

EERI Annual Meeting and National Earthquake Conference, Memphis, TN
Conference Theme: Learning from the Past to Protect the Future

Technical Session on URM Performance in Recent Earthquakes

**Seismic Performance of Unreinforced Masonry
Structures in Turkey:**

**Van Earthquakes of 23 October and 9 November,
2011**

Polat Gülkan

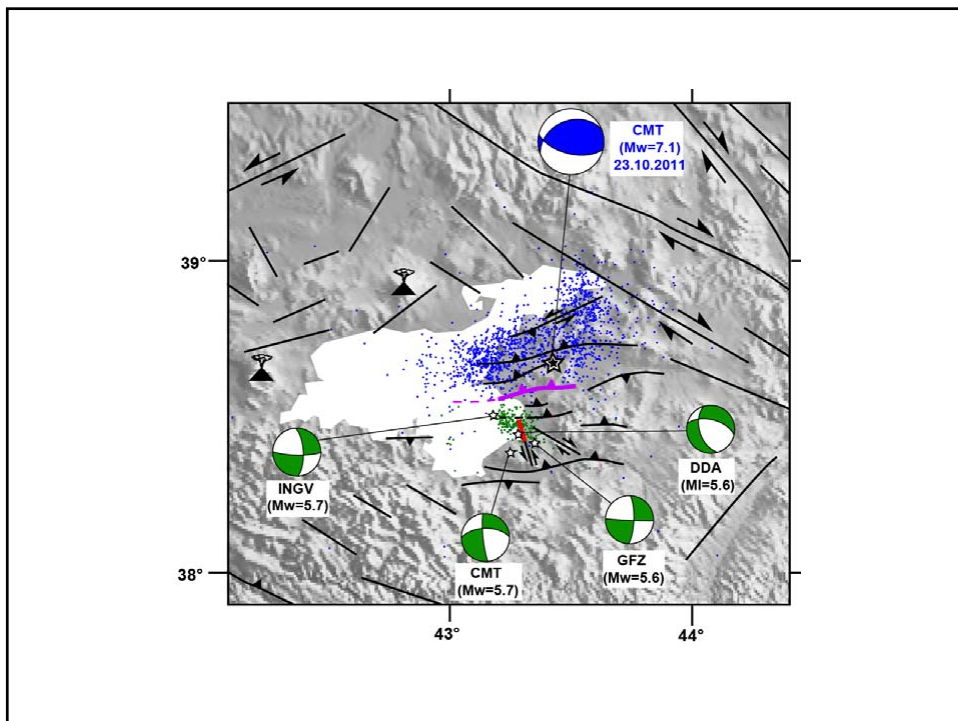
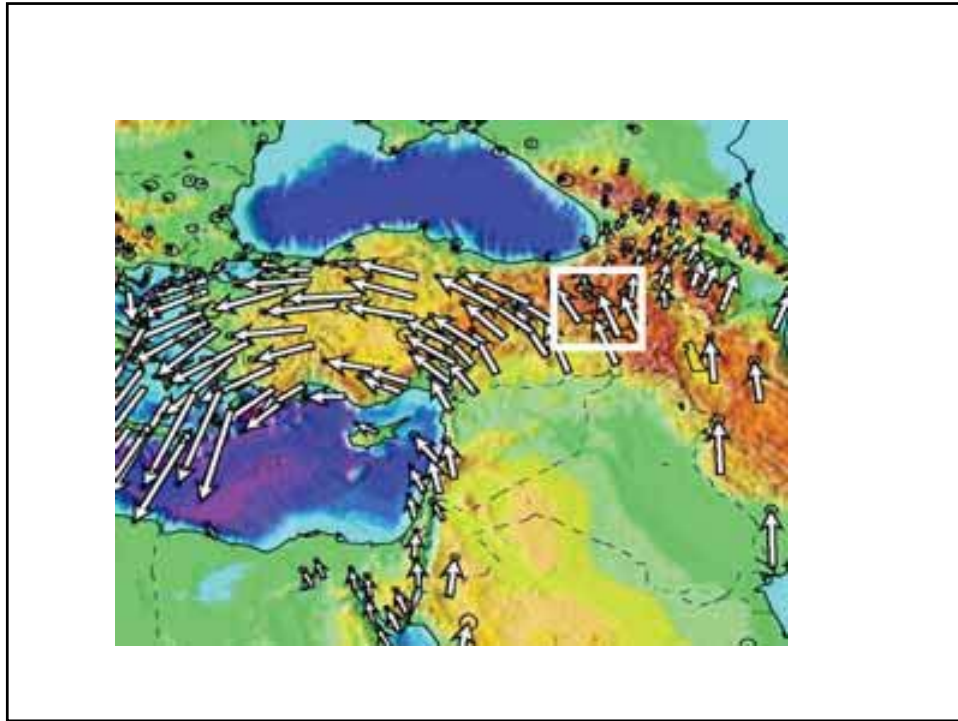
Çankaya University,
Ankara, Turkey

