Proceedings of the 2nd Croatian Conference on Earthquake Engineering - 2CroCEE
Zagreb, Croatia - March 22 to 24, 2023

DOI: https://doi.org/10.5592/CO/2CroCEE.2023.108

CUSTOMIZED SEISMIC SCREENING TOWARD SUSTAINABLE PUBLIC BUILDINGS ENERGY EFFICIENCY

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Abstract

Increasing energy efficiency of final energy consumption is a very actual and important topic, in parallel with activities and measures worldwide targeting an increased share of renewable energy sources. Despite recent expansion in building construction, old buildings characterized by high energy consumption still represent a great majority of both residential and public building stock in many countries in the Balkan region. Located in seismic-prone countries, such as the Republic of North Macedonia, these old buildings are also characterized by the high risk of partial or complete destruction during earthquakes. This imposes the need for mandatory screening at the outset of an energy efficiency program, which will categorize buildings according to seismic risk and thus determine which buildings are suitable for energy efficiency investments. This paper presents how the methodology for high-level seismic screening, originally proposed in the World Bank's Country Report (North Macedonia), is extended and customized by the Institute of Earthquake Engineering and Engineering Seismology, IZIIS, Skopje to correspond to the country specificities, i.e., to be based on overall knowledge on aseismic design and construction practice in the country, detailed on-site inspection of each particular building, and to be carried out by structural engineers with appropriate knowledge and experience in earthquake engineering. The high-level seismic screening was performed in the Republic of North Macedonia, applying this extended and customized methodology, for a total number of 27 medical facilities, dominantly healthcare centers, and 50 municipality buildings (schools, kindergartens, and municipal buildings).

Keywords: seismic performance of existing structures, knowledge level, aseismic design practice, construction practice, nondestructive testing, public buildings

1. Introduction

Situated in the southern part of the Balkan Peninsula, the territory of the Republic of North Macedonia belongs to the Mediterranean seismic belt. It is characterized by extensive neotectonics and recent destructive processes resulting in several regions' intensive seismic activity. According to the earthquake catalog, several hundreds of earthquakes have occurred on the territory of Macedonia over the last century, most of them with destructive nature and some even with catastrophic consequences. However, the studies related to seismic design, vulnerability and exposure modeling, and enactment of seismic code generally started after the Skopje earthquake in 1963, following the need for damage assessment, reconstruction, and recovery of the city of Skopje.

As there is no regular inventory of buildings in the country, official data can be obtained from the population and dwellings censuses (the last one was carried out in 2021 but is still without official data on dwellings). Summarizing cross-analysis of the statistical data from the last censuses (1991, 2002.) and the available data from the State Statistical Office, it can be concluded that in 2002 the percentage of buildings built before 1970, out of the total number of the particular type of facilities, is 35% for residential, 82% for school, 81% for tourist and 39% for health facilities [1, 2]. Based on the trend of newly built residential buildings in the last two decades, it can be estimated that the percentage of residential buildings built before 1970 is undoubtedly reduced, but the percentage of school and

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health facilities is still high. Thus, for a significant percentage of the construction stock in the country, the level of seismic protection is unknown. Besides their high seismic risk, these old buildings are also characterized by high energy consumption.

As a signatory of the EU and International Energy Charters as well as the Protocol for Energy Efficiency and Relevant Environmental Protection Aspects, North Macedonia is funding several energy efficiency programs through available financial instruments to reduce the energy consumption of public buildings. Since the vast majority of target buildings are characterized by high energy consumption and seismic risk, integration of seismic risk considerations into energy efficiency programs should be mandatory. This can be achieved by providing the high-level seismic screening process at the outset of an energy efficiency program, which will categorize buildings according to seismic risk based on knowledge of aseismic design and practice in the country, thus determining which buildings are suitable for energy efficiency investments.

2. Aseismic Design and Construction Practices in North Macedonia

The existing building stock in North Macedonia reflects the history of urban development, which, until 1990, is typical for the whole territory of former Yugoslavia. The prevailing building types differ from the building function to different regions where they have been built according to local traditional practices. Standard legislation defines the procedures and the demands for seismic protection and dominantly refers to problems of acceptable risk for buildings [3]. Briefly, there were three significant threshold changes in seismic standards during the Yugoslav (pre-1991) period.

