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

Reconnaissance Report on Seismic Damage Caused by Guanshan Earthquake and Chihshang Earthquake, Taiwan, 2022
(third edition, v3.0)

Chung-Che Chou, Chiun-Lin Wu, Juin-Fu Chai, George C. Yao

NCREE, Taiwan

September 23, 2022

承諾・熱情・創新

www.narlabs.org.tw
www.ncree.narl.org.tw

Members of the Emergency Response Team

Chairperson: Chung-Che Chou

Emergency Response Operation Manager (Deputy Chairperson): Chiun-Lin Wu

Deputy Emergency Response Operation Manager: Juin-Fu Chai

Executive Secretary: Chi-Hao Lin

Disaster Estimation

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Disaster Information Collection

Chun-Chung Chen , Hsiao-Hui Hung , Bo-Han Lee, Chih-Shian Chen

Damage Survey

Yuan-Tao Weng, Hsuan-Chih Yang

Emergency Response Support

Ho-Hsiung Yang, Wei-Choung Cheng, Mu-Hsuan Li, Hsien-chung Lin, Ruey-Chu Kao, Su-Yueh Lu, Chun-Yuan Ku, Chia-Chuan Hsu, Chung-Han Yu, Ching-Hsien Huang, Chiao-Chu Hsu, Che-Yu Chang, Shang-Yi Hsu, Jiun-Shiang Wang, Yu-Ying Lin, Kuan-Yu Chen, Chiu-Ping Fan, Chih-Wei Chang, You-Xuan Lin

Decision Making

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Members of Reconnaissance Team

Building and Bridge Damage Survey

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Geological Damage Survey

Chih-Chieh Lu, Yuan-Chang Deng, Wei-Kuang Chang

Nonstructural Components and Systems Damage Survey

George C. Yao, Fan-Ru Lin, Wei-Hung Hsu, Bai-Yi Huang, Wei-Chung Chen, Yu-Chiau Huang, Jian-Xiang Wang, Tzu-Chieh Chien, Kun-Ru Liu, Min-Chi Ko, Chen-Pei Hsu, Tzu-Ying Wu

External Support

Taiwan professional geotechnical engineers association

CECI Engineering Consultants, Inc.

SINOTECH Engineering Consultants, Ltd.

Introduction

- At 9:41 p.m. on Sep. 17 (UTC+8) and 2:44 p.m. on Sep. 18 (UTC+8) in 2022, two M_L 6.4 and 6.8 earthquakes hit Guanshan and Chihshang in Taitung (respectively named as Guanshan earthquake and Chihshang earthquake). According to the Central Weather Bureau (CWB), the M_L 6.8 quake is the mainshock and the M_L 6.4 quake is the foreshock. The epicenters of the two quakes are both near the Chihshang fault. The ground shaking reaches CWB Seismic Intensity Level 6 Upper (6+) and the peak ground acceleration 607 gal, leading to disasters including building and bridge collapse in Hualien and Taitung. Within 1 hour after the mainshock, NCREE convened the seismic disaster emergency response meeting. Damage surveys were quickly planned and scheduled based on the early loss estimation results reported by the disaster estimation team and the latest disaster information reported by disaster information collection team. On the next day, Sep. 19, Director General, Chung-Che Chou, led members of Building Engineering Division, Bridge Engineering Division, Earth Sciences and Geotechnical Engineering Division, Nonstructural Components and Systems Division to conduct on-site damage survey in Hualien and Taitung, inspecting damage sites and collecting information about the cause of disasters.

- After the earthquakes, disaster information collection is gradually completed. Information of the earthquakes and the report of disasters is published on the NCREE official website.

2022 09/17

– Information of Guanshan and Chihshang earthquakes in Taitung

- Report in Chinese Ed. 1 (v1.2): uploaded on Sep. 18, 2022. https://reurl.cc/aGDYX9
- Report in Chinese Ed. 2 (v2.3): uploaded on Sep. 19, 2022. https://reurl.cc/NRodM6

Outline of Disaster Investigation Report

- Ground Motion Characteristics
- Damage of Buildings
- Damage of Bridges
- Geotechnical Damage
- Damage of Nonstructural Components and Nonbuilding Structures
- Information for Earthquake Early Warning, Structural Monitoring and Control

Outline of Disaster Investigation Report

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CWB Earthquake Report

■ 【Earthquake No.: 111086】

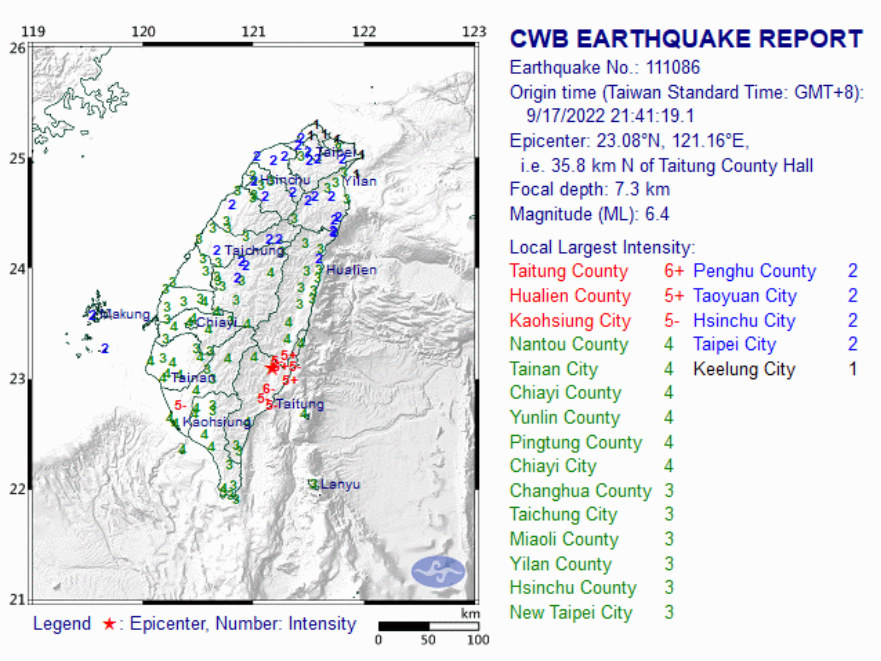
Origin time (Taiwan Standard Time: GMT+08:00): 9/17/2022 21:41:19.1

Location: 23.08N 121.16E, i.e. 35.8 km N of Taitung County

Depth : 7.3 km

Magnitude(M_L): 6.4

Guanshan Eqk.



■ 【Earthquake No.: 111111】

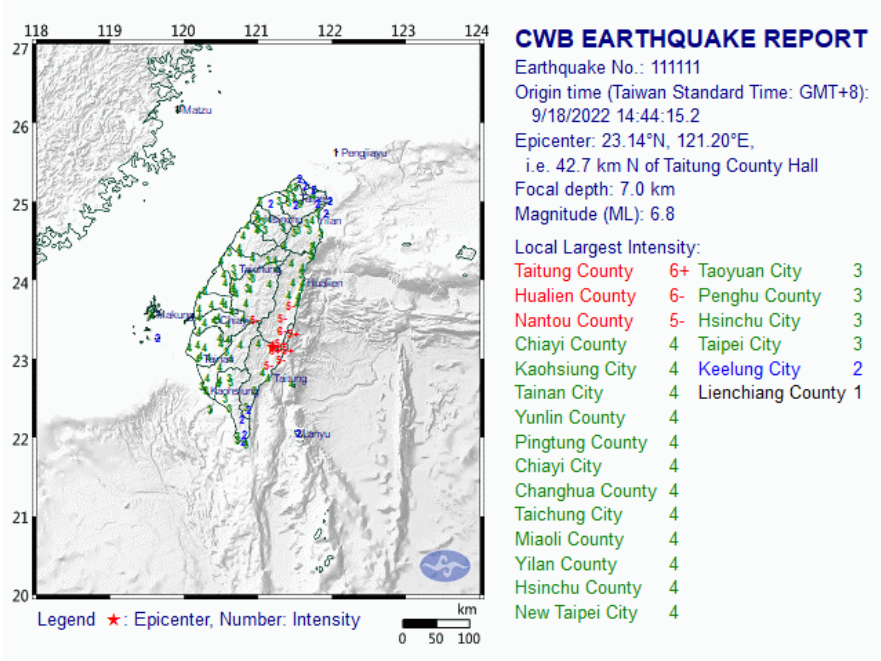
Origin time (Taiwan Standard Time: GMT+08:00): 9/18/2022 14:44:15.2

Location: 23.14N 121.20E, i.e. 42.7 km N of Taitung County

Depth : 7.0 km

Magnitude(M_L): 6.8

Chihshang Eqk.



According to the press conference of the CWB at 16:30 pm on September 18, the M_L6.8 earthquake on September 18 was the main shock, and the M_L6.4 earthquake on September 17 was the foreshock.

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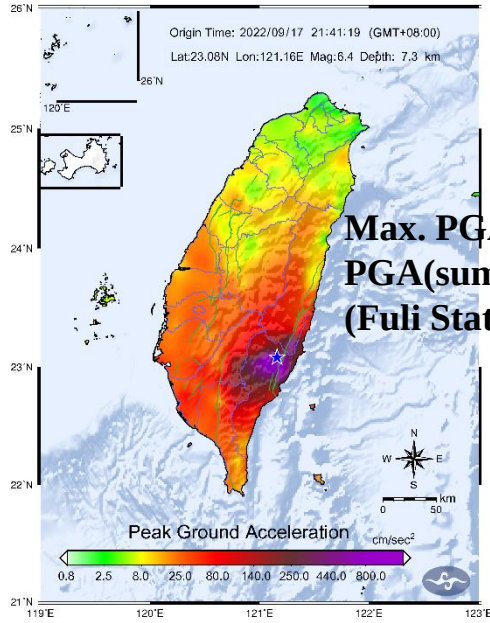
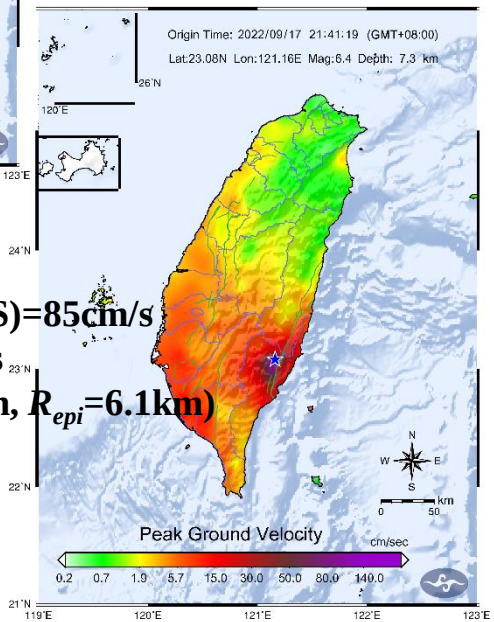
The Ground Motion Map from CWB

Guanshan Eqk. 0917M_L6.4

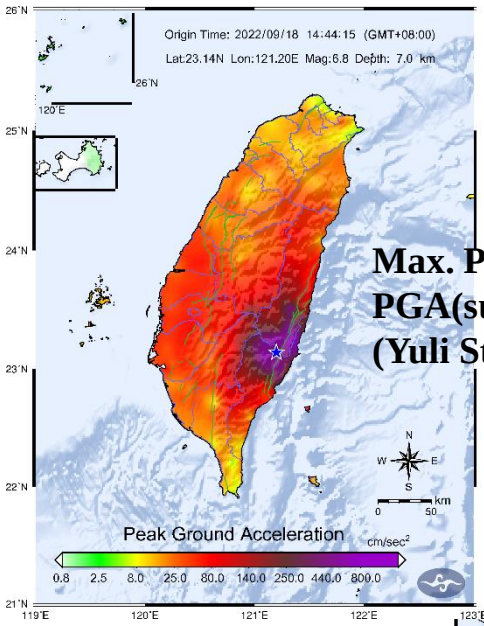


Max. PGA(EW, NS)=449gal
PGA(sum)=607gal
(Fuli Station, R_{epi}=19km)

