nature of roof thermophysical properties in the attempt to improve the total thermal performance of the structure (Sadineni, Madala, & Boehm, 2005) .

2.2. Building and Seismicity

Earthquake events are unexpected events that, based on the area's seismicity, occur only infrequently during the life of the building. Since earthquakes have such destructive strength, the stability and protection of buildings in areas prone to earthquakes should be checked for seismic loads. The verifications are tightly based on the results provided by certain seismological and geological studies that give information and data regarding seismic activities mainly in terms of parameters to be used in the assessment of seismic actions. To have a better understanding of the fundamental principles of seismic design analysis and construction of masonry structures, it is necessary to understand the origins of earthquakes and the properties of seismic ground motion (Tomazevic, 1999).

2.2.1. Seismic activity in Europe

Beside the progress made in terms of seismic safety of modern buildings, the great majority of older structures do not meet the new norms' safety regulations, Eurocode being one of them (Bournas D. , 2018). The recent earthquakes unfortunately are a proof of the vulnerability of these old RC structures.

The primary "disadvantage" of these older buildings is that at the period they have been built, basic knowledge, comprehension, and significance of seismic detailing were not fully developed, and because the basic design was focused on allowable stress design with a focus on gravity loads and omitting sufficient seismic detailing provisions, there seemed to be a limited control over the failure mode and resulting damage (Bournas D. , 2018).

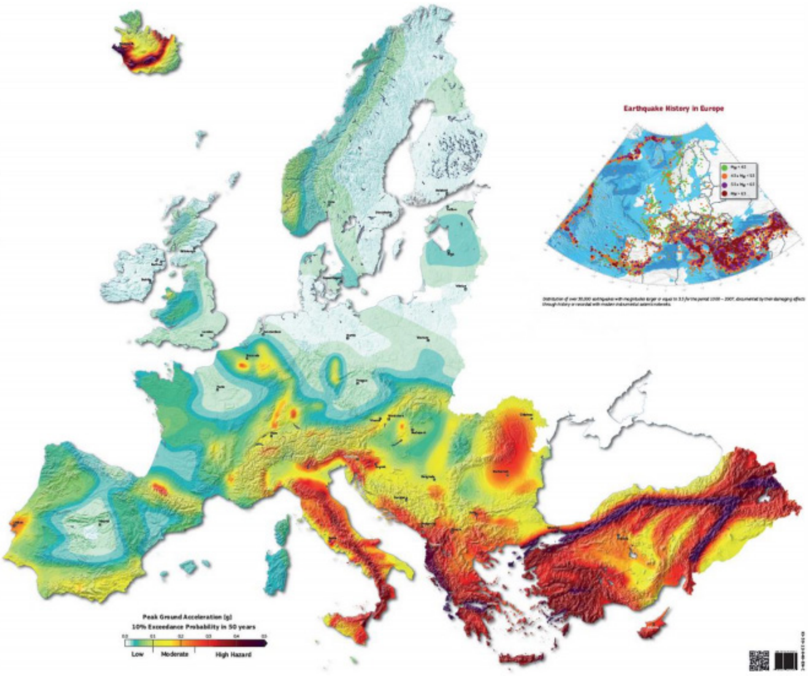


Figure 2-2 Map of Seismic Hazards in Europe and the Mediterranean (Source: Giardini D. 2013)

Accurate seismic risk assessments are critical for limiting earthquake-related fatalities, damage to property, and cultural - financial disruption. Large earthquakes, which occur regularly in isolated places, present a severe earthquake hazard but no risk; moderate earthquakes, on the other side, provide a moderate hazard but a significant risk (Giardini, Jiménez, & Grünthal, 2013).

Figure 2-2 depicts the Map of Seismic Hazards in Europe and the Mediterranean, which indicates a 10% likelihood of exceeding the Peak Ground Acceleration (PGA) in 50 years assuming a firm soil condition. The map's colors correspond to the real level of threat, with colder hues representing lower levels and warmer hues signifying greater levels. According to the map one of the highest earthquake hazards zones is the south- eastern area of Europe, in particular Greece, Italy, Turkey, the Balkans etc., with values of the PGA exceeding 0.4g

The Mediterranean area is a seismic prone area characterized by yearly intense earthquakes that cause high level of damages and victims, which demonstrate that the current building sector in Europe, when evaluated from a seismic perspective is not adequate and requires strong measures to be soon implemented and, in this framework, Eurocode 8 provides a complete information that is needed to assess the seismic behavior of buildings.

- *The 1963 Shkupi earthquake*

On July 26, 1963, at 5:17 a.m., Shkupi was struck by a shallow earthquake with a magnitude of M=6.1 (Richter scale) and an intensity rating of IX (Mercalli scale), resulting in significant loss of life and property, killing over 1,070 people, injuring approximately 4,000, and displacing over 200,000 people. Major sources estimate that almost 80% of the city was destroyed, and numerous public buildings, schools, hospitals, and historical landmarks sustained significant damage. The material losses were estimated to be in the neighborhood of one billion dollars (UNESCO, 1964).

Following the earthquake, an examination uncovered a number of design and construction flaws. Numerous private residential buildings with a ground floor and one storey sustained severe damage as a result of their engineering design failing to account for the horizontal force generated by the seismic action. The majority of the buildings had large load-bearing walls composed of masonry or solid bricks laid with lime and cement mortar, but lacked reinforced concrete columns and beams that would have provided a strengthened complete structural system. Between 1950 and 1962, numerous dwelling blocks with a ground floor plus four floors were constructed utilizing the classical building method, with two solid brick facades and one set of central load-bearing walls (Sinadinovski & McCue, 2013). The most fatalities occurred as a result of the collapse of these sorts of structures as a result of the earthquake.

Buildings with brick masonry walls, in general, suffered the most damage (figure 2-3) and were responsible for the greatest number of deaths. Mixed-use building was also severely harmed. While many of the structures did not collapse, they were completely destroyed and rendered unrepairable. The impact caused some damage to older adobe structures, particularly those with timber bracing, but they survived better than brick masonry or mixed structures. Only two modest structures with reinforced concrete skeletons came crashing down (Sinadinovski & McCue, 2013).

Figure 2-3 Images of damaged buildings from 1963 Shkupi earthquake (Source: Petrovski, 2004)

Situation before the earthquake

Prior to 1963, the city of Shkupi's physical and urban planning was based on experience and practice available in Europe at the time. Geological requirements and technical demands dominated land-use planning. Since there were no formal rules in place to deal with natural disaster control, earthquake risk was simply ignored during the town planning period (Petrovski, 2004). Rapid growth population of the city of Shkupi after 1950 required construction of a large number of apartment buildings, concentrated mainly in the Western Side of the city.

After Earthquake

After the earthquake, the city of Shkupi was rebuilt over a period of more than ten years. The severely affected flats were demolished and replaced with new or restored units. The reconstruction was done on two levels (Edilizia Popolare, 1985). The immediate one entailed repairing certain structures that were not severely affected, as calculations revealed that their destruction was not economically justified. The majority of the destruction was located in structural elements such as reinforced concrete columns, pillars, and huge load-carrying walls, so the repairs were often done on the ground floor level of the buildings. The rapid design of new structures was the second course of the rebuilding.

The National Building Codes were updated after the earthquake in Yugoslavia, and a new earthquake standard was recommended. The new architecture and construction phase continues to resolve earthquake issues, with assessments of building design and planning alternatives being required.

Thanks to a series of critical decisions made at the federal level and down through the Republic to the city, conditions were created for the successful resolution of issues connected to the immediate impacts of the earthquake. Additionally, various decisions were made that had far-reaching implications for the continued normalization of life and the city's future methodical rehabilitation and reconstruction.

Economic expansion was plain to see. Between 1963 and 1973, the economy's social output expanded by 713 percent (in current prices); national income increased by 677 percent; net salaries increased by 827 percent; finances increased by 100 percent; and jobs increased by 153 percent. (Petrovski, 2004).

- *The Vrancea, Romania earthquake of March 4, 1977*

This earthquake was one of the most devastating events globally during the 1970's. It claimed the lives of 1,578 people and wounded another 11,321, with 90 percent of the deaths occurring in Bucharest, Romania's capital (Craifaleanu, Georgescu, & Dragomir, 2016). There were 32,900 destroyed or severely damaged housing units, 35,000 homeless people, thousands of abandoned

houses, and many other losses and destructions in industry and infrastructure, according to the reports. Official damage figures indicated losses of about two billion dollars, 32,900 collapsed or severely damaged buildings, tens of thousands of demolished buildings, numerous other accidents and destructions in 763 commercial and industrial units, and other consequences throughout the country (Georfescu & Ponomis, 2008).
Seismological, engineering, and certain disaster management topics were discussed in the post-earthquake reconnaissance reports and studies. (Berg, Bolt, Sozen, & Rojahn, 1980).

Lessons from the behavior of specific types of structures,
The assessment of damages in buildings and infrastructure was provided by both, national and international engineers weeks after the earthquake. Despite the recommendations of the experts for a robust damage-safety assessments for all affected buildings, the order given by the government required that the repairs should be completed just about seven weeks after the earthquake (Craifaleanu, Georgescu, & Dragomir, 2016).
government conference was convened on July 4th, 1977, to discuss rebuilding progress; at the time, 14,063 buildings had been assessed as in need of renovation, with only 4,510 having been repaired.
Hundreds of thousands of buildings with little or no damage were deemed officially safe after the 1977 earthquake, despite the fact that experts recommended that all tested structures be evaluated further. The evaluation and future retrofit were never completed to the required standard (Craifaleanu, Georgescu, & Dragomir, 2016).
However, due in large part to decisions taken in the aftermath of a terrible earthquake that devastated Bucharest on March 4th, 1977, many of Bucharest's pre-1977 structures may be more seismically fragile than we understand. The 1989 opening of the State Archives, combined with painstaking investigation by a team of professionals, revealed a worrying history of latent danger that continues to affect Bucharest residents today, since hurried restorations left severe hidden threats (Georgescu E. , 2003).
Modern engineering simulations can forecast a building's performance under various earthquake conditions by taking into account the structure's age, number of floors, structural system, construction materials, proportions of the building, and level of maintenance, but they cannot determine the extent of damage caused by the 1977 earthquake. According to historical research (Georgescu & Pomonis, 2007), the potential impact may be greatly underestimated, despite the feasibility of estimating the damage caused by a future big earthquake in Bucharest and the surrounding area.

- *Montenegro Earthquake: M7.0 April 15, 1979*

It happened on April 15, 1979, 15 kilometers off the Montenegrin coast between Tivar and Ulqin, with a Richter magnitude of 7.0 and a Mercalli intensity of IX. At the disaster's conclusion, 101 people had been killed in Montenegro, 35 in Albania, and more than 100,000 remained homeless. According to the UNESCO survey, a total of 1487 cultural heritage pieces were destroyed, with nearly half of them being houses and the remaining 40% being churches and other religious resources. Over 1000 cultural monuments, as well as thousands of works of art and priceless collections, were damaged. The cost of damaged cultural property has been estimated to be over 10.5 billion USD (UNESCO , 1984).
To cover the disaster's total costs, the government established a legislative fund into which each worker in SFR Yugoslavia contributed 1% of their monthly wage to the reconstruction effort from 1979 to 1989.

All these countries have a history like Albania. They countries in development, affected by earthquakes like Albania, and show us how to overcome natural hazards. Shkupi is the best case that in a poor country, if planned well, can overcome the difficulties and more importantly prevent them.

2.2.2. *Seismic activity in Albania*
Albania is geologically and seismotectonically a very complicated zone. The country is characterized by a developed micro-seismicity with small earthquake, with average number of earthquakes (M = 5.5-5.9) and rarely of large earthquakes rarely (M.6.5). These earthquakes generally occur in three folds (Aliaj, Sulstarova, Peci, & Muco, 2004):

o Adriatic-Ionian Coast
o Belt Peshkopi-Korça
o Transverse belt Elbasan-Dibër-Tetovë

Albania is a country which is located on the border between two tectonic plates, that of Eurasian and Adriatic. As a result of the collision of these 2 tiles, it is created an active seismogenic belt which has often generated catastrophic earthquakes such as:
Vlora earthquake 16.04.1601 with I0 = 9 degree, Leskovik earthquake 23.12.1919 with I0 = 8-9 degree and M = 6.1, the earthquake of Tepelena 26.11.1920 with I0 = 9 degree and M = 6.4, the earthquake of Durrës on 17-12-1926 with Io = 9 degree and M = 6.2, the earthquake of Llogara 21.11.1930 with I0 = 9 degree and M = 6.1, Peshkopi earthquake 27.08.1942 with I0 = 8-9 degree and M = 6, Lushnja earthquake 01-09-1962 with I0 = 8-9 degree and M = 6.2, Fier earthquake 18.03.1962 with I0 = 8 degree and M = 6.2, the earthquake of 15-04-1979 with epicenter on the Montenegrin coast with I0 = 9-10 degree and M = 7.2
The damage caused by these earthquakes in most cases has been catastrophic. Causing very great damage is related to the fact that these earthquakes have fallen in areas where the population density has been high or constructions made in these areas have not sufficiently considered the seismic risk or it was not
properly calculated. Based on the studies done, it is concluded that along the Ionian-Adriatic "seismogenic zone" earthquakes with maximum expected magnitude M = 7-7.5 north of the transverse zone Shkodër-Pejë, while in its south, in the front part, earthquakes with M = 6.0-7.0 can occur. In direction of Tirana, in the east, earthquakes with M = 5.5-6.0 can occur. According to studies in Albania, the recurrence period of an earthquake with M = 5.0 is 3.6 years, of an earthquake with M = 6.0 is 29.1 years, of an earthquake with M = 6.5 is 93.9 years and of an earthquake with M = 7.0 is 505.6 years (Aliaj, Sulstarova, Peci, & Muco, 2004).

- *Seismic risk assessment*

The first seismic map of Albania dates back to 1952 as a product of the work done by experts of the Institute of Sciences and the Ministry of Construction of that time. Since then, studies on assessing the seismic risk in our country has continued with numerous publications to the present day. The map of seismic zoning that is still in force dates back to 1979 (figure 2-4, right). In figure 2-4 (left) is the map of 1963 (Sulstarova, Koçiaj, & Aliaj, 1980).

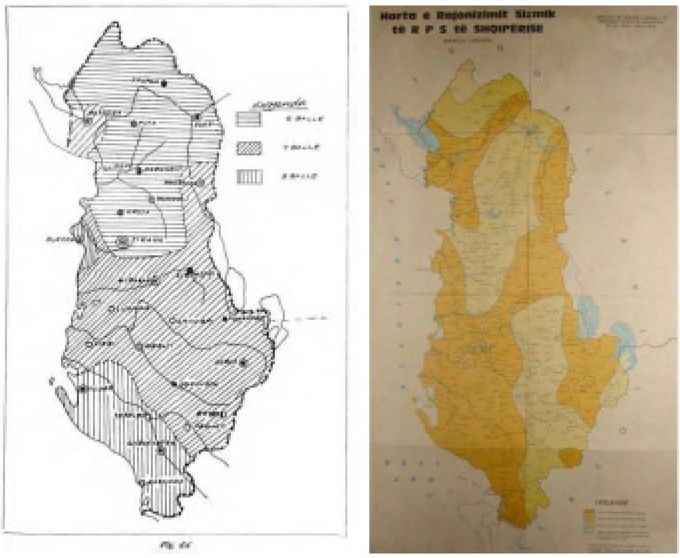


Figure 2-4 The proposed map of seismic zoning 1963(left) an actual map of seismic zoning 1979 (right) Source: Baballëku, 2014)

After the earthquake of April 15, 1979, there was an increase in the assessment of seismic intensities Albania, which were concretized in the map of figure 2-4 (right).
Thus, since 1952, seismic risk has been estimated always increasing. A good part of the buildings, object of this study, were built before the year 1979, which means that not only the technical

conditions were old, but also the zoning map seismic has had low values of the seismic intensities of the expected earthquakes.
Among the recent works (Aliaj, Koçiu, Muço, & Sulstarova, 2010) we can single out the map shown in figure 2-5, in which it is noticed that seismic risk assessments in Albania tend towards an increase in values compared to earlier editions.

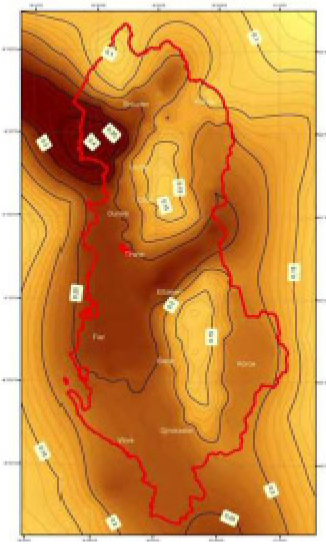


Figure 2-5 Seismic risk assessments *in Albanai (Source: Aliaj.Sh; Koçiu.S; Muço.B; Sulstarova.E, 2010)*

This has come not only as a result of increasing knowledge and experience in the field of seismology, but also as a consequence of the contemporary requirements of the Building Codes in this field (from KTP to Eurocodes).
On the other hand, the way the design codes calculate seismic actions has changed over the years. Although the use of "design spectra" for seismic analysis has been present in design codes in our country, the values have been much lower in compared to today. In figure 2-6, the spectra of KTP-N.2-78 are presented in the same coordinate system (according to the seismic map of '63), KTP-N.2-89 (according to the seismic map of '78) and Eurocode 8, EN 1998-1 (according to the seismic map of '04, not in force). The increase in the values of spectral accelerations between periods is clear. If we compare today's demand (for an area with ag = 0.25g) with that of 1978 for an area of intensity VIII point, an increase of about 5 times the spectral acceleration is observed (Baballeku, 2014) for the low-rise buildings. If we refer to the city of Tirana, this change can go up to 10 times, as many of today's studies give ag values up to 0.25g, while the intensity on the map has were VII in 1979 and VI on the 1963 map.

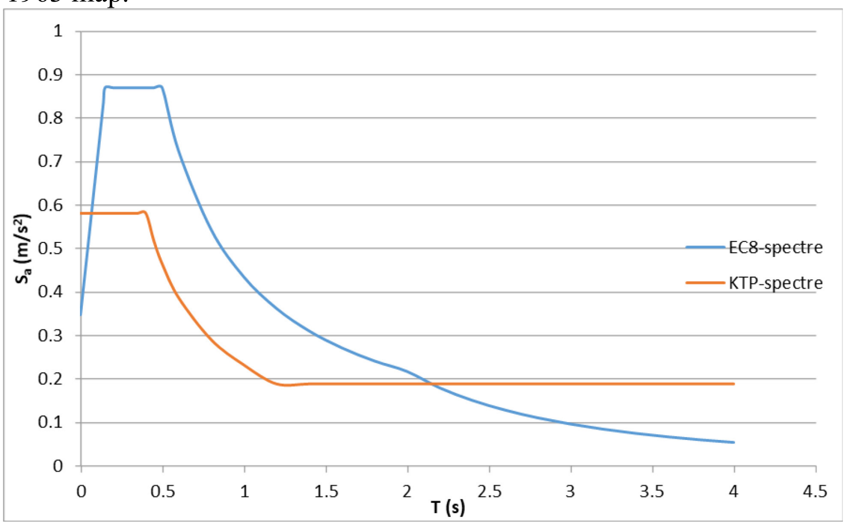


Figure 2-6 Comparison of spectral accelerations between KTP and EC-8 for Tirana (soil category II by KTP, and B be EC-8)

As we can see from the graphic below, there are deficiencies for KTP spectre in confront with EC-8 spectre for periods lower than 2.2 sec. With this spectre, have been designed the buildings in the period 79-90. This spectre, officially is still in use nowadays, but in practice the design engineer use the EC-8 one,

2.2.3. Previous Earthquakes in Albania

Earthquake of 15 April 1979

Among the most damaging seismic events in Albania was the earthquake of April 15, 1979. According to (Pistoli, 1982), among various engineering works in our country, the earthquake also hit new buildings with masonry or reinforced concrete structure constructed in accordance with the design codes in force at the time (KTP-63). This includes 5-storey masonry buildings, which according to KTP- 63 should not show problems.

The three-storey buildings have suffered corner damage. These effects are displayed on the upper floors where the displacements of the walls are greater where the compression that could serve as opposition is at a lower value.

From the overall conclusions of the ‘79 earthquake the damage is thought to have been caused also from the wrong use of soft storeys (RC structure at the base and masonry at the height), use of lime mortar, buildings with a height/length ratio of less than 1.5 as well as the lack of RC belts in some cases.

Earthquake of November 26

An earthquake of magnitude Mw 6.4, with focal depth of 20 km, struck northwest Albania The November 26 earthquake’s epicenter was north of the city of Durrës, although the macro-seismic effects were most extensive in the Shijak municipality that is situated about 10 km east of Durrës. The earthquake claimed 51 lives and resulted in at least 913 injuries (including 255 individuals hurt in the earthquake's aftershocks) (The World Bank GPURL D-RAS Team, 2019). The fatalities were mostly caused by the collapse of ten buildings in Durrs and Thuman (both in the Kruj municipality) (figure 2-7).

The November 26 earthquake was also preceded on September 21 at 16:04 hrs local time by magnitude Mw 5.6 earthquake, with focal depth of 10 km, that occurred 5 km north of Durrës city injuring 108 people and causing damage to more than 2,000 buildings and 47 educational facilities, including considerable damage in the capital city of Tirana (and in the port city of Durrës). These earthquakes are significant as it increased the vulnerability of buildings and of communities.

The housing industry sustained the most severe damage. 18% of all housing units in the impacted area were predicted to require reconstruction or restoration (Marinković, et al., 2021).

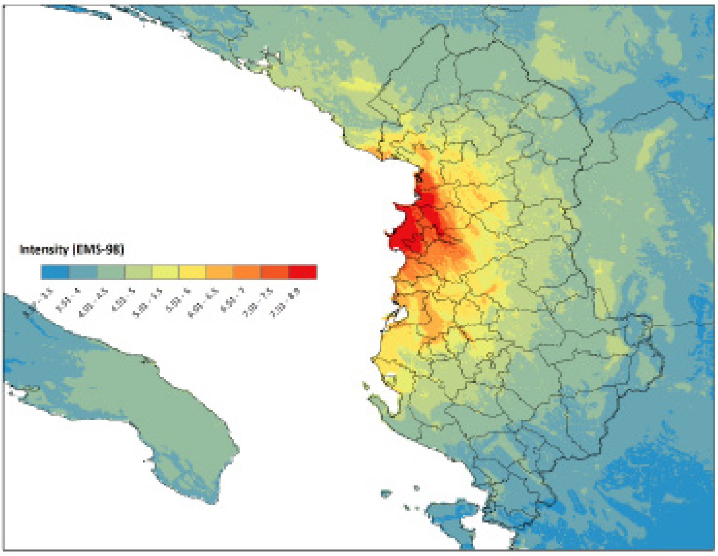


Figure 2-7 The main shock's modeled seismic intensity distribution. As per the EMS-98 scale, the darkest red corresponds to intensity VII (extremely severe), whereas the yellow and orange tints correlate to VI and VII (strong and very strong, respectively) (Source: World Bank Report, 2019)

Damage statistics in table 2-2 relate to single-family houses, apartment blocks that contain usually more than ten housing units, as well as non-residential buildings.

Table 2-2 Building damage statistics from three municipalities in the epicentral region (Source: World Bank Report, 2019)

	Durres M.	Kruja M.	Shijak M.	Combined
Inspected	2112	2499	1670	6281
Safe	1369	1533	346	3247
Uninhabitable	651	921	900	2472
Demolition	93	45	424	562
Demolished	34	12	0	46
Safe	64.80%	61.20%	20.70%	51.70%
Uninhabitable	30.80%	36.90%	53.90%	39.40%
Demolition	4.40%	1.80%	25.40%	8.90%

As these datasets do not include the number of “undamaged” buildings, it is difficult to draw definite conclusions; however, it can be seen that among the assessed buildings, those that were built prior to 1992 suffered more damage than those built in or after 1992 (43.6% of the pre-1992 buildings were classed as red or yellow as opposed to 28.4% of the post-1991 buildings). Damage was most extensive among the low-rise buildings that were assessed (70.2% were classed as red or yellow), and least extensive among the high-rise (6 or more floors) buildings (22% were classed as red or yellow). Some of the reason is that the low-rise buildings are old unreinforced masonry houses made of adobe or clay brick, whereas the tall buildings are virtually exclusively reinforced concrete buildings built after 1991 (table 2-3). The mid-rise buildings (3 to 5 floors), on the other hand, consist of a mixture of structural types (brick masonry, structural masonry, reinforced concrete) and were built across both examined periods of construction.

Table 2-3 Tirana Municipality building damage statistics analysis (by period of construction, number of floors, type of structure and 3- colour damage levels). (Source: World Bank Report, 2019)

Building Characteristics	Safe	Review	Evacuate
pre-1992	56.30%	23.60%	20.00%
post-1991	71.60%	15.30%	13.10%
Unclassified	47.00%	16.60%	36.50%
1-2 floors	29.80%	22.10%	48.00%
3-5 floors	60.60%	23.40%	16.10%
6+ floors	78.00%	14.00%	8.10%
Unclassified	66.30%	12.50%	21.20%
Adobe walls	17.40%	17.40%	65.20%
Brick Masonry	56.10%	20.90%	23.00%
Concrete Block Masonry	9.10%	9.10%	81.80%
Prefabricated	86.20%	10.30%	3.40%
Reinforced Concrete	71.70%	16.00%	12.30%
Structural Masonry	62.80%	21.80%	15.40%
Unclassified	4.00%	36.00%	60.00%
TOTAL	60.60%	19.20%	20.20%

• In terms of the impact on the built environment, the primary shock caused damage to buildings in Durrës, Tirana, and a number of other settlements in the surrounding area.
• The affected area's primary building types include unreinforced masonry structures and reinforced concrete (RC) structures with infill baked clay and/or concrete walls. Additionally, mixed kinds were seen. The majority of current structures were built in accordance with the KTPs – Albanian Technical Codes, which were first issued and implemented in 1963 and were last modified in 1989.
• The unreinforced structures with load-bearing masonry walls were the most severely damaged by the earthquake for a variety of reasons, including their age, poor quality of construction, poor workmanship, human intervention, the time period's design code - assuming it had been implemented - an absence of maintenance and poor repair following earlier devastating seismic events. This type of structure received both nonstructural and structural damage, including the partial or complete collapse of load-bearing masonry walls.

Dominant types of buildings

Masonry buildings with and concrete floor slabs are primarily composed of thick, heavy unreinforced masonry (URM) formed of solid clay bricks that provides structural support for the entire construction, including the horizontal concrete slab, which may be reinforced concrete. A significant characteristic of this type of structure, not only in Albania but also around the world, is the lack of concrete columns and beams. The solid brick walls are the only and the main load bearing elements of the structure. This masonry type is unreinforced and thus it presents brittle - non-ductile behavior. Due to the construction material (solid clay bricks), they also present small stiffness resulting in good performance and flexibility during an earthquake up to a certain limit. Once this limit is exceeded, the damage is instantaneous in this case, the earthquake shaking and displacement did not exceed this limit and these structures remained intact by the earthquake (Lekkas, Mavroulis, Papa, & Carydis, 2019).

Figure 2-8 Dominant types of buildings (source (Lekkas, Mavroulis, Papa, & Carydis, 2019))

A very positive characteristic in this type of buildings is that the best possible continuity between the soil and the construction is achieved, in terms of material and stiffness. These elements appear to have a positive effect on the antiseismic performance, particularly with respect to the vertical component of the earthquake ground motion. Taking into account these elements, this building type excel in antiseismic performance. Unreinforced masonry (URM) construction should not be used today. They do not present good performance during earthquakes. It is significant to mention that the majority of fatalities induced by earthquakes around the world have attributed to collapse of unreinforced masonry buildings. They are heavy brittle structures, which usually suffer heavy structural damage.

Figure 2-9 Structural damage (source (Lekkas, Mavroulis, Papa, & Carydis, 2019))

Heavy structural damage to masonry buildings with concrete floor slab in Thumanë town are presented. Damage comprised detachment of large pieces of plaster from the brick walls, cracks in brick walls and partial collapse of the building. The floor slabs were composed of simply supported prefabricated reinforced concrete hollow core strap slabs. The concrete strap slabs are not transversally connected to each other neither to the load bearing system. In this way, the diaphragmatic function of the floors, which is beneficial for the earthquake safety of the structure, is totally missing.

Also, below, are presented in the same graph the sprectre of September earthquake, November earthquake with two spectres from two codes, KTP and EC-8.

As we can see, the spectral acceleration of the September earthquake, is higher than the KTP-spectre (which the buildings was design with) for periods 0.2-0.3sec. The September earthquake caused structural damages in the buildings with these fundamental periods (URM type, the case of building in fig 2-9). When the November earthquake occurred, the building was damaged and therefore its shear capacity of bearing walls was reduced, and didn't withstand the last quake (although the November earthquake spectre is lower than the KTP one). If the building would have been designed with EC-8 spectre, it would had withstood both earthquakes with light and non-structural damages.

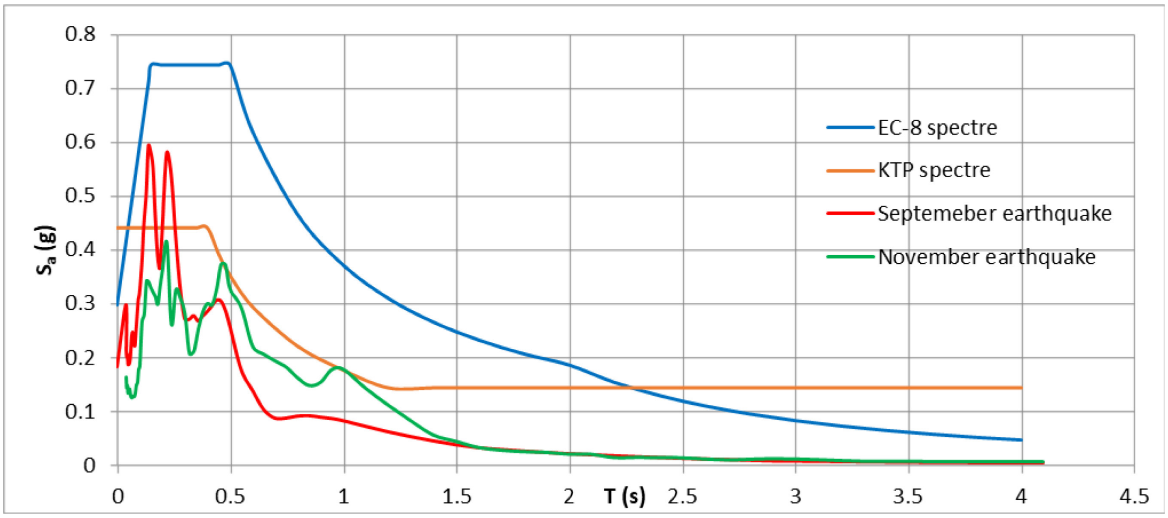


Figure 2-10 Comparison of the two latest earthquake spectre with the two design codes used in Albania

Conclusions

• The major structures in the affected area include (a) load-bearing solid brick walls with concrete floor slabs, (b) precast concrete panel structures, and (c) reinforced concrete frame structures with infill and partition walls. The bulk of these structures are characterized by the presence of precast concrete floor slabs with widths ranging from 0.7 to 1.0 m and no connections between them.

In Durres city, structures with masonry walls and concrete floor slabs did not sustain significant nonstructural or structural damage. However, structures of this type experienced severe structural damage in Thumane, including partial collapse, resulting in numerous fatalities.

2.3. Masonry building structural components

Masonry is a type of composites material for construction that consists of masonry units, mortar, concrete infill and/or concrete, and reinforcing steel.

A vast variety of raw materials, both natural and synthetic, are utilized in the manufacture of masonry units, both traditionally and industrially. Mortar is made out of various amounts of lime, cement, and sand that are combined with water, either with or without additions. To strengthen the masonry, deformed and smooth reinforced steel bars of different shape and qualities are inserted in mortar or grouted into holes. While each element of a masonry has its own distinct mechanical properties, whenever exposed to permanent and temporary loads, they are meant to work cohesively as an unified structural material. Naturally, not all materials are met simultaneously. Masonry construction techniques are further classified based on the materials used and/or the way they are combined in a structure:

• Unreinforced (plain) masonry, which consists of mortar and masonry units.

• Confined masonry is made up of masonry units, mortar, reinforcing steel, and concrete;

• Reinforced masonry is made up of masonry units, mortar, reinforcing steel, and concrete infill.

Due to the unique features of each constituent masonry material, particularly masonry units, it is difficult to forecast the mechanical characteristics of a particular masonry construction type using simply the constituent materials' characteristics, mortar and masonry units. It is vital, therefore, to undertake studies correlating the strength characteristics of constituent materials to the masonry properties for each type of brickwork. Due to its complexity, masonry and its constituent materials must adhere to certain standards and norms, much more so when employed in the building of engineered structures, where the resistance of individual elements and the entire structure to gravity and seismic loads is calculated. If the mechanical properties of the constituent materials and masonry as a structural material do not conform to the numerical verification assumptions, incorrect results may be drawn. Eurocode 6: "Design of masonry structures" (EC6-1, 2008) specifies the fundamental requirements for masonry materials and construction methods. Eurocode 8: "Design standards for earthquake resistance of structures" (EC8-1, 2004) specifies that earthquake regions, additional standards for masonry materials and construction techniques must be considered. The Eurocodes are complemented by a collection of European standards that define the essential properties of masonry materials and their testing methods.

- *Masonry Materials*

Design of masonry buildings against earthquakes

Masonry is a special building material and requires a convenient structural configuration. Structural simplicity and regularity (figure 2-11) not only improve the expected behavior of structures, but also enable the simplification of calculation methods and ways of verification of resistance in seismic situation.

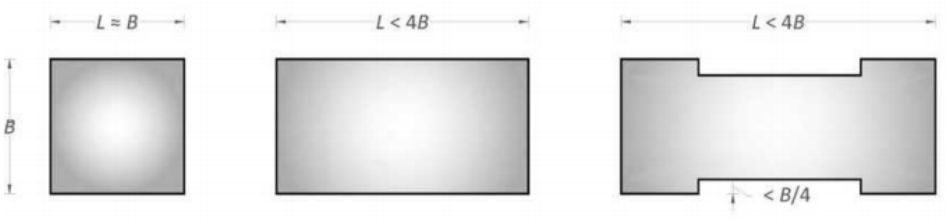


Figure 2-11 Examples of buildings with regular masonry in plan (Source: Tomazevic,1999)

In order to avoid the effects of torsion in the case of tall buildings, it is recommended that the length of the building should be limited to four times the width. If a longer length is needed then the building should be divided by joints. Division of large buildings into several part is made in order to obtain structural symmetry and simplicity. To avoid collision of the components of the building with each other during the earthquake joint should have a minimum distance, obtained from the calculations.

Physico-mechanical properties of masonry

During the verification of the bearing capacity of the masonry under the action of vertical loads and horizontal, rather than the characteristics of the composite materials are needed characteristics of masonry as a composite material. EN 1996-1-1 (CEN, 2005) requires the definition of the following mechanical characteristics relying on standard testing methods, described in EN 1052-1 to 5 (EN 1052-1, 1998), (EN 1052-2, 1999), (EN 1052-3, 2002), (EN 1052-4, 2000) and (EN 1052-5, 2005)):

- compression strength f_k
- shear strength f_v
- bending strength f_x
- relation σ-ε (strain - deformation)

In addition to the above characteristics during various structural calculations and analyzes it is necessary to know other very important features such as tensile strength f_t, modulus of elasticity E, shear modulus G etc.

Compression strength

The characteristic resistance in compression of masonry (f_k) is influenced by the properties of its components (i.e., by the properties of mortar and masonry units). Laboratory tests for the determination of f_k should be in accordance with EN-1052-1.

The results of the tests are expressed in tabular form or described through the following equation given in EN 1996-1 (EC6-1, 2008).

$f_k = K * f_b^{\alpha} * f_m^{\beta}$ *[N/mm²]* *Eq 2.1*

In the above equation, K is a constant in units of "N/mm²" depending on the type of masonry, which should be modified as the recommendations given in Eurocode 6.

The sizes f_b and f_m are respectively the normalized average resistance of a masonry unit and compressive strength of masonry mortar. The coefficients α and β are constants.

Another way for determining the characteristic compressive strength of masonry is through the following equation for masonry with ordinary mortar, with joints completely of filled with mortar.

$f_k = K * f_b^{0.7} * f_m^{0.3}$ *[N/mm²]* *Eq 2.2*

However, the use of equation (2.2) requires that certain conditions be met, e.g., detail of masonry according to Section 8 of EN 1996-1-1, f_b value is limited at 75 N/mm2, f_m is limit at 20 N/mm^2 and the thickness of the masonry element should not be greater than the width or the length of the masonry units. Also, the coefficient of variation of the resistance of the units of masonry should not be greater than 25%. The values of K are given in Table 3.3 of EN 1996-1-1, in which is shown that for clay bricks and ordinary mortar, K takes values from 0.35 to 0.55. For the walls with thickness greater than the largest brick size, K decreases by multiplying by 0.8. In Eurocode 6, the bricks used in Albania for the structural walls of buildings can be classified in "Group 1" in terms of geometric features (because they are solid). Then, for ordinary mortar, equation (2.2) is converted to:

$f_k = K * f_b^{0.7} * f_m^{0.3}$ [N/mm^2] *Eq 2.3*

Determination of the value of compressive strength in KTP-9-78 (Ministry of Construction, 1978) is done also in function of the resistance of the mortar and the masonry units ("mortar class" and "brick class"). Design value of compressive strength for brick masonry (common, lightweight or silicate) with a wall height of up to 12cm is given in table 2-4.

Table 2-4 Compressive strength for brick masonry (Source: KTP-9-78)

Nr.	Brick class	Mortar class N/mm^2						
	N/mm^2	10.0	7.5	5.0	2.5	1.5	0.4	0.0
1	15	2.2	2.0	1.8	1.5	1.35	1.2	0.8
2	10	1.8	1.7	1.5	1.35	1.1	0.9	0.6
3	7.5	1.5	1.4	1.3	1.1	0.9	0.7	0.5
4	5.0	-	1.1	1.0	0.9	0.75	0.6	0.35

In the values of the above table, the thickness of the horizontal joint is accepted 15mm while that of the vertical joint is 10mm. The wall homogenization coefficient included in the calculation of the design resistance, when in compression, is taken as 0.5, while in tension, in tension with bending or shear, is taken 0.45 (Ministry of Construction, 1978).

Tensile strength

Tensile strength has a significant impact on the loss of masonry bearing capacity. Numerous researches have been carried out to correctly assess the tensile strength of the unreinforced masonry. For example, Backes (Backes, 1985) tested several masonry samples under the tensile forces and studied tensile failure, observing the contribution of mortar and masonry units. The author found that the resistance of masonry to tension, varied between the values 0.09 N/mm^2 to 0.82 N/mm^2 as a function of tensile strength of mortar and masonry unit.

Modulus of elasticity and strain-deformation relationship

Modulus of elasticity

In the literature equations are given to calculate the masonry modulus of elasticity E (Kornbak, 2000). In the absence of laboratory tests according to standard EN 1052-1, E can be calculated as a function of compressive strength of masonry (f_k) through equation 2.4:

$E = X f_k$ [N/mm^2] *Eq 2.4*

where X is a factor which takes values from 500 to 1000 depending on the type of mortar and brick used in masonry. In KTP-9-78, the X factor is labeled "elastic masonry coefficient" and is marked with the symbol α.

In Eurocode 6 (EC6-1, 2008) it is advised the value of 1000 N/mm^2 for service limit states, while for calculations in ultimate limit states (mainly in nonlinear analysis) it is recommended to use the value 600 N/mm^2. Based on numerous comparisons to experimental findings (Tomazevic, 1999) , it is concluded that the Eurocode recommendations result in an overvaluation of the young's modulus.

Authors Thomas Zimmermann (Zimmermann & Strauss, 2012) recommends the following equation (2.5) as the most appropriate and closer to the experimental values.

$E = 300\, f_k\ [N/mm^2]$ Eq 2.5

In KTP-78 (Ministry of Construction, 1978) similar values are recommended but they are also given in function of the elements of masonry and type of masonry. The KTP table is shown below (table 2-5) preserving the original units.

Table 2-5 Elastic masonry coefficient α for different mortar class (Source: KTP-9-78)

Nr.	Masonry type	Elastic masonry coefficient α for different mortar class			
		100-50 kg/cm^2	25 kg/cm^2	4 kg/cm^2	0 kg/cm^2
1	Brick masonry, concrete blocks and stone (unit weight up to 1800 kg/m^3)	1000	750	500	350
2	Brick masonry with vertical holes	2000	1500	1000	-
3	Brick masonry with horizontal holes	1500	1000	750	-
4	Brick masonry, concrete blocks (unit weight over 1800 kg/m^3)	2000	1000	750	-

Shear strength and shear module

The shear strength of masonry combined with tensile is one of the most important parameters in determining the lateral force that the structure is able to withstand.

The shear strength of unreinforced masonry is affected by three parameters, strength of mortar, vertical load (in compression) σ_v and ratio between wall height and length (size of the element). Numerous tests (Jukes & Riddington, 1997) have revealed a "Coulomb" type relationship between shear strength and compressive load applied. According to this relationship, masonry exhibits an initial shear strength which depends on the adhesion between the mortar and the brick.

To this initial resistance is added a proportional coefficient (Hendry, Sinha, & Davies, 2004) to the vertical stresses to give the value of shear strength (figure 2-12).

$\tau = \tau_0 + \mu\, \sigma_c$ Eq 2.6

In the above equation:

τ_0 - *shear strength when compression is zero;*

μ - *coefficient of "friction";*

σ_c - *vertical strain in compression.*

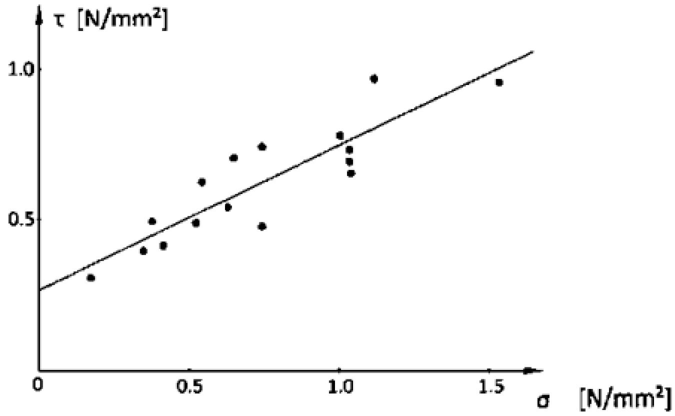


Figure 2-12 Graphical presentation of experimental results and their approximation with a linear equation (Source: Hendry,2004)

In EN 1996-1-1 (EC6-1, 2008) the calculation of the shear modulus G is recommended in function of the modulus of elasticity E. Specifically:

$G = 0.4E$ *Eq 2.7*

Loss of bearing capacity in shear

The shear strength of masonry is defined as its resistance to lateral loads. In modeling the loss of ability of a masonry element as a result of shear forces, should considered be two possibilities (Baballeku, 2014):

- sliding (figure 2-13);
- crack, according to the direction of the main tensile stresses (figure 2-14).