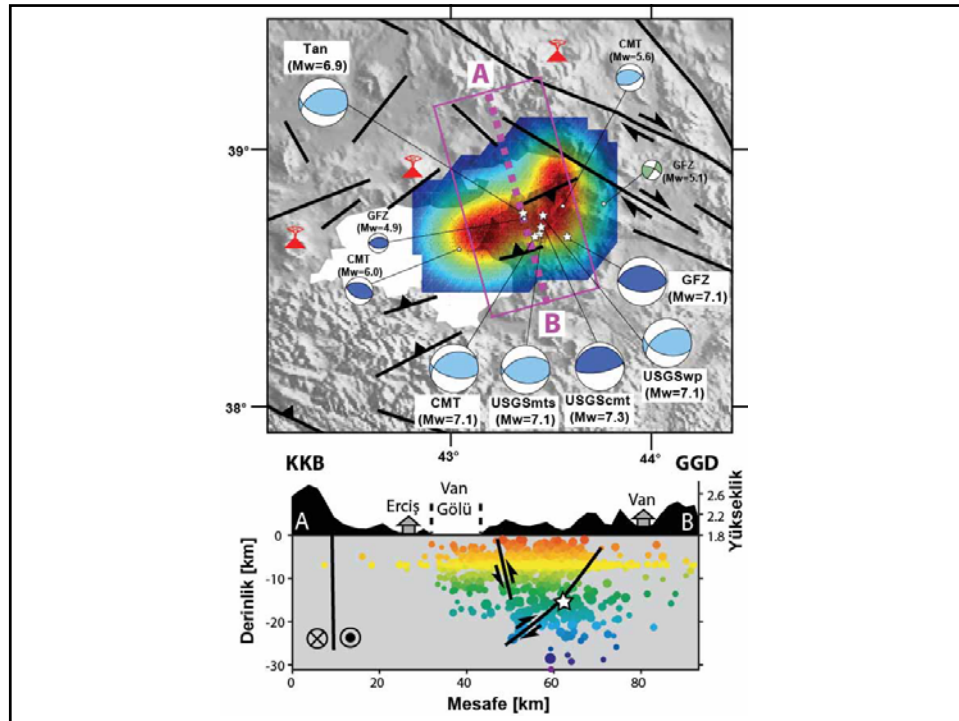
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Content

- 23 October and 9 November 2011 Van earthquakes
- General characteristics of masonry buildings in Turkey
- Examples of Turkish masonry construction
- Seismic performance of Turkish masonry buildings
- Field observations regarding masonry structures
- Conclusions

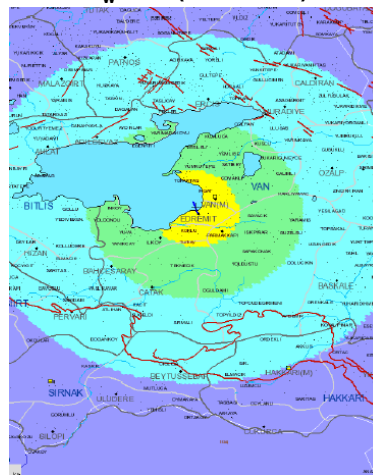
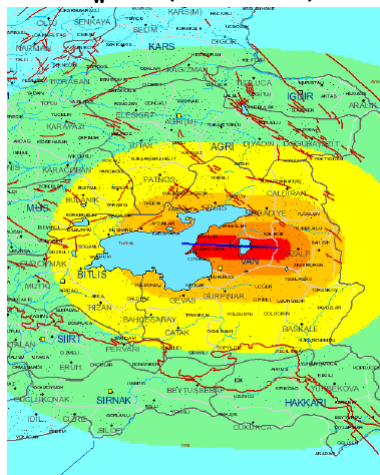




