49| Претходно саопштење
Preliminary report
doi 10.7251/STP1813664L ISSN 2566-4484

СЕИЗМИЧКА ОТПОРНОСТ ПОСТОЈЕЋИХ ОБЈЕКАТА ПО ДОКУМЕНТУ FEMA310

Marina Latinović, *mar.latinovic@gmail.com*,
Institut za urbanizam, građevinarstvo i ekologiju Republike Srpske
Žarko Lazić, *zarko.lazic@aggf.unibl.org*,
University of Banja Luka, Faculty of Architecture, Civil Engineering and Geodesy
Gordana Broćeta, *gordana.broceta@aggf.unibl.org*,
University of Banja Luka, Faculty of Architecture, Civil Engineering and Geodesy

Резиме:

У овом раду, укратко је приказан принцип примјене документа ФЕМА310 за оцјену сеизмичке отпорности постојећих објеката, за ма који тип објекта, и дат је примјер оцјене на првом и другом нивоу, кроз два типа зиданих конструкција. Примјена овог документа у првом и другом нивоу оцјене је конзервативан, поједностављен начин за одређивање сеизмичке отпорности, који је заснован на многим искуственим подацима и обухвата најважније параметре објеката који могу да утичу на сеизмичку отпорност. Упутства су једноставна за примјену, али мјестимично су прилагођена америчким правилницима. Разматрана су два типа зиданих конструкција са крутом и флексибилном међуспратном таваницом, кроз која је дат примјер оцјене на првом и другом нивоу.

Кључне ријечи: Сеизмичка отпорност постојећих објеката, зидане конструкције, FEMA310

SEISMIC EVALUATION OF EXISTING BUILDINGS ACCORDING TO DOCUMENT FEMA 310

Abstract:

In this paper, the principle of application of the FEMA310 document for seismic evaluation of existing buildings is briefly illustrated, for any building type, and examples of evaluation are given for the first and second tier of evaluation process, for two types of masonry structures. The application of this document at tier one and tier two of the evaluation process is a conservative, simplified way of determining seismic resistance, based on many experiential data and including the most important parameters of buildings that can affect seismic resistance. Instructions given by FEMA310 are easy to apply, but are adapted to US standards. Two examples for evaluation of masonry buildings on first and second tier of evaluation are given, for masonry buildings with rigid and flexible diaphragmas.

Keywords: Seismic evaluation, existing buildings, masonry buildings, FEMA310

1. INTRODUCTION

Many buildings in use date from the time when seismic analysis in applicable guidelines was not defined, and for many existing buildings, the original capacity in terms of accepting seismic forces was temporarily reduced by damage in earthquakes from the past or by some other ways. Determining seismic resistance of existing buildings has to be done in order to protect people, users of such buildings, in case of future earthquakes.

The largest earthquake-related damages and victims are the result of damage and demolition of existing buildings, which are not designed according to aseismic rules. For that reason, many countries have adopted guidelines for establishing the reliability and vulnerability of existing buildings, and in that respect, The United States have made the biggest progress.

Federal Emergency Management Agency (FEMA) issued guidelines for seismic rehabilitation of buildings within the NEHRP project (National Earthquake Hazard Reduction Program). The aim of this program is to reduce negative consequences, physical injuries and earthquake-related losses. Within this program, FEMA acts as an agency whose activities are based on its implementation and maintenance.

FEMA273 deals with earthquake impacts on site locations and refers to maps with an evaluation of earthquake hazard probability and the degree of vulnerability. Also, there are documents related to processes of rehabilitation FEMA273-276, FEMA356. [3]

FEMA310 - Handbook for the Seismic Evaluation of Buildings from 1998, defines the exact steps for analyzing existing buildings of different types, made of concrete, steel, masonry or wood elements. The FEMA310 is based on the FEMA178 - Handbook for the Seismic Evaluation of Buildings.

An analysis of existing buildings is not a simple activity. In order to evaluate the building, the scope of the necessary investigative works is large. The basis of the analysis is the examination, study, and computational analysis, which are accessed after getting familiar with the building and obtaining the available information. It is necessary to perform a global analysis of the system as a whole, as well as a detailed analysis of the main elements of the system, which is in the case of analysis of seismic resistance, a system for accepting horizontal, lateral forces. The expert should define the program of necessary testing of structural elements and materials used, and due to the impossibility of performing sufficient volume of investigative works, the evaluation is often done quite conservatively.

