NARLabs 國家實驗研究院
國家地震工程研究中心
NCREE National Center for Research on Earthquake Engineering

2023-02-06土耳其地震事件彙整報告
(Version 3.0)

國家地震工程研究中心

周中哲、吳俊霖、柴駿甫、姚昭智

2023/02/14

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林瑞良、紀凱甯

橋梁組

葉芳耀

簡述

- 土耳其當地時間2023年2月6日 4時17分35秒（UTC+3），臺灣時間2023年2月6日 9時17分35秒（UTC+8），土耳其加濟安泰普省(Gaziantep) 努爾達伊鎮 (Nurdağı) 東方26.2公里處，發生規模Mw 7.8之淺源地震。不幸的是於土耳其當地時間2月6日 13時24分49秒，於Mw 7.8地震震央北北西方向約85公里處，發生規模Mw 7.5之地震。 同日發生的Mw 7.8與Mw 7.5兩個地震釀成巨災重創土耳其與敘利亞，截至目前已有超過34,000人不幸罹難。
- 在Mw 7.8地震發生後，國家地震工程研究中心(簡稱國震中心)周中哲主任帶領團隊旋即啟動災情評估與彙整工作，並持續關注後續Mw 7.5地震的影響與災情狀況，國震中心團隊對2023-02-06土耳其地震事件(Mw 7.8與Mw 7.5地震)製作彙整報告，經由第一版與第二版報告的內部討論後，持續追蹤地震成因與蒐集災情，並對建築物與橋梁結構就土耳其以往的地震所見之破壞機制進行調研以及初步評析，相關成果彙整為此報告(第三版)經由中心官網公告，於2023-02-14對外發布。

報告大綱

- 地震資訊
- 媒體報導
- 大地災情資料
- 建物災情與歷史震損資料
- 橋梁災情與歷史震損資料
- 後續工作

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2023-02-06 土耳其地震 Mw 7.8

- 臺灣時間2023年2月6日09時17分35秒（UTC+8），土耳其當地時間2023年2月6日04時17分35秒（UTC+3），加濟安泰普省(Gaziantep)努爾達伊鎮(Nurdağı)東方26.2公里處，發生規模Mw 7.8之淺源地震。
- 震央位置為北緯37.174度、東經37.032度，震源深度為17.9公里。距離人口達一百萬之大城市加濟安泰普（Gaziantep）約33.6公里。

Nearby Places

Nurdağı, Gaziantep, Turkey 26.2 km (16.3 mi) W	Population: 12827
Gaziantep, Gaziantep, Turkey 33.6 km (20.9 mi) ESE	Population: 1065975
Bahçe, Adana, Turkey 40.4 km (25.1 mi) W	Population: 19566
Pazarcık, Kahramanmaraş, Turke 42.1 km (26.2 mi) NE	Population: 23850

資料來源:USGS

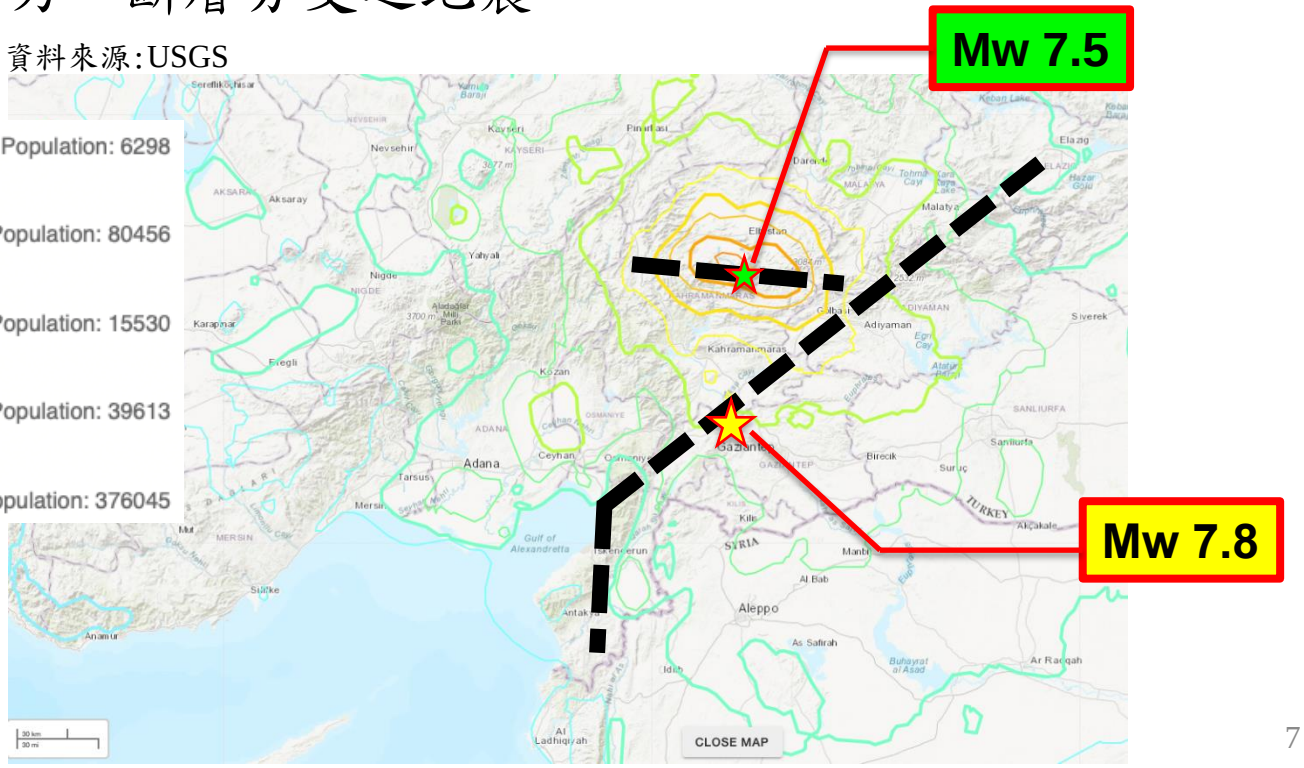
2023-02-06 土耳其地震 Mw 7.5

- Mw 7.8地震後約9小時，於臺灣時間2023年2月6日18時24分49秒（當地時間2月6日13時24分49秒），於Mw 7.8地震震央北北東方向約85公里處，發生規模Mw 7.5之地震。
- 位置為北緯38.024度、東經37.203度，震源深度為10公里。根據USGS提供初步震源機制解及有限斷層面解，研判此地震(Mw 7.5)應為Mw 7.8地震觸發另一斷層分支之地震。

資料來源:USGS

Nearby Places

Ekinözü, Kahramanmaraş, Turkey 4.2 km (2.6 mi) NNW	Population: 6298
Elbistan, Kahramanmaraş, Turkey 20.3 km (12.6 mi) N	Population: 80456
Çağlayancerit, Kahramanmaraş, Turkey 31.8 km (19.8 mi) SSE	Population: 15530
Afşin, Kahramanmaraş, Turkey 35.5 km (22.1 mi) NW	Population: 39613
Kahramanmaraş, Kahramanmaraş, Turkey 54.5 km (33.9 mi) SSW	Population: 376045

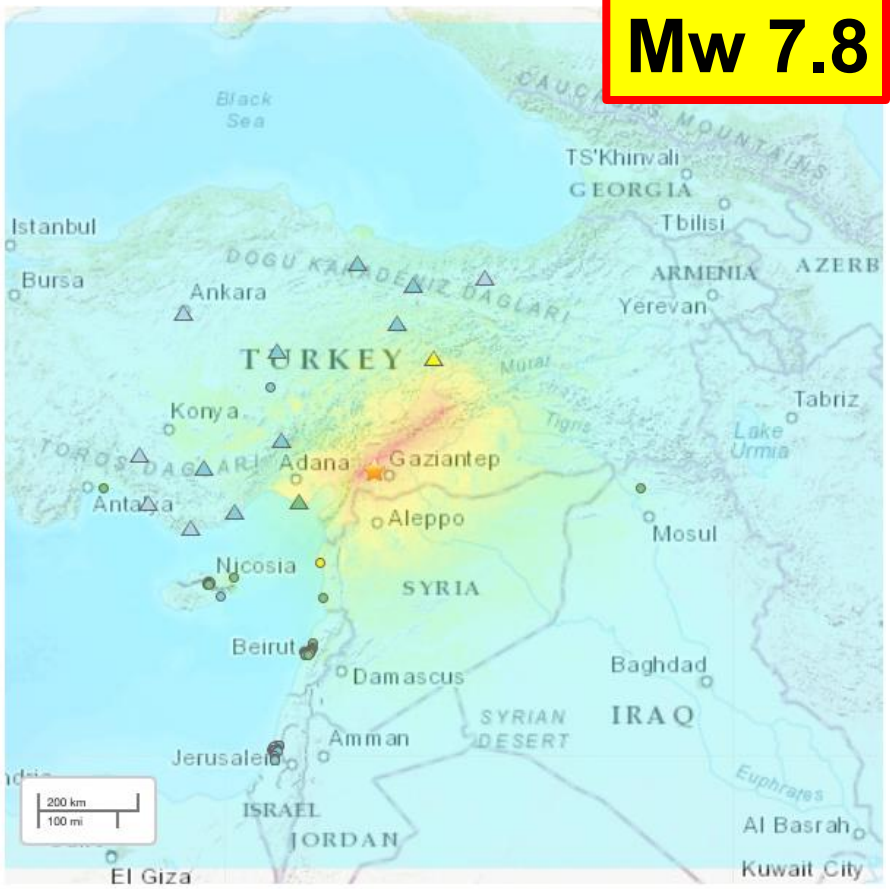


參考斷層跡線為USGS快速有限斷層解Version 1所提供，僅為參考。

查閱時間：臺灣時間2月13日10:00

Mw 7.8地震等震度圖

- USGS目前震央附近最近之地震測站收錄之觀測震度為MMI震度（Modified Mercalli Intensity）5.7級，距離約100 km，其大範圍格點化震度由地震動衰減式推估最大達到MMI震度9.02級，PGA約0.68 g、PGV約118.2 cm/s、0.3秒PSA約1.63 g、1秒PSA約1.11 g。
- 截至世界時間(UTC)2月6日10:00為止，由體感回報系統（Did you feel it），其最大震度（189公里遠）之回報為MMI 5.6級。



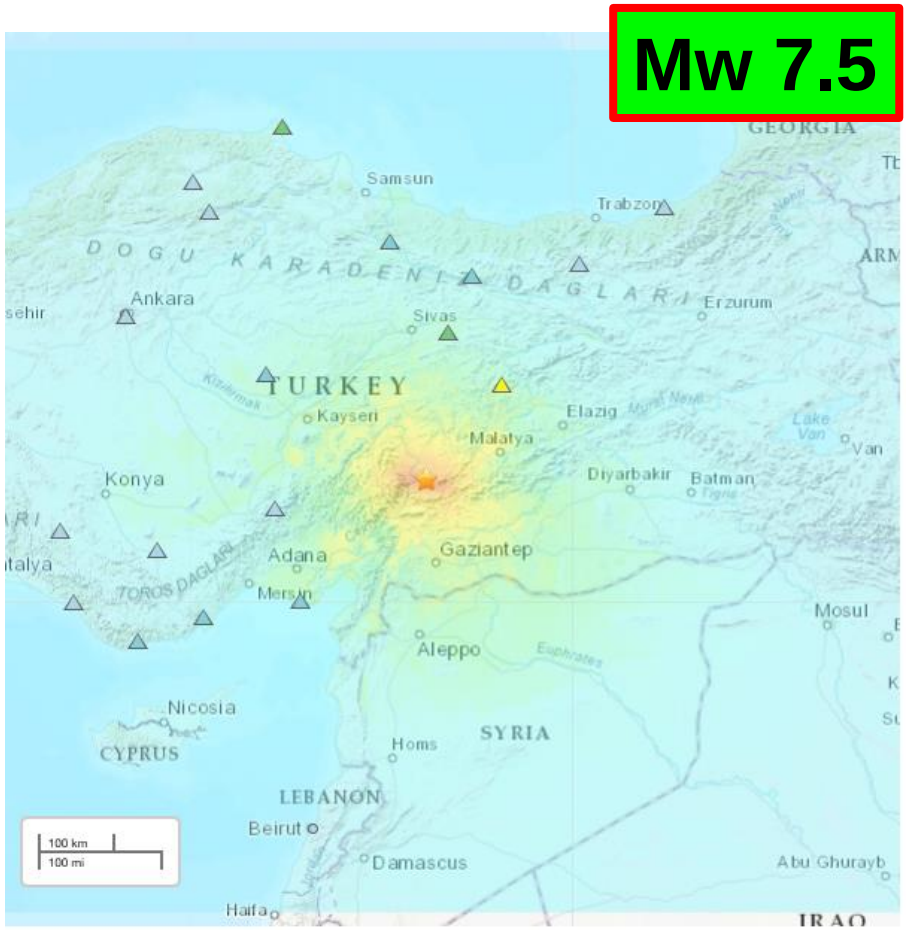
SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
DAMAGE	None	None	None	Very light	Light	Moderate	Moderate/heavy	Heavy	Very heavy
PGA(%g)	<0.0464	0.297	2.76	6.2	11.5	21.5	40.1	74.7	>139
PGV(cm/s)	<0.0215	0.135	1.41	4.65	9.64	20	41.4	85.8	>178
INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Scale based on Worden et al. (2012) Version 5: Processed 2023-02-06T05:11:59Z
△ Seismic Instrument ○ Reported Intensity ★ Epicenter ▭ Rupture

資料來源:USGS

Mw 7.5地震等震度圖

- USGS目前震央附近最近之地震測站收錄之觀測震度為MMI震度（Modified Mercalli Intensity）5.9級，距離約144 km，其大範圍格點化震度由地震動衰減式推估最大達到MMI震度8.64級，PGA約0.68 g、PGV約89.2 cm/s、0.3秒PSA約1.53 g、1秒PSA約0.76 g。
- 對比於Mw 7.8之地震，Mw 7.5地震之短週期震度為接近、長週期震度則較低。



SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
DAMAGE	None	None	None	Very light	Light	Moderate	Moderate/heavy	Heavy	Very heavy
PGA(%g)	<0.0464	0.297	2.76	6.2	11.5	21.5	40.1	74.7	>139
PGV(cm/s)	<0.0215	0.135	1.41	4.65	9.64	20	41.4	85.8	>178
INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Scale based on Worden et al. (2012) Version 5: Processed 2023-02-06T20:29:54Z

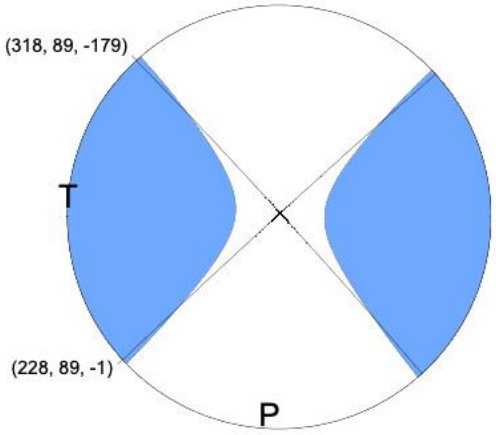
△ Seismic Instrument ○ Reported Intensity ★ Epicenter ▭ Rupture

