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Albania 2019 Earthquake: Building damage assessment

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Abstract

In autumn 2019 North-Western Albania was struck by series of earthquakes: the first major occurred on September 22nd (M5.6) and the second on November 26th (M6.4). After the second earthquake with more than 50 fatalities the EU Civil Protection Mechanism was activated at the request of the Albanian authorities. Immediately after mobilizing urban search and rescue teams (USAR) an EU Civil Protection Team (EUCPT) was deployed to help the authorities to coordinate the response (including logistic, in-kind help, humanitarian needs, etc.) and to assist in the damage assessment. For this purpose EUCPT and UNDAC (United Nations Disaster Assessment and Coordination) established Damage Assessment and Coordination Cell (DACC) which – among others – assisted local authorities in field operations in terms of coordination of assessment, registration / introduction of international experts and in compiling coherent credible daily assessment reports. Administration of the Republic of Slovenia for Civil Protection and disaster relief (URSZR) nominated the authors of presented paper to help coordinate international assistance in the aftermath of the earthquake. As members of EUCP Team Bravo they participated mainly as support to the local teams in on-site damage assessment. This paper points out the general aspects of EU Civil Protection Mechanism, its role/tasks and pros/cons of used assessment procedures and work in international assessment teams. The main aim of the paper is presentation of typical structural damage patterns observed in urban and rural areas of Durrës County.

Key words: Earthquake, Albania, 2019, Damage Assessment, EU Civil Protection.

1 Introduction

The Balkan - Adriatic region is one of the most prone earthquakes in Europe [1]. The Eurasian plate encompasses much of Europe's and Asia's mainland and moves with respect to the main neighbouring plates in the South (African plate), Southeast (Anatolian microplate), and West (North-America plate). A number of microplates between Europe and Africa add to the complexity of tectonics around the Mediterranean Sea including the Alpine region. Consequently earthquakes in this area do not occur only along well-defined zones but might affect also large areas.
Literature overview confirms intensive seismic activity in Balkan region (Slovenia, Croatia, Bosnia and Herzegovina, Montenegro, Albania, Serbia, Romania, Bulgaria, North Macedonia and Greece) and nearby Apennine Peninsula. Although general public is aware about the consequences of catastrophic 2009 L'Aquila earthquake not everyone is apprised with similar events in this province in years 1349, 1703 (5000 fatalities), 1915 (30.000 fatalities) and in 1958 [3].
Although information about the seismic activities from 18th centuries and back might not be as accurate as records from past decades the literature [2, 3] presents concerning information about earthquakes in Balkan region: 1677 - Dubrovnik, Croatia (M7.2, 5000 fatalities), 1963 - Skopje, North Macedonia, (M6.1, 1070 fatalities), 1979 Bar, Montenegro (M6.9, 129 fatalities) and many others. Furthermore the sum of numbers representing the effects of earthquakes in Balkan area emphasises the relevance of this events: in period from 1905 to 2010 62 deadly earthquakes occurred where more than 5000 people lost their life. More than 2 million people were directly affected and substantial damage is estimated to more than 10,000 million US dollars [2]. Estimations given are based on OFDA/CRED International Disaster Database [3] and United States Geological Survey [4], although the numbers from different sources might vary a lot [8].

Location	Date / Year	Fatalities	Affected	M
Durrës	1267, 1273	Many	City in ruins	-
Vlorë, Berat	Oct 1851	600+	-	-
Narta, Vlorë, Kanina	2.1.1866	60	-	-
Shkodër	1.6.1905	120+	-	6.6
Tepelenë, Gjirokastër	26.11.1920	200	-	6.4
Vlorë	Nov. / Dec. 1930	60	-	6.0
Dibër	27.9.1942	43	-	6.0
Shupenzë	30.11.1967	11	134	-
Bar / Kotor (MNE)	15.04.79 / 24.5.79	35 / 0	350 / -	6.9
Lushnjë	16.11.1982	1	5005	5.6
Tirana	9.1.1988	0	690	5.4
Kukës	20.9.1998	0	2100	-
Peshkopia	7.9.2009	0	150	-

