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Seismic Retrofitting of Central Market in Berat

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Abstract:

Berat is an ancient city in Albania, protected from UNESCO and the Central Market is located near old part. Design of this building it is carried out according to old national codes not renewed for more than 30 years. So, building designed according to old codes does not meet the new requirements of European Codes under design earthquakes, which can cause heavily damages on those structures.

In this paper it is described the analysis and design of retrofitted concrete structure realized several years ago according to nowadays European Codes.

Initially the article describes the existing structure conditions followed by linear analysis and structural measures suitable for this type of structure.

Recommendations are given for the design methodology and the most appropriate retrofitting strategy of existing structures in order to meet the required level of performance increasing level of security based on European Codes.

Key words: retrofitting, EuroCodes, response spectrum, existing structure

INTRODUCTION

In Albania recent years as result of various economical or political problems, upgrading design and constructions standards of reinforced concrete and masonry structures it is not fully performed. New design national standards absence, conduct the designers to work directly based on Eurocodes, meanwhile some of them followed to work based on old standards. Some of the structures designed based on Albanian old codes even generally detailed in a viewpoint can present problems as a result of insufficient reinforcement detailing and seismic demand change.

In this paper through the case study (Central Market in Berat) designed by Albanian codes and redesigned according to Eurocodes recommendations, are pointed out the main structural problems and suggest as essential obligation of the structural design, application of European standards.

The reconstruction of the existing facility includes:

- intervention and reinforcement of foundations,
- strengthening the central columns as key elements, vertical carriers of the existing structure.
- realization of perimetral reinforced concrete walls, symmetrically placed, in order to improve the behavior of the existing structure in terms of increasing parameters, which in the real situation do not meet norms (see EC-8, prEN1998-1, 4.4.3) according to the serviceability limit state (SLS).

The methodology of existing structures control and retrofit passes through the following stages [1,2]:

- Dimensions and geometric data information, reinforcement bars and detailing, material of the existing structure
- Static and dynamics analysis design as a improved structure with new structural elements (Shear walls and retrofitting of columns and foundations).
- Check of structure deformations, etc. Comparison of provided dimensioning and reinforcement with required dimension and reinforcement.
- Confirm the strategy of intervention, analysis and control the retrofitted structure and economic efficiensy.

Below the article will give in detail all these stages.

1. MODELLING OF STRUCTURE

1.1 Existing structure

The existing object of the former Central Trading center Berat is realized with 2 floors above ground, with heights L = 5.95m and L = and 4.25m, respectively. It contains in the central part between the axis 3÷5 and C÷F a lighting and a ventilation space which rises above the quota +10.20 L at a 1.85m in height.

Fig. 1. Central Trading Center Berat (outside)

Fig. 2. Central Trading Center Berat (inside)

We have the drawings of all structural elements and reinforcement. We don’t have data for other details and other possible changes during the construction.

From observations of the concrete elements is seen that the dimension of the structural elements are the same as in the design. We have done non-destructive and some destructive tests for taking the exact characteristics of the materials, and checking the height of the slab.

The building was designed based upon Albanian Design Codes KTP-89. We have the final design drawings, so taking into account also the real material characteristics we can consider that we have a very good level of recognition of the existing structure.

The dimensions are given in the figure below.

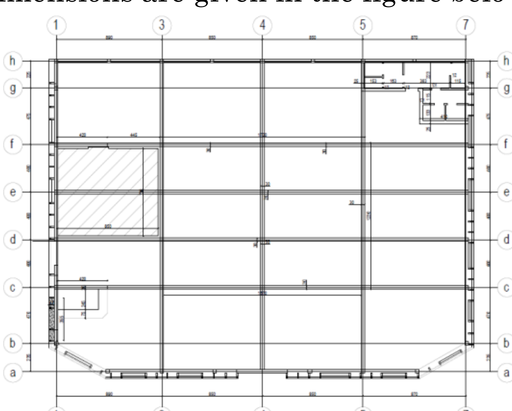


Fig.3. Plan of the structure (first floor)

1.2 Concrete properties investigations

Up to now there are used several methods for evaluation of Concrete properties. Based on their characteristics their results are more or less reliable.

We have done 2 core tests as described in UNI EN12504-1 standard and several Schmid hammer tests as described in UNI EN12504-2 standard together with ultrasonic tests (Sonreb).

