Rapid structural assessment of buildings – experience after the 26th November 2019 Earthquake in Albania

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Abstract. The authors represent a team who visited the areas affected by the strong earthquake of 26th November 2019 as part of the Bulgarian state support to Albania. The task of the Bulgarian experts comprised a rapid visual assessment of buildings in Tirana, as members of small international groups of structural engineers, local engineers and representatives of municipal authorities. The visit further aimed at gaining organisational and professional experience regarding ensuing operations and at assessing damaged buildings in the epicentral area of the city of Durrës. This summary report presents an overview of the assessed structural systems of the visited buildings in Tirana and the most frequent structural and non-structural damages there. Additional information is presented on certain characteristic damages of buildings in Durrës, and a brief analysis is provided of the reasons for building collapse or structural and non-structural damages. Finally, conclusions are drawn, and tasks for future expert, engineering and management activities towards strong earthquake pre- and post-disaster preparedness for Bulgaria are formulated.

1. Introduction

In the early morning of 26th November 2019, an earthquake of M 6.4 occurred in Albania. The event resulted from a thrust faulting near the convergent boundary of the African and Eurasian plates [1]. The source depth was estimated as 20 km [1] to 10 km [2]. The epicentre of the earthquake was approximately 30 km west of the capital city of Tirana between the coastal city of Durrës and Thumane inland. 51 casualties and more than 3000 injured were counted, predominantly in Durrës and in the surrounding epicentral area.

An immediate reaction by both the Albanian government and the international community followed. An urgent request for assistance was issued from Albania to all related international organisations [3]. As a result of this request and out of their own initiative, 30 countries, incl. the European Union, offered assistance and supported the immediate relief activities. Some of the latter grew into a long-term support of crucial relevance for the restoration of the affected regions and infrastructure components.

As is common under such circumstances, also the international professional community of civil engineers and all relevant experts in the field of Earthquake Engineering duly responded. The initiated activities addressed a variety of aspects. Further below, two of these will be outlined in more detail. The first one focuses directly on the structural condition of buildings and other civil engineering facilities immediately after the seismic impact. The answer of the question whether a building or facility can be safely used after the strong ground motion has finished is of crucial importance both for
the residents and for the operation of the particular civil structure. An adequate answer of this question can be given only by means of a rapid structural assessment of the affected building. Such an assessment is to be undertaken immediately after or parallel to the rescue activities due to the necessity of extreme clarity on the possible further use of the building. Moreover, the structural assessment certainly has to be performed by experienced structural engineers with specialised knowledge of Earthquake Engineering.

The second aspect to be highlighted here refers to the completeness of record and the dissemination of the experience gained during such missions. The professional community of civil engineers worldwide maintains a long tradition in this regard. All major earthquakes at least in the last century were carefully described in terms of geological and seismological parameters, detailed presentation of the damages of buildings, infrastructure components as well as social impact. Currently, large modern observation networks provide considerable amounts of real-time high-resolution information on strong motion events worldwide, and teams of all renowned Earthquake Engineering research centres provide on-site assistance and perform investigations as soon as possible after such events.

Regarding the November 2019 Albanian earthquake, reports by the participating teams from different countries were released for internal use [4]. Unfortunately, possibly the only professional studies publicly available are the comprehensive reports [5], [6]. However, their findings address all relevant aspects of the earthquake impact on the country.

In the days following the earthquake, a team of Bulgarian structural engineers, predominantly from the National Earthquake Engineering Centre (NEEC) at the University of Architecture, Civil Engineering and Geodesy (UACEG) in Sofia embarked on a short-term support mission in Tirana as part of the assistance offered by the government of Bulgaria. The mission was immediately followed by a longer one organised by the Bulgarian Chamber of Engineers in the Investment Design [7].

