1st Croatian Conference on Earthquake Engineering
1CroCEE
22-24 March 2021 Zagreb, Croatia

DOI: https://doi.org/10.5592/CO/1CroCEE.2021.222

Structural analysis of a Rc building failure caused by the earthquake of 26th November in Durrës, Albania

Anjeza Gjini[1], Hektor Cullufi[2], Princ Xhika[3]

[1] *Lecturer*, Faculty of Civil Engineering, Polytechnic University of Tirana, Albania, *anjeza.gjini@fin.edu.al*
[2] *Lecturer*, Faculty of Civil Engineering, Polytechnic University of Tirana, Albania, *hektor.cullufi@fin.edu.al*
[3] *Structural Engineer,* Kastrati Group, Tirana, Albania, *princxhika@gmail.com*

Abstract

On November 26, 2019, a magnitude 6.4 (Mw) earthquake occurred in Durrës, Albania, causing considerable damages to many surrounding buildings. In this paper, a six floor RC structure, with a frame system, located in Durrës is taken in consideration. The structure suffered significant structural damages due to strong ground motion. The institutions responsible for the situation assessment described it as a structure with the high-risk collapse. For this reason, on December 3, 2019, the engineer corps demolished this building with controlled explosion. The purpose of this study is to analyse the collapse mechanism of the six floor structure, based on well-established Finite Element Method. This structure will therefore be simulated with advanced modelling software, such as ETABS Ultimate. Analytical results, obtained by the numerical methods are then compared with the observed In-Situ damages.

Key words: collapse mechanism, finite element method, 2019 earthquake Durrës, RC frame structure

1 Introduction

During the time period between May to December of 2019, there were multiple occasions of recorded seismic activity in Albania. From this activity three cases pose special interest as case studies, namely the May earthquake in Korça and the two major ones in September and November, with the later one being the most devastating one in Durres region. The last one on the 26th of November was a 6.4 magnitude earthquake about 16 km off the coast of Mamurras at 3.54 CET [1]. Most damage was caused in masonry and reinforced concrete buildings, which in some cases resulted in loss of life. In this study we have compared the predictions from numerical and analytical modelling results, regarding the collapse mechanism, to the real life in-situ situation after the strong ground motion, for a six floor R/C structure.

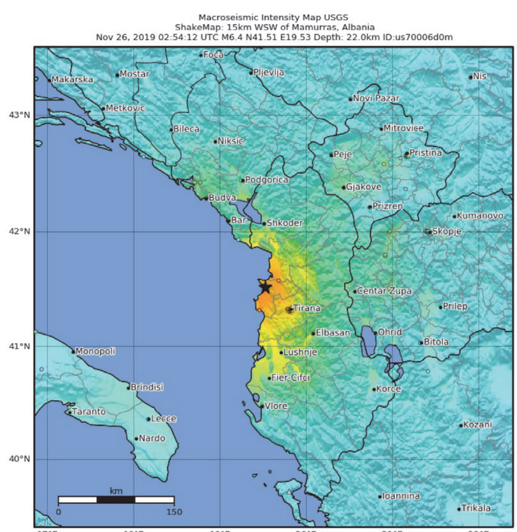
2 Seismic activity

According to the data obtained from USGS Earthquake Hazards Program [1], the November 26, 2019 earthquake in Albania occurred as the result of thrust faulting near the convergent boundary of the Africa and Eurasia plates. This seismic activity had the following properties:

- Event Time: 3.54 CET
- Event Location: 15.6 km WSW of Mamurras and 22 km SSW of Durrës, Albania
- Epicentre Depth: 22 km
- Magnitude (M_L / M_W): 6.3 / 6.4

3 Description of the building

In this paper is studied a building located in Durrës. This was a six floor RC frame structure. The ground floor and the first one were used for restaurant and the other ones for hotel. According the legal documents, the building was constructed in 2008, based on a structural project, approved by the urban planning department of Durrës.



SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
DAMAGE	None	None	None	Very light	Light	Moderate	Moderate/heavy	Heavy	Very heavy
PGA(%g)	<0.0464	0.297	2.76	6.2	11.5	21.5	40.1	74.7	>139
PGV(cm/s)	<0.0215	0.135	1.41	4.65	9.64	20	41.4	85.8	>178
INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Scale based on Worden et al. (2012) Version 1: Processed 2020-06-06T03:04:52Z
△ Seismic Instrument ○ Reported Intensity ★ Epicenter

Figure 1. Macroseismic intensity map [1]

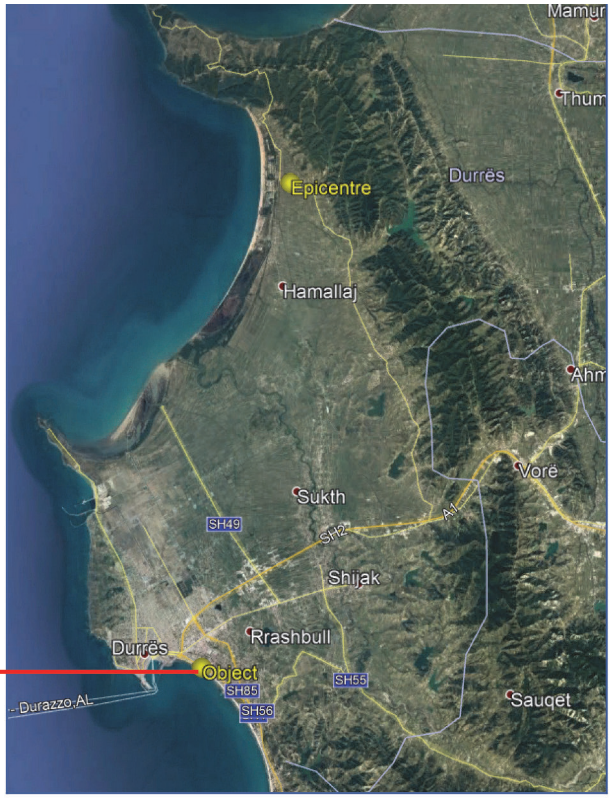


Figure 2. Building location in relation to the earthquake epicentre

Figure 3. Building location (orthophoto 2015, [2])

Figure 4. a) Building before demolition; b) The plot after demolition

3.1 Mechanical proprieties of materials

Referring to structural project, it results that the compressive strength of concrete is $f_{ck,cub}$ = 25 MPa and the yield strength of the steel is f_{yk} > 240 N/mm^2. Therefore, for structural modelling are taken the characteristics of materials shown in Table 1.

Table 1. Characteristics of materials

Material	Class	Characteristic comp. cylinder strength (f_{ck}) [MPa]	Characteristic yield strength (f_{yk}) [N/mm^2]	Partial factor	Compressive strain in the concrete [%]	Ultimate compressive strain in the concrete [%]	Characteristic strain of reinf. [%]
Concrete	C20/25	20	-	1.5	0.2	0.35	-
Steel	Ç-5	-	240	1.15	-	-	>10

3.2 Description of the structure

To analyse the structural data of the building, the researchers refers to all the technical documentation, photos taken before and after the demolition, as well as inspecting the site after the collapse of the building by the earthquake.

The structure of the 6-storey building is a reinforced concrete frame system. The height of the ground floor and the first floor is 3.50 m, and the other floors 3.15 m. The perimeter walls of the building are made of solid brick, with a thickness of 25m, while the partition walls with a thickness of 25cm and 12 cm. The columns have a rectangular section 70 x 25 cm up to the quota +3.50 (ground floor), and further the section is reduced to 60x25 cm (first technical floor to the fifth). They are distributed uniformly in plan. Beams are designed with a rectangular section (hxb) 25 x 50 cm. The ribbed concrete slabs are filled with polystyrene (b=20 cm). The width of the rib is 10cm and the axial distance between ribs is 30 cm. The total height of the slabs is 25 cm (5 cm topping slab).

