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European Journal of Environmental and Civil Engineering

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/tece20

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To cite this article: Roberta Apostolska , Veronika Shendova & Golubka Necevska-Cvetanovska (2020): The need of integrated renovation of the existing building stock in North Macedonia, European Journal of Environmental and Civil Engineering, DOI: 10.1080/19648189.2020.1798816

To link to this article: https://doi.org/10.1080/19648189.2020.1798816

Published online: 06 Aug 2020.

EUROPEAN JOURNAL OF ENVIRONMENTAL AND CIVIL ENGINEERING
https://doi.org/10.1080/19648189.2020.1798816

The need of integrated renovation of the existing building stock in North Macedonia

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ABSTRACT

Republic of North Macedonia is a seismic prone country with a long tradition and positive experience in the field of seismic design of new and strengthening of the existing buildings up to pre-defined levels of seismic protection. The principal seismic design philosophy which is stipulated in the regulations is based on protection of human lives against strong earthquakes and partially on controlled damage due to the so called frequent earthquakes. The current construction practice generally target only one of the seven basic work requirements for construction works defined in Construction Products Regulation (CPR, 2011) i.e. mechanical resistance and stability. Starting from 2013, when the first national regulation for energy performance of the building was issued, there are some positive initiatives/examples at national and local scale. These initiatives encompassed building capacities in construction sector in order to provide competent and qualified national workforce, necessary for achievement of national energy efficiency targets; launching the energy efficiency programs for public buildings at municipality level (pilot-project), research experimental program for developing innovative technology for earthquake resistant and energy efficiency buildings, etc. However, till today there is no integrated methodology which will target simultaneously earthquake resistance and eco-efficiency of the existing building stock in the country.

ARTICLE HISTORY
Received 1 April 2016
Accepted 14 July 2020

KEYWORDS
Earthquake resistance; strengthening; eco-efficiency; seismic hazard; integrated renovation

Introduction

Seismic hazard and building inventory in North Macedonia

The territory of North Macedonia, situated in the Mediterranean seismic belt, is quoted as an area of high seismicity. In the seismic history of North Macedonia, the Vardar zone appears as a region where earthquakes occur quite frequently, and the Skopje region is considered to be the most mobile part of the Vardar zone.

As a result of investigations done by different researchers and institutions, the set of seismic hazards maps of Macedonia have been compiled, covering different recurrence time periods – 50, 100, 200, 500, 1000 and 10,000 years. In Figure 1a, the seismic zoning map with return period of 500 years is presented, while in Figure 1b is shown the map of maximum observed seismic intensities.

The total residential exposure according to the data from 2002 Census (the last official one) is 49.67 mil m^2 of dwellings with 82.26% in urban and 17.74% in rural regions of the country. The roughest general building categorization could be done according to the main structural system and year of construction meaning three basic building types (Table 1).

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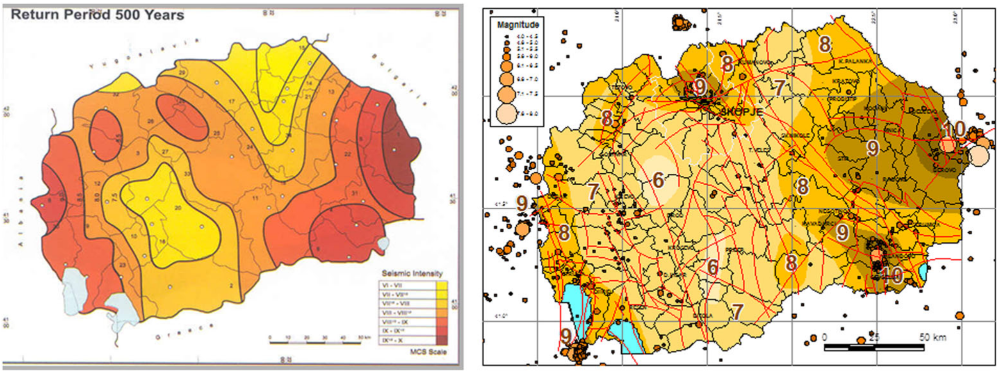

Figure 1. Figure 1a. Seismic zoning map of RN Macedonia (RP = 500 years). Figure 1b. Maximum observed seismic intensity map of RN Macedonia.