The present work attempts a strictly professional report by the authors towards sharing their personal experience as members of international engineer teams for rapid assessment of the structural condition of residential buildings in Tirana. These teams were joined by Albanian colleagues and representatives of the respective municipality. The activities were organised by the local operational control centre in Tirana. The international expert teams wherein the Bulgarian engineers participated were assigned to the central part of the city of Tirana. Buildings were visited for which the owners had filed notices to the municipality on damages caused by the earthquake. Moreover, a task force was formed within the Bulgarian group of engineers to apply specific laboratory equipment, such as: laser roulette, binoculars, micrometric magnifier for crack width estimation, devices for non-destructive determination of the probable compressive concrete strength and of the corrosion level of reinforcement bars, devices for localisation and size determination of reinforcement bars and of the concrete cover as well as equipment for determination of the level of concrete carbonisation. Thus, important material parameters could be determined on site.

Finally, the authors visited also Durrës for completion of their professional records. Further below, all findings are shortly discussed, and the lessons learned are presented, which, as we hope, should help the management of similar future events.

2. Structural systems of residential buildings in Tirana

As typical for cities, various structural systems for residential buildings in Tirana exist due to historical development and bearing the imprint of the time when constructed. The main building types in Tirana can be summarised in four groups allocated to mainly five time periods [6].

During the rapid structural assessments of buildings performed by the authors, they examined residential buildings of basically three types: unreinforced masonry buildings up to five storeys, buildings of large prefabricated panels, and newer buildings with reinforced concrete (RC) frame skeleton and infill masonry.

The unreinforced masonry structures prevailed. A typical structural system for the city of Tirana consists of masonry load-bearing walls and partition walls, made of solid bricks. The thickness of the walls on the first and second floors is 50 cm, on the third is 38 cm and on the fourth and fifth ones –
25 cm. Partition walls are of the same type of bricks, but their thickness is 12.5 cm. The floor slabs of the older buildings are of hollow bricks and connected with reinforcement bars passing through the brick holes. This makes the floor slabs relatively soft in their plane, so that they do not act as diaphragms, which results in a poor interaction between different masonry bearing walls. The floor slabs of the more recent buildings were often of strip-like prefabricated panels built on the walls. For better connection between the walls and the floor slabs, reinforced concrete tie-beams are constructed. The measured compressive strength of the concrete floors is 12-15 N/mm².

The Albanian masonry buildings and their seismic vulnerability have lately been subject to intensive research. In this regard, the comprehensive study [8] is particularly to be considered. There, the typical structural systems of the masonry buildings from the 1960s till 1990 are discussed in detail together with results from experimental studies towards determination of key material parameters for computational modelling. Special attention is also paid to the resistance of such buildings to near and far-fault ground motion. In general, the observations presented further below correspond to the conclusions in [8].

The load-bearing systems of the contemporary RC buildings in Tirana are predominantly of two types: large-panel stiff walls, mostly built in the 1980s and 1990s, and skeleton moment-resisting frames, as a rule – newer ones, since the 1990s.

3. Observed problems

3.1. Earthquake-induced structural issues

The 26th November 2019 earthquake in the city of Tirana area was classified as strong according to MMI (Modified Mercalli Intensity), with Instrumental Intensity VI, causing slight structural and non-structural damages. The recorded PGA in Tirana (41.3351N 19.606E, Stiff soil, epicentral distance 33.647 km) was 1.08 m/s² (0.11 g), and the duration of the main ground motion was ca. 30 to 40 seconds [6]. It was not a highly destructive earthquake, but the social tension and fear in the population were clearly perceptible in the meetings of our teams with building owners and inhabitants. The rapid structural assessment was performed according to a version of [9] developed by the local authorities.

The most frequently observed damages in the masonry structures were cracks in the corners between load-bearing walls and partition walls, or diagonal cracks in the walls. Cracks in the ceiling were also observed in a number of buildings due to the practice of using prefabricated panels for floor slabs. Cracks had formed straight-like lines between the panels, caused by the inevitable shear occurring in the floor diaphragms and caused some shear deformations between the single panels. All these damages could be classified as slight, and in very rare cases slight-to-moderate. None of the buildings visited had to be classified as dangerous, so to be abandoned by its residents.