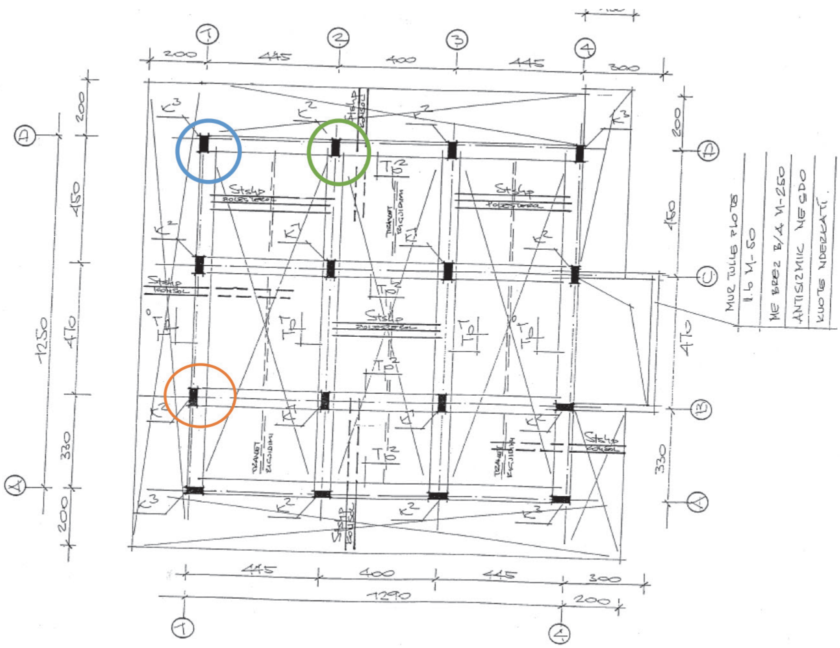


Figure 5. Layout in +3.50 m

4. 3-D Modelling of structure and results

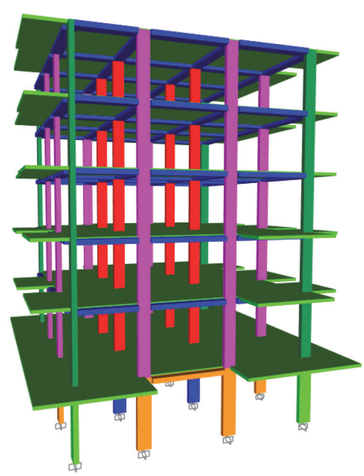


Figure 6. 3D Modelling of structure using ETABS Ultimate 19

The structure is modelled using advanced software such as ETABS Ultimate 19. This mathematical model can capture to a satisfying degree all actions on structure exerted by self-weight, imposed loads, seismic events and the effects of their combinations. The analyses are conducted using provisions from EN 1998-3 (2005) [3], 4.4.3 Multi-modal response spectrum analysis (1) P and 4.4.4.1 (1) P Nonlinear Static. Judging by the results obtained by both types of analyses it is clear that this building has major issues regarding ULS and SLS.

The structure has large drifts, especially in ground and first floors, going up to 0.004 (ground floor) and 0.006 (first floor), as shown in figure 7. These drift result from low structural rigidity, slender columns, incorrect column orientation and uneven distribution rigidity in plan and lack of shear walls. Due to the considerable displacements, major damage was caused in structural and non-structural elements such as masonry walls during the strong ground motion.

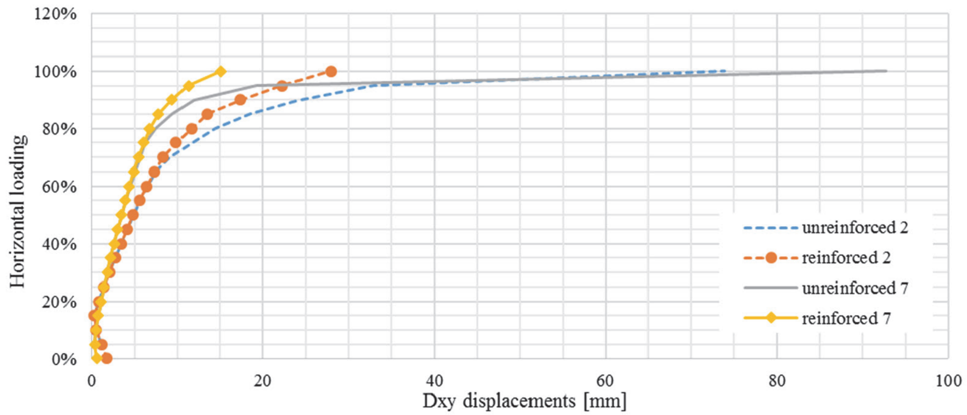


Figure 7. a) Structure drifts in X direction; b) Structure drifts in Y direction

Columns dimensions are decreased from (bxh) 25x70 cm on ground floor to 25 x 60 cm on first and upper floors, which has caused an increase in plastic rotation in first story hinges. In the deformed shape it is visible that we have a concentration of strains (larger degree of deformation) in first story.