資料來源:USGS

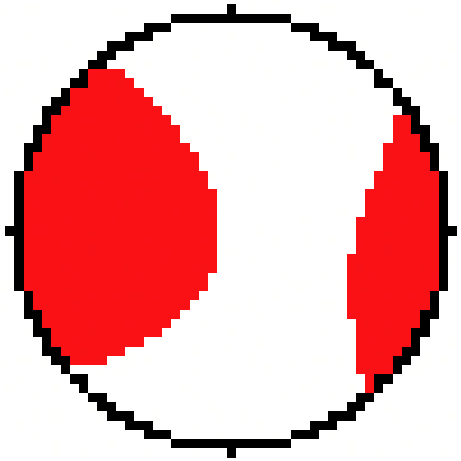
Mw 7.8地震震源機制解

- USGS所公佈之震源機制解算結果(W-phase and Centroid Moment Tensor)，顯示此次地震震源破裂形式屬走向滑移之斷層型態。
- 由GCMT及IRIS提供之震源機制解相互間較相近，與USGS解算之結果比較更為偏逆斷層分量，整體之斷層機制仍為走向滑移斷層。

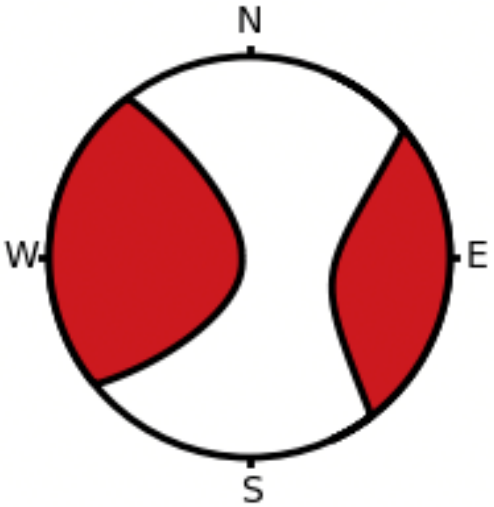
Mw 7.8



(USGS)



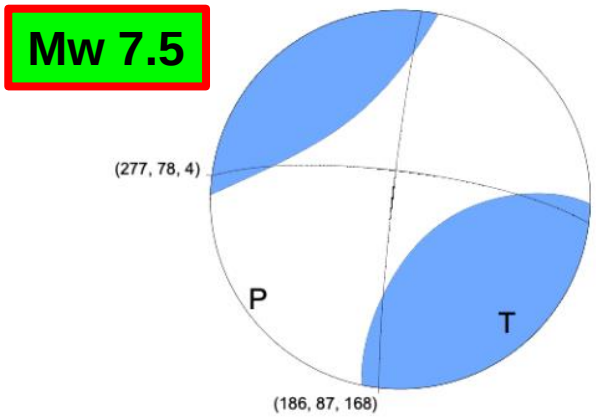
(GCMT)



(IRIS)

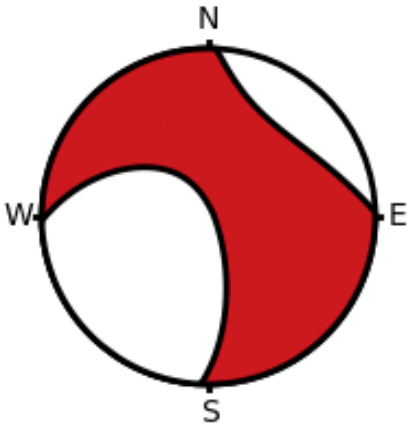
Mw 7.5地震震源機制解

- USGS所公佈之震源機制解算結果(W-phase and Centroid Moment Tensor)，顯示此次地震震源破裂形式屬走向滑移之斷層型態。
- 由GCMT及IRIS提供之震源機制解相互間較相近，與USGS解算之結果具明顯差異，其中，由USGS有限斷層解之偏東西向走向來看，USGS所解之斷層傾角較接近垂直（Dip 78度）其餘二單位傾角則較緩（Dip 42度），此差異可能為缺乏近震源紀錄控制或缺乏部分方位角之紀錄所致，整體而言此三單位之解之共同處為此地震仍為走向滑移斷層型態（Rake角接近0度）。



(USGS)

(GCMT)



(IRIS)

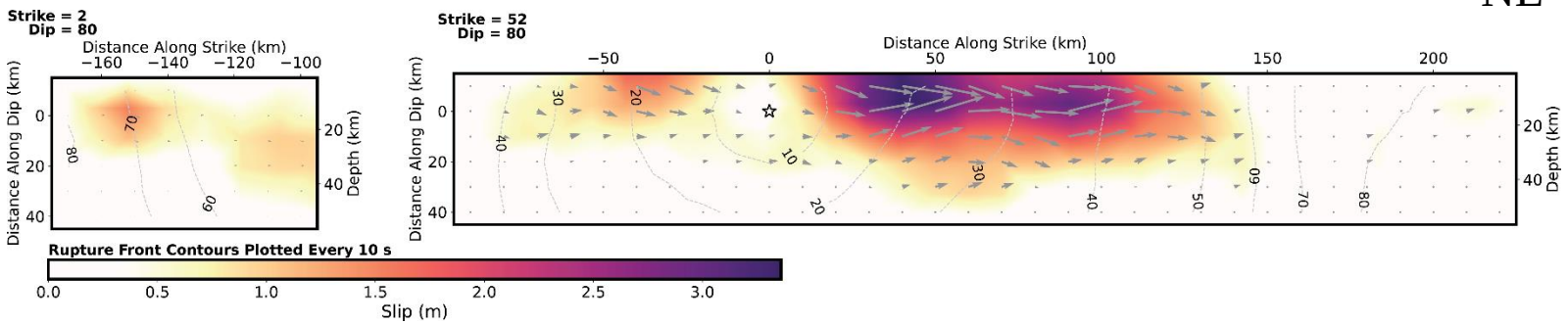
有限斷層解

- 由USGS之快速有限斷層解可得Mw 7.8地震之斷層走向為第一段東北-西南向，及第二段接近南北向，而其後發生之Mw 7.5之走向為接近西北西-東南東走向，推測為觸發另一斷層分支之地震，Mw 7.8地震之斷層面快速解根據已知之構造分段並轉彎改變其走向。