One of the possible reasons for crack formation in the masonry bearing walls was that relatively flexible floor slabs did not help walls distributing loads between them. On the contrary, they concentrated part of the loading to a particular wall causing its overloading. In some floors, cracks indicating tension stresses were formed on the top side of the floor near the damaged wall. In some buildings, longitudinal cracks between the stone foundation and the masonry walls also were observed, which means that the connection between the foundation and the bearing wall was lost. Another reason for crack formation in the masonry walls was the poor quality of the mortar, i.e. a very low cement content in the latter. Such mortar literally turns to dust when even touched with fingers.

Among the most recent generation of buildings constructed with RC frames, only slight damages were observed as cracking or separation of partition or infill walls in the contact area with the beams and columns. In both types of building structures – masonry ones and skeleton RC structures, the more visible and significant damages were concentrated in the lower storeys. This can be explained by the larger drifts in the lower storeys of structures responding in shear type lateral displacement mode typical for RC frames and masonry structures. Structural damages, jeopardising the overall condition
of a building – figure 1 and figure 3 (all photos in this work taken by the authors), were relatively rarely observed by the authors during their mission in Tirana.

Large-panel buildings showed nearly zero damages, neither structural nor non-structural ones. In certain cases, slight openings of joints between the panels were identified. The measured compressive strength of the concrete in contemporary RC buildings was 20-25 N/mm$^2$.

The most common damages in the residential buildings in Tirana, however, were non-structural: cracks (mostly diagonal or horizontal) in non-bearing brick walls in the masonry and RC-frame buildings – figure 2, around doors and windows – especially due to missing lintels with adequate structure and bearing capacity, between slabs and walls, between stairs (mostly made from low quality concrete in the masonry buildings) and walls, collapsed chimneys.

3.2. Safety-related structural issues not caused by the earthquake

The city of Tirana is marked by the urban development characteristic for the last ca. 30 years. The identified structural issues, although not caused by the earthquake of 26$^{th}$ November 2019, directly affect the structural quality and integrity of the buildings as well as their seismic vulnerability, respectively. These issues are based on the observations of the authors and are summarised below.

Perhaps the problem most closely related to the seismic performance of the buildings was represented by various reconstructions. It was not uncommon to detect a diversity of building appendixes, encased balconies and removal of internal walls aimed at increasing living space. In some cases, removals have been undertaken on the first floor, and moreover, without adequate design and construction of a lintel. The lack or the actual structure of a lintel was a general problem observed during the mission in Tirana. Furthermore, even additional floors on panel buildings were observed – figure 4. In certain cases, the reconstructions were based on a structural design, however, without seismic performance analysis of the whole building. Unfortunately, this was no standard, when, e.g. a subsequent cutting of a column (including reinforcement) at the foundation was undertaken to enable a pipe connection. A similar case was observed as an additionally created door opening in a wall panel to enable an independent entrance in a flat.

All these reconstructions and upgrades increase the vertical loads on the load-bearing elements. The mass of the building is increased, too, causing bigger horizontal seismic forces. Also, the regularity of the structure in both horizontal and vertical directions is often violated, which additionally affects its seismic performance by causing torsion and other negative effects.

Another common problem was the lack of any seismic joints between adjacent buildings constructed at different times, of different materials and as different structural systems. As a result, local damages of the facade walls were observed around the contact area with the slabs of the neighbouring buildings.
It is also worth highlighting a social aspect of this technical problem. After the earthquake of 26th November 2019, the concerned citizens grew aware of the high vulnerability of seismic non-resistant buildings, and how the illegal interference to the building structure by one owner jeopardises the safety of all residents and of their shared property. This inevitably results in confrontations and social tension both within the neighbourhood in the “Kolektive” residential buildings and in their relation to the authorities.

In the authors’ opinion, some typical design solutions were identified during the performed rapid structural assessment in Tirana, which need discussion. Relatively frequently encountered damages of the non-structural elements should be outlined as a weak point in the seismic performance of RC frame buildings. It also is worth reminding that the earthquake was not so strong in the region of Tirana. Buildings with such damages may need to be stiffened, if possible, by adding RC shear walls to them and connecting the existing RC frames to these walls. Undeniably, such an intervention can be undertaken only after a detailed seismic structural analysis. Furthermore, an applied beam-column connection with a large eccentricity also can be classified as unfavourable design – figure 5.