Table 2. Modal periods and frequencies

Case	**Mode**	**Period** [sec]	**Frequency** [cyc/sec]	**CircFreq** [rad/sec]	**Eigenvalue** [rad²/sec²]
Modal	1	1.479	0.676	4.248	18.048
Modal	2	1.091	0.916	5.757	33.141
Modal	3	1.025	0.976	6.130	37.579
Modal	4	0.480	2.085	13.098	171.552
Modal	5	0.345	2.901	18.229	332.297
Modal	6	0.328	3.048	19.152	366.783
Modal	7	0.278	3.595	22.588	510.211
Modal	8	0.200	4.996	31.394	985.578
Modal	9	0.191	5.248	32.974	1087.291
Modal	10	0.183	5.468	34.359	1180.562
Modal	11	0.156	6.430	40.399	1632.104
Modal	12	0.129	7.727	48.551	2357.229

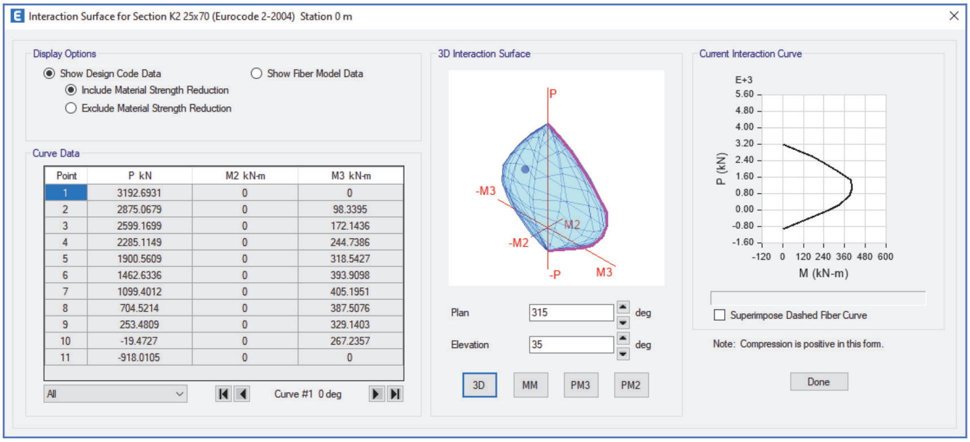


Figure 8. Typical interaction diagram for ground story column

Regarding ULS, analyses show that some of the columns in ground and first stories are overstressed, which means that the required reinforcement exceeds the maximum allowed. Furthermore, by comparing required longitudinal reinforcement of frames to the reinforcement provided by the designer, we can see that this design is insufficient and presents major structural issues (table 3). This is also demonstrated by pushover analysis results where structural capacity is smaller than structural demand by a large margin.

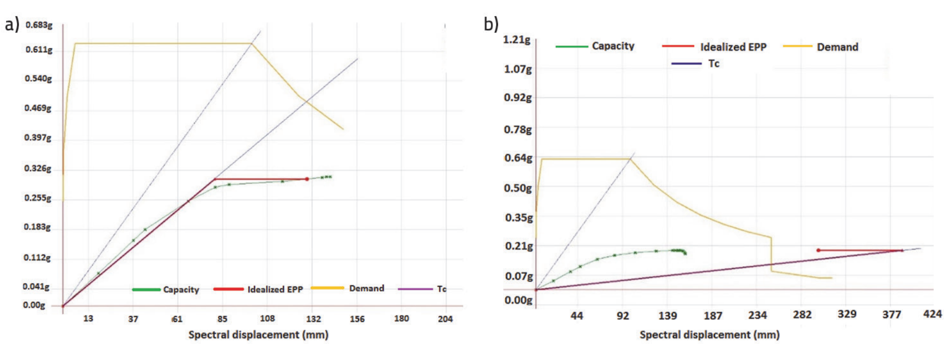


Figure 9. Structural capacity and demand curves for a) X direction; b) Y direction

In the table below is shown the need for reinforcement and the designed one for columns in the ground and first floor (ref. Figure 5).