Mw 7.8

SW Direction

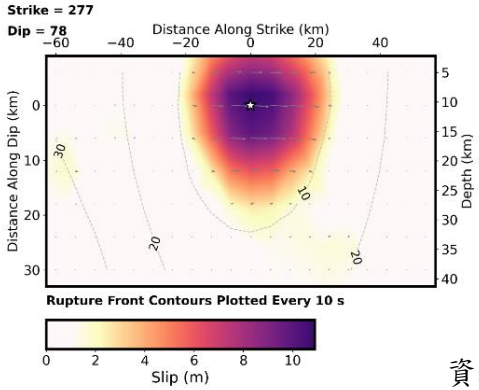
NE



Mw 7.5

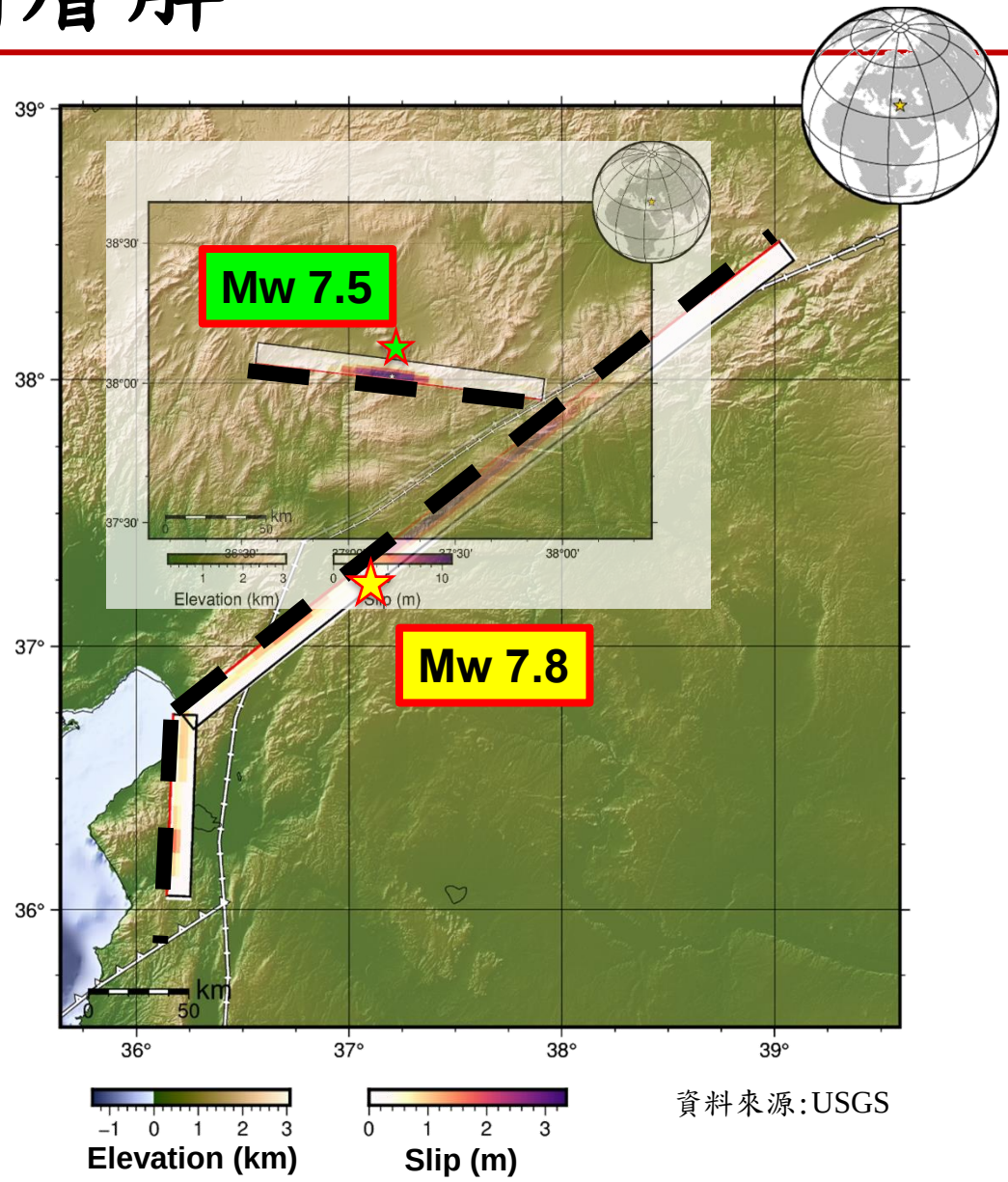
ESE Direction

WNW



資料來源:USGS

有限斷層解

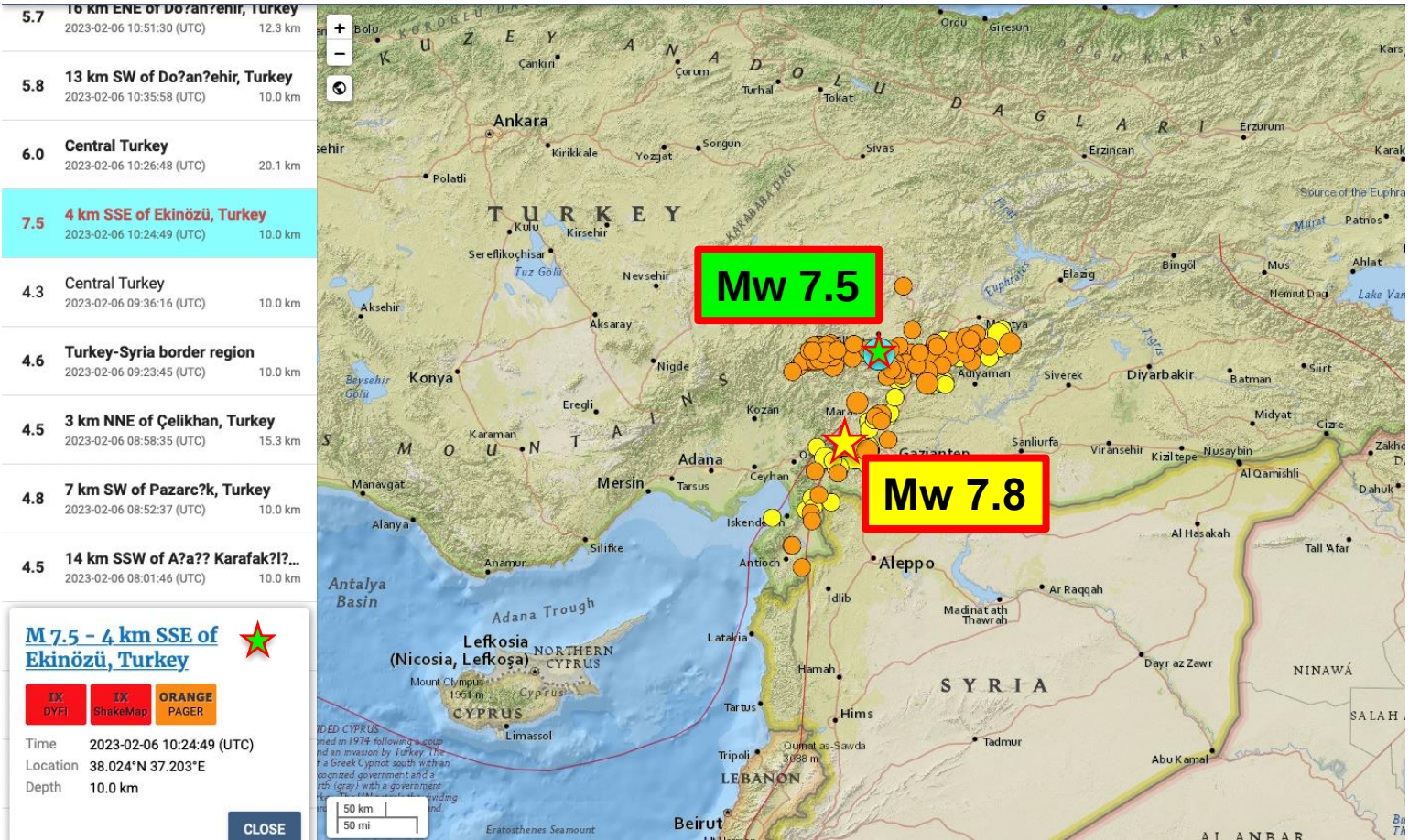


資料來源:USGS

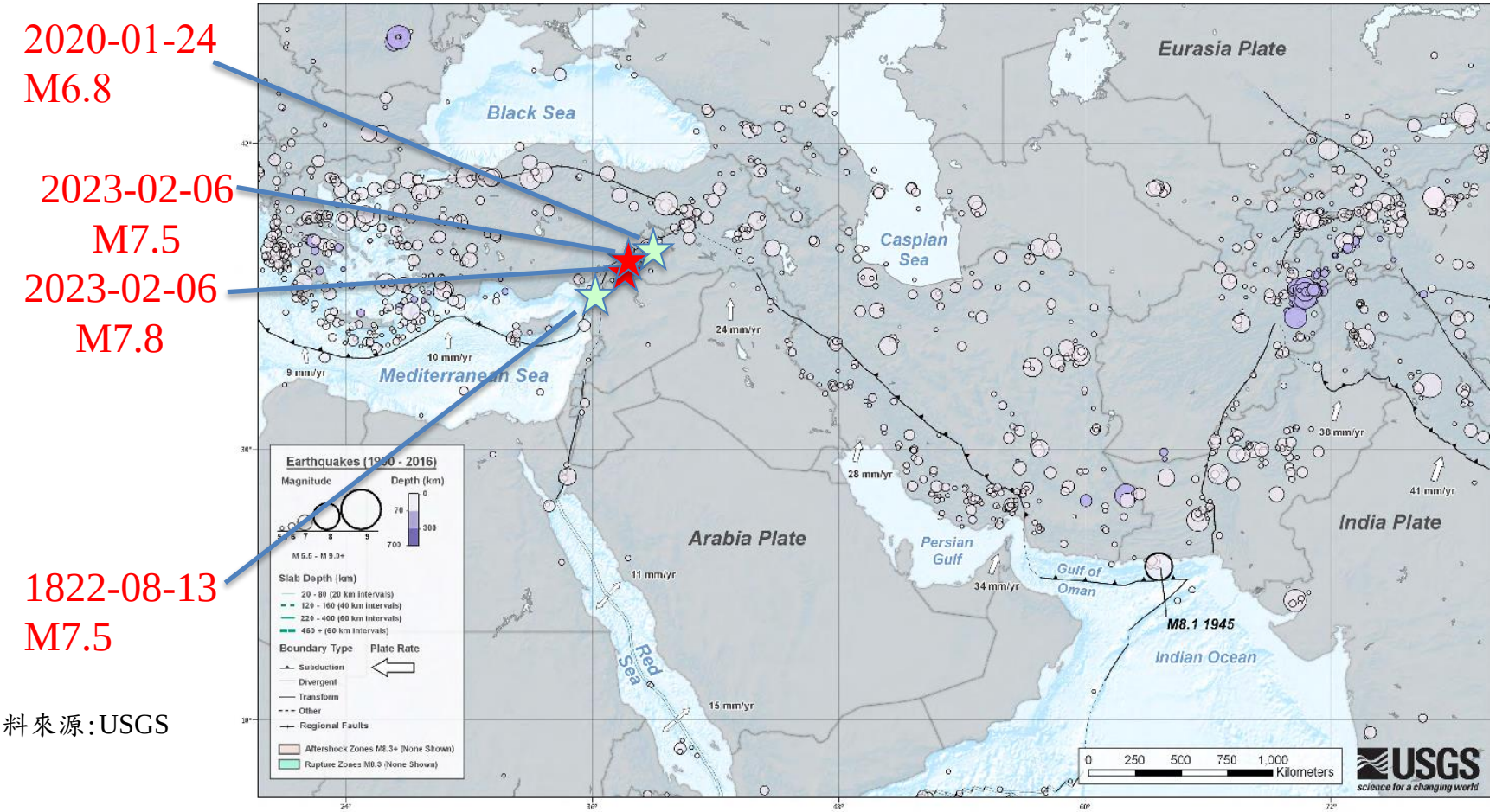
Mw 7.8與Mw 7.5地震餘震活動

- 截至世界時間2月13日10:00為止，USGS發佈之Mw 7.8與Mw 7.5兩地震餘震共有199筆(M 2.5+)，最大餘震規模分別為Mw 6.7及Mw 6.0，由此些地震序列可見明顯之兩條發震斷層系統。

資料來源:USGS



鄰近震央之歷史地震及構造活動



資料來源:USGS

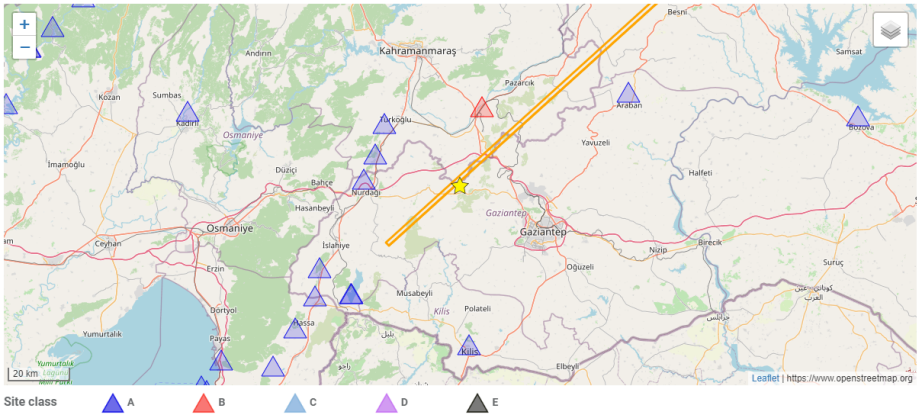
土耳其努爾達伊區域位於南側阿拉伯板塊（Arabia Plate）及北側安納托利亞板塊（Anatolia Plate）的交界帶，主要受東安納托利亞斷層作用影響，由其南部主控為走向滑移之死海轉型斷層系統往北延伸連結，鄰近區域於歷史上曾產生最大規模7.5之地震，值得注意的是，此斷層系統於本次地震之東側曾於2020年發生規模6.8之地震，可能與本次地震有關。

ESM Database歷時紀錄

ESM, the Engineering Strong-Motion Database, provides a set of facilities to search, select, download and analyse ground-motion data and associated metadata. The waveforms contained in ESM are relative to events with magnitude ≥ 4.0, mainly recorded in the European-Mediterranean regions and the Middle-East.

ESM ID INT-20230206_0000008
EMSC ID 20230206_0000008
ISC ID 625613033
INGV ID 34068041
USGS ID us6000jllz
Country Turkey
Region
Municipality Yamaçoba

震源資料(from ESM database)
Country: Turkey
Date: 2023-02-06 01:17:36 (UTC)
Magnitude: Mw 7.8
Depth: 20km
Style of faulting: Strike-slip faulting



Origin

	Date	Latitude [°]	Longitude [°]	Depth [Km]	Reference	Location
★	2023-02-06 01:17:36	37.170	37.080	20.0	EMSC-CSEM	No Information
☆	2023-02-06 01:17:35	37.174	37.032	17.9	USGS-webservice	No Information
☆	2023-02-06 01:17:34	37.200	37.130		ISC-webservice	No Information
☆	2023-02-06 01:17:36	37.202	37.064	19.5	SURVEY-INGV	No Information

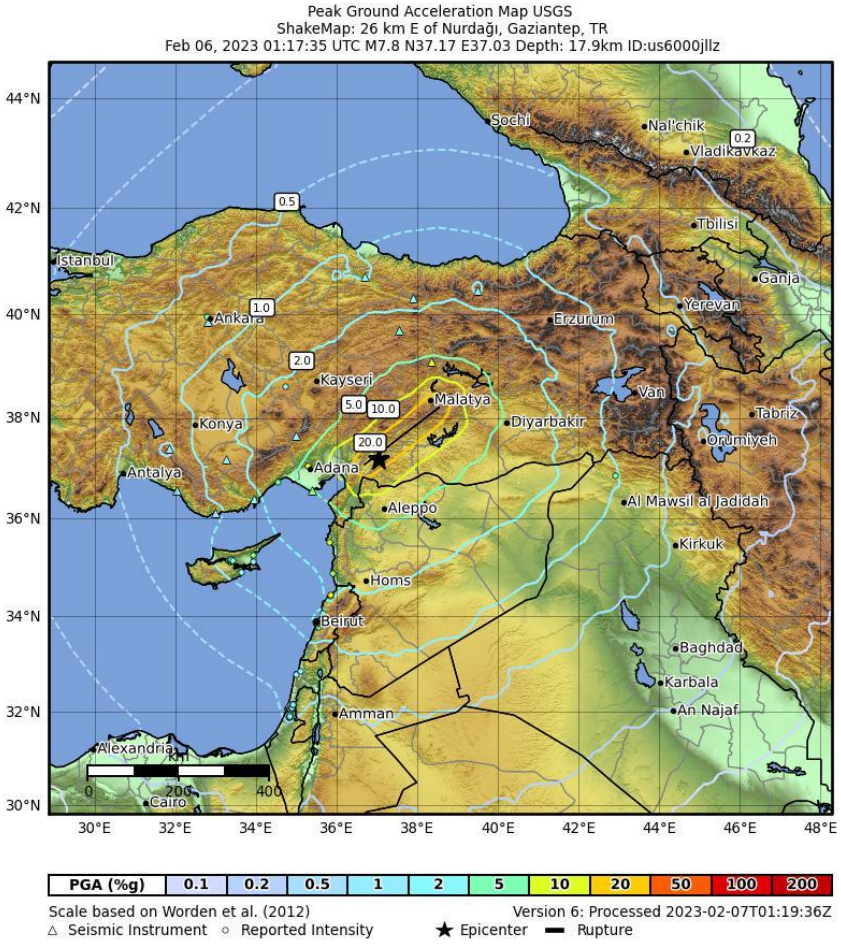
Magnitude

	Value	Type	Method	Reference
☆	7.8	Mw	Mw from USGS	USGS-webservice
★	7.8	Mw	unknown	EMSC-CSEM
☆	7.6	Mw	unknown	ISC-webservice
★	7.9	M	unknown	INGV-TERREMOTI

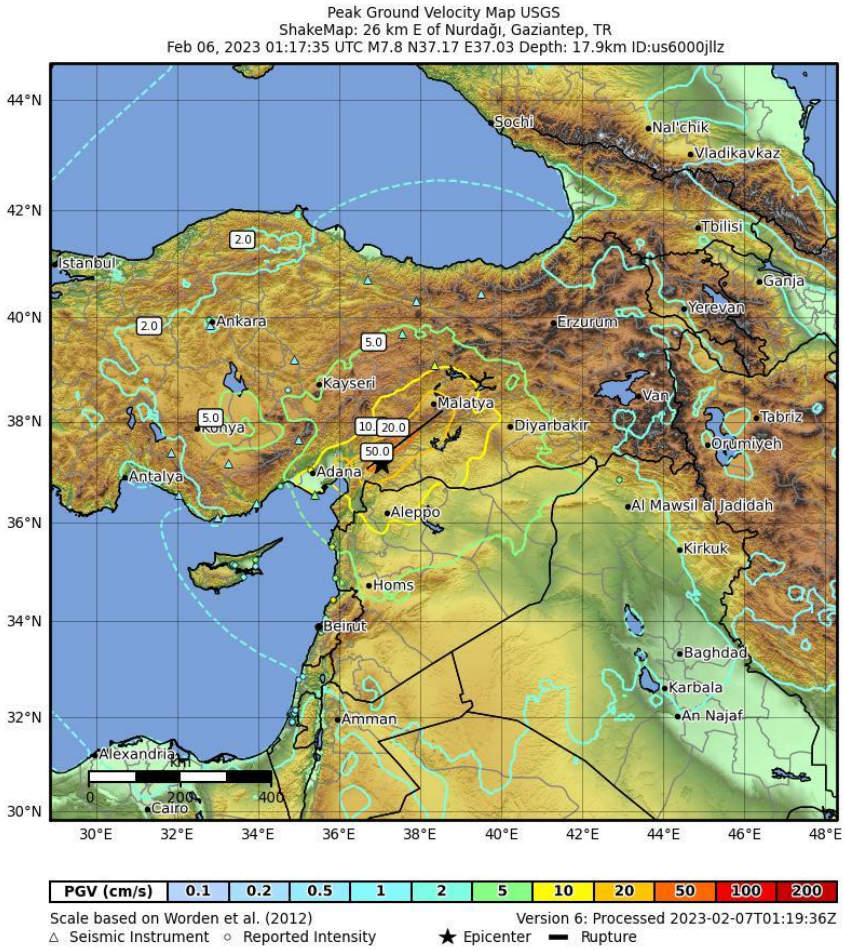
資料來源：https://esm-db.eu/#/event/INT-20230206_0000008

