



SM2.11: Active tectonics of the Mediterranean as seen by recent seismic sequences

Factors controlling building damage distribution of the November 26 2019 Mw 6.4 Albania earthquake

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THE NOVEMBER 26, 2019, Mw 6.4 DURRËS EARTHQUAKE

On November 26, 2019, an earthquake struck the central western part of Albania. It was assessed as Mw 6.4. Its epicenter was located offshore northwestern Durrës, in a distance of about 7 km north of the city and 30 km west from the capital city of Tirana. Its focal depth was about 10 km. Based on the focal plane solutions provided by several seismological institutes and observations, the mainshock was generated by the activation of a NW-SE striking reverse fault. The main shock was felt in the neighboring Montenegro, Italy and Greece, especially in Corfu Island.

The aftershock sequence until 30 November included hundreds of aftershocks, 22 with magnitude larger than $M=4.0$ and 4 with magnitude larger than $M=5.0$ (aftershocks by USGS until December 1, 2019).

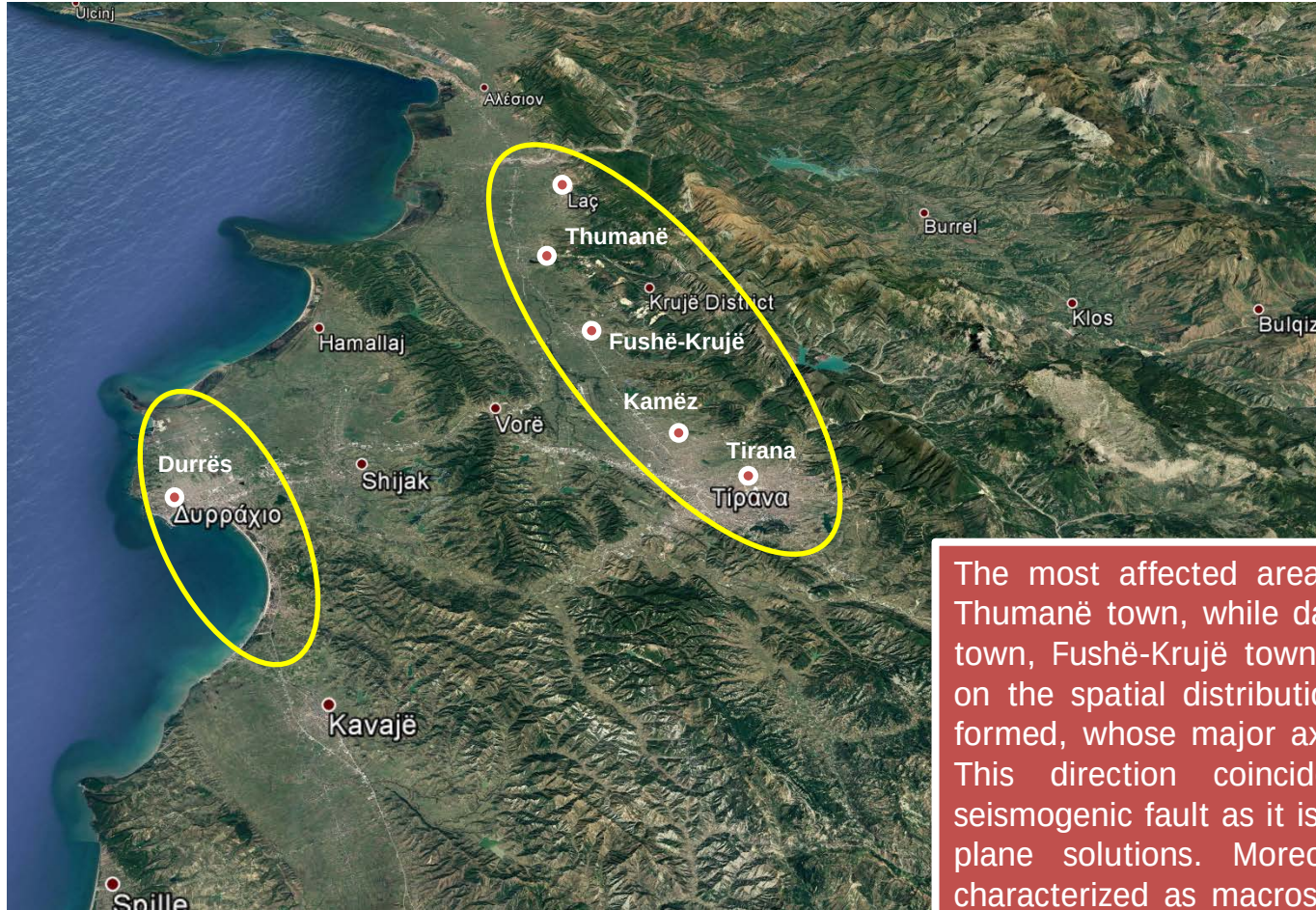
The most earthquake-affected areas are the city of Durrës and the town of Thumanë at the central-western Albania. More specifically, Durrës city is located along the coastal part of the central-western Albania in a distance of 30 km west from the capital city of Tirana, while inland Thumanë in a distance

of about 25 km northwest from the capital city of Tirana. Damage was also reported in Laç town, Fushë-Krujë town, Kamëz and Tirana city.

Unfortunately, the earthquake claimed the lives of 51 people. The number of injured are large reaching more than 750. More than 900 families have been evacuated from the affected areas and were in post-earthquake shelters and assembly areas including stadiums, not-affected hotels and other public facilities for the first days of the emergency phase.

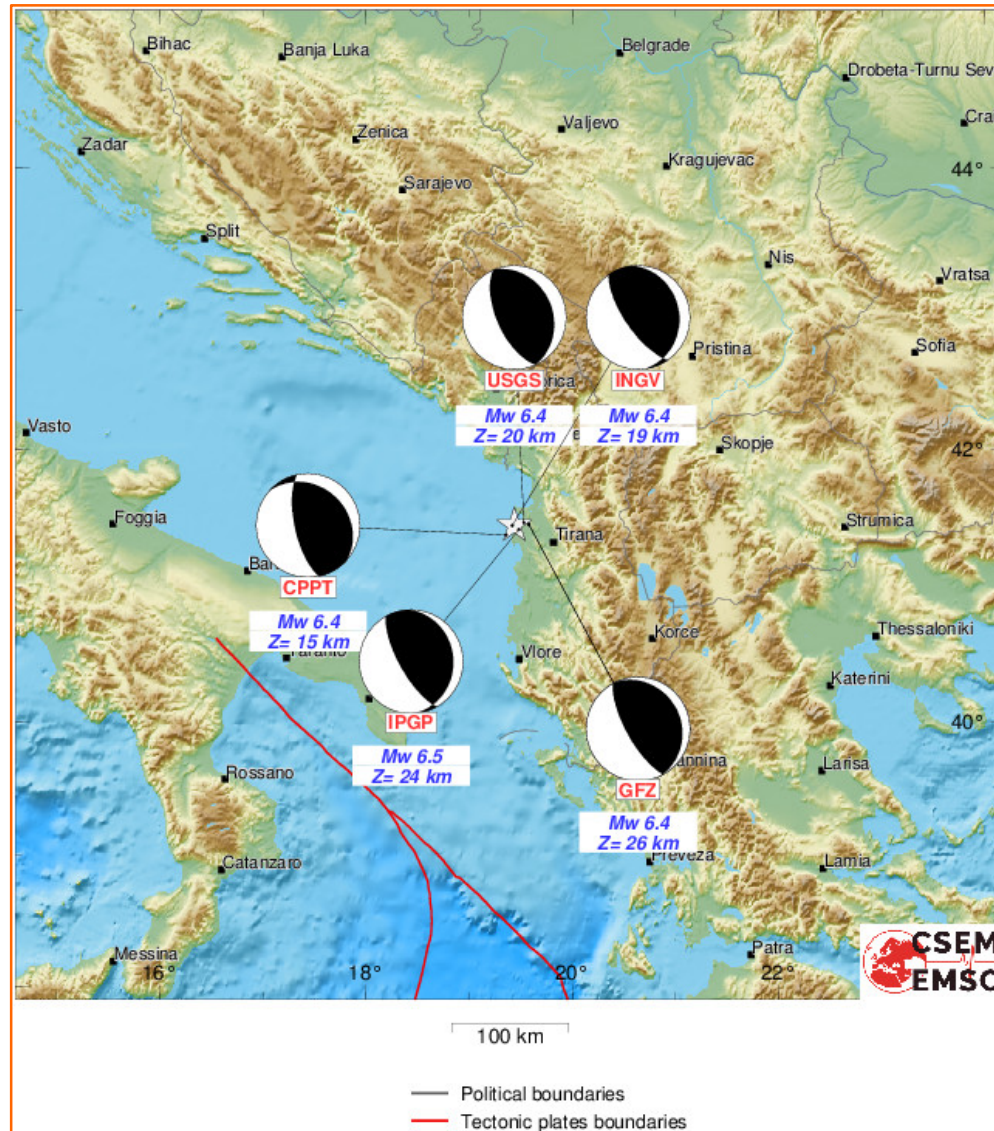
Based on the emergency report of the International Federation of Red Cross and Red Crescent Societies, displaced people in Durrës have been moved from the tent camp that was initially set up in a stadium and are now accommodated in hotels in Vlora. Based on this report, the total number of people affected in terms of damage in property is estimated to be 80000-100000.