Table 1. General building categorization.

Building categorization	Description
Non-earthquake resistant Masonry buildings	Unreinforced, plain masonry buildings with several sub-categories, that have been implemented dominantly in urban and rural areas up to 1964, that is enforcement of the first seismic code
Moderate earthquake resistant confined Masonry buildings	Plain masonry structure strengthened by vertical and horizontal reinforced concrete belts in both orthogonal directions, or by jacketing of the bearing walls; very frequently implemented after Skopje earthquake (1963) for seismic upgrading of existing buildings as well as in constructions of new houses, dwelling and low-rice public buildings
Earthquake resistance reinforced concrete buildings	Low, mid and high-rise reinforced concrete, used dominantly after 1965 for construction of mid and high-rise public and residential buildings, residential complexes in urban areas, with extensive usage after 1970

According to some raw estimation, the percentage of non-earthquake resistant buildings built up to 1970 of the existing building stock is 34.7%. The most of the building structures constructed after 1991 belong to the category of earthquake resistant structures.

Existing national regulation and practice of design of earthquake resistant structures

The territory of the Republic of North Macedonia is situated in a seismically active region with an increasing seismic risk. As in many other countries exposed to seismic hazard, technical regulations for design of seismically resistant structures have been elaborated and adopted in North Macedonia, as well. As part of former Yugoslavia, North Macedonia represents one of the first European countries that passed its first Rulebook on Technical Norms for Construction of Buildings in Seismic Areas (PIOVS) as early as 1964. The passing of this Rulebook was initiated by the catastrophic Skopje earthquake of 1963 that, in fact, drew the attention of the national and world professional public toward design of seismically safe structures. Chronologically speaking, the second issue of PIOVS was published in 1981 (Official Gazette of SFRY no. 32) and it was revised on three occasions with the Rulebooks on Modifications and Amendments (1983, 1988 and 1990). According to the existing National code and in correlation with the established world practice, the principal design philosophy is based on protection of human lives against strong earthquakes and partially on controlled damage during occurrence of the so-called frequent earthquakes.

Improvement of earthquake resistance of existing buildings – case studies

Most building codes in the world explicitly or implicitly accept the occurrence of structural damage in buildings during strong earthquakes as long as the life hazard is prevented. Indeed, many earthquakes