These are exactly the two main mechanisms that control the resistance of masonry to lateral loads. To assess the capacity in shear of a structural wall, considering only sliding mechanism, the value of the masonry characteristic strength to shear (f_{vk}) is multiplied by the masonry area that provides resistance against this action.

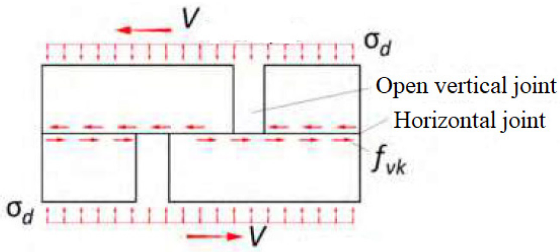


Figure 2-13 Capacity in shear from sliding mechanism (Source: Baballeku, 2014)

Meanwhile, in various works (Turnšek & F, 1971) explains the mechanism of diagonal cracks, according to which, the resistance of the wall to shear forces is determined by the tension according to the direction of the main stresses. The plane of tensile strength causes cracks according to the angle of the main stresses plane (figure 2-14).

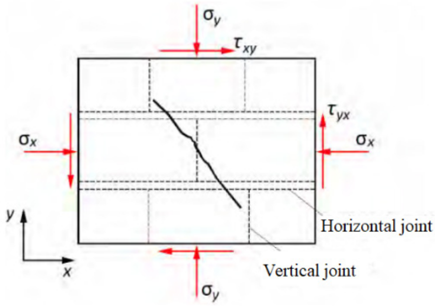


Figure 2-14 Mechanism of diagonal cracks (Source: Baballeku,2014)

- *Risks affecting the safety of masonry buildings*

Damages due to their age (deterioration of materials)

Masonry structures can be degraded according to mechanisms (Guri, 2016) which can be categorized:

- Chemical / biological degradation in both mortar and brick components by the action of waters containing acid, sulfate, pollutant and chemical substances emitted by plants.
- Corrosion of metal components in masonry (usually steel), especially ties, straps, reinforcing bars, etc. - A special case is chemical degradation.
- Erosion of bricks or mortar by particles derived from water and wind, frost and degradations from salt.
- Effects of stresses related to: foundation movements, consolidation of soil, overloads, movement from moisture of bricks, thermal movement, movement by plant growth.
- Bleaching due to mold and the spread of microorganisms.

Damage due to the foundation

The foundation is the most vital part of the structure. Even in cases where the structures are well designed, can be damaged due to foundation problem. Problem that may be very difficult to repair, has difficulty in implementation and high costs. To determine if a foundation can survive the horizontal forces conveyed to it, it is required to evaluate its type, material, and embedding.

Weakening of the foundation

There are two concerns about foundation damage: Degradation and cracking (Guri, 2016).

a. Degradation: Degradation of the foundation is an inevitable phenomenon, which comes as a result of the action of environmental factors. By inspecting the foundation, it can be verified if there are cracks or erosion, then give repair recommendations.

b. Foundation cracks: Cracking is a common occurrence when foundations are constructed with insufficient proportions. Cracks that are broader in the upper section than in the lower section are frequently produced by soil settling. For cracking that is wider at the bottom than at the top, the issue is not with the earth, but with the foundation bending.

Damage due to static and seismic loads

The process of designing masonry walls requires consideration of several modes of destruction as well as limit states (CNR-DT 200, 2004; CNRDT 200 R1 / 2013) (NATIONAL RESEARCH COUNCIL, 2014).

Static and seismic loads operate on masonry structures during the construction and operational phase, which may act in and out of the plane of the wall (figure 2-15).

Masonry is not an isotropic material and consequently has different mechanisms of destruction under the action of loads. Masonry is resistant to the forces in compression and very weak in shear, tension and bending. Structures with masonry the have high requirements for tensile or flexural strength, should be reinforced by adding steel bars or other elements with high tensile strength.

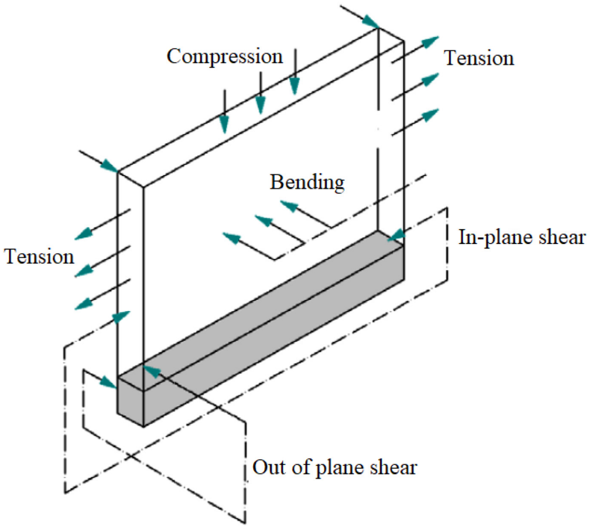


Figure 2-15 Static and seismic loads operate on masonry structures (Source: Guri,2016)

Buildings designed before the 1980s did not have antiseismic columns. It has been nearly 50 years since their construction and operation, and this period of time has surely impacted the masonry's decay and decreased its bearing capability. This degradation is also dependent on the occupants' activity. who may have harmfully affected, by intervening in the structural elements such as: in the construction of additional floors, balconies, interventions in the foundations of the building, cracks in the walls on the first floors, construction of new adjacent buildings to the existing building etc. (Guri, 2016). As a result of this interventions, they have increased their static loads in the structure, the masonry calculation scheme has changed, and some of the structural elements are overstressed.

Collapse of the wall in its plan due to seismic loads
The in-plane resistance of the wall with unreinforced masonry is based on the resistance of mortar and brick. If the acting force has a value greater than the shear capacity of the masonry then the masonry will be damaged (figure 2-16). Usually, the damages in this case are cracks with an angle of 45 degrees caused by major stresses.

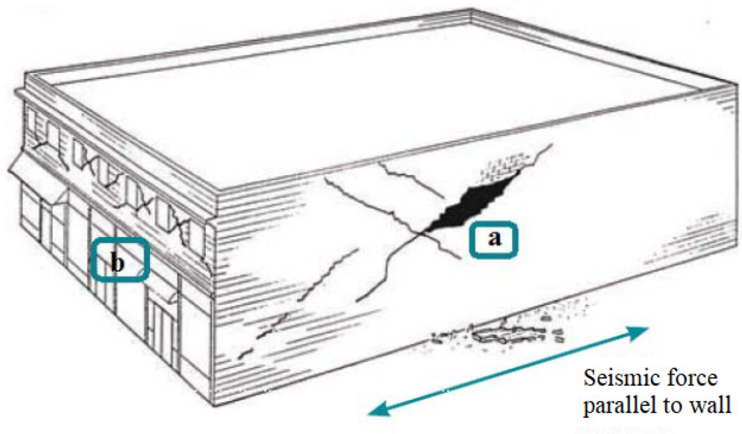


Figure 2-16 Collapse of the building due to seismic loads (Source: Guri, 2016)

Damages of the bearing walls of buildings with simple and complex masonry (with and without reinforcements) can be classified in three types (Guri, 2016), which depend on the cross-sectional size of the wall and the physical-mechanical characteristics of materials:
1. Damage caused by seismic shear forces (figure 2-17a, b) that is characterized by:
Horizontal cracks according to the joints when the shear stresses are bigger than the allowable ones.
Crossed diagonal cracks as a result of the main tension stresses are greater than the allowable one

2. Damage from compression with bending (figure 2-17c), which is characterized by the destruction of part in compression of masonry as a result of the reduction of its cross section after the horizontal crack in the tension area of the masonry.

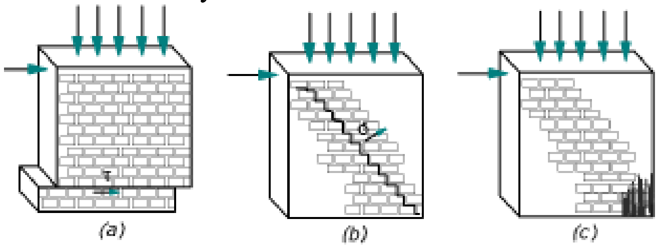


Figure 2-17 Damage of masonry: from shear forces a) from main tension stresses b) from compression with bending c) (Source: Guri,2016)

2.3.1. Seismic performance of masonry building

Masonry constructions only need to be assessed for their ability to withstand gravity loads if there is no threat of earthquakes occurring in the vicinity of the structure in issue In the event of an earthquake, on the other hand, the structure will be subjected to a large number of cyclic horizontal actions, which will frequently result in large additional bending and shear stresses in masonry walls, which can frequently exceed the elastic range of the behavior of masonry materials in the event of an earthquake. It is inevitable that building structures will be damaged by seismic loads. When they're not designed and detailed sufficiently to resist deflections and release energy, the resultant inertia forces can cause significant damage or perhaps even destruction of the structure. Because of the usual structural structure and reserve in strength of masonry materials when it comes to supporting vertical gravity loads, it is not often essential to assess the load-bearing capacity of masonry walls and floors for vertical seismic action. However, due to the uniformly distributed of walls in both transverse directions, the geometrical criteria for shear walls (effective elevation, thickness, and location of openings), and the connection among floors and walls, out-of-plane resistance to earthquake motions is typically not an issue. Only severe spans between structural walls that exceed the code-recommended values are required to undergo seismic resistance testing for lateral out-of-plane loads, as a result of which only extreme spans between structural walls are tested. When subjected to in plane seismic stresses, the seismic behavior of structural masonry walls can be categorized into three categories of processes and failure modes, based on the findings of earthquake damage analysis and subsequent experiments. The processes are dependent by the shape of the wall (altitude ratio) as well as the type of materials, but they are also influenced by boundary constraints and stresses pressing on the wall, among other factors. (Tomazevic, 1999).

Seismic stresses are frequently responsible for the splitting of walls into two parts, as well as the sliding of the upper half of the wall along one of the horizontal mortar joints, particularly in the case of walls with a low vertical load and poor-quality mortar. Sliding shear failure is the term used to describe the failure mechanism. Unless the vertical load and axial compression stresses in the wall are significantly more than the typical limits, the wall is likely to break in shear or bending, depending on the conditions of the situation. It occurs when the principal tensile stresses developed in a masonry wall as a result of a combination of vertical and horizontal loads exceed the tensile strength of the masonry materials used in the wall's construction. Shear failure is one of the most common modes of failure for masonry walls subjected to seismic loads. The development of characteristic diagonal fissures in the wall occurs shortly before the achievement of lateral resistance. In some cases, the cracks can follow the mortar joints, in others they can penetrate through the masonry units, or in other cases both. Although better shear resistance and a high moment/shear ratio are desirable, crushing of compressed zones at the extremities of a wall is almost always observed, indicating that the wall has failed in the flexural mode (Tomazevic, 1999). It is difficult to model the non-elastic, non-homogeneous, and anisotropic nature of brickwork using mathematical equations alone. Predictions of the lateral load-bearing capacity and deformability of masonry walls are frequently made by drawing parallels between masonry walls and reinforced concrete structural members. Because the behavior of reinforced grouted masonry and concrete under seismic loads is nearly identical, only minor modifications are required in the case of reinforced grouted masonry. In the case of completely grouted masonry walls, good agreement with experimental data can be obtained by employing general computer programs for forecasting the inelastic cyclic behavior of reinforced concrete structures (r.c. structures) (Shing, Schuller, & Hoskere, 1990). To account for the mechanical features of traditional ordinary or strengthened masonry construction, mathematical models initially created for reinforced concrete elements must be adjusted to account for the unique particular mechanical qualities of masonry materials. In order to better understand lateral load-displacement connections, numerous different physical models have been used to create simulations. Researchers have considered a combination of arch and truss mechanisms as well as a combination of dowel, pullout, and friction mechanisms in order to predict the lateral load-displacement skeleton curve in the case of shear failure of reinforced masonry walls, as well as cyclic hysteretic behavior. On the basis of experimental data from cyclic testing of strengthened masonry walls, a global implied dimensionless mathematical stress - strain model has been created (Bernardini, Giuffre, & Modena, 1984). The hysteretic behavior of simple brick walls that fail under shear has also been characterized using parameter functions, such as the shear modulus and its viscous equivalent, which were both determined by testing on the structures (Tanrikulu, Y, & McNiven, 1992).

A new seismic code has been introduced recently that incorporates limit states verification of masonry structures' seismic resistance, which has been in use for many millennia and has been used for decades with permitted stresses methods. When it comes to designing masonry structures, the philosophy behind Eurocode 6: “Design of masonry structures” (EC6-1, 2008) and Eurocode 8: “Design provisions for earthquake resistance of structures” (EC8-1, 2004), both of which governs the design and implementation of masonry structures, is founded on the basic necessity of creating a structure in such a way that it will stay in use with a reasonable probability for the estimated lifetime – and under the predicted service conditions. That implies that the building must be capable of resisting all actions and forces that may occur over its lifetime without suffering significant damage, but it should also be able to avoid being damaged disproportionally in the event of an accidental event such as an explosion, an impact, an earthquake, or a human error. In seismically active areas, two fundamental needs are taken into consideration throughout the design process: the demand for no collapse and the necessity for damage limitation.
Construction of the structure should be such that it can sustain the design seismic action without experiencing local or widespread collapse. Additionally, the structure should retain its structural stability and load-bearing ability during an earthquake of estimated intensity (design earthquake). If the building is exposed to strong actions that have a greater likelihood of occurring than the design earthquake but are less intense, no damages to architectural or non-structural elements shall occur, which would prevent the structure from being used or would result in costs that are disproportionally high compared to the design earthquake. As a result, in order for a structure to withstand seismic loads, it is necessary to verify two fundamental limit states, which correspond to the criteria listed above:
• “Ultimate limit state, which is associated with collapse or other forms of structural failure that may jeopardize the safety of people”, and • “Serviceability limit state, which is associated with the occurrence of damage, deformations, or deflections that exceed the point at which the specified service requirements of the building are no longer met by the structure”.

Seismic and design response spectre
There are many different ways to describe seismic action, including ground acceleration or velocity time-history (either recorded or artificial), and response spectrum (to name a few). According to the relevance and complexity of the structure under consideration, the type of seismic action to be used in seismic verification would vary (Tomazevic, 1999). When considering seismic ground motion, it is necessary to take into account its tridimensional nature in some instances. However, when the regularity of masonry structures is taken into consideration, the response spectra representation will provide appropriate results in the vast majority of masonry construction scenarios. Ground acceleration or velocity time-history constitute the most direct form of representation of seismic activity, and it is used to compute the structural response and, consequently, the impacts of the seismic action on the ground. On the other hand, response spectra presuppose the computation of the structural response in advance. Calculating action effects is only necessary when design seismic loads are estimated using response spectra. The only method available for obtaining accurate information on the current response of a masonry caused by earthquakes loads is direct non-linear

dynamic analysis, which considers the non-linear properties of masonry structural elements. To avoid the more complex direct non-linear dynamic analysis, the structure's non-linear behavior and energy dissipation capacity are considered by performing a simple linear elastic analysis (Tomazevic, 1999) but accounting for a reduced response spectrum, referred to as a design spectrum, which is obtained by introducing the behaviour factor, i.e. force reduction factor q.

Behaviour factor

Despite the widespread belief that masonry is a brittle structural material, investigations and study of seismic damages have showed that even simple masonry structures have a very high energy dissipation capacity, allowing elastic seismic stresses to be reduced. The well-known concept of behavior factor q (force reduction factor) is summarized in figure 2-18, which compares the seismic response envelope curve of an actual building, idealized as a linear elastic - perfectly plastic envelope, to the response of a perfectly elastic structure with the same initial elastic stiffness characteristics..

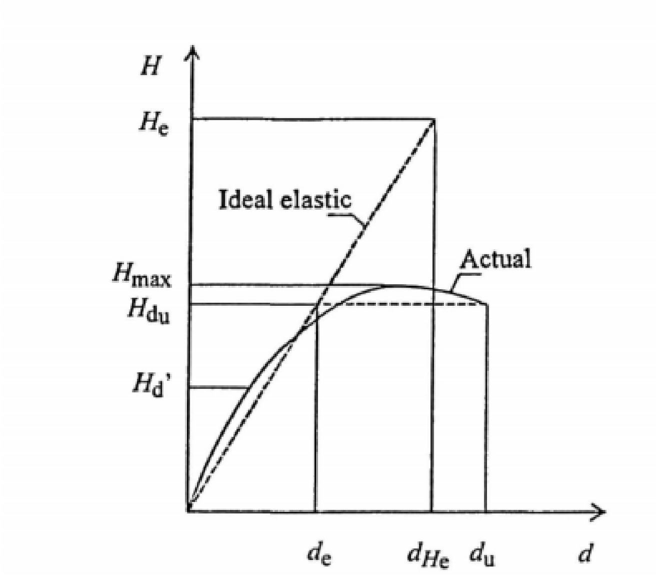


Figure 2-18 Definition of structural behaviour factor q (Source: Tomazevic,1999)

It is advised to use the following values of behavior factors q for evaluating the seismic resistance of masonry structures:

• For unreinforced masonry, the q value is 1.5; for confined masonry, the q value is 2.0; and for reinforced masonry, the q value is 2.5.

Specifically, when designing a structure, precise specifications for the structural arrangement and details of the structure should be taken into consideration. These requirements include things such as material quality and quantity, placement and spacing of structural walls, the use of bonding elements and reinforcement, among other things. Specific regulations for masonry structures are provided in EC 8, and they specify the minimum conditions that must be met in order to achieve the values of behavior factors specified above in the case of masonry buildings.

2.4. Building retrofit strategies

2.4.1. Energy retrofit

A building can gain eco-efficient qualities with the help of the application of different technologies, which are further explained. Various improvements were made to heating systems, however there is lack of development found in the adoption of innovative technologies in residential buildings. The absence of research in this sector is linked with findings strategies to improve the existing stock, which is dominant.

Retrofit techniques for energy efficiency in buildings can be classified into three groups (JRC (Joint Research Centre), 2012):

demand reduction for heating and cooling,

equipment upgrades for heating, ventilation, and air conditioning (HVAC),
installation of renewable energy sources.

To provide energy efficiency, the first step is to increase the thermal resistance of building envelope, which can be obtained through the application of insulation on walls and roof, replacement of poor insulated windows with windows of a higher performance, applying sun shading systems and devices, improving air-sealing in windows.
The second strategy is to install solar panels of any type, including photovoltaic, PV, and solar thermal, ST, which are now one of the most cost-effective on-site energy generation solutions, particularly in southern and central Europe, in which solar renewable energy systems have proven quite efficient.
Lastly, a third option is to integrate different renewable energy sources, such as solar thermal (ST) collectors, photovoltaic (PV) or hybrid photovoltaic and thermal (PV/T) panels.
Such alternatives are discussed in greater detail in the following subsections.

- *Thermal performance*

To provide and to increase thermal performance of a building through the envelope, insulation method and window typology play an important role. Some of the factors important to provide this is through:

Envelope insulation

Thermal conductivity of main building components is by far the most prevalent thermal performance criteria for buildings, with the aim of minimizing thermal conductivity of important construction parts. Specifically, thermal transmittance (U value) requirements (expressed in W/m2K) for the primary building envelope construction materials are used to develop these specifications. When it comes to energy efficient structures, the envelope becomes the most important component due to the fact that it accounts for 57 percent of total thermal loads in the building (JRC (Joint Research Centre), 2014).
Thermal insulation of the external walls is critical for both protecting the interior from the outside environment and reducing thermal transmission (heat losses or gains) via the envelope during the cold seasons, as well as during other seasons.
Insulation can be obtained by the combination of various materials of different qualities and rates concerning conduction, convection, and radiation. This combination and the method of insulation decrease energy loss and also does not require heating, ventilation and HVAC systems during design phase. As a result, the insulation of the building envelope is very effective for a higher energy performance in buildings.
Thickness of building insulation was higher until the 1970s, which was reduced firstly in northern countries of Europe (Papadopoulos, 2005). In order to obtain the best results from thermal insulation, it is important to position it closest to the surface of heat entry, while in the areas where cooling is more problematic it should be positioned in the outer surface (Commission Delegated Regulation (EU) No 244/2012 of 16 January 2012 supplementing Directive 2010/31/EU of the European Parliament and of the Council).
The choosing of thermal insulation should be carried out in an efficient manner. The thickness of insulation is determined by the thermal conductivity specifications of the material used. The rise in temperature and humidity of the thermal insulation causes it to become more thermally conductive, resulting in a reduction in its overall performance. As a matter of fact, investigations have demonstrated that water, whether in the form of vapor or liquid, has a negative impact on the material qualities of wool fibers and fiberglass (Low NMP, 1984). Furthermore, when considering a proper insulation, it is vital to consider environmental conditions as well as flammability characteristics.
The most commonly used insulation materials today can be divided into four categories: (a) mainstream insulation materials; (b) state-of-the-art insulation materials; (c) nano insulation materials; and (d) smart insulation materials. Traditional insulation materials are those that have been around for a long time.
A summary of the major attributes of conventional, state-of-the-art, and nanoinsulation materials is provided below (table 2-6) (Alotaibi & Riffat, 2014).

Table 2-6 Thermal insulation materials of the past against the state-of-the-art (Source: Alotaibi SS and Riffat S, 2014)

Material	Thermal conductivity (mW/mK)	Cost per thermal resistance	Environmental impact of production and use	A thermal insulation material and solution of tomorrow?
Conventional insulation materials				
Mineral wool	30-40	Low	Low	No
Expanded polystyrene (EPS)	30-40	Low	High	No
Extruded polystyrene (XPS)	30-35	High	High	No
Cellulose	40-50	Low	Low	No
Polyurethane (PUR)	20-30	High	High	No
State-of-the-art insulation materials				
Vacuum insulation panels (VIP)	8-Apr	High	Moderate	Near future
Gas-filled panels (GRP)	Oct-40	High	Moderate	Probably not
Aerogels	13-14	High	Moderate	May be
Nano insulation materials (NIM)	<4	High	Moderate	Yes

Appropriate insulation materials

a) Mineral wool

Mineral wool is composed of glass wool (fibre glass) and rock wool and is manufactured in the form of mats and boards, or as filler material. The form and heft of the object are determined by the environment in which it is used. Usually, lightweight and soft mineral wool is used to frame homes and structures with voids, while heavier wool is used to structures that will support pressures, such as floor slab. Mineral wool is also an excellent filler material for a variety of voids and spaces. Glass wool is made by heating borosilicate glass to roughly 1400 degrees Celsius and drawing it through revolving nozzles to create fibres. Rock wool is created by melting stone (diabase, dolerite) at approximately 1500 oC and then hurling the heated mass out from a wheel, so generating fibers. Dust abatement oil and phenolic resin are added to glass wool and rock wool to bind the fibers together again and enhance the product's characteristics. Mineral wool typically has a thermal conductivity of between 30 and 40 mW/m2 (mK). Mineral wool's thermal conductivity changes according to temperature, moisture levels, and density. As an illustration, the thermal conductivity of mineral wool can increase from 37mW/(mK) to 55mW/(mK) when the moisture content is increased from 0 to 10%. Mineral wool materials can be perforated, as well as cut and modified on-site, without compromising their thermal resistance.

b) Expanded polystyrene (EPS)

Expanded polystyrene (EPS) is a material consisting of small spherical of polystyrene (derived from crude oil) that carry an expanding agent, namely pentane C_6H_{12}, that expands when heated with vapour. At their points of contact, the expanding spheres are bonded together. Insulation material is produced in the form of boards or in continuous manufacturing on a production line. EPS has a porous structure that is partially open. EPS typically has a thermal conductivity of between 30 and 40 mW/m (mK). Temperatures, moisture levels, and density all affect the thermal conductivity of EPS. As an instance, the thermal conductivity of EPS can rise from 36 mW/(mK) to 54 mW/(mK) when the moisture content is increased from 0 to 10% (JRC (Joint Research Centre), 2018). Without sacrificing heat resistance, EPS materials can be perforated, as well as cut and altered on-site.

c) Extruded polystyrene (XPS)

Extruded polystyrene (XPS) is created from melted polystyrene (from crude oil) by adding an expansion gas, such as HFC, CO2, or C6H12, and extruding the polystyrene mass through a funnel with pressure release. The insulation material is manufactured in standard lengths and is then chopped once it has cooled. The pore structure of XPS is closed. The thermal conductivity of XPS is typically between 30 and 35 mW/m2 (mK). XPS thermal conductivity is temperature, moisture content, and density dependent. For instance, the thermal conductivity of XPS can rise from 34 mW/(mK) to 44 mW/(mK) as the moisture content increases from 0 to 10%. XPS products can be perforated, as well as cut and altered on-site, without sacrificing thermal resistance.

d) Cellulose

Cellulose (polysaccharide, (C6H10O5)n) is a type of thermal insulation composed of recycled paper and wood fibers. The manufacturing technique imparts a consistency comparable to that of wool on the insulation material. Cellulose insulation is typically utilized as a filler in cavities and voids, however cellulose insulation boards are however manufactured. The thermal conductivity of cellulose insulation is typically between 40 and 50 mW/m2 (mK). Cellulose insulation's thermal conductivity changes with temperature, moisture levels, and density. For instance, the thermal conductivity of cellulose insulation can rise from 40mW/(mK) to 66mW/(mK) when the moisture content is increased from 0 to 5%. Cellulose insulation materials can be pierced, as well as cut and modified on-site without compromising their heat resistance.

e) "Polyurethane (PUR)"

Polyurethane (PUR) is generated when isocyanates and polyols react (alcohols containing multiple hydroxyl groups). The closed pores are filled with an expansion gas such as HFC, CO2, or C6H12 during the expansion process. The insulation material is manufactured in sheets or in continuous production on a production line. PUR can also be used on-site as an expanding foam, for example, to seal around windows and doors and to fill various voids. PUR typically has a heat conductivity of between 20 and 30 mW/(mK), which is significantly less than mineral wool, polystyrene, and cellulose materials. PUR's thermal conductivity is temperature, moisture content, and bulk density dependent. As an example, the thermal conductivity of PUR can increase from 25 mW/(mK) to 46 mW/(mK) when the moisture content is increased from 0 to 10%. PUR materials can be perforated, as well as cut and altered on-site, without sacrificing thermal resistance.
It's worth noting that, even if PUR is safe in its intended application, it poses major health risks and hazards in the event of a fire. When PUR burns, it produces hydrogen cyanide (HCN) and isocyanates, which are extremely hazardous. The toxicity of HCN is due to the cyanide anion (CN), which stops cells from respiring. Generally, hydrogen cyanide is present in the smoke produced by plastics containing nitrogen (N).

To emphasize the importance of energy retrofitting existing building envelopes, the thermal conductivities of popular load-bearing building materials are quoted at this point. Typical comparisons include wood (100–200), carbon steel (55,000), stainless steel (17,000), aluminum (220,000), concrete (150–2500), lightweight aggregate (100–700), brick (400–800), stone (1000–2000), and glass (800), with all values in brackets expressed as mW/m2 (mK).

The main building elements that indicate the thermal performance of a building envelopes are:
a. Walls

Due to lack of standards, most of the old buildings in Europe suffer from the effects of missing insulations in walls. Those countries are those that did not implement the Energy Performance Buildings Directive (EPBD) with no prior enforced insulation laws, such as Portugal, in contrast to Northern and Western Europe, which have had thermal insulation requirements in place since before the 1970s, prior to the EPBD. For example, in Sweden, similar criteria for building energy performance have been in place since 1948 (JRC (Joint Research Centre), 2014).

Thermal insulation can be combined in two manners:

- Firstly, by increasing the thickness of the insulation. Such methodology was followed mostly these 20 years. However, is not efficient in costs, and reduces indoor spaces
- Enhancing the thermal insulation qualities of the insulation material by lowering its thermal conductivity.

b. Roofs insulation

Roofs can be insulated similarly to walls by increasing the amount of thermal insulation materials. However, apart from this method, there are various methodology for obtaining this, for instance green roofs. (JRC (Joint Research Centre), 2012)

Thermal installation of roofs is very efficient for low story buildings and large surface area. The effect of roof insulation is not very considerable in buildings of more than three floors high, which actually consider more efficient the insulation of walls and windows.
RC roofs are widely used in the southern United States not only due to their high resistance to loads and weather conditions, and also due to the presence and affordability of concrete ingredients. They can, nevertheless, show adverse thermal properties during hot summers, such as a greater ceiling temperature and a prolonged heat holding capacity, which affects indoor environment comfort and increases energy expenditures. Increased roof temperatures cause them to radiate infrared radiation with a long wavelength toward the occupants. Worse yet, it may persist into the night thanks to the slab's heat capacity. Insulating concrete roofs with an antisolar coating was extremely effective in extremely hot climates (Ahmad, 2010). By decreasing the roof temperature with this technology, summer roof heat gain was decreased by 45 kWh/day for a 208m2 roof area. Additionally, the roof's thermal conductivity is decreased from 3.3W/m2 K to 0.54W/m2 K. Thus, simple and low-cost RC roof insulation could be accomplished by the use of antisolar coatings (Sadineni, Madala, & Boehm, 2005).

Windows replacement

Windows are delicate elements for a building in terms of thermal performance. During winter they can easily be places of heat loss, while during summer they gain heat. However, they provide ventilation and natural light furnishing, which are very important for providing comfort for the users. As illustrated in figure 2-19, the total energy flow via a window is composed of three major elements (JRC (Joint Research Centre), 2012).

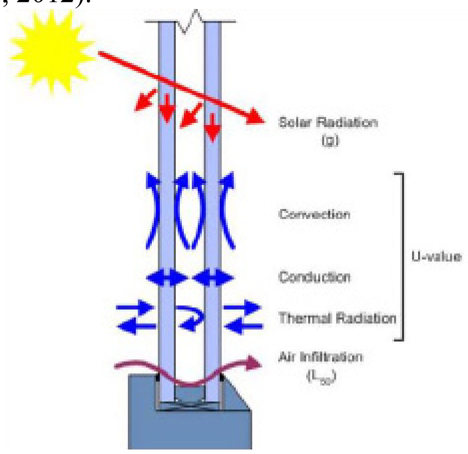


Figure 2-19 The transmission of energy via a window (Source: JRC, 2012)

- Solar radiation-induced heat increase. This is quantified by the solar factor (g), which quantifies the gain in energy from sun radiation. The magnitude of g is specified as a range between 0 and 1, with a greater value indicating greater solar heat gain.
- Heat losses and gains due to conduction, diffusion, and reflection caused by all window components. The U-value indicates this, therefore a window with a smaller U-value loses less energy to heat loss.
- Heat loss due to infiltration of air through a window. This is quantified by the L50 value, which indicates the amount of uncontrolled air leaking through a window. Air leaking through the windows is regarded to be a characteristic of the frame's efficiency.

The main aspect concerning efficient thermal insulation in windows is the connection joint of window with the wall, which if not done properly can result in failure of the whole thermal system. Other heat transfer elements are glazing, window frames, which should provide all low heat transfer coefficients.

- *Energy performance*

In relation to energy performance, there are several technologies for "improving HVAC and lighting systems:"

HVAC systems

The HVAC system's (heating, ventilation, and air conditioning) objective is to offer maximum comfort for its users. However, these systems vary across Europe, as heating loads are lower in the south and cooling loads can be ignored in the Nordic regions. HVAC systems incorporate a variety of technologies, and it is critical to consider their integration into the design, as well as the accurate calculation of heating system requirements. HVAC technology is improving not only to reduce energy consumption while maintaining a higher standard of indoor air quality, but also to handle new concerns (more renewable energy sources, increased primary energy efficiency) and new needs (hot water, heating, and cooling).
Particular emphasis is placed on heating and cooling methods.

a. Heating technologies

Passive solar air heating, solar thermal systems, and heat pumps are all examples of heating systems.
Solar air heating using passive solar radiation
This system has the potential to significantly reduce HVAC energy usage. When paired with suitable orientation, a sound structural foundation, an optimum envelope and construction materials, and internal heat gain recovery, the overall efficiency of the building is greatly boosted. Passive solar solutions can cut total heat loss by 35%.
Photovoltaic systems
These systems, which utilize evacuated tube collectors, are a popular and extremely efficient type of basic solar heat collector. Sunrays penetrate the tube glass and are absorbed by metal stripes through which the heat medium circulates. Nonetheless, the manufacture of collectors is an energy-, CO2-, and particularly material-intensive process. Thus, the total energy balance becomes positive after approximately two to three years (energy payback period), depending on site-specific factors such as collector type and sun intensity.
Technologies for heat pumps
Heat pump technology enables low-energy heating requirements and cost savings.

b. Cooling technologies

The purpose of space cooling methodologies (JRC (Joint Research Centre), 2012) is to reduce demand by utilizing many of the following techniques: - heat absorption during the daytime in summer by increasing the amount of heat sinks; - usage of cool roofs (reflecting incoming solar radiation); - green and brown roofs (cooling by evaporative absorption).

- Passive cooling

This method allows for cooling without the use of mechanical devices that use energy. To this end, the urban microclimate has a significant impact on the effectiveness of passive cooling solutions via the following:
- Optimal insulation, shadings, and overhangs, as well as air change rate. Integrated designs that account for internal heat gains throughout the summer and how to dissipate this heat to the surrounding environment should be thoroughly examined.

- *Renewable technologies*

The use of the renewable energy sources is the most appropriate technology concerning environmental management. Heat pumps and geothermal systems make use of renewable energy sources such as aerothermal, hydrothermal, and geothermal, but they still require considerable amounts of conventional energy (usually electricity) to function.

2.4.2. Seismic retrofit

By definition, "repair" refers to the post-earthquake restoration of damage produced by earthquake ground motions that does not significantly raise a structure's seismic resistance over its pre-earthquake state. However, "strengthening," "seismic strengthening," or "seismic upgrading" refer to technological changes in a building's structural system that increase its strength and ductility. As per the recommended nomenclature (Todd, 1994), reinforcing a structure prior to an earthquake is referred to as "rehabilitation," while strengthening a structure following an earthquake is referred to as "retrofit." Thus, the decision to repair a structure following an earthquake or to enhance it in advance of an earthquake is contingent on the structure's seismic resistance.

Many existing buildings, both non-engineered and engineered, that are considered "old" by earthquake-resistant design standards, rather than simply by construction age, collapse or sustain severe damage, as demonstrated by all recent earthquakes. Modern buildings (such as masonry structures) designed to meet the demands of state-of-the-art seismic design effectively resist strong ground motion. Due to the fact that older masonry structures are typical examples of non-engineered traditional construction, their seismic susceptibility is generally quite significant. Indeed, the majority of earthquake damage and fatalities in these locations are caused by the insufficient seismic behavior of existing masonry structures, most commonly residential residences in urban and rural areas constructed in the conventional manner.

Seismic retrofitting entails several unique considerations in comparison to static load strengthening or energy efficiency upgrades. For a good seismic upgrading, three separate characteristics of a structure must be examined and well-coordinated: stiffness, ultimate resistance, and deformation capacity (Sigmund, 2019). When contemplating seismic retrofitting, it is important to avoid retrofit schemes that are too focused on a single distinguishing feature of a structure without taking into account the potential negative repercussions of the other aspects.

When retrofitting an existing structure for seismic protection, one or a combination of the following measures should be applied (Uihlein & Eder, 2010):

- Improving the building's regularity
- Reinforcing structural parts
- Increasing ductility by avoiding brittle failure
- Softening the structural system by reducing its rigidity
- Damping the building's foundations
- Changing the building's use

Measures and criteria for retrofitting

In a recent report from the JRC, they talked about how to make existing RC buildings less likely to be damaged by earthquakes. It is said that structural assessment is used to find problems in existing buildings. This is proceeded by the identification of the best measure or mixture of initiatives to enhance the performance of the building.

In Tsionis et al. (Tsionis, Apostolska, & Taucer, 2014) , they came up with a list of the most widespread retrofit measures and the characteristics they influence. This was based on the two main goals of repair and strengthening (reducing demand or increasing capacity) and the three major response characteristics (strength, stiffness, and deformation capacity) (Table 2-7). It has been shown that some actions have an effect on more than one thing about the structure, and one of them could have an unwelcome effect. An increase in rigidity, for example, could result in higher force demands that could exceed the as-built capacity of some parts.

Table 2-7 The effect of local and global retrofit initiatives on the physical attributes of buildings (Source: Tsionis G, Apostolska R and Taucer F, 2014)

		Strength	Stiffness	Ductility	Irregularity	Force demand	Deformation demand
Local measures	Concrete jacket	✓	✓	✓		X	✓
	Steel jacket	✓		✓			
	FRP jacket	✓		✓			
	Post-tensioning	✓		✓			
	Strength reduction	X					
Global measures	New frames, shear walls braces	✓	✓		✓	X	✓
	Mass removal				✓	✓	X
	Partial demolition				✓	✓	
	Isolation		✓		✓	✓	✓
	Dampers					X	✓
	Expansion joints				✓		
	Connect independent sections				✓		

A suitable retrofit design is typically evaluated in terms of vertical components (e.g. columns, walls, braces, and so on) because of the importance of vertical components in providing lateral stability and resistance to gravitational load transmission. Large inter-story deflections cause vertical element failures because they impose excessively high force or displacement demands on the structural members. It is possible that walls and columns are strong enough to sustain seismic and gravity stresses, but the structure as a whole is inadequately connected, creating the risk of partial or complete collapse during an earthquake, depending on the kind of building. To develop an effective retrofit scheme, it is critical to have a complete understanding of the existing building's predicted seismic reaction and all of its flaws.
In the classical sense of enhancing the performance of an existing structure, there are three fundamental types of retrofit measures (FEMA 547, 2006):

- Increase the strength or rigidity of an element by adding components.
- Enhance current elements' performance by boosting their strength or deformation capability.
- Enhance component connections to ensure that individual elements do not detach and fall, that a complete load path exists, and that the designer's force distributions can occur.
- Along with enhancing the strength or ductility of existing structural parts, there are less conventional approaches for enhancing the entire structure's performance. These techniques can be classified as follows:
- Seismic demand can be lowered by eliminating upper floors or other bulk from the structure, installing dampening devices to limit displacement, or seismically isolating the entire structure or portions of it.

Selected elements can be eliminated or weakened in order to avoid detrimental interactions between different systems, to prevent element damage, or to minimize vertical or horizontal irregularities.

Strategies for Developing Rehabilitation schemes
Consider the Technical Aspects
A retrofit designer's initial review should focus on the issues found during the examination. Certain frequent seismic defects are extremely localized and can be effectively remedied by targeting retrofit efforts narrowly. It is quite usual to add strength or stiffness, and a few new pieces may resolve issues with strength, drift, and configuration.
Review that the revised structure will (FEMA 547, 2006):
Possess a comprehensive load path
Possess the necessary strength and rigidity to conform to the design standard

Compatibility with and protection of the current lateral and gravity systems
Have a suitable foundation to support a permanent base structure, or have considered foundation flexibility appropriately in the design

Considerations of a Non-Technical Nature
The retrofit option is nearly typically guided by building-user concerns rather than purely technical requirements. Five fundamental challenges [108] concern building owners and users:
Cost of construction
Performance during earthquakes
Disruption of occupants in the short term
The building's long-term usefulness
Aesthetics, taking historic preservation into account
Structural weakening as a result of dynamic loads, foundation sinking, planar and off-plan deformations of the wall, can lead unreinforced masonry structures to collapse. Unreinforced masonry buildings are in the future dangerous structures for human life due to the fragile nature of their structural elements, therefore their level of performance must be determined (figure 2-20). Different countries organizations dealing with these problems like Federal Emergency Management Agency (FEMA) in USA, which define the damage to unreinforced masonry structures during an earthquake.

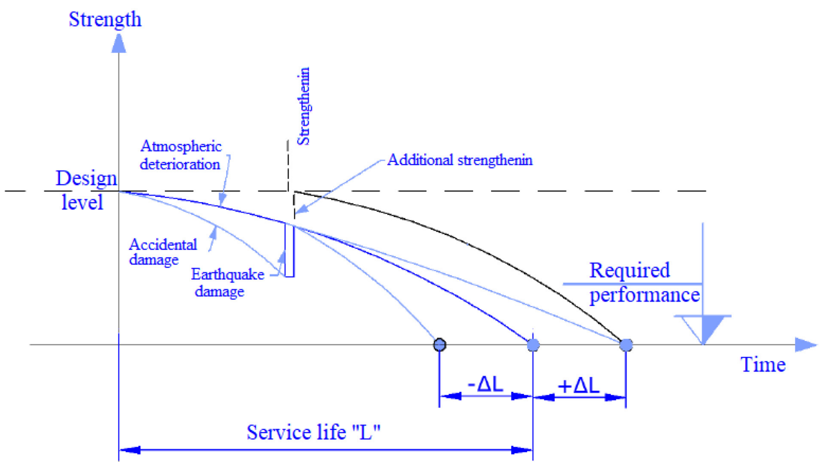


Figure 2-20 Level of performance of structures (Source: Guri, 2016)

Strengthening of masonry with structural elements in critical parts
There is a wide variety of intervention techniques for strengthening and repair of masonry structures, which have suffered damage due to degradation, overload, basement sinking, change of temperatures, natural disasters such as wind, earthquake, etc. These techniques are divided into "traditional" and "modern". "Traditional" techniques use materials and construction processes that are originally used for structure construction, while modern techniques aim more efficient solutions using new materials and technologies.
Here are some of the most commonly used reinforcement techniques (Biondi, 2014):
“Traditional”
o Demolish-rebuild intervention.
o Placement of concrete belts.
o Installation of steel tie rods.
o Reinforced injections.
o Reinforcement of openings with metal profiles in the form of boxes.
o CAM systems etc.