THE NOVEMBER 26, 2019, Mw 6.4 DURRËS EARTHQUAKE-AFFECTED AREA

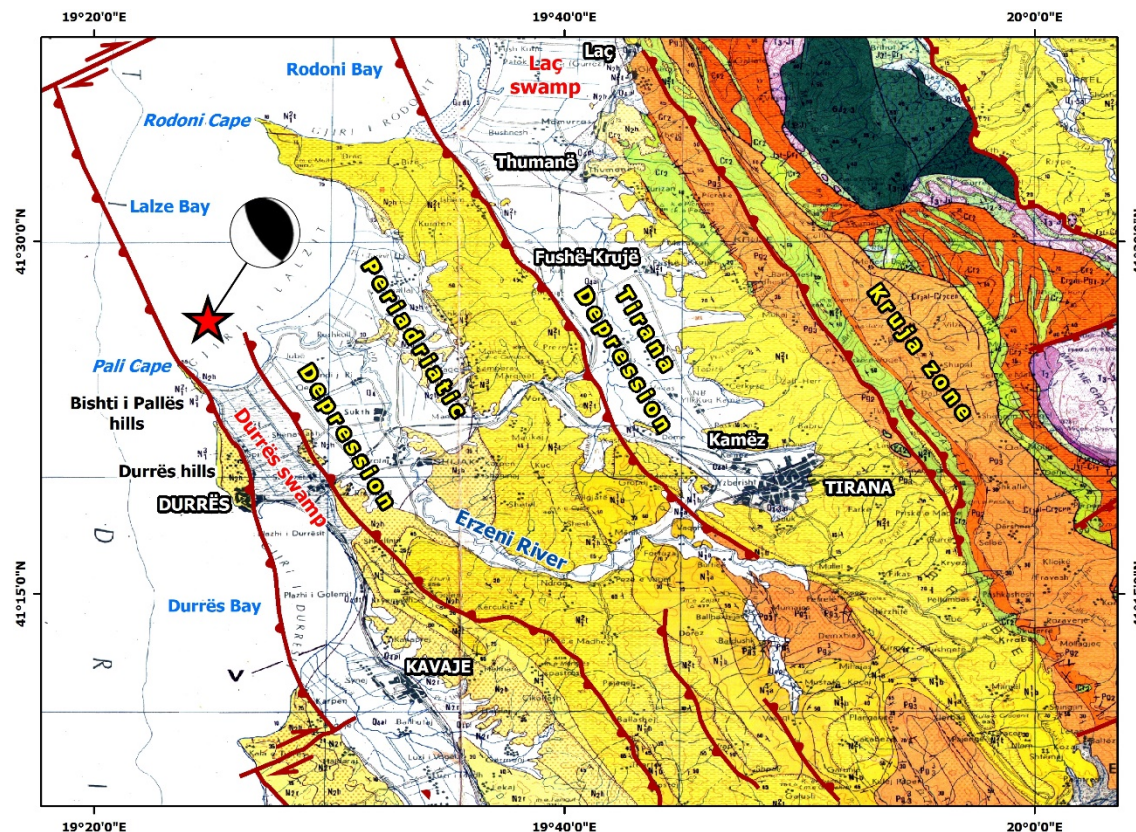


The most affected areas are the Durrës city and the Thumanë town, while damage was also reported in Laç town, Fushë-Krujë town, Kamëz and Tirana city. Based on the spatial distribution of damage, two ellipses are formed, whose major axis is oriented generally NW-SE. This direction coincides with the strike of the seismogenic fault as it is derived from the provided fault plane solutions. Moreover, these ellipses could be characterized as macroseismic epicenters as a result of the interaction between the seismotectonic setting and the soil conditions and as the outcome of various reflections, refractions, conventions, directivity phenomena of seismic waves and resonance resulting in destruction in the earthquake-affected area.

QUICK SOLUTIONS AND REGIONAL MOMENT TENSORS FOR THE NOVEMBER 26, 2019 EARTHQUAKE



GEOLOGY OF THE NOVEMBER 2019 EARTHQUAKE-AFFECTED AREA



Tectonic Structures

- Strike-slip fault
- Thrust fault
- Normal fault

Seismological Data

- Earthquake epicenter
- Fault plane solution

Quaternary Deposits

- Marine deposits with sand and gravels
- Alluvial deposits with sand and gravels
- Marshy deposits with sand, gravels and peat
- Mixed deposits including alluvial and marshy deposits

Neogene Deposits

- Pliocene clays
- Messinian sandstones, clays and gypsum
- Tortonian sandstones, clays and conglomerates
- Burdigalian marls, clays and limestones
- Lower Aquitanian gray marine clays, moraines and coal

Alpine Formations

- Upper Oligocene clay-sandstone with limestone, massive sands, clays and coal
- Middle Oligocene flysch with clays and sandstone, conglomerates, limestone, coals
- Lower Oligocene flysch with clay and sandstone
- Middle Oligocene flysch with clays and sandstone, conglomerates, limestone, coals

- Upper Cretaceous limestones with rudists and radiolarites
- Serpentinites
- Middle - Upper Jurassic limestones and dolomites
- Middle Triassic - Lower Jurassic limestones
- Middle Triassic limestones



GEOLOGY OF THE NOVEMBER 2019 EARTHQUAKE-AFFECTED AREA

The geology of the area affected by the September 21 and November 26, 2019 Durrës earthquakes comprises mainly recent deposits. Their age ranges from Oligocene to present based on the *geological map of Albania (scale 1:200.000, 1983)* and *Shallo et al. (2002)*. These formations constitute a large part of the Periadriatic and Tirana depressions.

The Oligocene formations comprise flysch with clays and sandstones, limestone, conglomerates and coals.

The Neogene deposits include:

- (i) gray marine clays, moraines and coals of Lower Aquitanian,
- (ii) marls, clays and limestones of Burdigalian
- (iii) sandstones, clays and conglomerates of Tortonian age and
- (iv) sandstones, clays and gypsum of Messinian age.

The Pliocene is represented by clays.

The Quaternary deposits comprise Holocene marshy deposits, clays, sands and peat as well as Pleistocene and Holocene alluvial deposits with

gravels, sands and clays.

The city of Durrës is composed of Pliocene clays and Holocene marshy deposits including clays, sands and peat. It is significant to note that one of the most affected parts of Durrës with many severely damaged buildings is composed of marshy deposits. The geological structure of this area is also revealed by its name (Keneta in the Albanian language means marshes).