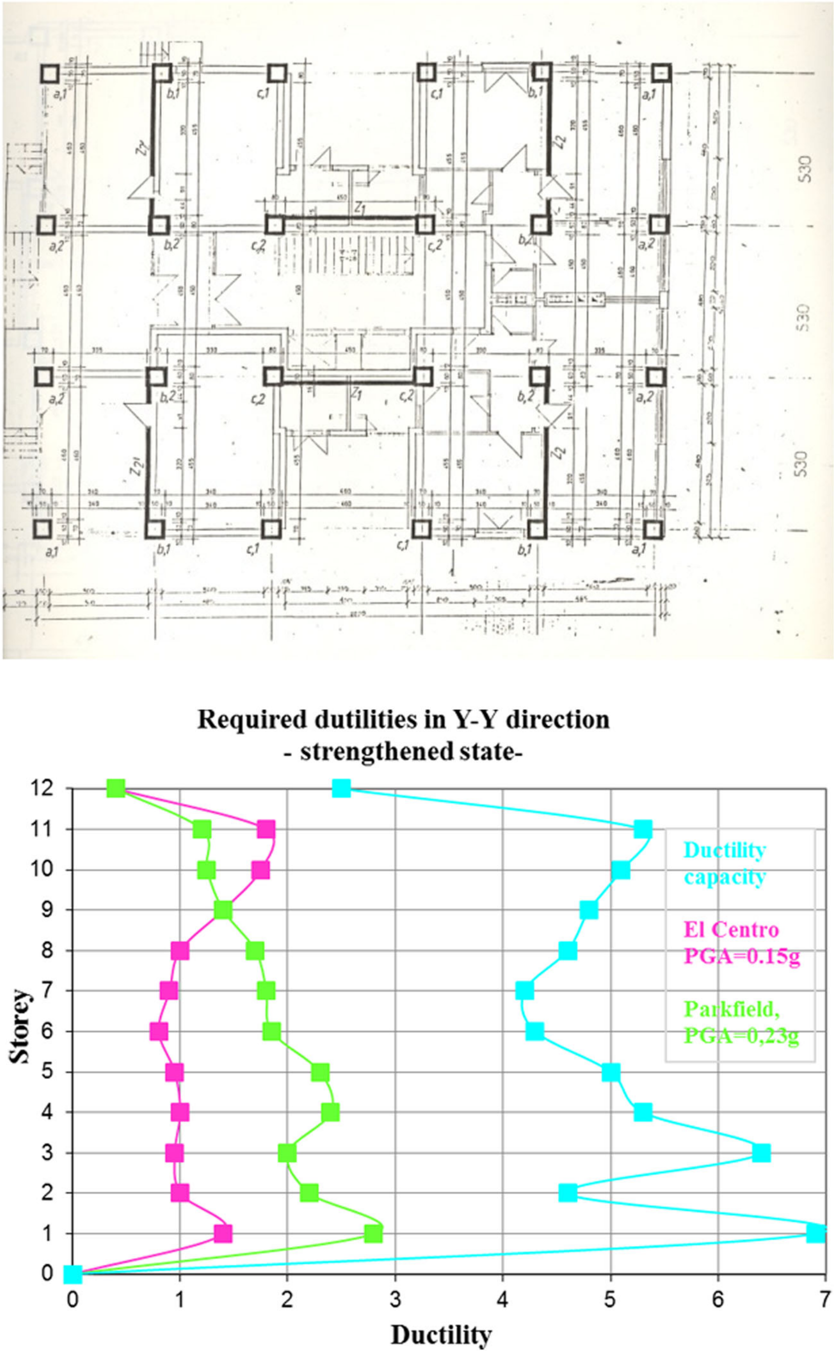

Figure 2. Figure 2a. RC building tower 5 - layout of the solution for retrofitting. Figure 2b. RC building tower 5 - demand versus capacity in terms of ductilities.

(Haiti, Chile, Japan and New Zealand) caused such damage in the past. Seismic design codes were improved after each earthquake disaster, but existing structures were left unprotected by a new technology. As a consequence, seismic assessment and retrofitting of existing structures has become top priority issue worldwide. Within this, the undertaking of corresponding engineering measures for reduction of the seismic risk in densely populated urban regions represents the main component of the policy of earthquake risk management.

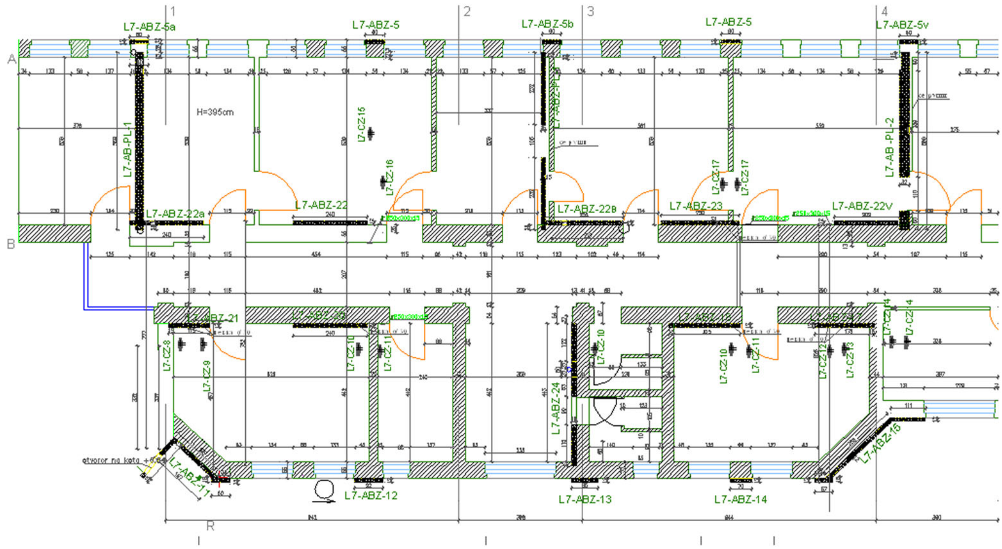

Figure 3. Parliament Building, Unit 5- layout of the solution for strengthening with insertion of RC shear walls and RC jacketing.