“Modern”
o Reinforcement with composite materials FRP (Fiber reinforced polymer),
o Reinforcement with composite materials TRM (Textile-Reinforced-Mortar)

Fiber-reinforced composites (FRCs) have been used as building materials for more than 3000 years, according to historical records. The use of straw in clay bricks is one of the most well-known examples. Other natural fibers are used to reinforce the walls of mud in order to increase the strength and ductility of building materials. Combination of polymers as high strength materials but with low stiffness with the fiber of high stiffness and high strength, has made possible their use in a large number of applications to increase and improve the structural performance.
These include uses in high carbon fiber technologies in resin systems (CFRP) for aircraft parts and sporting goods or Fiberglass Reinforced Glass (GFRP) systems for car parts and boat gear (Guri, 2016).
In civil engineering it has been an ever-increasing use of composites FRP for rehabilitation and reinforcement of reinforced concrete, metal elements and wooden, etc.
The purpose of their use in the structure is to increase:
o Compression & tension capacity
o Shear capacity
o Bending capacity
o Stability of the elements
o Ductility
o Stiffness
o Durability of constructive materials
o Lifespan of the structure

Their application is also done on these purposes (Guri, 2016):
1. Changing non-structural elements into structural elements.
2. Eliminate structural problems, which are the result of excessive stresses on of structure that can be caused by overload, fire, foundation sinking, corrosion phenomena, effects of fatigue, chemical actions, agents atmospheric etc.
3. Allow feasibility in changing the function of a structure.
4. To correct possible errors in the design and construction of the structure.
5. Improve environmental conditions, which have not been properly understood during design phase.

Installation of reinforcing concrete or metal elements

To strengthen masonry objects must be well understood the way of their collapse under the action of seismic loads. Structural damages very often are not identified as such, and light repairs have been undertaken, which hide obvious damages. Therefore, the repair strategy should include design for the current situation and structural requirements in order to achieve an acceptable level for structure safety. To analyze the causes that favor damage to a building without antiseismic masonry belt during seismic action, we study a section of it (figure 2-21). It is composed of two systems orthogonal walls A and B. In those buildings where, for reasons of poor implementation and lack of antiseismic bands, the connection between the structural walls is weak, and the behavior of the walls is different. Thus, in the first sequences of seismic events, the wall of one direction always tries to push the wall of the perpendicular direction to it. For these reasons it becomes inevitable their detachment in the contact area, by causing the development of vertical cracks in any of the corners of the wall or near the bottom, as the tensile strength from bending outside the plane is insufficient (figure 2-21a).
In these conditions the walls on which the seismic force acts perpendicular to their plan (walls A), will swing independently of the other perpendicular walls to them (walls B). In these cases, the walls resist the inertia force, mainly by their bearing capacity in bending. Walls subject to seismic forces according to their plan have a greater resistance, because also the stiffness to this direction is larger, (the mode of damage will depend on their geometric dimensions, height to width ratio and physic-mechanical characteristics of construction materials). A typical damage is horizontal cracking that spreads along the mortar joint as a result of horizontal sliding (figure 2-21a).

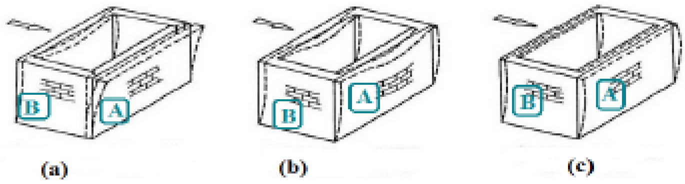


Figure 2-21 Typical damages: a) without antiseismic bands and flexible slab; b) with antiseismic bands and flexible slab; c) with antiseismic bands and rigid slab (Source: Guri, 2016)

It is known that one of the essential requirements in antiseismic design, is that the intersection slab must act as a rigid horizontal diaphragm, well connected to the vertical supporting elements (figure 2-21c).

Effects of antiseismic band on masonry objects

We will analyze these structures again by referring to a section element of the building, consisting of perpendicular faces well connected between them, in the present conditions of a rigid slab or antiseismic belt (figure 2-22).

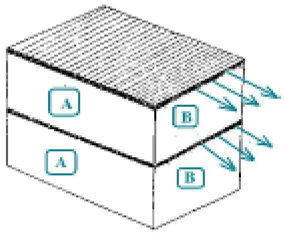


Figure 2-22 Seismic action to a section of the building with a rigid slab or antiseismic belt (Source: Guri, 2016)

As can be easily distinguished, the walls A are the ones that will withstand mainly horizontal seismic forces, which represent:

The masses of the respective slabs which are transmitted to walls A through the connections that exist between them and concrete bands.

o Loads of walls B transmitted to walls A.

o The mass of the walls A and B located in the upper and lower half and of the story that we are studying.

The presence of r.c. belts at the interstory level, makes the walls vibrations to be synchronized. However, it should be noted that even in this case it still exists the possibility of bending outside the plane of the walls, which is associated with the reduction of resistance of the structure as a whole.

Installation of concrete bands

This intervention is performed through the adding of a structural element that will act as s concrete belt. It can be realized at floor levels or on top of building.

It can be applied in those cases when efficient connections between walls or between walls and horizontal floor / roof structures are missing. It encourages the behavior or concept "box" by creating a continuous link between structural elements (walls, floor-walls, wall-roof). When applied in the upper part e of structure, it limits the bending of the walls outside of his plan.

Improving "box" behavior is difficult to measure with numbers. Intervention, if well implemented, enables the prevention of local collapse mechanisms. If performed at the top of the structure reduces the length of the free refraction of the upper part of the wall faces.

Surface Treatment

Surface treatment is highly regarded due to the fact that it may be carried out by untrained laborers. The method begins with the exterior of the structure being covered with a steel or polymer mesh that has been coated with a layer of high-strength mortar. This strategy boosts the out-of-plane resistance

of masonry structures by increasing the height-to-thickness ratio of the walls, hence reducing any arching movement (Smith & Redman, 2009).
This procedure involves a variety of strategies:
(1) Reinforced mortar
(2) ferrocement,
(3) reinforced plaster, and
(4) shotcrete.

Reinforced mortar is realized by placing a metal mesh in the surface of the wall which is then filled with mortar. Instead of wire mesh, can be used another high resistance material with adhesion which is bonded to the masonry via steel straps (5 every 4m2 wall surface).
It is the right intervention for walls in advanced degradation condition (when we have complex and widespread cracking) and in cases where it is required a significant increase in resistance.
It increases resistance and ductility without modifying of the wall, reduces cost and has easy execution. The intervention also presents disadvantages: modification of rigidity, increase in mass; change in the external appearance of the wall.
The efficiency of the intervention is closely related to the capacity of the transverse connectors for transmitted forces. It is not advisable to apply only to one side of the wall.

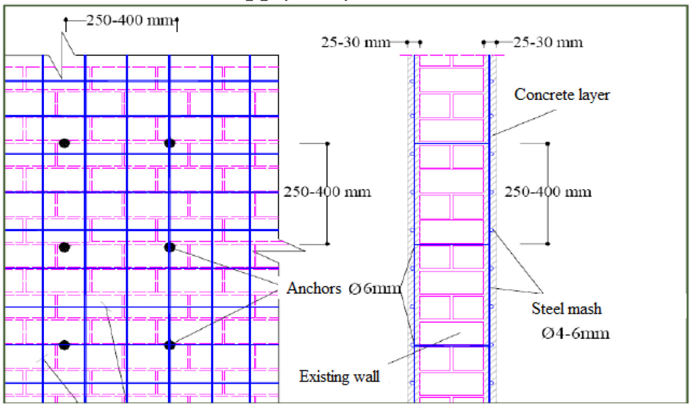


Figure 2-23 *Reinforced mortar (Source: Guri, 2016)*

This intervention involves insertion with pressure in the composition joints, depending on the state of wall degradation, in the existing openings in order to improve the mechanical characteristics of the wall. It can be applied in the presence of widespread cracks and for walls with internal voids and good mechanical properties of aggregates (although damaged).
It is a "passive" intervention that guarantees an increase in resistance and improvement of local damage without changing the balance and external appearance of the wall and improves the mechanical characteristics of the wall.
The effectiveness of the intervention is closely related to its ability to spread the mixing. It is nevertheless important to conduct mechanical tests on the existing wall in site to check if the material reached the required values of design resistance. An easy and fast control can be achieved through ultrasonic tests.

Ferrocement is a type of concrete composed of wire mesh and cement mortar. It may be reinforced with mesh totally embedded in a high-strength cement mortar at a ratio of 4–9%, as seen in Fig. 2-24(a). The fundamental downside of ferrocement is that the reinforcing materials corrode due to the mortar's insufficient covering of the metal. Additionally, tying the wire meshes and rods together takes time.
Another popular way for strengthening URM constructions is *reinforced plaster*, which includes covering the walls with RC layers. This procedure begins with the placement of a mesh of reinforcing bars on the wall's faces and the subsequent layering of reinforced faces with concrete (Fig. 2-24(b)).
Finally, *shotcrete* is a method that includes shooting cement mortar or cement concrete onto the masonry surface using a nozzle. Impinged shotcrete forms a uniform pile on the wall. The injured

member's surface and the shotcrete layer are glued together using an appropriate epoxy adhesive. Shear keys are used to ensure shear transfer between the old and new concrete layers. The addition of fibres increases the tensile strength and toughness of the material. Fig. 2-24(c) illustrates the process schematically.

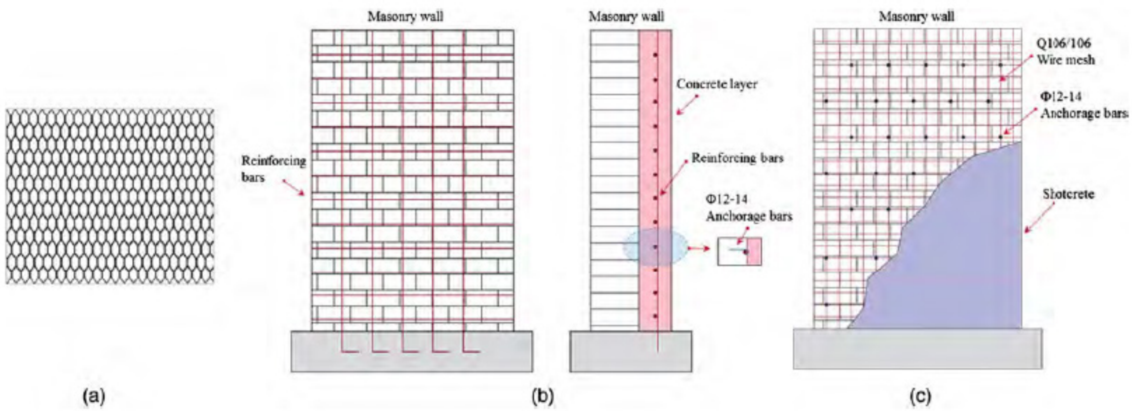


Figure 2-24 *Techniques for surface treatment include the following: (a) ferrocement; (b) reinforced plaster; and (c) shotcrete.*

Reinforcement of masonry with FRP composite materials

Advanced composites are used as reinforcing materials of masonry structures from several decades, in the form of laminates, mesh and strips. These reinforcements of masonry structures increase their bearing capacity in bending as well in and out of the plane, against the seismic loads.

One of the main drawbacks associated with the adaptation of structural elements is the choice of FRP configuration as well as the dimensioning of their elements (FRP cross section) for obtaining the required resistance (CNR (Commissione Nazionale Delle Ricerche), 2013).

Masonry structures are very common and built-in different time periods, they need strengthen interventions because they accumulate technical problems and present difficulties for their utilization. Their technical problems associated with inappropriate materials and techniques, the action of seismic and wind loads, basement sinking and atmospheric conditions, or the need to increase bearing capacity responding to the demands of new seismic codes, or their change in function. "Traditional" methods of improving masonry structures are mentioned above.

Of course there are disadvantages with some of the above mentioned techniques like: increasing thickness and mass from coating with reinforced concrete layer, difficulty in their implementation work, have made researchers study technology with modern material; using as reinforcement the polymer fibers, commonly known as FRP (Reinforced Polymer Fiber). These typical materials are made of carbon fiber (CFRP), glass (GFRP) or aramid (AFRP) joined by polymer matrix (epoxy), which are produced and combined for a variety of properties (Hollaway & Teng, 2012).

- *Polymer Fiber Reinforcement (FRP) Materials*

Some definitions have been made for the meaning of advanced composites polymers. A clear essential definition of their meaning is given in 1989 by a study of the group of the Institution of Structural Engineers, who defined an advanced polymer composite for construction industry as follows:

"Composite materials normally consist of two discrete phases, a matrix of continuous which is often resin, surrounding a reinforcing fibrous element. Reinforcement has high strength and stiffness, as the matrix binds the fibers together, allowing the strain to be transferred from one thread to another by produced a consolidated element. The orientation of the fibers is to safely withstood high mechanical stresses. In the anisotropic nature of these materials lies their great advantage; the reinforcement can be adapted and oriented to follow the stress patterns in the main element, which makes a more economical compared design than the design with traditional isotropic materials. Reinforcements are usually glass fiber, carbon or aramid. Resins which must carry distinctive

properties such as chemical or thermal resistance" (CNR (Commissione Nazionale Delle Ricerche), 2013).
Structural composite polymers have a wide range of mechanical properties.
These properties depend on:
o the relative proportions of fibrous materials and matrix (volume / weight ratio of fiber / matrix)
o mechanical properties of components (a set of carbon fibers will give greater rigidity than a set of glass fibers in the same amount)
o production method
o fibrous orientation within the polymer matrix (fiber orientation can take shape without one direction, in two directions and randomly oriented fiber groups)
Use of FRP system in masonry structures is normally part of the global structural interventions. The basic role of the FRP system is the transfer of tensile stresses both within a structural element and between structural elements. The new greater tensile strength modifies the reaction of the structure to external loads.
In particular, the FRP system in the masonry structure can be used in:
o Increasing the bearing capacity and durability of the walls.
o Transformation of structural elements into supporting elements by increasing strength.
o Restricting in the opening of cracks.
o Wrapping columns to increase their strength and ductility.

- *Physical-mechanical characteristics of FRP*

The data on physical-mechanical properties of reinforcing materials in this study are obtained from the experience of working in groups of twelve laboratories from European universities with RILEM, Technical Committee 223-MSC "Masonry Strengthening with Composite materials". Below (table 2-8 and 2-9) we give a summary study test results for GFRP (Glass Fiber Reinforced Polymer) and CFRP (Carbon Fiber Reinforced Polymer) (Valluzzi, 2012).

Table 2-8 Mechanical properties of primer, resin and fibre from tension test (Source: Valluzzi, 2012)

Material	Nr. of test	Tensile strength (N/mm^2)	Young's modul (N/mm^2)	Deflection
PRIMER	9	52.6 (7%)	2176 (8%)	3.59 (10%)
SATURAN HM	9	32.7 (8%)	1308 (10%)	3.77 (6%)
SATURAN HMT	9	32.9 (8%)	1605 (5%)	3.13 (5%)
GLASS UNIDIR 300HT73(GFRP)	21	1310 (13%)	84251 (10%)	1.69 (15%)
BASALT UNIDIR 400 C95 (BFRP)	21	1673 (11%)	88397 (4%)	1.96 (12%)
CARBON UNIDIR 320 HT240(CFRP)	21	2735 (10%)	233861 (5%)	1.26 (11%)
STEEL 3X2-B 12-12-500	18	2997 (7%)	195054 (5%)	1.74 (14%)

Table 2-9 Physical-mechanical characteristics of fibre (Source: Valluzzi, 2012)

Material	Elastic modulus (Gpa)	Tensile strength (Mpa)	Deflection (%)
Carbon (CFRP)			
High resistance	215-235	3500-4800	1.4-2.0
Very high resistance	215-235	3500-6000	1.5-2.3
high elasticity	350-500	2500-3100	0.5-0.9
Very high elasticity	500-700	2100-2400	0.2-0.4
Glass (GFRP)			
E	70	1900-3000	3.0-4.5
S	85-90	3500-4800	4.5-5.5
Aramid (AFRP)			
Low elasticity	70-80	3500-4100	4.3-5.0
High elasticity	115-130	3500-4000	2.5-3.5

- *Matrix*

The matrix, by its shear strength, must allow conduction and distribution of stresses in fibers. It protects the fibers from physical - chemical attacks, that come from the environment. Also, it connects the fibers to each other, opposing disintegration of the fibers. The matrix (bonding material) can consist of polymers, metals, ceramic materials. Polymer matrices are more spreads, because they have high tensile strength, high resistance to corrosion, low weight, are simple in realization. In their initial unmixed state, these matrices have low viscosity, facilitate the process of manipulating them. They have very good bonding properties and good resistance to atmospheric agents. The downsides of these resins are sensitivity to ambient temperatures and sensitivity to moisture in the phase of preparation. In the study we will refer only to polymer matrices. Depending on the type of fiber used FRP are divided into (CNR (Commissione Nazionale Delle Ricerche), 2013):
GFRP (Glass Fiber Reinforced Polymers), with fiberglass; CFRP (Carbon Fiber Reinforced Polymers) with carbon fiber; AFRP (Aramid Fiber Reinforced Polymers), or ARP (Aramide Reinforced Polymers) with aramid fibers etc.

- *Adhesive material*

Preparing a FRP reinforcement requires the use of adhesives. The choice of the right type of adhesive, as well as the surface treatment where the FRP will be placed, depends mostly from the type of FRP as well as from the element where they will be placed (e.g., reinforced concrete, metal, masonry, etc.). The FRP technical files also contain the type of adhesive material that is recommended to be used. The market offers several types of materials adhesives with different chemical bases, such as polyester, acrylic, etc. Epoxy resins have better properties than other adhesives. Epoxy resins used as adhesives have these disadvantages: are sensitive to environmental conditions (temperature, humidity, etc.) and are sensitive to fire.

- *FRP reinforcement systems*

The reinforcement design should aim at absorbing stresses in tension in the FRP system. The FRP system that is subject to compressive stresses does not have direct impact on the masonry structure as their cross-sectoral area is negligible compared to that of a structural element.
Structural modeling of a masonry structure is a complex job. Distribution of forces and moments within a structure or the distribution of stresses in a single element of the masonry structure can be calculated by linear elastic analysis or by nonlinear analysis for the inelastic behavior of the masonry material.
All available types of FRP materials can be used for reinforcing the masonry structure. However, it is generally believed that fiberglass polymers are more preferred than other types of FRPs in strengthening masonry, not only because of their low cost but also of the small module of elasticity,

which connects it to the masonry and prevents premature detachment of reinforcement after small critical cracks in the masonry (Hollaway & Teng, 2008).
FRP can be used for masonry reinforcement in different systems (figure 2-25):
o FRP laminate system: carbon (CFRP); aramid (AFRP); glass (GFRP).
o FRP mesh system: glass (GFRP); aramid (AFRP); carbon (CFRP).
o FRP rod system, NSM (Near Surface Masonry) reinforcement: glass (GFRP); aramid (AFRP); carbon (CFRP).
o Global reinforcement system: carbon (CFRP); aramid (AFRP); glass (GFRP).

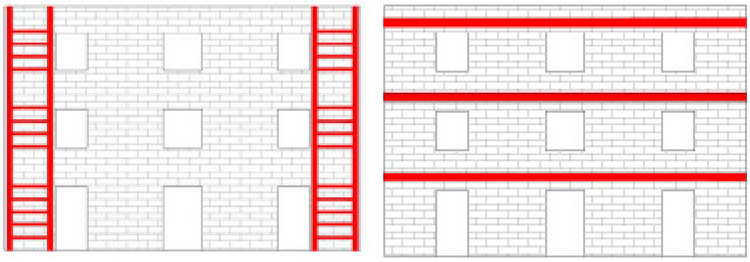


Figure 2-25 *FRP system application for masonry reinforcement (Source: CNR, 2012)*

- *Reinforcement with TRM (Textile-Reinforced Mortar)*

The application of external reinforcement with TRM is considered as an alternative method of FRP (Fiber-Reinforced Polymers). This alternative method, called TRM (Textile-Reinforced Mortar), consists of a FRP mesh attached to the inorganic matrix masonry, cement mortar (Papanicolaou, Triantafillou, Karlos, & Papathanasiou, 2007).
This technique combines the good sides of both interventions ("traditional" and "Modern") through the use of textiles in the form of knitted fibers (mesh), glued to the surface of the structure with cement- mortar replacing the organic adhesive (resins), which are very expensive compared to cement-mortar. Use of an inorganic material as adhesive instead of an organic adhesive, eliminates its disadvantages such as: low properties at high temperatures, high cost, difficulty painting the masonry surface, lack of recycling.

TRM (Textile-Reinforced Mortar) materials

Textile-reinforced mortar consists mainly of from two materials: (1) cement mortar adhesive and (2) textile mesh produced with FRP reinforcing fiber. The success of reinforcing and adapting the structure by using TRM, depends on the properties of these two components of TRM (Papanicolaou, Triantafillou, Karlos, & Papathanasiou, 2007).

Physical-mechanical characteristics of TRM

Data on the physical-mechanical properties of reinforcing materials with TRM for our study are taken from the study of Papanicolau C. (Papanicolaou C. , 2010) and laboratory tests performed e University of Patras, Greece. The most commonly used fibers and physico-mechanical properties for TRM fabrication are given in table 2-10 and 2-11 (Papanicolaou C. , 2010).

Table 2-10 Physico-mechanical characteristics of TRM (Source: Papanicolau, 2010)

Specification	Carbon fiber	Fiber E- glass coated with bitumen	Basalt fiber	Polypropylene mesh
Grid distance G.S	10 mm	25 mm	26 mm	27 mm
Grid width N.G.S.	6 mm	23 mm	24 mm	16 mm
Weight W	168 g/m2	290 g/m2	192 g/m2	265 g/m2
The thickness of the textile t	0,047 mm	0.47 mm	0.07 mm	1,14 mm
Tensile strength ft	157 kN/m	54 kN/m	66 kN/m	10 kN/m
Deflection	1.50%	2.90%	3.15%	5.00%
Elastic modulus Ef	225 Gpa	70 Gpa	89 Gpa	2 Gpa

Table 2-11 Result of test in compression and tension for mortar (Source: Papanicolau, 2010)

	Samples					
Physical properties (Mpa)	Age of the cube (days)	1	2	3	4	average
Compressive strength	7	37.32	34.04	35.88	36.4	35.91
	28	51.5	52.1	50.9	54.1	52.2
	3	2.4	2.1	2.4	2.3	2.3
Tensile strength	7	2.8	2.9	3.8	3.7	3.16
	28	4.46	4.3	4.33	4.51	4.4

TRM reinforcement systems

TRM can be used for masonry reinforcement in the same way as FRP, replacing organic adhesive with inorganic adhesive (cement mortar):

o FRP laminate system: carbon fiber mesh (CFRP); aramid (AFRP); GLASS (GFRP).

o FRP rod system, NSM (Near Surface Masonry) reinforcement: glass rod (GFRP); aramid (AFRP); carbon (CFRP).

o System against the mechanism of global destruction: wrapping the structure with carbon mesh (CFRP); aramid (AFRP); glass (GFRP) etc.

Figure 2-26 provides an overview of the TRM reinforcement procedure.

Figure 2-26 Practical application of TRM method (Source: Papanicolau, 2010)

2.4.3. Possibilities of integrated retrofit

To make seismic plus energy retrofit economically viable, unique solutions based on sophisticated material and system combinations must be developed. As a result, new research should advance many steps further than the present state and address how seismic and energy retrofit technologies might be coupled to provide an integrated retrofit solution. Achieving this goal will require a multidisciplinary and cross-sectoral approach, combining skills in structural engineering, building physics, and sophisticated production techniques for composite materials, for instance

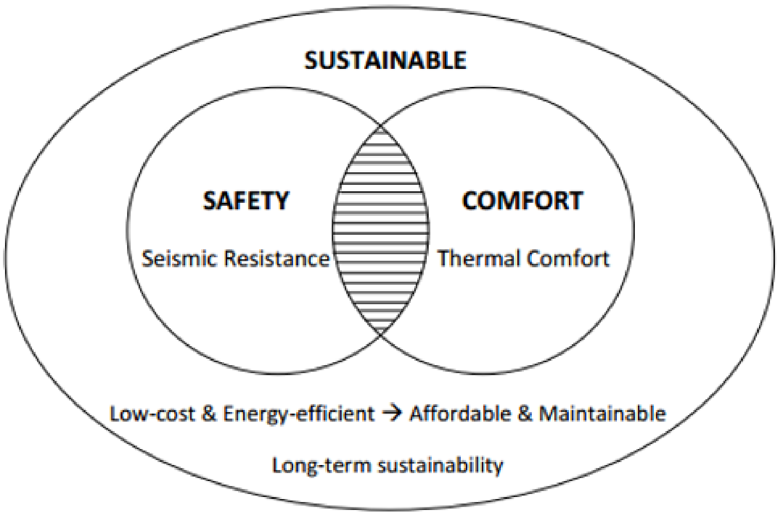


Figure 2-27 Interaction between safety and comfort

As illustrated in the diagram, seismic provisions and thermal comfort are taken into account when determining safety and comfort. The combination of these two factors, along with an extra component of sustainability (shown by the shaded region), results in economical and durable housing systems that are both safe and comfortable, thanks to the low cost and energy-efficient nature of the proposed solutions.

The simultaneous energy and seismic retrofit notion is explored by taking into account materials that address each of these considerations while developing the retrofit strategy for the walls, specifically TRM jacketing combined with thermal insulation or energy retrofit alternatives on building external walls, in which mortars are used to connect the applied external reinforcement or insulation material to the masonry surfaces. The integrated retrofit enables the achievement of both essential safety and energy performance with a standalone treatment, lowering the overall cost significantly through labor savings.

Till lately, seismic and energy retrofitting were viewed as two distinct and unrelated upgrade schemes that might be applied to a structure at different times, and hence their interconnectedness was always assumed (Calvi, Sousa, & Ruggeri, 2016), (Belleri & A, 2016). This interdependence, though, does occur, as a possibly high seismic risk can have an effect on an existing building's environmental impact (Belleri & A, 2016). simply put, a structure that simply receives energy upgrades will always be susceptible to structural damage if it is located in an area prone to earthquakes. If an earthquake were to occur in that case, the structure would sustain damage that, depending on its magnitude, may result in collapse and the loss of lives. Even small to moderate earthquakes, however, have the potential to harm the thermally insulating materials placed to the building's exterior, jeopardizing the funds invested in the building's energy retrofit. But at the other side, a structure which has been retrofitted solely for seismic reasons will be structurally sound in the future, but will continue to consume substantial quantities of energy to compensate for intrinsic heat losses caused by the structure's older construction practices.

A solution to all of the above-mentioned issues is to stop thinking of the two sorts of upgrading as distinct, but rather as inextricably linked. This means that both should be used concurrently, resulting in seismically and energy-efficient buildings. Naturally, such an integrated method will necessitate a greater initial financial expenditure, which may be unaffordable economically. However, when one considers the cheaper construction costs (in comparison to those associated with performing the identical upgrades separately), as a result of reduced labor and scaffolding expenses, combined retrofitting is a feasible course of action to take, as demonstrated in this research.

More precisely, a building that has only received an energy update would constantly be susceptible to structural failure if it is placed in an area prone to earthquakes. In that circumstance, if an earthquake occurs, the structure will sustain damage that, based on its degree of magnitude, may result in its collapse, threatening the lives of its occupants and effectively destroying the initial investment. On the other hand, a facility which has been renovated simply for seismic reasons will always be potential in case of structural performance, but will still lose a large level of energy compensating for fundamental heat losses produced by outdated construction techniques.

The apparent solution to all of the aforementioned issues is to cease thinking of the two sorts of upgrading as distinct, but rather as inextricably linked. This means that both should be applied concurrently, so that as a result, we end up with a structure that is both seismically and energy-efficient. resistant. Naturally, this integrated strategy requires a larger upfront expenditure, which may not be feasible in many circumstances. Although, when labor and scaffolding expenses are included, in addition to the financial benefits of performing the retrofits concurrently, it is actually the more rational choice to make, as will be explained in a further chapter. As a result, it is strongly advised that the government consider supporting retrofitting efforts up to a certain amount. Table 2-12 contains further discussion.

Table 2-12 Disadvantages and benefits of various retrofit strategies

Retrofitting scheme	Possible drawbacks	Possible benefits
Energy retrofitting	Investment is lost and life-safety is compromised when destructive earthquakes occur (for seismic areas)	Energy efficient buildings
Seismic retrofitting	Running energy costs remain high, especially in harsher climates	Safe building in seismic areas
Seismic and Energy Retrofitting independently applied	Higher initial investment is needed, which might not be available	Both life safety and energy efficiency are provided
Integrated/Combined Energy and Seismic	Overall cost could be reduced	Both life safety and energy efficiency are provided

The proposed approach for performing structural and energy retrofits simultaneously in a building envelope is illustrated in Figure 2-28 for unreinforced masonry structures. This method combines high-strength lightweight reinforcement for seismic retrofitting (of structural and non-structural parts), while also incorporating an extra insulating material or heating system for energy retrofitting. The reinforcement is bonded to the external walls using an inorganic cement-based mortar to ensure the hybrid retrofitting system's durability and fire resistance. The intervention concept is similar to that of existing seismic retrofit methods, in that externally applied reinforcement, insulation material, or energy heating systems are bonded to concrete or masonry surfaces using inorganic mortars. This enables the achievement of both needed safety and energy performance with a single intervention, while keeping the overall cost low due to the considerable reduction in operating expenses

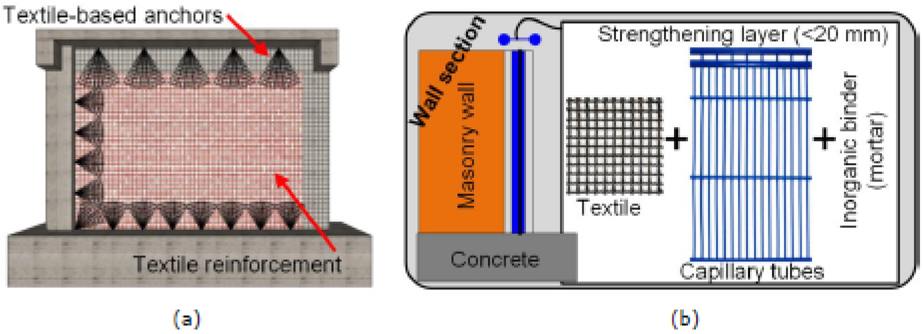


Figure 2-28 (a) Configuration for seismic reinforcement; (b) Textile reinforcement and capillary tubes will be incorporated and embedded in a thin mortar coating (Source: Bournas, 2018)

The combination of various insulation materials into the textile reinforcement may result in a variety of mixed retrofit solutions, such as TRM+PUR, TRM+VIP, TRM+NIM, TRM in a matrix incorporating PCM, or TRM + heating system, as seen in Figure 2-28b. The strengthening technique begins with the seismic reinforcement of the masonry with TRM, followed by the addition of the thermal insulation material while the mortar is still fresh. This reinforcing process is similar to External Thermal Insulation Composite Systems (ETICS, figure 2-29), that also reflect a new solution for building restoration aimed at improving indoor acoustic and thermal conditions, but it demands first bonding high strength textile fibers (i.e. carbon, glass, or aramid) to the unreinforced masonry to provide the required seismic upgrading.

Figure 2-29 Composite External Thermal Insulation Systems (Source: Bournas, 2018)

Recently, Triantafillou et al. 2017 (Triantafillou, Karlos, Kefalou, & Argyropoulou, 2017), proposed a new solution for structural and energy retrofitting of masonry walls that combines polymer-coated glass fiber textile with expanding polystyrene (EPS), finding that TRM jacketing can be efficiently integrated with thermal insulation.

Another possibility is to suggest an effective "integrated" strategy for promoting the long-term renewal of the enormous masonry building stock. External "integrated" double casings are proposed and planned to improve the energy efficiency, architectural and urban environment quality, and stability of the structure (figure 2-30). Exterior structural and technological double casing techniques are investigated (Feroldi, et al., 2013), with a particular emphasis on meeting basic standards for environmental effect and rehabilitation costs.

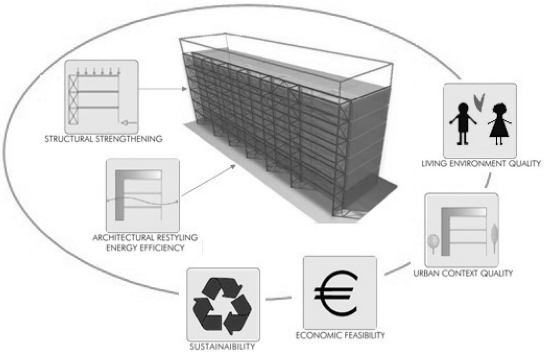


Figure 2-30 An external "integrated" adaptive-engineered double skin façade system intended to provide simultaneous architectural renovation, energy efficiency improvement, and structural performance upgrading while minimizing environmental effect, rehabilitation costs, and resident impairment. (Source: *Feroldi.F et al. 2013)*

The term "dual skin façade solutions" refers to those that were formerly employed for the sole purpose combining energy efficiency upgrades and architectural renewal. "The double skin" solution is envisioned here as a double-valued "exoskeleton": on the one hand, the structure provides seismic strength that is required for existing buildings and its dry installation eliminates the need for lengthy phases of construction; alternatively, the external solution ensures minimal effect on residents during the repair of a structure and provides for future functional and aesthetic modifications. Dependent on urban planning constraints, the "engineered double skin" can be attached to the existing structure or expanded on one side, so generating additional living spaces, balconies, and solar greenhouses. The approach may even enable the construction of new stories, the profits from which might partially offset the expense of the upgrading. This novel technique is presented as a paradigmatic solution that is easily adaptable to various geographical, climatic, and urban situations, as well as to various seismic intensity levels. To identify common building flaws and requalification requirements, it is important to conduct a typological examination of the architectural, energetic, structural, and urban quality characteristics. Illustrations are shown in the figures below.

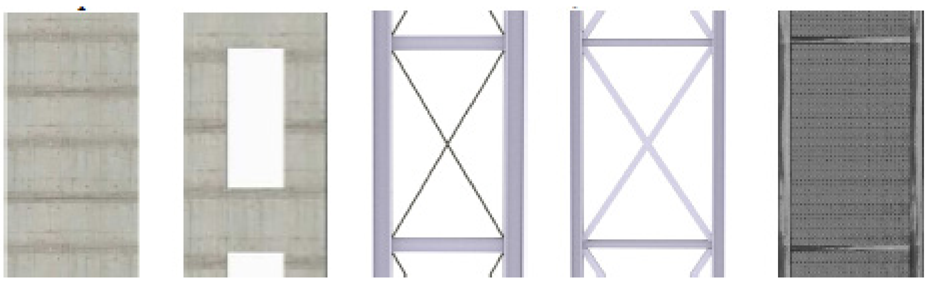


Figure 2-31 *Numerous forms of earthquake-resistant constructions* (Source: *Feroldi.F et al. 2013)*

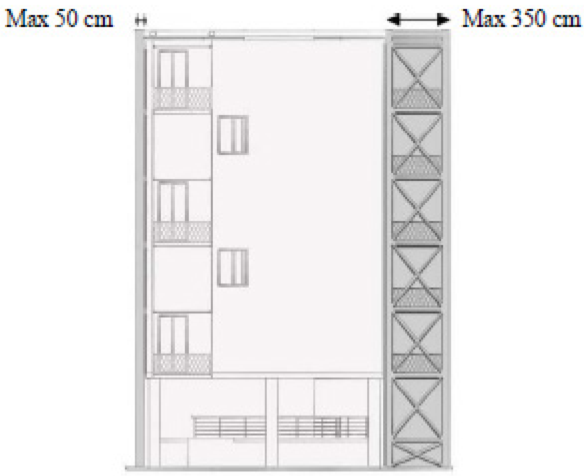


Figure 2-32 Expanding the current structure just on one side, while adhering a second skin to the existing structure on the other (left side). (Source: *Feroldi.F et al. 2013)*

2.5. Albanian existing building stock

Historical background

Today's buildings in Albania, in almost over half of them were built in the years 1945 -1990 (INSTAT, 2014). These buildings, which are designed to a different standard from today, really have problems, especially in relation to energy performance and comfort conditions. The apartment stock today, for the most part, does not meet the modern construction criteria for quality of life. An important role is played by the part of the stock that has been built by the state, in emergency conditions, for the solution of housing problems during the period 1945-1990. In this period, the priority was to build quickly and at a low cost to enable housing and to solve the problem from a quantitative point of view. It is these buildings that today are the real problem for living standards as well as for the impact they have on the health of their residents. Today, the problem is a problem where in 22% of the apartments the heating is insufficient, in 13% the presence of moisture appears and in about 10% they have doors and windows in bad conditions (INSTAT, 2014). Among other things, the problems in housing conditions are related to the economic situation of the residents, but the main factor that affects the quality of life are the buildings themselves, their construction technology and depreciation. Although housing energy consumption is lower than the European average (26.28%), this figure does not refer at all to the conditions of buildings and their energy performance.

The fact that in Albania the construction policy has proceeded according to the conditions and policies conditioned as well as the quantitative tendency to enable housing or often times copied in construction standards from other former communist countries has created major problems in the stock created for this period, so 1945-1990. After the privatization of housing in the early 1990s, maintenance and care has been the responsibility of residents, and for a period of almost 30 years, interventions have been only at the individual level and mainly at the interior of the apartment. Today, these dwellings are characterized by a lack of comfort conditions and large heat losses, parameters which are directly related to the quality of life and health of residents. The problem is that residents living in them generally have average and low incomes and cannot afford high energy payments and large investments to renovate buildings. Also, co-owners' assemblies are not functional and important decisions in these buildings are quite difficult. Faced with this situation, there are two scenarios for improving this situation: demolition and reconstruction or interventions for their renewal and energy rehabilitation. The scenario of demolition and reconstruction of buildings, of course, has higher costs and is accompanied by a complex mechanism where the state has an active and coordinating role in partnership with homeowners and potential investors. The main condition that would impose this scenario would be the problems of building sustainability and the risk to the lives of residents. Considering that the age of the apartments is mostly 25-35 years old, and that no high-risk sustainability problems have been identified and assessing the economic capacities of the residents but also of the limited state, the most realistic alternative would be intervention, for the renovation

and energy rehabilitation of buildings. In this context, rehabilitation interventions are the most appropriate solution to the problem of housing quality and energy performance in buildings with prefabricated panels. If these interventions come integrated with structural reinforcements, the efficiency of the intervention increases, bringing about an energy and structural rehabilitation, improving the performance of the building and increasing its lifespan.
In this study we will focus only on the energy aspect by neglecting the possible structural problems that such buildings may have. Since the interventions for energy rehabilitation are directly related to the climate, the context that will be studied is limited to the city of Tirana, where the largest number of dwellings are located.

2.5.1. Energy efficiency evaluation

Albanian legislative on Energy Efficiency

Albania, as a signatory to the Energy Community Treaty, is required to transpose and implement the EU Directive 2009/28/EC "On the promotion of renewable energy consumption". The National Action Plan for Renewable Energy (PKVER) defines national objectives for renewable energy in the final total energy consumption of the country, as well as supportive actions to attain them. The Albanian government has also seen promoting renewable energy as a vital strategy for increasing energy security, economic development, energy sector sustainability, and environmental protection. Although Albania generates over 94% of its electricity from hydropower, it imports between 30% and 60% of its total primary energy supply. (INSTAT, 2014).
Renewable energy can help lessen this reliance on imports and strengthen not only the country's energy security, but also its macroeconomic and political security by reducing the country's budget deficit or reallocating major sums to other areas for the society's strategic growth.
The current legal framework regarding energy conservation and saving in buildings in Albania and in the field of energy as well as European ones is:
1. Decision No. 584, dated 02.11.2000 "On energy saving and heat storage in constructions";
2. Decision No. 38, dated 16.01.2003 "Norms, rules and conditions of design and construction, production and storage of heat in buildings";
3. Law no. 10 113, dated 09.04.2009 "On indicators of energy consumption and other resources, from equipment for domestic use, through labeling and information of product standards";
4. VKM No. 619, dated 07.09.2011, "On the approval of the national action plan for energy efficiency, 2011-2018 which provides for a 9% reduction in energy consumption among consumers";
5. Law No. 124/2015 "On Energy Efficiency";
6. Law No. 116/2016 "On Construction Energy Performance";
7. Law no. 7/2017 "On the promotion of energy use from renewable sources";

Importantly, the main goal lies in establishing norms and rules for heat storage in dwellings, public and private buildings, as well as controlling, identifying and managing energy consumption in them. So, in the design and construction of buildings to fulfill the technical parameters necessary for the storage, saving and efficient use of energy, all buildings built within the existing Albanian and European legal package must respect the normative thermal losses, as well as provide for the installation of thermal installation of central or local heating.
The decision to approve the Energy Code for Buildings in our country goes in the same direction regarding the European Directive 2002/91 / EC "On Energy Performance in Buildings".

The origin of the Albanian legislation regarding energy saving dates back to 2000, when the then government approved VKM No. 584, dated 02.11.2000 "On energy saving and heat storage in construction". According to this decision, all facilities that would be built for housing, as well as public or private constructions are obliged to place in the buildings local or individual central heating installations with energy sources of organic, solid, liquid and gaseous fuels. In no case should heating systems be provided with the use of electricity. In this framework, in order to create the legal basis necessary for the establishment of rules and making it mandatory to take measures for the preservation of heat in buildings, Law no. 8937, dated 12.09.2002 "On heat storage in buildings" which was later repealed by adopting another law that is in line with European directives for this purpose. According to this law, the design and construction of buildings had to be carried out

according to the technical parameters necessary for the efficient storage, saving and use of energy. This decision also determines the thermal insulation requirements and the measures to be taken to provide thermal insulation of buildings as well as to calculate the heat demand required for heating and cooling of public and private buildings.
Over the years, the implementation of heat storage laws and regulations in buildings has encountered a number of problems. Not only the mentality, the lack of experience, but also the way of conceiving as a second hand problem has made that, although in the projects designed for construction permits, the facilities have been equipped with central heating systems, in reality during the construction phase, the construction companies are satisfied only with the installation of distribution pipes, leaving it again unoccupied and in contradiction with VKM No. 584, dated 02.11.2000 "On energy saving and heat storage in construction". Therefore, the purpose of creating the legal framework is to make possible the design and implementation of a national policy to promote and improve the efficient use of energy, with the aim of increasing supply security, improving economic competitiveness, minimizing negative impacts on the environment and mitigating climate change. The legal framework also helps to promote efficiency and energy saving, improve the energy performance of buildings and develop a market for energy services.
In 2014, the first draft of the law on Energy Performance in Buildings was drafted and approved during 2016, which is Law No. 116/2016 "On Construction Energy Performance". This law aims to promote the rational use of energy, improve the energy efficiency of buildings, and inform the public about the level of energy consumption in buildings.