Figure 1. Left: Seismic Hazard in Balkan Peninsula [1]. Right: List of earthquakes in Albania [2,5,8]

2 Albania 2019 earthquake

On September 21st 2019 2:04 PM Albania was hit by an earthquake with magnitude M5.6 (41.338° N 19.530° E). More than 500 buildings were damaged but there were no fatalities (110 injured). The earthquake was classified as the strongest earthquake to hit Albania in more than 30 years with epicentre 3 km WSW of Shijak, estimated depth was 10 km. Estimated earthquake intensity according to Modified Mercalli Intensity Scale (MMI) was VII (very strong) with Peak Ground Acceleration (PGA) up to 0.2g and Peak Ground Velocity (PGV) 10 cm/s [6]. Presented event was most likely only foreshock of main earthquake which occurred in November, significantly contributed to the damage on built environment.

On November 26th 2019 2:54 AM main earthquake event with magnitude M6.4 occurred with epicentre 15 km WSW of Mamurras (1.514° N 19.526° E), in 22.0 km depth (Figure 2). Event lasted at least 50 seconds, its effects were felt almost 400 km away (Belgrade, Serbia). Estimated earthquake intensity according to MMI was VIII (severe) with PGA up to 0.5g and PGV 43 cm/s (Figure 3). Earthquake is characterized as strongest in Albania in last 40 years, deadliest in 99 years and the world's deadliest earthquake in 2019 [5]. The worst affected municipalities were Shijak, Durrës, Krujë, Tirana, Kamëz, Kavajë, Kurbin and Lezhë, representing 38 % of total population in the country (Figure 2). It is estimated that 38,000 residents were exposed to intensity MMI VIII and 580,000 to MMI VII [8]. The characteristics of earthquake combined with the soft soils around the Durrës bay and surrounding areas resulted in significant effects on built environment including complete collapse of structures and in permanent geotechnical deformations.

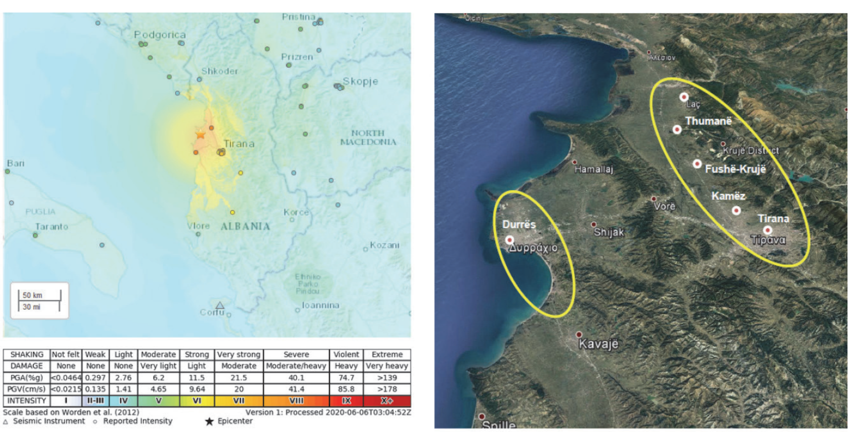

Figure 2. Left: Macroseismic intensity image [4]. Right: Worst affected areas [9]

