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CASE STUDY REPORTS

Reconnaissance analysis on buildings damaged during Durres earthquake Mw6.4, 26 November 2019, Albania: effects to non-structural elements

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Abstract
At 03:56 local time on November 26, 2019, an earthquake with a Mw = 6.4 struck western part of Albania. The duration of the tremor lasted less than 50 s and was felt largely also in Albania's capital Tirana, and in places as far away more than 300 km northeast of the epicenter. It caused damage to many public and residential buildings in districts of Durres, Tirana, Lezha, Shkodra, Diver, Berat and surrounding areas. This paper describes rapid visual assessment of the damaged buildings (169 in total) in affected areas by IZIIS teams' inspection of damaged buildings. Severe damages were identified in structural and non-structural elements as a result of inconsistent application of recent knowledge in design, construction and quality control of earthquake resistant structures. Structural errors in design and construction as well as inappropriate quality of built-in materials have been observed. Such results from the rapid damage assessment leads to the necessity of taking specific measures as detailed engineering inspection of vital structures as a basis of definition corresponding technical solutions for repair and strengthening with aim of restoring their operational mode. Last but not least, the biggest effect of earthquake damage was observed in non-structural elements which made the structures not-usable for citizens of the earthquake region.

Keywords Durres earthquake · Rapid visual assessment · Structural damage · Repair and strengthening

1 Introduction

When earthquakes occur and seismic activities are present, most of the non-structural elements in RC buildings suffer varying from small cracks to collapse as given in the work of Braga (2011). Although, many seismic codes have provided additional measures for

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non-structural elements still there is a lack of attention in building/proofing of non-structural elements. In the work of Massi (2011) the interstory drift parameter has been given attention for representing the nonstructural damage level of structures experiencing natural earthquake recordings and synthetic data. More recently, different procedures such as RISC-UE (Spence and Le Brun 2006) proposed the use of displacement response spectra depending on the objectives of the evaluation. This study focuses on the overall effect and quantities of non-structural damages which take great part in Durres Earthquake Mw6.4, 26 November 2019, Albania.

On November 26, 2019, the northwest part of Albania was hit by a strong earthquake with magnitude $M_L = 6.3$, hypocentral depth of 40 km and epicentral distance of around 7 km of Hamallaj, 16 km form Durres and 35 km from Tirana (AMBS 11/19). According the strong motion record on Durres Station (DURR) the earthquake lasted around 50 s (https://www.geo.edu.al/newweb/?fq=durres) and was felt in radius of more than 300 km. The maximum intensity in the epicentral area in radius of 13 km was IX degree according to the EMS-98. Until 01.12.2019, the instruments recorded over 1300 aftershocks, out of which 30 earthquakes were felt in a large area by the population (Fig. 1).

As evident from official data, the earthquake took 51 human lives and more than 900 people reported injuries (PDNA). According to the assessment made by PDNA, more than 200.000 people were affected by this earthquake and around 12.000 housing units were fully or partially damaged. The total economic loss was estimated to be 985.1 million EUR affecting mostly educational, health, housing, infrastructure, productive, social protection as well as civil protection & disaster risk reduction sectors.

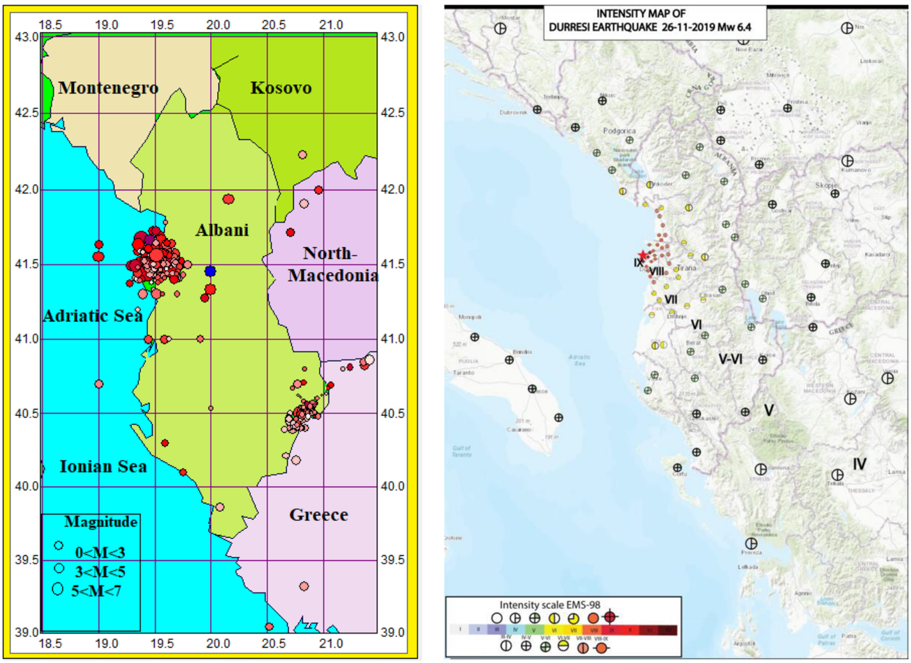

Fig. 1 Epicentral and maximum intensity (EMS-98) map (AMBS 11/19, Monthly Bulletin of Seismology, No 5, Institute of GeoSciences, Energy, Water and Environment. Polytechnic University in Tirana. ISSN: 2664-410X)

Immediately after the earthquake, the international community responded with solidarity assistance of 12 EU and 8 non-EU countries helping affected people and society to overcome the first impact of an earthquake. Republic of North Macedonia provided assistance with its own donations. In the first phase, the Government and the Skopje city sent rescuing teams to search for and rescue people from the ruins, fire—fighting brigades and doctors along with corresponding equipment and financial aid. The European Civil Protection Mechanism (EUPCM) was activated, through which emergency response phase was coordinated. Immediately upon termination of search and rescue phase (by announcement made by the Albanian Prime Minister on 30.11.2019), started the second phase i.e. rapid post-earthquake damage assessment in the affected region. The entire operation was led by the EU Directorate-General of the European Commission for Civil Protection and Humanitarian Aid Operations (DG ECHO with participation of teams of engineers from over 15 countries (Fig. 2) and local experts.

Upon the call of Government of N. Macedonia (29-11-2019), the Institute of Earthquake Engineering and Engineering Seismology (IZIIS) in Skopje was involved in the reconnaissance mission with three teams composed of a total of 9 experts. The rapid damage assessment mission was held in the period 2–13.12.2019, with support of local engineers in which were inspected total of 169 structures in the territory of Durres and Shijak, (IZIIS Report 2019-73).