- The first standards addressing the seismic requirements were the "Temporary Technical Provisions for Loading of Buildings" (PTP-2), adopted in 1948, that prescribed structural analysis by additional horizontal forces (representing effects of wind) taken as 2% of the total building weight. However, it was required only for higher buildings, and no specific reinforcement detailing was defined.
- Prompted by the devastating Skopje earthquake of July 26, 1963, the first seismic design code, "Temporary Technical Provisions for Building in Seismic Regions," was adopted in 1964, which improved methods for determining design loads on buildings and introduced quality requirements for materials and construction. Significant progress in structural design, construction practice, and scientific development in the field of earthquake engineering took place in the entire region in the 1970s, led by the Institute of Earthquake Engineering and Engineering Seismology (IZIIS) established in 1965 upon UN recommendation for the recovery of Skopje and conducting research, education, training, development, and improvement of technical regulations in the field of earthquake-resistant structures.
- In the 1981 "Rulebook on Technical Regulations for Construction of Buildings in Seismic Regions," a significant update was made to the seismic design, partly in response to the 1979 Montenegro earthquake, and it was mandatory for any type of building. Along with the amendments from 1982, 1983, 1988, and 1990, it is still an official and valid regulation in the country. Macro-seismic maps for several characteristic return periods were incorporated to comply with the seismic hazard levels. The seismic shear base coefficient was introduced and calculated according to building importance, structural system, local soil conditions, and region seismicity. Limits on permissible heights of masonry construction, introduced in 1964, were further revised based on the construction method. Importantly for reinforced concrete moment frame systems, detailing requirements in the heavily loaded zones at the end of beams and columns were introduced. Also, the regulations that were adopted in the designated period and are still in power are the "Code for Repair and Strengthening of Earthquake Damaged Buildings" (1985) and the "Rulebook on Concrete and Reinforced Concrete" (1987).

The period from 1964 to 1991 is considered a period of exceptionally high-quality structural design and control that resulted in safe buildings with a seismic risk equal to or lower than the maximum acceptable. However, the period from 1991 to 2005, after the country gained independence, was a transition period in which many individual initiatives for the design and construction of residential and

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business areas were taken. Although seismic design regulations existed, Macedonian society struggled with the strict implementation of technical standards that regulated the construction of building structures. Material and construction quality control was not mandatory by any regulations. As a result, there is no clear picture of the building quality during this period.

This period ended in 2005 with the enactment of the Law of Construction. This law established the Technical Chamber of Architects and Engineering to control professional competencies by enforcing the certification requirements for structural design, project revision, construction execution, and supervision. There are no laws mandating seismic assessment of existing structures unless they are undergoing structural modification, nor specific licensing process or qualification for demonstrating competency in the seismic assessment of existing buildings. Structural engineers with appropriate knowledge and experience must carry out seismic assessments and strengthening designs. Many structural engineers who are highly experienced and skilled in designing new buildings may not have experience in assessing old buildings or the field of seismic assessment. The effective implementation of seismic assessment and design of strengthening requires a range of specialist skills characteristic of the discipline of earthquake engineering.

In 2013, an Annex to the Law on Construction of Building Structures was adopted, further improving the construction regulation process mandating the expert review of the scientific institution with respectful experience (IZIIS, http://www.iziis.ukim.edu.mk/en/) to obtain a construction permit for all buildings and usage permit for buildings above 300 m^2 area.

In 2020, Eurocodes were adopted in the Republic of North Macedonia as parallel legislation to the currently valid Codes, after which the building design and construction practice is expected to be more harmonized with the European practice.