Since the disastrous 1963 Skopje earthquake, North Macedonia has gathered an ample experience in seismic assessment, but also definition of measures for retrofitting of buildings. It is important to note that North Macedonia, as part of Former Yugoslav Federation, was the first European country which enforced the regulation for seismic retrofit of buildings in 1985 (PSOROV, 1985).

As a result of the ample analytical and experimental studies, carried out at the Institute of Earthquake Engineering and Engineering Seismology, IZIIS in Skopje, a method and a corresponding package of computer programs have been developed in-house for seismic assessment of existing RC building structures (Necevska-Cvetanovska & Apostolska, 2000). Special attention was also put on seismic strengthening of historic buildings and monuments due to their individual historic, architectonic, documentary, economic, social and even political or spiritual value. The methodology which is based on the philosophy of 'minimal intervention – maximal protection' has originally been developed at IZIIS, Skopje and it has been experimentally and analytically verified (Shendova et al., 1994, 2012).

The developed methodologies have been widely applied in North Macedonia and in the region and only few selected case studies are briefly presented in the following paragraphs.

Case study # 1: RC building 'tower 5', Skopje

The building structure consists of a basement, a ground floor and ten stories. The load bearing system is designed and constructed as a RC frame system with ribbed floor structure. The structural system was designed in 1968 without dynamic analysis. The obtained results showed that the earthquake demands expressed in terms of relative displacements were far beyond the displacement capacity, leading to structural failure. The results from the analysis of ultimative limit states for gravity loads show that, in most of the columns running up to the seventh story, the normalized axial force factors and safety factors for concrete are bigger than those allowed by the regulations.

The strengthening solution anticipated both, the insertion of columns with RC jackets ($d = 10$ cm) and concrete compressive strength of 40 MPa and also incorporation of new RC walls with $d = 15$ cm up to the tenth story (two walls in longitudinal and four in transversal direction) (Figure 2a). Distribution of the ductility demands versus capacities along the height of the structure is given in the Figure 2b.

Case study # 2: Parliament building of the Republic of North Macedonia

The structure of the Assembly of the Republic of North Macedonia exists more than 70 years. After the Skopje earthquake 1963 it has been repaired but strengthening of the structural system wasn't

Table 2. Bearing and ductility demand/capacity (Unit_5).

	Required bearing capacity (% of weight)		Bearing capacity (% of weight)		Ductility demand (max)		Ductility capacity (max)	
UNIT_5	x–x	y–y	x–x	y–y	x–x	y–y	x–x	y–y
Existing state	30		11.54	12.5	3.33	2.81	1.63	1.72
Strengthened state	24		23.1	23.7	1.8	2.2	2.74	2.75

performed. In its life time the building structure experienced a lot of changes, adaptations and annexes. The structural system is massive masonry (seven units in total) which consists of massive bearing walls with lime mortars in two orthogonal directions. The floor and roof structure is RC fine ribbed ceiling.

Different variant solutions from the aspect of stability, economy and possibility for construction were analyzed. Finally, selection of most appropriate solution using classical methods and elements (insertion of RC shear walls and RC jacketing on existing masonry walls) were applied (Figure 3). An example of the efficiency of the selected methodology for one of the structural units of the building was presented in Table 2 (Bozinovski et al., 2011). It is obvious that ductility capacity for the existing state is less then ductility demand (highlighted in red in Table 2) and is bigger for the strengthened state (highlighted in green in Table 2).

Case study # 3: St Panteleymon church in Plaoshnik, Ohrid

The above referred methodology was applied for rehabilitation and seismic strengthening of St. Clement's Church, Plaoshnik, Ohrid. To renovate the structure based on the original foundation dating back to the IX century, complex multidisciplinary investigations were performed in the field of archaeology, conservation, engineering and construction. The concept of repair and seismic strengthening of the church consisted of incorporation of horizontal and vertical steel ties in the bearing walls of the structure (Figure 4a and b). The techniques of consolidation of the authentic foundation of the structure and the existing walls with original fresco-paintings have been performed also (Necevska-Cvetanovska & Apostolska, 2008; Ministry of Economy of Republic of Macedonia, 2011).