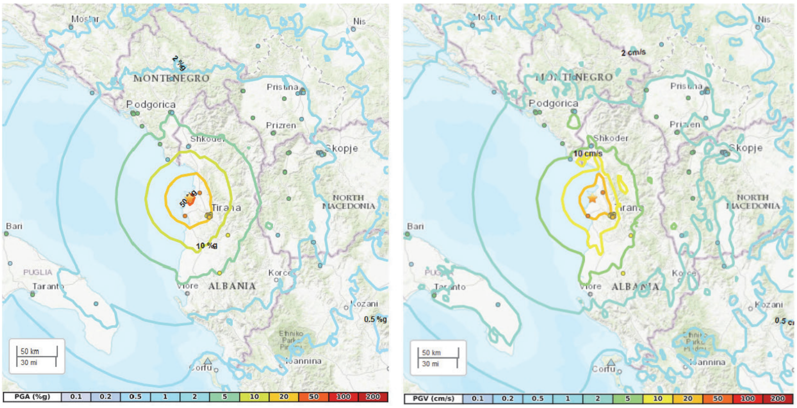

Figure 3. Left: Peak Ground Acceleration [4]. Right: Peak Ground Velocity (right) [4]

By December 1st 2019 there was more than 1,300 recorded aftershocks and 33 with the magnitude more than 4.0 (till January 1st, 2020). Immediately after event the search and rescue operations began. Sadly the earthquake claimed the life of 51 people, number of injured varies from 750 to 3000. State of emergency was declared for the Durrës and Tirana prefecture. Firefighters, civil protection, medical emergency personnel, the armed forces and state reserves were immediately deployed. Due to the extent of damage and as the last severe earthquake in Albania was in 1979, the complete response system lacked expertise. Therefore the Government of Albania requested international assistance on November 26th and activated the European Civil Protection Mechanism.

3 European Civil Protection Mechanism and damage assessment

European Civil Protection Mechanism (the Mechanism) assures an assistance of governmental aid (in-kind assistance, deployment of specially-equipped teams, or experts assessing and coordinating support) delivered in preparation for or immediate aftermath of a disaster in Europe and worldwide. The Mechanism primarily protects people, but also the environment and property. The Emergency Response Coordination Centre (ERCC) as part of the Mechanism operates within the European Commission Directorate-General for European Civil Protection and Humanitarian Aid Operation (ECHO), and acts as a coordination hub to facilitate quick well-coordinated and effective response to natural and man-made hazards / disasters. The Mechanism brings together resources from all EU Member States and Participating States (Iceland, Norway, Serbia, North Macedonia, Montenegro, and Turkey) ready for deployment to a disaster zone at short notice. Following a request for assistance through the Mechanism, the ERCC mobilises assistance or expertise. The ERCC monitors events around the globe 24/7 and ensures rapid deployment of emergency support through a direct link with national civil protection authorities. Since 2001, the Mechanism has been activated more than 420 times to respond to emergencies in and outside the EU.

EU Member States and Participating States may commit national resources for emergency response to the European Civil Protection Pool (ECPP). More than 150 Civil Protection (CP) modules and 12 Technical assistance and support teams (TAST) are currently registered. For search and rescue operations 30 Medium Urban Search and Rescue (MUSAR) and 12 Heavy Urban Search and Rescue (HUSAR) teams are available.
Following the activation of the EU Civil Protection Mechanism at the request of Albania, the ERCC coordinated the deployment of 1 medium urban search and rescue team from Greece and 2 certified search and rescue teams from Italy and Romania that form part of the ECPP (Figure 4). Additionally, the EU's Copernicus emergency satellite mapping service produced satellite images of the affected zones to evaluate the intensity and scope of the damage resulting from the earthquake. On the bilateral basis neighbouring and nearby countries also participated in search and rescue operations and in related activities (medical assistance, delivering / building shelters, etc.).

Figure 4. USAR search and rescue operations on six story reinforced concrete building in Durrës built in 1996: Before and after earthquake [10]

