Integrated approach for rapid seismic assessment of the existing building stock

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ABSTRACT: The building stock in Republic of Macedonia is aging and needs certain maintenance or repair/strengthening. Moreover in the existing economic and social environment, increasing construction of building extensions of any kind, particularly for the last two decades, became everyday engineering practice. In these conditions the issue of seismic stability and safety of such new “hybrid” structures is posed as an imperative. Engineering experience showed that the level of seismic protection of such structures is often unknown.

The above challenge has been motivation for the cooperation between the Institute of Earthquake Engineering and Engineering Seismology, IZIIS and Karposh municipality in Skopje within which integrated two-level approach for rapid seismic assessment of the existing building stock in the municipality was developed. This was a pioneering activity at national level whose ultimate goal observed in wider perspective is to decrease the level of the imposed seismic risk to the citizens and society at whole. Based on this integrated approach, the visual screening (level_1 activity) has been performed on 161 existing buildings and for two selected buildings level_2 assessment was carried out. Selected results from these activities are presented in the paper.

1 INTRODUCTION

The territory of the Republic of Macedonia is situated in a seismically active region characterized by an increasing seismic risk. As many other countries exposed to seismic hazard, Macedonia has also had its technical regulations for design of seismically resistant structures elaborated and adopted, PIOVS (1981). The main design philosophy in these regulations is based on protection of human lives in conditions of strong earthquakes and enabling partially controlled damage during the occurrence of the so called frequent earthquakes.

In addition to the modern technical regulations for design, one of the most efficient engineering approaches to mitigation of adverse effects due to the effect of natural hazards is the control over the construction of structures. Although, many of the investigations in developed technological countries are directed to new, modern structures, the main risk for the safety comes, in fact, from the existing structures. Different types of intervention in these structures, many of them designed and carried out non-professionally could disturb their seismic stability.

To respond to the challenge of rapid seismic assessment of the existing building stock in Karposh municipality in Skopje, IZIIS realized the project for definition of a methodology for geo-referenced inventory and observing the conditions of the existing building stock in the municipality from the aspect of seismic stability and safety, Necevska-Cvetanovska et al. (2012, 2013). This is a pioneering activity at national level, whose final goal was an increase of the level of seismic protection of the citizens and structures in this municipality. The final objective of this project is definition of a two-level methodology for geo-referenced inventory toward seismic stability and safety of the existing building stock in the Karposh municipality, as well as upgrading of GIS of the municipality with new attributes.

Based on this integrated approach, the visual screening (level_1 activity) has been performed on 161 existing buildings and for two buildings level_2 assessment was carried out. Selected results from these activities are presented in the paper.

2 ASSESSMENT OF THE EXISTING BUILDINGS – BRIEF REVIEW

The assessment of the seismic stability and safety of existing structures and 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. In conditions when detailed assessment (at the level of a structure) is practically technically impossible and extraordinarily costly, simplified methods for assessment of the seismic stability and safety of existing structures are used worldwide. The general frame is most frequently designed per levels and it includes the following procedures:

- Level_1 procedure – Rapid visual screening – involves only visual screening of the structure and provides limited data. This procedure is recommended for all buildings;
- Level_2 procedure – Simplified seismic vulnerability assessment – involves limited engineering computations on the basis of data obtained by visual screening and drawings or performed measurements. This procedure is recommended for all buildings with large concentration of people;
- Level_3 procedure – Rigorous seismic vulnerability and safety assessment – involves detailed computer analyses, similar and even more complex analyses than those in design of new structures. This procedure is recommended for all important structures and buildings which have to remain functional immediately after an earthquake (hospitals, firefighting stations, shelters and alike).

Among the most worldwide used are FEMA Rapid Visual Screening Procedure (2002), methodology developed by the Turkish researchers Ozcebe et al (2003) etc.