Taking the above into account, the roughest general building categorization could be done according to the main structural system and year of construction, meaning three basic types:

- *Non-Earthquake Resistant* Masonry Buildings (pre-Code) involving unreinforced, plain masonry buildings with several sub-categories that were implemented dominantly in urban and rural areas up to 1964 when the first seismic code was enforced
- *Moderate Earthquake Resistant* Confined Masonry Buildings (Low-Code) involving plain masonry structures strengthened by vertical and horizontal reinforced concrete belts or by jacketing of the bearing walls, frequently implemented after the Skopje earthquake for seismic upgrading of existing buildings as well as the construction of new houses, dwellings, and low-rise public buildings
- *Earthquake Resistant* Reinforced Concrete Buildings (High-Code) involving low, mid, and high-rise public and residential buildings, residential complexes in urban areas, with extensive usage after 1970 until nowadays

3. High-level Seismic Screening Methodologies

3.1. High-Level Screening – Level 1 according to the World Bank's Country report

Within the Public Sector Energy Efficiency Project (REP No: MK-MOF-001-2021-CS-SC), financed by the International Bank for Reconstruction and Development (IBRD) with the Ministry of Finance of the Republic North Macedonia as the implementing agency, IZIIS has been assigned to provide technical assistance for seismic screening of public facilities in the country, following the methodology described in the Country Report (North Macedonia) on Integrating Seismic Risk Consideration into Energy Efficiency Investments World Bank #1265632, applying Level 1 seismic screening and using the template data record Level_1_Data_Record_form [3].

This screening process, according to the given methodology, includes two types of information that should be filled in the Form: (1) General information that anyone could gather and does not require specialist expertise (construction date, location, input information from hazard maps and a number of storeys) and (2) Specific information that requires engineering judgment (general structural type,

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structural irregularities, evidence of strengthening, and other structural issues). Several methods are proposed that could be used to collect data depending on the quality of existing records:

- Desk study and remote data collecting (if there is good coverage of Google Street-view or Google 3D buildings in the region being studied)
- Building manager questionnaire
- A rapid visual survey by a structural engineer (if data and photo records are incomplete).

According to the Country Report, two different seismic hazard information are required in the screening form to obtain a hazard comparison rating of A, B, C, or D, irrespective of the knowledge of local seismicity (Table 1):

- The seismic hazard at the building location is defined using the current earthquake hazard map produced for the country's Eurocode National Annex.
- The seismic hazard value that was applicable at the time of the building's construction. This value can be obtained from the historic hazard maps published in 1964, 1982, and 1990.

Table 1 - Hazard comparison rating (according to Country Report)

		Eurocode peak ground acceleration agR								
		0.05	0.10	0.12	0.15	0.20	0.25	0.30	0.35	0.40
	Band	0.04-0.08	0.09-0.11	0.12-0.13	0.14-0.18	0.19-0.23	0.24-0.28	0.29-0.33	0.34-0.38	0.39+
MSK Intensity from 1964, 1982 or 1987 Map	pre1964	A	C	C	C	D	D	D	D	D
	VI	A	C	C	C	D	D	D	D	D
	VII	A	B	B	C	D	D	D	D	D
	VIII	A	A	B	B	C	C	C	D	D
	IX	A	A	A	B	B	B	C	C	C

Table 2 - Seismic risk rating (according to Country Report)

	Green: The building is suitable for the EE programme without further seismic assessment. This is either because it has acceptable document records to indicate that the building meets current building standards or because the building is in a region of low earthquake hazard and is judged likely to have good earthquake resilience, although document records are not available to formally validate this status.
	Yellow: The building could progress in the EE programme, but compliance with modern standards is not guaranteed. A further assessment is likely to conclude that the building has reasonable seismic performance. However, there are some uncertainties. A deficiency-based or detailed assessment is needed to confirm seismic risk status and identify recommended strengthening interventions. The building may require localized earthquake-strengthening work to achieve acceptable seismic performance, and these may be achievable for a cost within 10% of the building value.
	Orange: The building could progress in the EE programme, but building performance is likely below modern standards. A further assessment will likely conclude that the building has moderate seismic performance. However, there are some uncertainties, and the building may contain critical weaknesses that are not detectable in the high-level screening. A deficiency-based or detailed assessment is needed to confirm seismic risk status and identify recommended strengthening interventions. The building may require strengthening to reach acceptable seismic performance. Bringing the building closer to modern standards is likely to require moderate costs in the range of 10 to 50% of the building value.
	Red: A detailed assessment is likely to conclude that this building has a high vulnerability which may include a critical structural weakness. Strengthening the building to meet a reasonable benchmark performance level would likely require significant investment exceeding 50% of the building value.