On November 29th all missing persons were found – from 22 only two were found alive. On that day MUSAR teams ended their mission. Due to the damage extend two days earlier on November 27th the Government of Albania requested also for international help in damage assessment.
Following a request for assistance, an initial EU Civil Protection (EUCP) Alpha team was deployed to Albania. The main priorities of EUCPT were: 1.) To coordinate the orderly delivery of incoming in-kind assistance, 2.) To transfer the initial USAR Coordination Cell (UCC) into a Damage Assessment Coordination Cell (DACC), 3.) To moderate the DACC daily operations and to ensure its handover to the national authorities, 4.) To liaise and cooperate with the national / local authorities and 5.) To assess humanitarian needs through the United Nations Disaster Assessment and Coordination (UNDAC) associated colleagues [11]. EUCPT consisted of team leader, its deputy, ERCC liaison officers, technical assistance and support experts, structural engineers, local emergency management representatives and associated UNDAC representatives. There was a EUCPT

rotation on December 4th (Bravo team) in which the authors of this paper participated as structural engineers, mainly as part of the daily field operations support in Durrës area. This enabled to mirror their experiences together with observations back into the EUCPT and the DACC which emerged as very important source of information about actual activities on site.

In general the main task of structural engineers in the EUCPT was training/briefing international engineering teams arriving in Albania. Besides sharing information about the current situation in country a peer briefing was focused on the assessment approach: international engineers were always deployed in pairs as a support to home damage assessment teams helping in assessing the severity of damage (level of damage), habitability and safety recommendations and restrictions. Support of foreign experts also had a strategic role in terms of a psychology - fostering the reputation of domestic engineers. The level of trust of inhabitants regarding the work of domestic assessments teams was in general low. All together 185 structural engineers from 18 countries (Bulgaria, Croatia, Cyprus, Czech Republic, France, Greece, Hungary, Israel, Italy, Kosovo, N. Macedonia, Poland, Romania, Slovenia, Switzerland, Turkey, UK and USA) were involved in damage assessment.

The assessment process in the beginning struggled of non-consistency in information, figures / numbers, assessment criteria and not unified work of the assessment teams, but was continuously improved. From September earthquake it was noticed that each Municipality or Prefecture used a different Inspection form, resulting - together with different assessment approaches - in miscommunication issues throughout different data collection. In general all structures were classified depending on their damage level into green, yellow and red; green meaning lightly damaged, red medium damaged and red heavily damaged. However most of the assessments were based on six steps rapid assessment approach using five grade scale (Figure 5). Furthermore the inspection forms also covered whether or not the building was habitable, safety recommendations and restrictions. The sum of assessment results foreign experts should report to DACC daily, but this did not always prove to be the case. In the last two weeks of the assessment the forms were filled in electronically using online forms. This did not prove to be advantage for local commissions since paper forms had to be filled in anyway due to legal requirements.

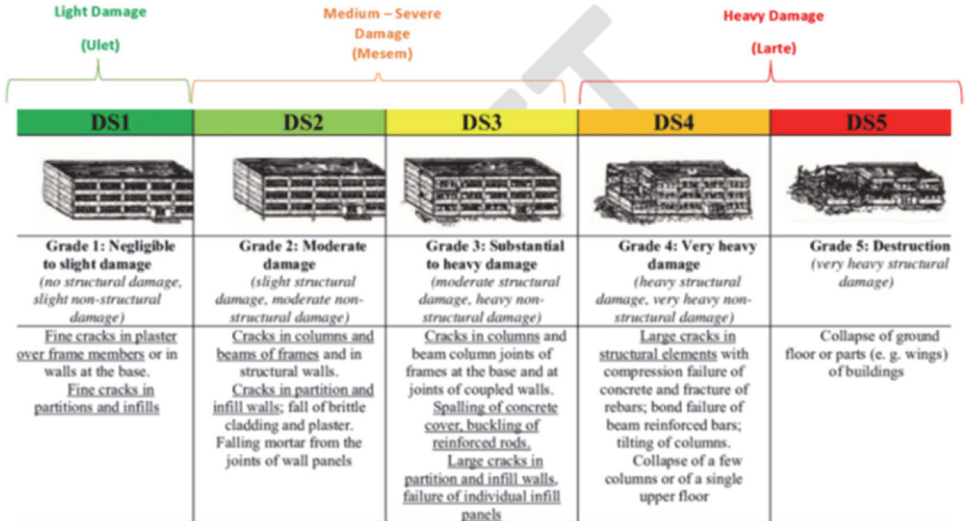

Figure 5. General criteria for the assessment [11]