3 INTEGRATED APPROACH FOR RAPID SEISMIC ASSESSMENT OF THE EXISTING BUILDINGS STOCK – FIELD SURVEY KARPOSH MUNICIPALITY, SKOPJE

The gathered knowledge in this field has shown that the general frame of the assessment methodologies is the same and is based on the multi-level concept, while the specificities are connected with the traditional construction practice and the seismicity of the region.

The traditional construction practice is reflected upon definition of matrices of typologies of buildings characteristic for the investigated region. The local specificities do not refer to the structural system but the additionally performed interventions of the type of enlargements, additional storeys, reconstructions, adaptations, etc. Such a situation points out that the seismic stability and safety of such new “hybrid” structural systems is unknown and that their definition is a serious and complex task.

For that purpose, it is necessary to make a certain modification of the existing methodologies for assessment of seismic stability of buildings based on national specificities.

An extensive field work aimed at collecting data on the existing building stock in the territory of Karposh municipality has been done in the period August -November 2013, (Necevska-Cvetanovska et al., 2013). A corresponding form for fast screening was elaborated for this purpose. The form contains the following attributes: (1) data and purpose of the structure; (2) screening data; (3) layout and photos of the structure (structural unit); (4) year of construction and interventions on the structural unit that have so far been done; (5) type of structural system, presence of irregularities and whether the structure is seismically designed or not; (6) soil conditions and (7) seismic hazard parameters.

In total, 161 buildings have been inspected. The findings from the visual screening have shown that 60% of the inspected buildings were built before enforcement of the seismic design codes (1965) and 51% need more detailed evaluation of their actual seismic performance.

Based on the data obtained by field screening, five groups of activities have been selected to be realized for the purpose of realistic definition of the seismic stability and safety of the structures, which have been the subject of screening, (Fig. 1). A corresponding group of activities to be realized has been defined for each screened structure depending on its current conditions (existing conditions, enlargements, additionally built stories, adaptations, demolished parts, combination of the stated). With such uniformly defined groups of activities for each screened structure, the current geo-referenced database on Karposh municipality has been updated with new attributes for inventory toward seismic stability and safety of the existing building stock in GIS environment. In such a way, policy decision makers get relevant data in making their decisions in the procedures of issuance of permits for construction of enlargements, additional stories, reconstructions, etc. of existing structures.

This integrated approach has been applied for part of the Karposh municipality in Skopje – Republic of Macedonia. In the course of 2012, several selected structures were analyzed in details (level_2, group 4 & 5 activities). In 2013, professional teams from IZIIS performed visual inspection of the existing conditions of the structures on the considered location (level_1 activity). In this phase, part of the territory of Karposh municipality, which consists of 14 individual blocks was screened. Presented further in the paper are selected results from the carried out activities.

3.1 Visual inspection – level_1 activity

A visual inspection of 161 structures was performed on the location which consists of 14 individual blocks marked as Block 1, Block 2, Block 3, Block 4, Block 5, Block 6, Block 7, Block M1, Block M2, Block M3, Block M4, Block M5, Block M6 and Block M7.