According to our standards, design recommendations in seismic areas are simple and correct solutions of the building layout, even distribution of load-bearing walls in both directions, application of simple constructive systems, rigid diaphragms, use of suitable quality materials. [4] Also the evaluation according to the FEMA310 manual is based on the general characteristics of the building that is considered to be seismically favorable, and further evaluation demands more detailed analysis, when initial demands are not met, or in case of doubt in the regularity of some structural element or parameter of the construction material. Detaility of evaluation is graded in levels. The instructions for analysis are general, but each building is unique and may contain certain problems that are not defined in this Manual. Herein, a description of the evaluation process according to the FEMA310 manual, is given, and two examples of the evaluation at the first and second tier are shortly described, through two types of masonry structures. Examples were conducted in order to gain general insight into the evaluation principle according to the document. The evaluation is not detailed, with several assumptions.

2. SEISMIC RESISTANCE OF EXISTING OBJECTS ACCORDING TO THE DOCUMENT FEMA 310 – GENERAL NOTES

Evaluation according to the FEMA 310 document is performed in three levels (tiers), for any seismic area, and before evaluation certain evaluation requirements have to be met.
Evaluation levels defined in the Manual are as follows:

- Tier 1 – screening phase;
- Tier 2 – evaluation phase;
- Tier 3 – detail evaluation phase.

Evaluation in first and second tier can be conservative, as many rough assumptions are used in the analysis. By a detailed analysis in third tier of evaluation, it is possible to prove that buildings with identified deficiencies in the first and second tier of the evaluation have adequate seismic resistance, according to the criteria of the third tier.
Prior to the evaluation, the expected level of performance of the building is determined, upon which depends the type and the scope of the evaluation. Buildings can be evaluated according to one of the two levels of performance listed below:

- Life safety performance level, LS;
- Immediate occupancy performance level, IO.

The criteria are more stringent for buildings that should satisfy the requirements for immediate occupancy performance level.
For both performance levels, the seismic demands are based on spectral response acceleration values for maximum considered earthquake.

Maximum considered earthquake is an earthquake with a probability of exceeding 2% for a return period of 50 years, with the maximum expected value based on known data for that area. For the purpose of comparison, when designing towards Eurocode 8, the buildings are designed to withstand an earthquake with a probability of exceeding 10% over a return period of 50 years, without collapsing.

2.1. Evaluation requirements

The evaluation at all tiers should be based on facts as much as possible, in relation to the assumptions, so before the evaluation, for each building, it is necessary to determine the following:

- The scope of previous investigations required;
- Perform a visual inspection of the building, site visit;
- The level of performance;
- The area of seismicity;
- The building type.

An expert should evaluate the level of additional works. Prior to evaluation, an expert should have an insight into the geomechanical characteristics and soil parameters, the constructive system, the details of the reinforcement, as well as data related to the behavior of the building in the event of any previous earthquakes. Certain data can be obtained from the available project documentation, and additional information is collected by performing physical testing, measurements and structural overview.
The site visit is done in order to check the compliance of collected data with the state on the site, as well as in order to collect additional data, determine the general condition of

the building and inspect the accessibility to the structure elements. The expected level of performance is defined before the start of the evaluation by the expert performing the evaluation and/or by the relevant competent institutions.