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Building structural systems should be classified, and eventual structural irregularities or evidence on structural strengthening should be noted following the given guidance. Then, using the rating schedule, preliminary color classification (red, orange, yellow, green) should be chosen by selecting the row matching the characteristics of the building. If there are unknowns in the building data, the rating corresponding to the most conservative (highest vulnerability) assumption has to be used. A preliminary color classification might be revised in relation to the seismic risk rating descriptions for each color (Table 2), thus leading to the final color status.

3.2. IZIIS' Approach for customized seismic screening

Data requirements for the screening process according to the given methodology in the Country report have been established to balance the effort required to collect the data with the benefit in terms of reliability of seismic assessment. This will undoubtedly lead to more conservative decisions if the screening takes place rapidly, based on a desk study and remote data collection, and especially without trying to increase the knowledge level for the particular structure, thus minimizing the uncertainties. Despite precise general building classification, for reliable seismic safety assessment, the method of detailed site inspection of the building is indispensable and irreplaceable.

To achieve a more reliable seismic risk rating, IZIIS proposed and carried out the extended and upgraded technical approach for customizing the high-level seismic screening to correspond to the specifies of medical facilities in the country, represented by the following steps, [4]:

STEP 1: Desk study, remote data collecting, putting efforts in providing the technical design documentation and reviewing it;

STEP 2: On-site screening inspection by survey teams involving the following activities:

- conducting the interview with the facility representatives who has sufficient knowledge of the facility since its commissioning,
- outdoor/indoor visual inspection with control measurements of building geometry,
- indoor visual inspection for identification of overall integrity of the structural system, irregularities, structural and non-structural changes during exploitation, damages to the bearing elements, evidence of strengthening, other operating and maintenance problems, and control measurements of structural elements geometry,
- nondestructive measurements (NDT tests) of selected structural members (were available) applying the following testing equipment:
    - SCLEROMETER Digi Schmidt, a mechanical device designed to define the compressive strength of a material (primarily concrete)
    - PROFOMETER, a rebar detection system for identifying the presence of the columns hidden in the walls and obtaining data on the built-in reinforcement
    - TROMINO portable ultra-mobile seismometers for a definition of structural fundamental dynamic characteristics (natural frequencies);
- filling the Level 1_Data_Record_Form during the survey with the preliminary seismic color rating (green, yellow, orange, red) for each structural unit within the medical facility.

(STEP 3): Post-screening desk study involving:

- Reconsidering the information obtained during the survey,
- Definition of the final color status in accordance with complete findings and observations on existing seismic structural stability.+

(STEP 4): Repeated on-site screening involving more detailed (destructive) control investigation of the quality and quantity of built-in materials (concrete grade, reinforcement type) in case this additional information was needed to justify the final color rating.

To realize the activities mentioned above, IZIIS engaged the following teams:

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- One supervising team, consisting of four key experts in the field, who set up the criteria for seismic screening, coordinated all the activities, revised and harmonized the survey data, and confirmed the screening rating of each building assigned by the survey teams,
- Five survey teams, consisting of two to three structural engineers (one expert as team leader and collaborators), who interviewed the representatives of each of the selected medical facilities to obtain the necessary information and better organize the on-site visual survey, reviewed the technical documentation, provided the on-site visual survey along with NDT tests and filled-in the Level_1_Data_Record_Form.

Structural analysis of the surveyed structures was not carried out, so the seismic assessment was qualitative and based on the IZIIS' knowledge and expertise in addition to the conducted interviews, project and drawing reviews, visual observations, nondestructive measurements, and limited control investigations (destructive testing).

4. Comparative Presentation of the Seismic Screening Results

4.1. Results for 27 medical facilities

The high-level seismic screening was performed for a total number of 27 medical facilities with different functions, selected by the Ministry of the health of North Macedonia, including dominantly healthcare centers, but also infirmaries and pharmacies [5]. The vast majority of the selected healthcare centers represent complexes with several separate structural units, thus, the total of 65 structural units with a total floor area of 54005 m^2 was surveyed. Among them, 47 are reinforced concrete structures, 14 are masonry structures, three are reinforced concrete ground floor upgraded with additional steel structures, and one is wooden.