Mw 7.8 地震Shake Map

PGA



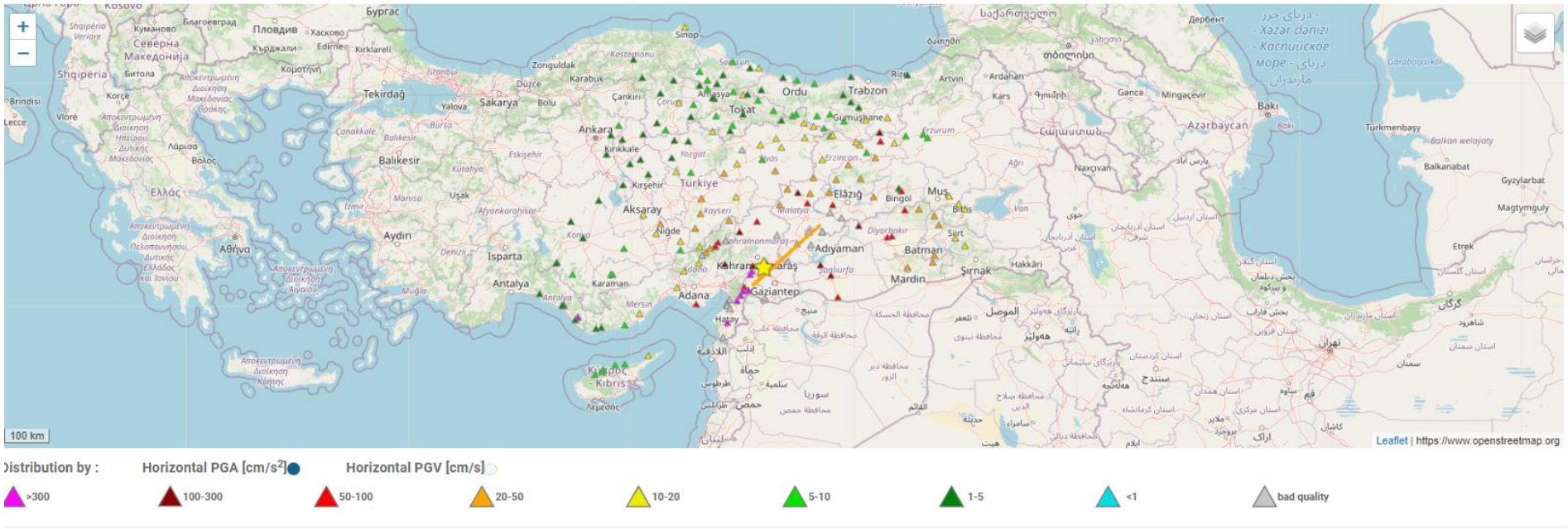
PGV



資料來源：https://esm-db.eu/#/event/INT-20230206_0000008

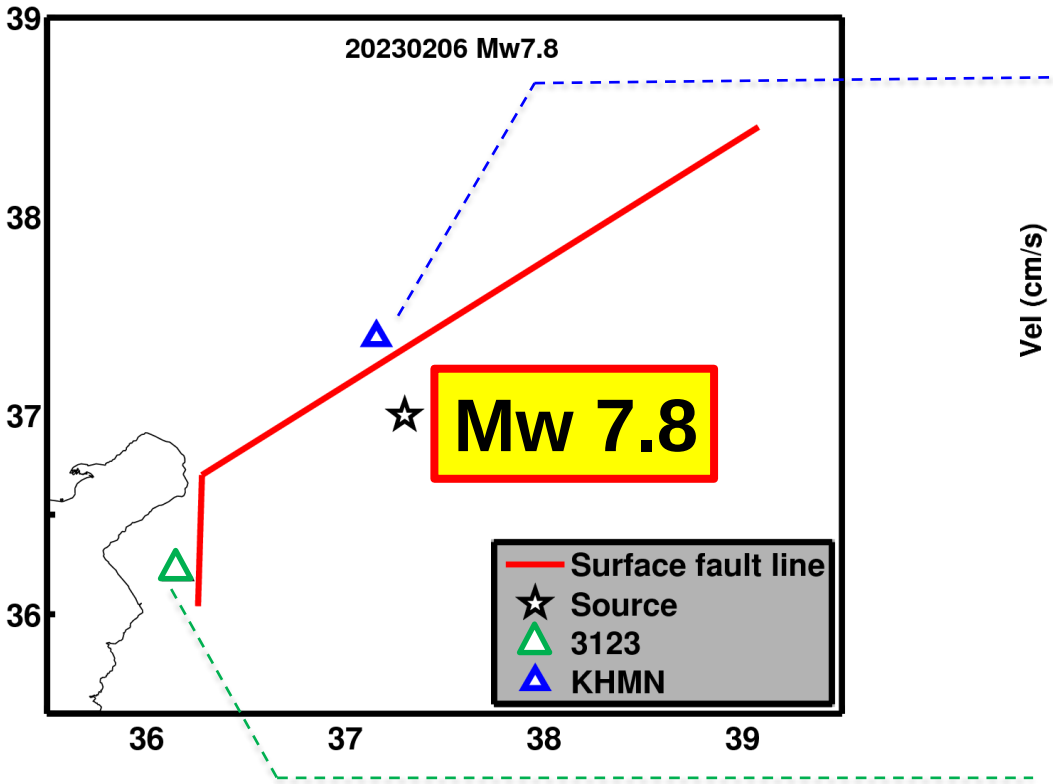
測站分布

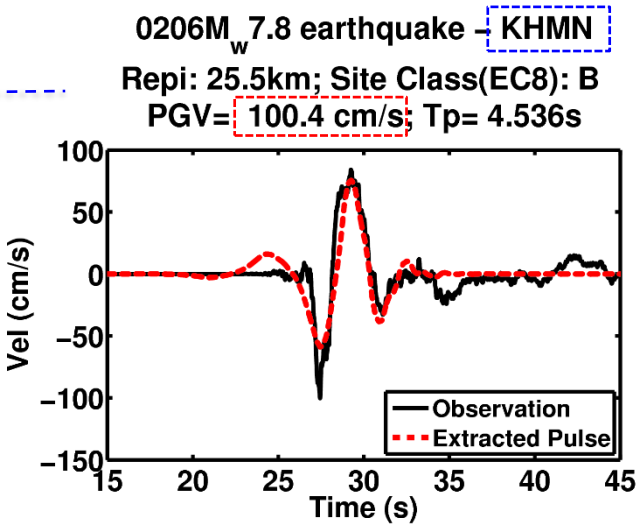
資料來源：ESM Database

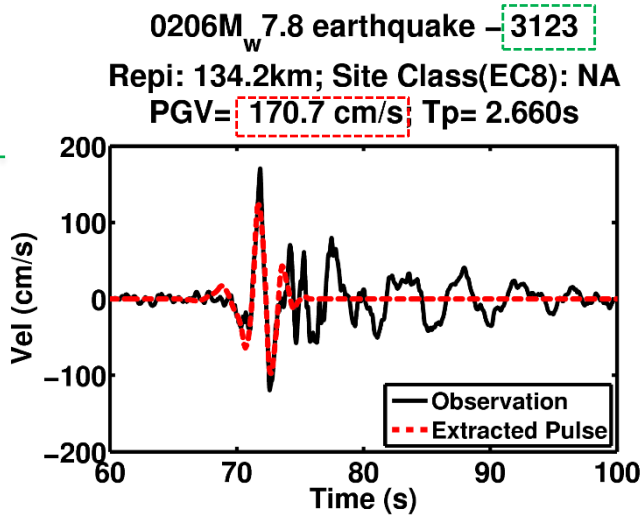


https://esm-db.eu/#/event/INT-20230206_0000008

Mw 7.8地震具近斷層效應之地震歷時



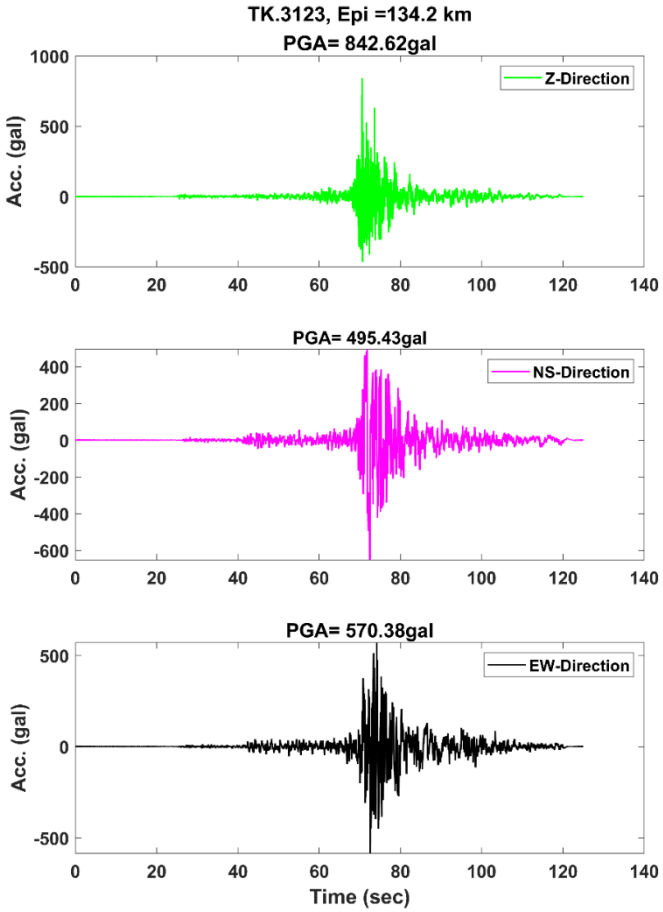


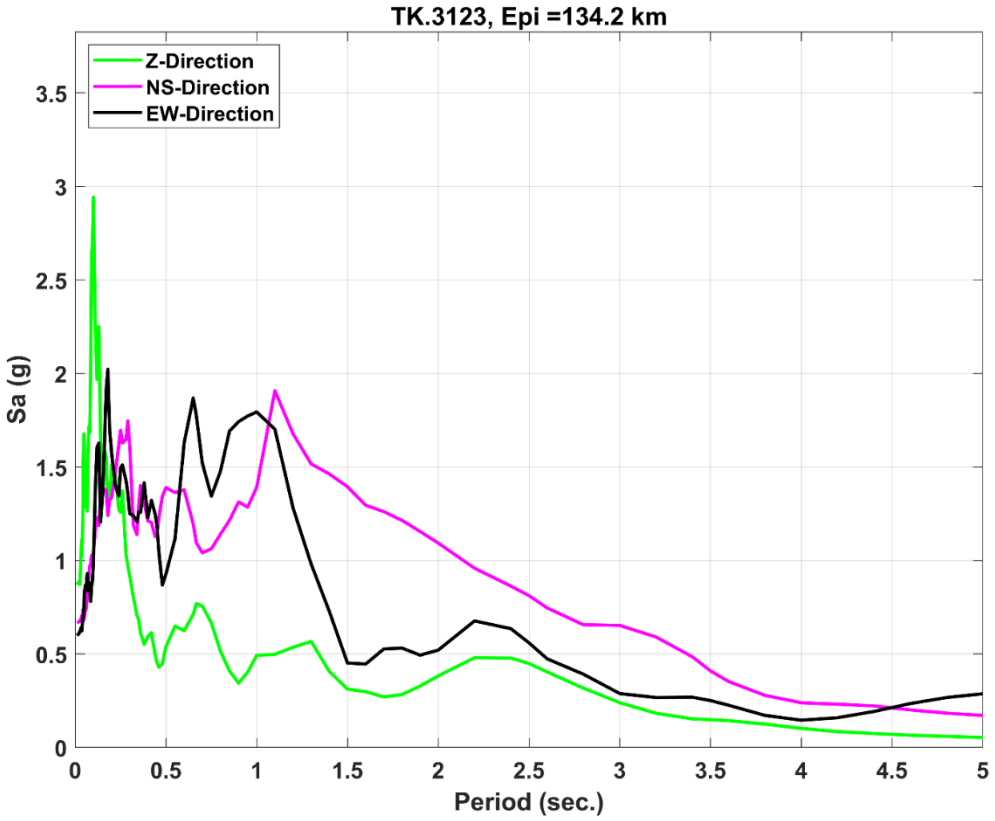


根據Shahi and Baker (2014)之速度脈衝擷取模式，將目前ESM Database已釋出之強震紀錄進行分析，Mw 7.8 地震之近斷層測站擷取出兩測站之速度脈衝如右圖，其斷層距離(Rrup)約10-20公里、紅色線段為USGS提供之快速有限斷層解之地表位置、星號為推估震源位置。截至臺灣時間2月10日11點57分，其餘測站及Mw 7.5地震所收錄之測站紀錄並未擷取出速度脈衝波。

資料來源：ESM Database

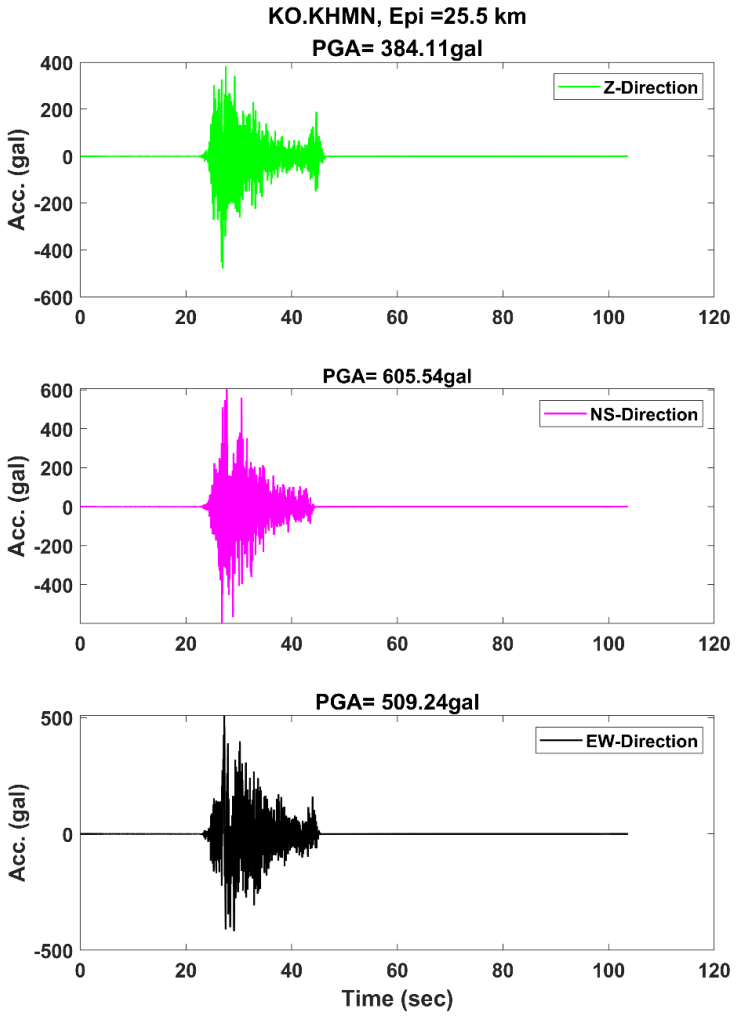
Mw 7.8 地震PGA較大的測站紀錄 (Station 3123)

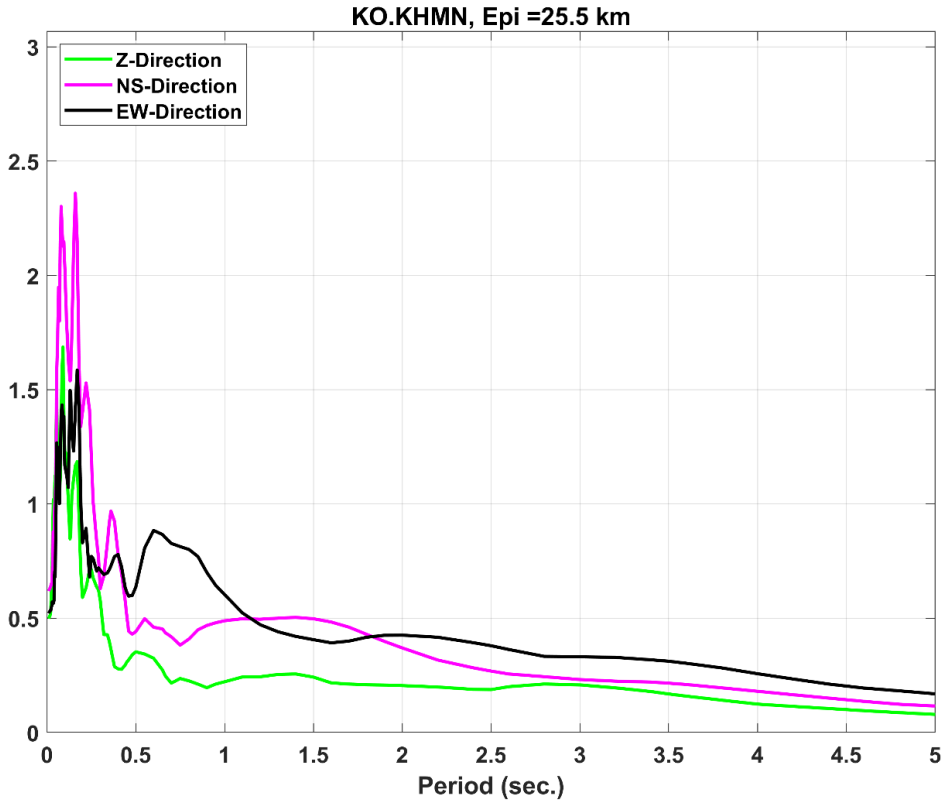




資料來源：ESM Database

Mw 7.8 地震PGA較大的測站紀錄(Station KHMN)





資料來源：ESM Database

報告大綱

- 地震資訊
- 媒體報導
- 大地災情資料
- 建物災情與歷史震損資料
- 橋梁災情與歷史震損資料
- 後續工作

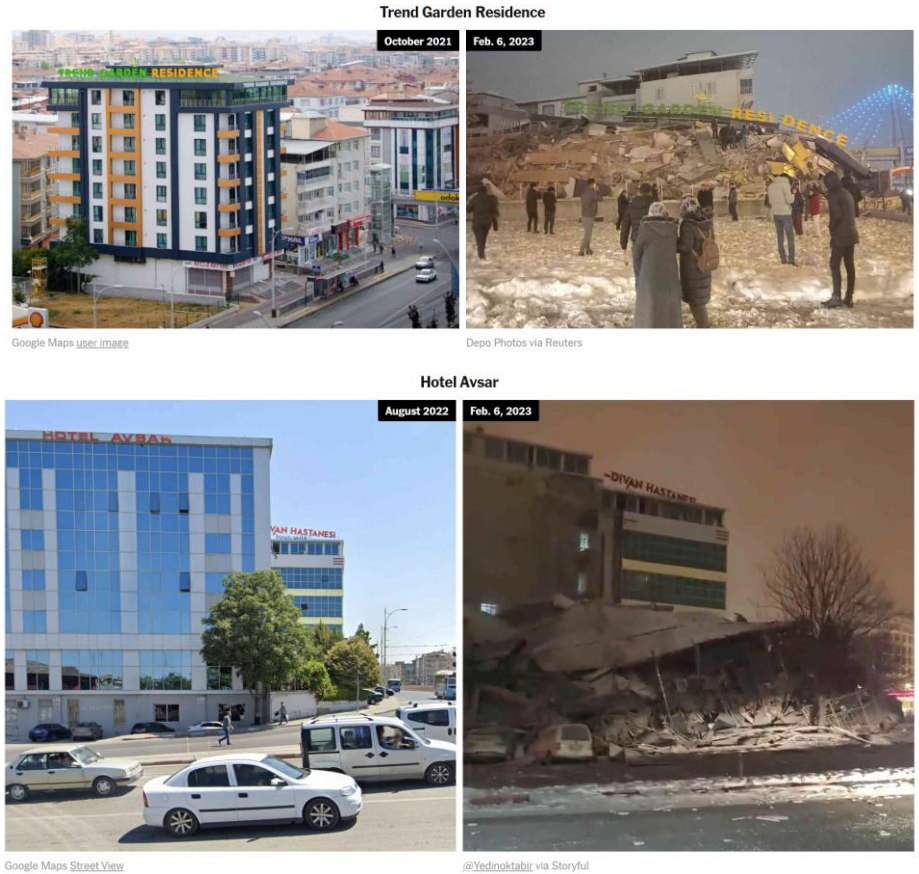
平面及電子媒體的災情資料

資料取得時間: 2023-02-13 09:40 (UTC+8)

- More than 34,000 people have been killed and tens of thousands injured after a magnitude 7.8 earthquake struck Turkey and Syria on Monday, officials said.
- Survivors, many of whom are homeless, could face "a secondary disaster" as cold and snow lead to "worsening and horrific conditions," the World Health Organization said Thursday.