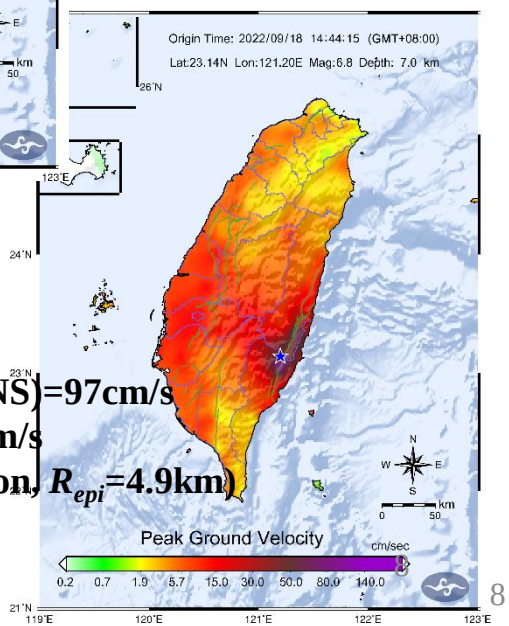


Max. PGV(EW, NS)=85cm/s
PGV(sum)=91cm/s
(Chihshang Station, R_{epi}=6.1km)

Chihshang Eqk. 0918M_L6.8



Max. PGA(EW, NS)=501gal
PGA(sum)=550gal
(Yuli Station, R_{epi}=26km)

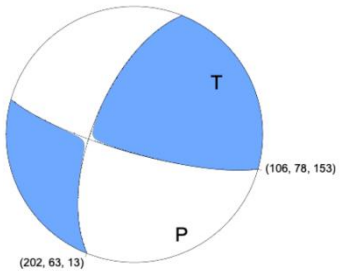


Max. PGV(EW, NS)=97cm/s
PGV(sum)=109cm/s
(Chihshang Station, R_{epi}=4.9km)

Focal mechanism

Guanshan Eqk. 0917M_L6.4

- From USGS (W-phase Moment Tensor (Mww)): the source rupture type belongs to strike-slip faulting, Mw = 6.53, Depth=13.5km.
- From Broadband Array in Taiwan for Seismology of Institute of Earth Sciences, Academia Sinica (AutoBATS MT) : the source rupture type also shows the strike-slip faulting, M_w = 6.5, Depth=13.5km 25km.

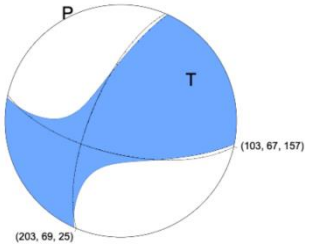


(USGS)

(AutoBATS MT)

Chihshang Eqk. 0918M_L6.8

- From USGS (W-phase Moment Tensor (Mww)): the source rupture type belongs to oblique reverse fault, Mw = 6.93, Depth=11.5km.
- The moment tensor solution from Broadband Array in Taiwan for Seismology of Institute of Earth Sciences, Academia Sinica, including GMRT and W-Phase, have similar results.

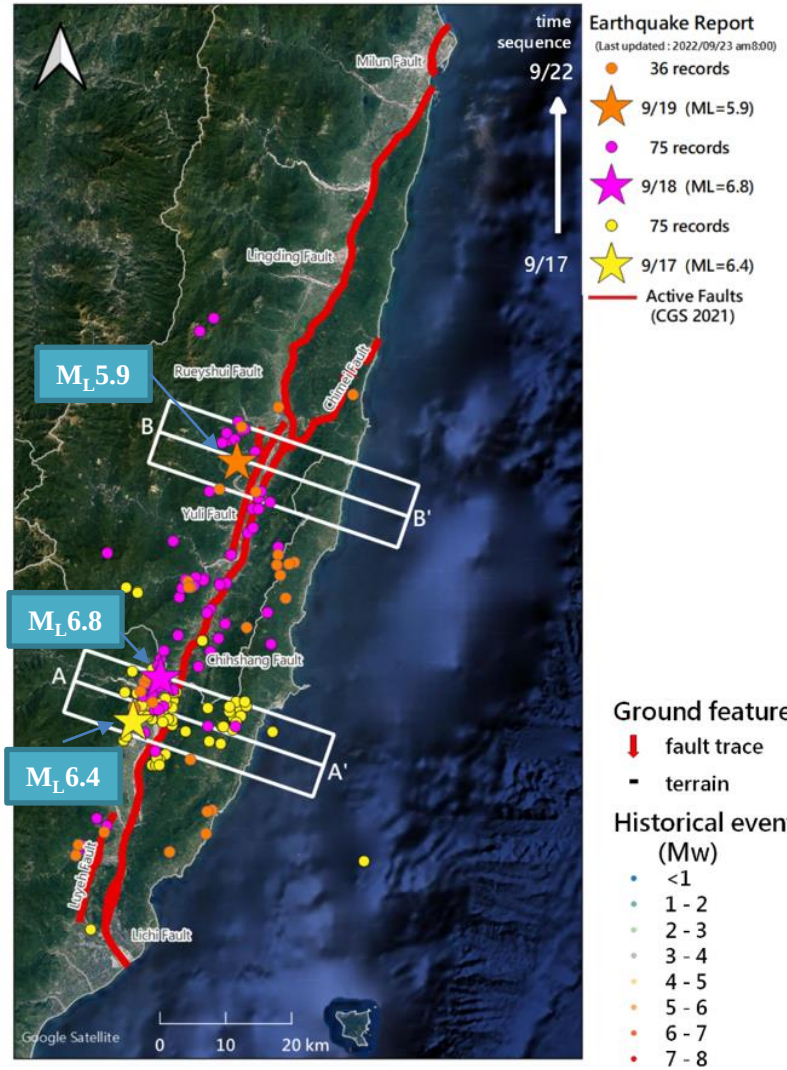


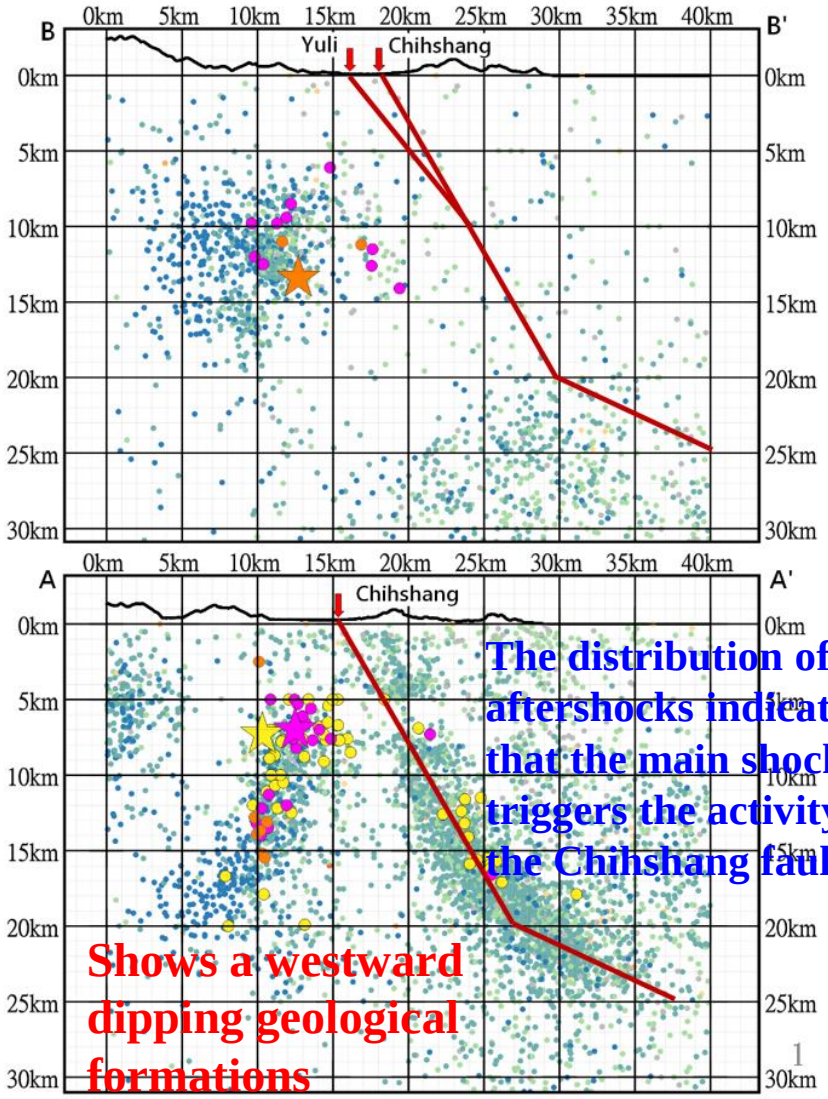
(USGS)

GRMT
(IES、TEC)

W-Phase
(IES、TEC)

Location of the Earthquake and Fault



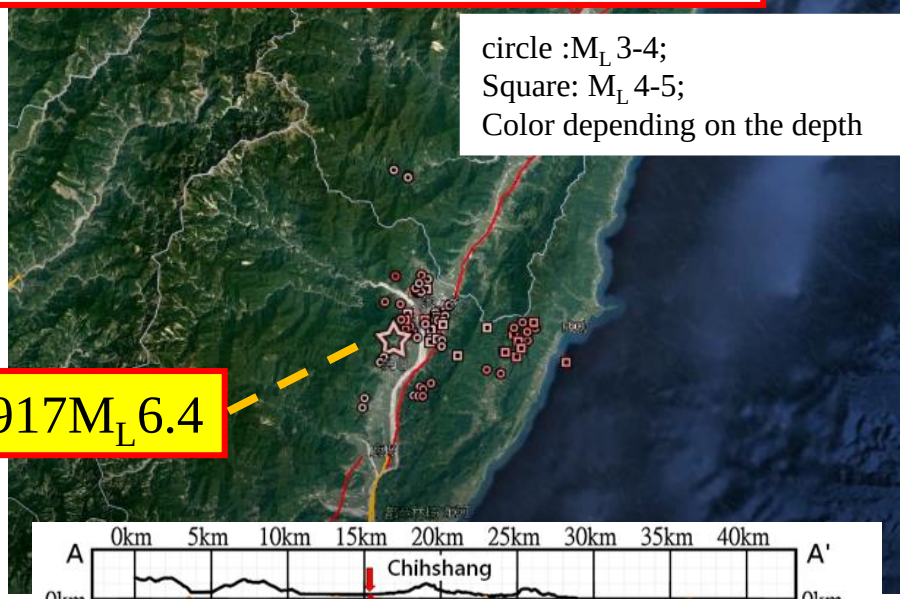


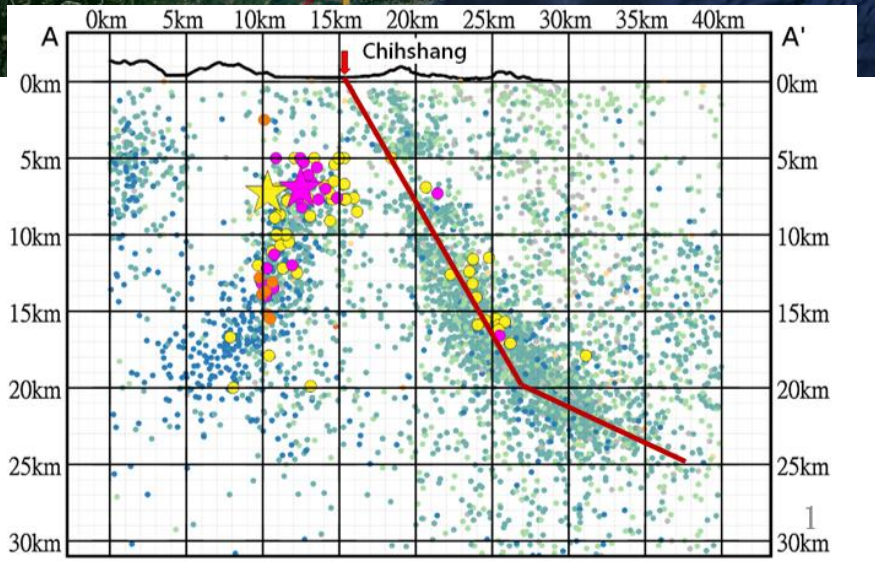
The distribution of aftershocks indicates that the main shock triggers the activity of the Chihshang fault.