According to the relevant standard when the structures were designed (Table 3), which according to the methodology is one of the deciding factors for the color rating, the facilities have been dominantly designed according to the first seismic code in the country, while only small part of them have been designed according to current standards. However, there is not an insignificant number of facilities older than 60 years, which have not been designed as earthquake-resistant structures, and, according to Table 1, are automatically excluded from the energy efficiency program, irrespectively the existing state of their structural systems.

Table 3 - Distribution according to the relevant standard when the medical facilities were designed

year of issuing the relevant standard	number of facilities	number of structural units	total floor area in m^2
1948	7	14	8119
1964	16	43	40298
1981	4	8	5588

An on-site visual inspection of the medical facilities was carried out in August –September 2021. During the visual survey and inspection (step 1 and part of step 2), the Level_1_Data_Record_Forms for all the buildings were filled in by adopting the color rating status in accordance with the methodology given in the Country Report (North Macedonia). Results for color rating presented in Fig.1 show that none of the structural units is categorized as green, meaning that no one is suitable for progression in the EE program without further seismic assessment. 22 (yellow) units with about 35% of the total floor area could enter the EE program if further assessment satisfies the criteria. For the 32 (orange) units, with 54% of the total floor area, it is not cost-effective to enter the EE program since it will require structural strengthening, while the rest 11 (red) units, with about 10% of total floor area are automatically excluded from the EE program.

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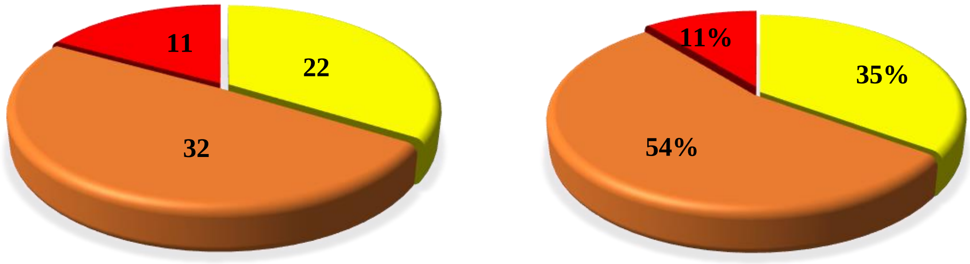
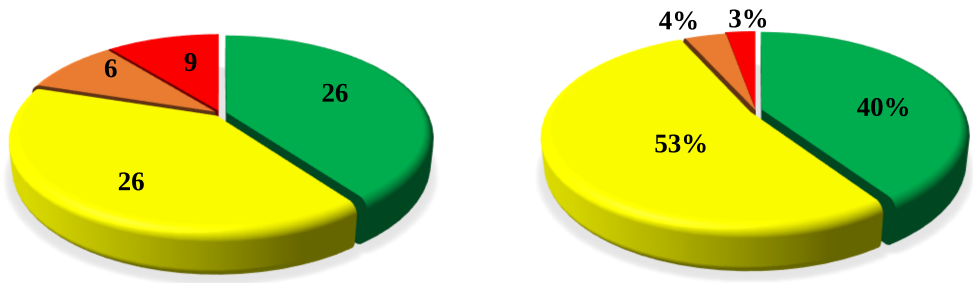


number of units | total floor area

Figure 1. Distribution of medical facilities according to Country report' methodology



number of units | total floor area

Figure 2. Distribution of medical facilities according to IZIIS' methodology

However, implementing IZIIS' extended and upgraded methodology, (steps 2, 3 4) which gives the possibility to take into account and reconsider the in-situ situation of each of the structural unit, confirmed with the site inspection and nondestructive measurement, as well as the elaborated acceptable level of risk from the deficiencies to meet the current seismic code, results in significantly different building categorization, (Fig. 2). Due to these reconsideration, vast majority of the structural units are categorized with lower seismic risk by at least one level, although there is one structural unit which turned in "red" from "orange" since it was seriously damaged.