The town of Thumanë, where the majority of the fatalities were reported, is composed of Pleistocene and Holocene alluvial deposits with gravels, sands and clays as well as Pliocene clays.

The towns of Fushë-Krujë and Kamëz present geological setting similar to Thumanë. They are founded on Holocene marine deposits comprising mainly sand, on Pleistocene and Holocene alluvial deposits and Pliocene sandstones, clays and conglomerates.

The 2019 earthquake affected area is dominated by NW-SE striking reverse active faults.

GEOLOGY OF THE NOVEMBER 2019 EARTHQUAKE-AFFECTED AREA



As regards the earthquake-affected areas of Laç town, Thumanë town, Fushë-Krujë town, Kamëz and Tirana city, they are located along the eastern margin of the Tirana depression. The alpine basement of the eastern margin comprises Oligocene flysch and Upper Cretaceous limestone, while Miocene formations are overlying the alpine basement. The Miocene formations dip westwards and southwestwards. More specifically, they dip 15° to the W in Thumanë, 15° - 30° to the SW in Fushë-Krujë, 5° - 15° to the SW in Kamëz and 10° - 15° to the SW in Tirana area. Pliocene, Pleistocene and Holocene deposits are overlying Miocene formations. The most affected towns along the eastern margin of the Tirana depression are founded mainly on Holocene deposits.

BUILDING TYPES FOR ALBANIA

	1 - Detached house	2 - Semi-detached house	3 - Row/ terraced house	4 - Multifamily apartment
A - 1960				
B 1961- 1980				
C 1981- 1990				
D 1991- 2000				
E 2001- 2011				

The buildings in Albania are classified into 4 types:

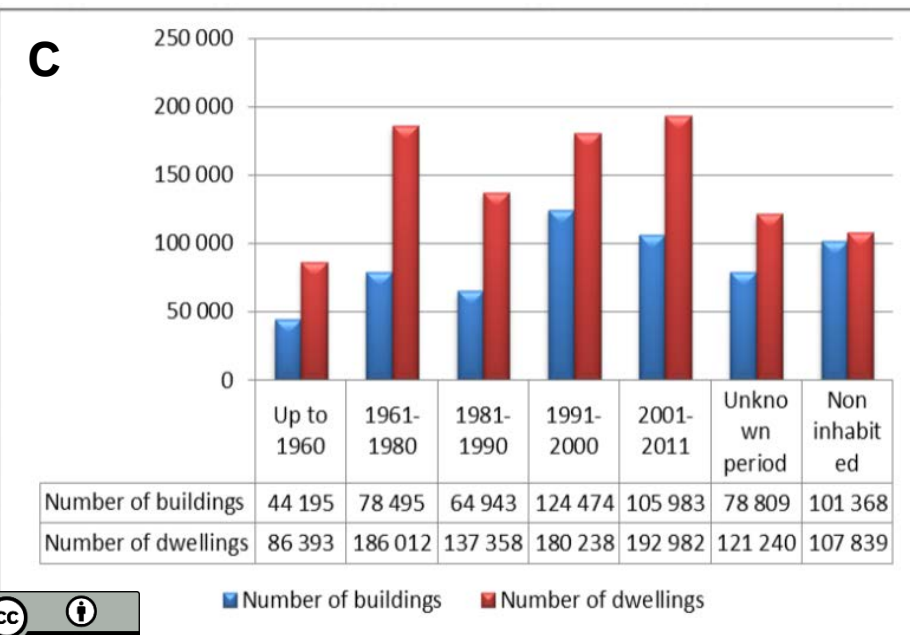
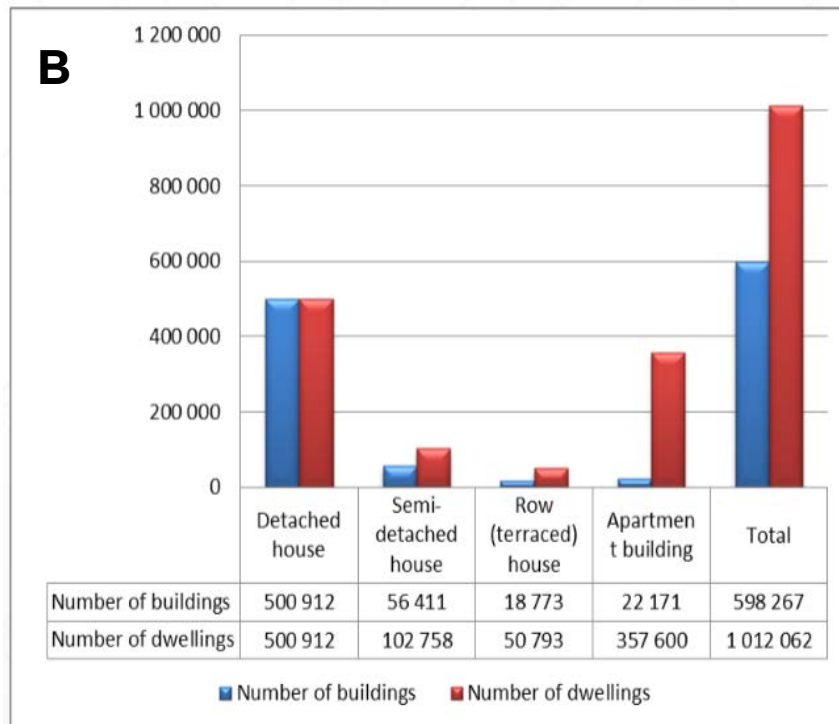
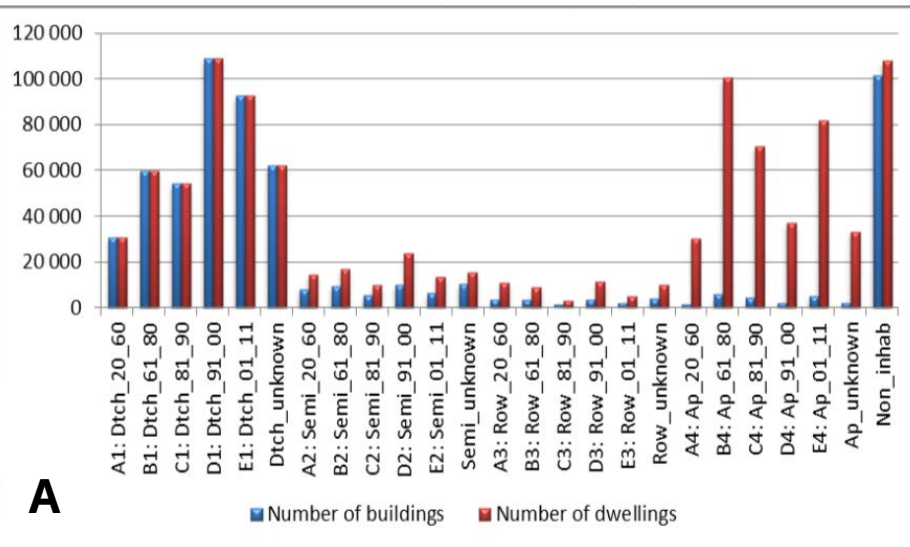
- detached houses
- semi-detached houses
- row houses
- apartment buildings

They constructed in 5 construction periods:

- before 1960
- between 1961-1980
- between 1981-1990
- between 1991-2000
- between 2001-present