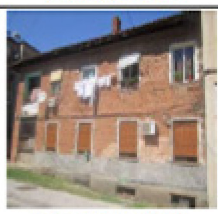
Residential sector:
The objectives in this strategic direction go in the framework of general housing policies and find application in the requirements of Article 40 of Law no. 10112, dated 09.04.2009 “On the administration of co-ownership in residential buildings” as well as the legal regulatory framework in force for energy efficiency, referring to the relevant interventions in order to reduce energy consumption through the realization of investments for energy efficiency.
The main and very important objective of these legal acts is the application of requirements for the renovation of existing buildings in co-ownership in order to:
• Awareness for the functioning of the assembly of co-owners according to the requirements of the law;
• Reducing energy losses;
• Increasing the value of the building;
• Improving living conditions and increasing real personal income;
Voluntary community participation throughout the project phases will ensure its sustainability.

The impact on Albanian buildings
The National Action Plan for Energy Efficiency 2011-2018 envisages a series of measures to reduce energy consumption in dwellings such as: thermal insulation of housing stock, recognition and use of central and local heating schemes, use of solar systems for water heating, sanitary, use of labeled electrical equipment and use of efficient lamps. Assessing the problem in the European context, Albania faces challenges that need to be addressed in the short term on the issue of energy performance in buildings. To this date (2021) these measures still remain in their infancy. It remains to be seen whether the effectiveness of the General Consumption Plan in housing will be achieved, while the result of the application of these measures may not exceed the growing need for energy.
As a candidate country for membership in the European Union, Albania must pursue a general European policy orientation by adapting legislation and other development orientation instruments.

Statistical data on the building stock, energy purposes
The construction typology was compiled based on the latest census data of 2011 (Simaku, 2017). The experts used the data made public by the statistical institution of Albania. As CENSUS was not conducted to collect specific data on the energy stock valuation of housing stock, some data are not available at the level of detail required by the study. For this reason, estimates from the extrapolation of data for the existing housing stock have been used.

It is estimated that the typology of construction consisting of 20 types of dwellings (Simaku, 2020), according to the following considerations:
- The classifications of construction are represented by statistical data: detached houses only with one wall, range houses, range houses with concrete slabs, and mansions.
- Construction period: structures are grouped into six distinct construction periods: pre-1960, 1961–1980, 1981–1990, 1991–2000, and 2001–2011.
- Building size: data are available only for the number of dwellings in a structure: a single-dwelling structure; a two-dwelling structure; a three- to four-flat structure; or a five- or more-dwelling structure; and
- Floors: apartments are classed as having one, two, three to five, or six or more floors.
Types of dwellings in Albania are presented in table 2-13 below:

Table 2-13 *Type of construction in Albania (Source: Simaku, 2014)*

	Dtch	Sem_Dtch	Row_Terr	Mult_Fam_Ap
A ... 1960	 Dtch_20-60	 Sem_Dtch_20-60	 Row_Terr_..60	 Mult_Fam_Ap..60
B 1961 1980	 Dtch_61-80	 Sem_Dtch_61-80	 Row_Terr_61-80	 Mult_Fam_Ap_61-80
C 1981 1990	 Dtch_81-90	 Sem_Dtch_81-90	 Row_Terr_81-90	 Mult_Fam_Ap_81-90
D 1991 2000	 Dtch_91-00	 Sem_Dtch_91-00	 Row_Terr_91-00	 Mult_Fam_Ap_91-00
E 2001 2011	 Dtch_01-11	 Sem_Dtch_01-11	 Row_Terr_01-11	 Mult_Fam_Ap_01-11

Stock of buildings

According to the 2011 census (INSTAT, 2011), Albania has a total of 598,267 residential properties for a populace of 2,837,356. (54.6 percent of the population lived in urban areas and 45.6 percent in rural areas). There were 1,013,522 residences, of which only 719,835 were inhabited. Private dwellings accounted for 732,242 of these.
The number of buildings and households for each form of development is shown in Table 2-14. Individual houses constructed between 1991 and 2000 (type D1) comprise the largest group, accounting for 109,672 structures. The apartments built between 1961 and 1980 and 1981–1990 are the other significant housing group.

Table 2-14 T*he share of buildings and dwellings for each period of construction (Source: INSTAT, 2011)*

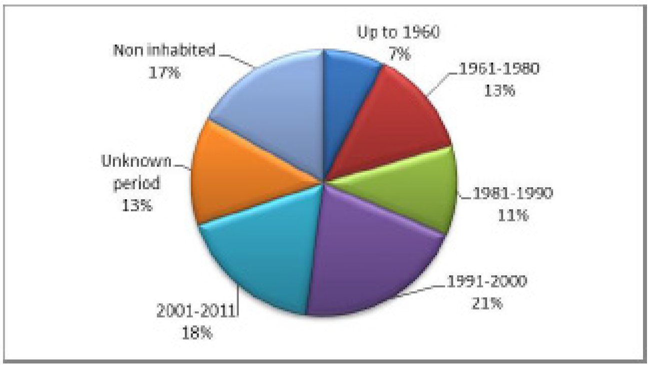
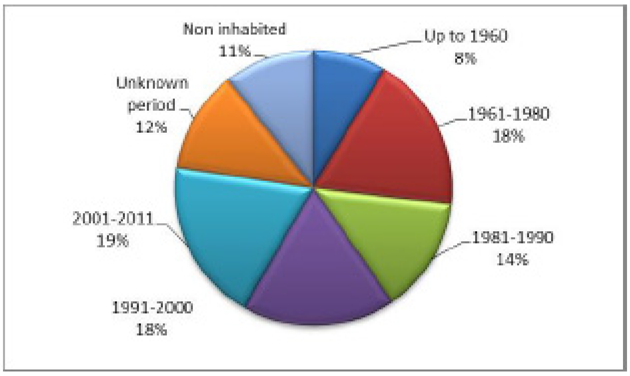


Table 2-15 T*he share of dwellings for each period of construction (only for buildings) (Source: INSTAT, 2011)*



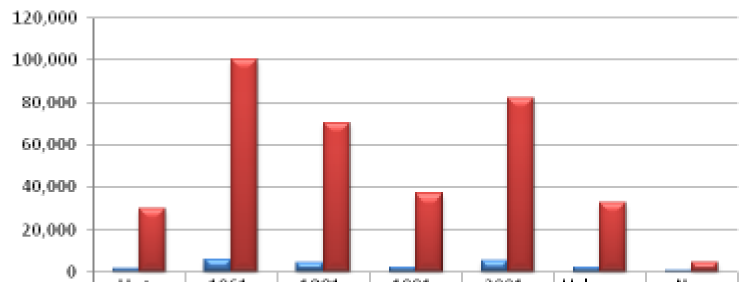
Apartments according to the type of building

Detached dwellings account for the lion's share of the building stock, accounting for 84.6 percent of all structures. Apartments account for only 4.8 percent of the housing stock, despite the fact that these multi-story structures contain a considerable number of households, accounting for 37% of all dwellings. Houses divided by a wall account for 10.5 percent of the total, whereas buildings in a row or with concrete soles account for a lower proportion.

Residence buildings classified by construction time

Prior to 1960, only 8% of the nation's building stock was constructed. Following World War II, and particularly after 1960, there was an expansion in the construction business, particularly for the creation of big structures housing several families. Between 1961 and 1990, 34% of buildings and 32% of homes were constructed (table 2-16). Following 1990, there was another development boom, this time geared toward single-family homes rather than apartment buildings.
After 2000, the number of buildings resumed its upward trend. The construction period is unknown for 13% of the building stock, as well as a large proportion of vacant structures (18 percent of buildings).

Table 2-16 Number of buildings and dwellings, according to construction period (only for buildings) (Source: INSTAT, 2011)



	Up to 1960	1961-1980	1981-1990	1991-2000	2001-2011	Unknown period	Non inhabited
Number of buildings	1,604	5,912	4,242	2,252	5,195	2,215	751
Number of dwellings	30,234	100,370	70,495	36,800	82,051	33,232	4,418

Statistical data related to construction materials

The 2011 census was unable to collect data on construction materials, although the 2001 census did. Albania had a total of 507,180 residential buildings at the time of the census. The vast majority of residential buildings (88 percent) were constructed of brick or stone, whereas 5% were prefabricated (Simaku, 2020). Although the quantity of prefabricated buildings is less than that of Masonic structures (made of stones and bricks), they are nevertheless multi-story structures with numerous apartments. After 1960, the majority of apartment complexes are constructed utilizing prefabricated block technology. Clay and mud are examples of "other" building materials.

Energy properties of building materials

After 1960, residential buildings were built using prefabricated technology with a kind of ‘sandwich’ type insulation, which was part of the building panel. Buildings built in the peak years, in the 1990s had partial or insufficient insulation (Simaku, 2020). But even in the 2000s, building codes were not very restrictive and many buildings did not meet the criteria set out in them. Generally, the insulation of buildings is poor and energy consumption is high. Part of the building stock has been renovated. The most common interventions are roof insulation and replacement of single-glazed windows / windows with double-glazed (Simaku, 2020).

Energy consumption in Albania

The final energy consumption in 2012 is equal to 1841 Ktoe. The contribution of the sectors is respectively: 25% housing sector, 38% transport sector, 15.4% industry, 8.55% services, 5% agriculture. According to the 2008 energy balance, the housing sector ranks first for electricity consumption at 47% of the total. In addition, this sector consumes in high values firewood with about 42% of total and oil by-products with 3.8% and others with 7.2% solar energy. The fact that Albania has not developed a natural gas system, because it has a negligible production of it and at the same time is not connected to the European gas network, almost all energy services (space heating, cooking and sanitary water), for the housing and services sectors are covered by electricity, firewood and oil by-products. The fact that energy resources are used in all sectors of the economy, including the housing sector, the link between economic development and energy demand is considered a key problem and requires the development of a strong and efficient energy system.

Energy consumption in the housing sector takes into account the following services: space heating, air conditioning, hot sanitary water, and cooking, lighting and household appliances. Consequently, it is very important to know what are the ways and possibilities for saving energy resources, such as: electricity, firewood.

The most important problems that the country's economic development and the energy sector in particular will face in the future are the higher energy usage per capita and concurrently maintaining energy intensity relatively low, necessitating the development of a competitive and sustainable economy. The energy sector in Albania will continue to face two challenges which are maintaining the intensity at medium levels, and increasing the energy consumption per capita (increasing the comfort of life).

Energy estimates for the Albania buildings stock

There is no specific method or indicator to assess the standard energy situation or the current consumption of the building stock inventory in Albania. (Simaku, 2017)

There isn't also, an indicator expressed in terms of consumption per $1m^2$ of area heated/cooled in the span of one year, expressed in [kWh/m^2year]. The indicator of this nature, as in all EU countries, serves to reasonably develop the assessment of energy consumption in the sector of existing buildings at the state level.

Official statistics on energy consumption in the housing, public buildings and services sectors are not found in Albania. Today, in the National Cadaster, we can find limited but important information about the physical inventory of the current housing stock. According to INSTAT information (INSTAT, 2014), non-residential buildings are estimated at a total area of 16.5 million m^2, which together with residential ones are about 63 million m^2. The classification according to functional categories has also been calculated and an even more detailed inventory is being updated to be developed on behalf of CENSUS 2021. The basis for energy consumption forecasts for study purposes of the building sector, is only the number of inhabitants and the size of stock.

The evolution of the housing stock in Albania depends first of all on the demographic dynamics of the country. For this reason, the number of residential buildings and the demand / supply for buildings during the study period have been calculated.

To calculate the number of residential buildings, we relied on population data from the INSTAT statistics office. We have assumed population growth by 2031 according to the average growth scenario of INSTAT projections.

In line with the European trend, we have assumed that the average number of members in an Albanian family will descend. This difference comes from factors such as the aging of the population, the smaller number of children per household and a larger share of single-parent housing (BPIE (Building Performance Institute Europe), 2011). According to censuses in Albania (INSTAT, 2014), the average number of members per household is 4.2 in 2001 and 3.93 in 2011. If this trend continues in the future, in 2050 this indicator will be 3.0 members for each family. According to the latest census, the number of households per dwelling is 1.02 and it is assumed that this number will remain unchanged in the coming years.

Based on the expected trends for population growth and the number of members per household, was calculated the total number of households. According to our calculations, the number of Albanian families will reach 813,000 in 2030, and 880,000 in 2050 (Simaku, 2020).

Also, from the studies of developed European countries the number of people per dwelling decreases with the increase of the standard of living. This tendency is also for transition countries like Albania. As above, this decrease in countries like Albania is happening relatively quickly and, like some other countries in transition, Albania is already very close to the level of two-person housing, equivalent to most developed European countries. The decrease is due to the aging of people and lifestyle, according to which the percentage of housing with one member and two members is constantly increasing. In Albania, the number of persons per dwelling is expected to decrease from 3.92, in 2013, to 3.50, in 2020.

With the decrease in the number of persons per dwelling and with a comparable number of inhabitants, the number of housing units is increasing. This movement is reflected in the increase in the number of housing units in large cities, as the population there is growing intensively and the number of persons per dwelling decreases faster than in small cities and, in particular, in rural areas. According to forecasts provided by the World Bank, the average living space in Albania is 57 m^2, a figure that is significantly lower than the EU average. A further increase of the living space is foreseen, which corresponds to the tendency and dynamics of the increase of the living space in European countries, so that in 2020 the living space per dwelling, in Albania, will be 62 m^2.

The most common number of rooms in dwellings is 3 (43.8%), which are followed by 2-room dwellings, 28.7% and 4-room dwellings, 17.9%. The standard housing density is about 14 m2 / person.
According to CENCUS 2011 (INSTAT, 2014), the resident population in Albania was 2,822 mil. and in 2014 it is 2,980. The population has fallen by about 5.3%, in comparison to the 2001 Census, where the population was 3,078,366 and the number of private buildings was 713,171. This shows a reduction of 4,566 households or 0.7 percent in the total number of households from the previous census. According to the 2011 Census, the number of swellings in Albania was 587,074. More than 80 percent have been mostly one-story as detached houses, with only one dwelling. Only 3.7% of them were residential buildings, of which 31.3% are located in the prefecture of Tirana. On the contrary, public buildings have increased by only 1.5%.

How much energy do homes in Albania consume?
In some evaluation models, the basic European standard is the heating standard in relation to the heated surface. Regarding the heating indicator, we can say that the problem starts with the fact that almost all Albanian apartments are partially heated, only for a few hours a day (Profka D. , 2017). In most buildings heating is provided only in one room or in certain parts of it, not creating the proper comfort of living. From the calculations, the average heated area of the apartment in Albania for 2014, was determined on the basis of statistical data and energy balance data. Preliminary estimates show that the part of the heated area occupies about 45% of the total living area (load factor) and is a result of the purchasing power of the population of energy materials, such as firewood, electricity, LPG, which mainly come from tradition. and cultural heritage. Therefore, with the increase of standards, the further increase of the share of heated area, by 2030, will occupy 63% of the total area of housing units.
Along with the high levels of indoor air pollution and respiratory ailments caused by firewood heating (Legro, Novikova, & Olshanskaya, 2014), it also contributes to deforestation, which is related with a variety of environmental problems, including deforestation, biodiversity loss, pollution of the air, and soil degradation. If no new trees are planted, there is no way to compensate for the greenhouse gas emissions caused by the burning of this biomass.
Up to 60% of the electricity consumed in dwellings and public spaces is spent on their heating. The demand for heating energy is mainly covered by electricity (65%), LPG (18%), firewood (15%) and others (mainly oil), while for mountainous areas it is provided by firewood (65 %), electricity (25%), LPG (10%) and others (mainly diesel) (Simaku, 2020). The heating appliances used mainly in the city areas are of new Western European brands and in recent years a strong penetration of Turkish and Chinese products are evident in the market. There is a clear trend of Albanian households moving towards energy brands of household appliances due to very strong campaigns carried out by major suppliers. Rural areas are using more heating stoves produced in Albania or second-hand appliances of brands from Western Europe.

Estimated energy consumption for Albanian dwellings
Albania's housing sector accounted for around 24.58 percent of total final consumption in 2012 (INSTAT, 2013). This percentage has increased gradually over the last 25 years and is expected to remain relatively stable in the future. However, this is a global average since the share of Albania's housing sector varies significantly throughout the Western Balkans countries due to climatic circumstances, energy resource availability, energy infrastructure, income, economic structure, and other country-specific factors and preferences. During 2014, housing in Albania (Residential sector) contributed more than 30% to the national energy consumption (EUROSTAT, 2015)) and less than 60% to the electricity consumed in the territory.

Current legal framework for PEN evaluation.
In terms of PEN, in Albania during the past 15 years, very limited changes have been made. Except for DCM 38/2003 which provides at least a legal basis for reasonably performing buildings in Albania, almost nothing has been done.

The implementation of the Energy Code in buildings has been used very little by builders and no enforcement mechanism is included in the enactment of law no. 8937. date 12.09.2002 "ON STORAGE OF HEAT IN BUILDINGS" on an implementation basis.
Finally, a draft law on Energy Performance in Buildings is being finalized and includes the main parts of directive 2010/31. This draft provides:
a. Performance as a European concept and indicator
b. National PEN Calculation Methodology
c. Minimum PEN requirements
d. Implementation on Stock of New / Renovated Buildings, Public and Private.
e. Issuance of PEN Certificate and certifying authority
f. Audit and Inspection of technical systems
g. Information, Expertise, Institutional and independent regulation
h. Penalties for disobedience.

Energy Code - Thermal Properties of Building Elements Materials and Typical Interventions in Building Coating.
In the Albanian engineering definition, "construction elements" are the construction systems that make up the building envelope. Definition in terms of Energy Performance in Buildings "coating" means the type of construction and the materials used to separate the interior space of a building or a building unit from the external environment. In Albania "thermal properties of building elements" as a sub-typology of the Code, consist of 50 types of masonry and floors. As for roofs and floors, the Energy Code of Albanian Buildings does not have any calculations analyzed accurately, but has a limited number of recommended fixed values, mainly borrowed from foreign literature. It provides some values (30-40 types). The elements considered are reflected as most common construction types in the stock of residential buildings. For each type of element, the thermal transmission coefficient (value U) is determined together (table 2-17, 2-17, 2-18, 2-20).

Table 2-17 Thermal Properties of building elements materials (Source: Simaku, 2020)

Building wall thermal property elements by Code DCM 38/203	K [W/m^{2o}C] U-Value
01. Lightweight concrete wall with external plaster	1.868
02. Lightweight concrete wall with external plaster	1.088
03. Lighter combined dense concrete wall with external plaster	1.089
04. Lightweight concrete wall with air layer with external plaster	0.698
05. Dense concrete wall with air layer with external plaster	1.115
06. Dense concrete wall with insulating layer with external plaster	1.271
07. Lightweight concrete brick wall with holes in external plaster	2.780
08. Lightweight brick concrete wall with internal insulation	0.467
09. Dense brick wall with internal insulation	1.006
10. Prefabricated wall / block with air layer inside	1.313
11. Prefabricated wall / block with thermal insulation layer inside	1.277
12. Prefabricated wall / block with thermal insulation layer inside	1.094
13. Brick wall	2.589
14. Brick wall with holes	1.655
15. Brick wall with air layer	1.571
16. Brick wall with insulation layer inside	1.225
17. Brick wall with insulation layer inside	1.003
18. Brick wall with insulation layer inside	0.907
19. Brick wall with holes with insulation layer inside	0.361
20. Concrete wall without external plaster	3.778
21. Brick wall combined with concrete wall with insulation layer inside	0.786
22. Irregular stone wall	2.717
23. Brick wall combined with stone wall with insulation layer inside	1.387
24. Plaster wall on the inside and outside	2.954
25. Full brick wall plastered on both sides	3.240
27. Mantle insulation system	0.707

Table 2-18 Values of thermal coefficient U (W /m^2K) (Source: Simaku, 2020)

Walls	PA	3 cm	5 cm
Brick wall 10cm - without insulation on both sides	3.25	0.95	0.65
Brick wall 10cm - isolated on both sides	3.05	0.95	0.64
Brick wall 10cm - with layers of brick outside	2.50	0.85	0.61
Brick wall 10cm - with layers of stone outside	2.80	0.90	0.63
Double brick wall 10cm - without insulation on both sides	2.30	0.85	0.60
Double brick wall 10cm - isolated on both sides	2.20	0.85	0.59
Double brick wall 10cm - with layers of brick outside	1.90	0.80	0.57
Double brick wall 10cm - with layers of stone outside	2.10	0.80	0.59
Double brick wall 10 cm - with ventilation layer inside	2.51	0.85	0.61
Brick wall 20cm - without insulation on both sides	2.30	0.85	0.60
Brick wall 20cm - isolated on both sides	2.20	0.85	0.59
Brick wall 20cm - with layers of brick outside	1.90	0.80	0.57
Brick wall 20cm - with layers of stone outside	2.10	0.80	0.59
Stone wall 30cm - without insulation on both sides	4.25	1.05	0.68
Stone wall 30cm - isolated on both sides	3.85	1.00	0.67
Srone wall 30 cm - lined with brick	2.85	0.90	0.63
Concrete bearing structure	PA	3 cm	5 cm
Reinforced concrete - without plastering on both sides	3.65	1.00	0.67
Reinforced concrete - plaster on both sides	3.40	1.00	0.66
Reinforced concrete - with brick cladding	2.45	0.90	0.61
Reinforced concrete - with stone cladding	2.90	0.90	0.64
Roofs	PA	3 cm	7 cm
Conventional roofs	3.05	0.95	0.50
Floors under the roof without insulation	3.70	1.00	0.50
Reinforced concrete slabs lined with ceramic tiles	4.70	1.05	0.50
Wooden columns lined with ceramic tiles	4.25	1.00	0.50
Green roof	1.20	0.70	0.49

Table 2-19 Thermal properties of window (Source: Simaku, 2020)

Window	U_value	g_value
With a metal frame glass	6.1	0.58
With a wooden or plastic frame glass (synthetic)	4.7	0.58
Double glazing, Wooden frame	2.3	0.51
Double glazing (6mm), metal frame	4.5	0.51
Double glazing (6mm), metal frame, 12mm thematic separation	3.5	0.51
Double glazing (6mm), metal frame, 24mm thematic separation	3.3	0.51
Double glazing (6mm), plastic frame (synthetic)	3.3	0.51
Double glazing (6mm), wooden frame	3.1	0.51
Double glazing (12mm), metal frame	4.1	0.51
Double glazing (12mm), metal frame, thermal separation 12mm	3.2	0.51
Double glazing (12mm), metal frame, thermal separation 24mm	3	0.51
Double glazing (12mm), plastic frame (synthetic)	2.9	0.51
Double glazing (12mm), wooden frame	2.8	0.51
Double glazing (6mm), low e, metal frame, thermal separation 12mm	4	0.45
Double glazing (6mm), low e, metal frame, thermal separation 24mm	3.1	0.45
Double glazing (6mm), low emission, synthetic frame	2.9	0.45
Double glazing (6mm), low emission, wooden frame	2.6	0.45
Double glazing (12mm), low emission, metal frame	3.5	0.45
Double glazing (12mm), low em, metal frame, 12mm thematic separation	2.7	0.45
Double glazing (12mm), low em, metal frame, 24mm thematic separation	2.4	0.45
Double glazing (12mm), low e, synthetic frame	2.3	0.45
Double glazing (12mm), low em, wooden frame	2.1	0.45

Table 2-20 Parameters that affect energy performance in typical buildings (Source: Simaku, 2020)

Infiltration (m^3/hm^2_{window})	
Single glazing, wooden frame	13.45
Double glazing, wooden frame	11.15
Single glass, aluminum frame	8.052
Double glazing, aluminum frame/ PVC	6.05
Thermal bridge	
Before 1980	No
After 1990	Yes, average $U_{opaque\ elements}$ 0.1W/m^{2}K
Space heating system controls	
Before 1980	no control
After 1990	Zonal thermostat for outside/ inside temperature compensation
Performance of given heat components- space heating	
Medium heating: high temperature Stove / water (wood stove for example wood thermos, radiator)	0.4
Performance of central heating systems- Heating0.8	
local systems (electric heaters)	0.98
Central system	0.95
performance of heat distribution systems- Heating	
Local systems (electric heaters)	1
Isolated central systems	0.92
Central systems, not isolated	0.84
Domestic hot water	
Daily consumption lt (daily person)	30

Statistical data on service systems in buildings

The census data presents the situation regarding heating systems and typical energy sources in Albania. Unfortunately, this data is not found in separation, so it is impossible to use it directly in the typology of buildings. As for private housing by counties, there are data, but they are not specified by construction period or type of building.

Energy materials used for heating

Only data on the type of energy consumed is provided for private residences. According to the 2011 census (INSTAT, 2011) , wood was the most frequent source of energy (57.5%), followed by gas (20.8%) and electricity (15.4%). Solar energy and other sources of energy such as coal and oil are insignificant. Around 6% of dwellings are unheated. There is a significant distinction among rural and urban areas: In rural areas, the use of wood for heating is much more prevalent than in urban areas. Firewood heating systems make up 85% of private dwellings in rural areas. Poverty and inequality are significant issues in these regions. In urban, the scenario is much more balanced: the 3 primary energy sources are wood (38.3%), electricity (23%), and gas (32.4%).

The statistics of the National Agency of Natural Resources (NANR) (National Agency of Natural Resources, 2010) present a different picture in terms of percentages of heating materials. The percentage of electricity is much higher than the registration data. Also, the use of electricity has an increasing trend: from 43% in 2011, the amount used reached 53%, in 2012. Gradually we have a lower consumption of wood and liquefied gas.

Nowadays, many homes in Albania buy secondary heating systems, which are usually heat pumps, in order to increase the comfort of heating inside their homes. Secondary heating systems are not included in the registration. Perhaps, they are used to extend the time of exploitation, as their use is more convenient than burning firewood. Second, the recording may contain inaccurate statements by users about a portion of the energy used. Also, NANR data show mixed energy sources and not the share occupied by residential buildings. Electricity is in direct proportion to the share it occupies in relation to the number of residential buildings.

Heating systems

Stoves are the most common heating device (63.3 percent), followed by electric heaters (8.5 percent) and heat pumps (air conditioners) (6 percent). Only 3.2 percent of private residences are equipped with a central heating system (for buildings or dwellings), whereas 4.4 percent are equipped with a chimney. Even if a central heating system exists, experts assert that there are no meters to monitor and manage the temperature level (Simaku, 2020). Concerning the distinctions between rural and urban areas, the same pattern as with energy sources may be observed: in rural areas, stoves predominate (by 81 percent), followed by chimneys (7 percent). In metropolitan areas, half of households are heated by wood or gas stoves. 10% of residences are heated by electric heaters, heat pumps, or other forms of heat.

There are no statistics on alternative heating systems, however based on NANR data on energy sources, it is reasonable to estimate that the number of heat pumps is greater than stated by the census.

Mechanical cooling systems

According to the census, air conditioning is installed in 6% of households (INSTAT, 2011). Air conditioners are classified as a form of heater on the registration questionnaire. Generally, the majority of cooling systems are heat/cool heat pumps that may be utilized for both heating and cooling. However, statistical evidence does not support the usage of these units as cooling systems.

Domestic hot water

The census omitted questions about the hot water supply system, despite the fact that one of the common aspects of a residence in Albania is the use of an electric boiler to heat water for hygienic purposes. This is corroborated by NANR statistics, which indicates that 62% of energy used for water heating in the United States comes from electricity, 23% from wood, 10% from liquefied natural gas, and 5% from solar energy. The percentage of wood used as an energy source is higher in climate zone C than in other climate zones with compact heating spaces.

Energy consumption in residential sector

As it is reflected in every statistic, it turns out that the housing sector is one of the largest consumers of electricity in the country. For example, in 2012, electricity consumption for households was 54% of final electricity consumption. In the winter season the activities that most affect the consumption of electricity inside an apartment are heating the space by 60% and heating the water by 25%.

The energy performance of the housing stock in Albania is currently low. This low performance has been created over the years by poor quality constructions and without special care on the thermal comfort of apartments. As a result of rising living standards, homes are unable to meet expectations for their thermal performance at reasonable energy costs. The tradition of building "bad" begins with the period 1945-1990 and unfortunately is carried to the present day. One of the main reasons for this continuity is the lack and non-implementation of thermal insulation legislation in buildings. On the positive side, in recent years, with the increase in the level of awareness of buyers as well as with the increase of competition in the construction sector, an improvement has been noticed in the quality of the constructions offered in the market. Some entrepreneurs are commercializing the "thermally insulated" apartment by applying thermal insulation to the facades and quality windows. In these cases, the market is a step forward by setting standards that exceed the expectations of legislation which unfortunately are still quite low.

But in the vast majority of housing stock that faces significant energy performance issues, the fact that the need for rehabilitation intervention is high is evident. This is in line with the provisions of Directive 2010/31 / EU on PEN which provides for measures to reduce energy consumption when renovation interventions are made in buildings. Implementing the provisions of the directive is an obligation that our country faces. In this context, the renovation of the housing stock is a real opportunity that should be used for energy rehabilitation and at the same time for the improvement of the urban, architectural, social, etc. context.
Co-owned apartments have the biggest problems in relation to the possibilities for applying for rehabilitation interventions. Due to co-ownership, but also economic impossibility, the cases of interventions in these buildings for energy rehabilitation are minimal. Below we have an overview of the statistics of the last years of energy and electricity consumption in Albania, which goes for services such as heating, cooling, hot water, cooking, electrical equipment and lighting, according to the following percentages.
The increasing consumption of total energy and electricity due to the increase of the required comfort but at the same time the increase of the price of energy commodities, has led to the increase of the use of Energy Efficiency (EE) measures and the use of Renewable Energy Sources (BRE) in dwellings.
The residential sector consumes a substantial amount of energy. It accounts for between 25% and 32% of total final energy usage (compared with the EU average of 27 percent). Simple modifications like as insulation, heating system upgrades, and window and lighting upgrades might lower consumption in this sector by approximately 9%, with payback periods typically less than eight years. These enhancements may help mitigate the impact of future tariff hikes while also assisting in closing the region's expected energy supply/demand deficit.

Energy Performance on Albanian Buildings

The stock of apartments in our country has a series of problems that are directly related to the quality of life of residents in them. Partly due to the low design and construction standards and partly due to the lack of maintenance, this stock is presented to us today with critical living conditions. Among the collective housing typologies, dwellings offer the lowest standards of comfort and the lowest performance in relation to energy consumption. This situation affects living standards and the health of residents. For this reason, the possibility of integrative reintegration intervention in these structures should be seen as a priority. Since these structures have not yet met their life cycle and the costs of their demolition and reconstruction would be unaffordable for the local economy, the rehabilitation scenario is seen as the most realistic opportunity that could affect the solution of the prefabricated problem, as well as on the overall improvement of the minimum housing standards in the country. In general, in these dwellings that show problems in relation to the conditions of comfort and the general standard of living, their inhabitants are mainly from the social strata with medium and low incomes. This makes it more difficult for interventions to be reinstated if financial contribution from the residents themselves is needed to perform these interventions. Another barrier to performing rehabilitation interventions in buildings is co-ownership. From the construction point of view, the typology of dwellings presents a high level of energy losses due to poor thermal insulation, infiltration, depreciation and lack of maintenance of buildings. In some of them, moisture appears due to direct penetration, capillary or condensation. As a result of this poor thermal performance, comfort levels in dwellings are problematic and the energy required to create comfort conditions is quite high. Due to the economic impossibility for most residents to cope with the necessary energy consumption to create comfort conditions, they are faced with temperatures and / or humidity levels outside the comfort band during the hot and cold periods of the year. According to studies conducted by the World Health Organization, it has been proven that there is still an immeasurable influence that exposure to temperatures outside the comfort zone has on human health. There has also been an increase in the mortality rate in winter due to housing conditions. It is estimated that 40% of increased mortality in winter is related to housing conditions (World Health Organization, 2007). Referring to these data, the need for intervention in order to improve the conditions of comfort in stock apartments is not simply presented as a need to improve living standards in general, but as a need to improve the health of residents in these structures. In finding a solution to this problem, the role of the state as a regulator of public interests as well as a promoter of development and welfare policies is very important.

Buildings in Tirana

According to the 2001 census, Tirana is the largest city, accounting for about 17% of the stock housing. The 1989 and 2001 censuses showed that the housing stock in Tirana increased by 40%, reaching 134,000 flats in 2001, which are located in the suburbs of the city (Profka & Mico, 2015). According to 2011 Census data (INSTAT, 2011), the coastal belt, which accounts for only 12.78% of the total area of the Republic of Albania, is inhabited by 1/3 of the total population (35.3%). Meanwhile, according to the same source, the district of Tirana in 2011 owned 26% of total dwellings where about 73% are ordinary dwellings and about 27% are dwellings common non-inhabited and unusual dwellings. The population of the Tirana district is around 27% of the country's total population.

The most usable exterior wall constructions in Tirana and Albania are with full brick wall, full silicate brick wall, perforated brick wall, prefabricated concrete wall, block wall as well as an earlier part with adobe and stone wall. According to Census 2001 data, brick and stone buildings occupied 88% of the total of all buildings, prefabricated buildings occupied only 5%, while those with wood only 1%. Of course, brick buildings include full brick buildings, full silicate bricks and perforated bricks. While in the 2011 Census, instead of being further detailed, no information was collected on this data.

2.5.2. Seismic design of masonry buildings

Masonry buildings occupy a significant place in existing buildings of our country, which were built in different periods of time. During the period of their use, they have suffered various damages because of: changes in the function of the building; degradation of the structure; seismic loads; aggressive atmospheric conditions, corrosion; accidental explosions; design and implementation errors, etc.

Over half of Albania's residential building stock was constructed prior to the 1980s and so does not meet modern energy efficiency and seismic safety standards. Low to mid-rise brick masonry constructions comprise the typical historic buildings seen across Albania, with virtually little construction of reinforced concrete structures prior to 1985. The majority of mid- and high-rise structures, on the other hand, were constructed utilizing reinforced concrete after the 1980s.

The following sections detail several common problems seen in older structures that influence their structural seismic performance.

Design standards have not been constant since their inception, but have evolved over time in lockstep with the advancement of knowledge and acquired experience. Particularly when it comes to seismic loads, the changes in active codes throughout time are so significant that buildings can even be categorized as according their period of construction.

The very first seismic regulations were enacted in 1963 and were based on a straightforward modeling of ground motion under static lateral loads. Albania developed its first national-level code in 1963, which was later supplemented in 1979 and 1989. Simultaneously, the European Commission began the Eurocode initiative in the 1970's with the goal of standardizing the construction industry in European countries.

However, because the bulk of buildings predate the majority of present laws, it is obvious that their seismic resistance is likewise far lower than that of newer constructions. This is because the seismic actions considered in older buildings are less than half of those considered today, the concepts of plan regularity were absent, the computational models used to calculate internal forces were simplistic and highly inaccurate, and no further measures (detailing provisions, capacity design principles, etc.) to ensure adequate ductility for the structure were applied. The obvious consequence of the above is an under-design of a building's bearing parts.

As a result, many structures do not comply with the criteria of new building rules. The majority of European countries have adopted "Structural Eurocodes," which demonstrate a high degree of competence in the field of structural engineering. Already, these codes are ingrained in Albanian design practice, and work on them has begun several years ago, both via formal initiatives by responsible authorities and through individual initiatives by Albanian engineers. KTPs (Albanian construction code) were last updated in 1989 with the ratification of KTP-N.2-89 (Academy of Sciences, Ministry of Construction, 1989). On the other hand, many existing buildings were realized before this year, designed in accordance with even older design codes. Especially the buildings treated in these studies have been designed with codes in force at the time of construction starting in 1963 (KTP-63, KTP-78). The figure 2-33, shows the schematic design of the buildings regarding the changes of KTP after major earthquakes event.

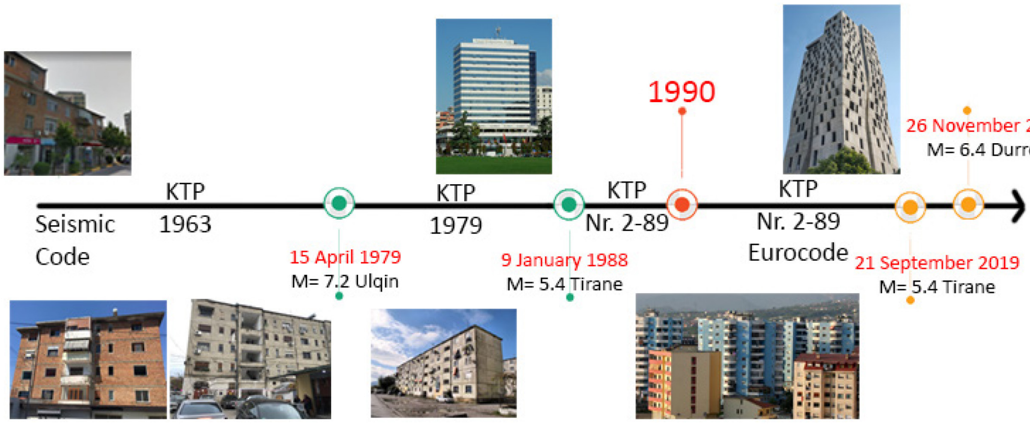


Figure 2-33 Schematic time period of buildings typologies according to National Codes and seismic events

Social buildings are spread throughout the Republic of Albania and are of different types from a structural point of view. However, there are common elements between them and this fact can serve to carry out a structural assessment of buildings based on a study performed on a limited number of them. In this context, it can be mentioned the fact that most of the buildings in Albania were built using brick masonry as a building material. The main structural elements in these buildings are the "bearing walls", who are the key responsible of the overall seismic response of the structure. Also, the number of floors is limited to five, and in some cases six. In the similarity between social buildings in Albania, it is worth considering the fact that the architectural and structural projects have been "type projects", also as a consequence of their function, which means that the same project has been implemented many times in different locations, with corresponding adaptations.

Although every building is unique - in the sense that atmospheric factors, geological conditions of the construction site, the quality of implementation of workmanship, etc., constitute difference from one building to another - it is possible to use different techniques that enable the structural assessment of buildings or groups of buildings based on the preliminary analysis of type buildings. Assessment of potential damage or vulnerability to an earthquake with certain probability of occurrence constitutes a key aspect in the protection of buildings in situations of severe seismic events.

Since most of the buildings in Albania are designed and built according to the old technical conditions, it is expected that they will not meet some of the requirements of contemporary codes, especially when today the seismic forces are quite greater.

The purpose of this study is to evaluate and improve methodologies for seismic performance of typical projects of residential masonry buildings stock, selected in Albania which are designed in accordance with the codes (KTP-63, 1963; KTP-78, 1978). This assessment will be performed according to the instructions of EC8, ATC40 and FEMA 440, given the nonlinear behavior of masonry. However, developments in the field of design are substantial, in our country as well as in many European countries still do not have a proper procedure or a code, specifically for capacity assessment and rehabilitation of this type of construction in a seismic event.

Among the typical residential building projects, one has been selected as representative coded 77/11. The model project was taken from the state construction archive. By modeling with finite element of nonlinear analysis will be determined building capacity curves for the two main directions. Performance seismic assessment will be performed in accordance with FEMA 440 guidelines (Applied Technology Council (ATC-55 Project), 2005). Examination of capacity curves will identify structural deficiencies.

In this study it is applied the strengthening of the building with high resistance materials. This method is expected to increase the seismic bearing capacity of the building by redistributing the shear stresses

arising on the first floor. In fact, this kind of reinforcement makes only a distribution of forces and increases the efficiency and integrity of the masonry against earthquake.
We have several types of reinforcements for masonry. The study will focus on methods with fiber-reinforced polymers, fiber CFRP carbon, GFRP glass, Ferrocement and steel frames.
This study aims to produce a methodology of analysis and strengthening for older masonry buildings. These are applied in the same way to the selected building, for comparison. It was then evaluated the improvement of the performance of the building for each case and conclusions and recommendations are drawn for applications in similar cases.

Albanian design code KTP 9-78 for masonry

This technical code determines the method of calculating the wall section and foundation. For constructions in seismic regions, the technical instructions are set out in KTP 2-78. These general guidelines were published in 1978. The calculation of the wall and foundation section is specified in this technical code with the ultimate limit states.
Loads and their combinations are taken in accordance with the instructions techniques that are defined in KTP 6-78 (Determination of loads on social and economic facilities). All masonry cases are specified in this code; brick, stone, concrete block and concrete and stone, class and plasticity of mortar, thickness of mortar joints and their leveling, row height, connection method and quality of construction.
The most important part of this code is shown below.
First the calculation of the characteristics resistance of the masonry is the product that results from the multiplication of the standardized resistance by homogeneity coefficient. It varies according to the stress state of the element and of the type of materials used for wall construction.

Table 2-21 Compression strength (R kg/cm^2) for brick masonry, 12cm row height (Source: KTP- 78)

Nr.	**Brick class kg/cm^2**	**Mortar class 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 2-22 Compression strength (R kg/cm^2) for concrete block, up to 18cm row height (Source: KTP- 78)

Nr.	**Block class kg/cm^2**	**Mortar class 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

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Table 2-23 Compression strength (R kg/cm^2) for stone wall and foundation (Source: KTP- 78)

Nr.	**Stone class kg/cm^2**	**Concrete class kg/cm^2**		
		100	75	50
1	above 100	20	18	17
2	under 200	16	15	14

Albanian Code of Seismic Design KTP-N2-89

Seismic events pose a significant threat to those who live and work in not appropriate designed structures. Earthquakes often cause damage only in the immediate vicinity of the epicenter. Disasters are produced by a combination of intense ground vibration, earthquake magnitude, poor construction quality (low structural capacity results in poor performance during earthquake occurrences), and a large population density in the earthquake's epicenter area. When earthquake risk is compared to other natural hazards, it is clear that earthquake risk is significantly greater than other natural hazards,

especially in low seismic locations. Earthquake damage increases significantly as the chance of occurrence decreases (as the recurrence period grows), which means that huge earthquakes are relatively rare but extremely destructive (Ministry of Construction, 1989).
Albania has a history of intense minor and medium earthquakes, which have been documented. But, the zone where Albania is located, several catastrophic earthquakes have happened over the centuries, destroying entire cities. As a result, the Albanian community has established various norms to ensure stronger housing since ancient times. Over time (particularly over the last century), these empirical norms and experiences evolved into comprehensive legal building codes that have evolved continuously via considerable revisions and improvements represented in the most recent design code. While it would be ideal to have a level of security for practically every structure, this results in an economically and financially unattainable solution. As a result, experts determined that the most critical, crucial, and emergency structures would have a higher level of protection against predicted dangers.
One reason for a higher level of security in a building is the probable number of occupants at the time of the occurrence (Albanian Seismic Code (1952, 1963, 1978, 1989) and revised versions).