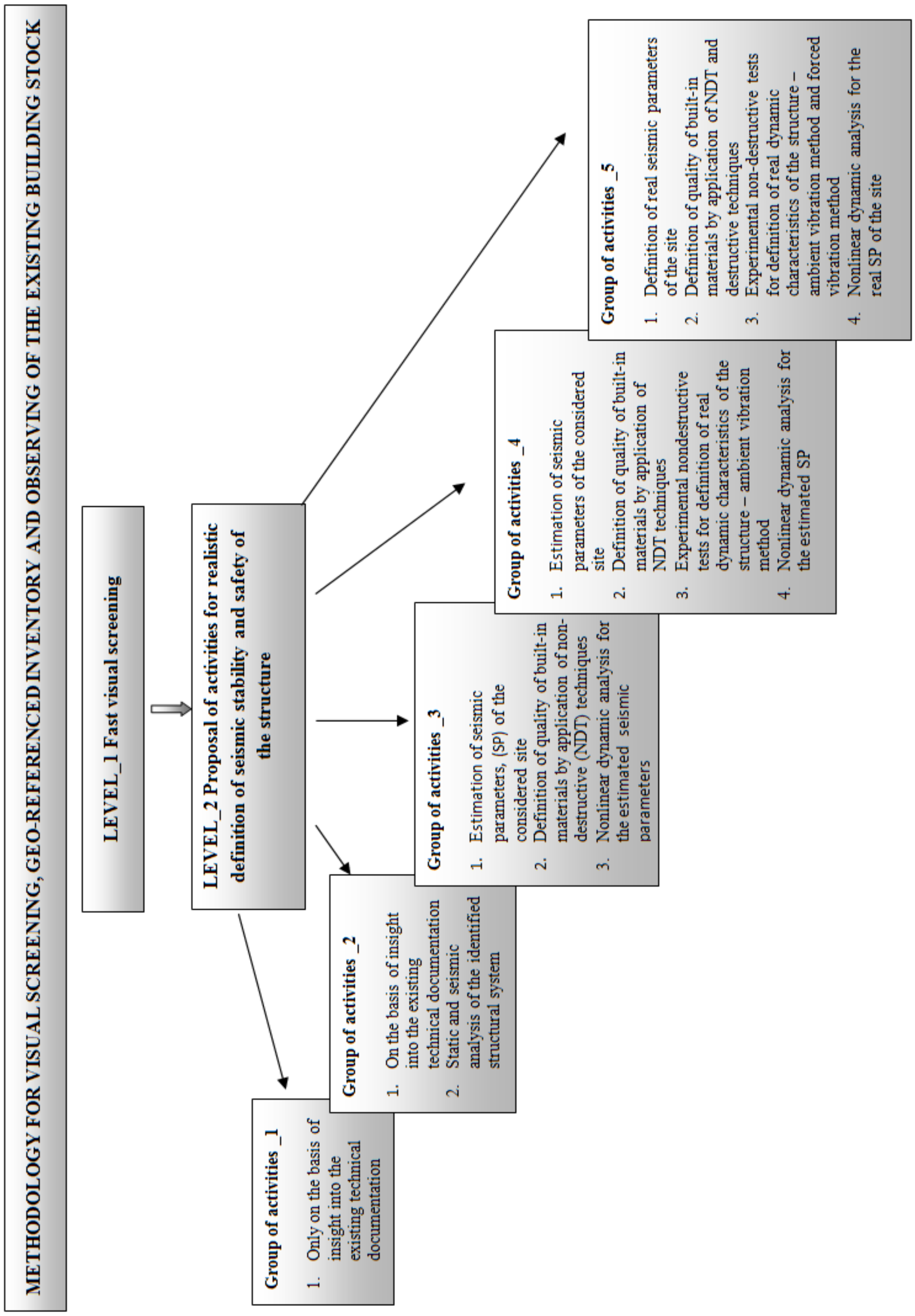
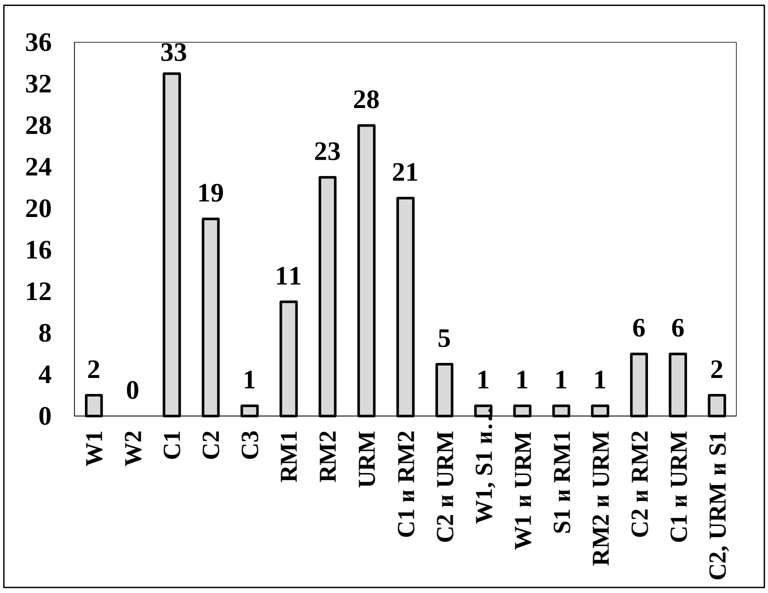