Case study # 4: Mustafa Pasha Mosque, Skopje

The main principles of seismic strengthening of the Mustapha Pasha Mosque in Skopje were: (i) application of new technologies and materials, (ii) reversibility and (iii) invisibility of the applied technique. Based on the submitted architectonic data, the investigations of the soil conditions, the investigations of the characteristics of the built-in materials, visual inspection of the structure as well as previous experimental investigations of a mosque model (Figure 5a), a solution for repair and strengthening of the existing structure is elaborated (Figure 5b), followed by a detailed analysis and computation of the bearing system under gravity and seismic loads (Shendova et al., 2012).

Case study # 5: innovative methodology for earthquake resistance and energy efficiency – ROFIX case study

Providing both the earthquake resistance and energy efficiency of existing buildings was the triggering issue for developing an innovative technology called System ROFIX SismaCalce by the company ROFIX, member of the of Fixit Gruppe from Austria. It combines the system ROFIX Sisma for seismic upgrading and the multilevel ROFIX system for thermal insulation; applied together they enable earthquake resistant and completely thermal insulated structure. The testing programme which main goal was experimental investigation of the efficiency of this newly developed integrated methodology was carried out in IZIIS (Figures 6a and b) (Shendova et al., 2013).

Eco-efficiency of new/existing buildings – regulations, training skills and supply chains

The National Status Quo Analysis (February, 2013) showed that around 70% of existing buildings in North Macedonia are more than 25 years old with the high average specific energy consumption. The lack of