Shows a westward dipping geological formations

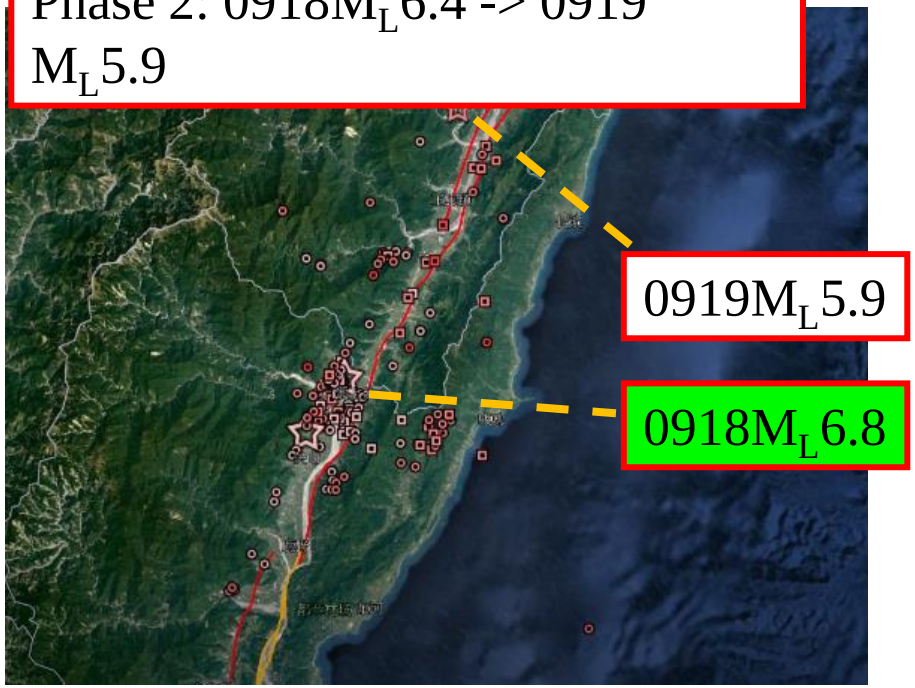
Spatial and Temporal Distribution of Aftershock

Phase 1: 0917M_L6.4 -> 0918 M_L6.8





Phase 2: 0918M_L6.4 -> 0919 M_L5.9



(↑Video from Chih-Wei Chang, https://www.youtube.com/watch?v=Ea2pmS6E2aM)

The aftershocks of 0918M_L6.8 occurred along the longitudinal valley to the northeast, and a larger aftershock occurred on the north side on September 19.

Spatial and Temporal Distribution of Aftershock(Video)

Earthquake catalog from CWB. Video made by Chih-Wei Chang(NCREE)

NCREE Real-time Earthquake Information Display Platform

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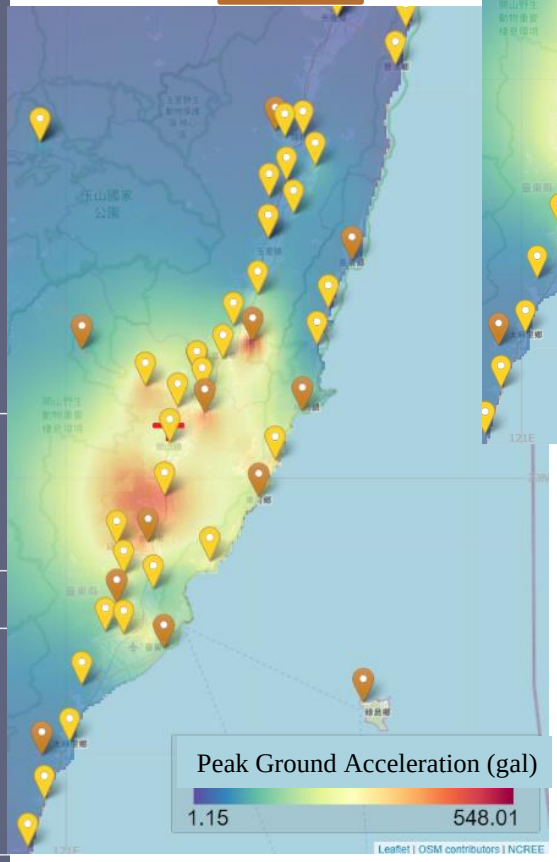
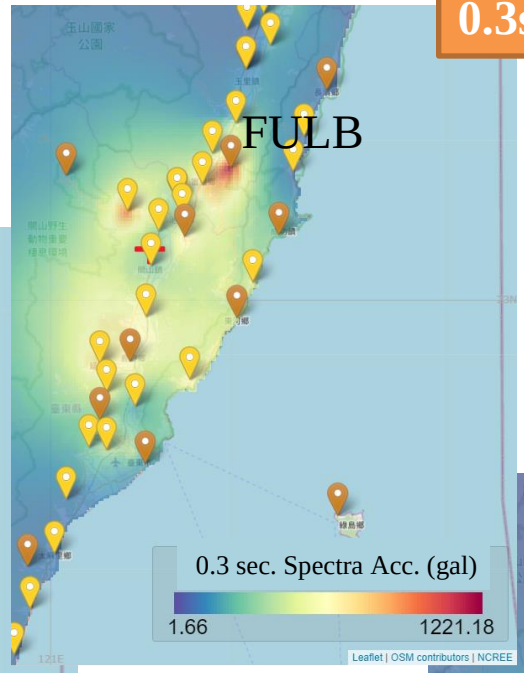
Guanshan Eqk. 0917M_L6.4

PGA

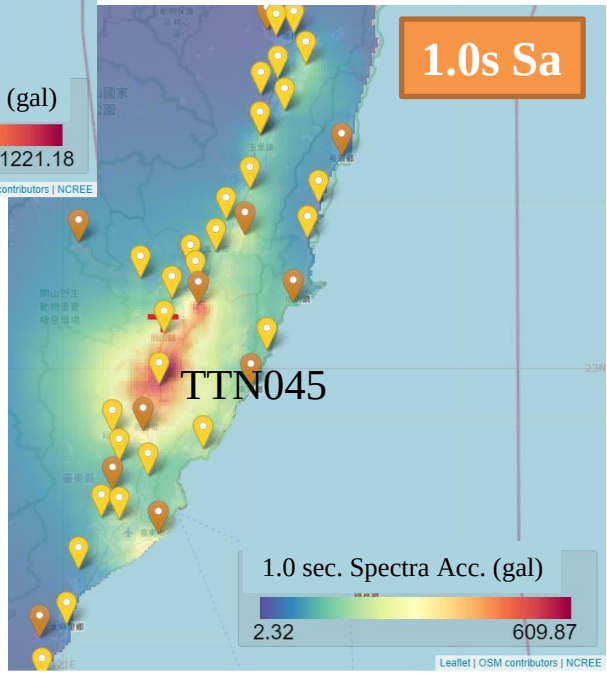


0.3s Sa



Integrate the real-time observation records of the CWB, the NCREE, and the ground motion parameters estimated by the advanced ground motion prediction model to display the ground motion information in real time.