These building types dominate the earthquake-affected area

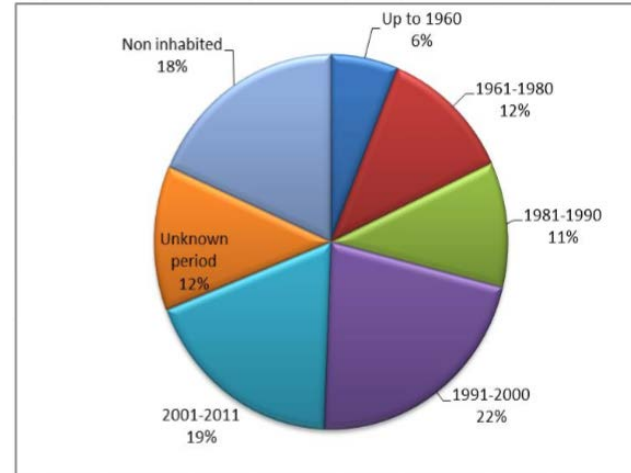
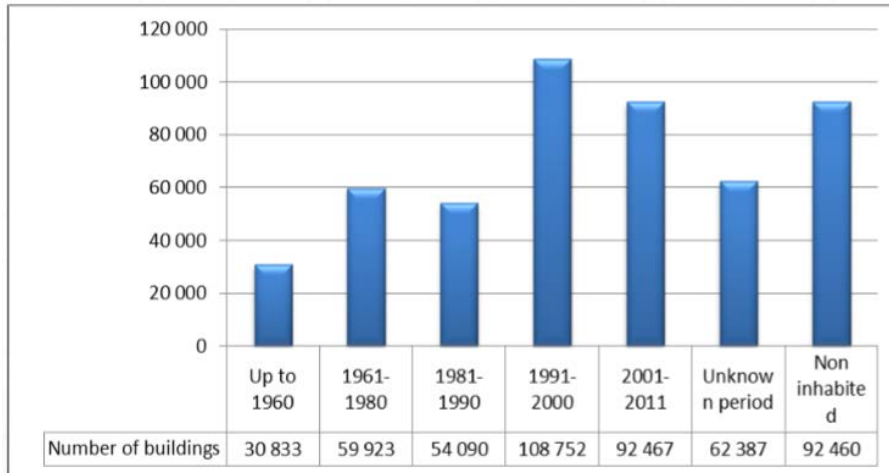
RESIDENTIAL BUILDINGS AND DWELLINGS FOR ALBANIA



(A) Number of residential buildings and dwellings per building type
(B) Number of residential buildings and dwellings by building type
(C) Number of residential buildings by construction period based on the 2011 census data on Albania building stock

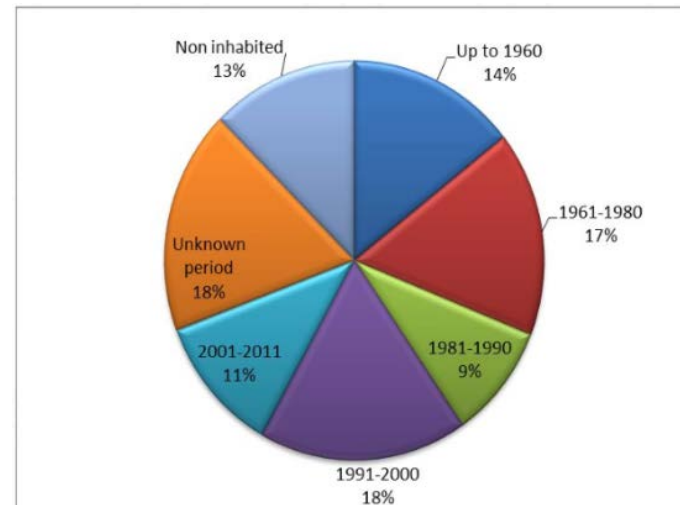
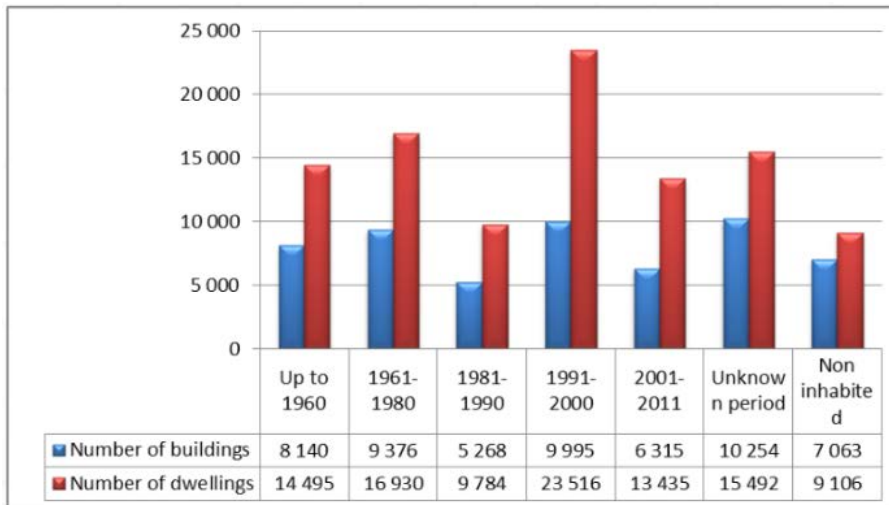
BUILDINGS AND CONSTRUCTION PERIODS IN ALBANIA

Detached houses by construction period



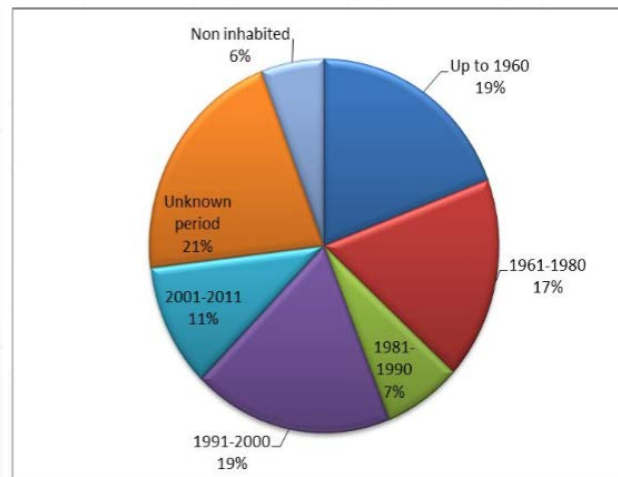
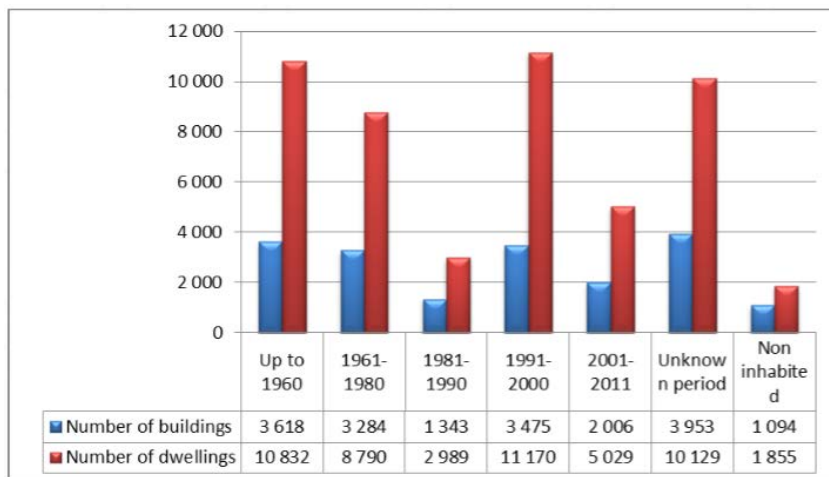
Semi – detached houses by construction period