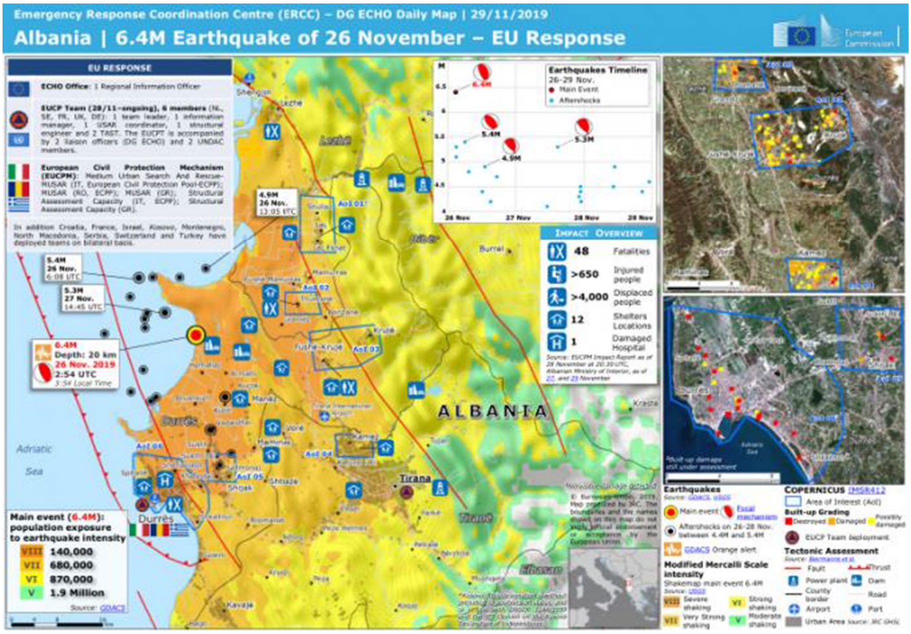

Fig. 2 EU response (https://reliefweb.int/map/albania/albania-64m-earthquake-26-november-dg-echo-daily-map-29112019)

2 Seismicity of the wider region of durres

Albania belongs to Mediterranean countries which are characterized with very high seismic hazard and risk. The strong historical seismicity is very well known in this region. Besides the earthquake which had happen in Durres in 2019, according Aliaj et.al 2004, six strong earthquakes affected Albania after 1900 (1905, Shkoder earthquake Ms = 6.6, 1911 Ohrid lake earthquake Ms = 6.7, 1920 Tepelena Ms = 6.4, 1926 Durres earthquake Ms = 6.2, 1967 Diber earthquake Ms = 6.6 and 1979 Montenegro earthquake Ms = 6.9). The region of Durres itself is very frequently exposed to local seismic activity from moderate to strong earthquakes (1237, 1273, 1617, 1852, 1870, 1895, 1896 and 1926). Recently in 2007, the region of Durres was affected by medium size earthquake of Mw 5.0, causing only slight effects (WBGD 2019).

Present seismicity in the western part of Albania is a result of collision between Eurasian and Adriatic plate, part of collision zone with African plate, due to which active compression tectonic processes are spreading from Croatia in the north, up to Greece in the south. Neotectonic investigations presented in Aliaj et al. (2000), underline the existence of a current E–W shortening across external Albanides whereas internal Albanides experience a multidirectional extension with directions varying from E–W to N–S extension (Jouanne et al. 2012). According geological data, region between Durres and Tirana is the site of Neogene thrusting and folding (Xhomo et al. 1999; Handi et al. 2019, 2020). The Albanides are crossed by two transversal fault zones, the Vlora-Elbasani-Dibra and Shkoder-Peja. Up to Shkoder-Peja fault zone Albanides-Helenides are characterized by NNW-SSE structural trend and post Miocene rotation (Jouanne et al. 2012) (Fig. 3).

3 Geotechnical effects and site amplification

The geotechnical effects of soil layers distribution and material composition of the site plays an important role in affecting the amplitude and frequency characteristics of ground motions during seismic events. The problem of spreading and amplification of seismic waves by soil layers stiffness's has been studied often although topographical irregularities (geology) have been given minor importance.

As given in the work of Shehu (1983) the geological map of the Durres region shows that in the greater part of Durres region the local soil conditions are deposits. Figure 4 shows mainly two different soil media which are considered to be of weak soil layer stiffness. Consequently, the amplification of the seismic energy is expected to take part.

On the other hand, Stein and Sevilgen (2019) in their work have also shown the distribution of Vs,30 and expected amplification of shaking considering the soil conditions as given in Fig. 5.

According to Fig. 5 the Durres region has variety of values Vs,30 shown with different colors. The black color defines the regions where the amplification factor is up to four-five times over the shaking experienced at the bedrock which proves the destructing effect of this earthquake. As can be seen from the Fig. 5 the Durres region has spots where the Vs,30 values change abruptly implying the possibility of topographical irregularities such as tilted soil layers. The possible tilted soil layers contribute to the spreading of earthquake energy in both N-S and E-W directions which is in agreement with the impressions of interviewed local people who explained that they have felt the