For the core tests we have used the correction given by Masi (2005)

$$Fc,i=(C_{h/D} \text{ x } C_D \text{ x } Cs \text{ x } Cd)\ _{fcore,i}$$

Where $C_{h/D}$ correction for h/D different from 2, C_D correction for D different from 100mm, Cs correction for steel presence inflation, Cd correction for core disturbance.
From this expression we have the following characteristics.

1.3 Materials

The class of concrete provided for the foundation in the project is C20/25, while regarding the columns, reinforced concrete walls, and roof beams, the class is C25/30. The steel used in the structure is class S500 . This class of steel is provided for all types of reinforcement used in the structure (mesh, longitudinal, transversal etc.).

Design strength for concrete and steel are taken from the reduction of the characteristic resistances by using concrete class with appropriate safety factor as follows:

$$fcd = fck \ / \ y_c$$
$$fcwd = fcwk \ / \ y_c$$
$$fyd = fyk \ / \ y_s$$
$$fywd = fywk \ / \ y_s$$

where; y_c - partial safety factor for steel = 1.15, (EC2 2.3.3.2) and y_s - partial safety factor for concrete = 1.5

2. STRUCTURE EVALUATION BASED ON EUROCODES

2.1 General

As recommended by the Eurocodes and the reference documents, structural evaluation of existing buildings in general requires an «additional» limit state. The new buildings are design to fulfill the hierarchy of resistances and appropriate ductility, and evaluated structures are design according to these requirements.

These requirements are based on the definition of three damage states of the structure

- limit state with limited damage (immediate occupancy) IO
- limit state with significant damage (from damage control- life safety) LS
- limit state of structural stability (total or partial collapse) CP

The evaluation of the existing structure proceeds according to the following steps:

- Identification of existing data
- Determination of levels of recognition and selection of computer models
- Determination of seismic loads in every limit stage
- Modelling and Analysis
- Verification of elements

The first two items we have described in the beginning of the article, the others are given below.

2.2 Seismic action

Albania is a very seismic zone. In the existing Albanian code the seismic input is taken from an Intensity map multiplied by soil conditions and some other factors. According to EC8, seismic hazard should be given only with one parameter a_{gR} on ground type "A" that correspond to rock or rock like geological formations, including 5m weak formations (soil) at surface. The values of a_{gR} (maximum acceleration PGA) are taken from the Probabilistic Hazard Map of Albania recommended (not officially) recently by "Geoscience Institut" (fig.4). The return period of the reference event is T_R=475 years that corresponds to a life time of 50 years.

The horizontal PGA in ground type A for the site is taken $a_g = 0.25g \cdot \upsilon$

2.3 Static Analysis

Static analysis of the structure involves the solving of the following system linear equations:

$$[K]\{u\}= \{r\} \qquad (4.1.1)$$

where, [K] is the matrix of rigidity, {r} is the vector of loads acting on the structure, and {u} is the displacement vector. In any case, the program automatically creates vector {r} and determines the displacement vector by solving the system of linear equations. After displacements definitions on all nodal points it is possible to define all values of generalized forces (M11, M22, M33- bending moments , Q22, Q33-shear forces, N-axial forces, T-moment torques for each "frame" element. F11, F22, F12- axial forces according to two directions and shear forces, to perpendicular plans and in plane for each "shell" element. Naturally the modeling of the structure in whole and each element is realized on the basis of the methodology of finite elements (FEM), which is an approximate method practiced widely nowadays in the terms of the superiority created by using softwares.

2.4 Dynamic Analysis

The dynamic analysis of the structure has as its base the modal analysis with spectrum response method. The calculated dynamic loads (seismic) are accepted as equivalent static loads and exercised in concentrated place measures.

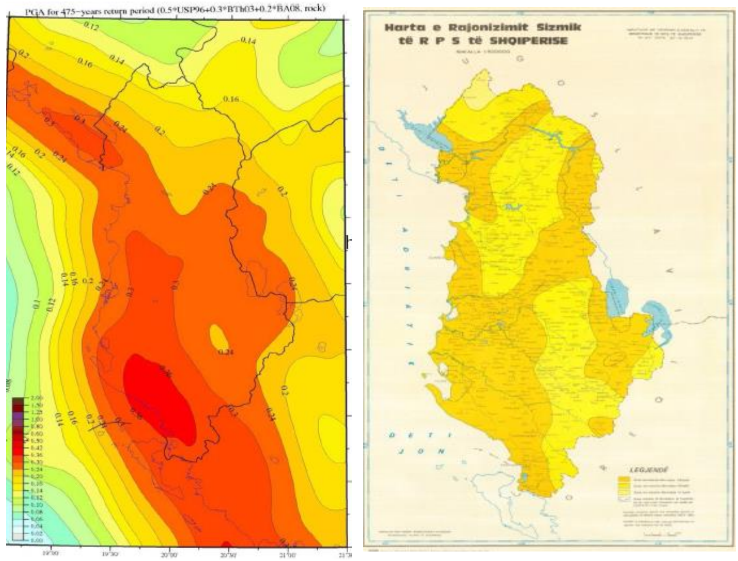


Fig. 4.a) Peak ground acceleration Map of Albania (Duni &Kuka 2010)
b) Seismic zonation map of Albania (Sulstarova 1980)