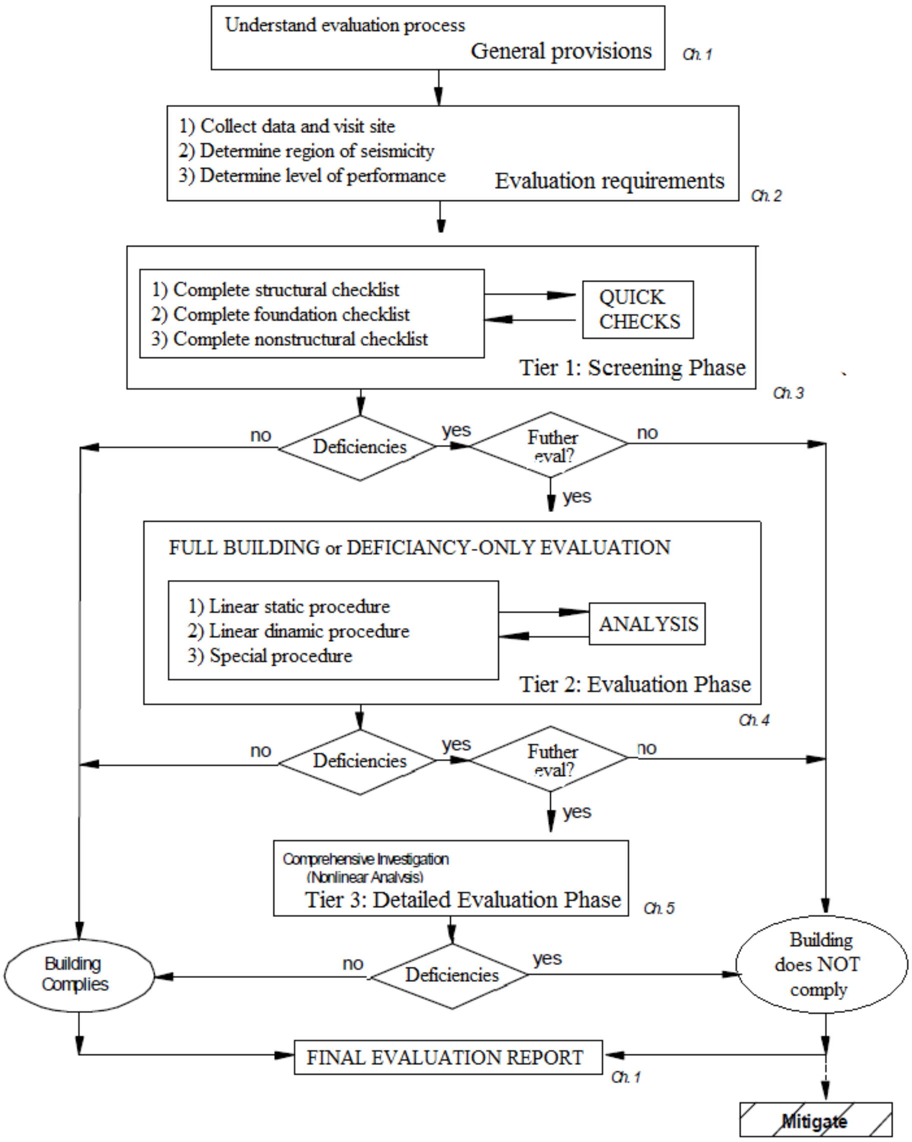

Figure 1. Schematic representation of the evaluation process [1]

Also, it is necessary to define the area of seismicity, which is defined as the area of low, medium or high seismicity, according to the values given in the Manual, and based on the design spectral response acceleration parameter at one second period - SD1 and design short period spectral response acceleration parameter SDS, which are determined on the basis of spectral response acceleration parameter at one second period S1 and short period spectral response acceleration parameter Ss. These parameters are read from seismic maps.

There are no such maps in area of Bosnia and Herzegovina. For the purpose of evaluation, the seismological map of the Banja Luka region was used [5], [6], and the maximum acceleration can be determined was determined according to the orientational formula proposed by Murphy and O'Brien [2]:

$$\log at = 0{,}25 \cdot I + 0{,}25 \quad (1)$$

where I is the degree of seismicity in Merkali.

If we have some other known data, soil and object parameters can be determined more precisely.[6]

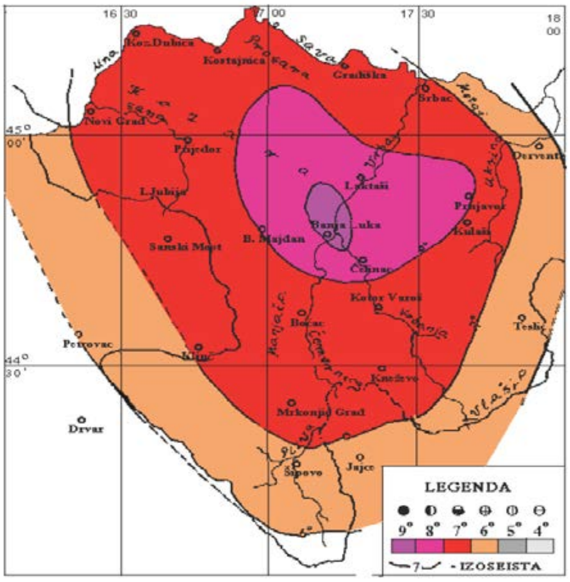

Figure 2. Figure 2. Seismological map of earthquake isotope for the territory of Banja Luka [3]

The type of building depends on static system, in terms of transmission the lateral forces and the type of diaphragm. According to the Manual, the buildings are classified into 12 types.

2.2. Tier 1 evaluation process

The objective of the first tier evaluation is to quickly identify buildings, through the corresponding checklists, which meet the basic constructive parameters defined in this Manual and to identify possible deficiencies. In the first tier, in case of doubt, quick checks are defined for certain checklists statements. The first tier evaluation is done for the whole building.

2.2.1. Selecting and using particular checklist

Different checklists are used for each building type in estimation. Also, there are general checklists for buildings that cannot be classified into the listed building types.

The checklists used for the evaluation at the first tier were formed on the basis of observing the behavior of various building types and their damage during numerous earthquakes. The only building type for which there is no tier one structural checklist, but a special analysis is defined, which is placed in the second tier of evaluation, are masonry buildings with flexible diaphragms. Non constructive checklists are defined in first tier of evaluation for this building type.

Depending on the defined performance level and region of seismicity, for each building type, three checklists are defined:

- Structural checklist;
- Nonstructural checklist;
- Geological site hazard and foundation checklist.