KTP-N2-89 was published in 1989 approved by decision No. 40, dated 10.01.1989, by the Scientific Council of the Ministry of Construction. Technical Rules of Design for earthquake-resistant constructions are applied both during the design and implementation of buildings and engineering works in seismic areas. The purpose of these codes is to ensure that in the event of an earthquake:
• Human lives will be protected;
• Damages will be kept to a minimum.
•Civil protection-related structures will remain functional (operational)

The path of seismic protection in Albania can be distinguished in three characteristic construction periods:
(1) before 1960 - seismic protection at a very low level or absent at all;
(2) 1960-1990 - low and completely insufficient level of seismic protection;
(3) after 1990 - level of protection KTP-N.2-89, which, keeping in mind new seismic studies, can also be called, insufficient.
The first seismic map of Albania dates back to 1952 as a product of the work made by the experts of the Institute of Sciences and the Ministry of Construction of that time. Since then, the work for the most accurate seismic risk assessment in our country has continued with numerous publications to the present day.

European Code of Seismic Design EN1998
Since the earthquake is a possible event, to make a more precisely estimate, a larger number seismic events should be statistically processed. This method is very applicable in the seismic design of buildings. Design acceleration refers to the seismic acceleration of the ground rock that does not exceed the probability by 90%, within a time period t = 50 years, or in other words the acceleration caused by the earthquake with a recurrence period of 475 years is called the design earthquake (EC8-1, 2004).
For seismic design purposes, the conclusions of each analysis of a region are given through seismic hazard risks. A popular way today for the conception of seismic hazard maps is the contouring of the same values of ag or PGA accelerations which for a certain probability do not exceed a certain period of exposure. These are called seismic acceleration maps.
In European regulatory standard (EC8), the time of recurrence of design seismic event or design earthquake is used as the suggested value for the recurrence of design seismic action or design earthquake. RP equals 475 years. This value corresponds to a probability of only 10% for overcoming the design earthquake intensity within a time period 50 years. As a measure of the intensity of this seismic action in EC8 is used the design acceleration ag, on rocky or solid ground, used as an 'input function' in verification of sufficient strength and ductility to meet the basic design requirements of buildings, related mainly to the ultimate limit states ULS. Earthquake corresponding to service limit states SLS is taken much smaller.

The possibility of a very large, extraordinary, seismic action is also addressed in the European technical literature. This, of course, is considered much rarer than 'design earthquake'. According to some indications the maximum possible earthquake can be considered the earthquake with recurring period RP = 1000 years. There are also recommendations to choose it with 2 times greater intensity than the design earthquake. If the latter corresponds to e.g., acceleration of 0.25g, according to these recommendations the maximum possible earthquake acceleration will take 0.5g. In EC8 for this earthquake as well as for the relevant design criteria there are no specific definitions.

Existing buildings stock

Traditional masonry construction is used to construct the majority of existing buildings in Albania. Masonry is a widely used material for the construction of low to medium-rise buildings not only in Albania, but also globally (Tomazevic, 1999). Until the end of the communist era in 1990, masonry buildings in Albania were constructed utilizing type projects. Masonry is employed to construct public and government buildings since it is a relatively low-cost construction option at the time. Today, these structures remain in use and are primarily used for residential purposes.

Albania is one of the Balkan countries most prone to seismic activity. Recent severe earthquakes in neighboring countries (Italy, 2009, Greece and Turkey-2008-1999), as well as in our own nation (Durres, 2019), have demonstrated that masonry structures sustain the most damage and are responsible for the greatest number of fatalities. These types of buildings are prone to earthquakes for a variety of reasons, including their antiquity, man-made local interventions, and an outdated design code at the time. As a result, it is critical to examine the seismic performance of these structures and to devise strategies for strengthening them to withstand possible earthquake damage. (Petrini, 1984).

To analyze better the characteristics and features of masonry buildings, built before the 90s, the projects of some of these buildings have been taken Central Technical Archive of Construction (AQTN). The selected building belongs to the designed projects of the year 1977.

Data on old masonry buildings

The building stock spans approximately 50 years. This era is shaped by a variety of architectural approaches, design codes, and key historical / economic events. We can classify buildings into five broad categories based on their construction date:

Masonry structures dating back about 50 years are impacted by a variety of construction processes, design codes, and significant historical/economic events. In terms of building date, we can divide the population into four large groups:

1. Building before 1944 (based on experience);
2. Building in the years 1945-1963 (based on KTP-1952);
3. Building in the years 1964-1978 (based on KTP-1963);
4. Buildings in the years 1979-1990 (based on KTP-9-78);
5. Building after 1991 (based on KTP-N.2-89);

(Albanian Seismic Code (1952, 1963, 1978, 1989) and improved versions)

Analyzing all residential buildings in Albania would need a great deal of time and effort that would exceed the scope of this study. As a result, our study is limited to the most prevalent kind of residential development between 1970 and 1980. To aid in the analysis of the characteristics and features of masonry buildings constructed prior to the 1980s, several of their projects are included. These projects are located near the Construction Central Technical Archive (AQTN).

The primary characteristic of constructions from the last few decades is their "type" design.

The structures were classified as "Type 55; 55/1; 77; 77/3; 77/1; 83/3, and so on." These marks refer to the year of design and construction of the structures, which were later adapted and built in various locations. When designing these types of structures, the design team considered all possible technical solutions, while deciding on the construction type based on a thorough investigation.

The bearing capacity of these structures is inextricably linked to the materials found or produced on-site; to factors of the building's activity (number of storeys, dispersion of internal areas, openings, and so on); to the climate; and to the body of practical and technical expertise accumulated at the period of the building's completion. Steel as an imported resource has been connected to a scarcity of or a high cost of masonry as the primary building material, which has been shown to be beneficial economically. For brick masonry were used M-50 kg/cm^2 brick and M-15 kg/cm^2 mortar. In some cases, was used M-50 kg/cm^2 mortar, mostly in the areas between the windows, with a length of less than 1.5m.
These types are built in all climatic zones. For cold places exterior walls of 38 cm were applied to all floors. Exterior plastering was done with bastard mortar, the windows were made single-glazed. Cold places were considered those above 500m above sea level.

In the 2011 database made available by Census (INSTAT, 2014) (table 2-24), are analyzed the residential buildings developed during years 1945 to 1990 with 2, 3-5 and 6 floors. In the context of data analysis, it has been made the classification of buildings based on districts, function, year of construction, number of floors, type of building, etc.

Table 2-24 Residential buildings according to type of building and the area city – village(Source: www.instat.gov.al)

Building type	Nr. of building			Inhabited dwelling		
	Total	City	Village	Total	City	Village
Total	785.515	364.181	421.334	696.977	316.310	380.667
Private dwelling	569.251	169.919	399.332	512.625	150.973	361.651
Apartment block	205.514	187.646	17.868	173.603	158.721	14.882
Other purposes	4.435	3.555	880	4.435	3.555	880
Collective housing	5.583	3.061	2.522	5.583	3.061	2.522
Others	732	0	732	732	0	732

The number of buildings inspected from the database is 785’515.
Their distribution by districts is given in figure 2-34 There are several districts as well Tirana, Elbasani, Durrës, Fier, Vlora who have a larger number of buildings built in the years 1945-1990 compared to other districts.

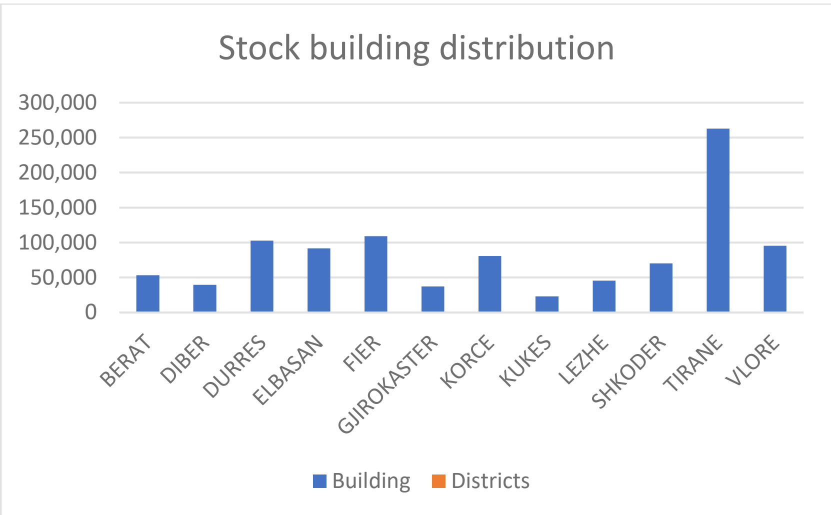


Figure 2-34 Distribution of stock building based on districts (Source: www.instat.gov.al)

Design solutions of buildings in Albania

Walling technique

Masonry bricks were generally used in our country. Their dimensions 250 × 120 × 65mm and weight 3 - 3.5kg. The mechanical resistance of bricks is determined by their class, which in Albanian practice is found with the values 35, 50, 75, 100, 125 and 150. In the following figure are shown the traditional techniques of applying brick walls with a thickness of 12cm, 25cm and 38cm (Papanikolla, 1973).

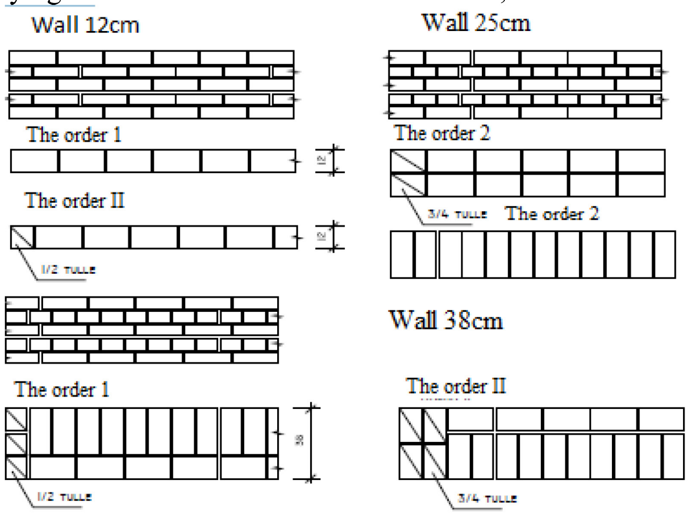


Figure 2-35 Walling technique (Source: Papanikolla, 1973)

Clay bricks better resist the action of atmospheric agents, high temperatures and moisture, therefore are widely used in Albania. In addition to clay bricks, were also used silicate bricks. Masonry with these bricks is built straight and clean (Papanikolla, 1973).

The object of study are the unreinforced masonry buildings with solid ceramic bricks. Generally, masonry structures in our country are unreinforced.

Materials

In EN-1998-1 the minimum values for the resistance of masonry units in seismic regions are recommended $f_{b,min} = 5$ N/mm^2 for the vertical direction according to horizontal joints and $f_{bh,min} = 2$ N/mm^2 for compression in horizontal direction (according to vertical joints). Meanwhile for the mortar it is recommended minimum resistance of $f_{m,min} = 5$ N/mm^2.

In the variants considered (by AQTN) social buildings are generally built of brick M-50-75 and mortar M-15, while for special parts (e.g., for masonry between two windows) may also have been used mortar with higher strength, like M-25 or M-50. This shows that the requirements for brick resistance are higher than $f_{b,min}$ of Eurocode 8, which makes them suitable in seismic regions. On the other hand, the mortar does not meet the minimum requirements of Eurocode 8.

Loads, actions and combinations

Inter-story slabs are generally provided with reinforced ceramics. The weight of the slab equal to 3.8 kN/m^2. For the terrace the weight of slab is approximately 5 kN/m^2.

For the analyzes that will be performed, the self-loads of slab have been accepted gs = 3.8 kN/m^2 for gt = 5.0 kN/m^2 for terrace.

It is noticed that the loads in the inter-story slabs according to Eurocode 1 are larger than those considered in the original projects in Albania. In this dissertation, the difference between the loads of the two codes will be seen in terms of the impact on the structure in seismic situation.

Structural solutions in function of seismic design

Today's design codes contain quite strict requirements for the use of structures with unreinforced masonry in seismic regions. If we refer to the materials used, it is noted that the mortar does not meet

today's requirements for use. In the above paragraph it was shown that Eurocode 8 recommendation for minimum mortar resistance is 5 N/mm^2.
The requirements of Eurocode 8 go further, even restricting the use of unreinforced masonry in seismic areas if the a_gS product is higher than a recommended value $a_{g,urm}$ (ag - seismic acceleration, S - soil factor). Paragraph 9.3 (2) and (3) of EN 1998-1 (CEN, 2004) explains that due to low tensile strength and low ductility, unreinforced masonry that meets only the criteria of EN 1996 should be restricted in construction. Following the values of recommended for limit value of $a_{g,urm}$, unreinforced masonry that meets only the requirements of Eurocode 6 should not be used for a product of a_gS larger than 0.20g. If we consider the values of factor S (from 1 to 1.8), it turns out that the ground acceleration for which these types of structures are allowed is from below 0.11g to a maximum below 0.20g for very good soil, type A. If the criteria for "simple masonry buildings" (by definition Eurocode 8) are met, Table 9.3 of Eurocode 8, Part 1 provides recommendations regarding the number of floors and the minimum surface area of the shear walls. It should be said that the most existing buildings in our country do not meet the criteria for their classification as “simple buildings of masonry” (from the materials used, regularity in the plan, etc.).

2.6. Renovation vs Demolition and Reconstruction

Among some of the strategies for improving the energy and structural performance of the existing building stock, the potential of demolishing and re-constructing a new structure that meets the new code standards must be mentioned. Thus, for each project, the critical question is whether it is more cost effective to pursue renovation or demolition and reconstruction.
Reuse of buildings should always be preferred over demolition or deconstruction (JRC (Joint Research Centre), 2012) because it:
• prevents the construction of new buildings from occurring, and thus the consumption of additional resources: as discussed previously, construction consumes 50% of raw materials each year.
• avoids the significant environmental impact that demolition and rebuilding projects have, particularly at the local level: the principal products of demolition, either traditional or selective deconstruction, are rubbish to be disposed, materials to be recycled, and a brownfield to be reclaimed for use as a green space or a new building.
• mitigates risks associated with hazardous materials handling, accidents, and other factors: demolition is a highly dangerous procedure that must adhere to a number of workplace safety rules.
• mitigates adverse effects on biodiversity. Often, historic towers and other structures serve as critical habitats for endangered species. Each modification to a land ecosystem has the potential to jeopardize the survival of specific species and even result in their extinction.
• acknowledges the worth of existing structures: for many people, a structure can hold a significant deal of personal meaning. Often, demolishing a structure involves relocating a family, a whole neighborhood, or a section of a city's skyline, all of which have historic and emotional ramifications.
Nonetheless, demolition may be required if the existing structure is in suboptimal condition due to, for instance, a risk of collapse, the presence of hazardous chemicals to human health, or the aftermath of fires or earthquakes.
A distinct challenge is the restoration of monumental and historic structures that must be preserved for the sake of a country's culture and memory. In this instance, demolition is ruled out and large-scale restoration, conservation, and maintenance initiatives must be devised.

Sustainability and Environment
Belleri and Marini (Belleri & A, 2016) provided an extremely illustrative map (figure 2-36) displaying three different situations for an existing structure in need of energy upgrading. Additionally, the structure is deemed vulnerable to seismic stresses and has reached the end of its structural useful life (50 years for ordinary buildings).
The first scenario entails demolition and reconstruction, due to the building stock's poor performance. After completion of the intervention, the new building's performance will meet all current energy consumption and structural safety standards; the new building's end-of-life scenario will include selective dismantling and possible recycling of the construction components.
Notably, if generally adopted, demolition and reconstruction may not be environmentally

sustainable; in fact, the environmental impact would be unbearable, both in terms of raw material consumption and hazardous waste generation. Additionally, this strategy would involve resident relocation.

The second example illustrates typical efforts aimed just at energy refurbishment. This method does not extend the structural service life and does not ensure structural safety in the event of an earthquake. Depending on the magnitude of the seismic event, little or significant repair efforts, relocation of residents, or building collapse may occur. At the end of the day, no virtuous recycling or reuse can be anticipated in post-earthquake emergency management; rather, all debris from fallen structures may be disposed of in landfills, hence worsening the environmental impact of the end-of-life phase.

The third scenario contemplates a more novel method that combines energy and seismic retrofitting. The structural refurbishment, in particular, entails the incorporation of new lateral force resisting devices within the building's new or upgraded envelope. This method eliminates the need for residents to relocate and satisfies safety criteria in the event of seismic stress. Notably, the structural intervention enables the building's structural service life to be extended, but any alteration aiming solely at improving architectural and energetic performance would leave it unchanged. Due to the fact that the environmental load may be distributed over a considerably longer time period, this integrated approach minimizes the equivalent annual impact of the embodied energy.

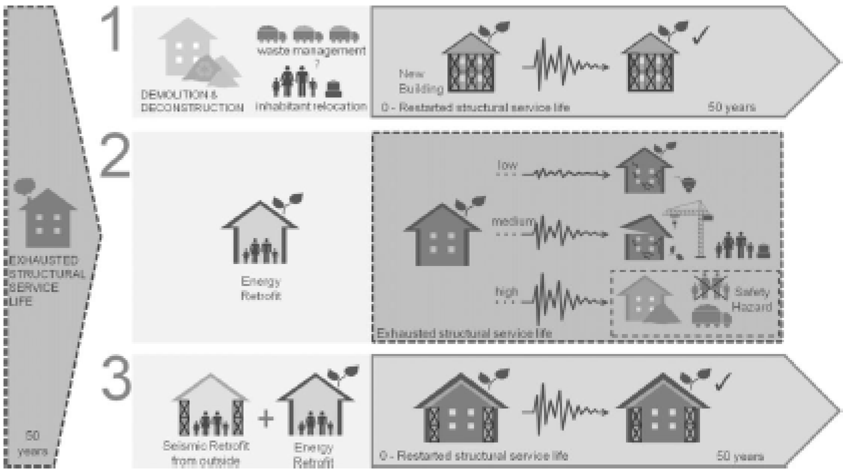


Figure 2-36 Retrofit scenarios conceptual map: (1) demolition and reconstruction; (2) only energy upgrade; and (3) combined energy and structural improvement. (Source: Belleri A, 2016)

- *Challenges in building retrofitting projects*

The authors Sigmund and Radujkovi [135] highlighted the following key impediments to construction projects on existing buildings: • Ownership concerns • Compliance with applicable laws, regulations, and requirements
• Risks associated with historic design documentation • Risks associated with past problem registers
• Risks associated with expert predictions and structural condition • Risks associated with investors and owners • Risks associated with user–heritage protection
• The project's sustainability

While these particular aspects have been acknowledged as vital throughout the retrofitting process, in the case of multi-family buildings with collective ownership, the risk factors identified as important take on a new dimension. According to the existing literature and the authors' expertise with a joint ownership building project, the choice criteria transition from a process based on research findings and the project management team's experience, such as in the case of an infrastructure construction investment or a private investment with a single investor, to a simple decision-making procedure based on crowd psychology. In this situation, the imprecise grasp of the topic at hand is trumped by the question of "why the investment and what is the immediate benefit to me?"

- *Cost*

A significant disadvantage of energy retrofit measures on existing structures is that the chosen refurbishing method does not extend the building operational life and does not ensure structural stability in the event of an earthquake. Depending on the magnitude of the earthquake, little or significant repair efforts, relocation of residents, or structural failure may occur. As a result, it is necessary to address structural and seismic security, particularly in projects involving substantial energy refurbishment. Naturally, the primary obstacle to providing seismic plus energy retrofitting is the intervention's entire cost. To contextualize the intervention cost, energy renovations are classified alongside the average overall project cost for energy efficiency measures. Table 2-25 summarizes four distinct types of energy renovations, together with their average total project costs, presented in euros per square meter of floor area. The expenses reflect the overall installed costs of measures, including materials, labor, and professional fees, but exclude any costs not directly related to enhancing a building's energy performance (BPIE (Building Performance Institute Europe), 2011).

Table 2-25 Types of energy renovations and associated costs (Source: *BPIE (Building Performance Institute Europe),2011)*

Description (renovation type)	Final energy saving (%reduction)	Indicative saving (for modelling purposes)	Average total project cost (/m^2)
Minor	0-30%	15%	60
Moderate	30-60%	45%	140
Deep	60-90%	75%	330
nZEB	90%+	95%	580

Saheb et al. (Saheb, Bodis, Szabo, Ossenbrink, & Panev, 2015) calculated comparable cost estimates. Investment requirements were determined using an average of 100 m^2 for homes and 75 m^2 for apartments, as well as the national average for housing prices. According to these criteria, 'economically feasible' technical solutions are those that cost less than € 300/m2. It was determined that extensive renovations make economic sense and are achievable if their cost does not surpass 25% of the building's value. Above this point, the authors reasoned, it may be more prudent to create an entirely new structure than to renovate an old one.
Costs are frequently a major consideration when considering renovation projects. Retrofit costs are highly dependent on a variety of variables, including the state of conservation, the type of intervention chosen, the number of stories, total floor area, irregularities in the plan, the presence of adjacent buildings, local seismicity, soil type, and local material and labor costs.
Recent studies have estimated the costs of retrofitting apartment buildings, which are one of the most frequently erected building types in urban settings. This cost presently ranges between 100 and 230 euros per square meter (Kappos & Dimitrakopoulos, 2008).
The seismic strengthening component accounts for the majority of these renovation expenses, ranging from around 50 to 150 €/m2. High costs, along with limited access to money and a reluctance to incur debt, sometimes dissuade building owners from adopting seismic rehabilitation methods, all the more so when earthquakes are unpredictable in terms of timing and location. As a result, owners frequently feel that earthquakes will spare their families and property, and hence suppress potential preventive measures.

- *Financial barriers*

From a financier's standpoint, energy efficiency initiatives have significant transaction costs, are frequently small in scale, and are seen as hazardous due to the difficulties of precisely forecasting energy savings. The term of the financing may also be incompatible with the lengthy payback period associated with energy upgrading in buildings. Additionally, appropriate experience with EE loan underwriting and standardised evaluation procedures for quantifying and validating energy savings remain insufficient.
Another significant impediment is the absence of secondary markets to give investors with exit alternatives or additional liquidity for their investments. As a result, interest rates rise.
It is widely agreed that governments can play a critical role in encouraging EE and mobilizing more investments in the building industry, particularly for the existing building stock, by implementing the appropriate set of regulatory measures.

Among the measures, economic instruments tend to dominate the existing building policy framework, as they are critical for mitigating risks associated with lengthy payback periods, a shortage of funding, and activating the market for energy improvements. Simultaneously, the necessity for further market activity and private sector involvement is becoming increasingly apparent, as this is the only sustainable path forward for scaling up existing activities.

Financing instruments to overcome financial barriers

Loans and incentives are typically used when governments determine that the market alone cannot support the ideal level of energy efficient (EE) investments. They can help overcome the upfront cost barrier in part because they directly fill a financial shortfall and so enable a temporary market change. Additionally, the grant and subsidy programs increase public awareness and trust in EE projects. Direct investment subsidies are resource constrained and so cannot provide a long-term solution or support significant market uptake programs. Additionally, investment subsidies boost investors' cash flow, which may increase their access to debt financing (Bertoldi & and Rezessy, 2010). Almost all MSs employ public grant programs to fund EE projects. The primary downside is that it is difficult to establish the appropriate budget for subsidies during times of fiscal austerity in numerous MSs. Additionally, the percentage of free riders — recipients who would have carried out economically viable projects even without the subsidy – is rarely checked, making it difficult to assess the efficacy of a subsidy program properly.

In comparison to grant schemes, debt financing in the form of loans can be a more sustainable type of financing. Loans give liquidity and direct access to finance, which is especially important for EE measures that have a significant upfront cost, such as those associated with substantial remodeling projects. Private debt financing for energy improvements is often limited, as financial institutions are unfamiliar with these initiatives and view EE loans as high-risk. High transaction costs for relatively minor initiatives and a lack of financing on long-term terms sufficient to support deeper measures all function as impediments to market adoption. International financial institutions and national governments have intervened to solve some of these difficulties by providing subsidies through public-private partnerships that enable financial institutions to offer attractive lending conditions to customers.

Soft credit programs, which offer lower-than-market interest rates and longer repayment terms, and loan guarantees, which act as a cushion against first-loss non-payment, are two strategies via which public financing encourages and spurs investments in EE. They provide long-term financial coverage to assist in bridging the financing gap for EE projects through direct interest rate subsidies and risk premiums. Extensive repayment durations, low or no interest rates, short-term interest deferral periods, and/or the inclusion of payback grace periods are all examples of loan conditions. The most well-known plan is Germany's KfW, which has sponsored energy-efficient building improvements for several years.

The EE obligations (EEOs) are based on the notion that obliged energy providers must demonstrate that they have achieved energy savings through efforts that encourage or fund EE improvements in end-use facilities. Italy and France have energy efficiency requirements coupled with tradable white certificates (WCs), which means that accredited parties (not simply required energy providers) can earn WCs that can be traded later. (Bertoldi, Financing Energy Efficiency, 2009).

Typically, Energy Services Companies (ESCO) conduct energy-saving programs at no expense to the end user. The investment expenditures are recouped by energy savings realized over the contract time, allowing the end user to avoid investing in an uncertain field. After the contract expires, the end user owns a more energy-efficient building, resulting in lower energy expenses.

Typically, an ESCO implements the measures and provides expertise and monitoring throughout the contract's duration. Essentially, the ESCO will not be compensated unless the project achieves the anticipated energy savings (Bertoldi & Rezessy, 2005). In an EPC, the ESCO provides a performance guarantee that might take a variety of forms. The guarantee may be based on the actual amount of energy saved as a result of a retrofit project. Alternatively, the guarantee can state that the energy savings will be adequate to cover the cost of monthly debt payment.

On-bill financing lowers first-cost barriers by tying EE investment repayment to the utility bill, allowing customers to pay back a portion or all of their EE investment expenditures over time. Funds may come from utilities, the government, or outside parties, such as commercial banks. Energy savings from installed measures must be substantial enough that the total utility bill following the renovation does not surpass the pre-renovation bill. This device is especially beneficial for multifamily or rented homes where the split incentive discourages investment.

Retrofit Interventions' Technical Feasibility

The notion of sustainability often favors renovation over demolition and reconstruction (Ding, 2013), as renovation allows for the retention and reuse of structural components of buildings, resulting in resource savings and waste reduction.

However, seismic retrofit is not always technically feasible or desirable. When addressing retrofitting shared ownership buildings, economic feasibility is sometimes overlooked or ignored entirely, as the potential cost of interventions concerns owners more than the potential repercussions of an earthquake, and hence economic feasibility is ignored entirely. The technical feasibility of interventions when conventional seismic strengthening would have a negligible or no effect on the building's seismic resistance is examined here.

Occupants' Temporary Alternative Accommodation

Retrofit operations entail extensive labor that may result in a obstructing access to a structure in part or entirely, requiring the house to be emptied and abandoned throughout the retrofit procedure, which may last several months. This causes significant inconvenience to the inhabitants, higher rental fees for alternative accommodation, a stressful interruption of daily routines, and psychological concerns about the restoration works being completed successfully and on time.

Ownership and tenure

Building ownership has a major impact on the rate and extent of retrofit strategies adopted in rehabilitation projects. The public sector, one could argue, should be a pioneer in "deep renovations," as its massive portfolio of buildings should provide various economies of scale. Private owners may be unwilling to act early, and suitable renovation rates and depths may require encouragement, incentives, and legislation (BPIE (Building Performance Institute Europe), 2011).

In a BPIE study, data on residential and non-residential buildings in the were classified according to their ownership, i.e. public versus private property buildings. According to the data, the majority of buildings are categorised as private property, while 20% are classified as 'pure' public property (BPIE (Building Performance Institute Europe), 2011). Another critical issue that surely affects the ability to implement rehabilitation initiatives to improve the performance of the residential building stock is tenure.

Discussions and Conclusions

However, the market for EE is complex, and many actors, including as multi-family building owners, tenants, small enterprises, and other non-creditworthy actors, are not often supplied by current systems (e.g. people not paying income tax). While grants and subsidies might operate as extra incentives, it can be challenging to negotiate favorable financing conditions for extensive renovations due to their lengthy payback periods. Commercial banks' conventional mortgage underwriting methods do not take EE characteristics and energy prices into account. Due to the difficulty of anticipating energy savings, uncertainty about the return on investment might operate as a barrier to diversifying current capital sources and attracting private investment.

This article examines several novel methods and measures.

On-bill financing is a strategy that lowers initial costs by tying EE investment payback to the utility bill. Additionally, it can be utilized to circumvent split incentive schemes. Several barriers to on-bill programs that must be overcome include increased administrative expenses (due to the demand for personal energy audits and new billing mechanisms), risk allocation in the case of insolvency, obligation transferability in the event of real estate purchase, and procedures to guarantee energy savings surpass loan or tariff payments.

In terms of interconnection with other policy measures, financial instruments could be linked to energy building codes, with incentives provided for projects exceeding current code requirements, or to Energy Performance Certificates. The latter shall be used to either establish the EE criteria for planned intervention work or as a compliance check tool, in which an Energy Performance Certificate certifier conducts a check prior to and/or following the intervention.

3. EMPIRICAL TRACK; REFERENCE BUILDING ANALYSE

3.1. Description of the structure of the structure

The buildings that will be used as a case study for analyses purpose is are designed before the year 1979, named as type 77/4, 77/5, 77/6 and 77/11 according to the previous institute of construction. Before this year, the design code used was the KTP-63. It had little knowledge for the seismic risk and design. Therefore, the 77/4-6,11 buildings, designed in 1977, has no seismic concrete belts. The buildings designed and built after the 1979 (the year of the significant earthquake talked in the previous paragraphs) have decent seismic measures and seismic columns and belts. These typologies of building are the most common pre-1979 URM buildings in Tirana and Albania These can serve as a reference for the social masonry buildings built in the communism era before the year 1980.
Also, these building have the highest number of storeys (five) among the other pre-1979 building. The thickness of the bearing walls is 38 cm for the first three storeys, and 25 cm for the upper two. The slab are ribbed slabs, with thickens 15 cm, and ribs every 20 cm. The height of on storey is 2.8 meters.

There have passed about 40-45 years since the building was builds. According to the European design codes (EC-8, 2004; NTC, 2008), the service life of the is in its end. Therefore, taking into account also the deficiency of the previous seismic codes in Albania, there is an immediate need for the study of the seismic performance and retrofitting.
In absence of the laboratory tests, the analysis will be done taking in consideration the mechanical properties of the material as in the time they were built, without considering the deterioration.
The analysis will be performed with ETABS software, and for the seismic performance will be used the KTP-89 spectre and EC-8 spectre (since Albania is trying to implement this code as a national standard).
In the figures below is shown the plan and elevation view of the reference building 77/4-6,11, taken from the from the Central Technical Archive of Construction (AQTN).

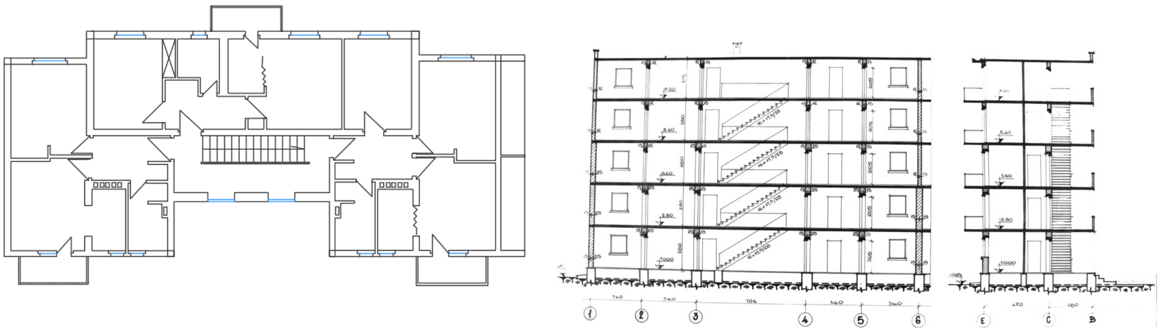


Figure 3-1 Plan and elevation view of building 77/4

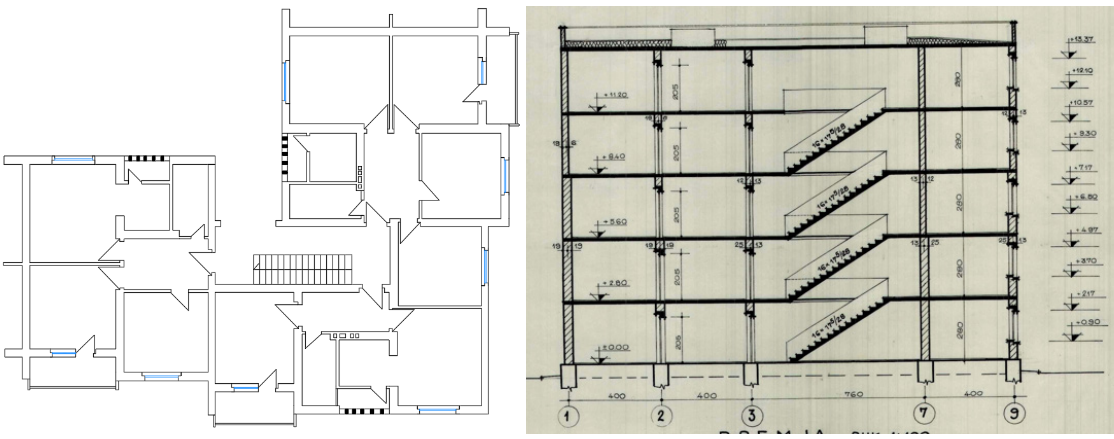


Figure 3-2 Plan and elevation view of building 77/5

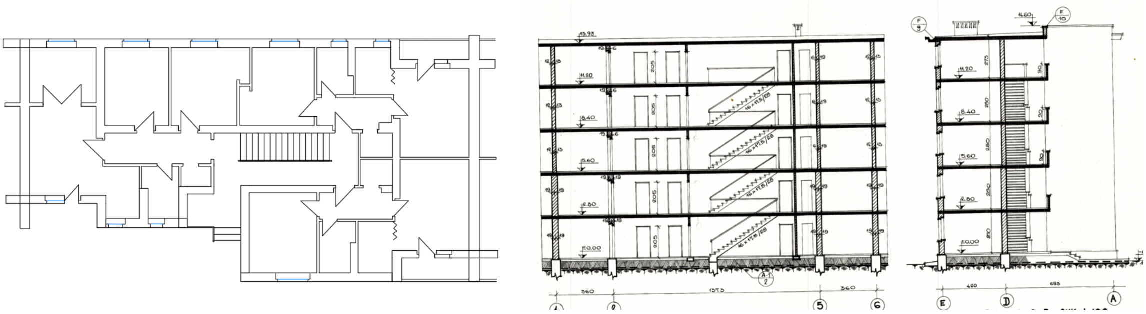
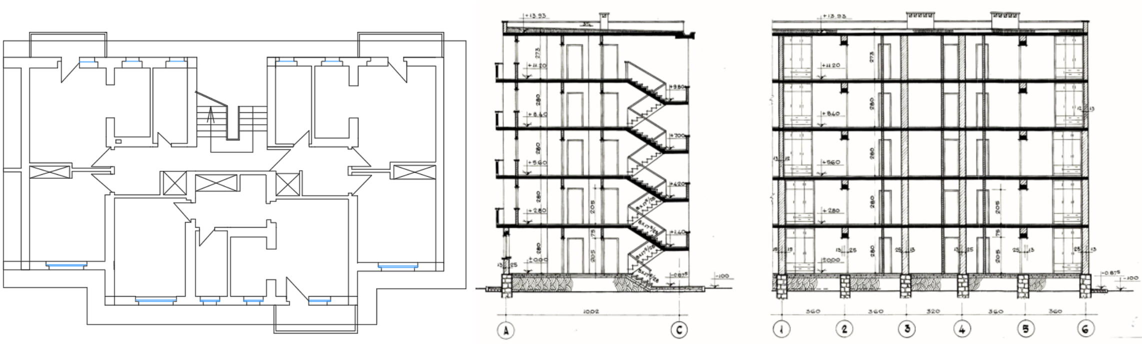


Figure 3-3 Plan and elevation view of building 77/6



Plan and elevation view of building 77/11

For research purposes only one typology will be studied; the most vulnerable building. For this purpose, a nonlinear analysis will be made with the computer software ETABS. From these nalysis will be determined the capacity curve of the building. The lowest capacity curve will identify the most vulnerable building.

Modeling the buildings

Static loads and seismicity

Will be taken in consideration the dead and live loads.

The dead loads include the self-weight of the building (slabs and internal non-bearing walls with their respective layers). The dead load calculated is g = 6 kN/m^2.

The live load is according to EC-1, and will be taken q = 1.5 kN/m^2 for the first four storeys, and q = 2 kN/m^2 for the roof.

Seismic spectre

As mentions above will be considered the analysis with two different spectres, KTP-89 and EC-8.

For the seismic spectre it has been chosen the city of Tirana (it has the major number of buildings).

According to KTP-89, the soils is of category II, intensity of I = 8 degree, and ductility $\psi = 1$.

For the EC-8 spectre are these characteristics; $a_g = 0.29g$ (IGJEUM, 2021), soil category of B and the behaviour factor q = 1. In the figure below are shown the two seismic spectre for Tirana.

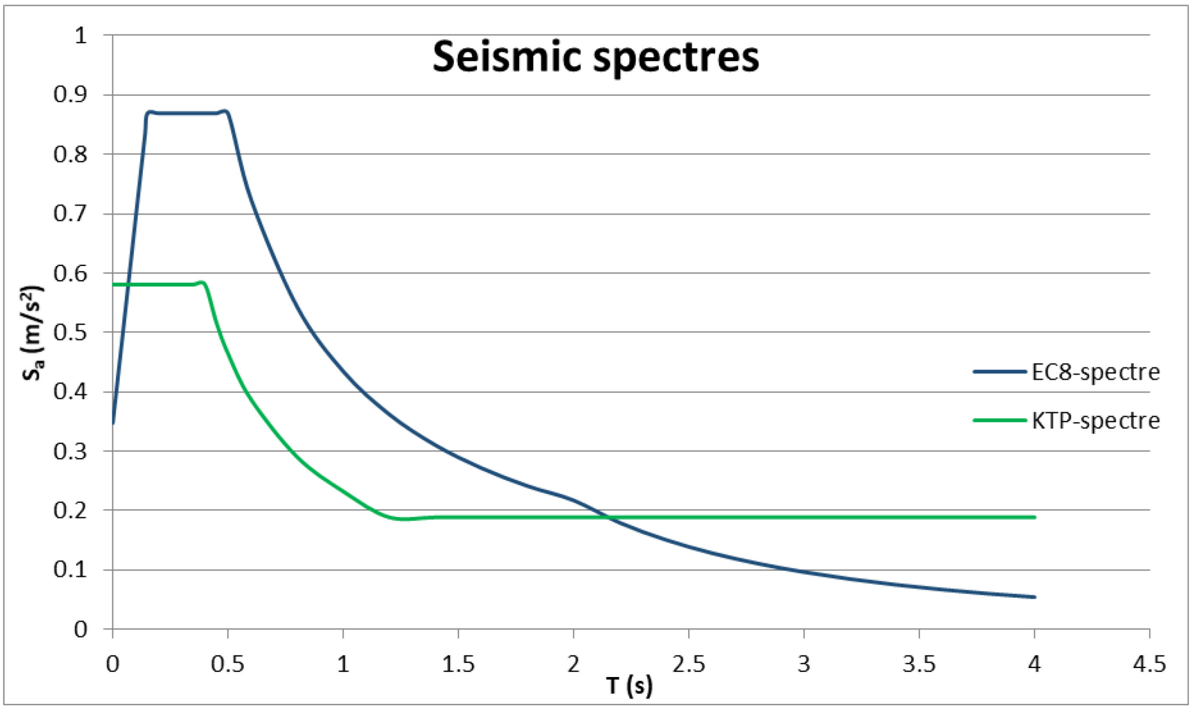


Figure 3-4 The KTP-89 and EC-8 spectre for Tirana

As we can see from the figure above, there are in a large scale differences of the two spectres. The EC-8 one is clearly more powerful and whith high reserves in seismic analyses. It also shows the deficiencies of the Albania current code. Further information for the comparison of the two codes are shown in (Marku, Guri, & Vesho, 2021)

Masonry properties
To properly analyse the structure, it is needed to determine the mechanical properties of masonry. The compressive strength of brick is f_b = 7.5 MPa and of mortar is f_j = 2.5 MPa (according to the original design specifications). We can determine the compressive strength of the masonry wall with te equation below:

$$f'_m = 0.63 * f_b^{0.49} * f_j^{0.32} = 0.63 * 7.5^{0.49} * 2.5^{0.32} = 2.26\ MPa$$

and the elastic module E = 550 * f'_m = 550 * 2.26 = 1240 MPa

The respective strain for the compressive strength is:

$$\varepsilon'_m = C'_j \frac{f'_m}{E_m^{0.7}} = \frac{0.27}{f_j^{0.25}} * \frac{f'_m}{E_m^{0.7}} = \frac{0.27}{2.5^{0.25}} * \frac{2.5}{1240^{0.7}} = 0.0033$$

The ultimate stress: $f_{mu} = 0.2 * f'_m = 0.2 * 2.26 = 0.453$ MPa
The ultimate strain: $\varepsilon_{mu} = 2.75 * \varepsilon'_m = 2.75 * 0.0033 = 0.0091$

With these values, we can generate the stress-strain graph as in figure below:

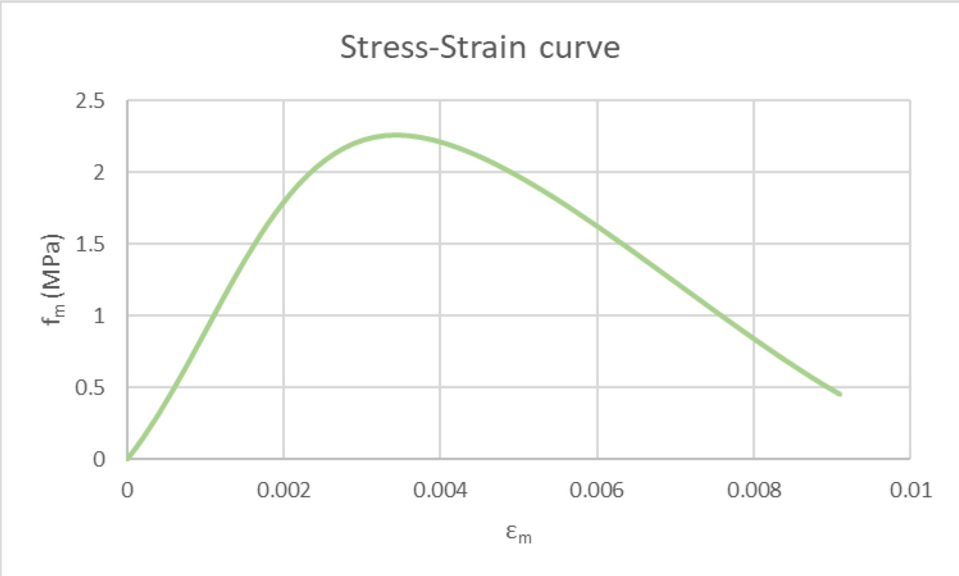


Figure 3-5 Stress-Strain curve for comprension S_{11} and S_{12}

For the shear strength (S_{12} stresses), KTP reccomends the for mortar with 2.5 MPa comprensive strength, the shear strenght is 0.11 MPa.
Eurocde gives two alternatives:
$f_{vk0} = 0.2$ MPa for mortar with 2.5 MPa comprensive strength or,
$f_{vk} = 0.065 * f'_m = 0.065 * 2.26 = 0.15$ MPa.
Will be taken into account the lowest value, which is 0.11 MPa, according to KTP.
The shear module, according to Eurocode is:
G = 0.4 E = 0.4 * 1240 = 490 MPa.
$\varepsilon_{el} = \frac{\tau_{el}}{G} = \frac{0.11}{490} = 0.00022$

With these values, we can generate the stress-strain graph for the shear stresses as in figure below:

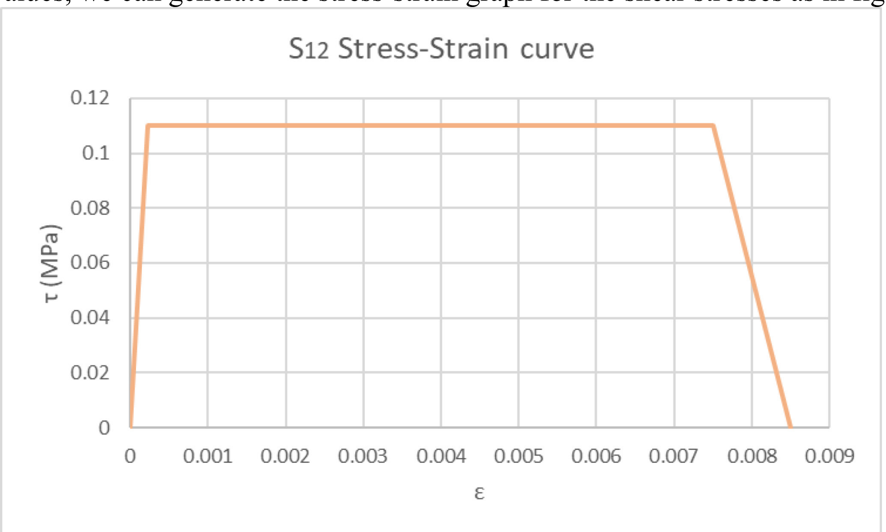


Figure 3-6 Stress-Strain curve for shear S_{12}

The curve is considered ideal bilinear with maximum shear strength as the cohesion between mortar and brick. This assumption is made because of true behavior is very close to the bilinear shape according to experimental tests. Elastic maximum deformation is obtained from the first part of the almost linear curve of experiments on masonry. In order for the program to calculate the maximum displacement of the building, the last part of the graph is added which reduces the shear resistance to zero. In this way the calculation stops when the bearing masonry is destroyed to the extent that overall stability is compromised.