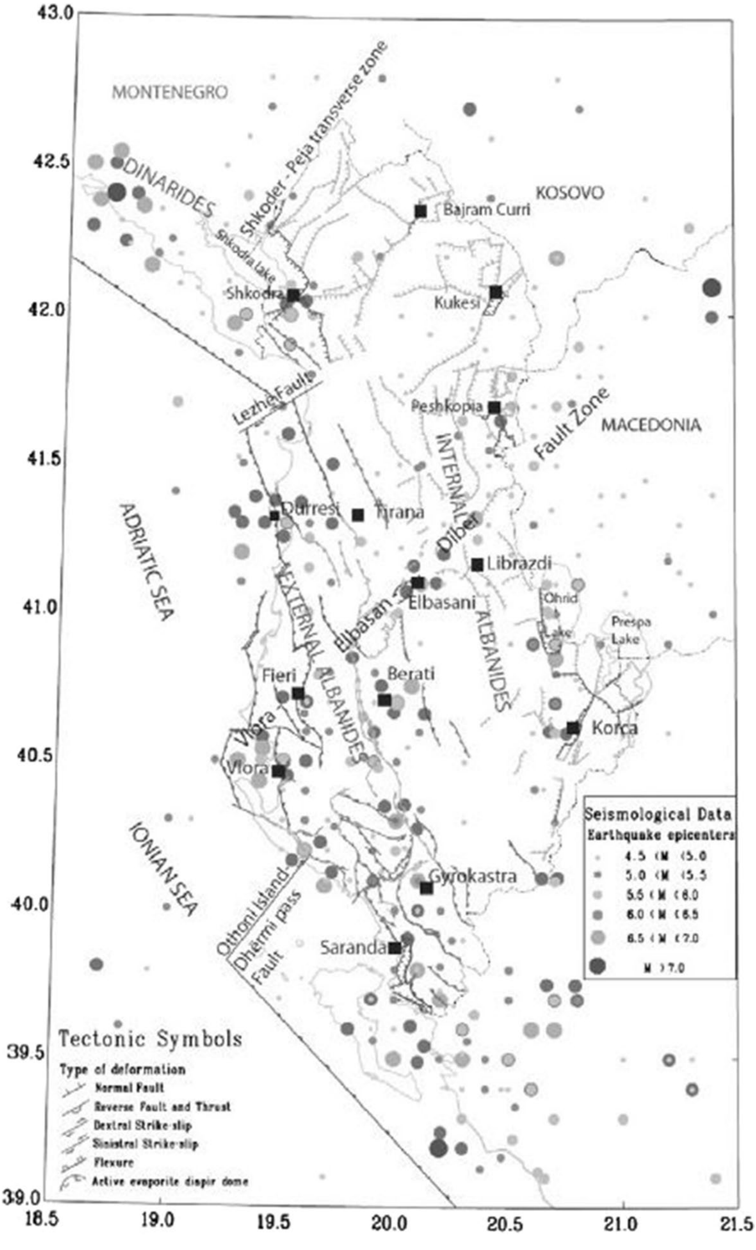

Fig. 3 Neotectonics map of Albania with plio-quaternary faults and folds from Aliaj et al. (2004), with location of historical seismicity redrawn after Aliaj et al. (2004)

shaking firstly in one direction then abruptly in perpendicular directions. The effects of energy spreading in both direction can be also seen in the acceleration records from different stations as given in Table 1 according to the work of Duni (2019).

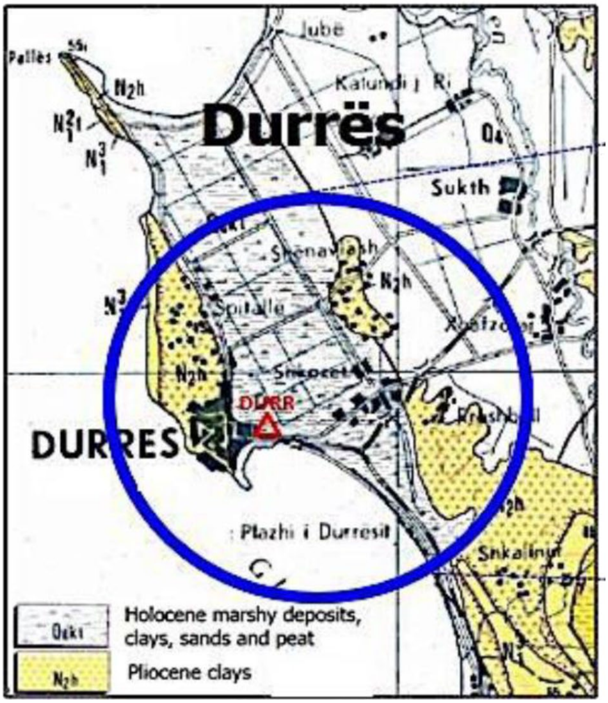

Fig. 4 Geological map of Durres region (Duni and Theodoulidis 2019)

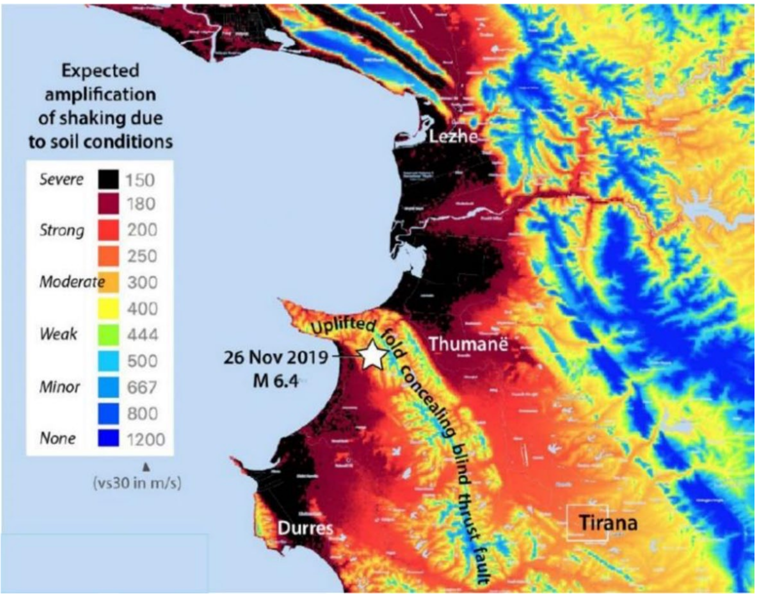

Fig. 5 Effects of soil conditions influencing the amplification of earthquake effects (Stein and Sevilgen 2019)

Table 1 Comparison of recorded acceleration from different stations (Duni and Theodoulidis 2019)

Recording station				November 26, 2019 Event (M6.4)									
Code	Site	Instrument	Vs30 (m/s)	Epic. Dist.(km)	E-W component			N-S component			Z component		
					Pga cm/s2	Pgv cm/s	Pgd cm	Pga cm/s2	Pgv cm/s	Pgd cm	Pga cm/s2	Pgv cm/s	Pgd cm
BERA1	Free field	Guralp: CMG-DM24	1010	93.7	15.10	0.92	0.29	10.65	0.68	0.16	7.91	0.53	0.13
DURR	Free field	Guralp: CMG-DM24	200	15.6	122.3	14.4	4.52	192.0	38.55	14.0	114.5	7.18	4.39
ELBAS	2 story building (with a pillar)	Guralp: CMG-DM24	405	65.8	13.69	0.87	0.22	19.75	1.70	0.44	11.88	0.96	0.23
FIER	2 story build-ing (without pillar)	Guralp: CMG-DM24	375	83.2	17.39	1.50	0.59	17.83	1.20	0.57	8.80	0.74	0.35
KKS	Small 1 story building (wit a pillar)	Guralp: CMG-DM24	740	105	7.87	0.95	0.51	7.87	0.79	0.40	–	–	–
TIR1	Free field	Guralp: CMG-DM24	310	33.7	113.9	7.57	1.80	110.0	6.65	1.77	43.49	2.16	0.73
TPE	2 story building (with a pillar)	Guralp: CMG-DM24	690	128.2	5.36	0.72	0.26	6.28	0.79	0.22	3.88	0.37	0.11