Consequently the statistics of assessments in which international experts participated is not as accurate as it could be: 199 buildings (8 %) did not suffer structural damage, 988 (42 %) light, 667 (28 %) medium and 532 (22 %) heavy damage. This presents a relatively small portion of total number of damaged / destroyed buildings (ca. 14,000). On December 20th the EUCPT Bravo hand over all DACC activities to local authorities.
Important lesson learned - from the structural engineer point of view - is that the damage assessment procedures could be improved. Unified and well prepared assessment approach - taking into consideration legal boundaries - with detailed briefing of not only foreign experts but also local assessment teams is crucial for obtaining realistic overview about the damage extent in future similar events.

4 Typical damage patterns

Predominant structural types in the urban area of Durrës are unreinforced masonry structures, structural masonry with reinforced concrete elements and slabs and reinforced concrete (RC) frames with infills (after 1995) and more rare RC wall structures. Mixed types are also used (Figure 5). Buildings usually do not exceed 6 - 8 floors (10 for modern RC frames). Ground floor unreinforced masonry structures present typical traditional one family dwelling in rural areas. Later structures in rural areas up to two storeys are based on kind of a light RC frame with infill (Figure 5). In general quality of materials, construction work, detailing and especially maintenance are rather poor. Unauthorised structural interventions or incremental construction (Figure 7a) ending up with additional floors in ensuing years without proper documentation / permits is quite widespread and as reported by media also the main reason for collapse of com-

plete structures (hotels in the Durrës coast). Settlements (ground displacements) as consequence of soil liquefaction, relatively strong vertical component of the earthquake ground motion and consequences of September 21st earthquake additionally amplified the structural damage in Durrës (costal) area.
Structures are or should be designed and constructed according to the Albanian Technical Codes (KTP) which were first issued in 1963 and continuously updated (1978 and 1989). KTP were not always taken into consideration [9]. Use of Eurocodes in Albania is currently not mandatory. Regarding the earthquake load the KTP requirements do not meet the Eurocode defined loads [7].

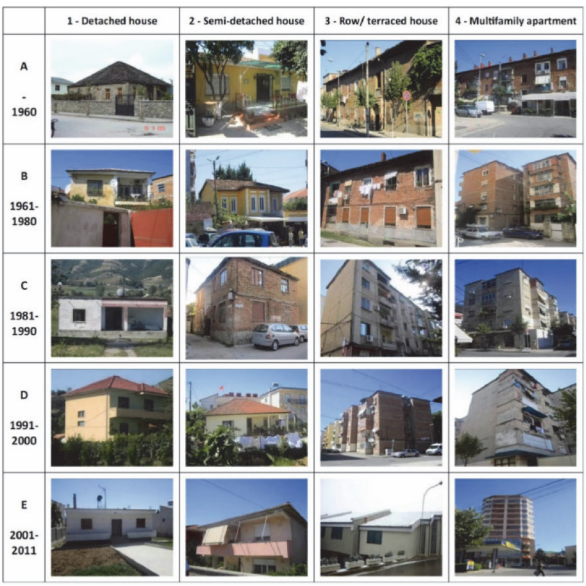

Figure 6. Typical urban and rural building types in Albania [12]

In Durrës unreinforced masonry (URM) structures with various types of concrete slabs performed in general well, but in other areas (Thumanë) - where flexibility limits of structures were exceeded - complete or partial collapses occurred, also due to poor connection between walls and floors, non-authorized interventions and poor materials / construction / maintenance (Figure 6a). As shear force increases shear stress develops in walls which leads to cracking, commonly observed near the openings (cracking of pears) (Figure 6b). Out of the plain cracks / failures also occur when connection between walls and slabs is poor. Similar reason is the cause for corner failures if connection between walls is in question (Figure 6c). Regardless the general performance of URM in Durrës, the vulnerability of unreinforced unconfined masonry structures, built according to Albanian authorities standardised design templates, has to be highlighted due to their brittle non-ductile behaviour. Poor performance is critical in cases where used hollow strap slabs are not properly connected into a rigid diaphragm.

