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Structural Investigations for the Refurbishment Project of the Municipal Building of Gjakova

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Abstract. This paper presents the structural investigations performed on the existing municipal building of Gjakova, intended to be refurbished as part of the Refurbishment project by the European Commission. The municipal building of Gjakova built in the end of 1960s is a reinforced concrete structure with bearing masonry walls which are scattered without any logical pattern. This structural system presents a difficult approach for the seismic assessment of this building. To obtain the confidence factors and the mechanical parameters for the appropriate numerical modeling, a series of structural investigations is carried out in detail. Initially a visual inspection is conducted, and a photographic survey is carried out with a detailed marking of each picture to visualize the building and plan the detailed inspection. The detailed plan is organized according to the gathered information and the existing documentation, so that maximal information about the structure is acquired with the minimal possible intrusiveness. The detailed inspection is accomplished in a series of frequent site visits and through the help of the measurement techniques a precise geometry is formed which supports the following phases. To obtain the correct mechanical parameters with very few damages to the structural elements a combination of destructive and non- destructive methods is utilized. Reinforced concrete core samples and reinforcement samples are drilled from the structural elements and combined with the rebound hammer measurements, a correlation is formed between these two. The reinforcement is located with the help of the profoscope and a discrepancy between the old drawings and the actual structure is noted. Afterwards, a spread-out testing utilizing the rebound hammer and the profoscope is carried out to achieve the required number of measurements. A compilation of all this information is utilized to assess the structural integrity of the structure and obtain the mechanical parameters. A qualitative measurement is performed for the structural arrangement of the elements and the regularity parameters are assessed as per the Eurocode 8 demands. With the data obtained from the measurements and the testing, reliable mechanical parameters and confidence factors are achieved to form a numerical model which represents appropriately the real building.

Keywords: structural investigation, NDT, refurbishment, retrofitting, RC structures

Introduction

The municipal building of Gjakova was built around 1960s with the purpose to serve as a municipal building of the city. There is no record of any change of use for the building and the new intended use of the building will remain the same. The total area of the site is 2344 m² and consists of the municipal building and the parking area. The existing five-story building consists of a basement, ground floor, three upper floors and an attic roof (Fig. 1). The existing space is not sufficient to accommodate the entire departments in one location and therefore a necessity for increase in space was essential. The solution was to remove the timber roof and accommodate another concrete floor and on top laying a green roof and making room for an open assembly hall. Furthermore, building a new annex building to the existing one. The scope of this study concerns mainly the existing building and thus the new annex building is of no interest. Since the structure is about 60 years old and is constructed in a period with different or no construction norms and especially with no seismic provisions, a careful and detailed assessment of the existing structure is done regarding its seismic capacity, structural stability and integrity. The structure is a public institution and is of high importance and therefore to have a more precise assessment a more thorough testing is to be done to achieve acceptable knowledge levels and confidence factors. This includes a preliminary inspection to be followed by a more detailed inspection in order to come up with acceptable structural parameters for the study. As such this study is concerned and is narrowed to the structural investigations performed on the existing structure of the municipal building of Gjakova.

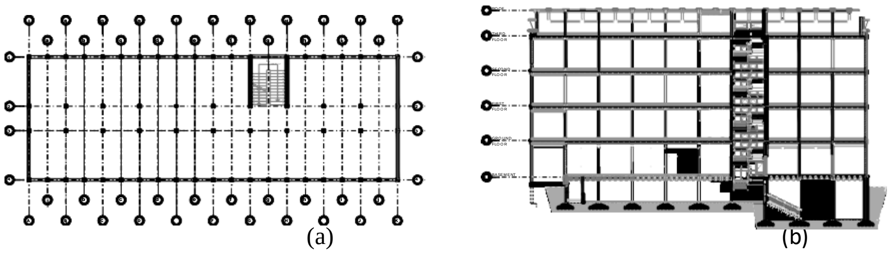


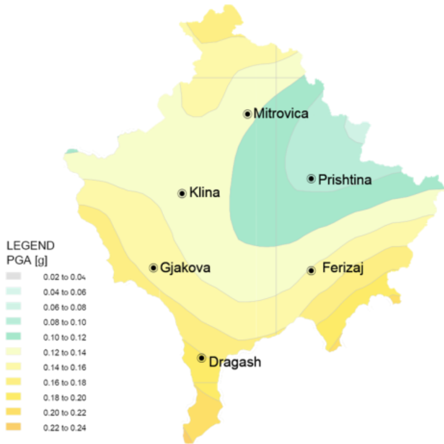
Fig. 1. (a) Existing base plan (Source: ARTING drawings); (b) Section drawing (Source: EPTISA drawings);