From Table 1, it can be seen that the region of Durres records have both N-S and E-W components of big magnitudes in which the biggest peak ground acceleration values of 122.3 cm/s^2 and 192.0 cm/s^2 have been recorded. Thus, it can be stated that, the local soil conditions have contributed to the effects of earthquake waves to spread to the surface.

Last but not least is the effect of liquefaction which has taken place in water saturated sandy soil regions near the city of Durres.

Figure 6 shows the manifestation of liquefaction effects where the sand blows and eruption of artesian water have accompanied the shaking due to the earthquake. The manifestation is limited to sandy boils having small to moderate effects on settlement of pavements.

4 Methodology for rapid damage assessment

The Rapid Damage Assessment was organized under the umbrella of European Commission's Directorate-General for European Civil Protection and Humanitarian Aid Operations- DG ECHO-UCPM. On the December 2, 2020 IZIIS teams had a meeting with the ECHO Regional Information Officer who presented the goal and the methodology for rapid building damage assessment (Table 2).

Guidelines for defining the level of habitability were explained also (Table 3). Importance of definition of the level of habitability of the high rise building structures with more dwelling units was emphasis.

Presented further is the methodology for rapid assessment (Table 2), the guidelines for definition of the level of habitability (Table 3), definition of damage classification (Table 4) and the guidelines for damage level (Table 5).

5 Performance of the buildings and observed damages

In the period 2–13 December, professionals and experts from the Institute of Earthquake Engineering and Engineering Seismology-IZIIS in three teams with total 15 members, did a rapid assessment of a total of 169 structures most of which were residential and residential-business structures of different structural system and year of construction. At a request, assessment of one RC bridge was also made. The assessed structures are located

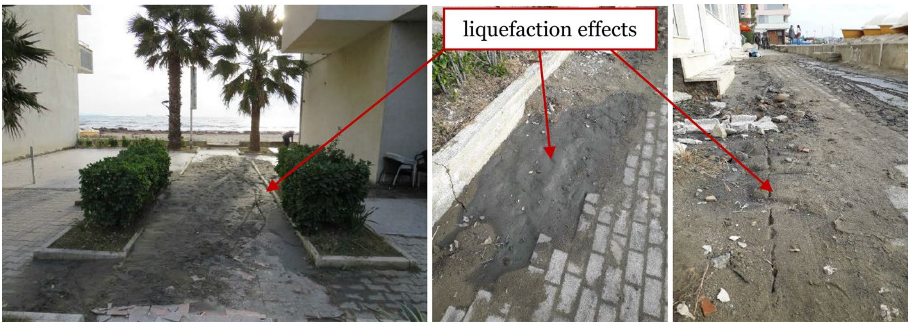

Fig. 6 Manifestation of sandy boils-effects of liquefaction. (*Source*: Newsletter of Environmental, disaster and crises management strategies, Issue nr.15, Nov.2019)

Table 2 Rapid assessment inspection procedure (ATC-20-2)

Examine the entire outside of the structure
Examine the ground and pavement in the general area of the structure for fissures, bulged ground, or signs of slope movement
Enter a building when the structure cannot be viewed sufficiently from the outside and when there is a suspected or reported problem such as non-structural damage (e.g., fallen ceilings or damaged partitions). Do not enter obviously unstable structures
Assess the structure by use of the criteria in Tables 3 and 5. Complete the Rapid Assessment Form. Make sure that exits are clear and usable. Questionable buildings should be given a detailed Assessment. Record any restrictions placed on use of the structure on the Rapid Evaluation form
Post the structure according to the results of the evaluation. Use one of the three placards INSPECTED, RESTRICTED USE or UNSAFE). Indicate on the placard whether the inspection included only the "exterior" or the "exterior and interior" by checking the appropriate box. Post every entrance to a building classified as Restricted Use or Unsafe (except single-family dwelling)
Explain the significance of "Restricted use" or "Unsafe" postings to building occupants, if they are available. Advise them to leave unsafe buildings immediately, but do not create panic. Unsafe areas must be also evacuated

Table 3 Guidelines for defining the level of habitability (Provided by UPCM)

Visual signs of damage	
Habitable	Slight cracks in render (plaster) of the wall and/or ceiling mortar
	Slight cracks in walls (load bearing and/or non-load bearing) with slight separation between load-bearing and non-load bearing elements
	Hairline, non-diagonal cracks in horizontal RC structural beams
	Hairline cracks in load-bearing masonry walls where the cracking covers less than 30% of the wall area
Uninhabitable	Total or partial collapse of a building
	Major damage and deformation, deviation from the vertical of the load-bearing structure
	Severe damage to the beam-column joints
	The load-bearing elements show any deformation
	Significant cracks (> 2 mm) in load-bearing elements constructed of reinforced concrete
	Significant cracks (> 2 mm) in load-bearing walls
	Hairline cracks in load-bearing masonry walls where the cracking covers more than 30% of the wall area
	Diagonal cracking or crumbling of the material in the walls between the windows or doors or similar elements of construction
	Damage or collapse, or significant distortion of the roof
	Slight damage, partial or complete sliding of roof
	Detachment of large pieces of plaster on walls and ceilings (sufficient to cause harm)
	Damage or partial failure of chimneys, parapets
	Non-load bearing walls: large diagonal cracks, collapse of infill walls and major separation between infill walls and structural elements

in the territory of Durres and Shijak. The members of Team 1 realized onsite training of two teams from the Civil Engineering Faculty consists of 6 post-graduate students and two local engineers. Within this context, inspections of structures damaged by the earthquake

Table 4 Guidelines for defining the level of damage

Damage level	Description
Light damage (D1)	This damage grade does not affect significantly the capacity of the structure and does not jeopardize the occupants safety due to falling of non-structural elements; the damage is light even when the falling of objects can rapidly be avoided
Medium-severe damage (D2-D3)	This damage grade could change significantly the capacity of the structure, without getting close to the limit of partial collapse of the main structural components
Very heavy (D4-D5)	This damage grade significantly modifies the capacity of the structure, bringing it close to the limit of partial or total collapse of the main structural components. This grade is characterized by damages heavier than the previous ones, including the total collapse

in the central area of Durres were carried out in the form of field educational laboratory. Team 2 performed rapid assessment of the structures in Durres (Fig. 7) while Team 3 performed rapid assessment of a total of structures within Shijak municipality and Shijak region (Fig. 8).