Selection and type of the checklist is based on:

- Performance level (IO or LS);
- The level of seismicity of the area;
- Building type.

If a building cannot be classified in any type, a general checklist is provided, giving a general insight into possible disadvantages. For each building type there are basic and supplementary lists for constructive and non constructive parameters, and depending on the level of performance and area of seismicity, it is determined whether both checklists or only basic one is filled, Tab 1.

Table 1. Selection of the checklist based on seismicity and the defined level of safety

Region of seizmi-city	*Perfo-rmace level*	*Zahtjevane kontrolne liste*					
		Region of low seismicity	*Basic structur-al*	*Supleme-ntal structural*	*Geological site hazard and foundation checklist*	*Basic nonstructu-ral*	*Supleme-ntal nonstructu-ral*
Low	LS	√					
	IO		√		√	√	
Moderate	LS		√		√	√	
	IO		√	√	√	√	√
High	LS		√	√	√	√	
	IO		√	√	√	√	√

Checklists are filled out by recording whether their statements are accurate, inaccurate, or cannot be applied to the building being evaluated. Each statement in the checklist is followed by an indication of a particular chapter of the second tier of evaluation, for a better understanding and description of further analysis of the second tier.

2.2.2. Computational analysis for the first tier of evaluation

In some cases it is necessary to perform quick checks in order to determine the fulfillment of the statements regarding the strength and stiffness of certain structural elements, with the previous determination of the lateral seismic forces. Checklist statements guide us to use cetran quick checks.

The pseudo-lateral force is calculated for the purpose of quick check in the first tier of the evaluation, but also in some cases for the second tier of evaluation. This force is used in linear analysis and causes expected deformation of the building at designed earthquake.

Pseudo-lateral force in a given horizontal direction is determined by equation:

V=〚C S〛_a W (2)

where:

C – modification factor regarding building ductility, defined tabulary by the Manual, and depending on building type and floor number;

S_a – response spectral acceleration at the fundamental period of the building in the direction under consideration;
W – total dead load and expected live load.

The pseudo-lateral force on the floor j is determined by the expression:

$$V_j=\left(\frac{n+j}{n+1}\right)\left(\frac{W_j}{W}\right)V \quad (3)$$

where:

n – total number of floors above ground level;
j – the number of floor under consideration;
W_j – total dead load and expected live load above the level j;
W – total dead load and expected live load;
V – pseudo-lateral force, defined by the expression (2).

Response spectral acceleration Sa is calculated according to the expression:

$$S_a= S_{D1}/T \le S_{DS}, \quad (4)$$

where:

$S_{D1} = 2/3\ F_v S_1$– design spectral response acceleration parameter at one second period; (5)
$S_{DS} = 2/3\ F_a S_s$– design short period spectral response acceleration parameter; (6)
F_v, F_a – the coefficients of the magnification given tabullary in the Manual, depending on the site class and the acceleration spectrum parameters S_1 i S_S;
S_1 – spectral response acceleration parameter at one second period, provided in FEMA Seismic Map Package;
S_S – short period spectral response acceleration parameter, provided in FEMA Seismic Map Package;
T – fundamental period of building vibration in seconds (defined by equation (7))

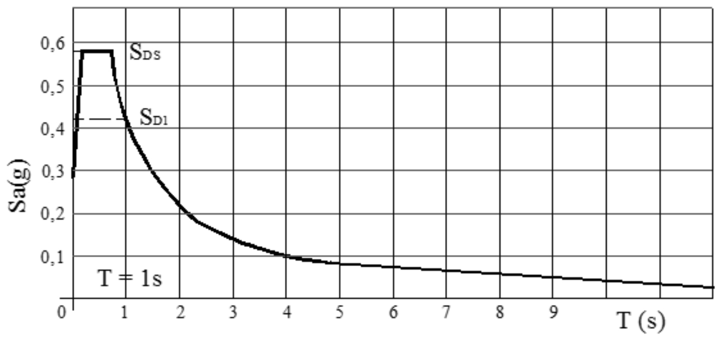

Figure 3. Meaning of design spectral response acceleration parameters

Fundamental period of building vibration T, is defined by the expression:

$$T=C_t h_n^{3/4} \quad (7)$$

where:

C_t – coefficient depending on the building type;
h_n – height in feet above the base to the roof level.

For evaluation at the first tier characteristics values of material parameters can be used.

2.3. Tier 2 evaluation process

If it is evaluated that certain elements of the building do not meet the criteria defined in the first tier checklists, the second tier evaluation may be performed for elements that did not meet the criteria defined in the particular checklist items or for the entire building.

Second tier evaluation does not require testing of materials, but characteristic values are not used as in the first tier. These characteristics are derived from certain guidelines depending on the year of construction of the building, construction diaries, and physical testing. Physical testing is not required.