Another problem was the observed design of external columns not in the corners but inward with built non-bearing infill walls at the corners. This resulted in separating the infill walls from the RC frame in the corners caused by the earthquake – figure 2, but such separation could occur without ground motion impact, too. A similar finding was identified at a single flat situated in two adjacent parts of a panel building, separated by a joint. Due to this, there were significant although mostly non-structural, internal damages in the apartments, including large cracks in the infill walls and opening a gap between the parts of the apartment belonging to the different buildings. Here again, severe cracks could occur without seismic excitation, e.g. due to different settlements of the two separate buildings.

An observed problem related to both design and maintenance of the buildings is shown in figure 6. On one hand, the use of non-ribbed reinforcement without sufficient overlapping for the column at the foundation was not an appropriate design solution. On the other, a relatively large spacing between transverse reinforcement in the critical zone of column-to-foundation reinforcement splice is not allowed by modern codes. Furthermore, the obvious lack of adequate maintenance has led here to a deterioration of the concrete, which could further enable more or less intensive corrosion of the reinforcement.

Other maintenance-based problems with unfavourable consequences were the observed permanently inundated cellars in basement floors of large panel buildings as well as the almost universally destroyed rain pipes on their facades. The surface impact of water on the facade panels and their connections, and especially the permanently flooded foundations, seriously affect the overall structural performance of the buildings with particular regard to their seismic vulnerability.
3.3. Impressions from Durrës
In the afternoon of 7th December 2019, the authors visited Durrës to gain professional impressions of the earthquake-induced damages in the city. The observed buildings were located along and near Pavaresia street within a sector of ca. 0.9 km length between the streets David Selenica and 3 Vellezerit Thanasi and the beach in the South-West. There were mainly relatively new buildings with RC beam-column structural framing system and infill masonry walls, characteristic for this part of the city, which underwent a rapid development thanks to the touristic boom after the changes in Albania. The height of the buildings ranged from 3 to 10 storeys. The majority of the buildings were apartment and family hotels, and residential buildings.

During the short mission to Durrës, the engineer team observed in general three types of damages, such as: 1) fully collapsed or few cases of severely damaged buildings, i.e. damaged load bearing building structures, 2) significantly damaged non-structural components, such as facade and partition walls in many buildings, and 3) certain occurrences of soil liquefaction.

The three fully collapsed buildings were the Vila Verde Beach Hotel (four-storey), Hotel Mira Mare (five-storey), and the five-storey Lubjana Hotel. At the time of the visit, all buildings said were completely destroyed, and the sites were already cleaned up. Based on available photographs, the most probable reasons for their collapse were the soft and weak first storeys due to the large open spaces in the restaurant and hotel lobby areas, and possibly an inadequate foundation in an area with a ground containing liquefiable saturated sands. This emphasises the vital relevance of the entire development chain of architectural planning, structural design and construction process and the equally important, inter-related compliance with the basic rules for design and construction in seismic regions.

A case of a seriously damaged building was shown to the team by local colleagues. The site was already inspected, and all residents evacuated. It is a judgment of the authors that the building was severely damaged and did not possess any residual strength. Most probably, it would be due to be demolished in the near future. A visible residual drift and many signs of nonlinear deformations were identified, mainly present in column-beam joints of the first storey, and a collapse of masonry infills due to a frame-wall interaction – figure 7 and figure 8.

![Figure 7](image1.png)
**Figure 7.** Deep crack in a column-beam frame joint.

![Figure 8](image2.png)
**Figure 8.** Completely damaged infill masonry walls.