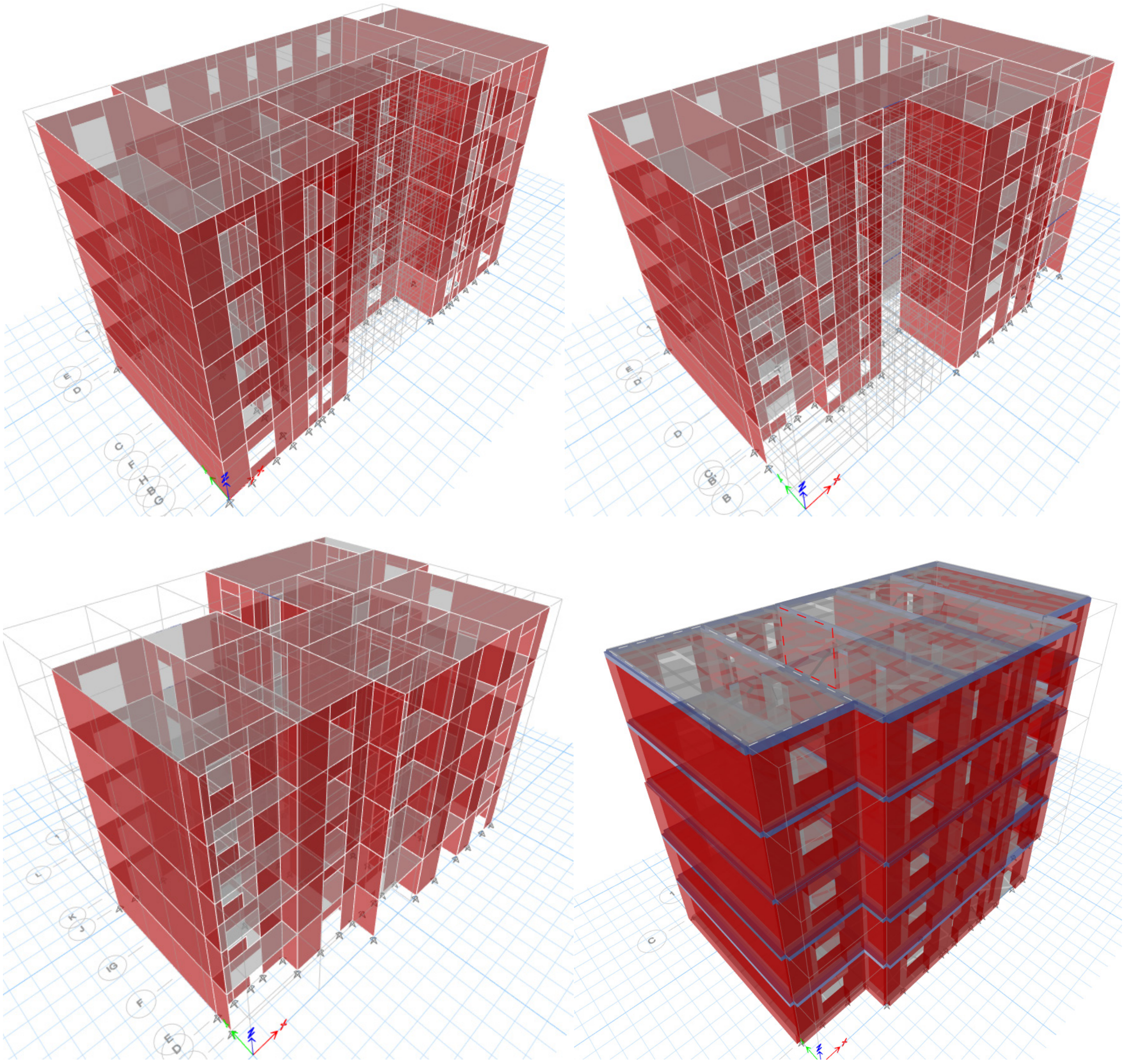


Figure 3-7 3d views of models a) 77/4 b) 77/5 c) 77/6 d) 77/11

From the structural analysis, we calculate the pushover curve, according to the two orthogonal directions.

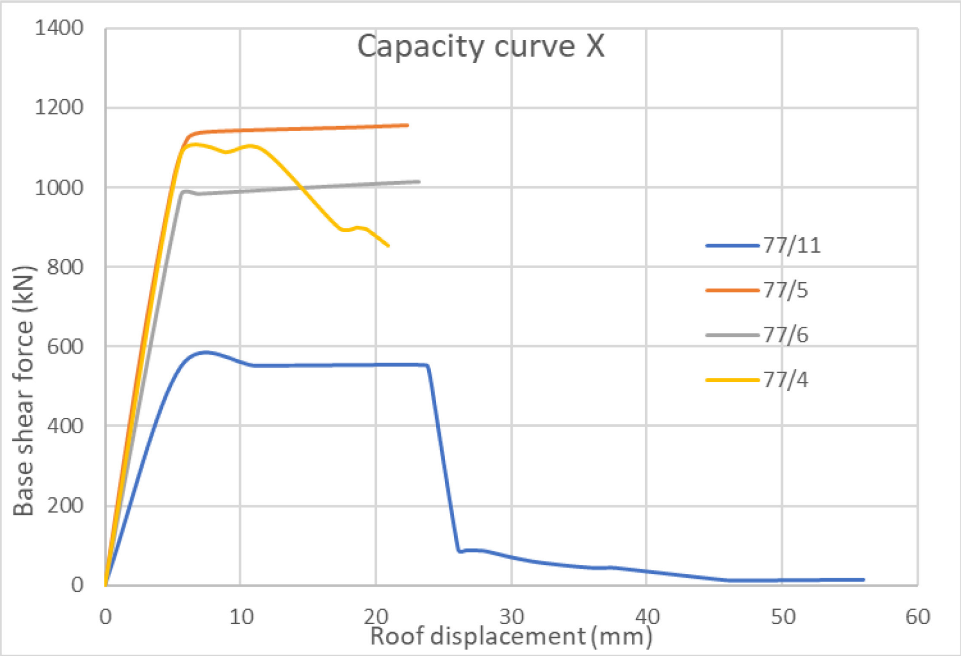


Figure 3-8 Pushover curves X-direction

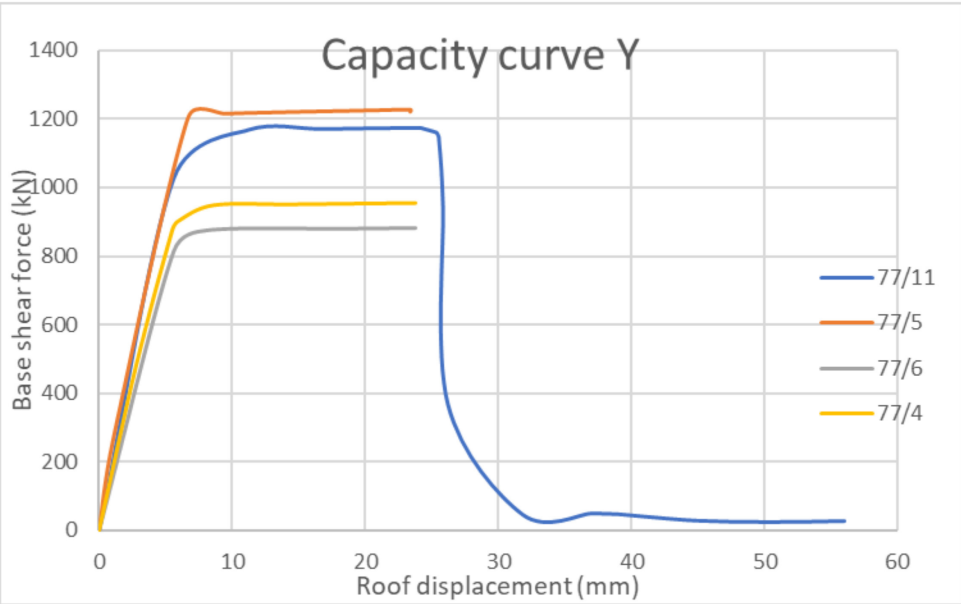


Figure 3-9 Pushover curves Y-direction

As shown in figure 3-8, building 77/11 has the lowest capacity curve, therefor it is the most vulnerable in X direction, while building 77/5 is the least vulnerable.
While regarding the Y-direction, the most vulnerable building is 77/6, and the least one is 77/5.

In order to assess correctly the most vulnerable building, pushover curves for both directions will be put in a single diagram. From figure 3-10 we can judge that the building 77/11 is the most vulnerable one, therefore, the further analysis will be done only on building type 77/11 (figure 3-11).

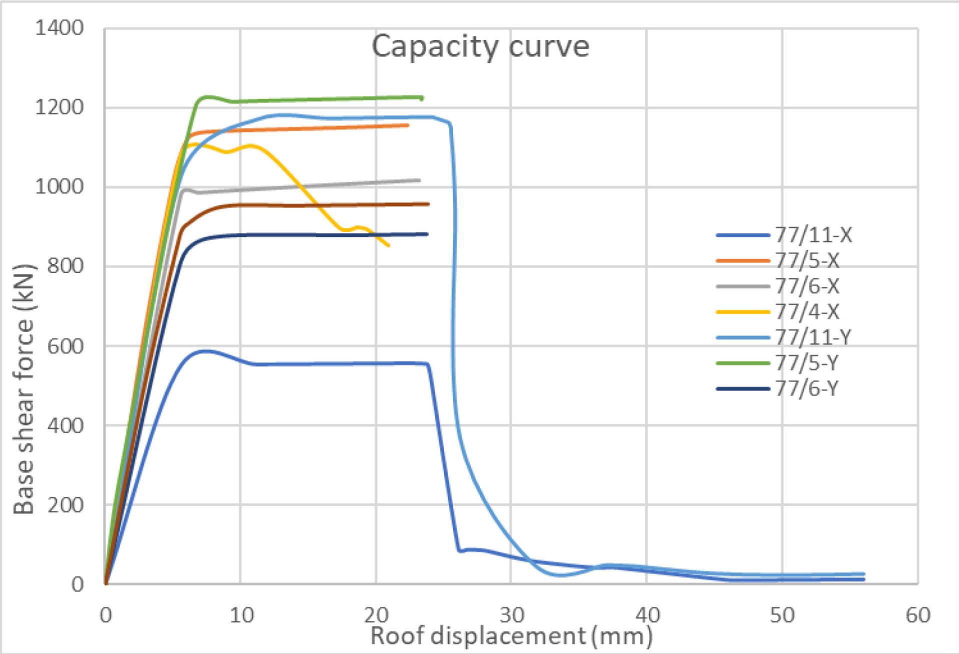


Figure 3-10 Pushover curves


Figure 3-11 Photo of the building 77/11

ETABS modeling of the structure
For modeling purposes are made these assumptions:
the masonry bearing walls are modeled as layered shell.
the slab is modeled as a rigid diaphragm that allows only vertical displacements.

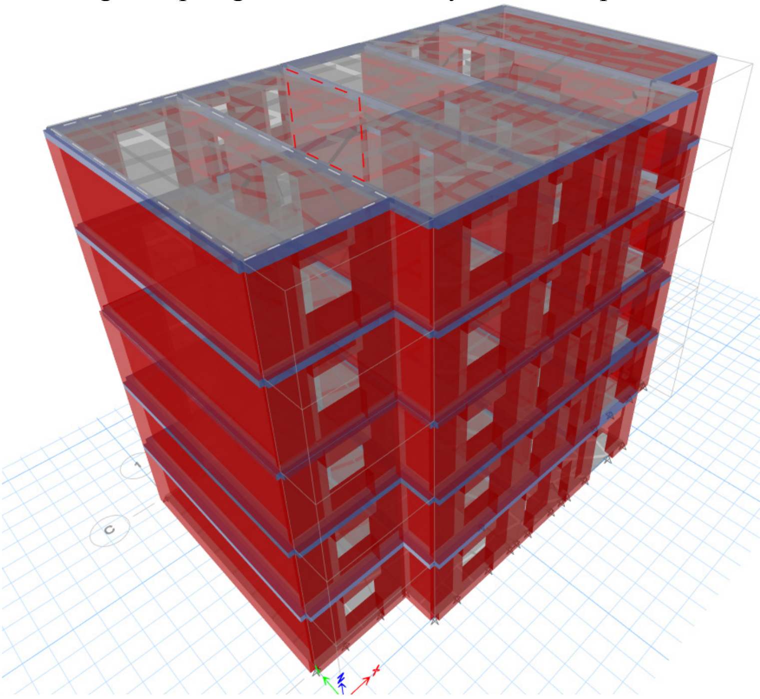


Figure 3-12 3D modeling of the structure

3.2. Nonlinear analysis

For the nonlinear analyses is considered the first modal vibration of the structure. The first mode is in X-direction. The period of first mode is $T_1 = 0.69$s, and for the second mode is $T_2 = 0.5$s. As for controlled displacement is considered a joint in roof.
The first analysis is done in the X direction:

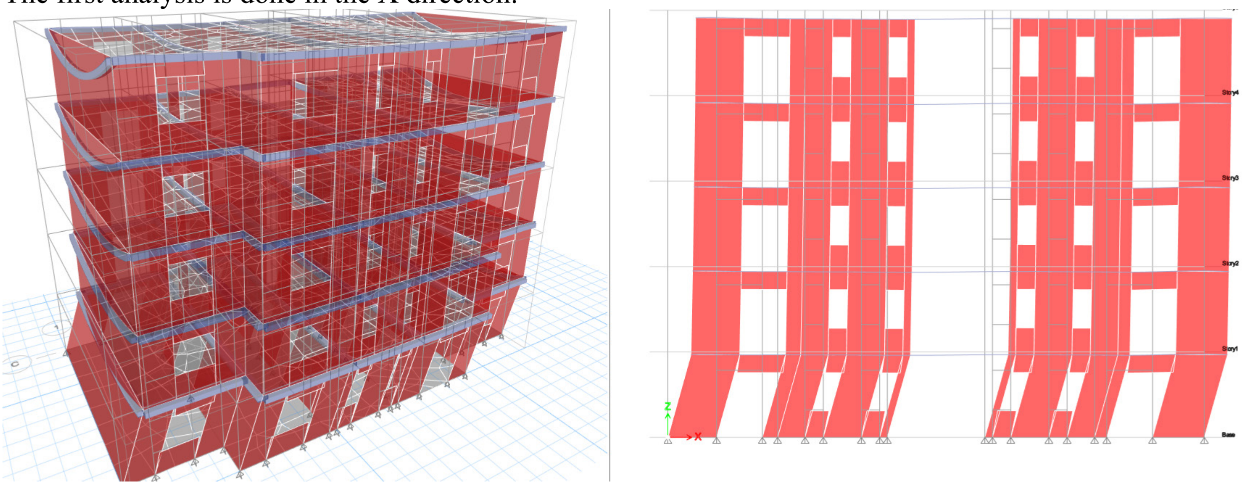


Figure 3-13 Maximum nonlinear displacements X direction

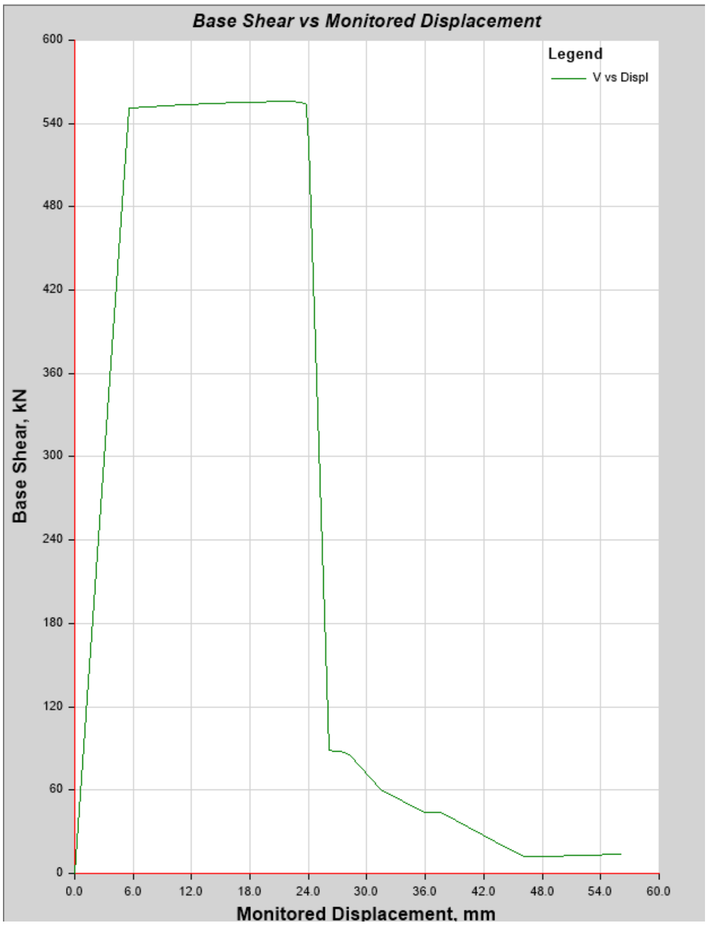


Figure 3-14 Capacity curve x direction

To analyse the structure according to the Calvi service limit states, it is necessary to calculate the interstorey drifts and compare them to limit drift as we discussed in the previous paragraphs.
The drifts for the service limit states are as below (story height is 2800 mm):
LS2 =0.1% * 2800 = 2.8 mm
LS3 =0.3% * 2800 = 8.4 mm
LS4 =0.5% * 2800 = 14 mm
Below are presented the interstory drift for each story corresponding to the steps of the pushover analysis.

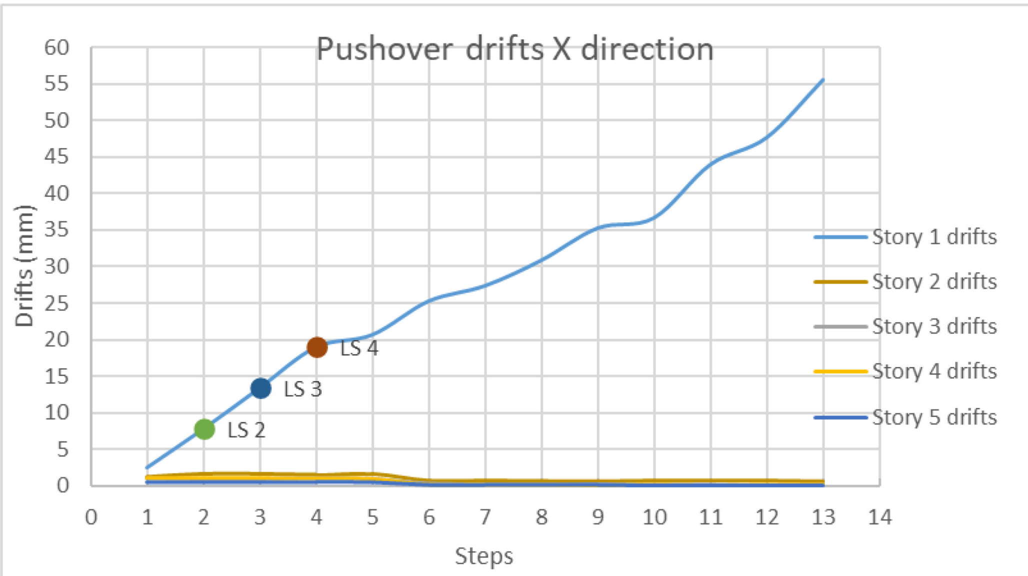


Figure 3-15 Pushover drifts X direction

As we can see from the above graph, the maximum drifts are in the first storey. This is attributed to the shear force which is greater in the first floor. Therefore, the first story acts as a soft storey, and will be needed to strengthen. All other storeys do not suffer plastic deformation since relative displacements are less than 0.1%.
To analyse better the structure, the service limit states are equivalented in the capacity spectrum curve as below:

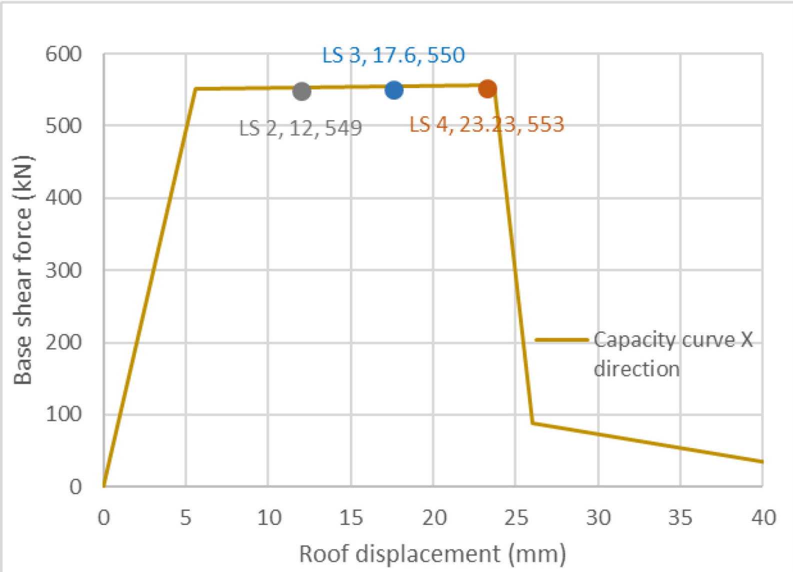


Figure 3-16 Limit states in the capacity curve x direction

To understand in which direction the structure is weaker, the same analysis was done also according to the Y direction.

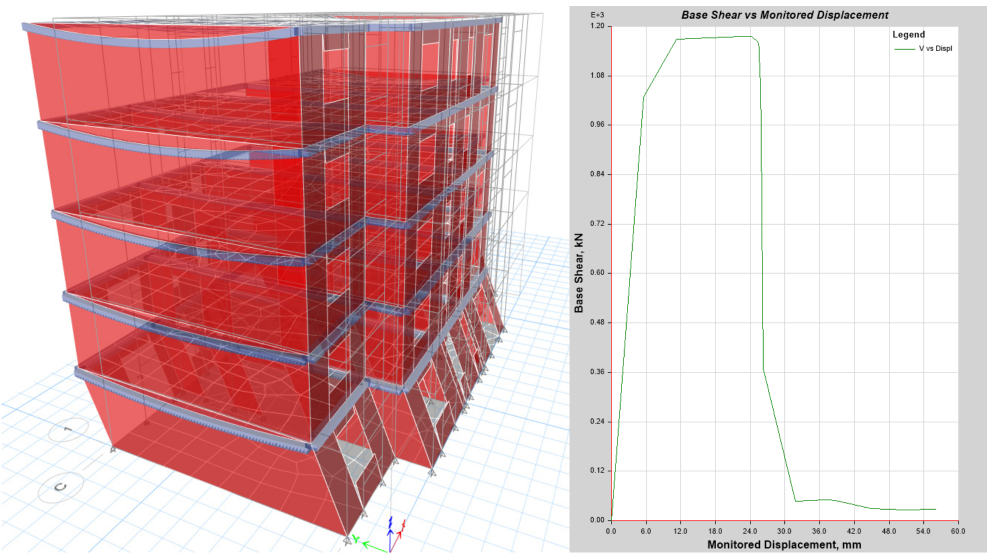


Figure 3-17 Maximum nonlinear displacements (a) and capacity curve (b) Y direction

The interstory drift for Y direction for each story corresponding to the steps of the pushover analysis are presented below:

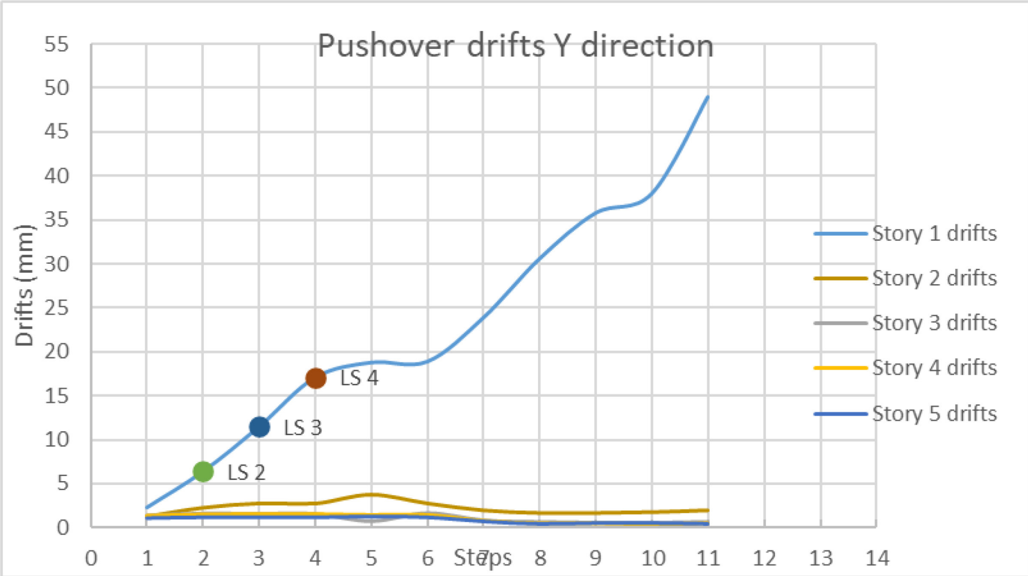


Figure 3-18 Pushover drifts Y direction

Also,in Y direction, the maximum drifts are in the first storey. This is attributed to the shear force which is greater in the first floor. Therefore, the first story acts as a soft storey in both directions. The service limit states are equivalented in the capacity spectrum curve as below:

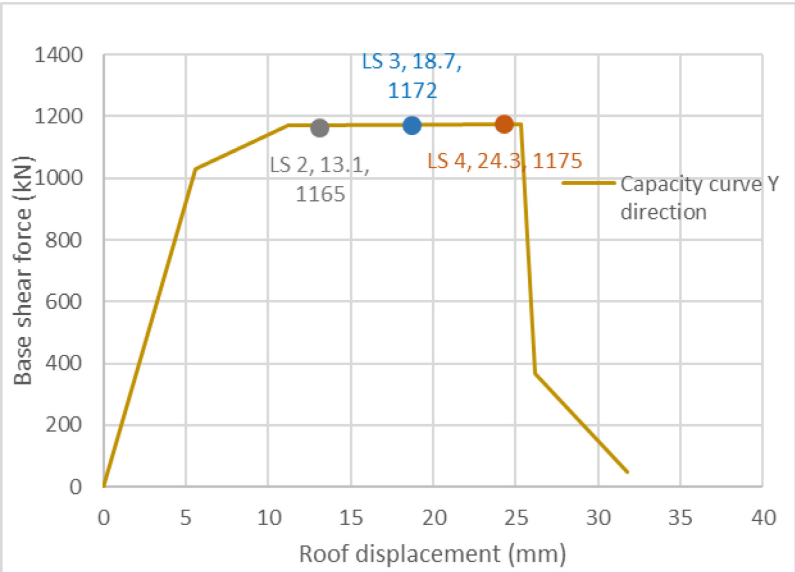


Figure 3-19 Limit states in the capacity curve Y direction

Discussions

The pushover nonlinear analysis expresses the bearing capacity of a building when it is subject to horizontal forces. Hence it is a very valuable procedure that helps us assess one of the most dangerous horizontal forces as is the seismic one.

For the 74/4 type building we notice that the seismic behaviour is weaker in X direction. The maximum shear force in X direction is 553 kN for roof displacement of 24 mm, while in Y direction is 1175 kN for roof displacement of 24.1. The base shear in Y direction is far greater then in X direction. This is mainly attributed to the bearing masonry walls; in X direction there are only two, while in Y direction are six.

The ductility is almost the same since the displacements at the moment of destruction are almost equal.

The building type 74/11 collapses by seismic shear force on the base floor. The reason is the greater shear force in the first floor.
As noted by the interstoreys drifts, the first floor suffers critical damage from seismic forces, while the other stroreys are hardly damaged at all. This is same for both X and Y directions. This is also shown in the 3-dimensional view of model at the point of collapse.
On the whole this behavior of the building in pushover analysis, but also in seismic, presents a poor horizontal load distribution. Given that the first floor is weak, this causes the building to be demolished before it is well utilized the bearing capacity of other floors. It would be more convenient if the building had interstoreys drifts which were in reasonable relation to each other. This thing can is achieved with reinforcements, as we will see below in this dissertation.

Seismic performance of the structure
The seismic performance of the 74/11 type building will be calculated below according to the improved "Equivalent Linearization" procedure found in the document FEMA 440. Its steps were explained in the previous chapters. The spectres used, are according to KTP-89 and EC-8.
Below we present the building performance degree for both X directions and Y. The same graph shows the performances of both KTP and Eurocode spectra.

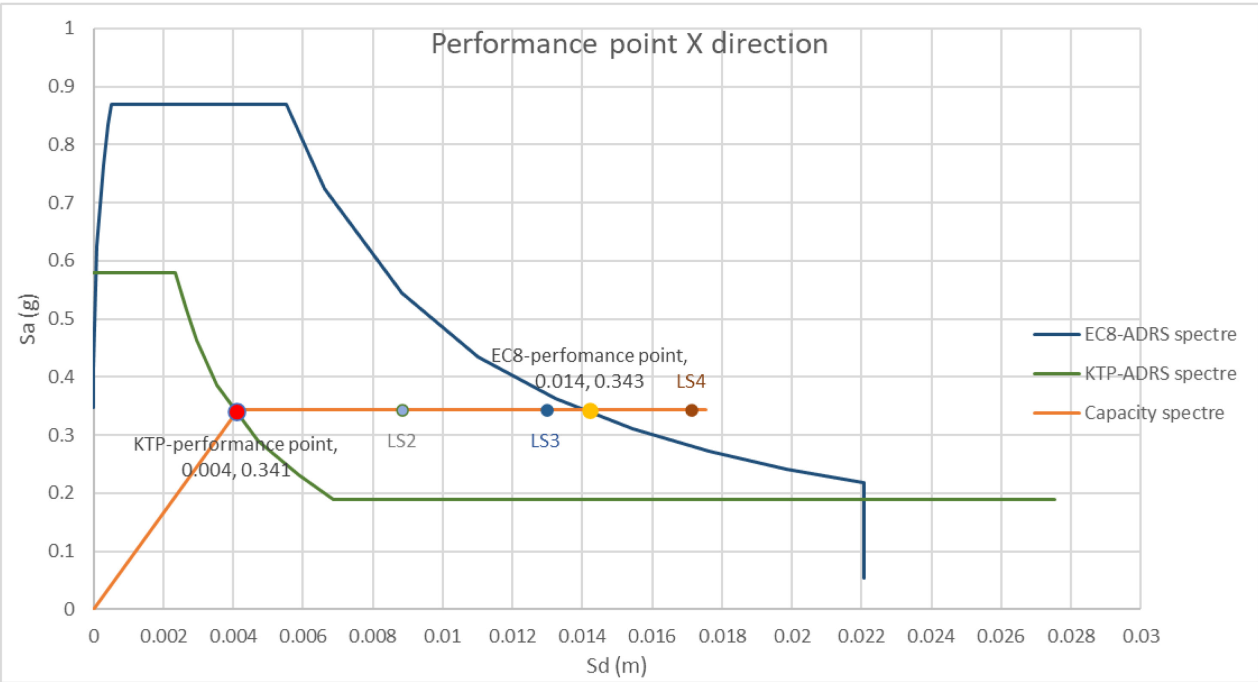


Figure 3-20 Performance point X direction

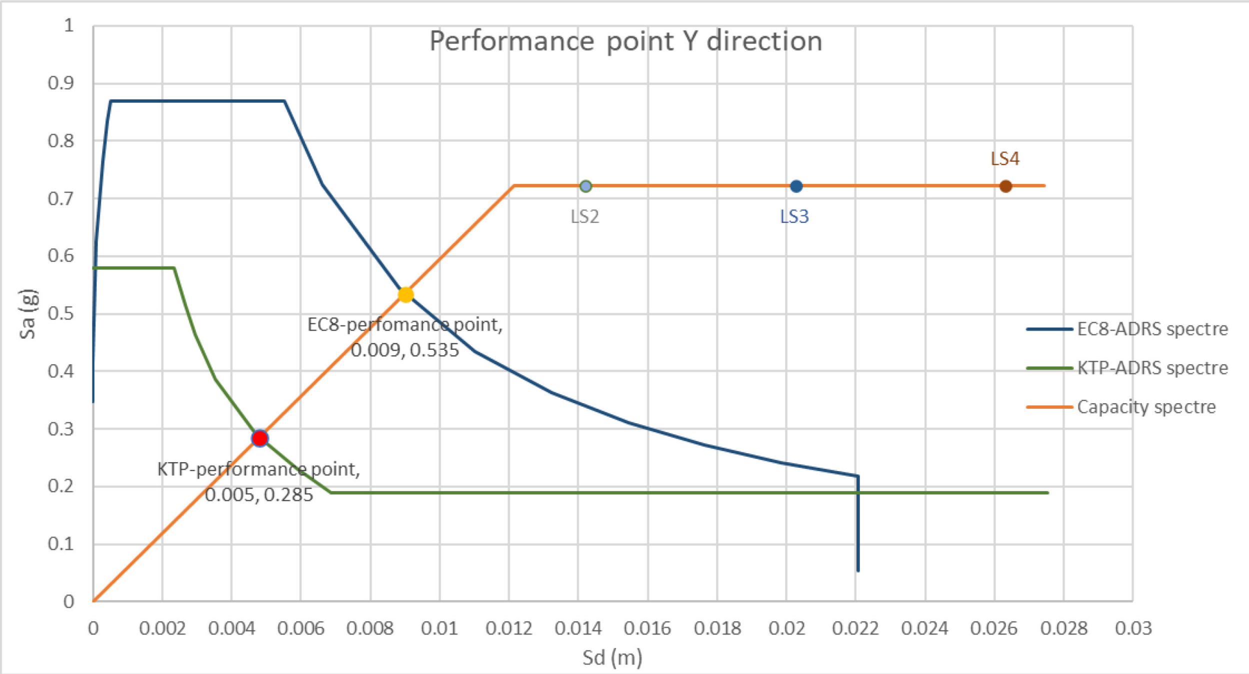


Figure 3-21 Performance point Y direction

As the graph indicates, the Eurocode 8 spectrum causes more damage to the building. This means that displacements, accelerations, vibration durations, and ductility are increased. This is to be expected, considering that the Eurocode 8 spectrum has greater values graphically than the KTP spectrum. Eurocode is significantly more advanced than KTP in terms of parameters and analysis of ground accelerations when it comes to risk calculation. The latter are determined by taking into account the area's historical earthquakes, geology, and geotectonic.
Although the building is safe in the X direction according to KTP, it still needs to be analyzed according to Eurocode 8, which is the most advanced and least favorable.
However, it is critical to demonstrate how significantly the two calculations differ.
In the X direction, according to EC-8, can withstand the earthquake, but it has a limit state of LS3. This mean that after the earthquake, the building must have deep structural repairs which are going to be costly.
According to KTP, the performance point is achieved without any minor damage.
In Y direction, since building does not have any damages, as KTP and EC, when withstanding the design earthquake, it does not need strengthening in that direction. Therefore, the further analysis and strengthening will be done only in X direction.

3.3. Strengthening of the building

The building type 74/11 withstands without destroying both spectra considered, but Eurocode 8 spectrum causes great damage approaching the point of destruction.
The building would have to be repaired at great cost to bring it back in good habitable condition. The situation could be even worse in reality if there are degradations in bearing walls. So, the best solution will be was the prevention of earthquake damage.
Nowadays there are several ways to prevent damages from earthquake or to increase the bearing capacity against horizontal shear force. Ways of strengthening have been discussed in previous chapters. In this chapter we will focus in these four types of reinforcement:
TRM, CFRP, Ferrocement and adding steel frames.
These solutions are given based on the possibilities of integration with the energy efficiency aspects. TRM, CFRP and ferrocement, in the phase of implementation in object, have the same methodology as the interventions on the building envelope, especially on the outside walls. Therefore, it can help to reduce the labour costs. Adding steel frames can help generate new shading system and also improving the facades.

In the ETABS program the reinforcements will be modeled as an add-on layer masonry on the outside.
To obtain economical solution as much as possible is not necessary to strengthen on all floors. From the above analysis we note that it should reinforced the first floor as the most unfavorable, as here the seismic shear force is maximum.

- *Nonlinear modeling of reinforcements in ETABS*

In ETABS, the reinforcements will be represented as a layer that overlaps on the exterior of the masonry. This will be accomplished by the use of the existing modeling of masonry with nonlinear layers. We're going to add a layer to the layered element to symbolize the new reinforcement. Due to the variety of reinforcements available, there are numerous possibilities for selecting reinforcements. We'll look at two of them in particular: CFRP and TRM.

• *Nonlinear modeling of carbon fiber TRM*
This mesh layer with 10mm squares of carbon fiber is applied with cement mortar on masonry. The elastic behavior is fragile and works only in tension. Once it reaches maximum in tension the material is destroyed. Same as above we must reduce the bearing capacity to zero after rupture. According to the study of C. Papanicolaou, 2010 (Papanicolaou C. , 2010), the equivalent thickness is 0.047mm. Also, the same study gives us details on tensile strength (157kN / m) and maximum deformation (1.5%). By means of equivalent thickness and bearing capacity per linear meter we find maximum tensile stress (Papanicolaou C. , 2010).

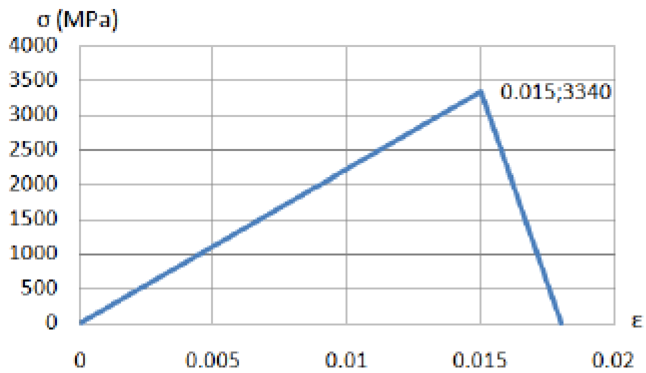


Figure 3-22 Stresses-strain graphs for carbon fiber TRM (Source: Papanicolaou, 2010)

• *Nonlinear modeling of FRP with carbon fiber*
This layer of carbon fiber is applied with epoxy adhesive over masonry.
The elastic behavior is fragile and works only in tension. Same as above we must reduce the bearing capacity to zero after rupture. According to the study of Valluzi, 2014 (Valluzzi, Da Porto, Garbin, & Panizza, 2014), thickness equivalent is 0.17mm. Also, the same study gives us details on maximum tensile strength (2735 MPa) and maximum deformation (1.26%). With these to the data graph is constructed below (Papanicolaou C. , 2010).