資料來源：CNN
https://edition.cnn.com

平面及電子媒體的災情資料



資料取得時間：2023-02-10 16:40 (UTC+8)

- 在土耳其興建難民中心的臺灣建築師裘振宇分析指出，當地法規不足，使建物鋼筋及柱子粗細不足以支撐，建商又大量雇用臨時工或難民變成工地工人。
- 裘振宇以自身經驗與觀察認為，肇因有政府法規不足、建商偷工減料等。
- 裘振宇指出，臺灣中心所在的土國哈泰省（Hatay）的雷伊漢勒市（Reyhanli），當時中心興建就有考慮一定會發生大地震，幸好這次Mw 7.8強震沒有將中心震垮。

資料來源：
https://news.ltn.com.tw/news/world/breakingnews/4205991
https://www.nytimes.com/interactive/2023/02/06/world/turkey-earthquake-damage.html

平面及電子媒體的災情資料

資料取得時間：2023-02-12 18:40 (UTC+8)

Mw　7.8這場地震中，擁有2000多年歷史的世界遺產「加濟安泰普城堡(Gaziantep Castle)」被震垮，不僅擋土牆倒塌，古堡瞬間成了一個個碎石塊，鐵欄杆也散落在周圍的道路上。

地震前

圖片來源： https://en.wikipedia.org/wiki/Gaziantep_Castle

地震後

圖片來源： https://www.middleeasteye.net/discover/turkey-earthquake-historic-gaziantep-castle-destroyed

資料來源：
https://news.tvbs.com.tw/world/2035071?from=world_extend

平面及電子媒體的災情資料

- TVBS News（發布時間：2023-02-09）

https://www.youtube.com/watch?v=YgX4DdOAerw

- BBC News（發布時間：2023-02-09）

https://www.youtube.com/watch?v=npow8eiaP0s

- 9NEWS （發布時間：2023-02-10）

https://www.youtube.com/watch?v=H3I-8ekrhaE

- Sky News （發布時間：2023-02-10）

https://www.youtube.com/watch?v=mvx2T50BCg4

報告大綱

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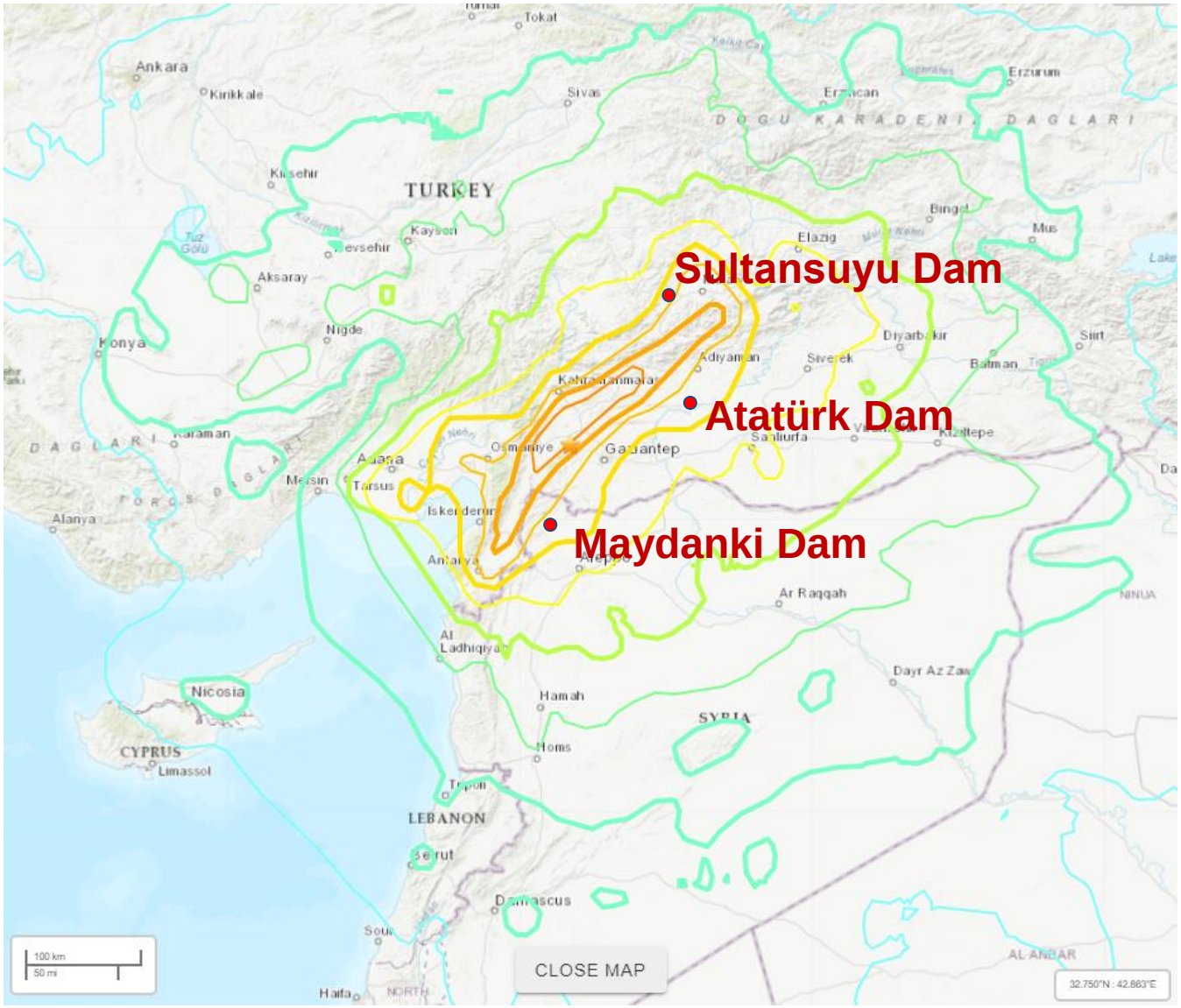
- 後續工作

山崩

大規模山崩導致路基嚴重損壞陷落

資料來源(AGU blog):
https://blogs.agu.org/landslideblog/2023/02/07/turkey-syria-earthquakes/

受損的水壩位置



USGS Map:
https://earthquake.usgs.gov/earthquakes/eventpage/us6000jllz/map

Sultansuyu水庫壩體受震裂損

Sultansuyu Dam in Malatya 水庫因地震而裂損，水位因此下降1.5公尺。

資料來源：https://expatguideturkey.com/earthquake-cracks-occured-at-sultansuyu-dam-in-malatya-dam-is-being-evacuated/

Ataturk水庫壩體受震裂損

土耳其東南邊的Ataturk Dam 因地震有許多裂損，目前已疏散附近居民，專家表示水壩可能在任何時間點破裂，影響範圍將及30平方公里。

資料來源：https://en.rua.gr/2023/02/06/cracks-in-the-ataturk-dam-after-earthquakes/

Maydanki水庫壩體受震裂損

敘利亞北部城市Afrin的 Maydanki 大壩出現了巨大的縱向和橫向裂縫。

資料來源：https://english.enabbaladi.net/archives/2023/02/turkey-syria-earthquake-maydanki-dam-cracked-what-is-the-consequence/

高速公路大規模破壞

高速公路因地震破壞嚴重，導致車輛翻覆。

資料來源：https://www.youtube.com/watch?v=matV5lEEubg

地表錯動與破裂

位於 Kahramanmaraş 以南約 35 公里處，出現嚴重扭曲鐵軌。

資料來源：
https://twitter.com/Przemys20985762/status/1623500838881710081/photo/1

在Türkoglu東邊觀察到的地表破裂。

資料來源：
https://twitter.com/akyuz24/status/1623457473297539073?ref_src=twsrc%5Etfw%7Ctwcamp%5Etweetembed%7Ctwterm%5E1623457473297539073%7Ctwgr%5Ec8c3c6e14171bf9f46986ee68c51367f9d3c1ade%7Ctwcon%5Es1_&ref_url=https%3A%2F%2Fearthjay.com%2F%3Fp%3D10772

報告大綱

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- 橋梁災情與歷史震損資料
- 後續工作

建築物受震嚴重損傷與倒塌

土耳其東南部哈泰省（Hatay）災區現場

照片來源：
https://www.middleeasteye.net/news/turkey-earthquake-hatay-owner-building-complex-arrested-airport

照片來源:
https://www.rti.org.tw/news/view/id/2158407

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Masonry Buildings in Istanbul

相關研究

It is appropriate to classify masonry buildings in Turkey as rural-type and urban-type buildings. Rural type masonry buildings…are low-rise dwellings built by using adobe or stone units. They may be called "non-engineered buildings"…On the other hand, urban-type masonry buildings are low-rise or mid-rise dwellings with a larger floor area when compared to rural-types. However, they are generally irregular in plan…They were constructed by using brick units and concrete blocks and they have an "engineering touch"…both rural- and urban-type masonry dwellings suffered severe damage or collapse.

資料來源： Erberik, M. Altug. "Seismic risk assessment of masonry buildings in Istanbul for effective risk mitigation." *Earthquake Spectra* 26.4 (2010): 967-982.

Masonry Buildings in Istanbul

相關研究

…increasing the number of stories in a masonry building generally means increasing the probability of its suffering damage in an earthquake…It should be also noted that reinforced or confined masonry construction is not common in Turkey, and it is not covered by the seismic code regulations. Another important structural parameter that affects the seismic performance of masonry buildings is plan geometry…In previous earthquakes, especially after the 1995 Dinar earthquake, it was observed that irregular buildings suffered localized damage and collapse due to torsional effects.

資料來源： Erberik, M. Altug. "Seismic risk assessment of masonry buildings in Istanbul for effective risk mitigation." *Earthquake Spectra* 26.4 (2010): 967-982.

Masonry Buildings

相關研究

Masonry dwellings…are constituted with adobe, brick and stone walls and mostly vulnerable to intensive seismic motions. However, these buildings had been lost their strength and durability due to their old age.

資料來源： Sayın, Erkut, et al. "24 January 2020 Sivrice-Elazığ, Turkey earthquake: geotechnical evaluation and performance of structures." *Bulletin of Earthquake Engineering* 19 (2021): 657-684

NARLabs

Effects of the Earthquake on Urban Buildings

相關研究

A total of 348 buildings were inspected in Van and Ercis…A majority of the collapsed or heavily damaged buildings exhibits a combination of very low concrete strength, use of plain reinforcing bars, inadequate stirrups and member-end confinements, and lack of lateral rigidity due to insufficient lateral load carrying systems. The most common structural deficiencies that lead to collapse are weak- and soft-stories. From the observations, it is also seen that damage state of buildings with four and five stories were higher than those with lower and higher numbers of stories.

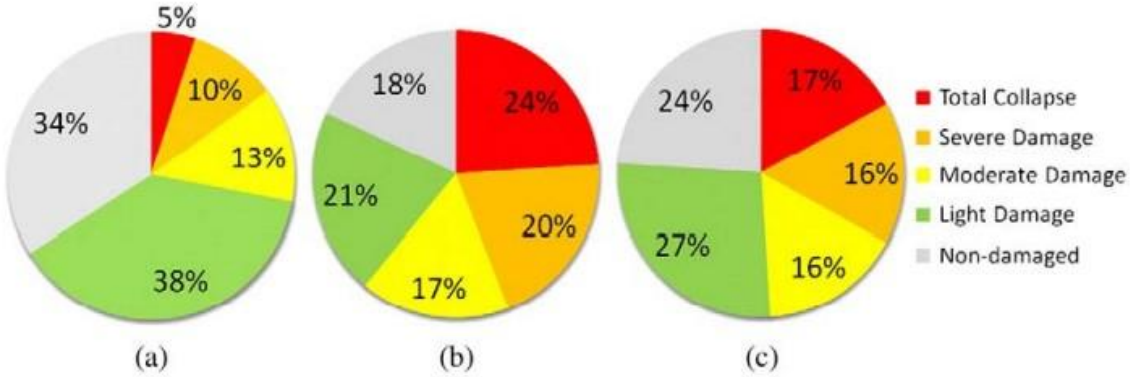

Figure 11. Damage statistics of reinforced concrete frame buildings in (a) Van, (b) Erciş, and (c) Van and Erciş (adapted from METU-EERC 2011).

資料來源： Akansel, V., et al. "The 23 October 2011 Mw 7.0 Van (Eastern Turkey) earthquake: Interpretations of recorded strong ground motions and post-earthquake conditions of nearby structures." *Earthquake Spectra* 30.2 (2014): 657-682.

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General Characteristics of Code-Deficient Public Buildings

相關研究

Most older public buildings in Turkey constructed before the 1990s are three-to six-story reinforced concrete frames with concrete slabs. Their framing systems are quite regular, especially in the school buildings that dominate the public building stock…Concrete quality is usually low, between 10-15 MPa. Plain reinforcement bars with nominal yield strength of 200 MPa are typical. Gravity loads dominate design; hence beams are stronger than the columns around a joint. Critical end regions of beams and columns are not confined; lateral reinforcement is basically provided for shear. Frame bays are infilled with unreinforced clay masonry walls at the exterior frames and at interior space separations. These buildings possess brittle seismic response confirmed by the past earthquakes consistently.

資料來源： Sucuoğlu, HalÛk, et al. "Seismic risk prioritization and retrofit cost evaluation of code-deficient RC public buildings in Turkey." *Earthquake Spectra* 31.1 (2015): 601-614.

Low- to Mid-Rise Reinforced Concrete Buildings

相關研究

Fifty-four buildings without structural shear walls suffered more damage, and all reported cases of collapse happened in this type of construction…but those with low-quality material and workmanship suffered substantial damage…The experience provided by the Bingol earthquake shows that there is a significant gap between the requirements established by the Turkish seismic design code and construction practice in rural areas…On the contrary, the performance of buildings with shear walls was satisfactory in terms of collapse prevention.

資料來源： Özhendekci, Nuri, and Devrim Özhendekci. "Rapid seismic vulnerability assessment of low-to mid-rise reinforced concrete buildings using Bingöl's regional data." *Earthquake Spectra* 28.3 (2012): 1165-1187.