Figure 1. Block diagram of the methodology for visual screening, geo-referenced inventory and observing.

From 161 inspected structures, 66 structures (41%) have up to 4 stories, 52 structures have 4 to 7 stories (32%) and a total of 43 structures with over 7 stories 27%). Distribution of structural system versus number of inspected buildings is given in the Figure 2.



Symbol	Description
W1	Timber structures
W2	Large timber structures
C1	RC moment frames
C2	Concrete shear-wall system
C3	C1 & unreinforced masonry infills
RM1	Masonry with flexible floor structures
RM2	Masonry with rigid floor structures
URM	Unreinforced masonry
S1	Steel moment frames

Figure 2. Structural system distribution on the considered location.

Classification of the building structures in the Karposh municipality according to the year of construction is presented in the Fig.3a and according to the number of carried out interventions & extensions in the Fig. 3b.

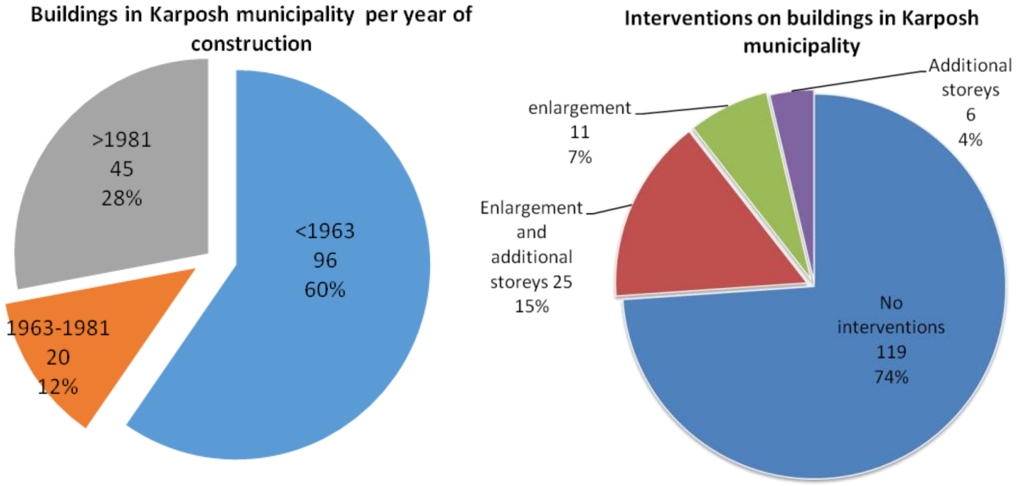
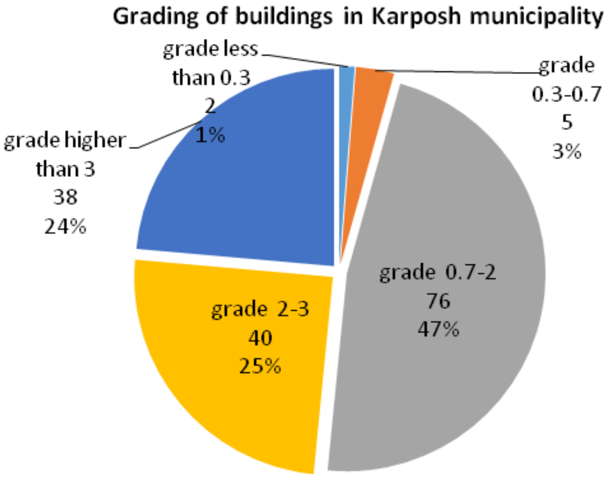


Figure 3. Review of structures in Karposh municipality classified according to: a) year of construction and b) number of interventions.