Out of the total number of inspected structures (169), 70% are residential structures, 23% are residential-business structures, 5% are public institutions buildings, and 1% are engineering and business buildings structures (Fig. 9).

According to structural system, the most numerous 41% structures have combined system (masonry + RC, local nonstandard practice) (Fig. 10 a), then follow reinforced concrete structures (Fig. 10b) (28%), masonry structures (Fig. 10c) are 16%, reinforced concrete flat slab structures (Fig. 10d) are 12% and irregular structures (3% of the total number of inspected structures) (Fig. 11).

Regarding the year of construction, most of the structures, 64% of the total number of inspected structures were built prior to 2000, meaning they are over 20 years old, while the remaining ones, namely 36% of the structures were built after 2000 (Fig. 12).

According to the damage grades (Table 5), it can be concluded that from the total number of structures, 10% of the inspected structures are characterized by slight nonstructural damage (grade 1), 35% of the inspected structures have moderate damage to nonstructural elements (grade 2), 50% of the inspected structures suffered major nonstructural damage and slight structural damage (grade 3) while 58% of the structures suffered major repairable structural damage (grade 4). Almost 16% of the total number of inspected structures suffered major structural damage (grade 5) and are anticipated to be demolished (Fig. 13).

5.1 Damage to public buildings

Discussions on the observed damages to the public buildings in this paper is mainly focused on schools. From total number of inspected structures, 5% are public institution structures—schools (Fig. 10) and they are mainly located in the Shijak region. The predominant structural system of school buildings is traditional masonry with rare presence of RC horizontal and vertical RC elements and height of ground floor plus one storey.

It was observed that for confined masonry structures (masonry + RC horizontal and/or vertical elements)—major damage occurred to the bearing masonry walls (separation of

Table 5 Guidelines for classification of damages (Grüntal 1998)

Light damage	Medium-severe damage		Very heavy damage	
DS1	DS2	DS3	DS4	DS5
Grade 1: Negligible to slight damage *(no structural damage, slight non-structural damage)*	Grade 2: Moderate damage *(slight structural damage, moderate non-structural damage)*	Grade 3: Substantial to heavy damage *(moderate structural damage, heavy non-structural damage)*	Grade 4: Very heavy damage *(heavy structural damage, very heavy non-structural damage)*	Grade 5: Destruction *(very heavy structural damage)*
Fine cracks in plaster over frame members or in walls at the base	Cracks in columns and beams of frames and in structural walls	Cracks in columns and beam – column joints of frames at the base and at joints of coupled walls	Large cracks in structural elements with compression failure of concrete and fracture of rebars: bond failure of beam reinforced bars: tilting of columns	
Fine cracks in partitions and infills	Cracks in partition and infill walls: fall of brittle cladding and plaster	Spalling of concrete cover, buckling of reinforced rods	Collapse of a few columns or of a single upper floor	Collapse of ground floor or parts (e.g. wings) of buildings
	Falling mortar from the joints of wall panels	Large cracks in partition and infill walls, failure of individual infill panels		

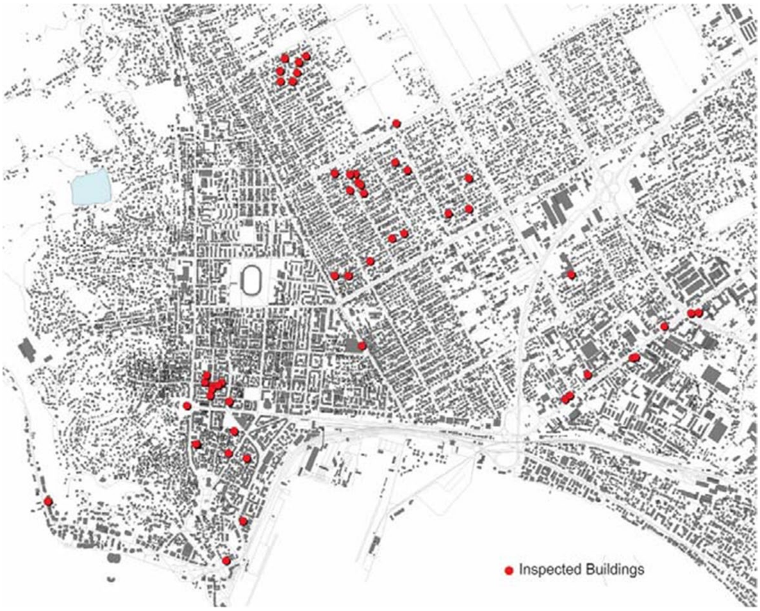

Fig. 7 Location of structures inspected by Team 2

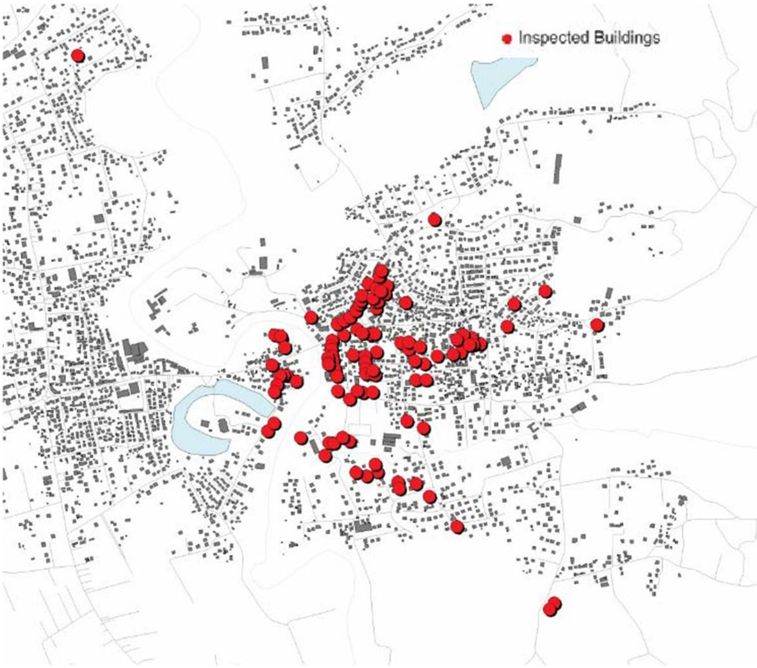

Fig. 8 Location of structures inspected by Team 3 (Shijak region)