From *Novikova et al. (2015)*



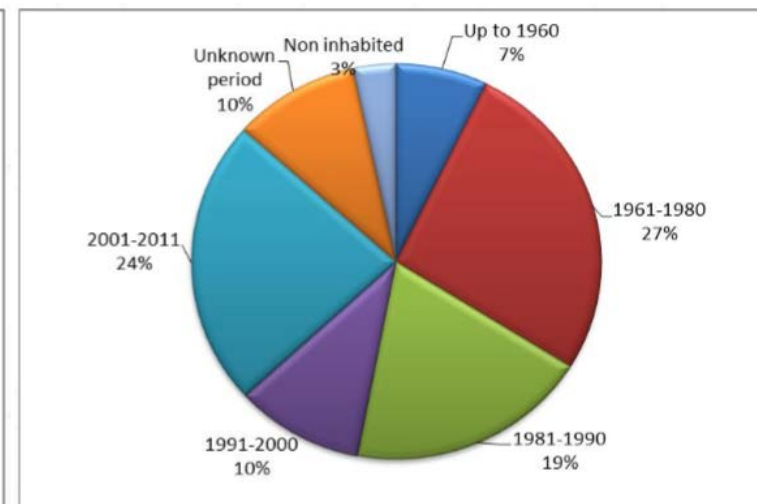
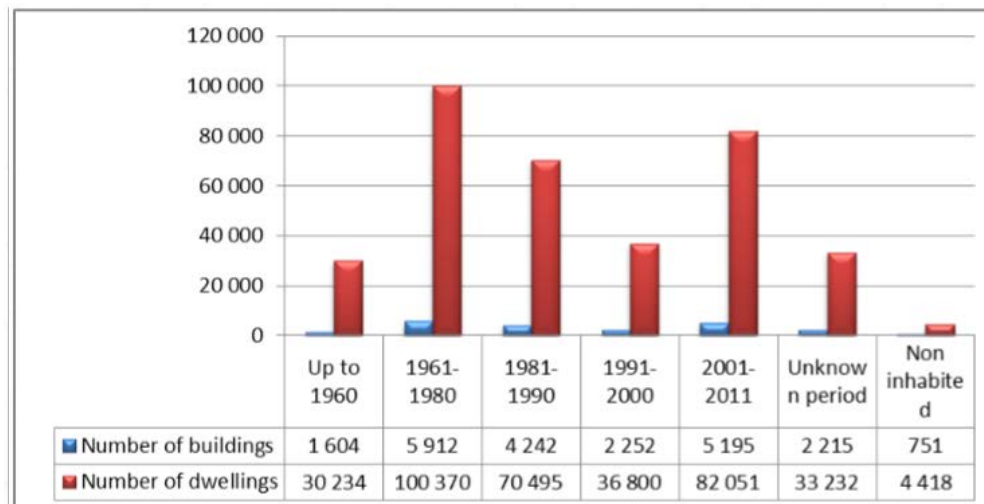
BUILDINGS AND CONSTRUCTION PERIODS IN ALBANIA

Row (or terraced) houses by construction period



Apartment buildings by construction period

From *Novikova et al. (2015)*



DOMINANT TYPES OF BUILDINGS

Buildings with load bearing brick walls and concrete floor slabs

in Durrës



in Thumanë



These buildings essentially consist of thick heavy unreinforced masonry (URM) of solid clay bricks, which supports the entire structure, including the horizontal floor slabs, which could be made of reinforced concrete members. A significant characteristic of this type of structure, not only in Albania but also around the world, is the lack of concrete columns and beams. The solid brick walls are the only and the main load bearing elements of the structure. This masonry type is unreinforced and thus it presents brittle - non-ductile behavior. Due to the construction material (solid clay bricks), they also present small stiffness resulting in good performance and flexibility during an earthquake up to a certain limit. Once this limit is exceeded, the damage is instantaneous.

DOMINANT TYPES OF BUILDINGS

Buildings with load bearing solid brick walls and concrete floor slabs

in Thumanë



in Thumanë



In this case, the earthquake shaking and displacement did not exceed this limit and these structures remained intact by the earthquake. A very positive characteristic in this type of buildings is that the best possible continuity between the soil and the construction is achieved, in terms of material and stiffness. These elements appear to have a positive effect on the antiseismic performance, particularly with respect to the vertical component of the earthquake ground motion. Taking into account these elements, this building type excel in antiseismic performance.

DOMINANT TYPES OF BUILDINGS

Buildings with load bearing brick walls and concrete floor slabs

in Durrës

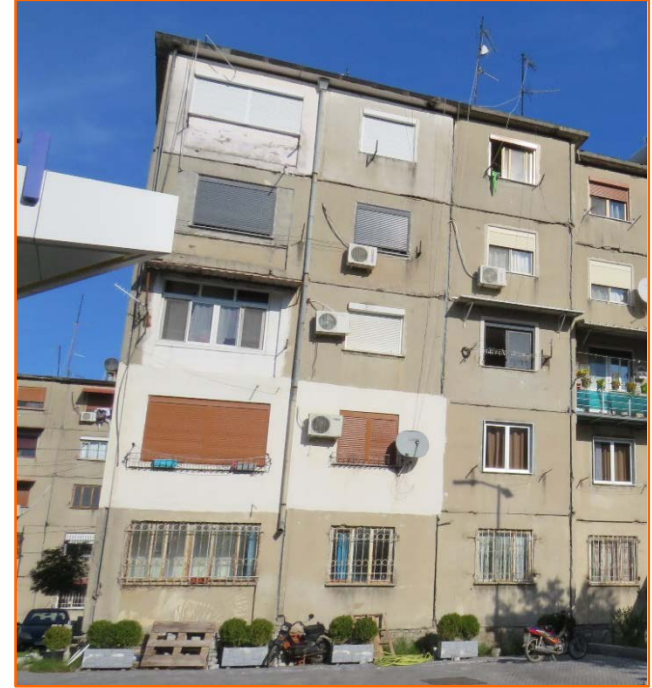


Unreinforced masonry (URM) construction should not be used today. They do not present good performance during earthquakes. It is significant to mention that the majority of fatalities induced by earthquakes around the world have attributed to collapse of unreinforced masonry buildings. They are heavy brittle structures, which usually suffer heavy structural damage.

DOMINANT TYPES OF BUILDINGS

Prefabricated concrete panel buildings

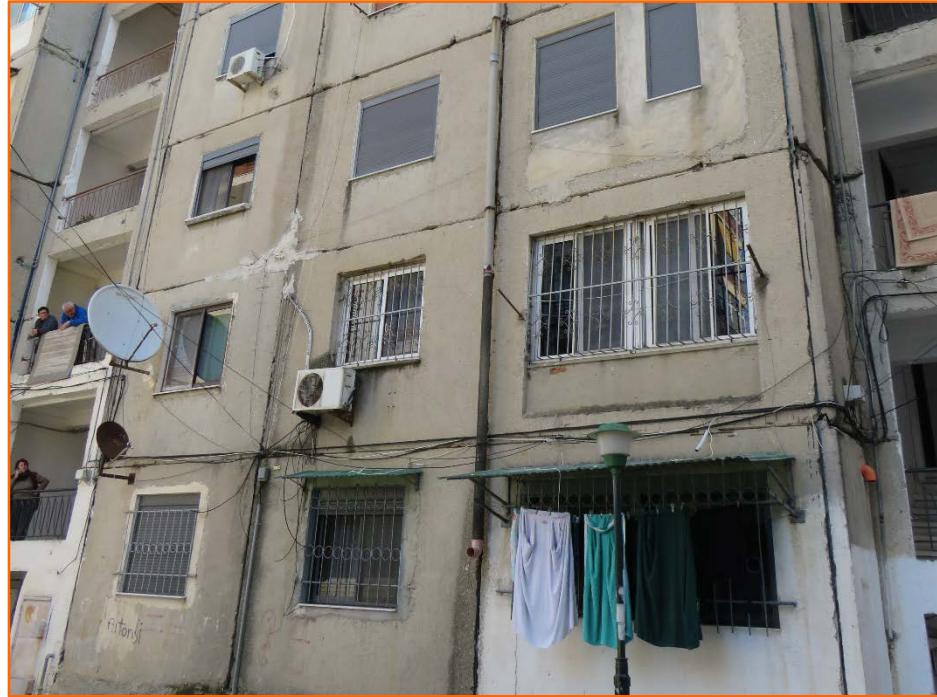
in Durrës



Heavy and light prefabricated construction methods were also applied in Albania as a mean to further lower building costs and provide rapid urbanization to meet demand. As a result of this trend, up to 60% of these prefabricated concrete wall buildings were built after the 1960s not only in the port city of Durrës, but also in Tirana and in other large cities and towns of Albania. Based on the 2001 census data, the majority of the building stock comprised brick or stone (88%) and 5% prefabricated panel construction. Even though the number of prefabricated concrete buildings is lower than in situ masonry buildings, they are usually multi-storey structures, which include residential buildings. Most of the apartment buildings constructed after 1960 were built with this methodology.