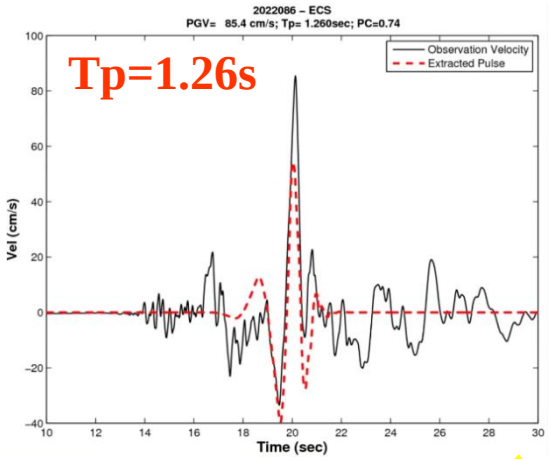
1.0s Sa



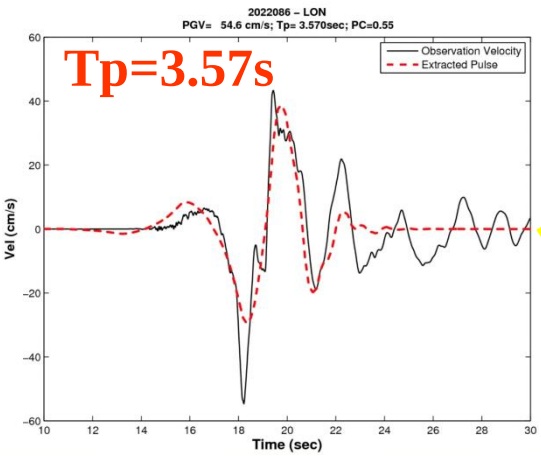
Pulse-Like Ground Motion

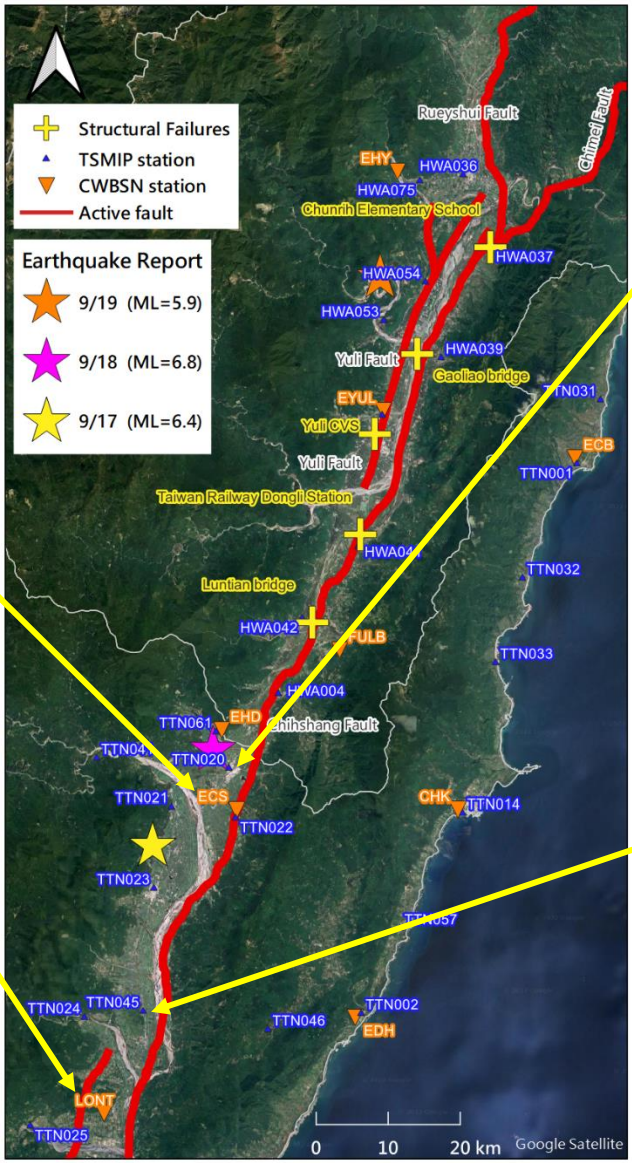
Guanshan Eqk. 0917M_L6.4

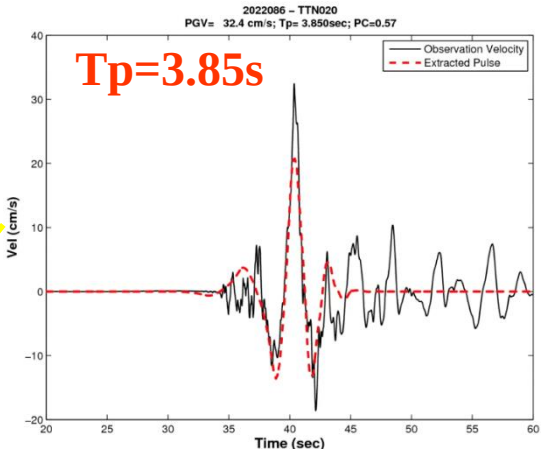
Chihshang Station

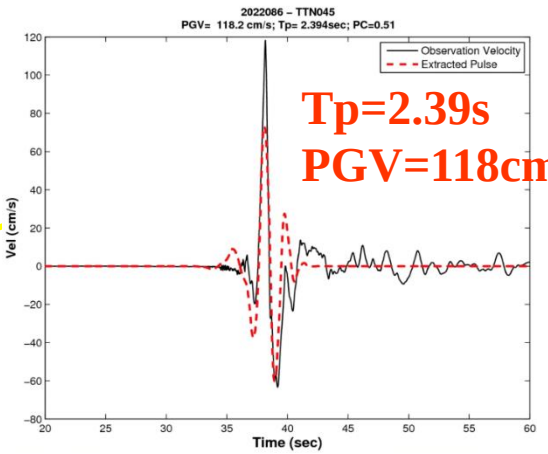


Luye Station



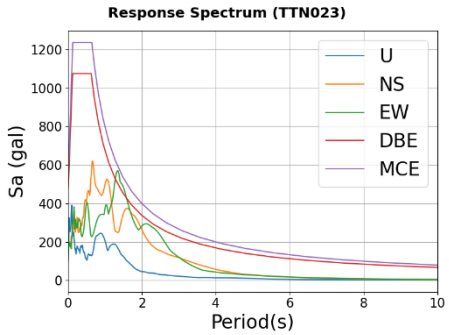


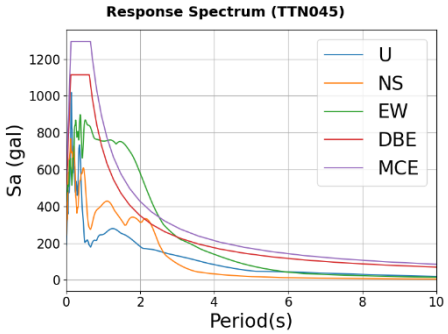




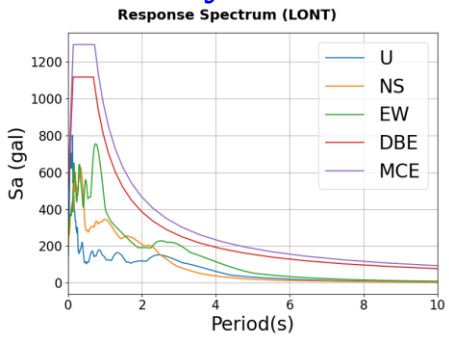
Observed Data and Design Spectra

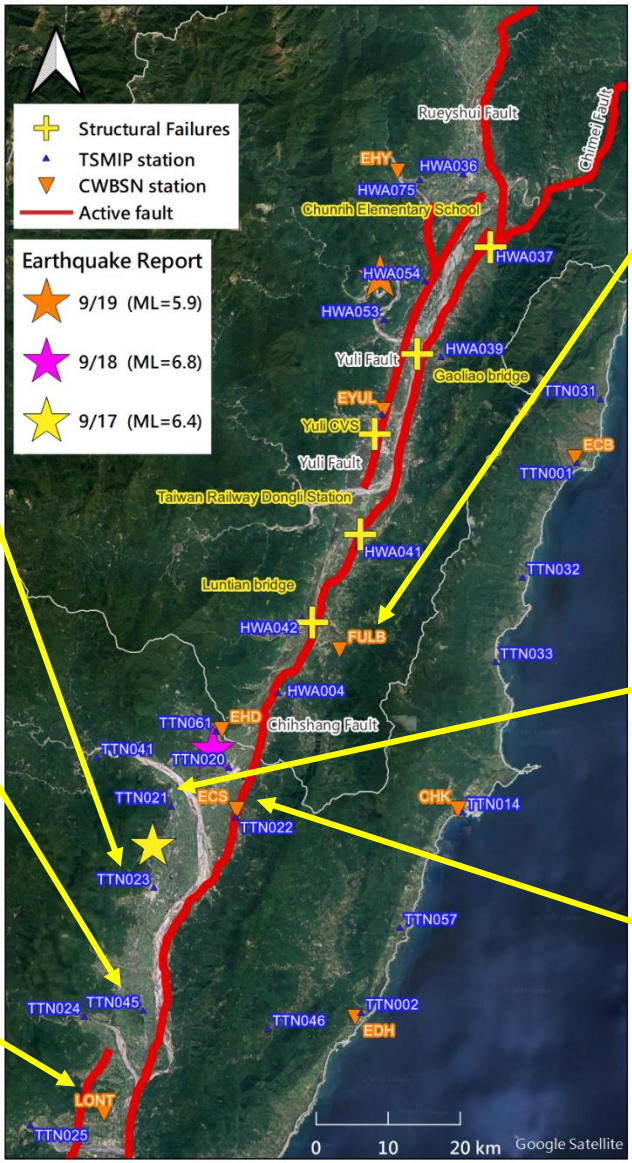
Guanshan Eqk. 0917M_L6.4



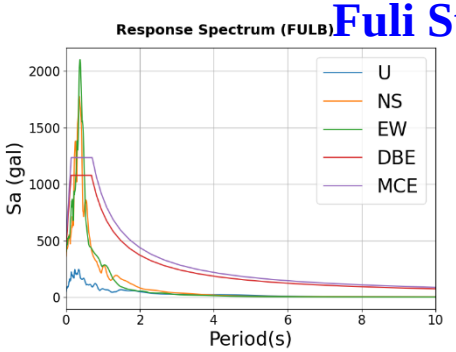


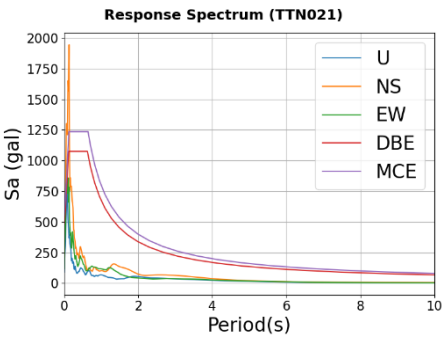
Luye Station



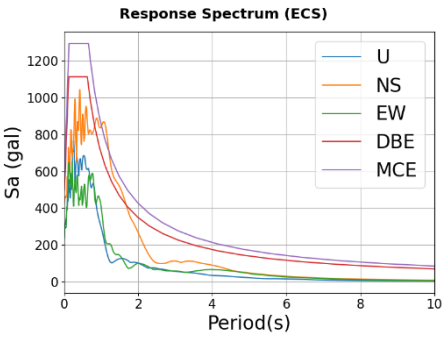


Fuli Station





Chihshang Station



NCREE Real-time Earthquake Information Display Platform

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Chihshang Eqk. 0918M_L6.8

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國家地震工程研究中心
National Center for Research on Earthquake Engineering

地震事件：

2022-09-18 14:44 規模：6.8

地震代號： 111111
發震時間： 2022-09-18 14:44:15
芮氏規模： 6.8
發震深度： 7KM
發震地點： 臺東縣政府北方 42.7 公里 (位於臺東縣池上鄉)
最大震度： 6強
震央經緯度： 121.2035, 23.1375
中央氣象局連結
中央研究院連結

顯示地震動類型

地表加速度峰值

讀取地震動分布圖

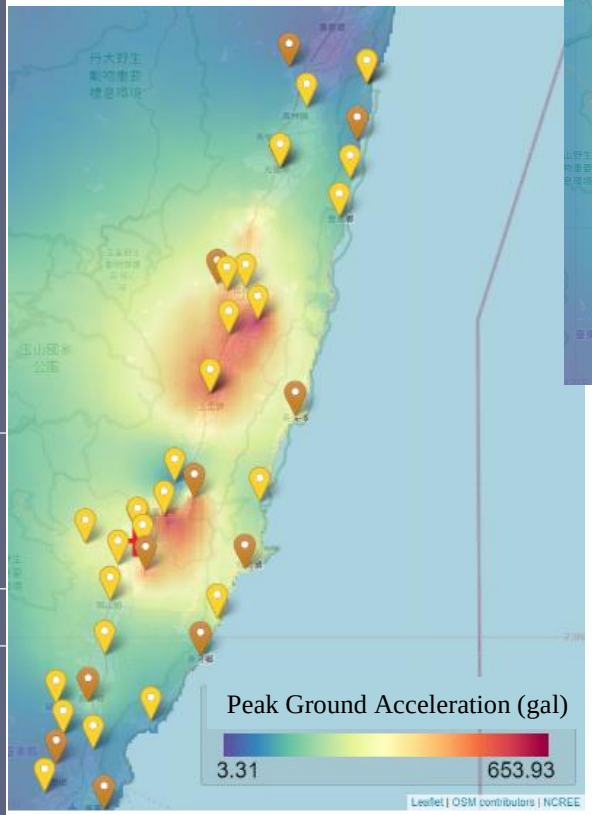
事件圖檔下載

測站紀錄

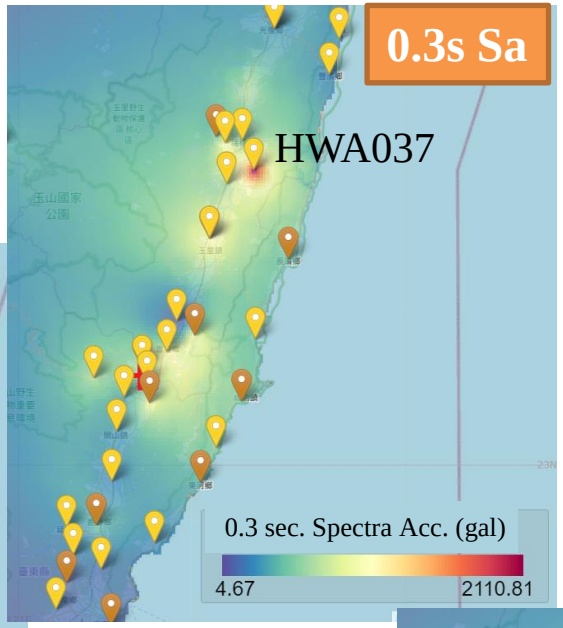
- 選擇全部
- 氣象局即時站(CWBSN)
- 國震現地型震預警系統(EEWS)
- 國震即時陣列(SANTA)
- 氣象局強震網(TSMIP)