2.3.1. Computational analysis for the second tier of evaluation

Based on the checklists in tier 1, the chapters of the second tier of evaluation are defined. Tier 2 analysis procedures, after first tier evaluation, and which only relate to the control of detected irregularities, are listed in parentheses after the checklist statement.

- At the second tier of evaluation, there are instructions for four types of analysis:
- Linear static analysis;
- Linear dynamic analysis;
- Special analysis (for unreinforced masonry structures with flexible diaphragms);
- An analysis by which non-constructive elements are controlled.

The analysis for all types of buildings, with respect to the control of the structural parameters, except for unreinforced masonry structures with flexible diaphragms, is performed according to a linear static or dynamic analysis. Herein the principle of analysis according to these two methods is briefly described. Analysis is carried out in order to check the capacity of the system for receiving lateral forces. Dynamic analysis must be carried out for buildings over 30 m, buildings with unequal distribution of mass or stiffness, or with geometric irregularities.

The first step in the analysis, static or dynamic, is to define a mathematical model. The basic guideline for the model is given by the Manual. The construction with rigid diaphragms can be analyzed in plane if the torsional effects are small and can be ignored or taken indirectly in the calculation. In other cases, the building is modeled three-dimensionally. Only the stiffness of the basic components of the building should be taken into the account, and if the secondary components are to be modeled, the total stiffness of the secondary components must not exceed 25% of the stiffness of the basic components taken into account for each floor.

When analisis is performed by a linear static method, the pseudo-lateral force is calculated according to the expression (2). The basic period of the model is calculated by equation (7) or alternatively, according to eigenvalue obtained after dynamic analysis.

The vertical arrangement of pseudo-lateral force is determined according to the expression:

$$F_x = C_{vx} V \tag{9}$$

$$C_{vx} = \frac{w_x h_x^k}{\sum_{i=1}^{n} w_i h_i^k}, \tag{10}$$

where:

$k = 1.0$ for $T \leq 0.5$ s; $k=2.0$ for $T>2.5$ s (for the values in between linear interpolation is performed);

C_{vx} – vertical distribution factor;

V – pseudo-lateral force, calculated by the equation (2);

w_i – part of the total weight of the building that belongs to the level i;

w_x – part of the total weight of the building that belongs to level x, which is considered;

h_i – height from base to level i;

h_x – height from base to level x;

The total diaphragm force at the level x:

$$F_{px}=\frac{1}{C} F_i \frac{w_x}{\sum_{i=1}^{n} w}, \quad (11)$$

where:

F_i – pseudo-lateral force at level i, defined by equation (9);

w_i – part of the total weight of the building that belongs to the level i;

w_x– part of the total weight of the building that belongs to level x, which is considered;

C – modification factor regarding building ductility, defined tabullary by the Manual, which depends on building type and floor number;

Structural deformation and displacements are calculated using the lateral force calculated by the equations (2), (9) i (11).

Prior to the dynamic analysis, it is necessary to define spectral acceleration, as by the analysis in the first tier of the evaluation, based on the equation (4) or according to the special conditions of the site, when a spectral analysis for the building is performed.

Diaphragms are analyzed for the effect of seismic force obtained by dynamic spectral analysis, and for the effects of horizontal forces that occur as a result of displacement or change in stiffness of vertical elements above and below the diaphragm.

The number of modes must be sufficient to cover more than 90% of the body mass involved in each of the horizontal axes.

Seismic forces determined by dynamic analysis must not be less than 85% of the force value determined by static analysis.

2.3.2. Acceptance criteria

Total loads are calculated from gravity loads (dead load, effective live load and snow load) and seismic loads. With these loads, component actions are calculated and compared to component strength.

All actions are classified as force-controlled actions or deformation-controlled actions.

Deformation controlled actions are those actions that cause deformation that are allowed to exceed the flow boundary, while force controlled actions are those that cause deformation which is not allowed to cross the flow limit. As an example, it can be said that the bending moment is deformation controlled action, while the shearing moment, or the axial force is force controlled action.

At the end of the analysis, the following conditions must be met:

$$Q_{CE} \geq Q_{UD}/m \geq Q_{UF} \quad (12)$$

where:

Q_{CE} – expected component strength;

Q_{UD} – deformation controlled actions;

Q_{UF} – force controlled action;

m – coefficient that takes into account component ductility, as defined in the Manual.

Tier 3 evaluation

The third tier of evaluation is taken into account, if there is a doubt that the criteria of the first and second tiers are too conservative for a realistic evaluation, and that a more detailed analysis is needed. It can be done for the entire building or for elements that did not meet the criteria of the second tier.