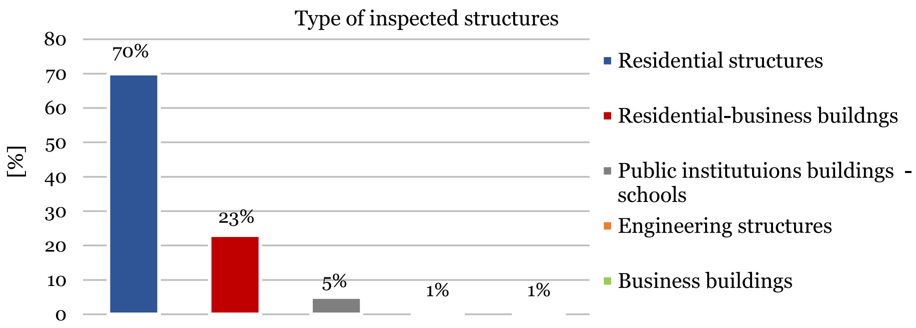

Fig. 9 Review of structures according to category of use

Fig. 10 Different structural systems in Durres and Shijak region

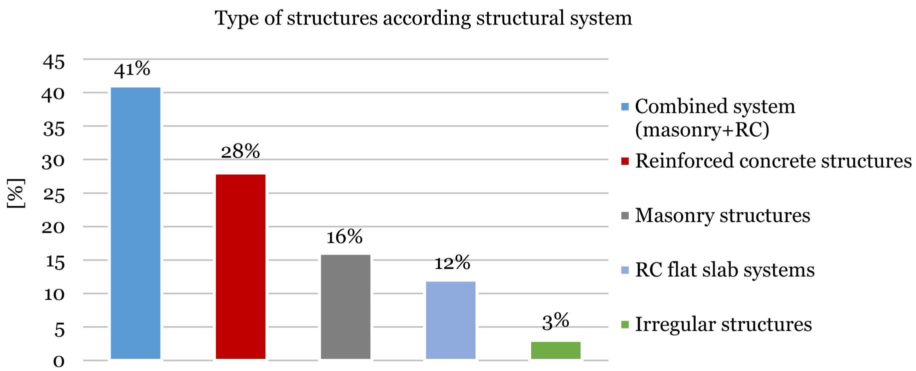

Fig. 11 Review of structures according to structural system

walls, diagonal cracks etc.), and extensive damage to the RC beams (Fig. 14). These buildings were not able to be used immediately and must be retrofitted (Figs. 15 and 16).

30% of the inspected school buildings suffered major structural damage therefore it is necessary to anticipate solutions for their repair and strengthening for the purpose of providing them with the necessary safety and stability and making them functional as soon as possible.

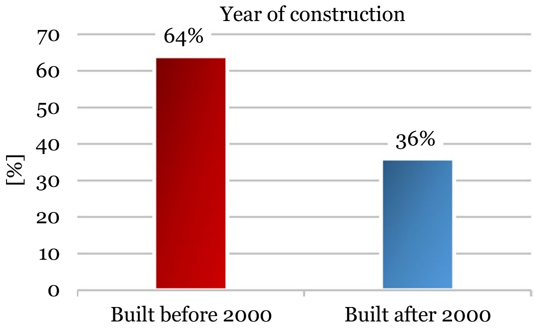

Fig. 12 Review of structures according to year of construction

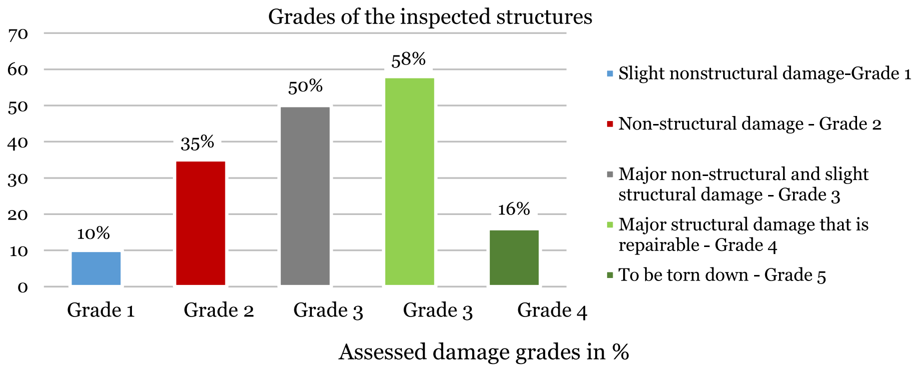

Fig. 13 Assessed damage grades in %

Fig. 14 Damages in school building GF + 1 (combined system of solid brick masonry and RC elements): **a** separation of orthogonal walls; **b** shear damage in facade wall with diagonal cracks

5.2 Damage to residential buildings

More than 20 residential building structures higher than 5 storeys were inspected. From total number of inspected structures, 70% are residential buildings (Fig. 10). These were mainly reinforced concrete structures (Figs. 17, 18, 19, 20, 21, 22, 23).