參考圖資

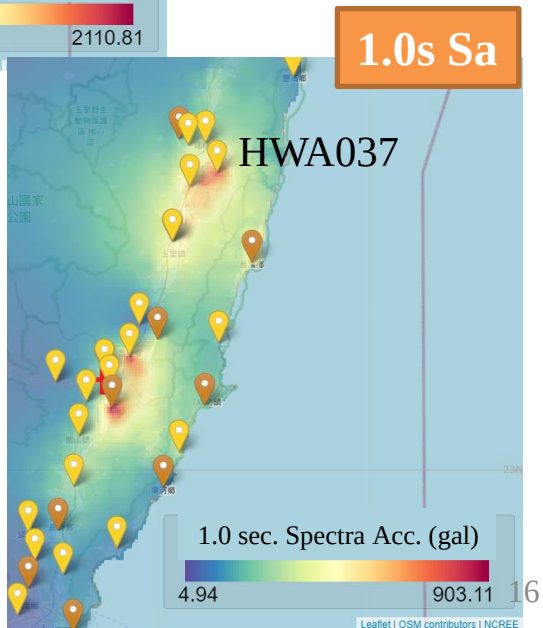
PGA



0.3s Sa



1.0s Sa



Pulse-Like Ground Motion

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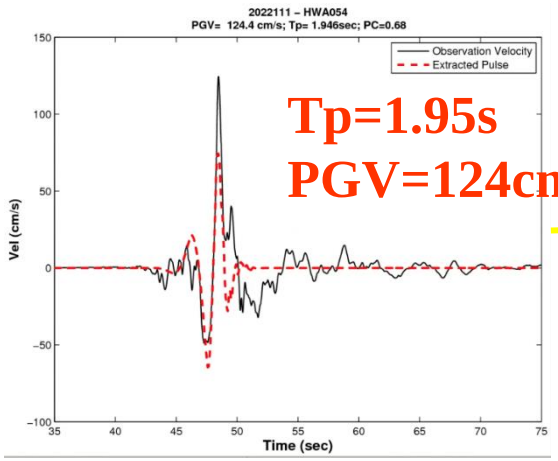
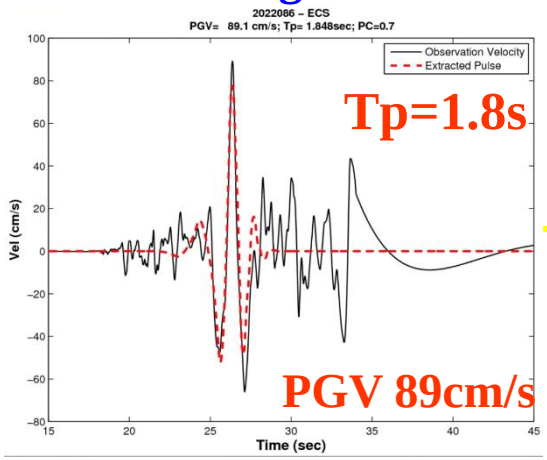
Chihshang Eqk. 0918M_L6.8



Tp=1.95s

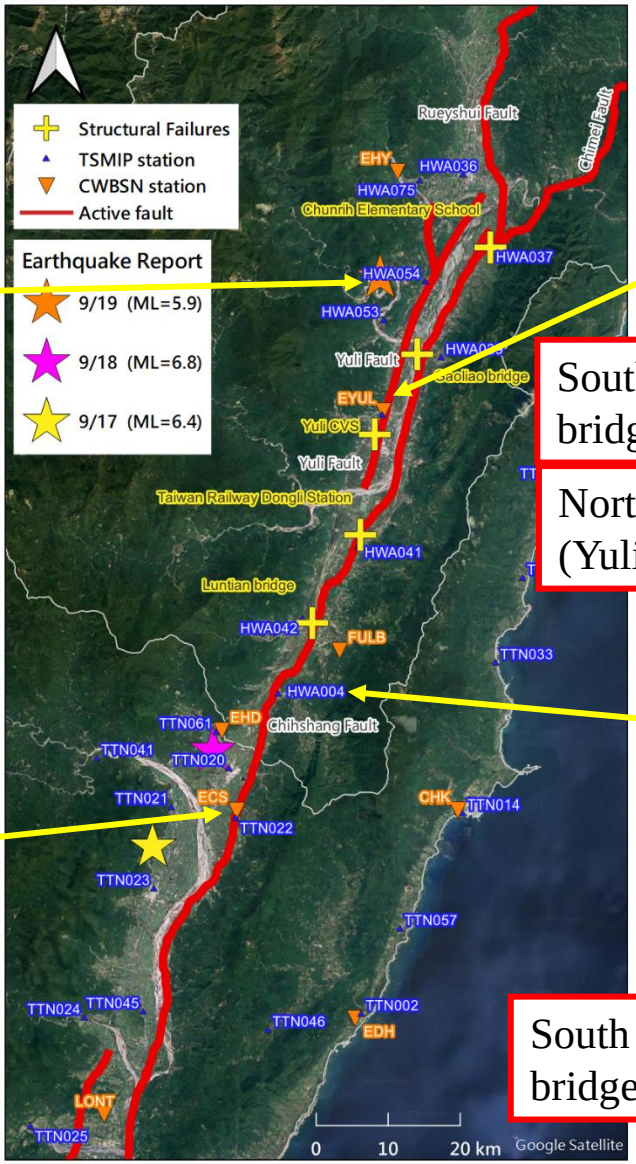
PGV=124cm/s

Chihshang Station

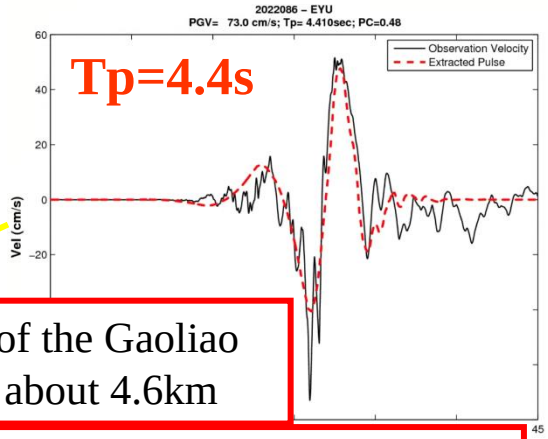


Tp=1.8s

PGV 89cm/s



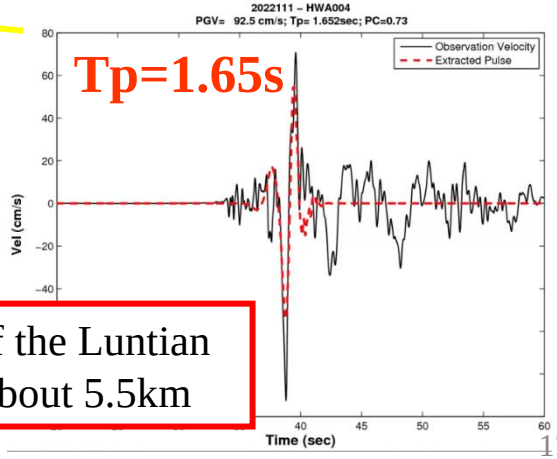
Yuli Station



Tp=4.4s

South of the Gaoliao bridge about 4.6km

North of the damaged building (Yuli 7-Eleven CVS) about 1.4km.



Tp=1.65s

South of the Luntian bridge about 5.5km

Observed Data and Design Spectra

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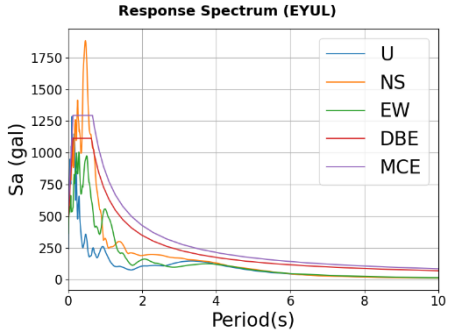
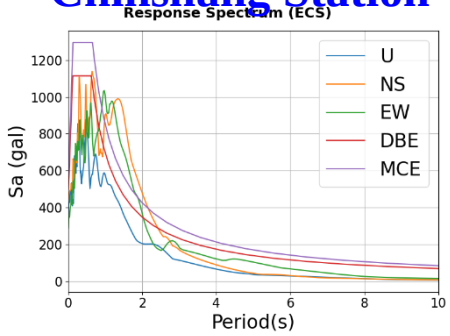
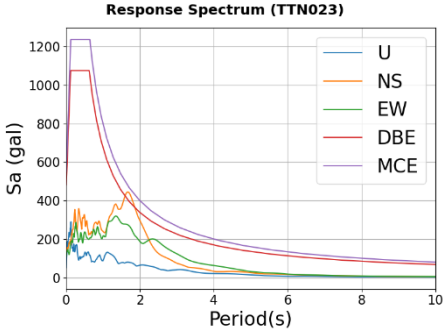
Chihshang Eqk. 0918M_L6.8