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Damage State vs. Number of Stories

相關研究

2011-10-23 MW 7.0 Van (Eastern Turkey) Earthquake

Table 3. Damage state of buildings with respect to number of stories (adapted from METU-EERC 2011)

Number of stories	Total collapse	Severe damage	Moderate damage	Light damage	Undamaged
1	0 (0%)	0 (0%)	0 (0%)	0 (0%)	5 (100%)
2	0 (0%)	1 (5%)	1 (5%)	2 (10%)	16 (80%)
3	4 (10%)	5 (13%)	6 (15%)	12 (31%)	12 (31%)
4	17 (31%)	7 (13%)	8 (15%)	15 (27%)	8 (15%)
5	26 (22%)	19 (16%)	18 (15%)	37 (32%)	17 (15%)
6	6 (10%)	15 (24%)	12 (20%)	16 (26%)	12 (20%)
7	3 (9%)	7 (21%)	8 (24%)	8 (24%)	7 (22%)
8	1 (8%)	1 (8%)	1 (8%)	5 (42%)	4 (34%)
9	0 (0%)	0 (0%)	0 (0%)	0 (0%)	3 (100%)

資料來源： Akansel, V., et al. "The 23 October 2011 Mw 7.0 Van (Eastern Turkey) earthquake: Interpretations of recorded strong ground motions and post-earthquake conditions of nearby structures." *Earthquake Spectra* 30.2 (2014): 657-682.

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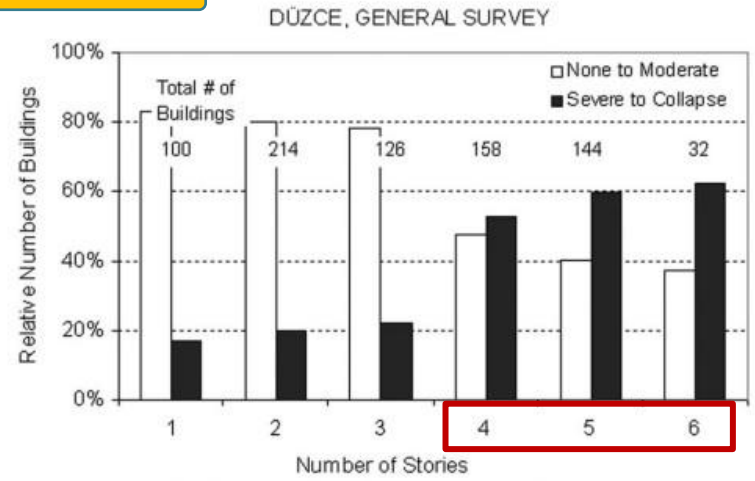
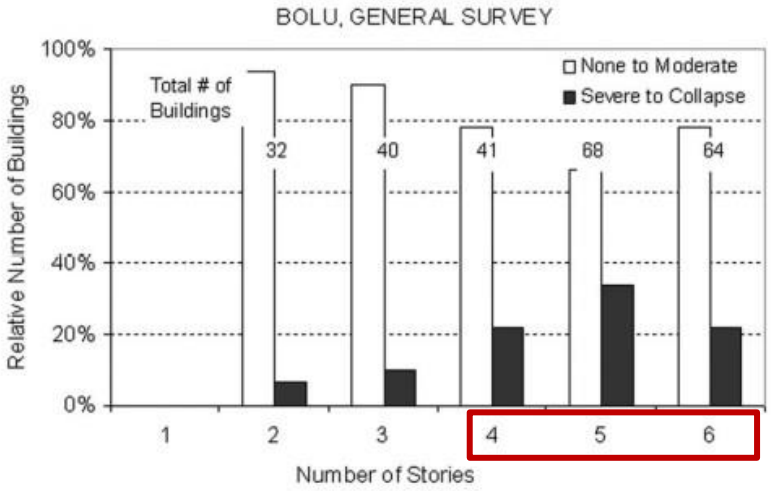
Damage State vs. Number of Stories

相關研究

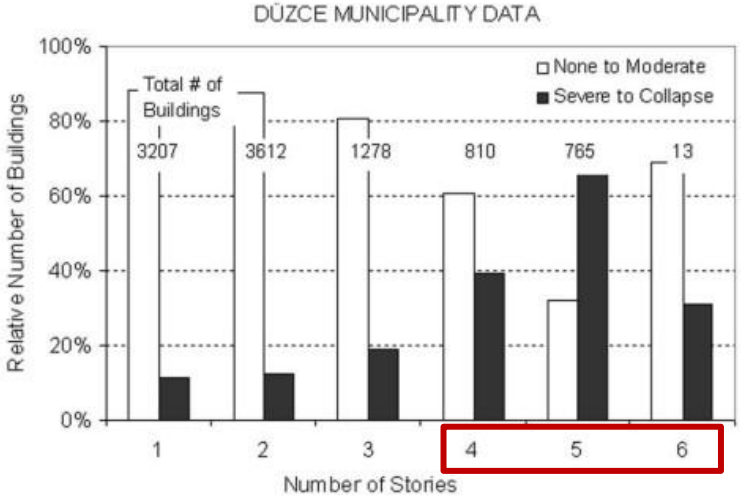
The 17 August and 12 November 1999 earthquakes in Turkey



(a) Number of stories vs. damage in Düzce



(c) Number of stories vs. damage in Bolu



(b) Number of stories vs. damage, reported by the municipality of Düzce

Figure 16. General survey results for Düzce and Bolu.

Buildings with 4 to 6 stories were seriously damaged or collapsed.

資料來源： Dönmez, C., and S. Pujol. "Spatial distribution of damage caused by the 1999 earthquakes in Turkey." *Earthquake Spectra* 21.1 (2005): 53-69.

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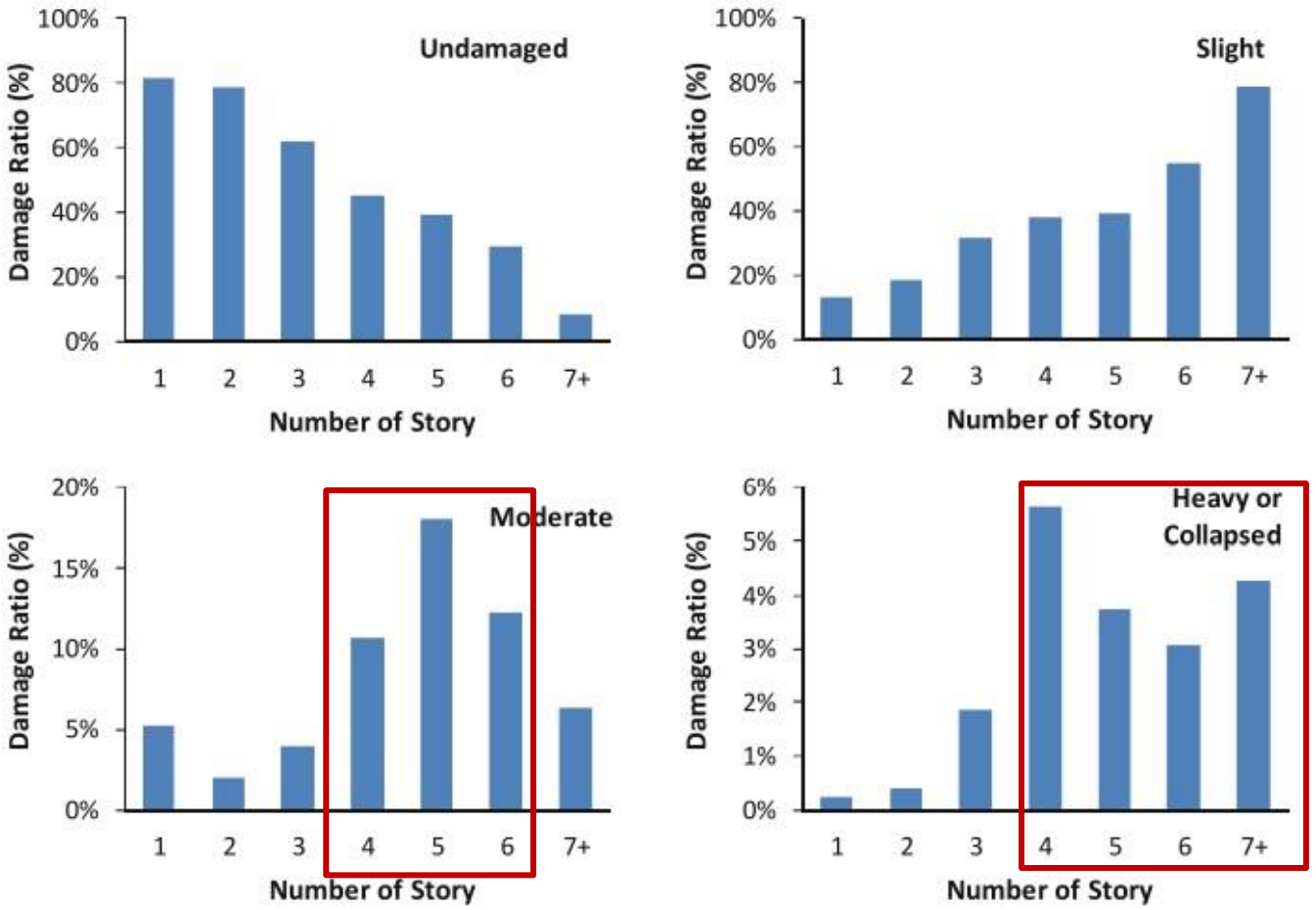
Damage State vs. Number of Stories

相關研究

2011-05-19 Simav (Turkey) earthquake



資料來源： Inel, Mehmet, Hayri Baytan Ozmen, and Erdal Akyol. "Observations on the building damages after 19 May 2011 Simav (Turkey) earthquake." *Bulletin of Earthquake Engineering* 11.1 (2013): 255-283.

Reasons of Damages of Structural Elements

相關研究

2020-01-24 Sivrice-Elazığ earthquakes in Turkey

Damages of the structural elements observed by the technical team can be listed as follows:

- **Insufficient transverse reinforcement in structural elements**
- **Short column**
- **Inadequate gaps between adjacent buildings**
- **Strong beam-weak column**
- **Poor concrete quality and corrosion**
- **Failure of gable walls**
- **Damages to infill walls**

資料來源： Sayın, Erkut, et al. "24 January 2020 Sivrice-Elazığ, Turkey earthquake: geotechnical evaluation and performance of structures." *Bulletin of Earthquake Engineering* 19 (2021): 657-684.

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Reasons of Damages of Structural Elements

相關研究

The 17 August and 12 November 1999 earthquakes in Turkey

Brittle behavior was a consequence of poor reinforcement detailing (Figures 7 and 8), presence of captive columns (Figure 9), soft stories, and torsional response.

Figure 7. Column failure, Bolu government hospital.

Figure 8. Failure of a shear wall in Bolu.

Figure 9. Typical example of captive columns. (Photograph by Mete Sözen)

資料來源： Dönmez, C., and S. Pujol. "Spatial distribution of damage caused by the 1999 earthquakes in Turkey." *Earthquake Spectra* 21.1 (2005): 53-69.

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Poor Concrete Quality

相關研究

Table 5. Results of case study buildings

Building no.	Type	Location	Construction date	No. of stories	Concrete compressive strength f_{cm} (MPa)	Steel reinf. yield str. f_{ym} (MPa)	Lateral force–resisting system	Perf. level from TEC (2007) linear elastic procedure	Perf. level from TEC (2007) nonlinear elastic procedure	Perf. level from new provisions
1	New	High seismic zone	2007	6	17	365	Moment resisting frame	Life safety	Life safety	Not critical
2	New	High seismic zone	2007	6	17	365	Shear wall+momen resisting frame	Collapse	Life safety	Not critical
3	New	High seismic zone	2007	8	17	365	Moment resisting frame	Life safety	Life safety	Not critical
4	New	High seismic zone	1975	6	12	191	Moment resisting frame	Collapse	Life safety	Not critical
5	Existing	Van	Not known	4	10	191	Moment resisting frame	Collapse	Life safety	Not critical
6	Existing	Bakırköy, İstanbul	1967	5	11	191	Moment resisting frame	Collapse	Life safety	Critical
7	Moderate damage	Adapazarı	1994	5	9.5	191	Shear wall+momen resisting Frame	Collapse	Life safety	Critical
8	Moderate damage	Ceyhan, Adana	Not known	3	8.3	191	Moment resisting frame	Collapse	Life safety	Critical
9	Heavy damage	Adapazarı	1993	6	9.5	191	Moment resisting frame	Collapse	Collapse	Critical
10	Moderate Damage	Düzce	Not known	5	12	191	Shear wall+momen resisting frame	Collapse	Collapse	Not critical

資料來源：Binici, Baris, et al. "Provisions for the seismic risk evaluation of existing reinforced concrete buildings in turkey under the urban renewal law." *Earthquake Spectra* 31.3 (2015): 1353-1370.

Poor Concrete Quality

相關研究

In Turkey, using of ready-mix concrete became common after 1999 Kocaeli earthquake. Before this earthquake, handmade concrete was generally used without using a vibrator. Because of this wrong application, a homogeneous mixing could not be obtained, and the expected compressive strength could bot be provided….Provincial Directorate of the Ministry of Environment and Urban Planning declared that compressive strengths of the concrete cored from the collapsed and damaged structures were around 7-10 MPa.

資料來源： Sayın, Erkut, et al. "24 January 2020 Sivrice-Elazığ, Turkey earthquake: geotechnical evaluation and performance of structures." *Bulletin of Earthquake Engineering* 19 (2021): 657-684.

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研究案例Case I

相關研究

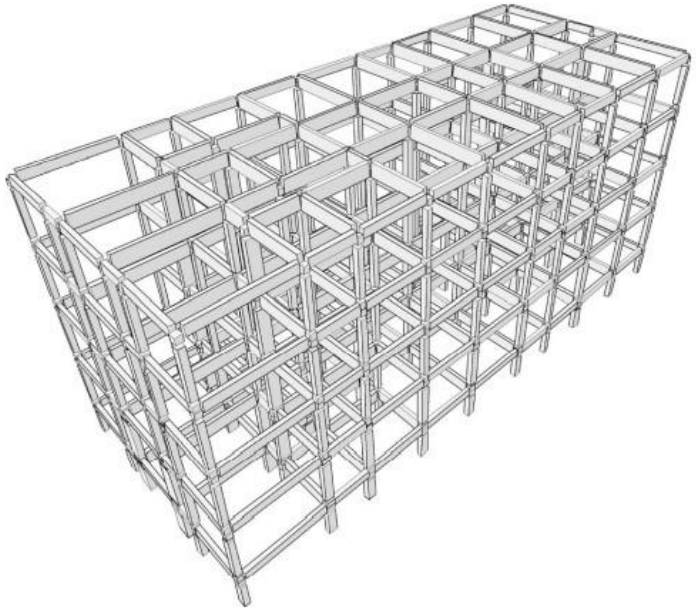

Figure 3. 3-D illustration of the reinforced concrete moment-resisting frame of the original apartment structure.

The concrete of the existing structure has a characteristic yield limit of 16 MPa …it was deemed to be highly representative of many residential apartment buildings in and around Istanbul and its design probably based on the 1967 code…

資料來源： Smyth, Andrew W., et al. "Probabilistic benefit-cost analysis for earthquake damage mitigation: Evaluating measures for apartment houses in Turkey." *Earthquake Spectra* 20.1 (2004): 171-203.

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研究案例Case II

相關研究

The case-study building is the main part of the typical branch office of MPWR which is a five-building complex designed according to requirements of the 1975 Turkish Seismic Design Code (TEC 1975) and constructed in the 1980s.