2011 Van Earthquakes: Iseismlal Maps

$M_w=7.1$ (23/10/2011)

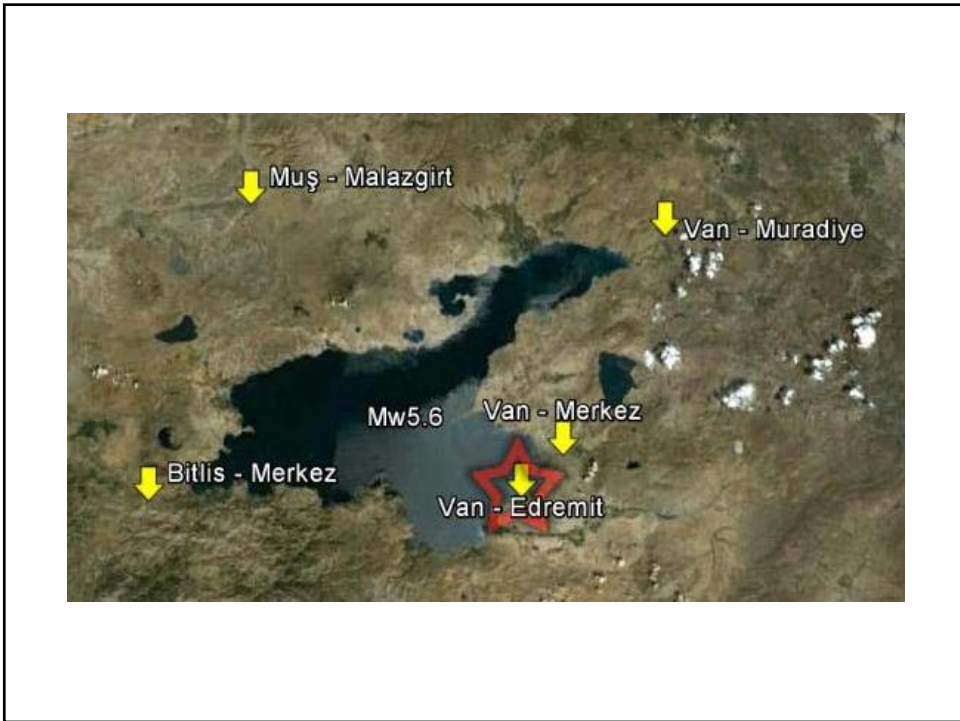
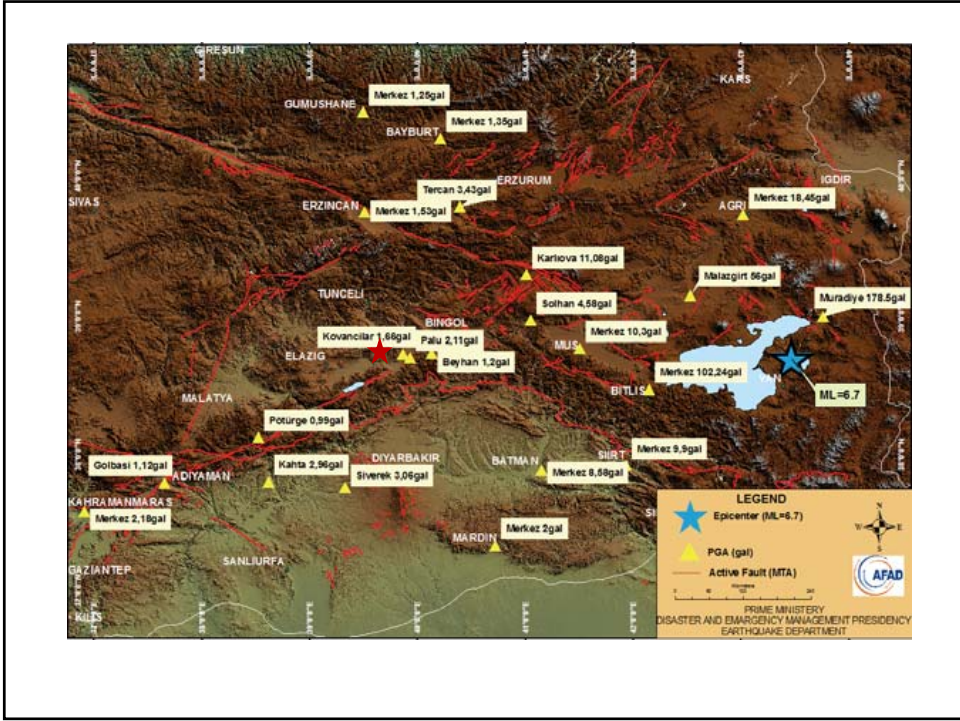
$M_w=5.7$ (9/11/2011)