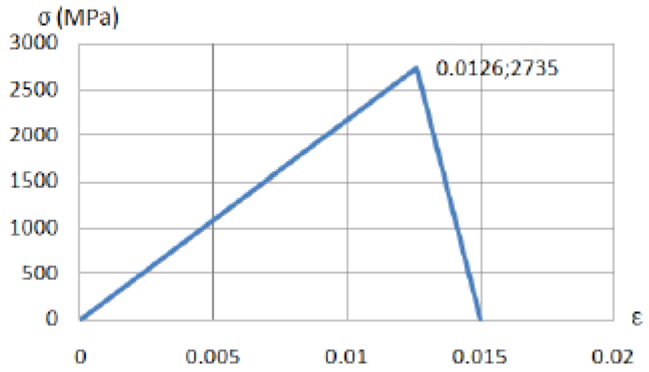


Figure 3-23 Stresses-strain graphs for carbon fiber FRP (Source: Papanicolaou, 2010)

Nonlinear analysis with TRM

For the nonlinear analyses is considered the first modal vibration of the structure. The fist mode is in X-direction. The period of first mode is T_1 = 0.69s, and for the second mode is T_2 = 0.49s. As for controlled displacement is considered a joint in roof.

The analysis is done in the X direction:

Below are given the results of the nonlinear analysis.

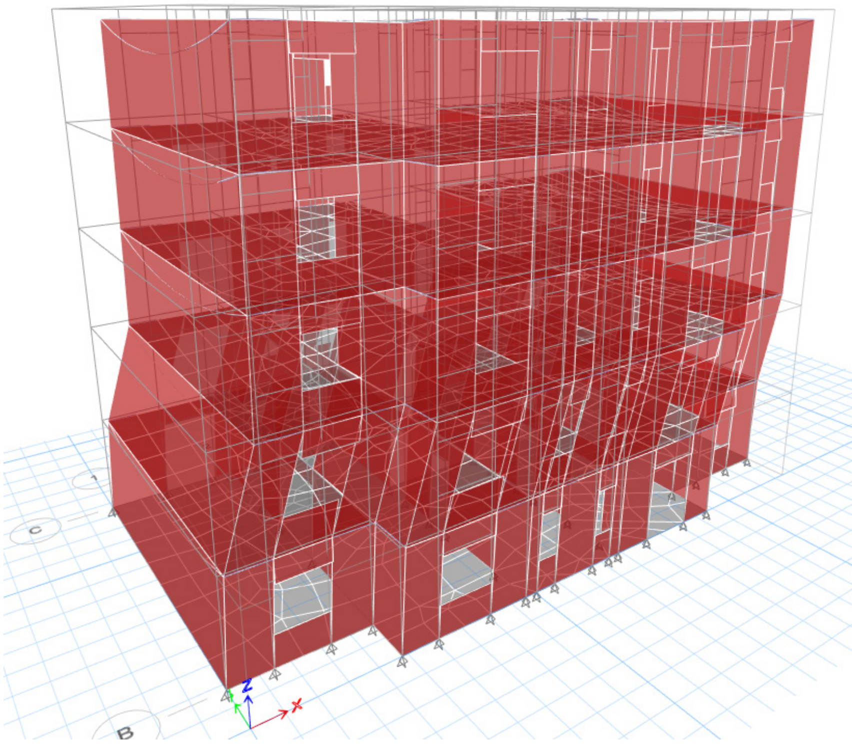


Figure 3-24 Maximum nonlinear displacements - TRM

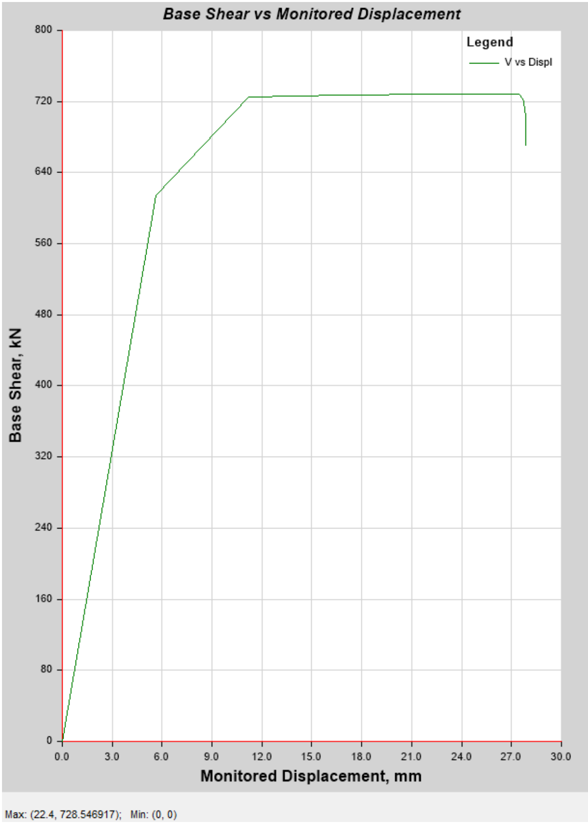


Figure 3-25 Capacity curve – TRM

The interstory drift for x direction for each story corresponding to the steps of the pushover analysis are presented below:

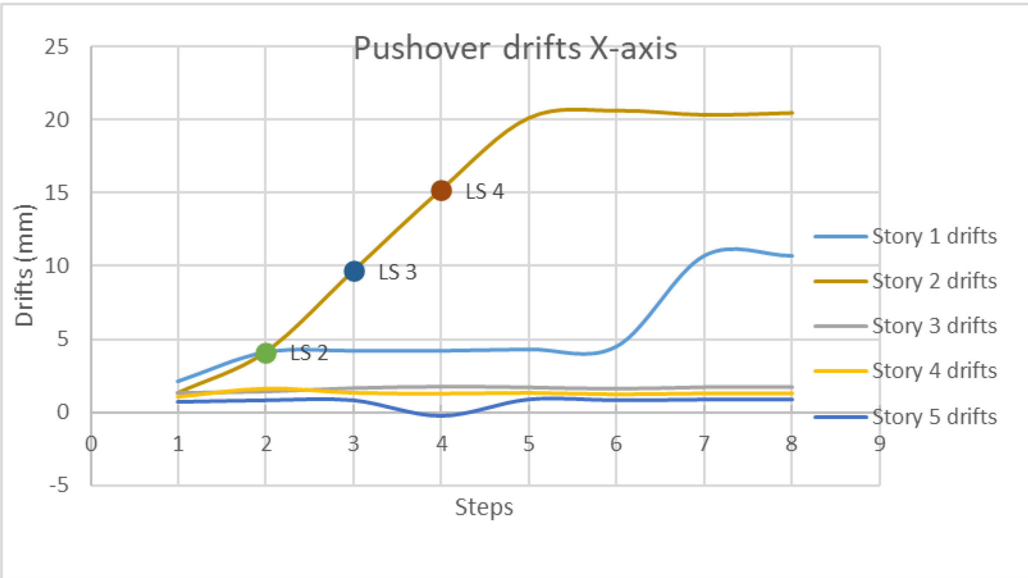


Figure 3-26 Pushover drifts - TRM

It is noted that interstitial displacements are more comparable to each other for the first two storey. This shows a better redistribution of shear stresses in masonry. Now the second storey floor is weaker and therefore acts as a soft storey

The service limit states are then presented in the capacity curve as below:

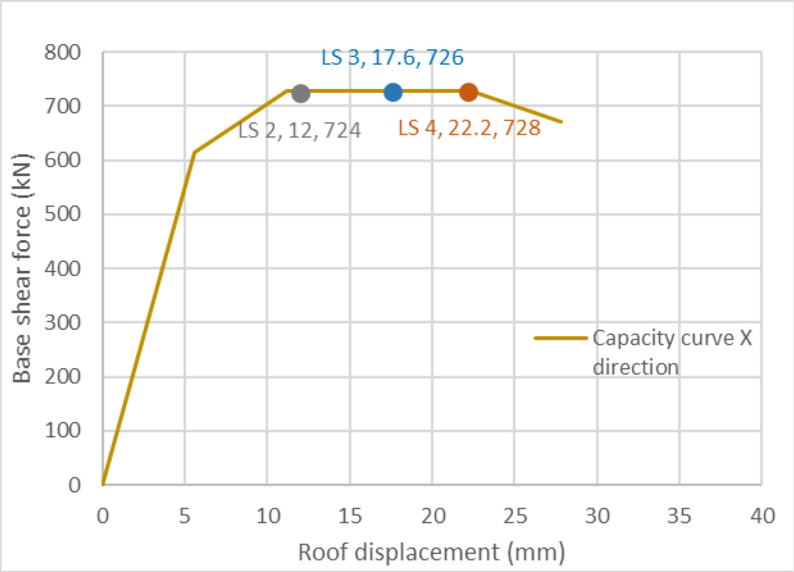


Figure 3-27 Limit states in the capacity - TRM

The strengthening of the masonry floor the capacity curve greater values of shear force. It raises it from 553 kN to 728 kN. But it doesn't raise the ductility since the ultimate displacement rest almost the same.

Seismic performance of the structure with TRM

The seismic performance of the reinforced building will be calculated the same as for the case without reinforcement. So, the nonlinear standard procedure will be applied FEMA 440. It will then be judged on improving the seismic capacity of the building type 74/11.

Below is presented the building performance degree with TRM reinforcement. The same graph shows the performances of both KTP and Eurocode spectra.

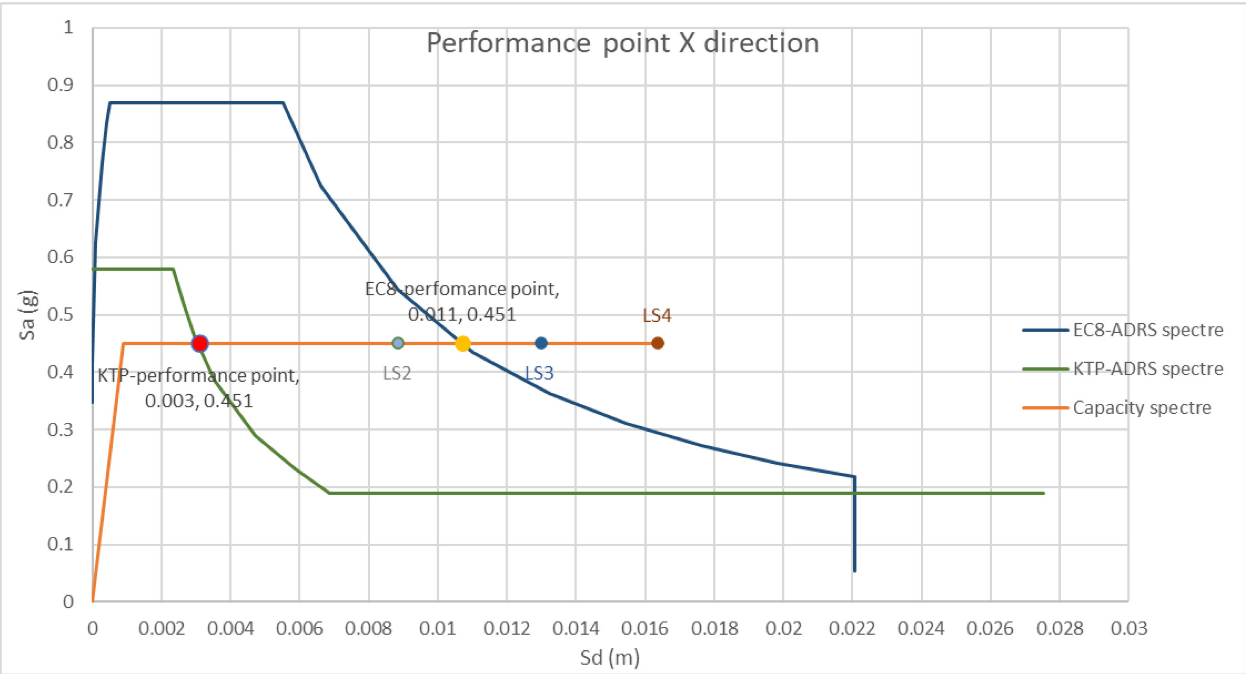


Figure 3-28 Performance point – TRM

The spectrum according to Eurocode 8 causes significant damage to the building without reinforcement.

With the reinforcement the performance point is achieved for higher displacements and higher spectral accelerations. So, in general the building more ductile and is safer. In terms of shear force capacity, we notice an increase of it. This increase is attributed to the increase in the effectiveness of masonry as a result of redistribution of stresses on the two floors.
Also, according to EC8, the building withstands without collapse the design earthquake. The service limit state is LS2 that mean it suffers minor damages, while without TRM it was the LS3 level.
The creation of the soft story in the second floor might be a problem, but since the structure is in LS2, it means that would no be major damages and therefore isn't a significant problem. From the structural point of view, it would be recommended to strengthen the second floor, but TRM is a high-cost material, there t is let to the investors and owners to decide.

Nonlinear analysis with CFRP
For the nonlinear analyses is considered the first modal vibration of the structure. The fist mode is in X-direction. The period of first mode is T_1 = 0.69s, and for the second mode is T_2 = 0.49s. The analysis is done in the X direction. As in the case of TRM, only the first floor is reinforced.

Below are given the results of the nonlinear analysis.

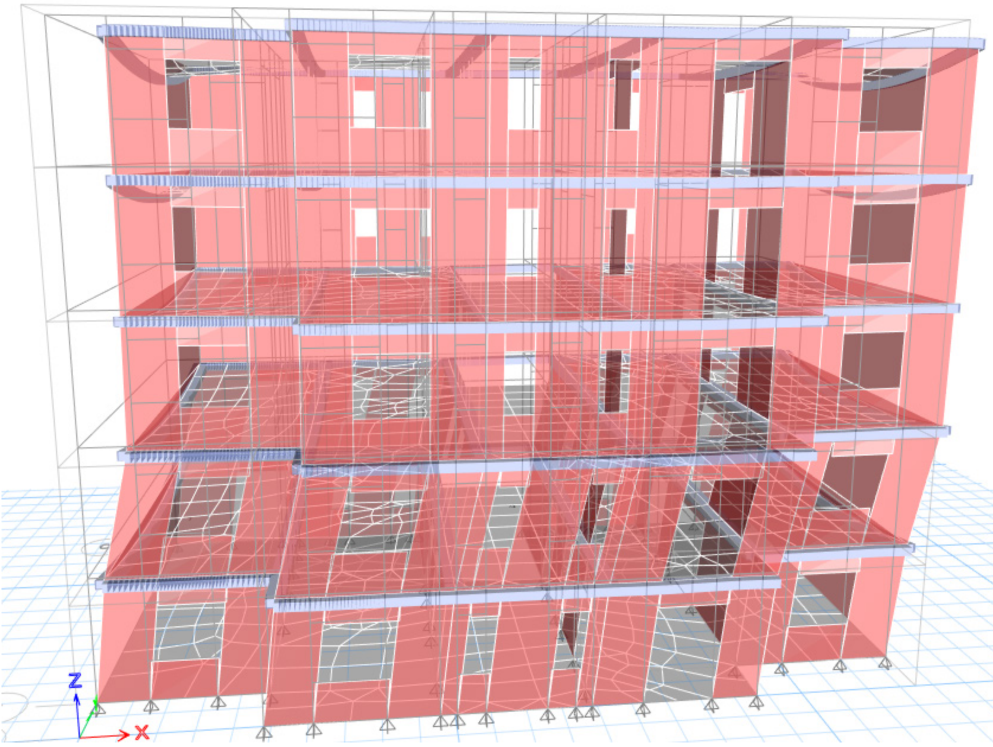


Figure 3-29 Maximum nonlinear displacements - CFRP

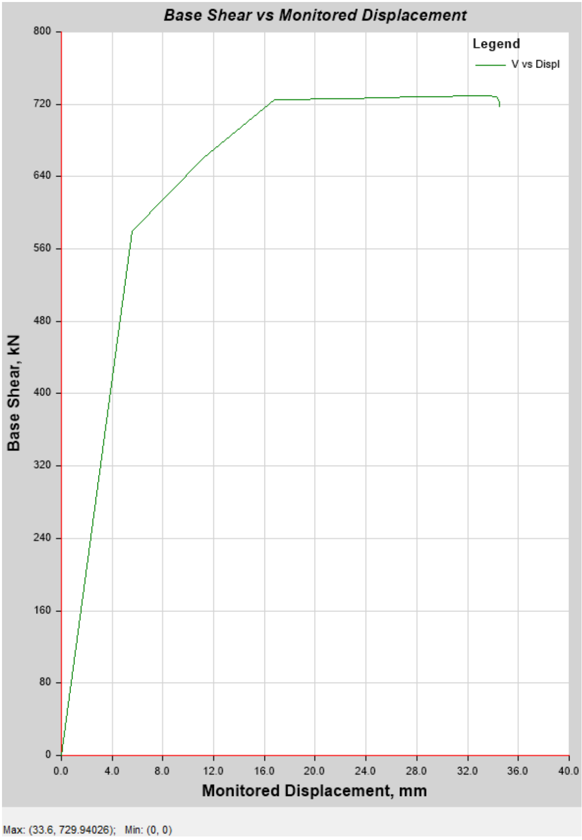


Figure 3-30 Capacity curve – CFRP

The interstorey drift for x direction for each story corresponding to the steps of the pushover analysis are presented below:

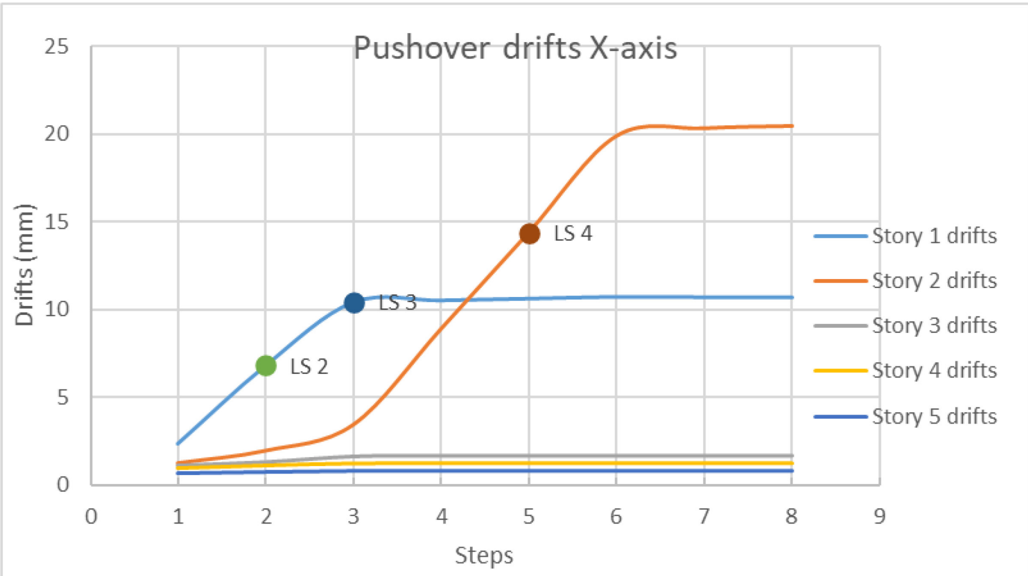


Figure 3-31 Pushover drifts - CFRP

It is noted that interstitial displacements are more comparable to each other for the first two storey. This shows a better redistribution of shear stresses in masonry. But, differ from the TRM case, the first story is now more rigid, after the LS3 displacement. Still as in the precedent case, the second storey floor is weaker and therefore acts as a soft storey.
The service limit states are then presented in the capacity curve as below:

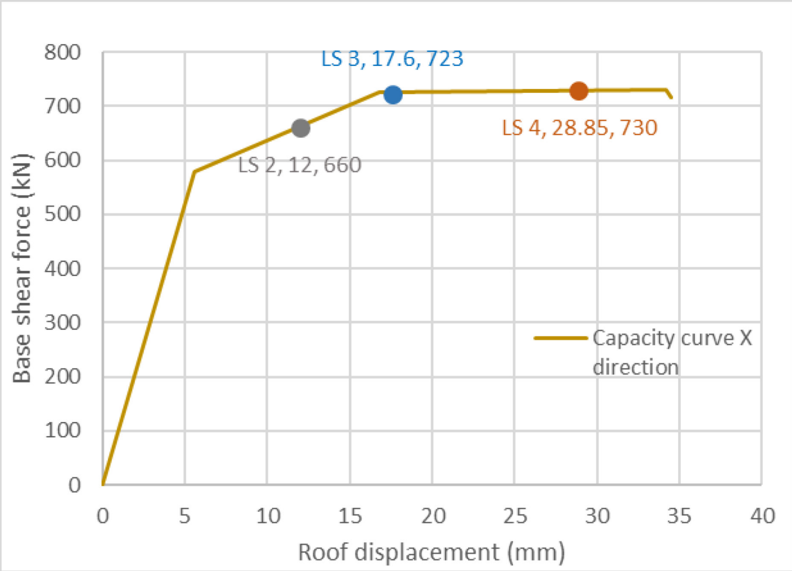


Figure 3-32 Limit states in the capacity curve - CFRP

The strengthening of the masonry floor the capacity curve greater values of shear force. It raises it from 553 kN to 730 kN. But, in contrast with TRM, it raises the ductility since the ultimate displacement increases from 22 mm to 33.6 mm. This is shown also in length of the horizontal part of the capacity curve (which represents the plastic behavior)

Seismic performance of the structure with CFRP

The seismic performance of the reinforced building will be calculated the same as for the cases before.

Below is presented the building performance degree with TRM reinforcement. The same graph shows the performances of both KTP and Eurocode spectra.

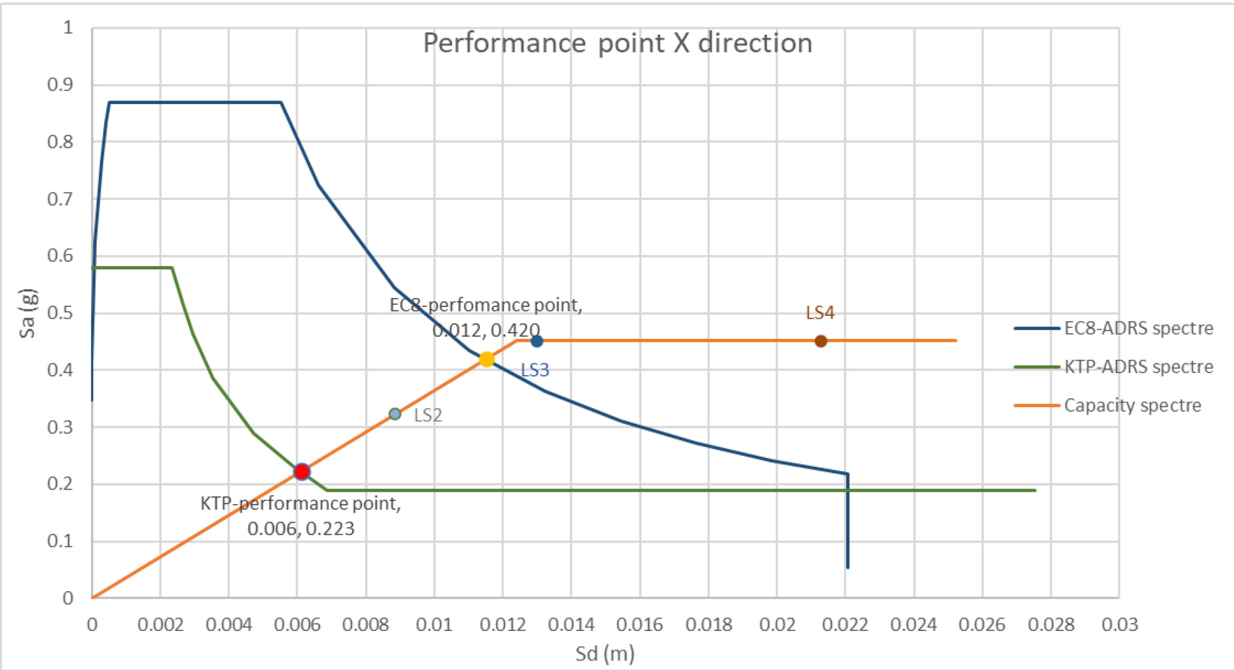


Figure 3-33 Performance point – CFRP

As we can see CFRP reinforcement acts almost as same as TRM reinforcement. In the TRM case, the performance point was reached in the plastic zone, while with CFRP is reached in elastic zone.

The spectrum according to Eurocode 8 causes significant damage to the building without reinforcement.
With the reinforcement the performance point is achieved for higher displacements and higher spectral accelerations. So, in general the building more ductile and is safer.
Also, according to EC8, the building withstands without collapse the design earthquake. The service limit state is LS2 that mean it suffers minor damages, while without TRM it was the LS3 level.
Regarding the reinforcement of the second floor, is the same discussion as for TRM case.

Nonlinear analysis with Ferrocement

For the nonlinear analyses is considered the first modal vibration of the structure. The fist mode is in X-direction. The period of first mode is $T_1 = 0.49$, and for the second mode is $T_2 = 0.33$s. As noted, reinforcement with ferrocement lowers the period of vibrations.
The analysis is done in the X direction. But, differ from other cases, the reinforcement is done on the first and second storey, taking the consideration the lower costs of ferrocement in comparison with TRM and CFRP. It was used 200 mm layer of Ferrocement with steel mash of φ6/150 mm.

Below are given the results of the nonlinear analysis.

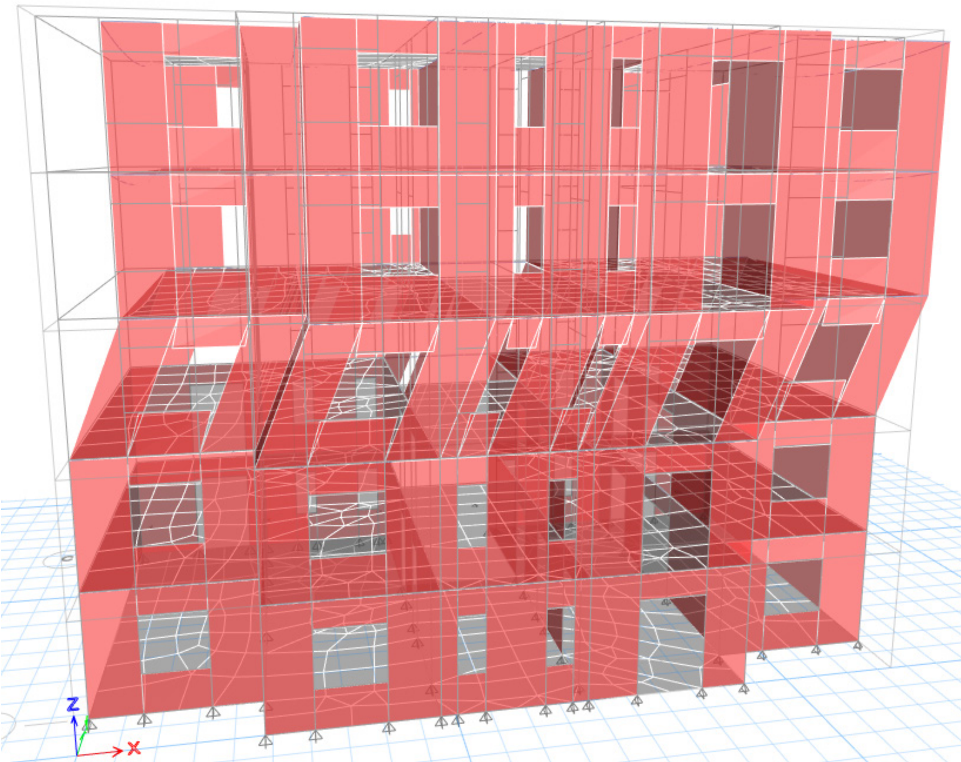


Figure 3-34 Maximum nonlinear displacements - Ferrocement

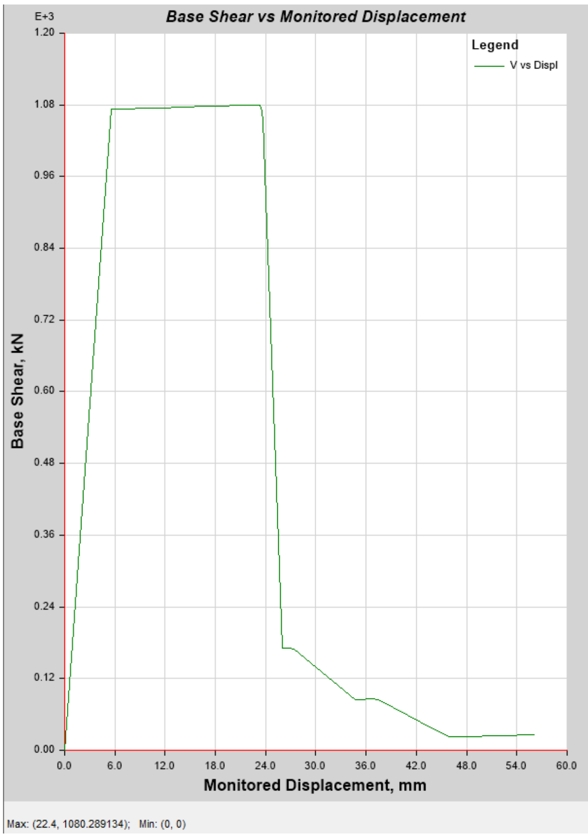


Figure 3-35 Capacity curve – Ferrocement

The interstorey drift for x direction for each story corresponding to the steps of the pushover analysis are presented below:

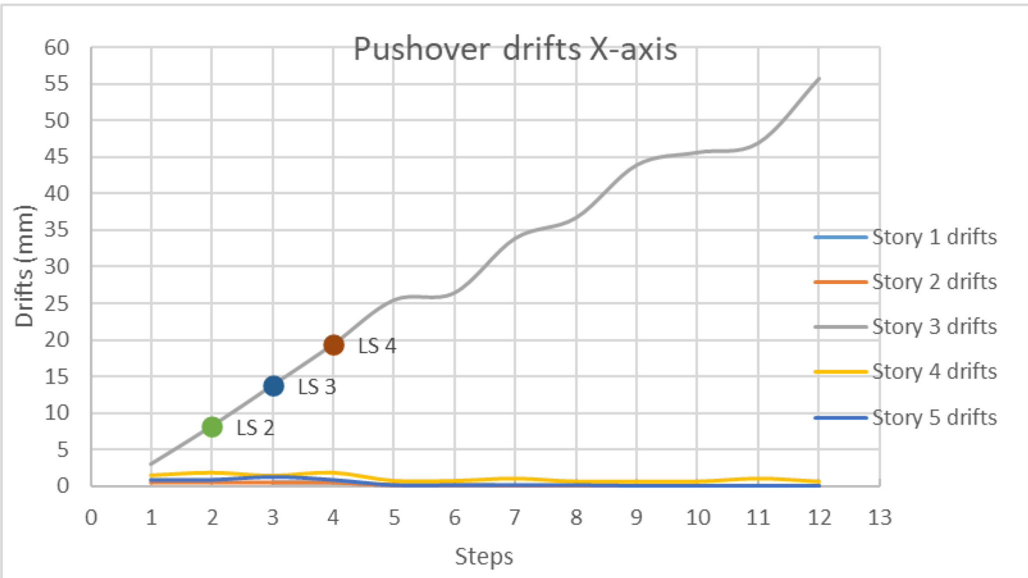


Figure 3-36 Pushover drifts - Ferrocement

It is noted that interstitial displacements are more comparable to each other for the first two storey. This shows a better redistribution of shear stresses in masonry. But, differ from the previos cases, the third storey floor is weaker and therefore acts as a soft storey. The rigidity of the ferrocement is the main case.

The service limit states are then presented in the capacity curve as below:

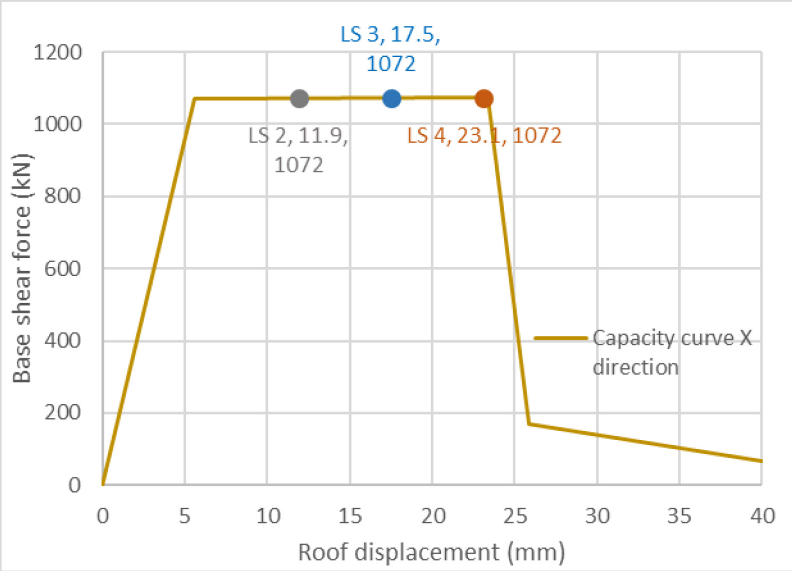


Figure 3-37 Limit states in the capacity curve - Ferrocement

The strengthening of the masonry floor the capacity curve greater values of shear force. It raises it from 553 kN to 1072 kN. But, in contrast with other cases, it only raises the shear force bearing, not the ductility since the ultimate displacement increases are lower. The ultimate displacements is almost equal of the case without reinforcement.

Seismic performance of the structure with Ferrocement

The seismic performance of the reinforced building will be calculated the same as for the cases before.

Below is presented the building performance degree with TRM reinforcement. The same graph shows the performances of both KTP and Eurocode spectra.

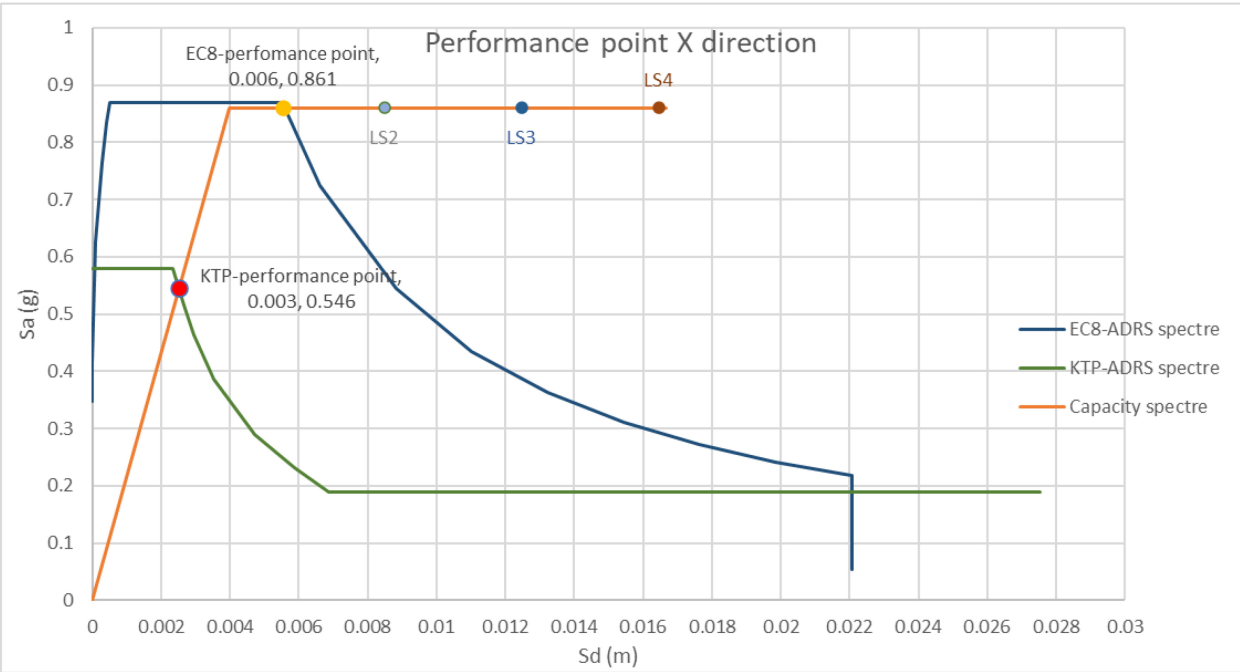


Figure 3-38 Performance point – Ferrocement

With the reinforcement the performance point is achieved for higher displacements and higher spectral accelerations, that in the case without reinforcement. So, in general the building more ductile and is safer.
Also, according to EC8, the building withstands without collapse the design earthquake. It doesn't cause any damages, since it reaches the performance point, before reaching the displacement that cause a limit state of LS2. We can see that with EC8, with the ferrocement, can reach the plastic properties of the materials, while with KTP it is only in the linear state.

Nonlinear analysis with adding Steel Frames
For the nonlinear analyses is considered the first modal vibration of the structure. The fist mode is in X-direction. The period of first mode is T_1 = 0.62s, and for the second mode is T_2 = 0.28s.
The analysis is done in the X direction.
The steel frames are added in the whole structure. From the point of seismic aspect, it wouldn't be needed. It is done only for architectural aspects as giving a new façade the building. Also it can serve on the energy efficiency aspects, acting as shading technology for the apartments.
For column the section we have RHS 300x150x28 mm, for beam RHS 70x35x5 mm and for the braces L50x50x5 mm

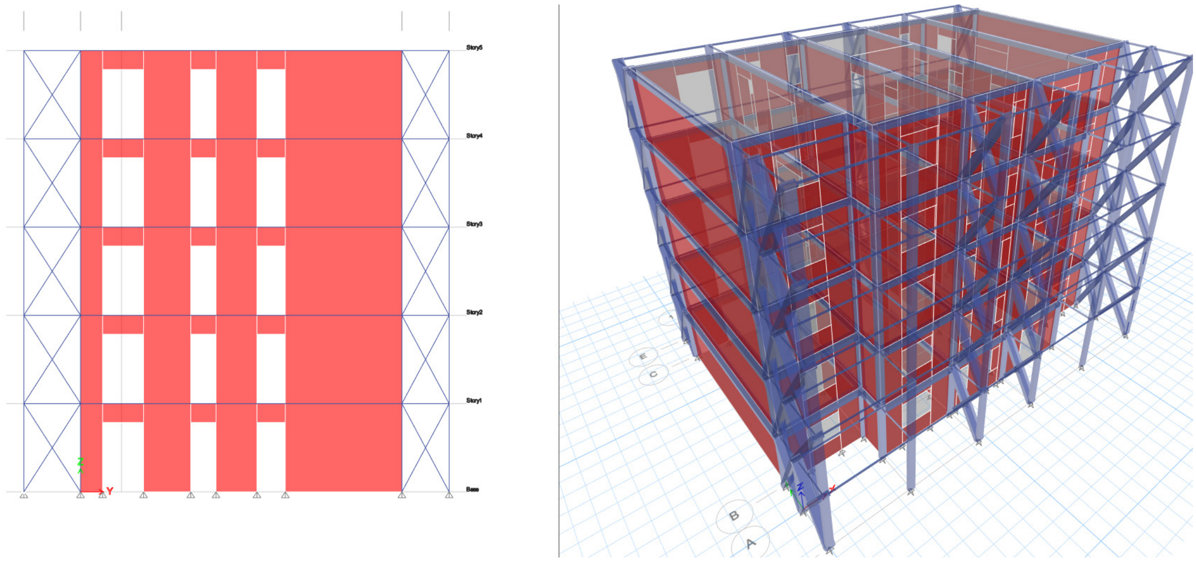


Figure 3-39 3d modeling of the steel frames case

Below are given the results of the nonlinear analysis.