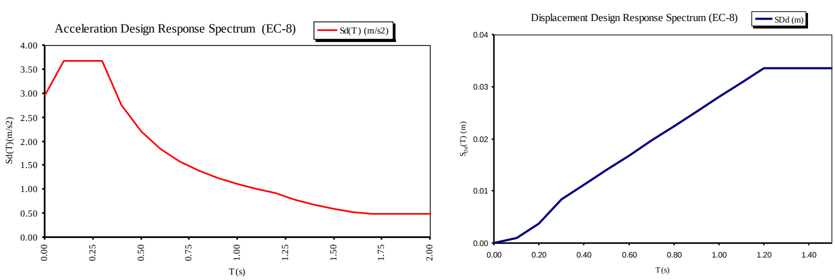


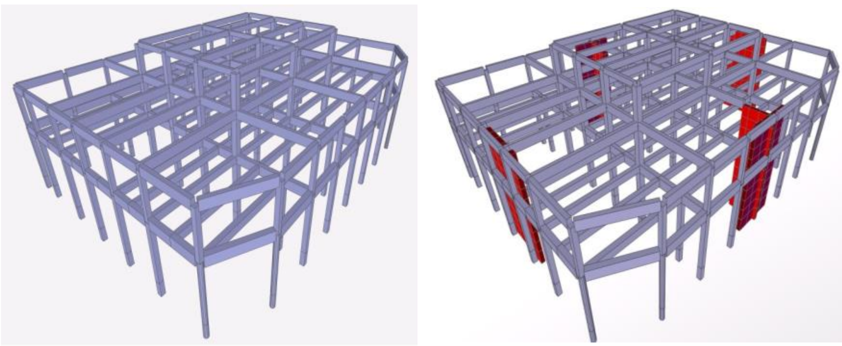
Fig.5 Graphical view of the elastic acceleration and displacement spectrum for soil type D

2.5 Linear analysis

Structural modelling aspects and the determination of seismic action given above is done in the same manner as for a new building according to EuroCodes 8 recommendations. The analyses and the determination of internal forces is done by spectral method with concentrated masses in the center of masses of each story. The combination of seismic loads and other actions is made according to EC1.

Model of the structure is the same as for a new building and the contribution of non-structural elements is neglected.

The 3D model of the structure is given below in fig. 4.



a) Existing structure b) Retrofitting

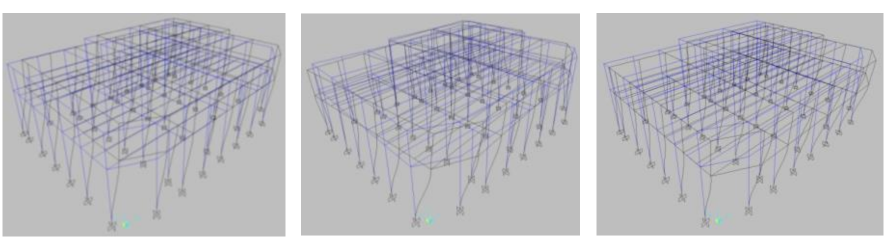
Fig. 6. Graphical view of the linear model

The modal results are given in the table and figures below.

Table 1. modal results of structure

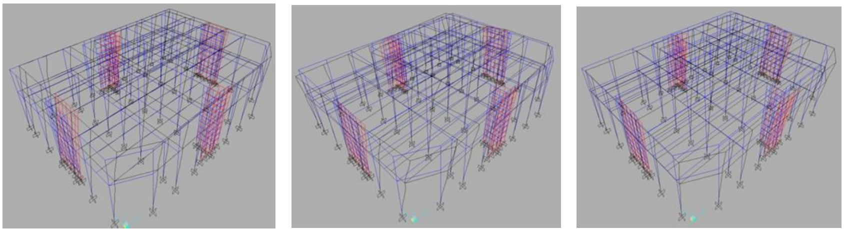
Existing situation, Eighen values (Before reinforcement)			
Mode	Period	Cyclic Frequency	Radial Frequency
	Sec	Cyc/sec	rad/sec
1	1.36	0.73	4.61
2	1.06	0.94	5.94
3	1.04	0.97	6.07