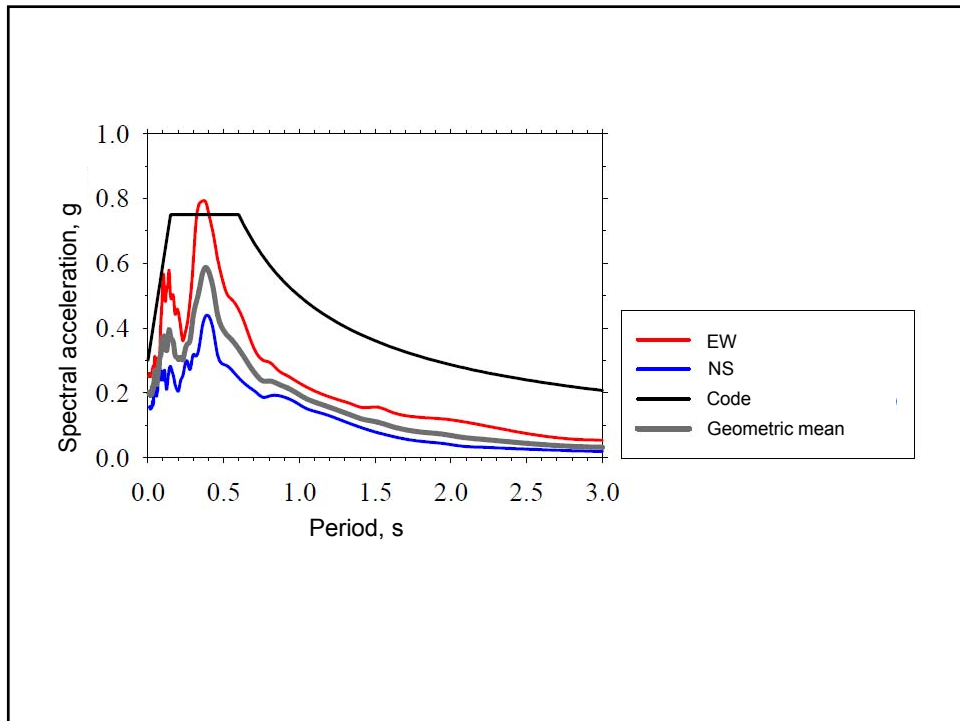
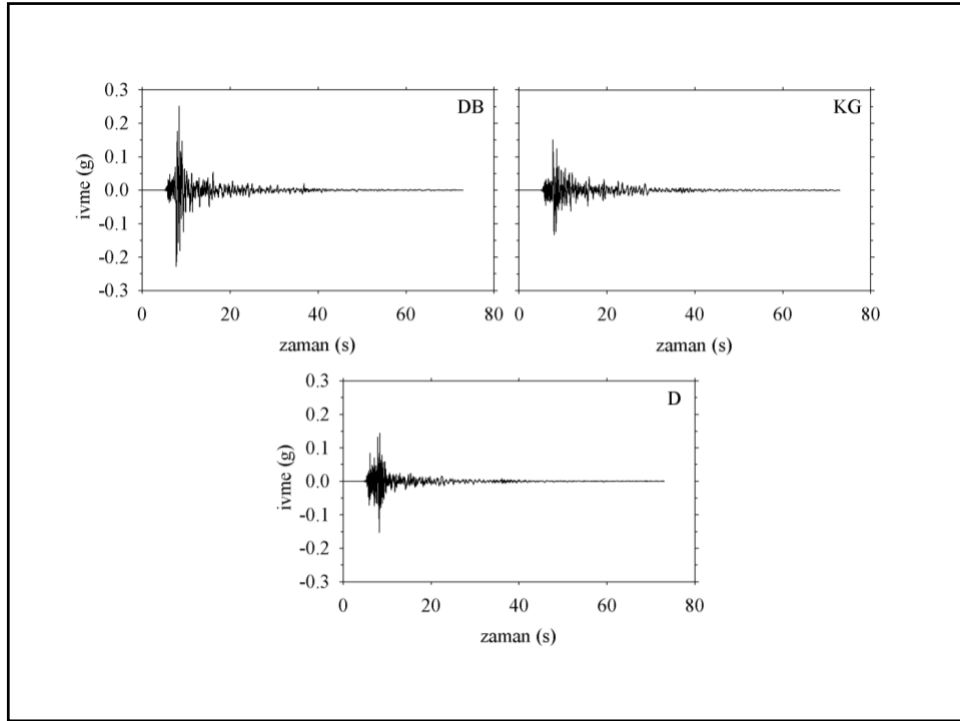