The observed nonstructural damages were expected for such structural systems and earthquake intensity (Figs. 17, 18 19). Some of the reinforced concrete residential structures suffered slight structural damages (Figs. 20, 21 22), but in some irregular

Fig. 15 Damages in school building GF + 1 (combined system of solid brick masonry and RC elements): **a** diagonal cracks between the windows; **b** cracks in the beam supporting area

Fig. 16 Damages in school building GF + 1 (solid brick masonry system)-diagonal cracks in brick walls. **a** facade wall; **b** infill wall

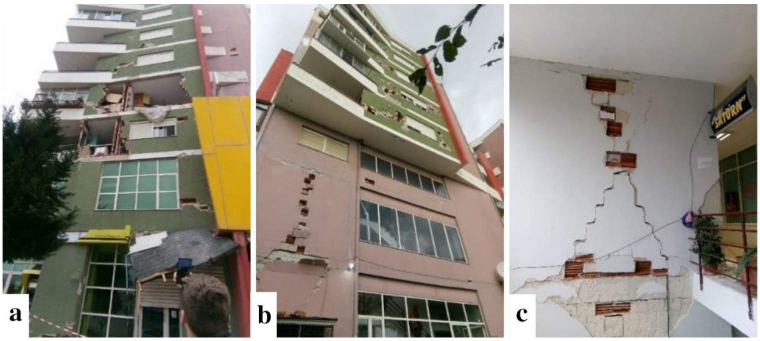

Fig. 17 Structures with major non-structural damage (Grade 3). **a** Failure in the front façade due to absence of belt courses; **b** damage of the rear façade in all levels; **c** shear damage emphasized with the diagonal cracks in infill wall on first floor

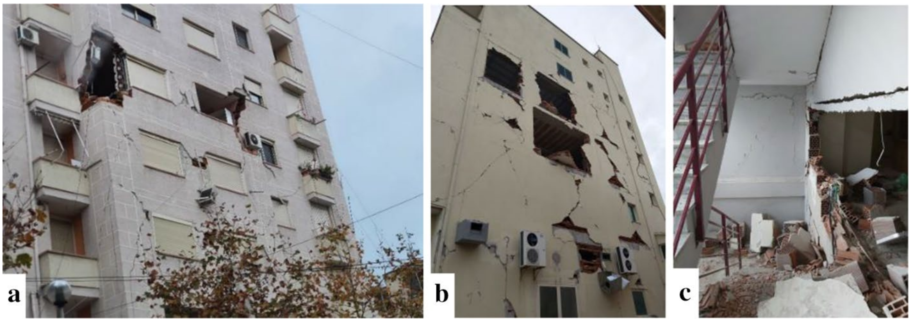

Fig. 18 Residential buildings in Durres (Grade 3). **a** Slight diagonal cracks and failure in the external facade; **b** Severe diagonal cracks and partial failure in the external facade wall; **c** failure in infill walls

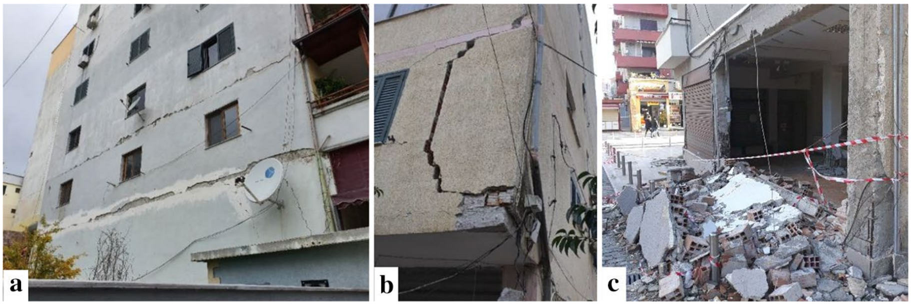

Fig. 19 Residential RC building with non-structural damage to the external façade (Grade 3). **a** horizontal cracks in facade; **b** cracks in cantilever part; **c** facade failure

Fig. 20 Residential RC building with severe non-structural and slight structural damages (Grade 3). a Diagonal cracks in infill walls **b** destroyed cover layer in beam **c** damage in colums

structures were observed severe damages (Figs. 21, 22). There were structures that were collapsed (Fig. 23).

In masonry buildings prevailed damages are in the form of diagonal cracks in the bearing walls, while in RC buildings diagonal cracks and separation of the infill walls from the bearing structural system, diagonal cracks due to shear and/or axial forces in RC columns, crushing of concrete in (asymmetric) RC joints, spalling of the protective layer of concrete, extensive damage (cracks) to nonstructural facade walls and alike

Fig. 21 Damaged bridge between two buildings located on the higher level (Grade 4). Warm connection of bridge between two buildings with undefined dynamic response

Fig. 22 Collision between two adjacent buildings (Grade 4). Expansion joint with small width

were observed. In few structures, extensive damage to the facade walls resting on cantilevers was noticed (Figs. 19b, 20c).

5.3 Damage to individual houses

During the examination activities, Teams 2 and 3 have inspected total number of 118 residential building, which means 70% of all structures (Fig. 10). In the Durres territory, the most of residential buildings were reinforced concrete and flat slab reinforced-concrete structures, while in the Shijak territory, confined masonry was predominant system. Most of the structures were built after 2000 by the owners themselves. The majority of them were assessed with the grade 2, which means that the

Fig. 23 Residential structures in the phase of construction that collapsed under the effect of the earthquake (Grade 5). Flat slab system where tiles and stirrups are with small diameter and stirrups located in long distance

Fig. 24 Individual house GF + 1 with major structural and non-structural damage due to lower quality of concrete, unsafe for habitation (Grade 5). **a** Plastic hinge in lower part of column; **b** separation of the stair structure

structures suffered non-structural damages predominantly in nonstructural partition walls. However, there were also inspected structures with the major structural damages and they suffered the most severe damage (Figs. 24, 25, 26). One of the main reasons for occurred structural damages is low concrete quality. It is noticed that the stirrups are with low diameter and are placed at a large distance.

Fig. 25 Individual house GF + 2 with plastic hinges in upper part of columns due to low quality concrete and stirupps with small diameter

Fig. 26 Individual house GF + 1. **a** Plastic hinges in lower part of facade column and failured facade wall **b** plastic hinge in middle column and separation of structural with non-structural elements

6 Observation from inspection

The Institute of Earthquake Engineering and Engineering Seismology (IZIIS) teams visited the mostly most affected seismic region of Durres and Shijak, inspecting the residential, individual houses as well as public buildings. The Rapid Damage Assessment organized by the European Commission's Directorate-General for European Civil Protection and Humanitarian Aid Operations- DG ECHO-UCPM showed that on the teritory if Durres, 12% of the structures suffered slight non-structural damage (Grade 1). 30% of the structures account for those with moderate damage to nonstructural elements. However, each third structure suffered major nonstructural damage with negligible structural damages most frequently in the form of hairline cracks in the columns. Almost 20% of the structures

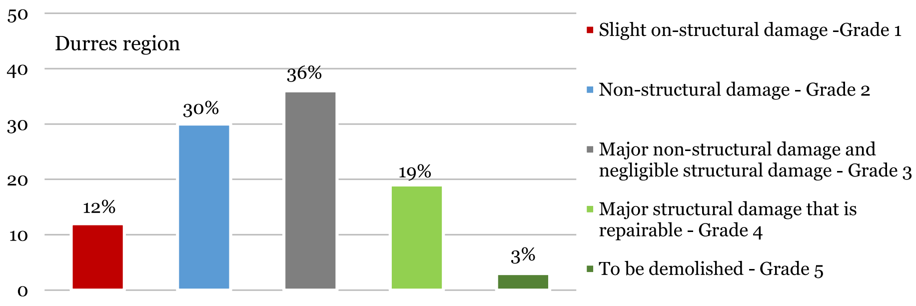

Fig. 27 Review of grades assigned to damaged structures in Durres region (Sesov 2019)

suffered major structural damage that was mainly concentrated in the columns and 3% of the total number of inspected structures were assigned grade 5, meaning that they have to be torn down (Fig. 27).