Seismicity of the Region

Kosovo does not have a national construction standard and thus no national accepted Seismic Hazard Map. Therefore, seismic analysis of structures is done either from previous maps, experience of engineers or with a careful and detailed assessment of the available resources and reports to come up with acceptable seismic parameters, which is done in the case of this study. According to [1], during 1456-2014 in Kosovo have occurred 152 earthquakes with magnitudes ranging from 3.5-6.3 in Richter scale. The ones relevant to the region of Gjakova are shown in Table 1 below.

Table 1. Relevant earthquakes to the region of Gjakova that occurred during 1456-2014

Region	Prizren	Peja	Gjakova	Prizren	Klina
Date	16 Jun 1456	11 Nov 1662	03 Sep 1922	26 Sep 1945	05 Feb 1947
Magnitude	MS = 6.0	MW = 6.0	MW = 5.3	MW = 5.0	MW = 5.2
Intensity	8.0	8.0	7.5	7.0	8.0



(b)

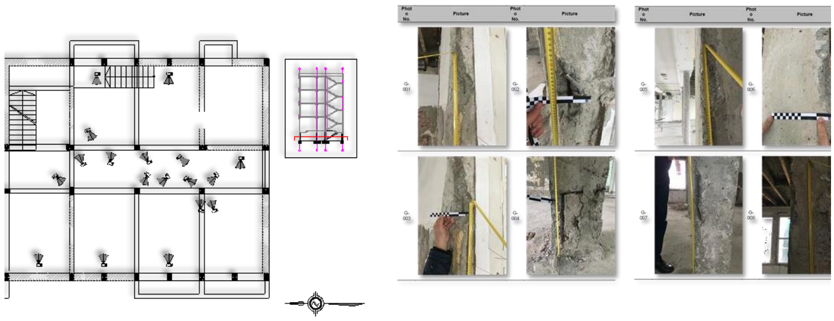
(c)

Fig. 2. (a) Seismic hazard map from [1]; (b) Seismic zonation from the former Yugoslavian construction standard; (c) Seismic hazard map from [2];

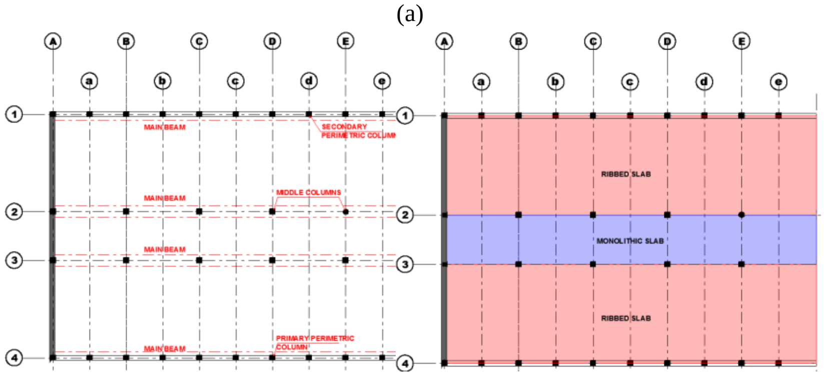
The aforementioned study also produced a seismic hazard map for Kosovo with PGA values for 10% of exceedance in 50 years with a return period of 475 years (Fig. 2-a). Furthermore, the map of Yugoslavian Construction Standard of 1964 (Fig. 2-b) presents a seismic zonation in the MCS scale which positions Gjakova in zone VII and correlates to PGA values between 0.18g-0.34g. Another study [2], extended their seismic research in Kosovo producing a seismic hazard map for 10% probability of exceedance in 50 years with a return period of 475 years (Fig. 2-c). Concluding all this information the PGA values for the region of Gjakova range from 0.10g-0.34g, and the most suitable value to be used further in the analysis is 0.20g.