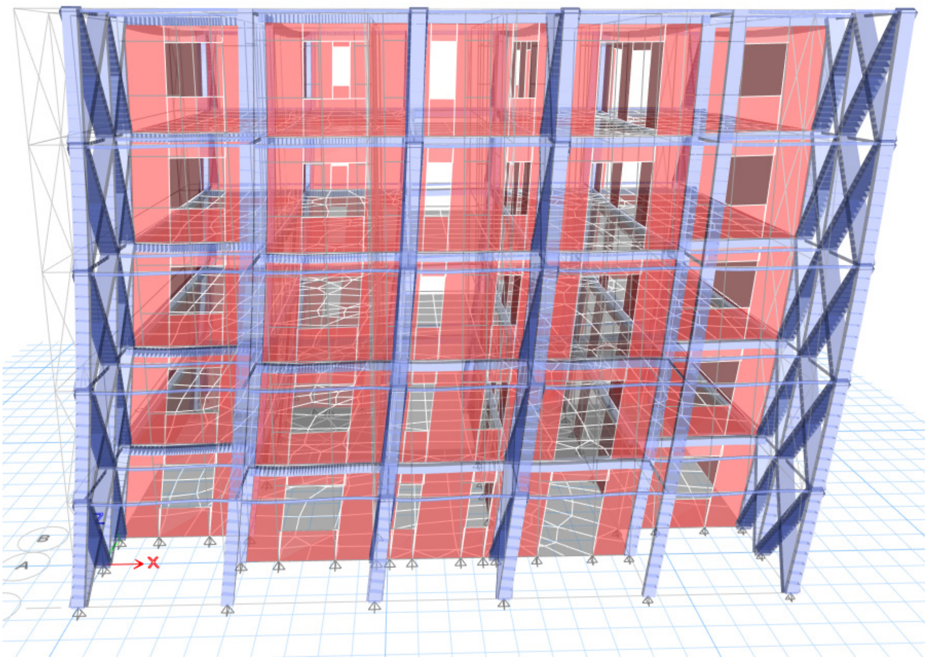


Figure 3-40 Maximum nonlinear displacements - Steel Frames

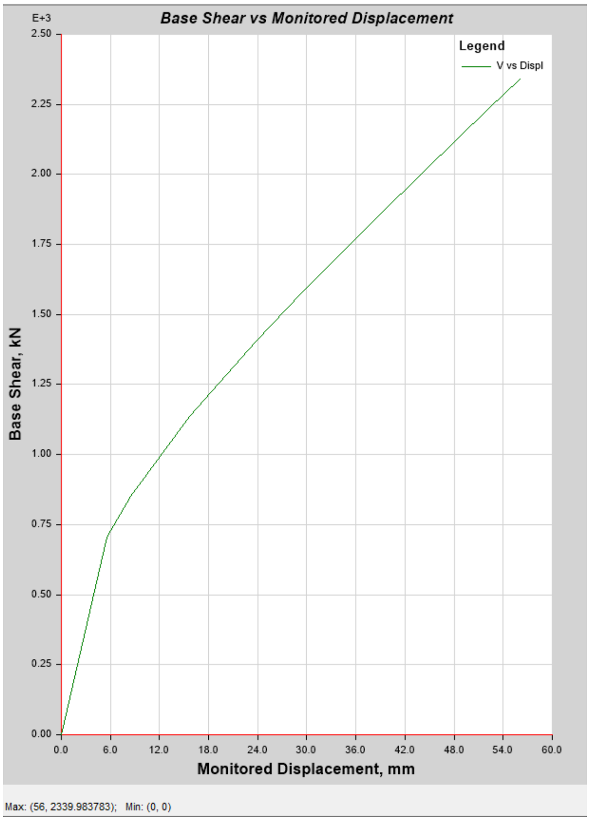


Figure 3-41 Capacity curve – Steel Frames

The interstorey drift for x direction for each story corresponding to the steps of the pushover analysis are presented below:

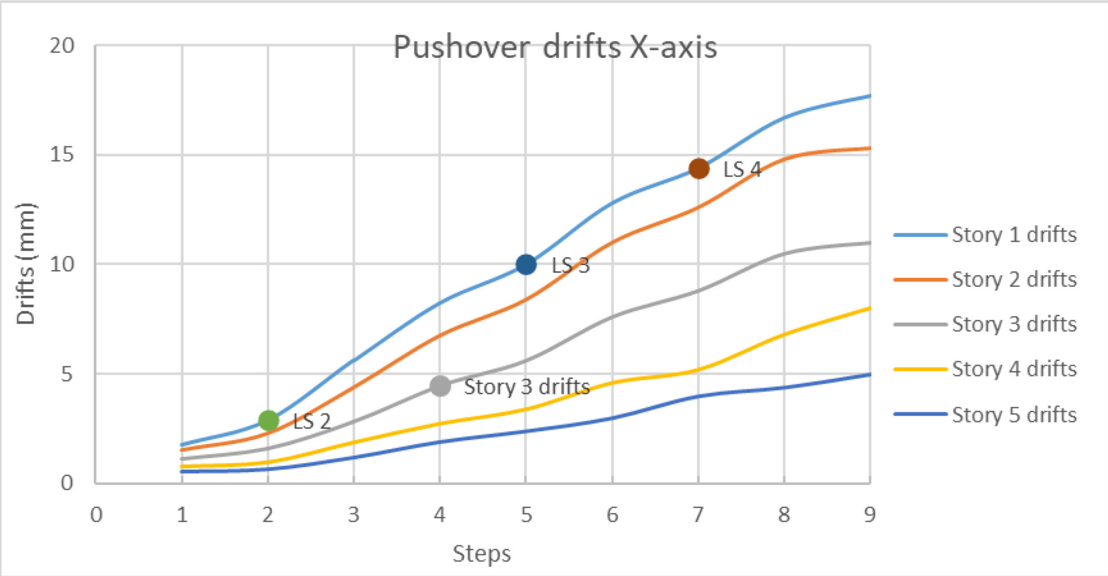


Figure 3-42 Pushover drifts - Steel Frames

It is noticed that the interstorey drifts are comparable to each other. We don’t have any soft storey. The steel frames have controlled the displacements. It is also observed that there is a greater improvement in the distribution of displacements the other cases. Consequently, the stresses in masonry have
better distribution.

The service limit states are then presented in the capacity curve as below:

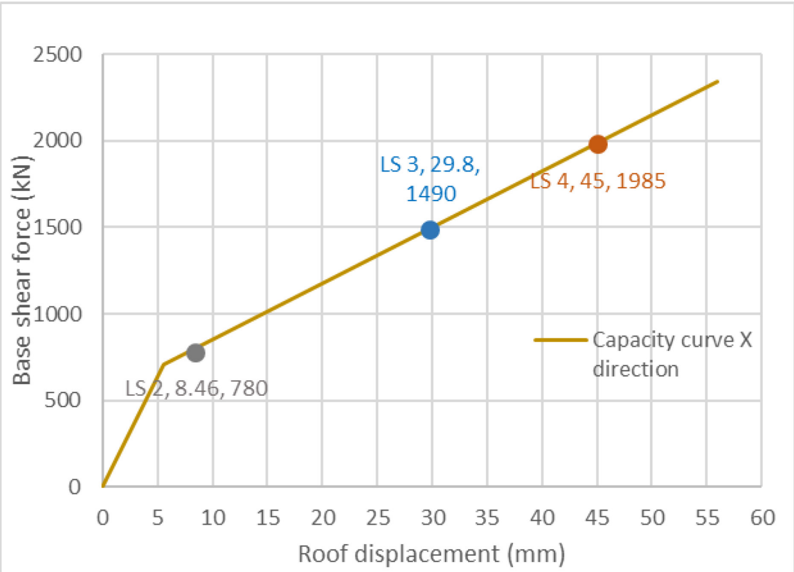


Figure 3-43 Limit states in the capacity curve - Steel Frames

The strengthening of the masonry floor the capacity curve greater values of shear force. It raises it from 553 kN to 2399 kN. It also raises the shear force bearing, and the ductility since the ultimate displacement increases are much higher.

Seismic performance of the structure with Steel Frames
The seismic performance of the reinforced building will be calculated the same as for the cases before.

Below is presented the building performance degree with TRM reinforcement. The same graph shows the performances of both KTP and Eurocode spectra.

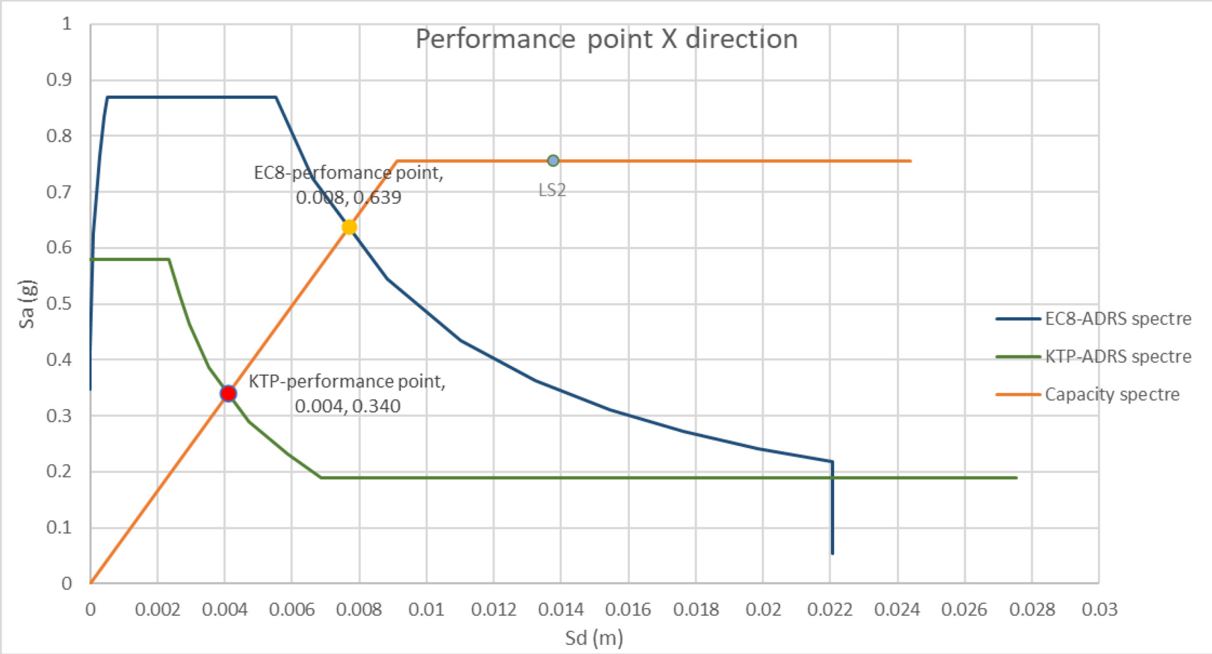


Figure 3-44 Performance point – Steel Frames

With the reinforcement the performance point is achieved for higher displacements and higher spectral accelerations, that in the case without reinforcement. So, in general the building more ductile and is safer.
Also, according to EC8, the building withstands without collapse the design earthquake. It doesn't cause any damages, since it reaches the performance point, before reaching the displacement that cause a limit state of LS2. We can see that with EC8, with the steel frames, the performance point is reached in the linear state. Also, the it allows very high displacements since the service limit state of displacement LS3 and LS4, are not in the graph.

3.3.1. Comparison of the strengthening techniques

The reinforcements studied above give different effects on the reference building under consideration. The parameters that affect the results are the modulus of elasticity of reinforcement and its equivalent thickness. Impacts of the modulus of elasticity and equivalent thicknesses are greater when these two values increase.
Below are presented the comparison of nonlinear analysis curves for the four reinforcements:

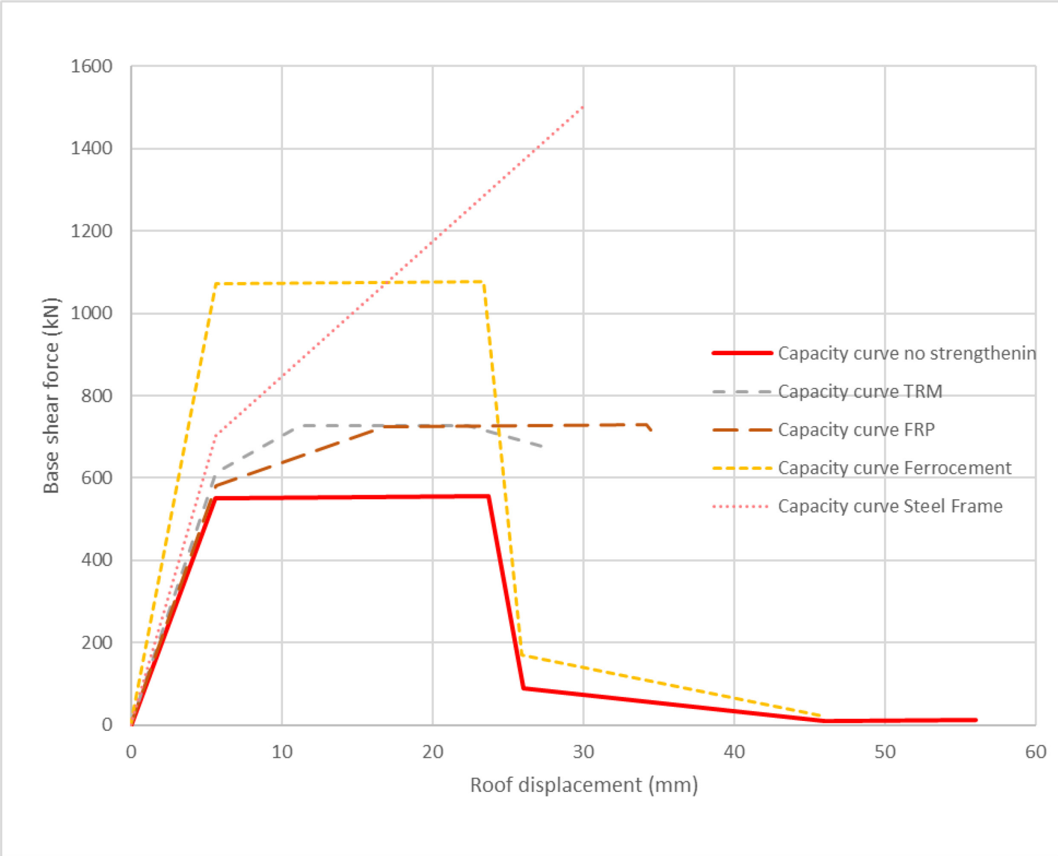


Figure 3-45 Comparison of the capacity curve X direction

From these curves it is observed that steel frames increase the capacity shear strength, but does not greatly increase ductility. On the other hand, CFRP and TRM reinforcements are very close to each other. CFRP also has quite good ductility although they have the same bearing capacity with TRM. However, to create an idea clearer what happens to the building is necessary to compare interstory drifts for all cases.

From the relative displacements it is observed that for carbon fiber reinforcement CFRP and TRM does not

we have good distribution of relative displacements. We have the creation of the weak floor in the second floor while on the other floors the masonry undergoes small displacements (the ferrocement case in in the third floor). This type of reinforcement is not suitable for the result if all carbon fiber floors were to be coated, but this would lead to cost increase by over 80%. Only the steel frames control the displacement and, in that case, we have a good distribution of the shear forces.

In addition to the bearing capacity of the structure, it is important to compare them in the term of performance degree. Seismic performance expresses the effect of a seismic spectrum on the building under study. Below are presented in tabular form the performance of the building for each case.

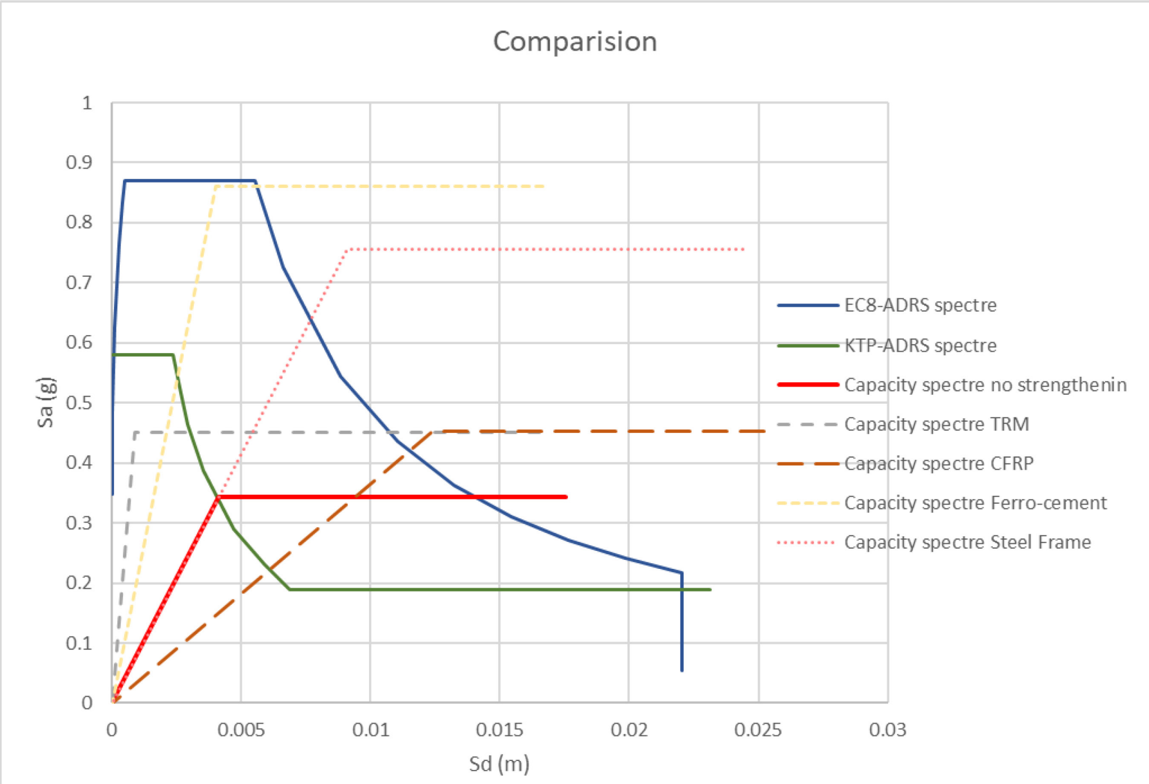


Figure 3-46 Comparison of the performance degree, X direction

The KTP spectrum does not cause damage to the building in the X direction in any case with reinforcement. Even in the case without reinforcement the ductility is not great, that even the damage is small. Changes in spectral acceleration and displacements are negligible.
Eurocode 8 spectrum causes less damage to the reinforced building, An increase in the stiffness of the structure that applies to all types of reinforcements.
t. Note that there is little change in displacement and ductility for CFRP and TRM. These are the same as the situation without reinforcement, but being accompanied with increasing spectral acceleration and shear force. Ferrocement reinforcement has an obvious advantage in this regard by marking minimum displacements and high shear force. Steel frame reinforcement allows more ductility than ferrocement.

3.4. Energy analysis of the structure

The case study is a 1977 structure located in Tirana, Albania's capital. The structure showed major evidence of deterioration, and the living areas were not up to modern living standards. The building's shell was uninsulated, and it lacked building integrated technical systems (BITS) for heating and cooling. There are barely a few standalone air conditioners "and no energy-saving lighting or household" equipment. Domestic hot water was heated using an electric heater connected to a storage tank. This structure lacked any type of insulation, and the rehabilitation scope included enhancing the performance of the façade, roof, ground floor ceiling (in touch with unheated floors), and windows. All decisions were made on technical and economic grounds, with one of the limits being that tenants remained in their homes during construction. The specific heating energy demand is 436 kWh/(m2a), which places the property in the energy performance class F, according to the energy performance certificate.

Figure 3-47 Energy performance certificate proposed in Albania (European Directive, 2012)

In terms of the building envelope, the outside walls were hollow brick walls plastered on one side, while the roof was a concrete slab. The ground floor is solid, and the windows are wood framed with single glazing. The table below summarizes the U-values of the building's components prior to refurbishment. The external walls have two distinct U-values due to their varying thicknesses.

Table 3-1Thermal characteristics before renovation

Parameter	Unit	PT
Building period		1970
Gross heated floor area (GHFA)	m^2	761
Façade area (excl. windows)	m^2	415.70
Pitched Roof area	m^2	0
Flat Roof area	m^2	161
Attic floor	m^2	161.00
Area of windows to N	m^2	0.00
Area of windows to NE	m^2	0.00
Area of windows to E	m^2	0
Area of windows to SE	m^2	49.2
Area of windows to S	m^2	0
Area of windows to SW	m^2	0
Area of windows to W	m^2	0.00
Area of windows to NW	m^2	51.90
Area of cellar ceiling	m^2	161
Ground floor	m^3	161
Average heated gross floor area per person	m^2	12.68
Typical indoor temperature (for calculations)	°C	22
U-value façade	$W/(m^2*K)$	3.24
U-value roof pitched	$W/(m^2*K)$	
U-value attic floor	$W/(m^2*K)$	0.497
U-value roof flat	$W/(m^2*K)$	0.261
U-value windows	$W/(m^2*K)$	4.7
g-value windows	Factor 0.0– 1.0	0.58
U-value ceiling of cellar	$W/(m^2*K)$	3.7
U-value Ground floor	$W/(m^2*K)$	0.9

Beginning with the "anyway renovation" scenario and progressing through more energy-efficient renovation scenarios, the cost-optimal levels were determined and the best cost-effective method for achieving a balance of zero primary energy usage was studied.

Renovation measures

- *Envelope renovation measures*

Common maintenance envelope measures used in Albania are as below:

- external insulation of walls through EPS layer and mineral wool
- insulation of the basement XPS layers and in rarely of mineral wool with high density
- insulation of the roof through XPS layer and mineral wool
- substitution of existing windows with new ones equipped with: double and simple glazing in the standard case of PVC or wood

- *Building Integrated Technical Systems (BITS) measures*

Common technical system in Albanian market are listed below

- Solar thermal system for contributing in 50% of DHW production
- Heat pumps

- *Renovation process*

The methodology utilized is described in Annex 56 of the International Energy Agency.

To begin, the energy performance of the building was calculated under the reference scenario (without energy improving performance). For the energy calculations, an excel-based program was utilized that, after inputting the geometric properties of the building's elements and information about the BITS performance, calculates the primary energy.

Each of the retrofit measures indicated in the table below was examined in terms of primary energy use and global cost using the same Excel-based technique.

Table 3-2 Measure proposed

Renovation Package code	Description	Wall	Roof	Floor	Windows	BITS (including RES)
Actual						
Reference	*In the reference case, for the wall a substitution of deteriorate external plaster is made and the new flat roof gets a new waterproof covering, and the windows are generally repaired and repainted. These measures do not improve the energy*	*New Plaster*	*Waterproof covering*	-	*new windows with a metal frame and a U-value for 4.7*	-
1	*100 mm insulation with EPS of the façade and new double glass windos with synthetic frame*	*100 mm EPS*			*double glass U=3.3*	
2	*100 mm insulation with mineral wool for the façade and 100mm for*	*100 mm mineral wool*	*100 mm mineral wool*			
3	*100 mm insulation of the facede with EPS and 100 mm insulation of*	*100 mm EPS*		*100 mm mineral wool*		
4	*100 mm insulation with EPS of the façade and new double glass*	*100 mm EPS*	*100 mm XPS*		*double glass U=3.3*	
5	*100 mm insulation with EPS of the façade, 100 mm XPS insulation for the roof and floor*	*100 mm EPS*	*100 mm XPS*	*100 mm XPS*		
6	*100 mm insulation with EPS of the façade, 100 mm XPS insulation for the roof and floor and new double*	*100 mm EPS*	*100 mm XPS*	*100 mm XPS*	*double glass U=3.3*	
7	*M1 + Heat PumP*	*100 mm EPS*			*double glass U=3.3*	*Inv. AC. Heat Pump, SCOP = 3*
8	*M2 + Solar Panels*	*100 mm mineral wool*	*100 mm mineral wool*			*120 m² solar thermal system for heating and DHW production*
9	*M5 + Heat PumP*	*100 mm EPS*	*100 mm XPS*	*100 mm XPS*		*Inv. AC. Heat Pump, SCOP = 3*
10	*M6 + Solar Panels*	*100 mm EPS*	*100 mm XPS*	*100 mm XPS*	*double glass U=3.3*	*120 m² solar thermal system for heating and DHW production*

There are going to be testes 10 package scenarios. Every measure comes with an upgrade. This is to test at what point can we go in improving the energy efficiency. It also serves to control the costs. Because sometimes the measures are cost-efficient (e.g. if we renovate a certain element, renovating an another would not have a major effect in the energy consumption reduction, while significally affecting the costs.)

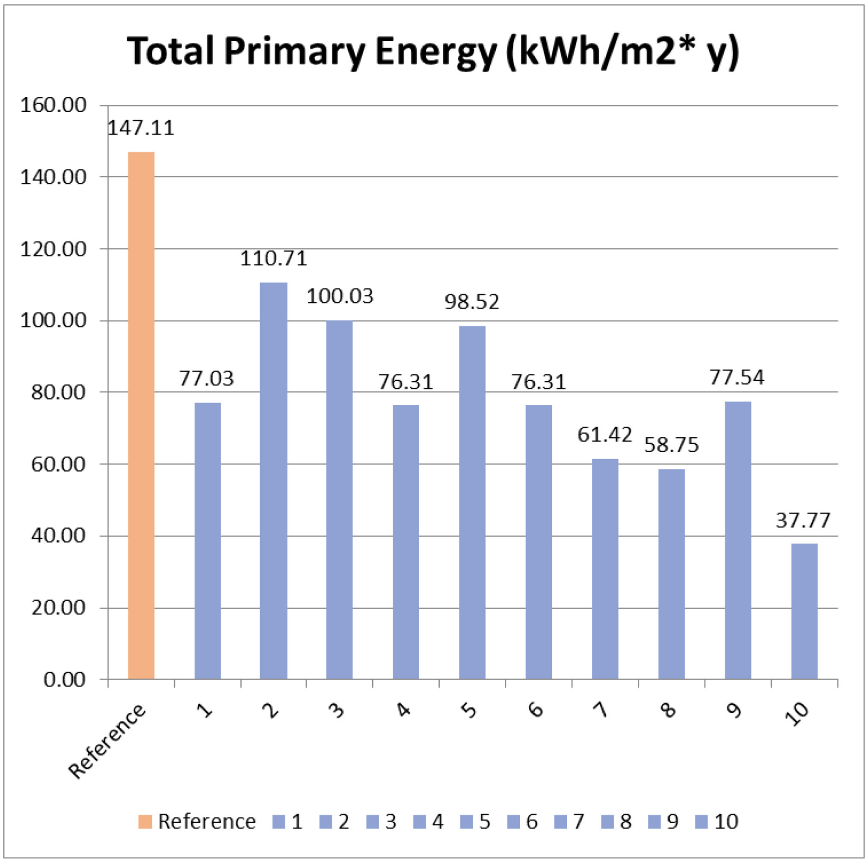


Figure 3-48 the different measures with the primary energy

The figure above shows how much energy is needed after the renovations. Even the reference scenario, had an impact on energy reduction. With these measures we can go from class F in energy certificate to class A. To select the right measures, we need to evaluate the costs. In figure below are presented the costs for the renovation packages.

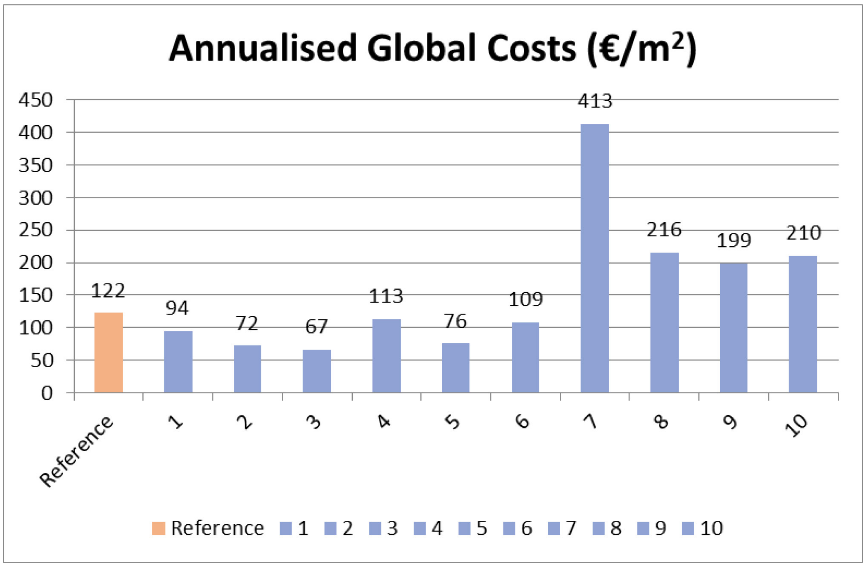


Figure 3-49 the different measures with the global cost

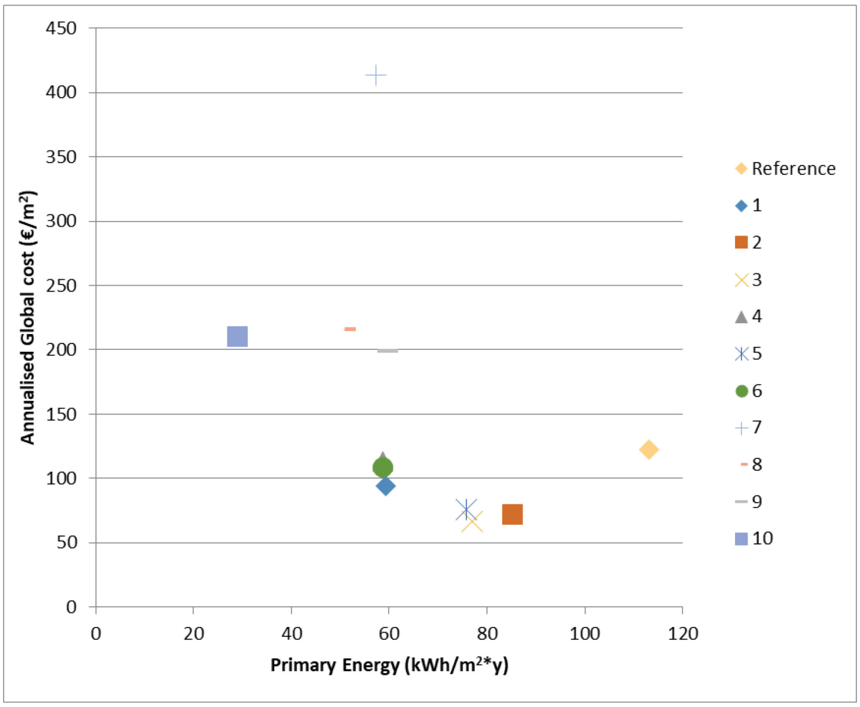


Figure 3-50 the diagram with the global cost and the primary energy

In the diagram above is shown the correlation between the energy demand and the measures cost. As we can judge from the diagram the cost-optimal solution, is measure three. The building in this case is in class C, which is accepted by the Albanian standard. The cost for measure three is 67 Euro/m^2.
If we want to achieve zero energy, we can choose the measure ten, which would bring the class A of the buildings. But its costs are at 210 Euro/m^2.
This gives an exploration of the measures and helps the stakeholder (government, technicians, investor, owners) to choose at what class they want their building to be in accordance with the costs, after the retrofit measures.

3.5. Cost analysis of the two retrofits

In this section will be analysed the cost of retrofits done together, and will be compared to the price if the building would be demolished and reconstructed.
The cost of the measures taken, both seismic and energetic, will be given per €/m2, where the area is the total net floor area of the building. The prices of the measures taken and for demolition are based on the official data give by the Ministry of Infrastructure of Albania (which is responsible also for constructions).
While the price of new construction is taken based on the practical experiences in market construction since no official data is given. For the relocation of the inhabitants for the scenario of "demolished and reconstruction", is supposed a monthly rent for around 200 €. The total period of reconstruction is considered 12 months. Since in the reference building there are three apartments per story, so 15 apartments total, the total cost of relocation is 36'000 €. For the demolition cost are also considered workmanship and transportation. All these data are given in the table below.

Table 3-3 Total cots for the "demolished and reconstruction" scenario

	Global costs (€)	Cost (€/m^2)
Demolition	9822	11.2
Relocation	36000	41
Reconstruction	264000	300
Total	309822	352.2

Regarding the energy retrofit, will be chosen only the measure accepted in section 3.4 as the cost-optimally solution, measure number three with cost of 67 €/m2.
While for the seismic retrofit, will be analysed all the measures taken in consideration. The cost of these measures includes cost of materials and workmanship. The costs of seismic retrofit measures are given in table below. The costs are also given per square meter of net floor area.

Table 3-4 Total costs for the seismic retrofit measures

	Global costs (€)	Cost of seismic retrofit (€/m^2)
CFRP	43890	49.9
TRM	33515	38.1
Ferro-cement	48835	55.5
Steel bracing	39425	44.9

As shown in table 3-4, the lowest cost would be choosing the seismic retrofit with TRM. Ferrocement is actually cheaper than TRM, but with ferrocement was reinforced two storeys, while for TRM was used only in the first storey.

Below is presented the total cost of both retrofits in comparison with the "demolished and reconstruction" scenario.

Table 3-5 Comparison costs for the retrofit measures and "demolished and reconstruction" scenario

	Cost of seismic retrofit (€/m^2)	Cost of energy retrofit (€/m^2)	Total cost of retrofit (€/m^2)	Cost of demolition and reconstruction (€/m^2)
FRP	49.9	67	**116.9**	**352.2**
TRM	38.1		**105.1**	
Ferro-cement	55.5		**122.5**	
Steel bracing	44.9		**111.9**	

As presented in table 3-5, all types of retrofits have lower cost than demolition and reconstruction scenario. By this result it is clear that is more economically feasible to retrofit these types of buildings than to build new structures. The costs of retrofit are around 30% to 35% to the costs of 'demolition and reconstruction' scenario.

3.6. Cost-Benefit Analysis

In order to perform a cost-benefit analysis, an evaluation of the costs of the retrofit strategies was developed by Caprino et al. (Caprino, et al., 2021) in the seismic and energy retrofit sector splitting the cost voices in structural interventions, demolition and finishing, and energy interventions.
The cost effectiveness can be evaluated using the payback period and the net present value, with an interest rate of 3% (a), the initial investment cost (I_0), and the life span (n). Using the equation 3-1, it is possible to evaluate the economic viability of the retrofit using the Net Present Value (NPV) as shown in equation 3-1, considering the actual cash flow generated by the energy savings (R) and considering the year in which the NPV is zeroed as the payback time (PBT). All the values will be in €/m2. As a measure for seismic retrofit will be chosen TRM, since it has the lowest costs.

$$NPV = -I_0 + R \sum_{j=1}^{n} \frac{1}{(1+a)^j} \qquad \text{Eq 3-1}$$

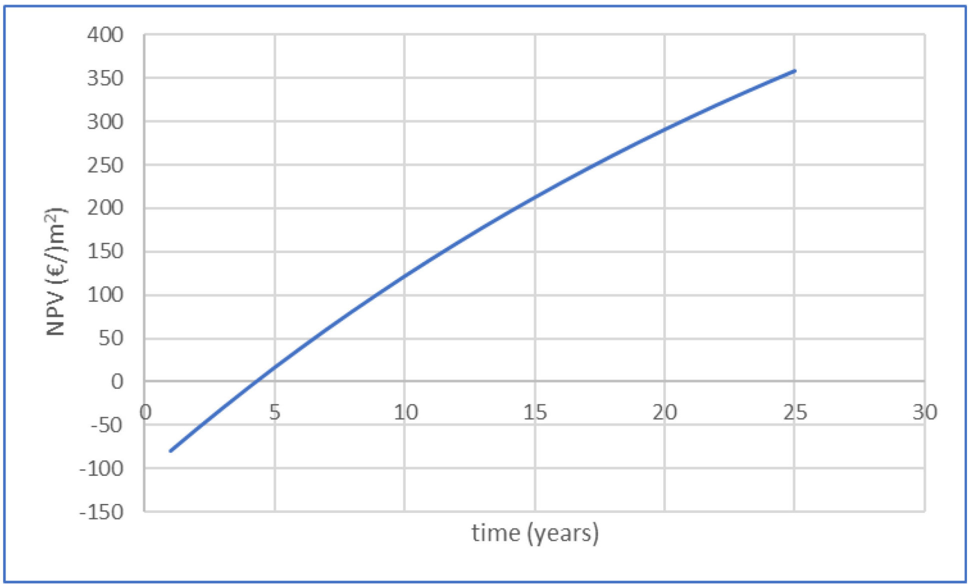


Figure 3-51 *NPV curves for retrofit interventions*

As shown in figure 3-51, the payback period is around 5 years. This shows the effectiveness of the both retrofits; where energy retrofit can cover up the initial investment, while the seismic retrofit will raise the safety and increase the structure service life.

4. CONCLUSION AND RECCOMANDATION

Following a brief introduction to the subject, the research's objective is emphasizing the significance of integrated methods to existing building rehabilitation and to stimulate future partnerships among diverse stakeholders such as architects, energy technologists, and engineers. To accomplish this goal, the notion was thoroughly described and a proposed retrofit measures to a reference building was shown. To be implemented effectively, the proposed measures needs be further designed and fitted to the buildings in question.

This thesis discussed contemporary techniques for reinforcing old buildings with brick masonry. Seismicity is a substantial threat for tall structures in nations such as Albania. It has been established that seismic activity is the primary factor affecting the modeling of structural elements.
In this dissertation the seismic risk in a typical masonry building is elaborated in detail. Seismicity is represented by the elastic design spectrum according to Albanian standard KTP-N2-89 and European EN-1998-1. To build these spectra such parameters were used to represent the seismic risk for the most part of Albania. To analyze the masonry building a model was built with finite elements in the ETABS program. The analysis was performed for the 74/11 type building, according to the project.

In this study it was shown that referring to the seismic demand of KTP, the expected damages differ from light on average for masonry type buildings in Albania. But, referring to the contemporary seismic demand (EC-8), these buildings in Albania result in high probability of heavy structural damages and on the verge of near-collapse.

Also, the designed methodology paves the way for economic evaluation and helps in obtaining appropriate measures for possible rehabilitation of masonry buildings Albania.

Seismic performance is a recent concept in the field of calculations of structures. It consists of nonlinear modeling of the structure to obtain its capacity curve and then in finding the performance point in this curve for a given seismic spectrum. Nonlinear analysis was used in this study described in document FEMA440 (2009). Masonry was modeled by behavior nonlinear and with computer analysis the capacity curve was obtained. To improve the bearing capacity of the building were applied reinforcing layers on the outer faces of building.

Five computer analyzes were performed respectively for situations: no strengthening, with fiber reinforcement carbon CFRP, TRM amplification, ferrocement and steel frames. The analysis that was performed is e pushover type where a horizontal loading model pushes the building up to destruction. The first two modal forms of the structure were used as the loading model correspond to the two orthogonal directions of the building. Then the capacity curve was processed together with the seismic spectrum to find performance degree.
The strengthened structure showed a better performance than it without strengthening. There were two key directions in which the improvement could be seen, in bearing capacity and in shifts from the seismic spectrum. Bearing capacity in shear is increased for all types of reinforcements but at different values. The increase in bearing capacity is explained by redistribution of forces in the masonry lined with reinforcing.
Growing of bearing capacity was observed more for ferrocement and steel frames and less for two the others.
In addition to the bearing capacity in the shear, the shape of deformed ductility was achieved.
Ductility does not explain enough the state of plastic deformation of the building. This as it is considered only by compared the displacement of the roof point with the elastic displacement in the curve of capacity. The relative displacement of the other floors is not taken into account here. If all storeys have relative deflections that are similar, the building will be more ductile. Conversely, when we have a soft storey that deforms further, the ductility is reduced. We have soft storey in cases without reinforcement and with reinforcement CFRP, TRM and ferrocement. Respectively in these cases we have soft storey in the first level and second.

In conclusion, it is recommended to reinforce masonry buildings with specifications as 74/11 studied above, use one of the Ferrocement reinforcements or steel frames (if the urban conditions are fulfilled). On reinforced floors they increase the stiffness and bearing capacity.

It was noted that current seismic code in Albania shows many deficiencies regarding the other codes, therefore it's an urgent need its upgrade. The structures built with this code do not perform accordingly with the present European codes.
Also, the total energy consumption is very high in the social buildings within the period 70-90. It has high costs for the owner, low living conditions and high carbon emission. In this study it was shown that with low costs could achieve great results.

Energy recommendations
It is preferable to increase the energy performance of various elements of the envelope rather than focusing just on one. If financial resources are limited, the best course of action is to improve various components of the envelope, even if energy efficiency standards are reduced;
To maximize the synergies between energy-related measures and BITS, it is prudent to mix renewable energy systems with building envelope conservation measures.

Seismic recommendations
In this dissertation was analyzed by means of the program with elements of we recently built a 5-storey building with designed masonry built between the years '70 -80'. The analysis performed is of the "pushover" type and is based on determining the capacity curve through analysis computer and its processing according to FEMA440 and ATC40.
The selected building is modeled on the original design variant but also by applying reinforcements to its perimeter. From the analysis of the building without reinforcement resulted the first floor as a soft storey.
For reinforcements were chosen polymer materials equipped with fibers with high resistance, ferrocement and steel frames It was concluded that reinforcement for this category the building should be located up to the first and second floor of the building, for him avoid the phenomenon of soft storey
Capacity curves were processed according to FEMA440 and ATC40 by used reference parameters for our country according to the spectra in the codes KTP-N2-89 and Eurocode 8. These parameters apply to the area of Tirana and for a considerable part of our country. From the capacity curve and seismic demand spectrum was determined performance point for each case.
All the reinforcement showed good results in upgrading the capacity of structure. The choose of the measures relies on the stakeholders, which can make evaluation regarding the costs.
Regarding the cost-effective strategies, TRM was the one with the lowest costs, while still improving the seismic capacity of the structure.

It was shown the for around 30% of the cost of the reconstruction, it be upgrades both seismic and energy retrofits of the building, while having a payback period for around 5 years.
These types of buildings should not be demolished, even though their service life is coming to an end. We showed that with little intervention for the seismic upgrade (in some cases only the first floor), we could achieve the demands of European seismic code. Also regarded the energy retrofit, it was shown that with low costs, we could achieve higher classes of energy efficiency.
Their demolition would be cost significantly more, taking into consideration also the relocation of the inhabitants (while all the retrofit measures above didn't require the movement of them)

About the integration of the two kinds of retrofits, all the seismic techniques can be integrated with the energy techniques studied above. Their integration comes on the similarity of the implementation work, therefor can significantly reduce the labuor cost.

Limitations of dissertation results and future research

It should be borne in mind that the findings of this dissertation (results) are in those areas where the spectral acceleration is 0.3g. For any concrete reinforcement case, it should special analysis is performed based on the analytical methodology treated in this dissertation.

The main barrier in Albania is informality. it isn't any research study, the last one was done in 2013, that show how many buildings are in Albania, or how many people still live in this building.

The market of materials is an informal one. There aren't official labour costs for the novel technologies and materials for energy and structural retrofit. This can affect the evaluation for the cost-effective techniques

One important other barrier is the absence of the laboratory tests. The reasons may be because they're expensive and lack on appropriate technical appliances for most of the needed tests. Therefore, it is not taking consideration the material deterioration. Analyses are done like the building is still in the actual state that it was build.

Because of the absence of the laboratory tests, it couldn't be verified if any of the two types of retrofits affected in the technical properties of the other; if for example could ferrocement serve as a thermal coating for the improvement of the energy efficiency?

Despite several simplifications, the information provided regarding

(i) the possible intervention techniques and their applicability in Albania (and other European countries),
(ii) associated effects on building behavior,
(iii) intervention costs, and
(iv) co-benefits between energy and seismic retrofit

These may be extremely valuable for engineers interested in performing loss assessments and cost-benefit analyses on specific buildings in Albania (and other European countries).

Strictly speaking, the reported retrofit costs are relevant only for the buildings featured in the case studies, however comparable patterns are expected for structures with similar characteristics. However, it should be remembered that numerous factors and variables can considerably alter the aforementioned expenses and, hence, the break-even times indicated previously. Future research should include an analysis of additional case study buildings in order to produce statistically more solid conclusions.

Additional case study buildings will be examined in the future to verify the results of the cost/benefit assessments conducted in this study. A broader inventory of RC frame buildings shall be considered, including those with varying shapes and dimensions, those located in areas with varying hazards, and those with varying intended uses (office rather than residential), among others, although the trends identified here are expected to be broadly applicable.

A fully representative analysis campaign is presented for consideration for further development in the previously specified environment. All possible combinations of building configurations, retrofit and improvement techniques, seismic hazard and energy requirements, as well as financial and economic parameters (such as interest rates and downtime losses) will be convoluted in order to generate a set of results that can adequately serve as the basis for developing integrated approach guidelines, according to the second approach.

Despite the fact that only financial aspects are considered in the current research, it would be interesting to consider additional decision-making variables that are directly related to the environmental counterparts of energy efficiency and earthquake loss, as well as the correlation between these two variables.

In the case of initiatives for rehabilitation interventions by decision-making institutions, due to the facilities provided by the developments of this study, it is possible to make a rapid assessment on the condition of the building in order to design a rehabilitation strategy as complete as possible.

Similar studies can be performed on buildings with other functions, with similar characteristics to those treated in this study, such as materials, construction technique and their typification.

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