DOMINANT TYPES OF BUILDINGS

Prefabricated concrete panel buildings



In the majority of these structures, the prefabricated concrete walls are not covered with plasters and the welding joints between the prefabricated concrete walls have not been sealed. Thus, these buildings are not protected from the aggravating environmental conditions including humidity, rainfall, temperature variations, snowfall resulting in quick and easy ageing of materials.

DOMINANT TYPES OF BUILDINGS

Buildings with reinforced concrete frame and infill walls



Buildings with a kind of light reinforced concrete frame and infill brick walls are also observed in the affected area. The performance of this type of buildings is strongly related to the presence or lack of strong columns and beams and the construction method of the slab. They are often multi-storey residential buildings, hotels and offices.

STRUCTURAL DAMAGE TO BUILDINGS WITH LOAD BEARING BRICK WALLS IN THUMANË TOWN



Heavy structural damage to buildings with load bearing solid brick walls and concrete floor slab in Thumanë town are presented. Damage comprised detachment of large pieces of plaster from the brick walls, cracks in brick walls and partial collapse of the building. The floor slabs were composed of simply supported prefabricated reinforced concrete hollow core strap slabs. The concrete strap slabs are not transversally connected to each other neither to the load bearing system. In this way, the diaphragmatic function of the floors, which is beneficial for the earthquake safety of the structure, is totally missing.

PERFORMANCE OF PREFABRICATED FLOOR SLABS DURING THE NOVEMBER 26, 2019 DURRËS EARTHQUAKE

Based on the field macroseismic reconnaissance survey conducted after the September and November Durrës earthquakes, it is concluded that many buildings of all observed construction types used precast floor slabs. These slabs are prefabricated and then lifted with cranes or elevators. The slabs that were usually observed in collapsed or heavily damaged buildings mainly in Thumanë and secondarily in Durrës were simply supported prefabricated reinforced concrete hollow core strap slabs, not transversally connected to each other neither to the load bearing system. In this way, the diaphragmatic function of the floors, which is beneficial for the earthquake safety of the structure, is totally missing. These elements were subjected to the earthquake motion resulting in destruction.

The simple support of these precast elements is not allowed by modern earthquake codes due to the fact that in most cases the existing joints are not adequate and/or strong enough to undertake the vertical and horizontal seismic actions. The joints at the supports must be constructed in order to rigidly withstand the up-down jumping movement of the slabs and the differential horizontal displacements, i.e diaphragmatic function. The lack of these provisions in the joints may be the basic reason for numerous heavy structural damage and collapses of the buildings with precast floor slabs. Recent examples of this performance were also observed in buildings affected by the 2009 L' Aquila and 2012 Emilia - Romagna earthquakes in Italy (*Carydis et al., 2009, 2012*).



A collapsed building in Thumanë with load bearing brick walls and simply supported reinforced concrete hollow core slabs.

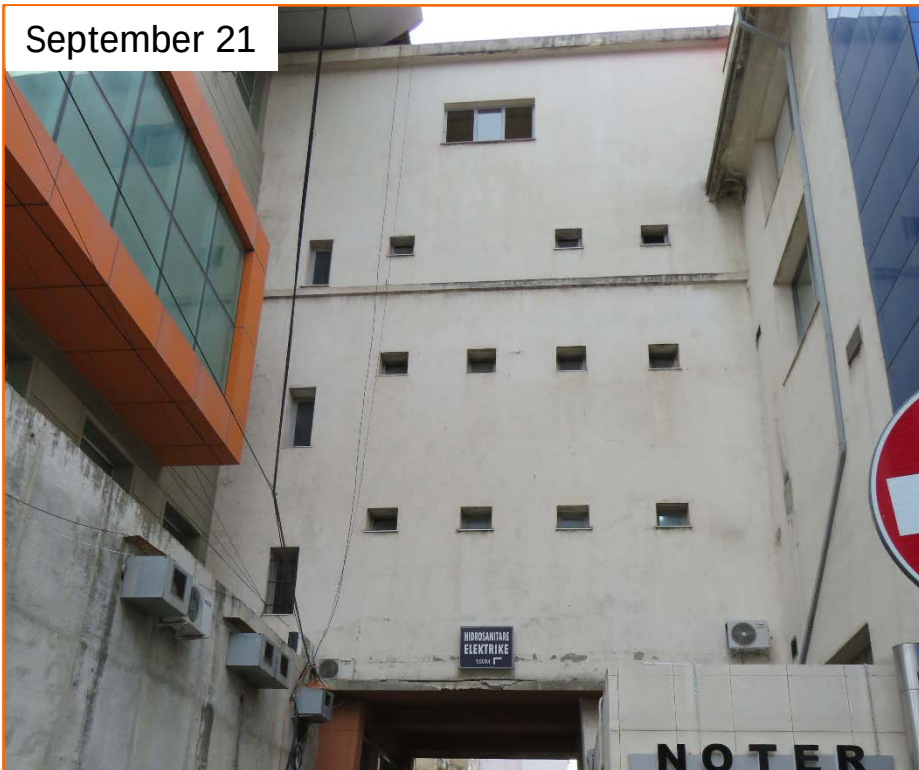
STRUCTURAL DAMAGE TO BUILDINGS WITH LOAD BEARING BRICK WALLS IN DURRËS CITY



Collapse of the two lower floors of the building. The deformation of the steel bars of the columns is attributed to the movement of the building under the effect of the dominant vertical component of the earthquake ground motion. This building is located in the area of the macroseismic epicenter, where the vertical component prevails over the horizontal one.

EARTHQUAKE DAMAGE TO BUILDINGS IN DURRËS INDUCED BY THE SEPTEMBER 21 AND NOVEMBER 26, 2019 EARTHQUAKES

September 21



The building in Durrës remained almost intact from the September earthquake.

November 26



The building suffered non-structural damage from the November earthquake including cracks in the brick wall, detachment of pieces of plaster from the wall and detachment of the brick wall from the surrounding slabs. No damage was observed in the upper level of the building. This type of damage (horizontal and no X-formed cracks) indicates the prevalence of the vertical component of the earthquake ground motion.

EARTHQUAKE DAMAGE TO BUILDINGS IN DURRËS INDUCED BY THE SEPTEMBER 21 AND NOVEMBER 26, 2019 EARTHQUAKES



Separation of brick walls from the members of the RC framing system, which is a common phenomenon due to the deformational incompatibility between the two structural elements.



Total collapse of infill and partition brick walls from the members of the RC framing system. Damage are limited to the three lower storeys of the building.

EARTHQUAKE DAMAGE TO BUILDINGS IN DURRËS INDUCED BY THE SEPTEMBER 21 AND NOVEMBER 26, 2019 EARTHQUAKES

September 21



Effect of the vertical component of the earthquake ground motion in combination with the horizontal one on brick walls on an RC cantilever.