Preliminary Inspection

A preliminary inspection was carried out in the structure to perform a qualitative investigation in order to obtain information about the structural system, the actual damages and decide on the testing to be performed on the structure. Initially, original drawings from the archive were analyzed and then processed and regenerated into CAD drawings. A detailed geometrical survey was required to verify the existing structure to the original drawings. New and more detailed drawings of the existing situation were created with the geometrical in-situ data obtained. The geometrical survey was complemented with a photographic survey which was also mapped in the drawings (Fig. 3-a). The photographic survey included the documentation of the different damages in the structure. The damages were additionally gathered in a table where their nature and severity were categorized to have a better understanding. A major number of serious damages were found in the structure including structural



(a)



(b)

Fig. 3. (a) Example of the photographic survey and mapping on the drawings; (b) Structural system of the existing building;

cracks, spalling and pop-outs of the concrete, extensive segregation, corrosion and exposed rebars, misalignments, warping, rebar buckling and installations going through the structural members and so on, where some can be seen in Fig. 3 (a).

The structural system of the building can be seen in Fig. 3 (b), where the vertical bearing system consists of reinforced concrete (RC) columns in the middle and perimeter whereas on the lateral sides and for the stairs core structural masonry is observed, thus creating a mixed structure. The horizontal bearing system is made of a combination of monolithic RC slabs in the mid-span and RC ribbed slabs on the sides, all supported in RC beams which go only in the longitudinal direction of the building. The foundations consist of RC isolated footings for the mid-columns and RC strip foundations for the perimeter columns and walls with no tie beams to connect them.

Detailed Inspection and Structural Investigation

The detailed inspection included structural investigations in the structure utilizing the non-destructive testing (NDT) and destructive testing (DT). The main focus was to assess the in-situ compressive strength of the concrete conform [3] and to quantify the actual condition of the structural members. The method of obtaining the concrete strength includes coring of multiple concrete samples, but due to the fragility of the structure only 4 cores were taken, namely 3 columns and 1 beam. The core sampling procedure shown in Fig. 4 followed the localization of the rebars with a profoscope (1,2), surface preparation with abrasive stone (3), 9 rebound hammer readings in the coring location (4), fixation of the core drilling machine (5) and then the coring of a 10 cm diameter concrete sample with no reinforcement inside (6).

(1) (2) (3) (4) (5) (6)

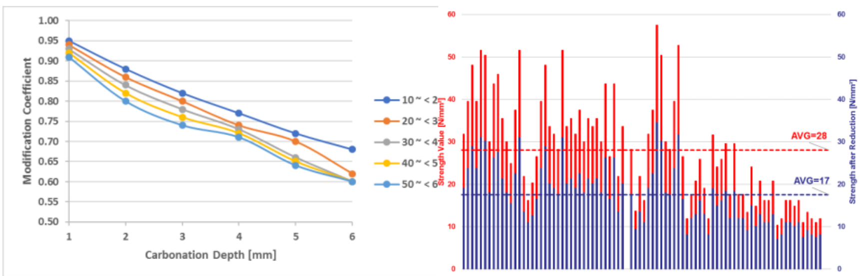
Fig. 4. Core sampling procedure;

Afterwards, a widespread NDT was carried out in the entire structure conform [4] taking 9 readings with the rebound hammer in each location avoiding the rebars which were initially located and measured with the profoscope. The NDT testing was performed on 52 columns (x9 readings) and 33 beams (x9 readings). Additionally, 6 steel samples were taken to be tested in tension, namely 3Ø10 mm and 3Ø12 mm.

The concrete cores and the steel samples were tested via destructive methods in a local laboratory conform [5,6] and the result processing is shown the following section. The concrete cores were additionally tested for carbonation depth by applying the phenolphthalein, conform [7].

Information Processing

The concrete compressive strength in-situ conform [3] can be obtained by correlating the NDT results with results from DT of cores. Initially the NDT results from the rebound hammer readings are reduced depending on the carbonation results of the cores. The average carbonation depth in the samples was found to be 27.5 mm, which is a relatively high value. The reduction values (Fig. 5-a) are given by a modification coefficient which multiplies the rebound hammer reading depending on the detected strength in MPa. It can be seen that the theoretical value for 27.5 of carbonation reaches a modification coefficient of zero, but for practical reasons readings are done for 6 mm of carbonation. The rebound hammer readings are shown in Fig. 5 (b), where can be observed the reduction of the average compressive strength from 28 N/mm² to 17 N/mm².