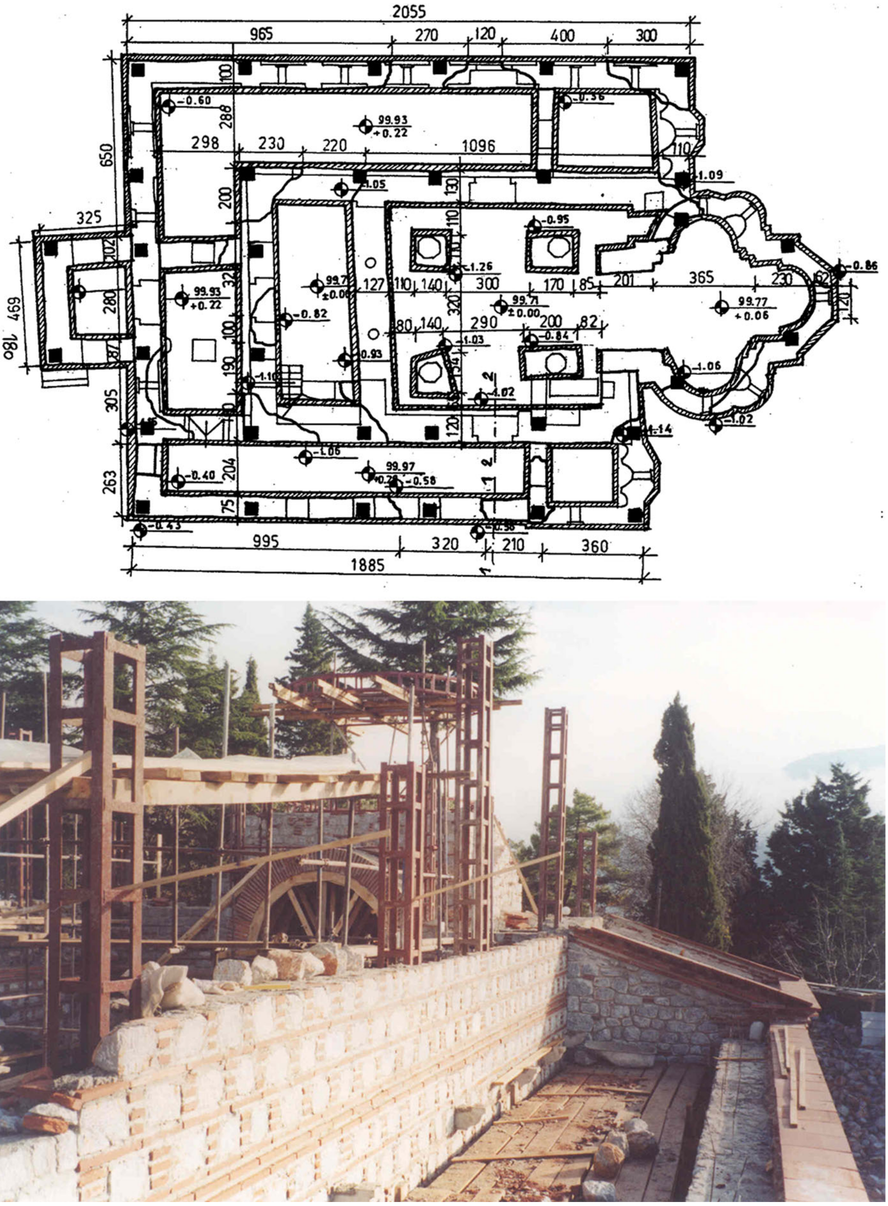

Figure 4 Figure 4a. St. Panteleymon Church in Plaoshnik - layout of the strengthening. Figure 4b. St. Panteleymon Church in Plaoshnik - construction phase.

National Regulations on energy performance of buildings in North Macedonia has been an obstacle for the improvement of energy and eco – efficiency of buildings for many years, together with education for certification of energy controllers. National Regulations were delivered in July 2013 (Official Gazette of the Republic of Macedonia, No. 94) pursuant to the directive 2010/31/EU and revised in 2015. Their application should lead to an improvement in the energy performance of buildings in the long term.

Following emerging needs for smart energy society, the ‘First energy efficiency action plan (EEAP) of the Republic of Macedonia by 2018’, was developed pursuant to the directive 2006/32/EC (Ministry of Economy, 2011). National indicative energy saving targets is presented in Figure 7 (Apostolska & Samardziovska, 2014). These targets should be achieved through set of comprehensive energy efficiency improvement (EEI) program and measures. The most efficient ones in the residential sector are adoption and enforcement of building energy codes and EE retrofits in existing buildings.

Figure 5. Figure 5a. Mustafa Pasha Mosque - model of original state. Figure 5b. Mustafa Pasha Mosque - model of strengthened state with CFRP bars and wrap.

Potential of energy savings of 57.1% in residential buildings and 28.6% in commercial and public buildings in 2020 have been identified refer to planned EEI program. The building sector is estimated to contribute with 1.660ktCO_2 saved by 2020.

One of the projects at national level which represent good practice and can boost development in this field is *BUILD UP SKILLS MK* – Building capacities in the construction sector - supported by Intelligent Energy Europe (http://www.buildupskills.mk). Its main objective was to provide competent and qualified Macedonian workforce in building sector, necessary for achievement of national energy efficiency targets. The target was training of 4800 on-site buildings workers on energy efficiency and renewable energy sources skills on two qualification levels by 2016.

Another positive example is Municipality of Karposh in Skopje who is a pioneer in the country in application of the energy efficiency policies at the local level together with different relevant stakeholders. As a first initiative the 'Program for energy efficiency 2008–2012' was issued and within this frame program the following activities were carried out: (1) reconstruction of public facilities − 10 primary schools and 3 kindergartens applying energy efficiency measures (EEM); (2) reconstruction of 4 residential buildings with collaboration with 'Habitat Macedonia', applying EEM ($Q \leq 100$ kWh/m^2/per year) and (3) construction of 63 new buildings according 'Regulation on energy efficiency measures' ($Q \leq 70$ kWh/m^2/per year). The Municipality of Karposh is one of the first users of the software tool for energy monitoring Ex-CITE with monthly data updating. The important outcome from this programme is 40–70% less consumption of energy in comparison with the same buildings construct/retrofit without applications of EEM.

Another example of positive practice, although in the very begging phase in North Macedonia, is building ecologically with hollow wood-chip concrete blocks (Figure 8a). These blocks are characterized with excellent noise insulation, heat storage and vapour diffusion, as well as fire resistance and earthquake safety (Figures 8b and c) due to their compact core (Samardziovska & Apostolska, 2016).