Two evaluation procedures were defined on the third tier of evaluation of existing buildings, according to United States standards, a procedure for the rehabilitation of an existing buildings or procedure applicable to the design of new buildings. In evaluation by the criteria of the third tier, the characteristics of all embedded materials, destructive or non-destructive methods, are examined.

If the rehabilitation procedure is carried out, 75% of seismic forces are counted.

Third tier of evaluation is done according to nonlinear methods, defined by US standards.

3. EXAMPLES OF MASONRY BUILDING ANALYSIS

The evaluation according to the Manual was applied on masonry buildings of type 15: Unreinforced masonry bearing wall buildings - URM, which has two subtypes URM and URMA.

URM-type buildings have external and internal bearing unreinforced brick walls. In older buildings, the framings on the floors and on the roof consist of straight or diagonal wooden beams. The diaphragms are flexible in relation to the walls. When they exist, the connections between the walls and the diaphragms consist of bent steel plates or anchors embedded in the couplings and attached to the framings. The foundations are made of brick or concrete.

URMA-type buildings are similar to URM type. They are distinguished by the fact that the diaphragms are stiff in relation to the unreinforced brick walls. In older constructions or large multipurpose structures, the diaphragms are cast in concrete on site

3.1. First tier of evaluation of building of type URMA

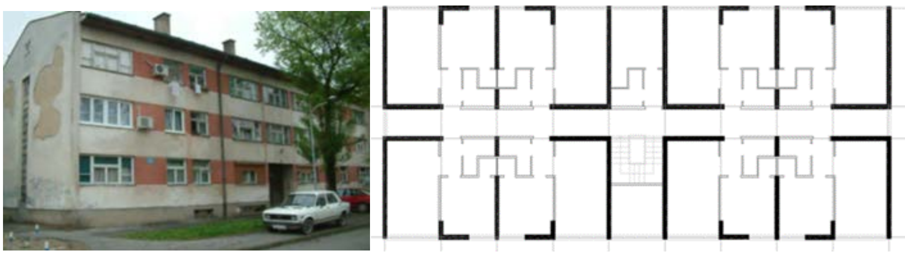

Figure 4. Example, building of type URMA - perspective and floor plan

In this example, the URMA-type building with three floors and the regular basis was analyzed. As the building was built in the 1950s, before the application of the rulebook on construction of buildings in seismic areas, it has no vertical or horizontal concrete elements. Vertical load-bearing elements are longitudinal and transverzal brick walls. The walls are 25 cm wide, made of full bricks. The diaphragms are of reinforced concrete, 12 cm thick, rigid in its plane. The mortar and lime mortar were used for masonry purposes.

The safety level on the basis of which the evaluation is performed is life safety level.

Basic characteristics of the soil are approximately determined using geological map of Republika Srpska. The seismic parameters are also determined approximately based on the available maps of the region.

In the basic constructive checklist, the controlled items for this building type are:

- Building system;

- System for absorbing lateral forces;
- Connections.

In each statement of the list, there is noted number of chapter from the second tier that clarifies the statement and gives directions for further analysis, in case of not meeting the statement requirements or doubt. Some of the statements cannot be applied to the subject building.

According to the checklist, this construction has some irregularities that have to be further analyzed in tier 2 of evaluation.

3.1.1. Control of the building system

Within the control of a building system, the following items are controlled:

- Load transfer path

It is demanded that the construction contains a single continuous trajectory for seismic load transfer for buildings rated as LS and IO for any horizontal direction of action, which should transfer the inertial forces from mass to foundations. Rigid diaphragms should accept the seismic forces, and transfer them through the brick walls to concrete foundations. There must be no discontinuity in this system. All the walls should extend to the foundation, and the diaphragm should transfer the lateral forces to the supporting walls. There is no computational analysis for this item.

- Mezzanines

If existing, the construction of the inner mezzanines must be a separate construction, independent of the main structure in aspect of receiving the lateral force, or must be anchored on the supporting system elements which receive the lateral forces of the main structure.

- The existence of weak and flexible floors

The strength of a constructive system for receiving lateral forces on each floor must be greater than 80% of the adjacent floor strength, below or above, for facilities rated as LS or IO, and the rigidity of a constructive system for receiving lateral forces on each floor must be greater than 70% of the adjacent floor stiffness, below or above, or greater than 80% of the average stiffness of three floors below or above for buildings rated as LS or IO. For the weak and flexible floor, analysis is conducted according to the second tier of evaluation. For the weak floor, the strength of the elements is calculated and the ability of the floor to accept half of the total pseudo-lateral force is controlled.

- Regularity of geometry

There must not be difference in the horizontal dimensions of the constructive system for receiving the lateral forces for particular floor by more than 30% relative to adjacent floors, for buildings rated as LS or IO, with the exception of one-story structures on the roof of the building. In the case of irregular geometry, a linear dynamic analysis is performed according to the second tier and the ability of the elements to accept the pseudo-lateral force is controlled.