It obvious that more than half of the inspected structures are older than 50 years and were build prior enforcement of the seismic design codes (Fig. 3a) which emphasis the need of their maintenance and/or retrofitting. An increasing trend of building of different structural interventions on existing structures, is also present (Fig. 3b) thus inevitably arises the question about the seismic stability and safety of such new "hybrid" structures. This is even more complicated because in most of the cases, the existing structures represent masonry structures which are design as non- seismic resistant structures.

Expected damage potential for the building evaluated according to the rapid visual inspection methodology presented in this paper is presented in Fig. 4. Based on these findings more than 50% of the inspected buildings (whose grades are less than 2) will need further more detailed evaluation.



Grade	Damage potential
S < 0.3	High probability for occurrence of damage 5 & Very high probability for occurrence of damage 4
0.3 < S < 0.7	High probability for occurrence of damage 4 &Very high probability for occurrence of damage 3
0.7 < S < 2.0	High probability for occurrence of damage 3 & Very high probability for occurrence of damage 2
2.0 < S < 3.0	High probability for occurrence of damage 2 & Very high probability for occurrence of damage 1
S > 3.0	Probability for occurrence of damage 1

Figure 4. Review of structures in Karposh municipality classified according to grades obtained from the visual inspection.

It should be noted that obtained grades and damage classification levels corresponding to FEMA (2002) methodology.

3.2 Integrated approach for evaluation – level_2 activities

To capture the effect of complicated interventions (added stories, enlargement etc.) on seismic performance of the existing structures, level_2 activities which are consist of five groups of actions are defined in the presented methodology (Fig. 1). Presented further in the paper is practical example of application of level_2 activities. For two particular case studies the group activities_2 combined with group activities_5 (Fig. 1) were carried out. For the first case study only the new constructed structure was consider while in the second one the integral structure (existing & new) was analyzed. Selected results are given below.

3.2.1 Intervention in the structural system of the Residential Structure at Rugjer Boskovic str, no 7

The existing residential structure has floor plan dimensions 51.48 m/9.52 m and GF + 4 storeys. The structural system consists of massive bearing walls constructed from solid bricks and horizontal and vertical belt courses constructed of reinforced concrete. In 2009, the main project on enlargement of the existing and building of an additional attic at level +14.25 on the common residential structure was elaborated. The structural solution was designed as a spatial fixed RC structure consisting of RC shear walls with thickness b = 35 cm along the entire height, longitudinal RC beams at the level of all floor structures and four transverse beams on a last platform. At the level of the floor structures, the RC walls are connected with an RC slab with thickness of d = 14 cm.

Figure 5 show the relative story displacements and ductility demand in y-y direction for maximum expected earthquake (a_{max}=0.34g) at the considered location. Ductility capacities are defined using the methodology and a corresponding package of computer programmes for optimal design of new and performance evaluation of existing structures, (UNDP/UNIDO Project 1984, Necevska-Cvetanovska et al. 2000).