4.2. Results for 50 municipal buildings

The high-level seismic screening was also performed for a total number of 50 municipal buildings selected by 14 Municipalities in the Republic of North Macedonia (Mogila, Kavadarci, Ohrid, Dojran, Valandovo, Gostivar, Resen, Kichevo, Skopje Centar, City of Skopje, Pehchevo, Struga, Rankovce and Kisela Voda), including dominantly elementary or high schools, but also kindergartens, administrative municipality buildings, fire stations, libraries, and cultural centers, [6]. Most of the selected municipal buildings represent complexes with several separate structural units or enlargements. Thus, 115 structural units with a floor area of 123339 m^2 were surveyed. Among them, 85 are reinforced concrete structures, 19 are masonry structures, 7 are steel structures, 2 are wooden structures, and 2 are mixed structures with masonry and RC parts.

According to the relevant standard when the structures were designed (Table 4), the structural units within the municipal building complexes have been dominantly designed according to the first seismic code in the country, while only a tiny part has been designed according to current standards. However, a significant number of facilities older than 60 years have not been designed as earthquake-resistant structures and, according to Table 1, are automatically excluded from the energy efficiency program, irrespectively the existing state of the structural system. Typical for many primary schools and kindergartens are enlargements, which were usually built in different periods compared to main buildings and often with different structural systems and according to different standards.

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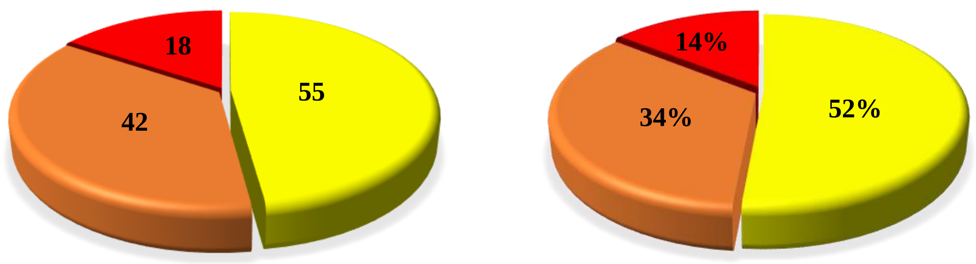
Table 4 - Distribution according to the relevant standard when the municipal buildings were designed

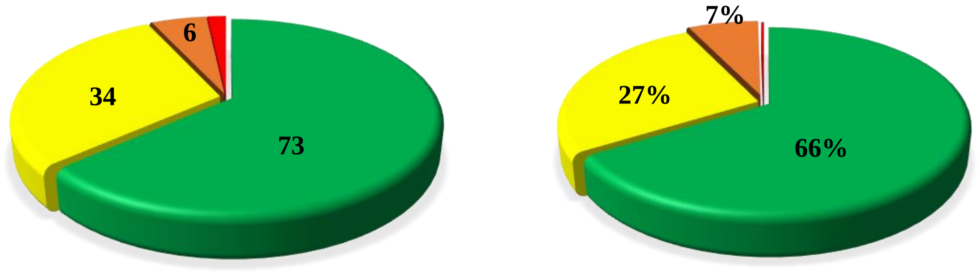
year of issuing the relevant standard	number of structural units	total floor area in m^2
1948	16	13437
1964	75	85601
1981	24	24302

An on-site visual inspection of the municipal buildings was carried out in March –April 2022. During the visual survey and inspection (step 1 and part of step 2), the Level_1_Data_Record_Forms for all the buildings and units were filled in by adopting the color rating status in accordance with the methodology given in the Country Report (North Macedonia). Results for color rating presented in Fig.3 show that none of the structural units is categorized as green, meaning that no one is suitable for progression in the EE program without further seismic assessment. 55 (yellow) units with about 52% of the total floor area could enter the EE program if further assessment satisfies the criteria. For the 42 (orange) units, with 34% of the total floor area, it is not cost-effective to enter the EE program since it will require structural strengthening, while the rest 18 (red) units, with about 14% of the total floor area are automatically excluded from the EE program.