Table 3. Reinforcement check

Columns	Longitudinal Reinforcement	
	Provided [cm^2]	**Required** [cm^2]
C 1B (ground floor)	44 (2.51%)	70 (4.02%)
C 1D (ground floor)	44 (2.51%)	92 (5.25%)
C 1D (first floor)	36 (2.38%)	69 (4.61%)
C 2D (first floor)	36 (2.38%)	80 (5.32%)

Plastic hinges are developed in a brittle manner as showed in figure 10. This phenomenon was also observed by in-situ investigations where near column joints on ground and first floors there were large cracks and concrete crushing of compression areas.

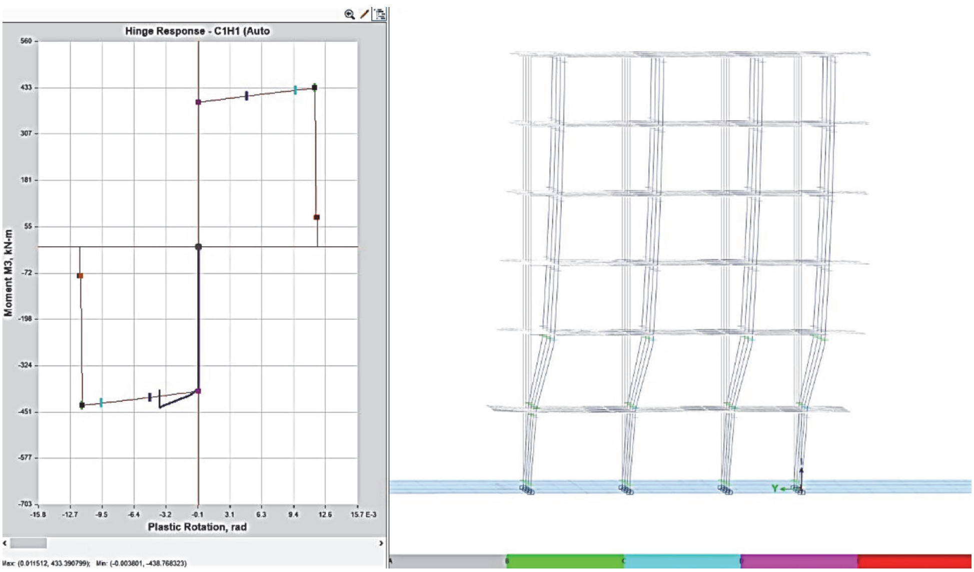


Figure 10. Typical plastic hinge development for ground story columns

Figure 11. Structural damages by the November 26, 2019 earthquake

5 Conclusion

The collapse (damage) mechanism, resulting from the structural analysis, shows that the damage is localized on the first two floors. The first floor is the most damaged, due to the reduction of the dimensions of the columns and also the reduction of the amount of reinforcement. The 3-dimensional structural calculations and the collapse (damage) mechanism resulting from the modelling, generally match the way the building was damaged by the November 26, 2019 earthquake. This technical interpretation clearly expresses the evidence of serious damage, with a plastic character, but not the collapse of the building.

References

[1] USGS Earthquake Hazards Program, https://earthquake.usgs.gov/, (accessed 30th November 2019).

[2] State Authority for Geospatial Information, https://asig.gov.al/.

[3] CEN. 2004. EN 1998-1. Eurocode 8: Design of Structures for Earthquake Resistance - Part 1: General Rules, Seismic Actions and Rules for Buildings.

[4] CEN. 2003. EN 1992-1. Eurocode 2: Design of concrete structures - Part 1-1: General rules and rules for buildings

[5] Akademia e Shkencave, Ministria e Ndertimit (1989): *Kusht Teknik i Projektimit per Ndertimet Antisizmike,* KTP-N.2-89, Albania.

[6] Institute of Geosciences, Energy, Water and Environment – Earthquakes, https://geo.edu.al/