Reconstruction; Eighen values (after reinforcement)			
Mode	Period	Cyclic Frequency	Radial Frequency
	Sec	Cyc/sec	rad/sec
1	0.41	2.45	15.38
2	0.31	3.25	20.41
3	0.30	3.38	21.25



a) Mode1, T=1.36191 b) Mode2,T=1.05858; c) Mode 3,T=1.03501

Fig. 7. Graphical view of modal forms (existing structure)



a) Mode1, T=0.40846　　b) Mode2,T=0.30791　　c) Mode 3, T=0.29565

Fig. 8. Graphical view of modal forms (retrofitting structure)

2.6 Spectral Analysis

Dynamic equilibrium equations associated with the response of structures to dynamic shaking of the foundation are generalized in written form:

$$Ku(t)+C\dot{u}(t)+M\ddot{u}(t)=m_x\ddot{u}_{gx}(t)+m_y\ddot{u}_{gy}(t)+m_z\ddot{u}_{gz}(t)$$

where: K is the matrix of rigidity, C is the fading matrix, M is the diagonal matrix of mass, u , $\dot{u}$, $\ddot{u}$ are displacements, velocities and acceleration relative of the points of the structure in relation to land, m_x, m_y dhe m_z are inertial forces for acceleration unit; $\ddot{u}_{gx}$, $\ddot{u}_{gy}$ dhe $\ddot{u}_{gz}$ are components of the acceleration of the ground under the global axes.

The spectral analysis requires the maximum response of the structure by equations (see expression 3.13 prEN 1998-1), in contrast to the analysis in the field of “time history" that defines the behavior of the structure at any point in time. In the case of spectral analysis the spectral acceleration curve (design spectrum) by three global axes in relation to the period of own structure oscillations is given. Results of further analysis include displacements, forces and strains. Analysis of the response spectrum method is carried out using modal superposal (Wilson and Button 1982).

Referring to the analogous geological-engineering studies near this land, it was classified as a square of type D with these values of the spectral parameters for type 2 (Table 3.2 prEN 1998):

$$S=1.8,\ T_{B(S)}=0.1\ T_{C(S)}=0.3\ T_{D(S)}=1.2$$

2.7 Displacement (relative) of interstorey under two directions

Interstorey displacements below will be given in tabular form, given to the limit values for non-structural elements and buildings associated with non-ductile framework for limit state service:

$$d_\gamma\, v \leq 0.005 \cdot h \qquad (6.5.a)$$

where:

d_Y- displacement (relative) of between floors

υ- reduction factor (see paragraph 6.2)

h- floor height

For a certain level of displacement (relative) of interstorey (interstorey drift) and displacement at the edge of destruction, the following expressions are given respectively:

$$d_{ri} = d_{si} - d_{s(i-1)} \qquad (6.5.b)$$

$$d_s = q \cdot d_e \cdot \gamma_I \qquad (6.5.c)$$

where:

d_s - displacement at the edge of destruction

q - behavioral factor (ductility)

d_e - elastic displacement caused by seismic load "design earthquake"

γ_I - factor of importance.

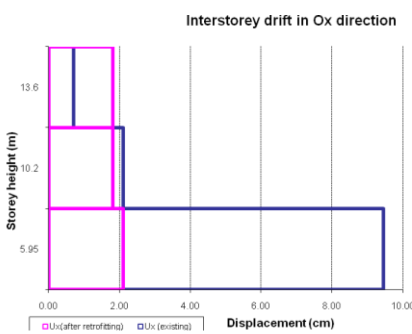
Existing situation (before strengthening)