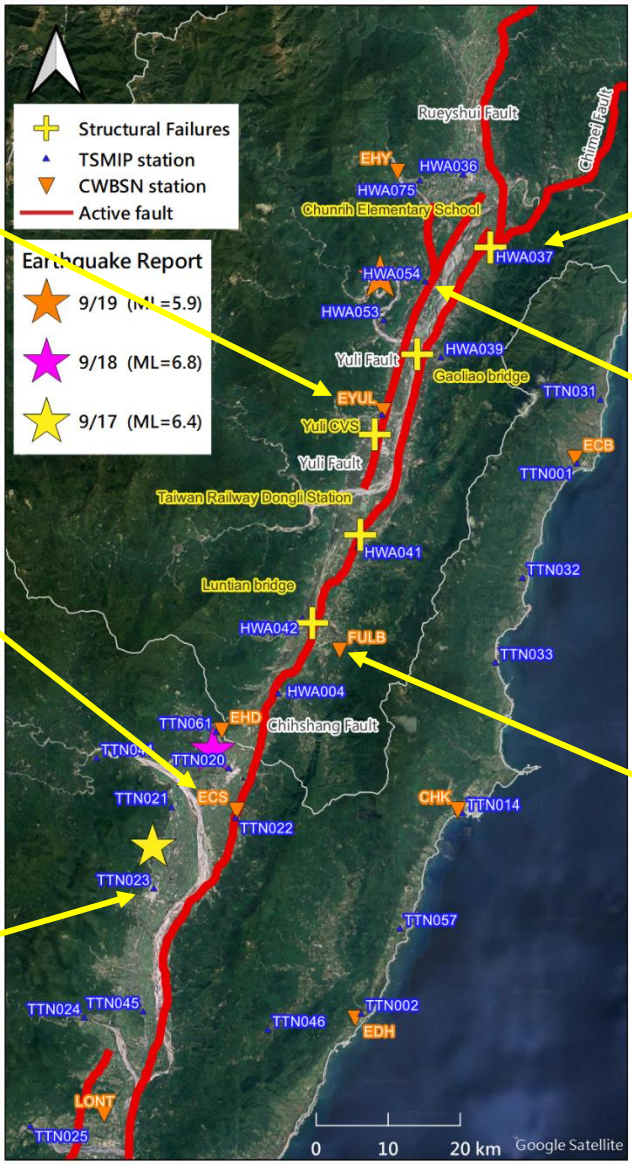
Yuli Station

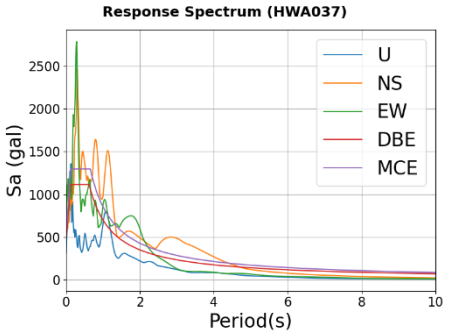


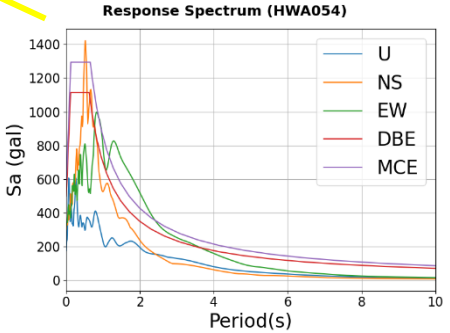
Chihshang Station



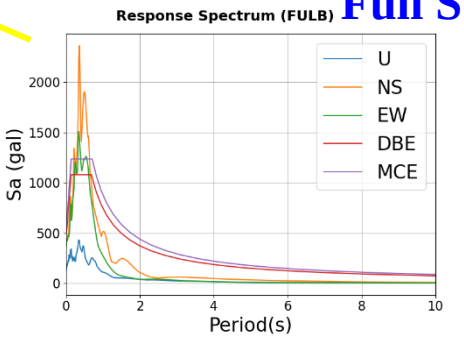








Fuli Station



Outline of Disaster Investigation Report

- Ground Motion Characteristics
- Damage of Buildings
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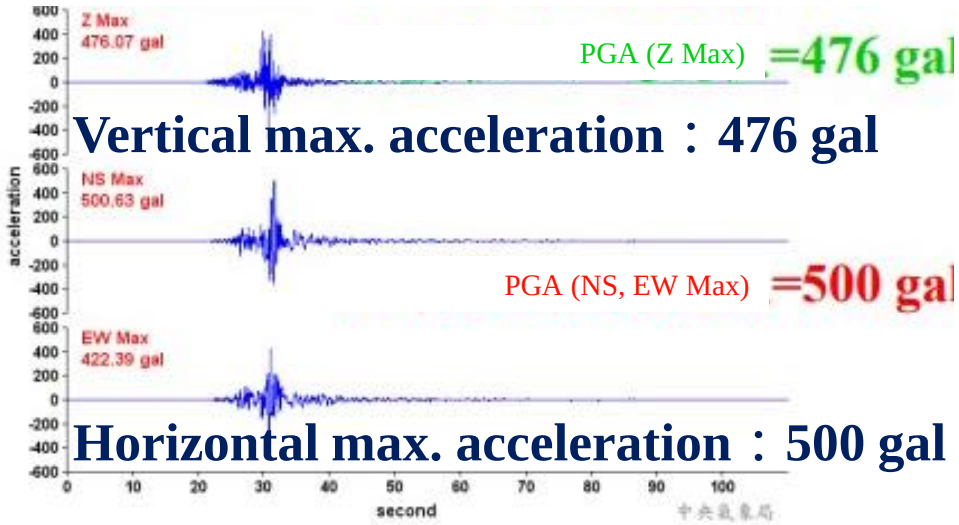
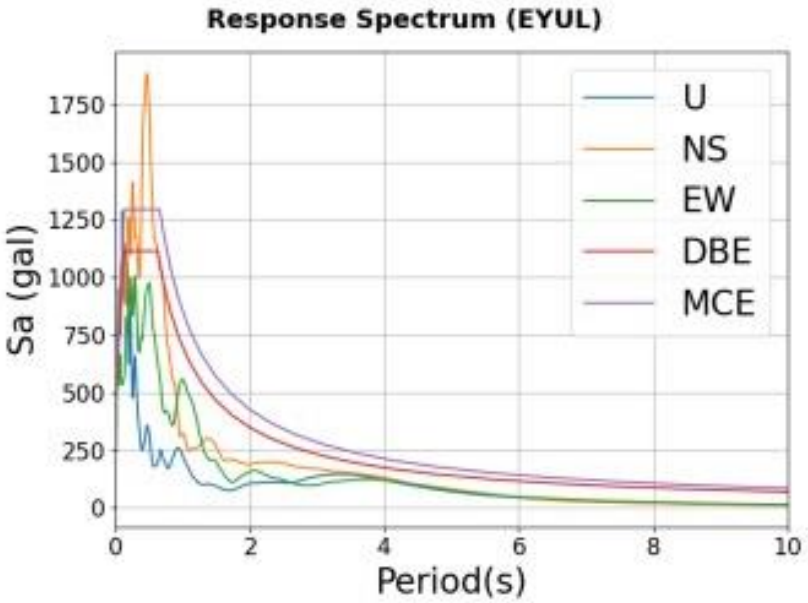
- Damage of Nonstructural Components and Nonbuilding Structures
- Information for Earthquake Early Warning, Structural Monitoring and Control

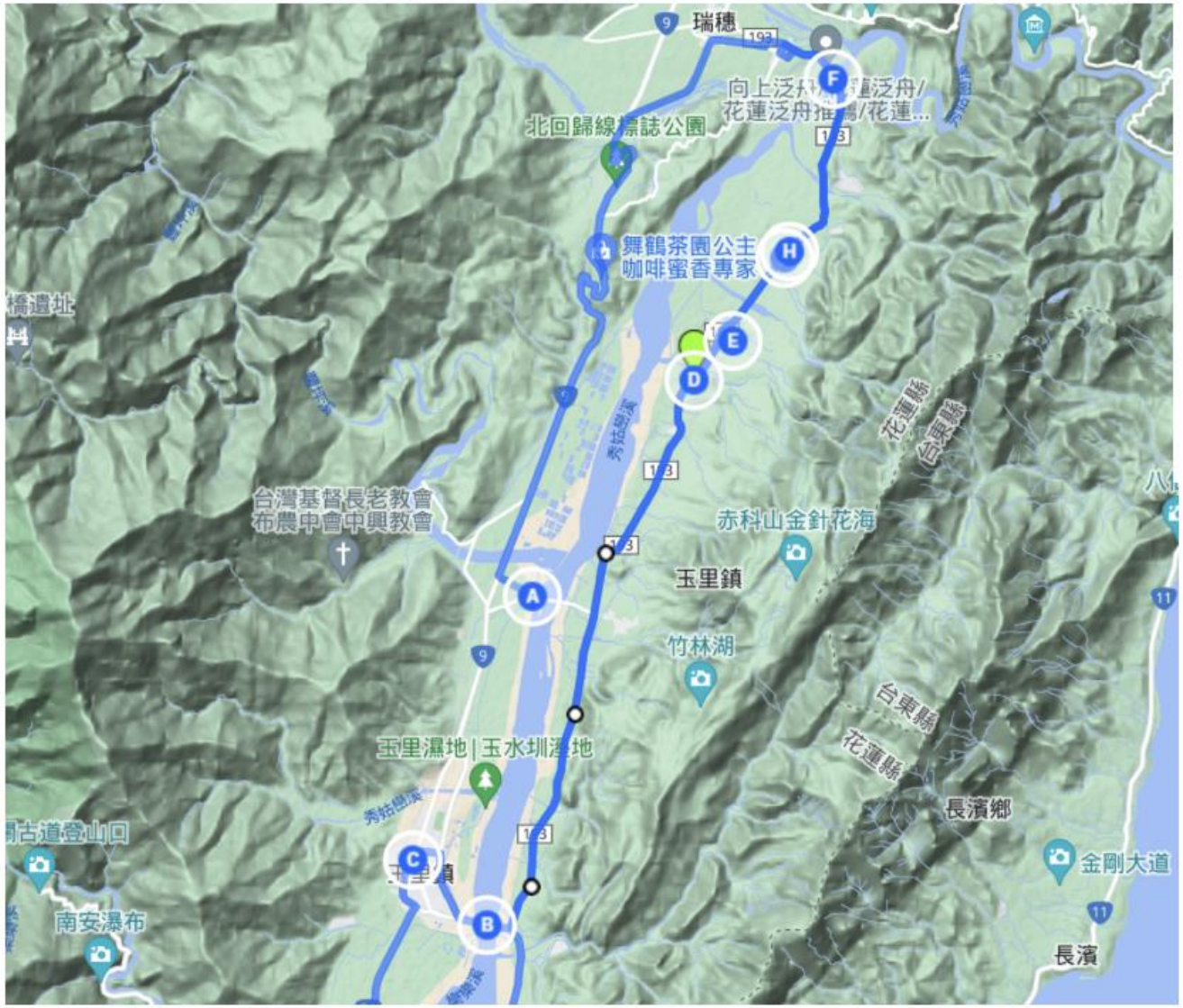
Earthquake records measured by Yuli Station





Max. horizontal acceleration：500 gal
Spectral acceleration exceeds the MCE level in the short period range)

2022.09.20 (Tue.) Earthquake Reconn. Itinerary



9/20 (Hualien)

- **Convenience Store (7-11) in Yuli Township（C）**
- **Songpu Church（D）**
- Song-Pu & Wan-Li communities (E)
- Chun-Rih elementary school（G）
- **Tianxuan Church（H）**

Itinerary

- 9/20 (Hualien)
  - **Convenience Store (7-11) in Yuli Township**
  - Song-Pu elementary school
  - **Songpu Church**
  - Chun-Rih elementary school
  - **Tianxuan Church**

GPS : (23.335610260597747, 121.3141130677523)

NARLabs

Convenience Store (7-11) in Yuli Township

No. 135, Sec. 2, Zhongshan Rd., Yuli Township, Hualien County

- Reinforced Concrete (RC) Structure
- 1F for commercial use, 2F~4F for Residential
- 1F~3F Build in 1994 (RC Structure).
- The Roof (4F) Build in 1996 (Brick Structure)

GPS : (23.3356102605977 47, 121.3141130677523)

Yuli 7-11 convenience store

Collapse along the transverse direction

GPS : (23.335760357922272, 121.31400648127511)

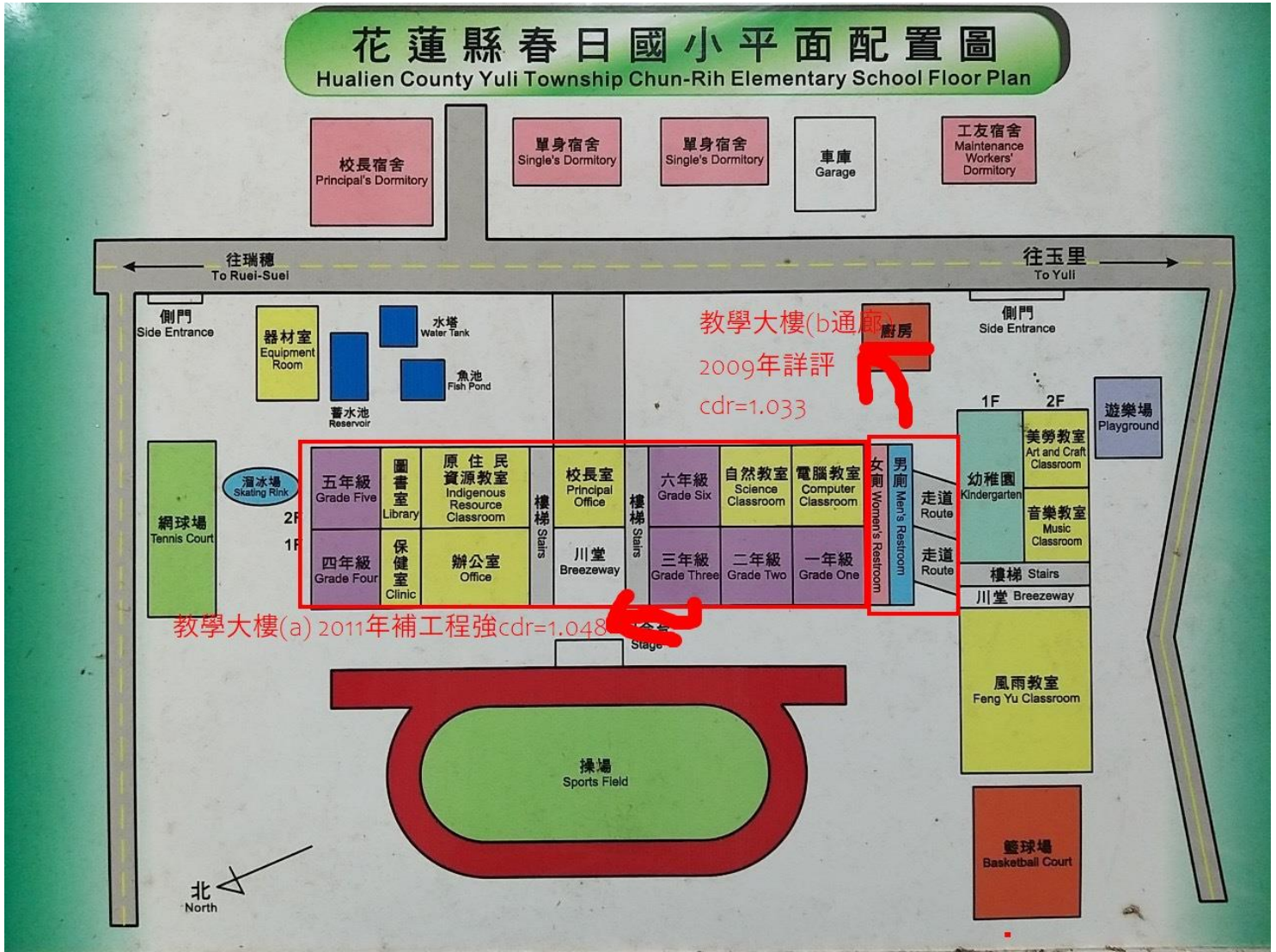
Telecom Company (中華電信)