On the teritory of Shijak, 3% of the inspected structures are characterized by slight nonstructural damage (grade 1). 15% of the inspected structures have moderate damage to nonstructural elements (grade 2). 26% of the inspected structures suffered major nonstructural damage and slight structural damage (grade 3) while 43% of the structures suffered major repairable structural damage (grade 4). Almost 13% of the total number of inspected structures suffered major structural damage (grade 5) and are anticipated to be torn down (Fig. 28).

From the realized mission for rapid assessment of damages to structures, it can generally be stated that there are several reasons for occurred damages as inconsistent application of recent knowledge in design, construction and control of earthquake resistant structures, structural errors in design and construction as well as inappropriate quality of built-in materials. The reasons for observed damages can be systematized as follows:

1. In the design and construction of most residential structures that were subject of assessment, the general principles of design of seismically resistant structures in compliance with modern seismic regulations were not consistently applied;
2. Inappropriate and unprofessionally finished expansion joints;
3. In many structures, it was observed that the built-in concrete was of a lower quality;

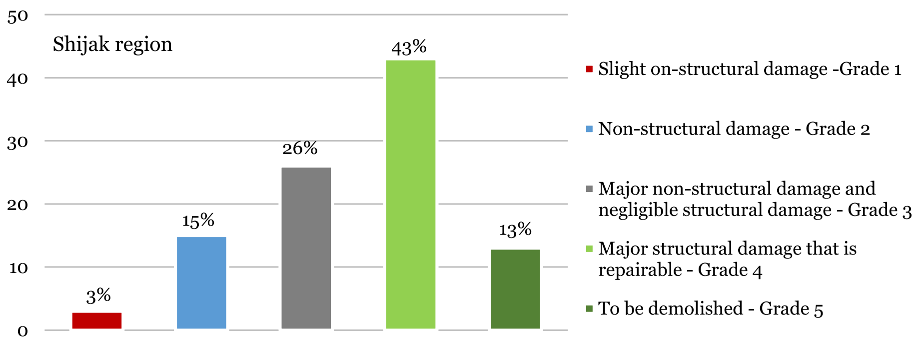

Fig. 28 Review of grades assigned to damaged structures in Shijak region (Sesov 2019)

4. Flexible flat slab or partial beam system structure are built in most prone region;
5. In most of the structures, corrosion of longitudinal and transverse reinforcement of the columns was observed despite that the protective layers of the elements were not damaged or fallen off prior to the earthquake;
6. In most of the structures with short columns in ground floor, severe structural damages are occurred in that columns;
7. In one of residential building (Fig. 17), there are built additional storeys (+4) on the designed GF+3 structure;
8. Plastic hinges in columns as a consequence of low quality concrete and inappropriate dimensions and distance between stirrups (Figs. 24, 25, 26).

7 Conclusion

Albania is one of the European countries with the highest seismic hazard, not only because it is located on the border between the Eurasian and Adriatic tectonic plates, but it is also the collision zone between these two plates with the African plate. In the early morning hours of November 26 2019, Albania was hit by a strong earthquake magnitude 6.4 with the epicenter in the western part of the country, at 30 km from capital city Tirana, near the city of Durres. This was the strongest earthquake in Albania in the last 40 years, which caused the deaths as well as significant economic losses. Consequences of this earthquake, such as the types and degree of construction damage facilities, as well as activities after the earthquake in Durres and Shijak regions are highlighted in this paper.

From the realized mission for rapid assessment of damages to structures, it can be concluded that the incurred damages to structures are the result of inconsistent application of recent knowledge in design, construction and control of earthquake resistant structures. Structural errors in design and construction as well as inappropriate quality of built-in materials have been observed. 19% of the structures in the territory of Durres municipality are classified as structures that have suffered considerable structural damage, while 3% of the structures are anticipated to be demolished. The situation is even more complicated in the territory of Shijak municipality, where 43% of the structures are classified as structures that have suffered major structural damage, while 13% of the structures are anticipated to be demolished.

Such results from the rapid assessment point to the necessity of taking specific measures for detailed inspection of critical structures, definition of corresponding technical solutions for their repair and strengthening and placing them into operation again.

This earthquake confirmed the importance of having an earthquake response strategy at the state and local levels, as well as effectively informed public about behavior during and after earthquake. It is also necessary that there are regulations in this regard rehabilitation and seismic strengthening of buildings due to earthquakes, which are based on modern methodology that defines the principles of rehabilitation of buildings after an earthquake. It is very important to develop and adopt a methodology for inspecting the damaged buildings before the earthquake and to train the engineers who should perform the inspection. It is also very significant that such a methodology is consistently applied at all locations.

Limiting flexibility or relative floor movements is the main solution problems. This problem in RC structures can be eliminated by confining the walls with installing the RC belt beams in facade and infill walls or by increasing the dimensions of sections of columns and beams, which reduces the flexibility of the entire structure. In some cases, this concept has been applied to the strengthening of existing building structures which did not suffer significant damage in this earthquake. Albanian regulation, although required analysis of "real" earthquake displacements, there are not clearly defined limitations for interstory drifts, which certainly contributed to the adoption of a fairly flexible frame structure with “shallow beams”, sensitive on stiffness changes.

Having in mind all activities realized on field it can be emphasized that severe damages were observed on modern buildings, as a consequence of untimely identification of gaps and possible areas of development of the current seismic design code. The 26th November earthquake underlined the deadly connection between the ineffective law enforcement in the construction process and the high seismic vulnerability due to the presence of unauthorized structural interventions leading to economical and human loss.

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