The most often observed damages were those of the infill walls – figure 9. There were partially as well as fully collapsed walls, cracks, and other damages in the facades and partitions. Generally, due to the climate on the Adriatic coast of Albania, the facade walls of the new buildings are of either double-layer brick masonry with insulation layer in the middle, or of single layer masonry with insulation system outside the wall. In both cases, hollow bricks placed on their narrow side are employed. Generally, all facade walls were non-confined, relatively long and slender and sensitive to
storey drifts. It is worth noting that, as a rule, there were no horizontal or vertical confining elements (tie-beams or tie-columns) or any other type of reinforcement. This specific feature of the structural system based on beam-column frame skeleton, performing good ductility but deformable, in combination of non-confined brick masonry infills results in many damages of the infill walls observed at every second or third building within the inspected district. Another severe structural problem observed was a damaged column in the 1st storey with built-in interruption of the vertical reinforcement bar, figure 11.

As said above, the visited district of Durrës is close to the beach, and the construction ground very likely contains saturated sands or even mud [6]. Under such conditions, the potential of soil liquefaction is high. Visible soil deformations were identified around some buildings – figure 10. In the authors’ opinion, such effects were relatively rare only thanks to the main earthquake having lasted for ca. 30-40 seconds. In the event of an earthquake of longer duration, the soil liquefaction effects would have been much stronger with much more serious consequences, respectively.

4. Lessons learned and conclusions
As a result of the mission performed by the authors, the following conclusions can be drawn with respect to the safety of residential buildings in earthquake-prone regions:

a) Inappropriate structural design solutions for the building should be avoided. This means that already at the design stage, all load cases comprising decisive seismic excitation should be accounted for. As a result, the load-bearing structural elements and their connections should be designed according to the obtained demands for them, respectively.

b) The “soft first storey” should be avoided. A common problem observed in masonry buildings was the additional weakening of the first floor caused by removing walls for shops and offices. Thus, a “soft first floor” occurred, which is well-known as one of the most frequent reasons for collapse of buildings during strong earthquakes. Although this was not the case in Tirana thanks to the not sufficiently strong seismic impact there, it occurred to numerous buildings in Durrës. Unfortunately, the problem of the “soft first floor” is almost always of economic nature, and therefore difficult to avoid.

c) Any inappropriate structural changes of the building should be avoided, i.e. any change of the structural system of the building should be assessed by a qualified structural engineer with respect to the overall seismic safety of the building.

d) The use of modern codes is of crucial importance for the seismic resistance of the buildings. On one hand, these represent contemporary design codes for structures in seismic regions. Their application enables the appropriate selection of the structural system, design of the bearing capacity of
the structural elements, their connections and detailing. On the other, these define the standards for construction materials, ensuring that the latter’s parameters correspond to the design ones.

e) Particular attention should be paid to the safety of the non-structural building elements. As said above, facade and internal infill masonry walls in buildings with RC frame structure should be adequately confined. Their structural integrity under ground motion excitation is of crucial importance for the safety and health of both the inhabitants and citizens near the building. In this regard, the use of adequately designed and constructed wall confining horizontal and vertical members and lintels above the openings in such walls substantially contributes to the building safety and reduces the costs of post-earthquake maintenance. Unfortunately, in both Tirana and Durrës, lack of masonry confining members or poorly constructed ones for this purpose were often observed.

f) The November 2019 earthquake in Albania confirmed the necessity and the relevance of the rapid post-earthquake structural assessment of buildings and facilities. For its successful performance, however, the presence of an adequate methodology and corresponding ready-to-use forms for the experts is inevitable. In this regard, the preparation and the operation of the local authorities in Tirana and Durrës can serve as a highly commendable example.

g) Apart from the purely structural issues, the role of the overall organisation of the rescue, supply, assessment and restoration works, the management, control and logistical support, of the coordination and communication of the various task groups after an earthquake event of such gravity definitely requires a very high level of emergency preparedness of all involved authorities. In this regard, the related activities in Tirana and Durrës observed by the authors can also be considered best practice.

The authors trust that the experience shared by this outline may help structural engineers and colleagues involved in the various aspects of Civil Engineering towards preventing as far as possible building deficiencies and damages in future earthquake events.

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