November 26



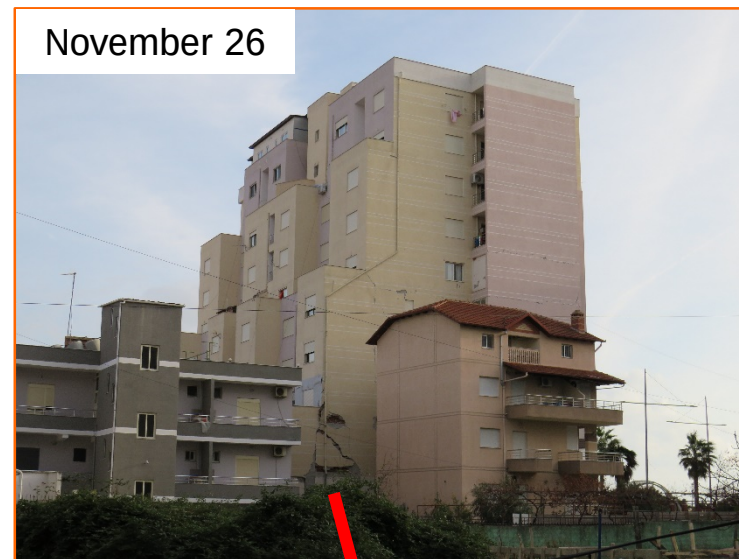
Partial collapse of the brick wall of the ground floor and light cracks.

EARTHQUAKE DAMAGE TO BUILDINGS IN DURRËS INDUCED BY THE SEPTEMBER 21 AND NOVEMBER 26, 2019 EARTHQUAKES



▲ No damage was induced to this building during the September earthquake.

► The lower floors suffered heavy damage by the November 26 earthquake including partial collapse of the brick walls at the lower floors.



EARTHQUAKE DAMAGE TO BUILDINGS IN DURRËS INDUCED BY THE SEPTEMBER 21 AND NOVEMBER 26, 2019 EARTHQUAKES

September 21



November 26



Hotel Vila Verde was founded on the coastal zone of Durrës, few meters from the sea. No damage was induced to the hotel during the September earthquake. The two lower floors totally collapsed during the November earthquake, while the structure above remained almost intact.



VERY HEAVY STRUCTURAL DAMAGE TO BUILDINGS IN DURRËS INDUCED BY THE NOVEMBER 26, 2019 EARTHQUAKE

September 21



November 26



Mira Mare hotel was founded on the coastal zone of Durrës, few meters from the sea. No damage was induced to the hotel by the September earthquake. During the November 26 earthquake, it totally collapsed.

LIQUEFACTION PHENOMENA CLOSE TO A COLLAPSE SITE



Few meters from the collapsed hotel Mira Mare, liquefaction phenomena were generated. Sand boils erupted during the earthquake from ground cracks resulting in the formation of small sand volcanoes and silt-covered pavements. The liquefaction phenomena observed in this site may contribute to the initial sinking and tilting of the building that led to its final collapse.

VERY HEAVY STRUCTURAL DAMAGE TO BUILDINGS IN DURRËS INDUCED BY THE NOVEMBER 26, 2019 EARTHQUAKE



It is significant to note that the hotel Lubjana, located few meters from Mira Mare, presented tilting that might be attributed partially to the failure of the columns of the ground floor and partially to liquefaction phenomena, but it did not collapse.

LIQUEFACTION PHENOMENA CLOSE TO A COLLAPSE SITE



Ejection of liquefied material through cracks resulting in small sand volcanoes and covered pavements. These liquefaction phenomena took place few meters away from the collapsed Mira Mare Hotel and other tilted buildings in the coastal Durrës. Small scale liquefaction phenomena were also generated in the coastal area of Durrës by the September 21, 2019 Mw 5.6 earthquake ([Lekkas et al., 2019](#), Newsletter of Environmental, Disaster, and Crises Management Strategies, Vol. 13)

LIQUEFACTION PHENOMENA AND VERY HEAVY STRUCTURAL DAMAGE



SPATIAL DISTRIBUTION AND TYPE OF THE EARTHQUAKE-INDUCED DAMAGE

As regards the distribution of earthquake-induced damage in the coastal area of Durrës, most damage were distributed in the areas north, west, east and southeast of Durrës port. These areas are composed of Pliocene clays, Holocene marshy and alluvial deposits and mixed phases of Quaternary deposits including Pleistocene formations and Holocene alluvial and marshy deposits.

The area, where three hotels suffered very heavy structural damage, is one of the most affected areas by the November 26, 2019 Mw 6.4 earthquake. Mira Mare Hotel totally collapsed, Vila Verde Hotel partially collapsed and Lubjana Hotel tilted after column collapse and probably liquefaction.

Close to the Mira Mare Hotel liquefaction phenomena were generated comprising ejection of sand through cracks, formation of small sand volcanoes and silt-covered pavements. The site with the three heavily damaged buildings is close to the sea and is composed of unconsolidated recent deposits that constitute the soft ground of the area.

The soft ground usually suffers differential displacements including subsidence among others. The multistorey buildings are trying to adapt to these displacements and restabilize. This adaptation and restabilization of the building is putting more strain on its structural and non-structural elements resulting in either slight deformation or failure of these elements. When a strong earthquake occurs in a distance from the soft ground and the multistorey buildings, then the synergy of the earthquake loading along with the local soil conditions, the shallow water table, the construction defects and the pre-existing stress of the building may result destruction. Moreover, damage from differential soil settlements are homologous to damage induced by an earthquake.

VERY HEAVY STRUCTURAL DAMAGE TO BUILDINGS IN DURRËS INDUCED BY THE NOVEMBER 26, 2019 EARTHQUAKE



A total collapse of a 5-storey building in Durrës. The short extensions of rebars in the columns of the first floor were only 30-40 cm long and adversely affected the performance of the building during the earthquake resulting in its collapse. The upper floors of the structure were overturned and crushed.

NON-STRUCTURAL AND STRUCTURAL DAMAGE TO BUILDINGS IN DURRËS ONLY LOWER FLOORS AFFECTED IN MULTISTOREY BUILDINGS



A multistorey building in Durrës with damage observed only in the three lower storeys, while the upper storeys remained intact by the earthquake. Cracking of plaster, detachment of plaster from the brick walls, cracking and partial collapse of brick walls were mainly observed. The adverse characteristics of this building comprise cylindrical and thin columns and almost triangular shape of the building in top view. Moreover, beams are totally missing, especially in the interior of the structure. This lack constitutes a rule in the affected area. The slabs are prefabricated reinforced concrete hollow core slabs with no connections between them.

NON-STRUCTURAL AND STRUCTURAL DAMAGE TO BUILDINGS IN DURRËS ONLY LOWER FLOORS AFFECTED IN MULTISTOREY BUILDINGS



A multistorey building in Durrës with damage observed only in the four lower floors, while the upper floors remained intact by the earthquake. Cracking of plaster, detachment of plaster from the brick walls, cracking and total collapse of brick walls between slabs were mainly observed. Moreover, the equipment of the apartments including furniture and electric devices among others overturned and slid. The equipment of the apartments was overturned and slid. This fact is attributed to high internal accelerations of the floors (floor accelerations). This is a rare phenomenon around the world and it is in accordance with all the seismic regulations of several countries. It is attributed to the action of a strong vertical component of the earthquake ground motion, which prevails in epicentral areas. However, this phenomenon is not rare in Greece and Italy due to the fact that most of the earthquakes that have struck these countries during the last decades have been shallow, moderate to strong seismic events with their epicenters located close to large urban areas.

NON-STRUCTURAL AND STRUCTURAL DAMAGE TO BUILDINGS IN DURRËS ONLY LOWER FLOORS AFFECTED IN MULTISTOREY BUILDINGS



A multistorey building in Durrës with damage observed only in the four lower floors, while the upper floors remained intact by the earthquake. Cracking of plaster, detachment of plaster from the brick walls, cracking and total collapse of brick walls between slabs were mainly observed. Moreover, the high plaster thickness generated sandwich walls and attracted seismic load that they could not resist.