No. 137, Sec. 2, Zhongshan Rd., Yuli Township, Hualien County

GPS : (23.4525771906309, 121.39301882730187)

Chun-Rih Elementary School (春日國小)

No. 95, Tailin, Yuli Township, Hualien County



GPS : (23.4525771906309, 121.39301882730187)

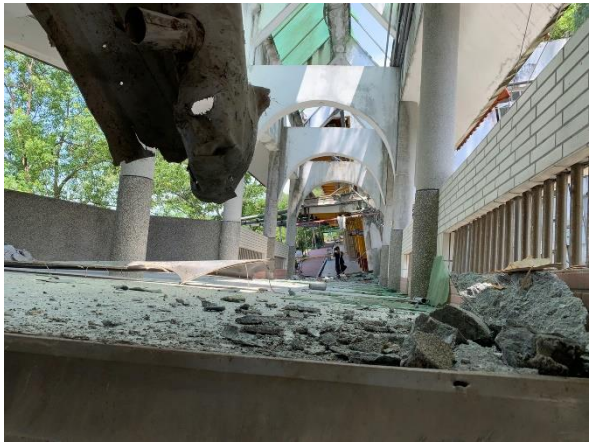
Chun-Rih Elementary School (春日國小)

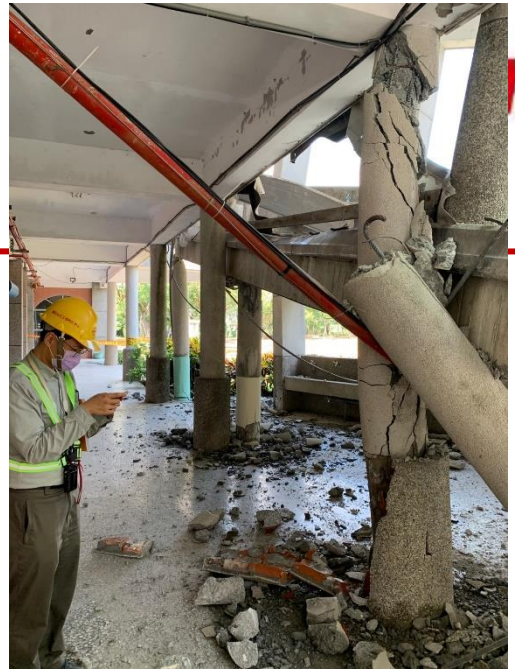
No. 95, Tailin, Yuli Township, Hualien County

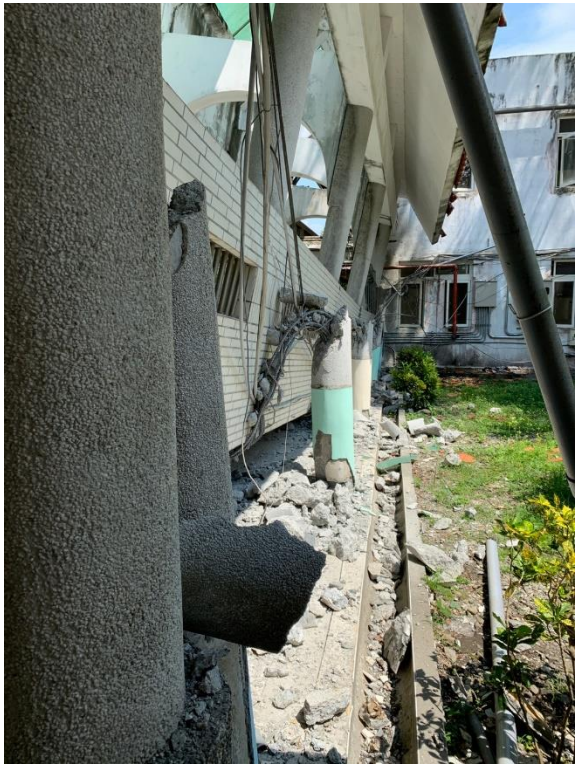
GPS : (23.4525771906309, 121.39301882730187)

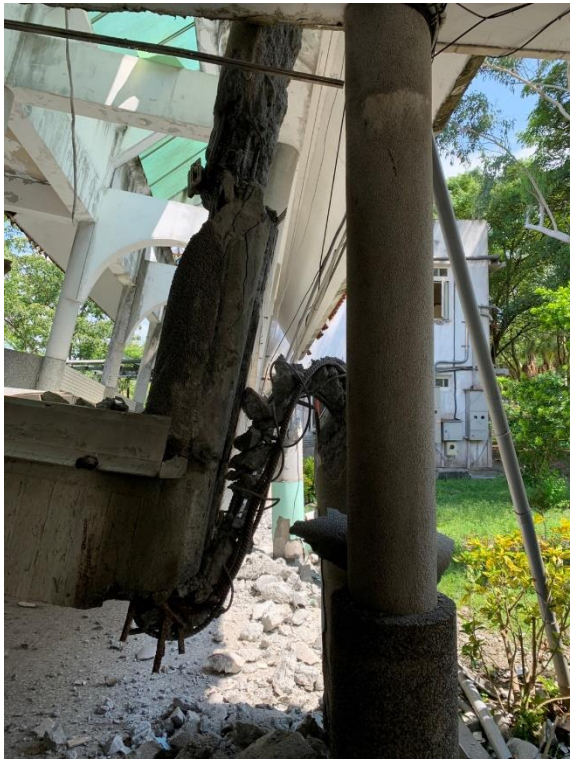
Chun-Rih Elementary School (春日國小)

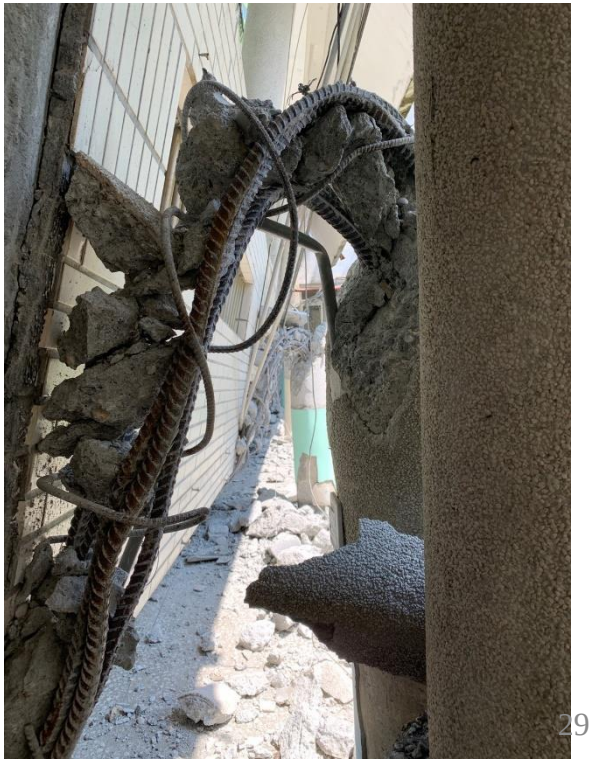
No. 95, Tailin, Yuli Township, Hualien County



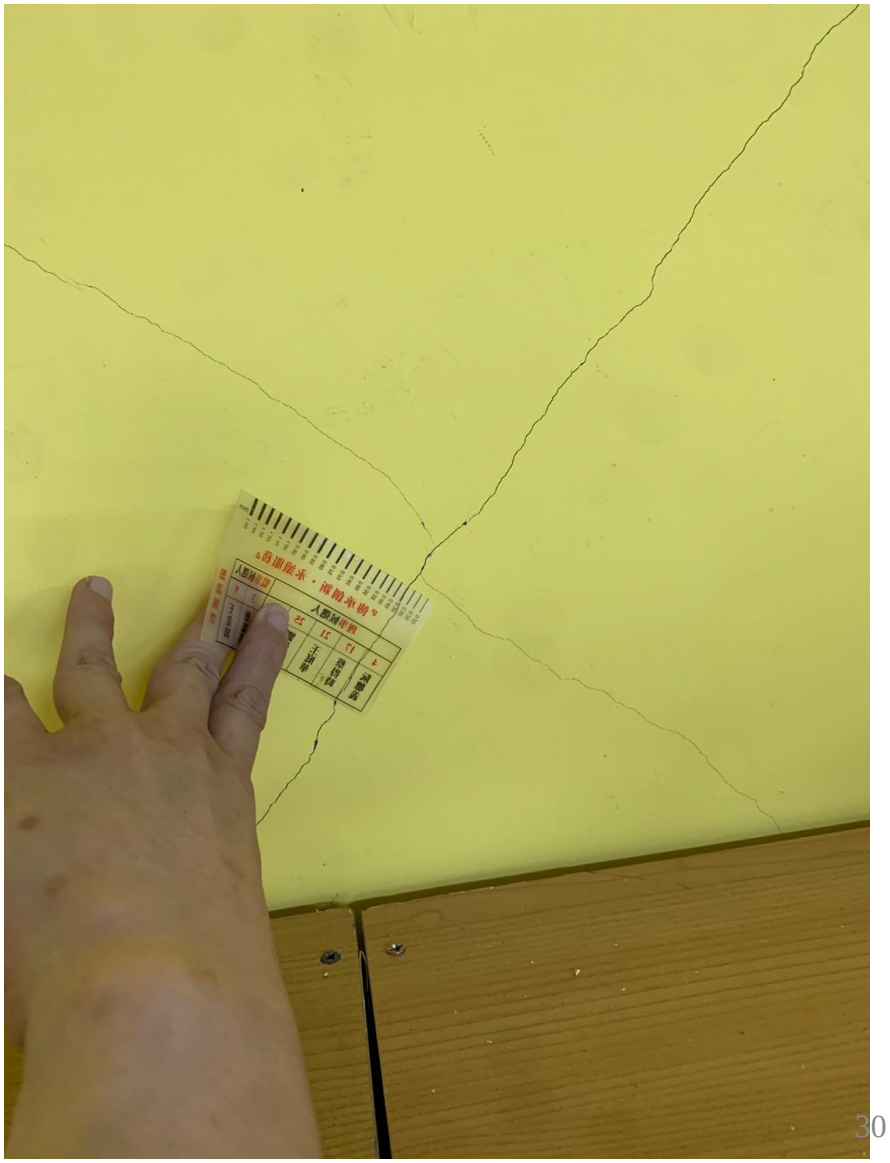




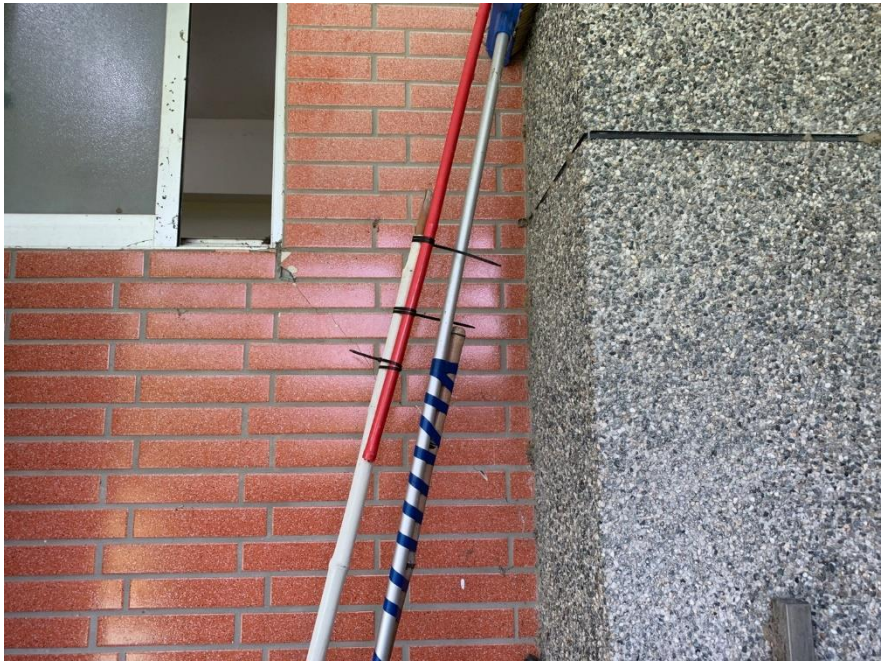




Partition Wall Cracking



Exterior Wall with Windows Cracking



GPS : (23.428664316759765, 121.37356820010618)