MSK Scale



Courtesy of Prime Ministry Disaster and Emergency Management Authority (AFAD)





General characteristics of masonry buildings in Turkey

- Constitute major part of the building stock, especially in small towns and rural regions of the country.
- A considerable percentage of the population lives in such buildings in earthquake prone regions.
- Constructed up to 3-4 stories and used for residential purposes in rural or urban regions.
- Solid or hollow brick, concrete masonry, stone or adobe used as the load-bearing wall material.
- Informally constructed in a traditional manner with little involvement of qualified engineers in their design and construction.

General characteristics of masonry buildings in Turkey



Generally encountered as unreinforced masonry (URM). Other types, e.g., confined masonry (CM) and reinforced masonry (RM) rarely constructed.

**Examples of Turkish Masonry Construction:
Brick Masonry (Solid Units)**



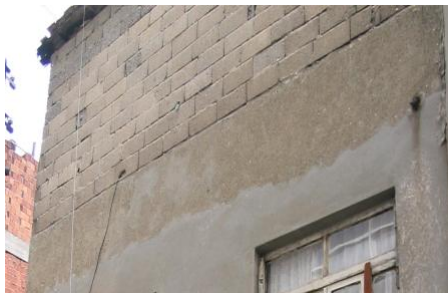
**Examples of Turkish Masonry Construction:
Perforated Brick Masonry**



**Examples of Turkish Masonry Construction:
Stone Masonry (Rural Type)**



**Examples of Turkish Masonry Construction:
Cellular Concrete Block Masonry**



**Examples of Turkish Masonry Construction:
Adobe Masonry (Rural Type)**



**Examples of Turkish Masonry Construction:
Hybrid Masonry (More Than One Type of Unit)**

Cellular Concrete Blocks



Adobe

Seismic Performance of Masonry Buildings



Significant part of structural damage and lifeloss after major earthquakes is due to the poor performance of masonry buildings.

Earthquakes with Significant Masonry Damage

- Bingöl (22/05/1971), $M_s=6.8$
- Muradiye-Çaldıran (24/11/1976), $M_s=7.3$
- Erzurum-Kars (30/10/1983), $M_s=7.1$
- Erzincan (13/3/1992), $M_s=6.9$
- Afyon-Dinar (1/10/1995), $M_L=5.9$
- Kocaeli (17/08/1999), $M_w=7.4$
- Düzce (13/10/1999), $M_w=7.1$
- Bingöl (1/5/2003), $M_w=6.4$

A Recent Moderate Earthquake (Elazığ, 2010)

- An earthquake with $M_w = 6.1$ occurred in the Elazığ region of Eastern Turkey on March 08, 2010
- 42 people lost their lives and 137 were injured during the event.
- The earthquake caused major structural damage in few villages where all the fatalities were reported after the earthquake.
- Most of the severely damaged or collapsed structures are rural type stone or adobe masonry buildings.

A Recent Moderate Earthquake (Elazığ, 2010)



Courtesy of METU EERC

A Recent Moderate Earthquake (Elazığ, 2010)



Courtesy of METU EERC

A Recent Moderate Earthquake (Elazığ, 2010)

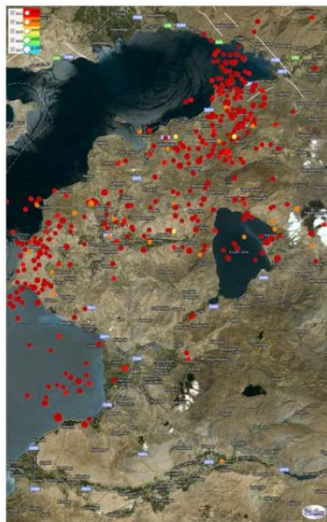


Courtesy of METU EERC

2011 Van Earthquakes

- Van (a city in Eastern Turkey) was hit by a $M_w=7.1$ earthquake on October 23, 2011.
- More than 600 people lost their lives and about 4,200 were reported injured during the event.
- As reported by Prime Ministry AFAD, 2,250 residential units collapsed during the earthquake. Another 5,700 were severely damaged.
- A second earthquake of magnitude $M_w=5.7$ struck south of the city on November 9, 2011 and caused the collapse of some previously damaged buildings
- During the second earthquake 25 further buildings collapsed, killing 40 people, including press and rescue team members.