Conclusions

From the presented above it can be concluded that in the Republic of North Macedonia there is a long tradition and positive experience in the field of seismic design of new and strengthening of the existing buildings up to defined by code levels of seismic protection. However, this practice generally target only one of the basic work requirements defined in CPR i.e. mechanical resistance and stability.

Starting from 2013, when the first national regulation for energy performance of the building was issued, there are some positive initiatives/examples at national and local scale. One of the unique case study who offers innovative technology for providing both, earthquake resistance and energy efficiency of the existing buildings, is System ROFIX. However, it should be pointed out that this is not national brand and IZIIS served only as an experimental logistic for verification of this integrated method.

Figure 6 Figure 6a. ROFIX case study - retrofitted model on shaking table. Figure 6b. ROFIX case study - failure mechanisms of strengthened wall element.

Therefore, the national roadmap for integrated renovation which should include not only structural safety but also energy efficient and environmentally friendly buildings should be elaborated further.

The possible drivers for setting-up the roadmap for the improvement of earthquake resistance and eco-efficiency of existing buildings and cities are:

- Appropriate institutional support (in the whole phase of renovation: preparation of technical documentation, obtaining the construction permits, construction, etc.)
- Transfer of knowledge and best practices from the economies/regions who already set the such roadmaps and adjusting available technologies to the local peculiarities

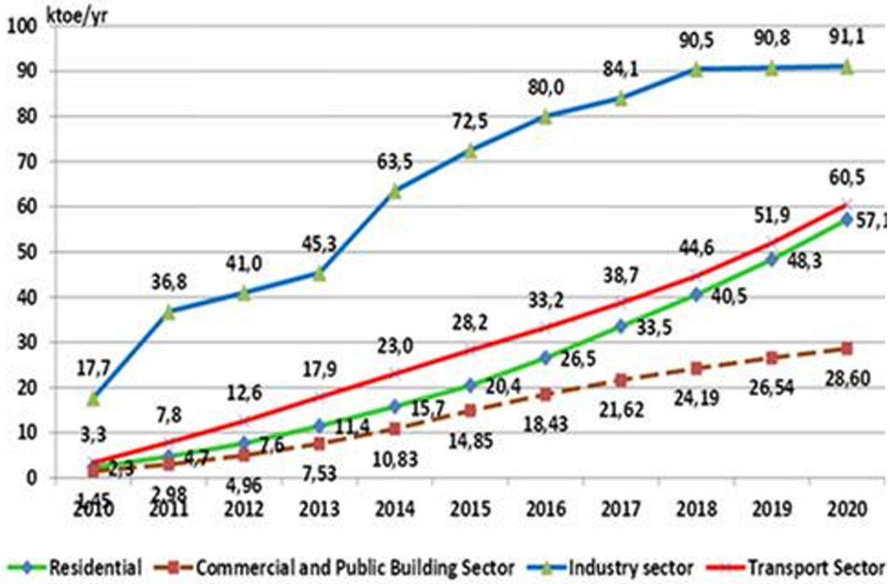

Figure 7. Goals in potential of energy savings according to the Strategy of EE, up to 2020.

Figure 8. a) Hollow wood-chip concrete blocks with integrated insulation; b) Hollow wood-chip concrete blocks - placing reinforcement in the wall; c)Hollow wood-chip concrete blocks – mounting elements.

- Mapping and networking of projects (finished/on-going) involving topics as eco-efficiency, smart renovation, low-carbon construction, sustainability etc. in order to profit from their gathered knowledge, etc.

Among a lot of open issues, there are several listed below which, if address properly, could facilitate definition of a Roadmap for the improvement of earthquake resistance and eco-efficiency of existing buildings:

- Facilitation of research in the field of integrated renovation of existing buildings (experimental verification of the proposed innovative methodologies/techniques/materials).
- Multidisciplinary education of the engineers who should deal with this integrative approach – updating of high schools curricula and training.
- Increasing public awareness concerning energy issues and necessity to live in eco-efficient buildings, (user behaviour is a key point to reduce consumption).
- Financial, institutional and regulatory barriers, etc.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

The part of the work presented in the paper was supported by the COST European Cooperation in Science and Technology, TU1104 Action: Smart Energy Region.

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