(a) (b)

Fig. 5. (a) Carbonation reduction factor according to strength detected; (b) Strength readings from rebound hammer and after reduction;

Following the procedure in [3], the correlation values are obtained by initially forming a basic curve and then shifting it as per the test results from the in-situ cores and the rebound readings. The final curve obtained, which correlates the rebound hammer readings to the in-situ compressive strength, is shown in orange in Fig. 6.

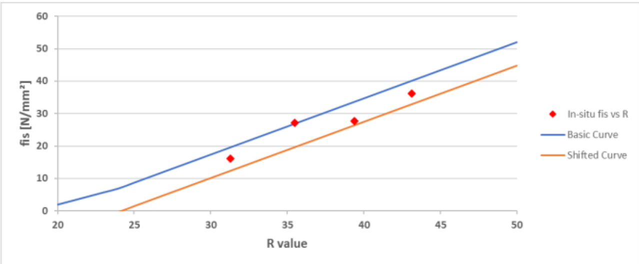
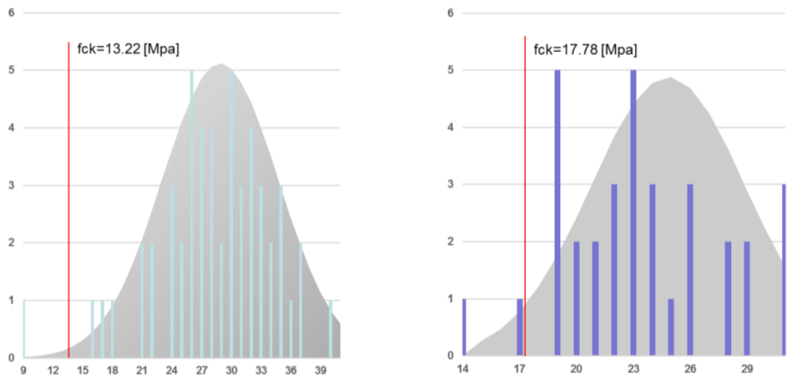


Fig. 6. The curve correlating rebound readings to the in-situ compressive strength;

The characteristic compressive strength of the concrete, which is directly related to the concrete class, is then obtained from the expressions available in the standard and the correlated values from the graph in Fig. 6. The characteristic compressive strengths are found to be 13.22 N/mm² and 17.78 N/mm² for the columns and the beams, respectively. A normal distribution of the compressive strengths for the columns and the beams which resulted from the graph above is shown in Fig. 7. It can be easily observed that the characteristic compressive strength values are at about 5% area that defines the characteristic compressive strength.



(a) (b)

Fig. 7. Normal distribution of the compressive strengths for (a) columns and (b) beams;

From these relations it can be concluded that the concrete class for columns can be set as C12/15 and for the beams C16/20, which are way lower than the classes foreseen in the initial original design. The results for the steel samples are shown below in Table 2 and it can be seen that the class can be set to the original steel class of the design which was S 240/360 and be on the safer side.

Table 2. Steel sample results

Sample	Diameter [mm]	Yield Strength [MPa]		Ultimate Strength [MPa]		Elastic Modulus [MPa]	
	Ø	fy	mean	fu	mean	E	mean

10-1	9.90	355.2		378.2		58527	
10-2	9.80	362.1	324.3	396.8	394.0	95263	125652
10-3	9.80	255.6		407.0		223166	
12-1	12.10	417.3		477.1		865999	
12-2	12.10	426.3	404.7	474.3	477.9	190318	411733
12-3	12.10	370.4		482.4		178881	

The material values to be used for the assessment of existing structures should be reduced with confidence factors according to the knowledge level of the structure as per the guidelines set by [8]. A knowledge level KL2 is obtained with the information available for the structure which results in a confidence factor of $CF_{KL2} = 1.20$.

Conclusions

The extensive studies carried out in the municipal building of Gjakova has provided with a better understanding of the structural state of the current building.
From the initial inspection it was able to achieve a thorough observation of the damages and deformations in the structure and achieve the desired level of geometrical accuracy. This helped in the next phase of analysis which included the numerical simulation of the entire building to assess its structural stability when subjected to external loading, especially seismic action. The structural investigation via non-destructive and destructive testing provided with the most valuable information on the structure which is directly applicable in the numerical model and provides a high level of accuracy in the model. The overall information aided to the decisions which were made in the later stages where retrofit or demolition were a matter of questioning.

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