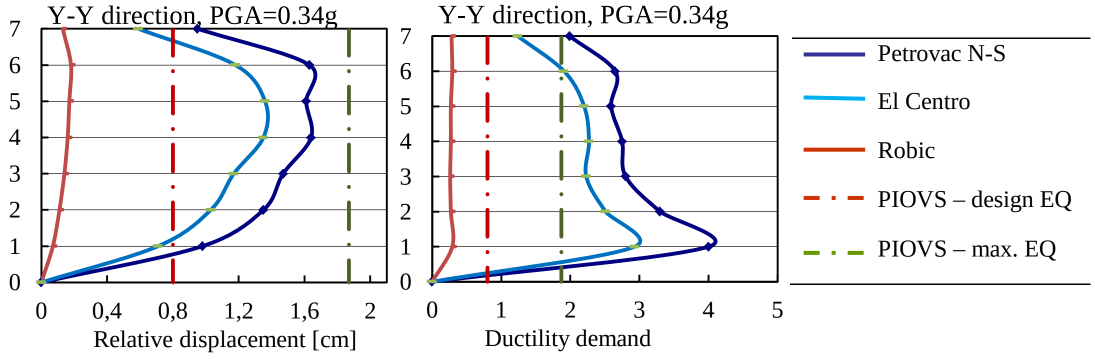


Figure 5. Relative displacement and ductility demands in Y-Y direction.

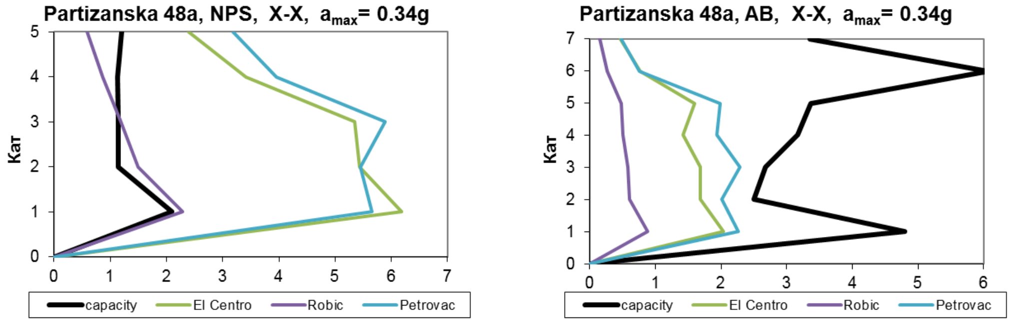
The presented results show that the ductility demands are higher than the traditional ones, Apostolska et al. (2012).

3.2.2 Intervention in the structural system of the Residential Structure at Partizanski odredi, 48a

The existing residential structure at Blvd. Partizanski Odredi 48a was built in 1958 as a structure consisting of B+GF+3, proportioned 30.70 m/9.50m at plan. From structural aspect, the structure represents a massive structure with bearing walls constructed of solid bricks in cement lime mortar in both orthogonal directions and fine ribbed floor structure. The only known retrofitting involve reinforced concrete elements with a height of 1.5 m constructed in the form of buttresses in the basement of the structure up to the terrain level. The newly designed enlargement and additional stories of the existing structure consist of a new RC structure that is designed such that it "bridges" the existing masonry structure. For the purpose of enabling communication between the existing masonry structure and the enlargement at individual levels, individual parts of the existing masonry, parapets below windows and new openings were demolished. In such a way, "the new integral" structure is enlarged and two additional stories are built whereat its total height from the fixation at the foundation to the top is H = 23.12 m (Necevska-Cvetanovska et al, 2015).

Figure 6 show the comparison between the ductility demand versus capacity for actual earthquake effects with intensity of a_{max}=0.34g, for each of the orthogonal directions and for both structures taken separately, Sendova et al (2012).

It could be seen that the ductility capacity of the masonry structure is considerably lower and vice versa, the ductility capacity of the newly constructed structure is considerably greater than ductility demand. This fact points to a considerably different behavior of both structures under the same earthquake intensity, i.e. different level of seismic protection.



4 CONCLUSIONS

Within the frames of the cooperation between the Institute of Earthquake Engineering and Engineering Seismology – IZIIS and the Karposh municipality in Skopje, integrated two-level approach for rapid seismic assessment of the of the existing building stock in the municipality was developed. This was a pioneering activity at national level whose ultimate goal observed in wider perspective is to decrease the level of the imposed seismic risk to the citizens and society at whole. Based on this integrated approach, the visual screening (level_1 activity) has been performed on 161 existing buildings and for two selected buildings level_2 assessment was carried out. The performed investigations represent a sound basis for the further development of the proposed methodology.

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