- The existence of vertical discontinuities

All the vertical elements of the constructive system for receiving lateral forces must be continuus to the ground. In the case of vertical discontinuities there must be control of the elements ability to receive the load, as well as the ability of the diaphragms and the connections to transfer the load from the discontinuous location to adjacent elements.

- Regularity of weight distribution

There should be no difference in the effective weight of more than 50% between floors, for buildings rated as LS or IO. In the case of a variable mass, a linear dynamic analysis is performed, according to the second tier instructions and the ability of the elements to accept the pseudo-lateral force is controlled.

- Torsion [7]

The distance between the center of mass and the center of the stiffness should be less than 20% the width of the building in each direction, for buildings rated as LS or IO. In the case of a distance between the center of mass and the center of stiffness of the floor greater than 20% of the width of the building in any direction, the analysis are performed according to the second tier instructions. The maximum movement of the floor is calculated including torsional effects, and the control of vertical elements after calculated displacements is performed.

- Deterioration of concrete and wall elements

There must not be visible concrete or reinforcement steel damage in any component of the constructive system for the reception of lateral forces, and also the deterioration of the wall elements must not be visible. It is necessary to identify the extent of the damaged elements and to determine the impact on the system for receiving lateral forces. For each damaged element based on the degree of damage, the actual bearing capacity has to be determined.

- Coupling control

The mortar in joints should not be easily scraped with a metal tool, and there must not be area with eroded mortar in the couplings. It is necessary to identify the depth and extent of the joint damage. The walls with unstable mortar in the couplings should be omitted from the analysis and the adequacy of the transmission system for the lateral forces has to be checked without them. Alternatively, actual shear strength can be determined by testing.

- The existence of cracks in unreinforced masonry walls

Diagonal cracks in wall elements may not be larger than 3.2 mm, for buildings rated as LS or 1.6 mm for buildings rated as IO, and horizontal offsets in horizontal couplings shall not be greater than 3.2 mm, for buildings rated as LS and 1.6 mm for buildings rated as IO. Taking into account the extent of damage and their impact on the bearing capacity of the elements, it is necessary to check the adequacy of the lateral force resisting system. The extent of damage, location, number, and the direction of the cracks must be considered.

3.1.2. Control of lateral force resisting system

Regarding lateral force resisting system, the following items are controlled:

- Renundancy

In each main direction, the number of axes with shear walls must be larger than two, for buildings rated as LS or IO. An analysis of the system for transferring lateral forces, according to the second tier of evaluation procedures, has to be performed. All elements and connections have to be checked. In the case of incorrect elements in one axis, these elements are excluded, and the analysis is performed for the remaining axes.

- Shear stress check

Shear stress in unreinforced masonry walls, calculated using quick checks according to the first tier analysis procedure, must be less than 0,10 MPa for brick wall elements and 0,20 MPa for concrete wall elements for buildings rated as LS or IO. A quick check is carried out according to the first tier of evaluation, according to the procedure described.

3.1.3. Connection control

Within the connection control of the building, the following items are checked:

- Walls anchorage

The exterior concrete or masonry walls must be anchored with steel anchors or strips which are left out from diaphragm to accept the forces acting out of their plane, at each level of the diaphragms.

- Transfer to the shear walls

Diaphragms must be reinforced and connected to transfer the load on the shear walls for buildings rated as LS, and the connections should transfer the shear stresses from the walls for buildings rated as IO. An analysis of the system for transferring lateral forces to the second tier is performed. Requirements for diaphragms and connections are checked.

- Grinder-column connection

The connection between the beam and the pillar should be positive.

After performing structural checklist in tier one of evaluation, and after control of lateral force resisting system, by quick checks, it is indicated that walls do not have capacity for accepting lateral forces.

3.2. Second tier of evaluation of building of type URM

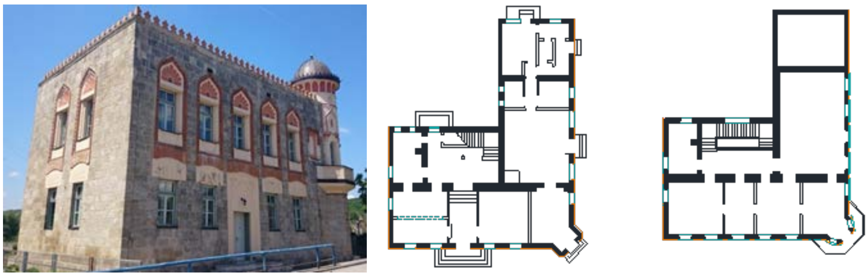

Figure 5. Example, building of type URM - perspective and floor plan

The second considered example of a masonry building is a building with a flexible diaphragm, with two levels. Floor plan is in shape of letter "L". The overall dimensions are 17,05x20,40 m. The diaphragms are wooden, made of wooden beams; over whom plasterboard is placed.