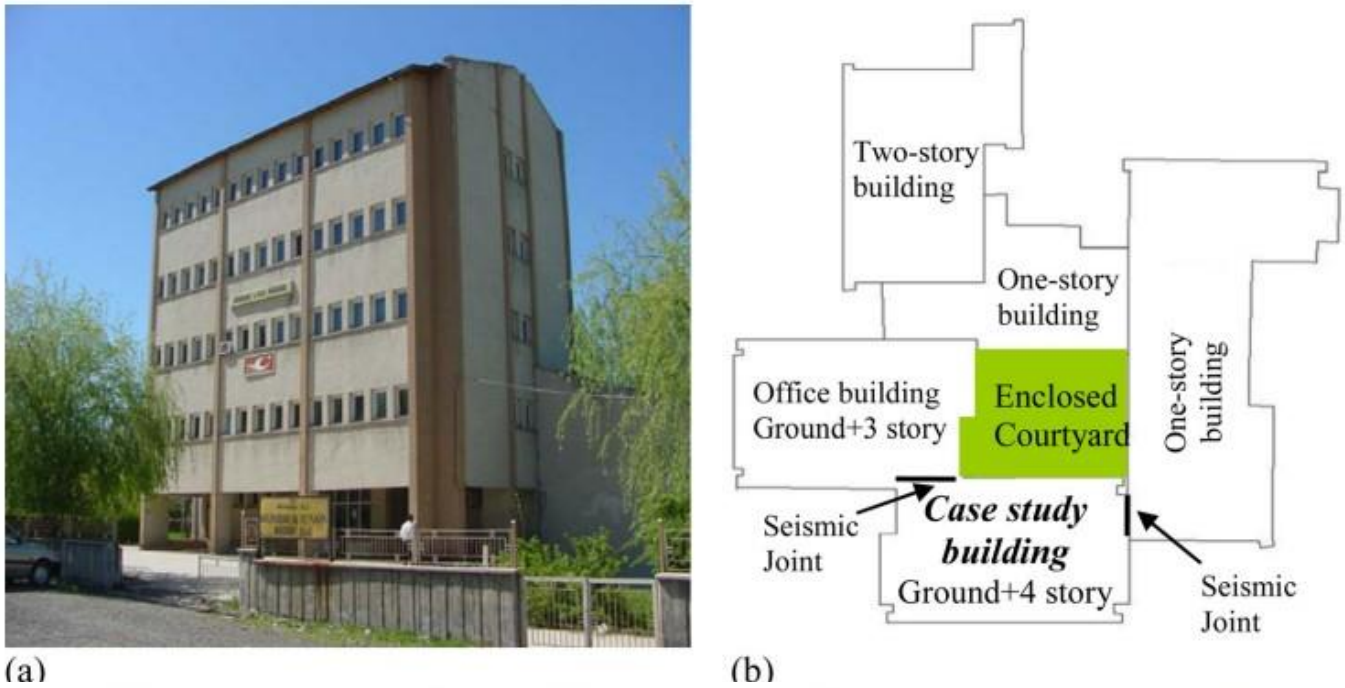

Figure 4. (a) General view of the building and (b) plan of the building complex.

資料來源： Bayhan, Beyhan, and Polat Gülkan. "Buildings subjected to recurring earthquakes: A tale of three cities." *Earthquake Spectra* 27.3 (2011): 635-659.

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研究案例Case II

相關研究

Figure 8. Captive column effect and buckling of longitudinal steel in Bolu (view from the courtyard).

Figure 9. Failure of infill walls.

Figure 10. Flexural beam cracks.

(a) (b)

Figure 11. Diagonal shear cracks developed in ground story L-shaped corner columns (C16) in (a) Bolu and (b) Bingöl.

資料來源： Bayhan, Beyhan, and Polat Gülkan. "Buildings subjected to recurring earthquakes: A tale of three cities." *Earthquake Spectra* 27.3 (2011): 635-659.

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研究案例Case II

相關研究

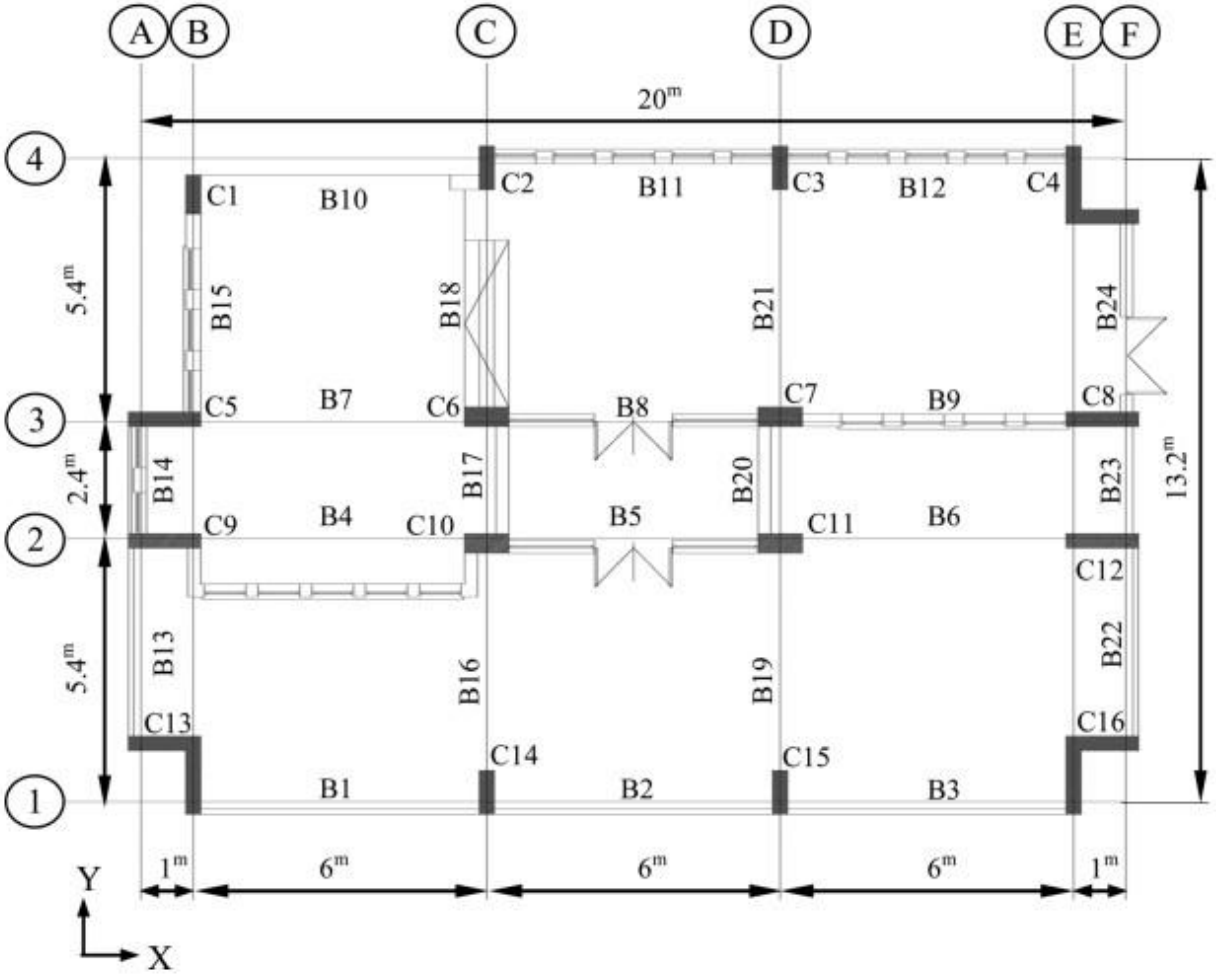

Figure 5. Typical floor plan (adapted from Çağnan 2001).

資料來源： Bayhan, Beyhan, and Polat Gülkan. "Buildings subjected to recurring earthquakes:
A tale of three cities." *Earthquake Spectra* 27.3 (2011): 635-659.

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研究案例Case II

相關研究

Beam Sections

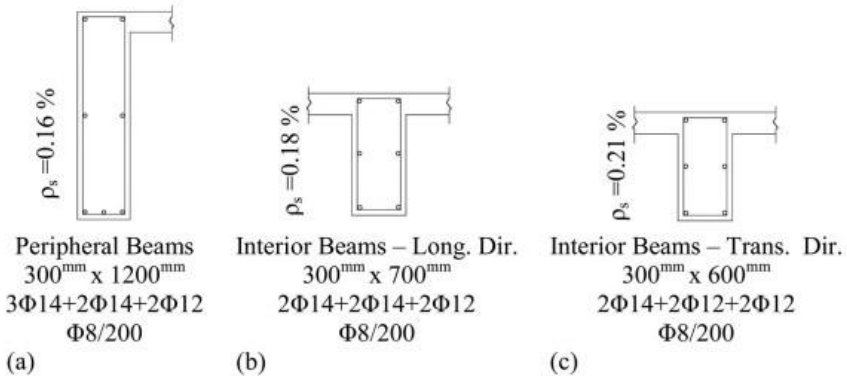

Figure 6. Cross-sectional dimensions, longitudinal and transverse reinforcement of the (a) peripheral beams, (b) interior beams in the longitudinal direction and (c) interior beams in the transverse direction of the building.

Reinforcement (beams): ϕ14
Reinforcement (columns): ϕ20, ϕ22

資料來源： Bayhan, Beyhan, and Polat Gülkan. "Buildings subjected to recurring earthquakes: A tale of three cities." *Earthquake Spectra* 27.3 (2011): 635-659.

Column Sections

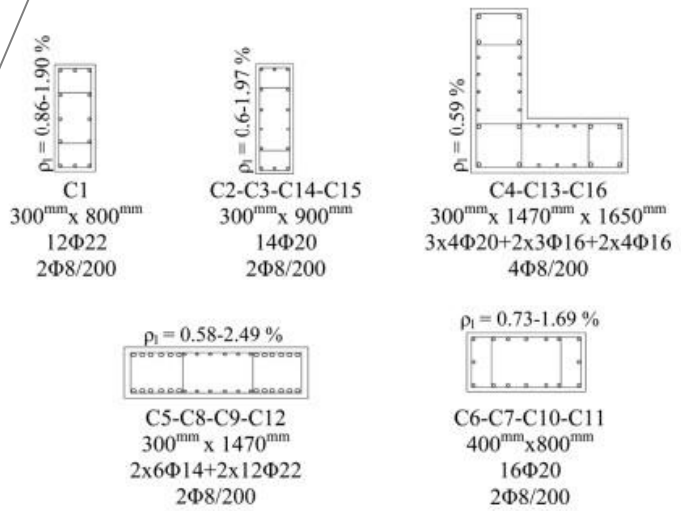

Figure 7. Cross-sectional dimensions, longitudinal and transverse reinforcement of typical column sections at ground level (adapted from Çağnan 2001).

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國際媒體特別報導

BBC NEWS

Turkey earthquake: Why did so many buildings collapse?

Failure to enforce building regulations

Construction regulations have been tightened following previous disasters, including a 1999 earthquake around the city of Izmit, in the north-west of the country, in which 17,000 people died.

But the laws, including the latest standards set in 2018, have been poorly enforced.

"In part, the problem is that there's very little retrofitting of existing buildings, but there's also very little enforcement of building standards on new builds," says Prof Alexander.

大量建築物震損原因評論:

1. **Little retrofitting of existing buildings**
2. **Little enforcement of building standards on new buildings**

資料來源： https://www.bbc.com/news/64568826

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國際媒體特別報導

BBC NEWS

Turkey earthquake: Why did so many buildings collapse?

Why is enforcement so weak?

In Turkey, however, the government has provided periodic "construction amnesties" - effectively legal exemptions for the payment of a fee, for structures built without the required safety certificates. These have been passed since the 1960s (with the latest in 2018).

Critics have long warned that such amnesties risk catastrophe in the event of a major earthquake.

Up to 75,000 buildings across the affected earthquake zone in southern Turkey have been given construction amnesties, according to Pelin Pınar Giritlioğlu, Istanbul head of the Union of Chambers of Turkish Engineers and Architects' Chamber of City Planners.

Just a few days before the latest disaster, Turkish media reported that a new draft law is awaiting parliamentary approval which would **grant a further amnesty for recent construction work**.

Geologist Celal Sengor said earlier this year that passing such construction amnesties in a country riven by fault lines **amounts to a "crime"**.

After a deadly earthquake hit the western province of Izmir in 2020, a BBC Turkish report found that 672,000 buildings in Izmir had benefited from the most recent amnesty.

大量建築物震損原因評論:
“Construction Amnesties”

資料來源： https://www.bbc.com/news/64568826

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建築物耐震能力評析

綜合2023-02-06土耳其地震事件建築物震損災情的觀察，參考相關文獻與媒體報導，對於土耳其建築物耐震能力的初步評析如下:

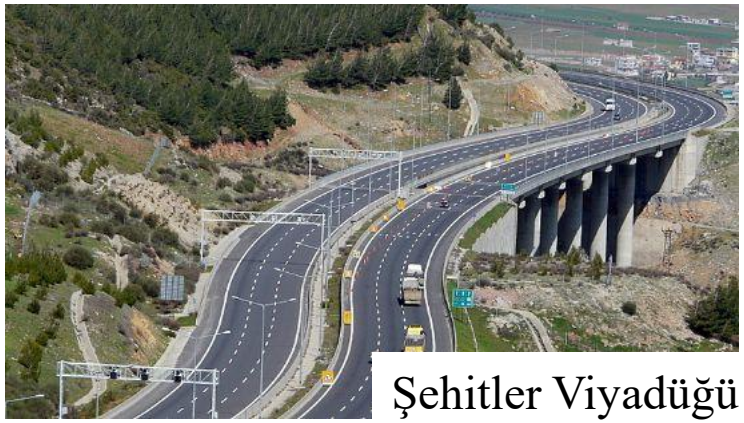
1. Because reinforced or confined masonry construction is not common in Turkey, typical masonry buildings seem to lack adequate seismic resistance.
2. Besides plain reinforcements, concrete compressive strength of old buildings is usually very low. Moreover, old buildings are usually strong beam-weak column.
3. The most common structural deficiencies that lead to collapse are weak- and soft-stories.
4. Little enforcement of building standards on new buildings.
5. Little retrofitting of existing buildings, especially under the policy of “construction amnesties”.