number of units total floor area

Figure 3. Distribution of municipal buildings according to Country report' methodology



number of units total floor area

Figure 4. Distribution of municipal buildings according to IZIIS' methodology

However, implementing IZIIS' extended and upgraded methodology, (steps 2, 3 4) which gives the possibility to take into account and reconsider the in-situ situation of each of the structural unit, confirmed with the site inspection and nondestructive measurement, as well as the elaborated acceptable level of risk from the deficiencies to meet the current seismic code, results in significantly different building categorization, (Fig. 4). Due to this reconsideration, almost all of the structural units are categorized with lower seismic risk by at least one level, resulting in 73 (green) units with 66% of total floor area suitable for progression in the EE programme without further seismic assessment, and another 34 (yellow) units with 27% of total floor area if the further assessment satisfies the criteria, i.e. only 8 (6 orange and 2 red) units with 7% of total floor area were excluded from the EE programme.

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It has to be noted that, besides the Ministry of Finance of North Macedonia, this approach resulted in the categorization of more than 90% of both the medical facilities and municipal buildings with the lowest seismic risk (green and yellow final color status) was accepted and approved by the World Bank too, which provide the financial support for overall energy efficiency program.

5. Conclusion

Improving existing buildings' energy efficiency is a very important and "hot" topic worldwide. For the seismic-prone regions, it is recommended to perform seismic screening before deciding whether the structure is suitable for energy efficiency investment. However, the seismic screening must be based on overall knowledge on aseismic design and construction practice in the country, detailed on-site inspection of each building, and to be carried out by structural engineers with appropriate knowledge and experience in earthquake engineering. Applying seismic screening, which is developed without considering the country specificities and allows only desk study and remote data collection, often leads to conservative and nonrelevant decisions.

Acknowledgments

The authors wish to extend gratitude to the Ministry of Finance of North Macedonia for the entrusted task and fruitful cooperation, to the World Bank for financial support, as well as to the colleagues from IZIIS for their participation in the realization of the project.

References

[1] Shendova, V., (2011): Building Inventory Data for Republic of Macedonia, NERA. European Building Inventory Workshop, EU FP7-infrastructures ID 262330, May 2011, Pavia, Italy

[2] Shendova, V., Apostolska, R., Vitanova M., (2019): Structural Classification of Building and Bridge Assets in R. N. Macedonia. SERA Balkans Seismic Risk Workshop, EU Horizon 2020, ID 730900, June 2019, Belgrade, Serbia

[3] Sesov, V., Apostolska, R., Shendova, V., Salic, R., Zhurovski, A., Poposka, M., (2020): Integrating Seismic Risk Considerations into Energy Efficiency Investments in the Western Balkans. Activity 1_Baseline Definition, Technical Proposal Selection #1265632, *IZIIS Report 2020-33*

[4] Apostolska, R, Necevska-Cvetanovska, G, Shendova, V, Bojadzieva, J., (2018): Seismic performance assessment of "hybrid" structures using two-level multy-group GIS oriented approach: case studies. Bull Earthquake Eng https://doi.org/10.1007/s10518-018-0366-0

[5] Sesov, V., Apostolska, R., Shendova, V., Bozhinovski, Z., Gjorgjiev, I., Bojadjieva, J., Vitanova, M., Jekic, G., Stojanoski, B., Zlateski, A., Zhurovski, A., Kitanovski, T., Zafirov, T., Delova E., (2021): High-level Seismic Screening of the Structures of Medical Facilities in North Macedonia. Summary Report, *IZIIS Report 2021-58*

[6] Sesov, V., Apostolska, R., Shendova, V., Gjorgjiev, I., Micov V., Bojadjieva, J., Vitanova, M., Jekic, G., Zlateski, A., Zhurovski, A., Kitanovski, T., Zafirov, T., Delova E., Chapragoski G., Poposka M., Shoklaroski A., Ivanovski D., Tomic D., (2022): High-level Seismic Screening of the Structures of Municipal Buildings in North Macedonia. Summary Report, *IZIIS Report 2022-35.*