All the walls are made of brick, tall, and without horizontal and vertical beams. The load-bearing walls can be divided into two groups: internal load-bearing walls made of full brick, with 30, 45 and 60 cm thickness, and facade double walls, with stone on the outside. The thickness of the brick part is 30 cm, and the stone facade 15 cm. Lime mortar was used as a bonding agent for all walls.

Data on the geomechanical characteristics of the site are taken from the available geomechanical maps.

The seismic parameters are determined approximately based on the data for the Banja Luka region.

For this building type in order to control the lateral force resisting system, the checklists are not used, but special procedure defined in second tier, which regards separate analysis for different elements of building.

The special procedure applies to unreinforced masonry structures, with flexible diaphragms at all levels, and for constructions that have a minimum two axes with bearing walls in the main directions. The analysis is defined separately for partition walls, diaphragms and load-bearing shear walls. In the example, the analysis was performed only to control the stress in the shear walls.

For the evaluation at this level, certain tests on the construction material were required.

With regard to the criteria for the shear capacity, after a calculation, it was concluded that the building has sufficient surface area for the reception of lateral forces.

Construction details, such as anchoring of walls and details of non-structural elements are not known in this case, so analysis was not carried out.

4. CONCLUSION

In this paper, the principle of application of the FEMA310 document to evaluate the seismic resistance of existing buildings, for each building type, is briefly described. In the examples, first and second tier analysis were performed for two types of masonry structures, with rigid and flexible diaphragms.

The application of this document at the first and second tier of evaluation is a conservative, simplified way to determine seismic resistance based on many experiential data and encompasses the most important building parameters that can affect seismic resistance. The instructions are easy to apply, but are mostly adapted to United States standards, concerning mostly usage of seismic maps and load definition.

The third level of evaluation is not analyzed, as the analysis is recommended by the linear or nonlinear dynamic method following the United States valid rulebooks.

In the first example, which is discussed herein, the building with rigid diaphragms, being analyzed, was constructed prior to the adoption of the rulebook on construction in seismic areas and does not meet the requirements for the aseismic design according to the technical regulations for construction on seismic sites. Such objects in the area of Banja Luka are mostly upgraded and reconstructed. According to a rough evaluation by document FEMA310, at the first tier, after performing a quick check control defined by the Manual, the evaluated building did not meet the requirements for lateral bearing capacity of the sharing walls.

In the second example, the masonry building with flexible diaphragms is analyzed. An analysis of share walls was performed in terms of accepting the seismic load. Although this is an old building, as the thickness of the walls is large, the requirements are met, according to the special procedure of the second tier of evaluation.

LITERATURE

[1] Fema 310 – Handbook for the Seismic Evaluation of Buildings, Federal management agency and American society of civil engineers, 1998

[2] D. Ančić, P. Fajfar, B. Petrović, A. Szavits-Nossa; M. Tomažević, “Zemljotresno inženjerstvo – visokogradnja”, DIP „Građevinka knjiga“, Beograd, 1990.

[3] M. Aćić; G. Ćirović, “The role and the significance of construction in reduction of seismic risk” International conference on earthquake engineering, Institute for Construction Banja Luka – ZIBL, Oct. 2009.
[4] M. Tomažević, “Earthquake resistant design of masonry buildings: 40 years after the banja luka earthquake” International conference on earthquake engineering, Institute for Construction Banja Luka – ZIBL, Oct. 2009.
[5] D. Trkulja, “Banjalučki zemljotresi” International conference on earthquake engineering, Institute for Construction Banja Luka – ZIBL, Oct. 2009.
[6] M. Herak; D. Herak, “Analyses of seismicity as input for earthquaqe hazard studies in Bosnia and Herzegovina” International conference on earthquake engineering, Institute for Construction Banja Luka – ZIBL, Oct. 2009.
[7] E. Zlatanović, G. Broćeta, N. Popović-Miletić: "Numerical modelling in seismic analysis of tunnels regarding soil–structure interaction", Scientific Journal - Facta Universitatis, Series: Architecture and Civil Engineering, Vol. 11, No. 3, 2013, M-24, UDC 624.19:624.042.7=111, ISSN 0354-4605, DOI: 10.2298/FUACE1303251Z, pp. 251-267.
[8] Ž. Lazić, Z. Koneski, J. Stanojević; “Accedental torsion in symmetrical structures”, XI International scientific technical conference Contemporary theory and practice in building development, Institute for Construction Banja Luka – ZIBL, May 2005