Figure 7. URM structures: a.) Heavily damaged URM [9]. b.) Pier cracks. c.) Corner failure

The most common damage pattern observed with RC frame structures were in-plane shear diagonal (X) cracks in infill, partial or full out of the plane failures of insufficiently confined / aligned infill (internal, external - facades / cantilevers) and cracks in stair legs. Hollow clay tiles are most commonly used as infill. RC frame structures suffered main damage in lower storeys (up to 4), damage in storeys above was minimal (Figures 7b and 7c). This is related to the characteristic of earthquake (long duration, large period), to soil characteristics, to undesired resonance phenomena and mainly to the flexibility of structures: usually no RC walls are incorporated in structures - the elevator shafts and stair case walls are as a rule also constructed in masonry.

Figure 8. a.) Incremental construction. b.,c.) Damage in lower storeys. d.) Insufficient gaps

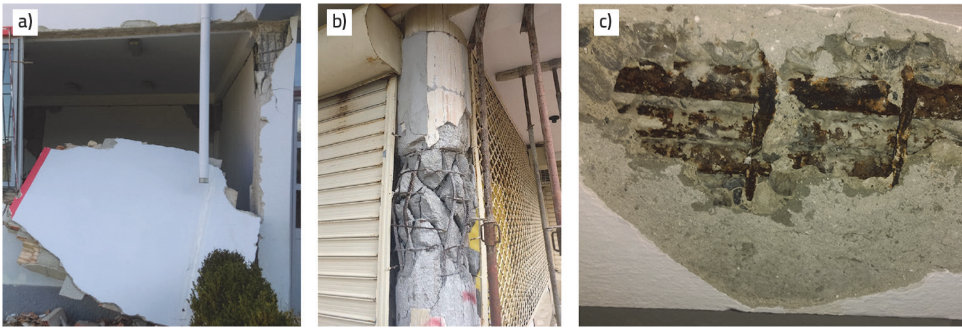

Figure 9. a.,b.) Buckling of reinforcement. c.) Corrosion of steel reinforcement.

Although 1/3 of collapsed buildings were constructed round 1990 the modern multi-storey RC frames also proved to be problematic due to still used combination rigid infills and too flexible load bearing RC structure as Albanian technical codes do not define drift limitations. Consequently gaps between adjacent buildings are inadequate or even do not exist (Figure 7c). The soft story effects were also noticeable since the majority of these types of buildings were in mixed use with open street façade causing torsional eccentricity. Due to aggressive costal environment too thin concrete covering layer proved to be problematic (Figure 8c). Buckling of longitudinal reinforcement, concrete core crushing, and shear cracking of short span beams and columns in RC buildings were also noticed (Figures 8a and 8b). Relatively short extension of steel rebars in problematic incremental construction have a negative effect in structural performance (Figure 7a).

Figure 10. Non efficient attempts for damage remediation.

In rural areas traditional clay brick dwellings with timber floor / roof structure and porticoes / terraces showed typical damage in terms of (diagonal) cracks in the walls or their overturning, falling of floor plaster and collapse of chimneys. With structures from 1990 onwards with mixed structural systems the damage observed is most commonly triggered by non-confinement of walls, structural irregularities in plan and elevation (like external staircases) and as with all structures with poor quality materials / construction / detailing.

5 Conclusions

Every severe earthquake reminds us that seismic threat is not to be ignored. With the current level of knowledge about the earthquakes and design / construction of seismic resistance structures modern societies should be able to cope better in extreme events as it has been presented. Poor implementation (of principles) of seismic codes, poor quality materials and construction works resulted in typical damage patterns for specific structural types. Without strict implementation of modern codes and systematic retrofitting (on contrary as presented in Figure 9) of existing building stock it cannot be reasonably to expect that loos of human lives and furthermore damage to build environment would - in similar future events - differ from presented one.

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