NON-STRUCTURAL AND STRUCTURAL DAMAGE TO BUILDINGS IN DURRËS ONLY LOWER FLOORS AFFECTED IN MULTISTOREY BUILDINGS



A multistorey building in Durrës with damage observed only in the lower floors, while the upper floors remained intact. Cracking of plaster, detachment of plaster from the brick walls, cracking and total collapse of brick walls between slabs were mainly observed. Exterior non-structural walls made of hollow clay bricks outside the reinforced concrete frame suffered damage. Floor systems consist of brick units and concrete beams.



NON-STRUCTURAL AND STRUCTURAL DAMAGE TO BUILDINGS IN DURRËS ONLY LOWER FLOORS AFFECTED IN MULTISTOREY BUILDINGS



Exterior non-structural walls made of hollow clay bricks outside the reinforced concrete frame suffered damage

NON-STRUCTURAL AND STRUCTURAL DAMAGE TO BUILDINGS IN DURRËS ONLY LOWER FLOORS AFFECTED IN MULTISTOREY BUILDINGS



It is significant to note that the high-rise buildings were damaged on their lower floors. Moreover, the same floors have been destroyed, indicating high floor accelerations, which is a rare phenomenon in relation to the intact upper floors. This is probably due to the action and prevalence of a strong vertical component of the earthquake ground motion in the affected areas. In this case, due to the shallow water table, the S waves are not easily propagated, while the P waves in the water are easily propagated with very small attenuation. In addition, such buildings have large fundamental period with a high base height ratio.

COLLAPSED BUILDINGS IN DURRËS



Residential building



Hotel



The presented residential building (upper photos) and the hotel (lower photos) were among the totally collapsed buildings in Durrës. The destruction was almost complete with collapsed slabs leaving no gaps and empty spaces between them. The tangled mass of earthquake building debris reflects not only the strong seismic motion but also the poor construction of buildings and the inadequate quality of construction materials.

CONCLUSIONS

Based on the geological reconnaissance and the field macroseismic survey conducted by the authors shortly after the Mw 6.4 Durrës earthquake, the following conclusions can be drawn:

- Building damage was distributed along two ellipses, whose major axis is oriented generally NW-SE. This direction coincides with the strike of the seismogenic fault as it is derived from the fault plane solutions provided by several seismological institutes and observatories. These ellipses could be characterized as macroseismic epicenters as the result of the interaction between the seismotectonic setting and the soil conditions and as the outcome of various reflections, refractions, conventions, directivity phenomena of seismic waves and resonance resulting in destruction in the earthquake-affected area.
- Major damage was observed along the NW-SE trending eastern boundary of a sedimentary basin, which is Tirana depression. The alpine basement is composed of flysch and limestone, while the sediments comprise Miocene, Pliocene, Pleistocene and Holocene deposits. Major damage was also observed in coastal area of Durrës port city, which is mainly consist of weak and unconsolidated marshy, alluvial and coastal deposits.
- The Durrës and Thumanë areas are composed of recent unconsolidated deposits comprising Holocene alluvial, marshy and coastal deposits. The effects of the earthquake on their building stock was probably amplified by the presence of this soft soil. The amplitude of the seismic waves can increase even 4 or 5 times compared to the amplitudes that would be in the same area but with hard and consolidated soil. Moreover, due to the shallow water table in the coastal area of Durrës, the S waves are not easily propagated, while the P waves in the water are easily propagated with very small attenuation. Thus, the prevailing movement is the vertical one, while the entire soil mass is oscillating in a wider basin as a flexible geological material.

CONCLUSIONS

- The buildings in Durrës are mainly founded in recent alluvial and marshy deposits in an area where, based on the microzonation map, big deformation on free surface are expected, with predominant periods larger than 0.5-0.6 sec and seismic intensities large than IX_{MSK64} .
- The damage induced by the differential displacements and the deformation of these geological formations are similar to damage generated by earthquakes. Thus, the November earthquake hit overstrained structures not only from these differential movements but also from the September earthquake. The synergy of the soft soil along with the construction defects of the high rise building in the area and the pre-existing stress of the buildings due to their foundation in deposits suffering differential displacements resulted in destruction in the coastal area of Durrës. These structures suffer also from materials ageing processes more than those founded on hard and consolidated soil.
- Liquefaction phenomena were generated along the coastal part of Durrës city. The liquefaction included ejection of sand from ground cracks resulting in the formation of small sand volcanoes and silt-covered pavements. These phenomena were observed in an area where buildings suffered very heavy structural damage including collapse and tilting due to columns failure, while the adjacent buildings suffered non-structural damage.
- It is not the first time that the coastal part of Durrës city has suffered liquefaction. On December 27, 1926 fountains with hot water and sand, sand and mud volcanoes were generated. This area was known to be highly susceptible to liquefaction.
- The dominant buildings in the affected area are (a) buildings with load bearing solid brick walls and concrete floor slabs, (b) precast concrete panel buildings and (c) buildings with reinforced concrete frame and infill and partition walls. The main characteristic in the majority of these structures is the presence of prefabricated concrete floor slabs with width of 0.7-1.0 m and no connections between them.

CONCLUSIONS

- The buildings with load bearing brick walls and concrete floor slabs did not present serious non-structural and structural damage in Durrës city. However, buildings of this type in Thumanë suffered very heavy structural damage including partial collapse resulting in many fatalities.
- The precast concrete panel buildings did not suffer significant non-structural or structural damage by the November 26, 2019 earthquake.
- The majority of the observed reinforced concrete multistorey buildings in Durrës suffered damage to the lower three to four storeys, while the above storeys remained intact. The equipment of the apartments comprising electric devices and furniture were overturned and slid. This is attributed to the prevalence of the vertical component of the earthquake ground motion, the flexibility of the structures, the thin flat slabs, the lack of beams, the high base height ratio (h/b) and the local soft soil conditions.
- The most observed damage to reinforced concrete buildings comprised hollow clay bricks failures, detachment of plaster from the brick walls, detachment and collapse of the brick walls as well as failures of walls on cantilevers.
- The epicenter of the earthquake was located in a large distance from the affected areas. Thus, it was a slow earthquake, with long duration and large period. Its uniform character resulted in matching of the large period of the soft soil with the large period of high buildings and consequently generated large oscillations and heavy damage possible in the lower storeys of the structures.
- The totally collapsed residential buildings and hotels in Durrës city present complete destruction. The slabs collapsed forming a pancake with no gaps and empty spaces between them due to the total lack of beams. Moreover, the tangled mass of earthquake building debris reflects not only the strong seismic motion but also the poor construction of buildings, the poor workmanship and the inadequate quality of construction materials.

CONCLUSIONS

- The main factors that have affected the type and the spatial distribution of damage are the following:
 - o the soft soils in the most earthquake-affected areas, which are characterized by resonance phenomena due to long duration, very low energy loss due to relative small amplitudes of the bed rock motion,
 - o the undesired resonance phenomena in high buildings, which have large fundamental periods,
 - o the large duration of the earthquake shaking due to the large distance of the affected area from the epicenter, the high buildings and the soft soils,
 - o the shallow water table, which affect the propagation of the P and S seismic waves,
 - o the pre-existing stress of the buildings founded on soft soils that characterized by differential settlements and possible liquefaction phenomena,
 - o the poor construction quality of the affected buildings,
 - o their poor workmanship,
 - o the interventions made,
 - o the ageing of materials due to differential displacements of the foundation soil,
 - o the applicable antiseismic regulations of the time, if ever were applied,
 - o the lack of maintenance and inadequate repair after previous destructive earthquakes and
 - o the impact of the September 21, 2019 Mw 5.6 earthquake on the buildings of the affected area.
- The damage are considered typical of an earthquake of this magnitude. The effect of the previous September 21, 2019 Mw 5.6 earthquake in the same area should be also taken into account.
- Based on the seismic zonation map of Albania from the Earthquake Resistant Design Regulations, issued by the Seismic Center, Academy of Science of Albania, Department of Design, Ministry of Construction (1989), it is concluded that the resulted intensities from the earthquake under consideration, are within the limits specified in the Seismic Zonation Map.