報告大綱

- 地震資訊
- 媒體報導
- 大地災情資料
- 建物災情與歷史震損資料
- **橋梁災情與歷史震損資料**
- 後續工作

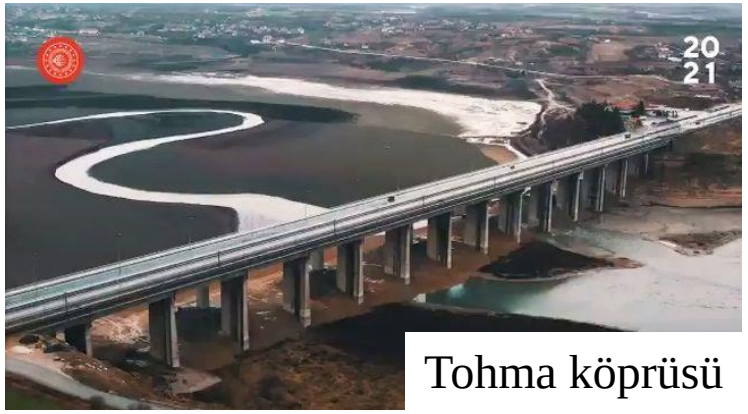
已知震損橋梁

- 截至臺灣時間2月10日9點50分，尚無中文或英文報導關於橋梁損傷的新聞，故僅能藉由土耳其當地官方道路封閉新聞找出下列震損橋梁
- Bulam 3 Köprüsü
- Balıkburnu köprüsü
- Tohma köprüsü
- Başpınar Viyadüğündeki
- Şehitler Viyadüğü
- Recepbey Köprüsü



Şehitler Viyadüğü

資料來源:
http://galeri.netfotograf.com/fotograf.asp?foto_id=331909



Tohma köprüsü

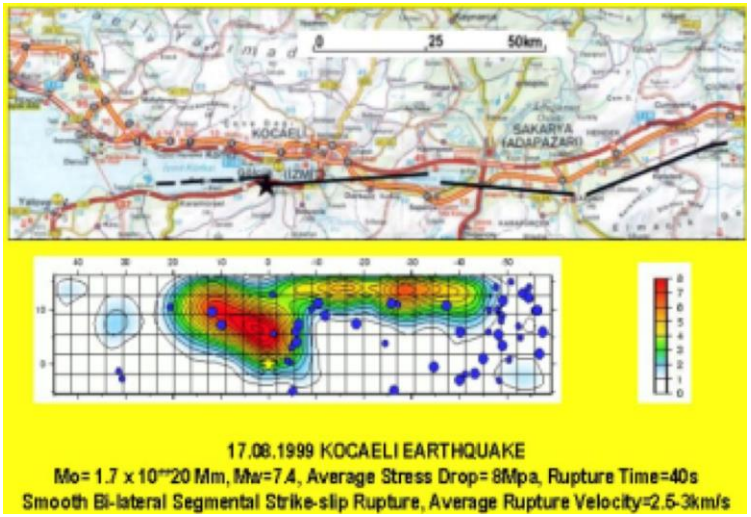
資料來源:
https://malatyahaber.com/haber/tohma-koprusu-2-kanadinin-acilisi-cumartesi

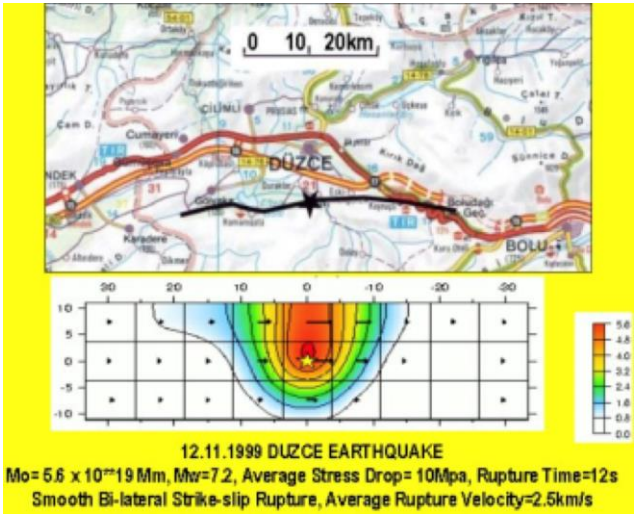
資料來源：
https://www.cumhuriyet.com.tr/turkiye/karayollari-genel-mudurlugunden-yol-aciklamasi-2048772
https://www.indyturk.com/node/607801/haber/deprem-bölgesinde-ulaşıma-kapalı-yollar-ve-alternatif-güzergâhlar-hangileri

土耳其以往地震的橋梁破壞案例

相關研究

1999 Kocaeli地震(Mw 7.4)及Düzce地震(Mw 7.2)





General view of highway and viaduct damages in Kocaeli and Duzce Earthquakes

資料來源： Erdik, Mustafa. "Report on 1999 Kocaeli and Düzce (Turkey) earthquakes." *Structural control for civil and infrastructure engineering*. 2001. 149-186.

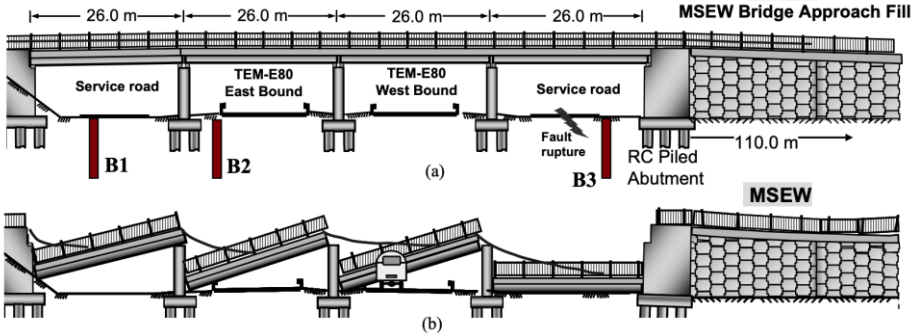
土耳其以往地震的橋梁破壞案例

相關研究

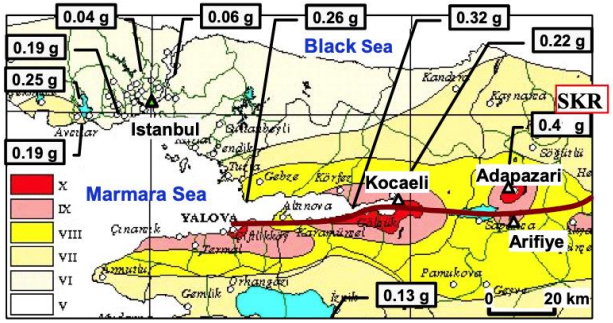
1999 Kocaeli Earthquake

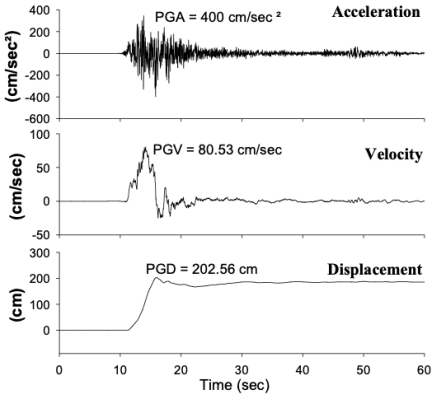
- Arifiye 跨越橋，結構型式為多跨連續橋，於土耳其Kocaeli 地震(Mw 7.4) 產生剪力榫破壞導致落橋。

Arifiye 跨越橋(1)



Arifiye 跨越橋損壞前、後(2)





KOCAELI 地震(2)

資料來源：

(1) Erdik, Mustafa. "Report on 1999 Kocaeli and Düzce (Turkey) earthquakes." *Structural control for civil and infrastructure engineering*. 2001. 149-186.

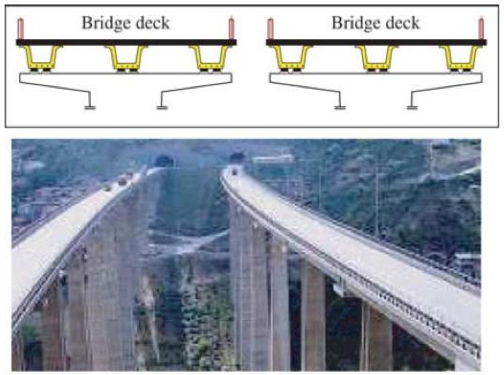
(2) Pamuk, Ahmet, et al. "Behavior of reinforced wall system during the 1999 Kocaeli (Izmit), Turkey earthquake." *Proceedings of the 5th International Conference on Case Histories in Geotechnical Engineering, New York, April*. 2004.

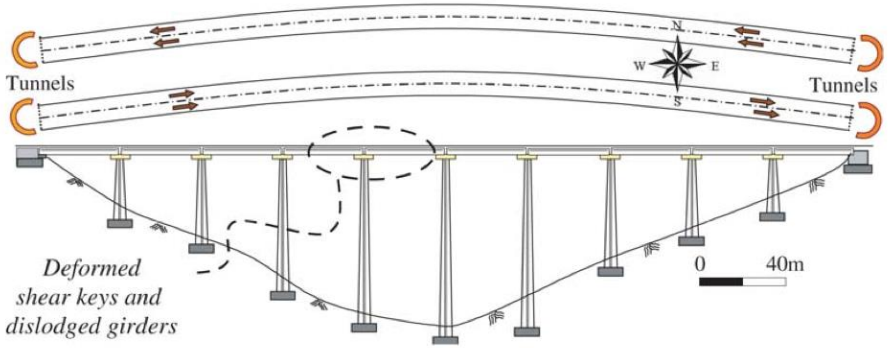
土耳其以往地震的橋梁破壞案例

相關研究

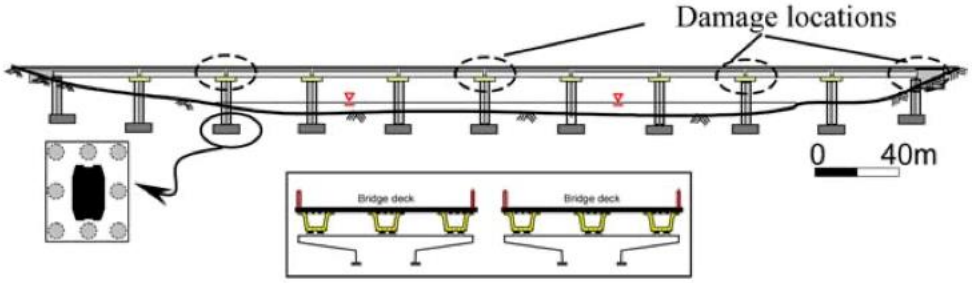
1999 Kocaeli Earthquake

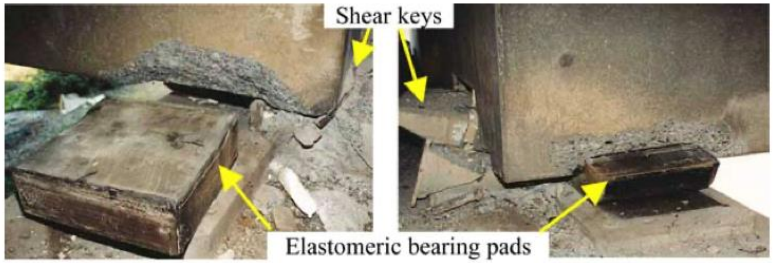
- Mustafa Inan高架橋及Sakarya 高架橋，結構型式皆為多跨連續橋，於土耳其Kocaeli地震(Mw 7.4) 產生剪力榫破壞。





Mustafa Inan 高架橋





Sakarya 高架橋

資料來源： Pamuk, A., E. Kalkan, and H. I. Ling. "Structural and geotechnical impacts of surface rupture on highway structures during recent earthquakes in Turkey." *Soil Dynamics and Earthquake Engineering* 25.7-10 (2005): 581-589.

土耳其以往地震的橋梁破壞案例

相關研究

1999 Düzce Earthquake

- #1 高架橋及位於Kaynasl的E-5高速公路，結構型式皆為多跨連續橋，於Düzce地震(Mw 7.2) 產生橋墩連接螺栓剪切破壞。

位於Kaynasl的E-5高速公路
橋墩連接螺栓剪切破壞(1)

#1 高架橋
橋墩連接螺栓剪切破壞(2)

資料來源：

(1) Erdik, Mustafa. "Report on 1999 Kocaeli and Düzce (Turkey) earthquakes." *Structural control for civil and infrastructure engineering*. 2001. 149-186.

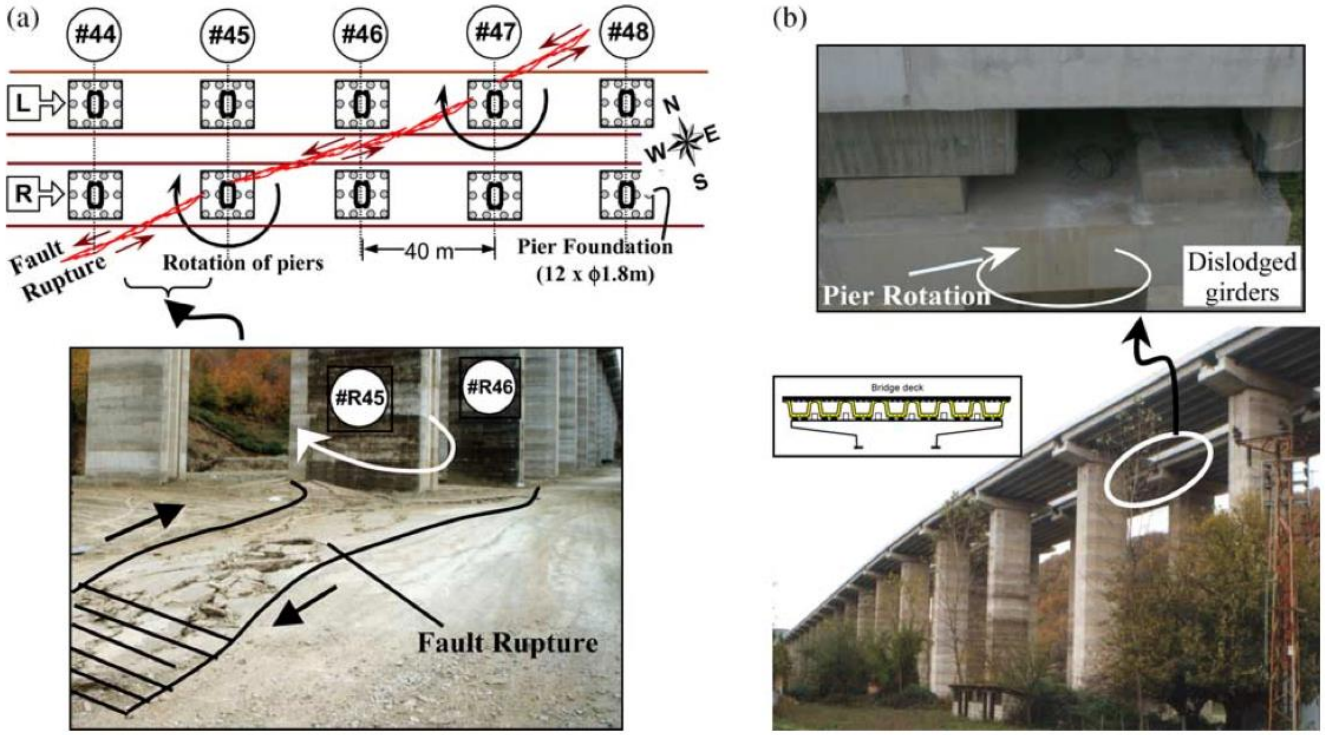
(2) Yen, W. Phillip, Hamid Ghasemi, and James D. Cooper. "Lessons Learned from Bridge Performance of the 1999 Turkish & Taiwan Earthquakes." *33rd Joint Meeting of the UJNR Panel on Wind and Seismic Effects, Tsukuba, Japan*. 2001.

土耳其以往地震的橋梁破壞案例

相關研究

1999 Düzce Earthquake

- Bolu高架橋，結構型式皆為多跨連續橋，於Düzce地震(Mw 7.2)因斷層錯動產生橋墩扭轉導致上部結構破壞。



Bolu高架橋因斷層錯動產生橋墩扭轉導致上部結構破壞

資料來源： Pamuk, A., E. Kalkan, and H. I. Ling. "Structural and geotechnical impacts of surface rupture on highway structures during recent earthquakes in Turkey." *Soil Dynamics and Earthquake Engineering* 25.7-10 (2005): 581-589.

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後續工作

- 國震中心將持續關注此次地震事件，追蹤土耳其與敘利亞受災地區的後續發展，並且以此巨災作為借鏡，與各級政府、工程界及學界共同合作，持續發展先進抗震技術、研擬與建議相關規範，期能保障國人的居住安全，並且降低臺灣在地震的威脅下可能造成的損失。
- 國震中心預計2023-02-18派遣人員前往土耳其，與美國及土耳其當地學者共同勘災及收集資訊供國內學界及工程界參考。

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