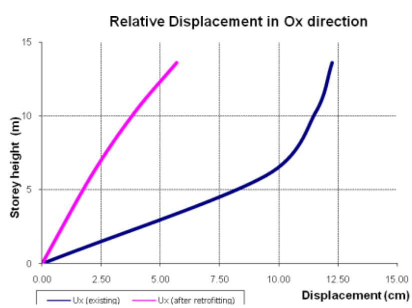
FLOOR LEVEL (QUOTE)	ELASTIC DISPLACEMENT $d_e(cm)$		IMPORTANCE FACTOR γI	BEHAVIORAL FACTOR q	TOTAL DISPLACEMENT $d_s(cm)$		RELATIVE DISPLACEMENT $d_r(cm)$	
	Displacement Direction				Displacement Direction		Displacement Direction	
	X	Y			X	Y	X	Y
0	0.00E+00	0.00E+00	1	3.5 3	0.00E+00	0.00E+00		
5.95	2.70E+00	2.70E+00	1	3.5	9.45E+00	9.45E+00	9.45E+00	9.45E+00
10.2	3.30E+00	3.17E+00	1	3.5	1.16E+01	1.11E+01	2.10E+00	1.65E+00
13.6	3.50E+00	3.31E+00	1	3.5	1.23E+01	1.16E+01	7.00E-01	4.90E-01

Reconstruction (after strengthening)

FLOOR LEVEL (QUOTE)	ELASTIC DISPLACEMENT $d_e(cm)$		IMPORTANCE FACTOR γI	BEHAVIOR FACTOR q	TOTAL DISPLACEMENT $d_s(cm)$		RELATIVE DISPLACEMENT $d_r(cm)$	
	Displacement Direction				Displacement Direction		Displacement Direction	
	X	Y			X	Y	X	Y
0	0.00E+00	0.00E+00	1	3	0.00E+00	0.00E+00		
5.95	7.00E-01	4.80E-01	1	3	2.10E+00	1.44E+00	2.10E+00	1.44E+00
10.2	1.30E+00	8.70E-01	1	3	3.90E+00	2.61E+00	1.80E+00	1.17E+00
13.6	1.90E+00	1.46E+00	1	3	5.70E+00	4.38E+00	1.80E+00	1.77E+00

As it can be easily observed from the tables above and completion of the condition (6.5a) is not guaranteed for the existing situation. Thus enhancing the existing structure is required to meet the criteria of state limit service (SLS) in accordance with EC-8 (see, prEN1998-1, 4.4.3).





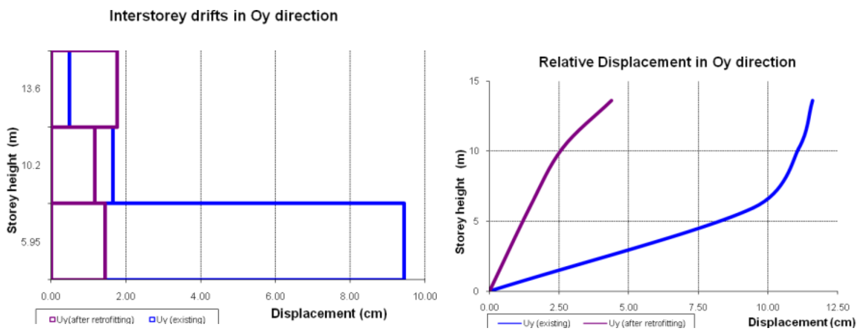


Fig. 9. Graphical view of relative displacement in Ox, Oy direction (Interstrorey drifts)

3. CONCLUSION

Reconstruction of facility: Former Central Market in Berat, Address: Street, "Antipatrea" Berat, in the absence of complete data with the most accurate full project implementation constructive to the existing facility, is being implemented based on:

- The architectural project implementation (Studio "B & L"),
- Evidence of some in-situ reinforced concrete columns elements (ALB CONSULT2).
- Engineering geological studies analog to building squares near this building square.
- Survey of existing topographic state

From the above, it is concluded that: The reconstruction of the facility under the present project structure satisfies enough at a degree of reliability the European technical conditions EC-2 and EC-8, according to the limit states, of the destruction (ULS Ultimate Limit State) and service (SLS Serviceability Limit State).

To rehabilitate the structures we can use four different approaches.

1. Increasing the global capacity (strengthening). This can be done by the addition of cross braces or new structural walls.
2. Reduction of the seismic demand by means of supplementary damping and/or use of base isolation systems.
3. Increasing the local capacity of structural elements. This approach recognizes the existing capacity of the structures, and adopts a more cost-effective approach to selectively upgrade local capacity (deformation/ductility, strength or stiffness) of individual structural components.
4. Selective weakening retrofit. This is an intuitive approach to change the inelastic mechanism of the structure.

From these four types of retrofit strategy approaches we have chosen to apply a combination of third and fourth type.

From the obtained results can be seen that after strengthening of elements the structures performance is improved and all elements meet the performance criteria in flexure, shear strength, deformative capacity and the surface layer of column concrete that in the existing structure crush and spall out is now assured.

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