2011 Van Earthquakes: field survey by METU teams



Epicenters of aftershocks for M7.1 earthquake in the first two weeks (courtesy of Kandilli NEMC)



Visited villages during field survey (courtesy of METU-EERC)

Field Observations on Masonry Structures

Owner-built, non-engineered and traditional construction



Courtesy of METU EERC

Field Observations on Masonry Structures

Owner-built, non-engineered and traditional construction



Courtesy of METU EERC

Field Observations on Masonry Structures

The basic rules of earthquake resistant design are ignored. Articles of the Earthquake Code are based on empirical approach with simple geometrical limitations and stress checks.



Courtesy of METU EERC

Field Observations on Masonry Structures

The use of low-strength masonry units (adobe, rubble stone, etc.) due to socio-economic and weather conditions of the region



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Courtesy of METU EERC

Field Observations on Masonry Structures

The use of mud mortar (in some cases even no mortar!) with low strength and poor bonding characteristics



Courtesy of METU EERC

Field Observations on Masonry Structures

Poor wall-to-wall and wall-to-floor connections, that prevent box-like behavior of the structure.



Courtesy of METU EERC

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Field Observations on Masonry Structures

Poor wall-to-wall and wall-to-floor connections, that prevent box-like behavior of the structure.



Courtesy of METU EERC

Field Observations on Masonry Structures

Flexible floor diaphragm, which prevents the transfer and distribution of lateral forces in a uniform manner.



Courtesy of METU EERC

Field Observations on Masonry Structures

Flexible floor diaphragm, which prevents the transfer and distribution of lateral forces in a uniform manner.



Courtesy of METU EERC

Field Observations on Masonry Structures

The use of different masonry wall materials in the same building, at the same floor and even at the same wall.



Courtesy of METU EERC

Field Observations on Masonry Structures

Inadequate amount of load-bearing walls, which causes high shear stresses during ground shaking.



Courtesy of METU EERC

Field Observations on Masonry Structures

Improper placement of door and window openings in walls, which creates vulnerable and weak zones in the structure.



Courtesy of METU EERC

Field Observations on Masonry Structures

Poor workmanship, which impairs the integrity and capacity of load bearing walls, and in turn whole the structure.



Courtesy of METU EERC

Field Observations on Masonry Structures

Poor workmanship, which impairs the integrity and capacity of load bearing walls, and in turn whole the structure.



Courtesy of METU EERC

Field Observations on Masonry Structures

Absence of horizontal bond beams to transfer of earthquake induced loads through the walls to the foundation



Courtesy of METU EERC

Field Observations on Masonry Structures

Absence of horizontal bond beams to transfer of earthquake induced loads through the walls to the foundation



Courtesy of METU EERC

Field Observations on Masonry Structures

Heavy earthen roofs, which increase the death toll during ground shaking since such type of roofs collapse inwards



Courtesy of METU EERC



Historic Tombs

1976



2011



Conclusions

- Due to the structural deficiencies listed above, masonry buildings in rural areas suffer damage even under moderate earthquakes. The 2011 Van earthquakes are no exceptions to this established fact.
- A large number of masonry structures were affected by the 23 October earthquake, especially the ones in rural regions.
- Devastating and wide spread damage (80%-90% of the buildings) was observed in some of the villages close to the epicenter and in the vicinity of the fault rupture.
- Since the 23 October earthquake occurred at noon on a sunny and warm Sunday, the death toll is not proportional to the extensive structural damage observed.

Conclusions

- The 9 November earthquake was a moderate one, but it caused the collapse of many severely damaged masonry buildings in towns and villages. Fortunately, there were no casualties in them because the buildings were mostly derelict.
- The governing type of damage was observed to be out-of-plane failure of walls due to aforementioned deficiencies (poor connections, low-strength material properties, poor workmanship, flexible floor diaphragms).
- The performance of masonry buildings during the 2011 earthquakes revealed that not many lessons had been learned in the last few decades regarding the implementation of earthquake resistant construction principles.