Songpu Elementary School (松浦國小)

No. 212, Neighborhood 12, Yuli Township, Hualien County

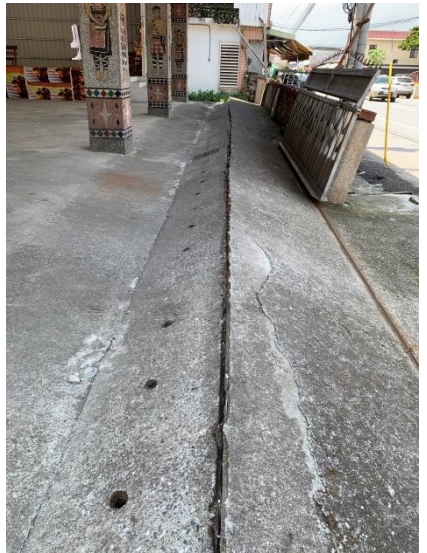
- **Ground Uplift**

GPS : (23.431902458405215, 121.37404963477468)

Songpu Church (松浦天主堂)

No. 174, Songpu, Yuli Township, Hualien County

- Ground Uplift about 20 cm
- Crack Length about 7 m
- Exterior Wall Sloping



GPS : (23.4283788620705, 121.37321414874656)

Residential in Songpu (松浦167號)

No. 167, Songpu, Yuli Township, Hualien County

- Ground Uplift, and Slope about 2°~14°
- Wall Sloping (about 2°)

Residential in Songpu (松浦140號)

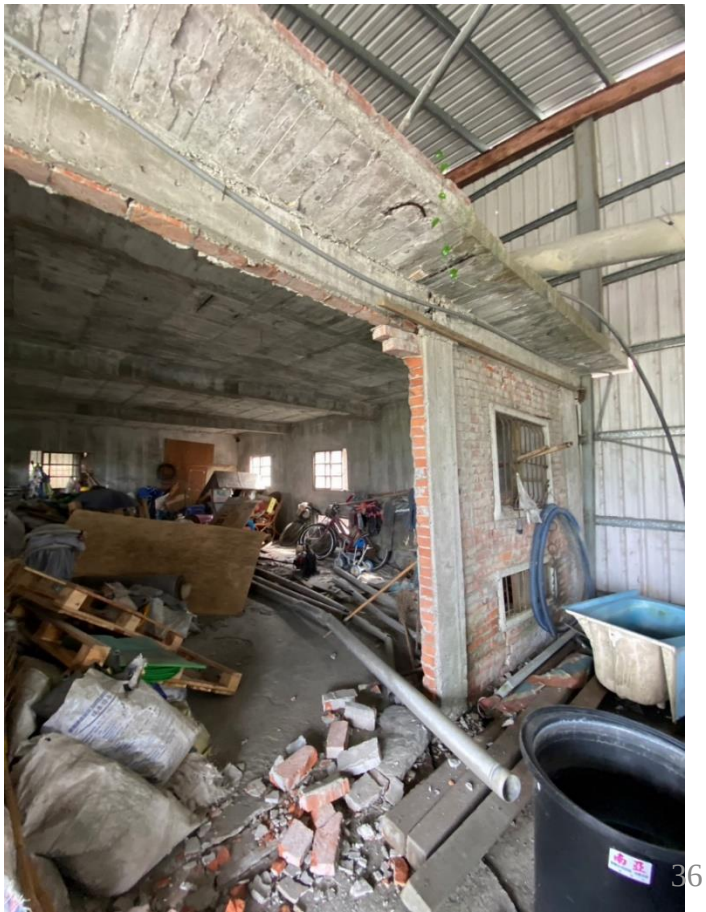
No. 140, Songpu, Yuli Township, Hualien County

- Ground Uplift, Cracking, and Slope about 2°
- Brick Wall Collapsed

Residential in Songpu (松浦141號)

No. 141, Songpu, Yuli Township, Hualien County

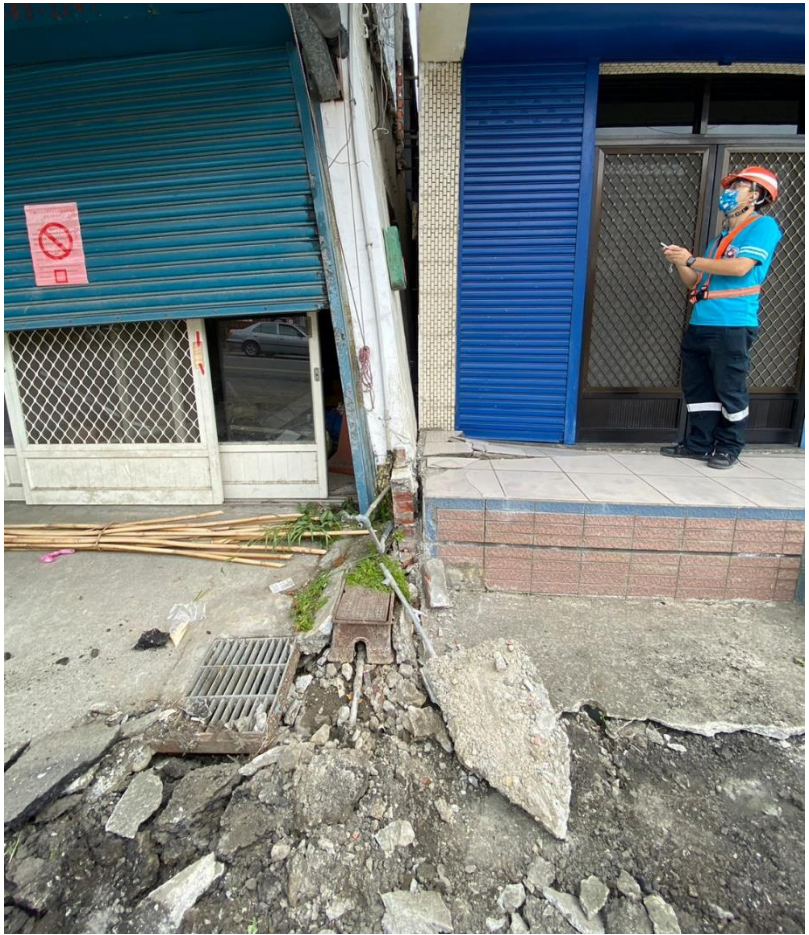
- **Ground Uplift**
- **Brick Wall Collapsed**
- **Plastic Hinge in Column**
- **Rebar rusted**



Residential in Songpu (松浦172號)

No. 172, Songpu, Yuli Township, Hualien County

- Ground Uplift
- Brick Wall Sloped about 8°



GPS : (23.428728615239386, 121.37386532545382)

Residential in Fuyin Community（萬麗143號)

No. 143, Wanli, Yuli Township, Hualien County

- 1F for commercial use, 2F for Residential
- Exterior Cracking, Brick Wall Collapsed

Residential in Fuyin Community（萬麗145號)

No. 145, Wanli, Yuli Township, Hualien County

- Wood Structure
- Ground Uplift

Residential in Fuyin Community（萬麗148號)

No. 148, Wanli, Yuli Township, Hualien County

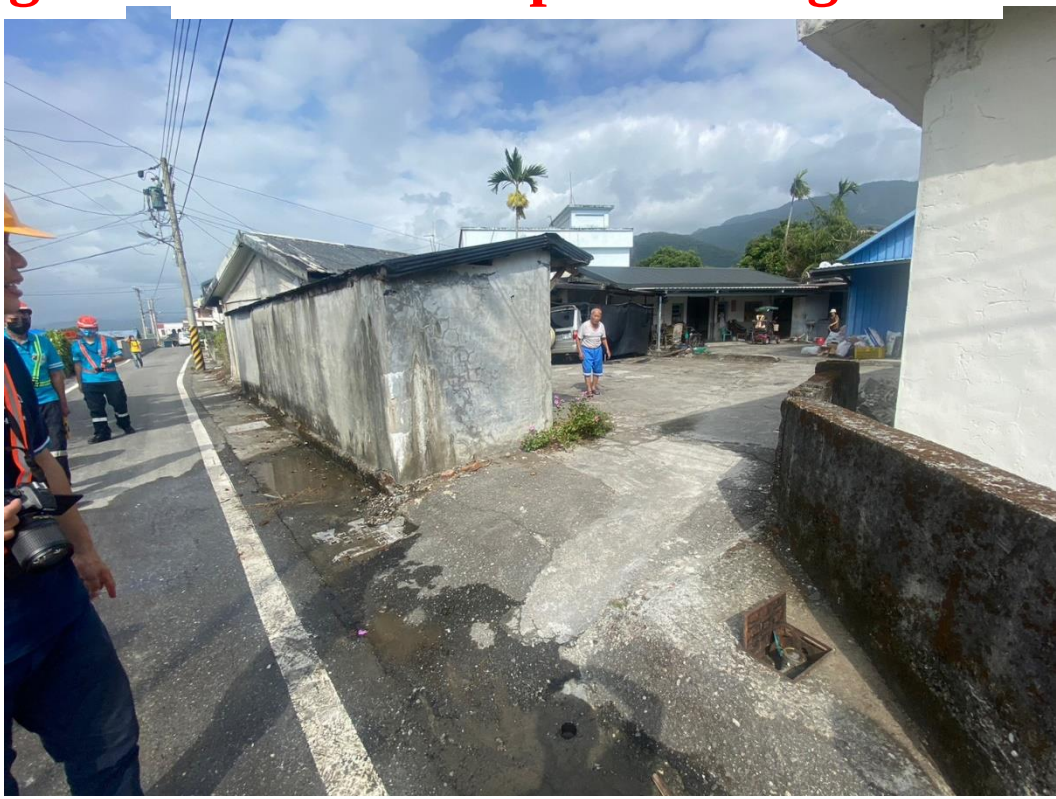
- **The uplift of the ground raises the structure about 5 cm**

Residential in Fuyin Community（萬麗112號)

No. 112, Wanli, Yuli Township, Hualien County

- **Ground Uplift and Cracking**

- **Water Pipe Breakage**



Residential in Fuyin Community（萬麗108號)

No. 108, Wanli, Yuli Township, Hualien County

- Column and Wall Collapsed (Rebar for Column is #3)

GPS : (23.452942977341934, 121.39477133465485)

Tianxuan Church (天宣道院)

No. 107, Yuli Township, Hualien County

- Longitudinal Rebar is #8
- Transverse Rebar is #3

- The First Floor Column Runs Through The Slab(Punching Shear)

- Spacing of Stirrup is 25 cm
- Width of Column is 50 cm

GPS : (23.097787509134697, 121.2188260768424)

NARLabs

Wanan Elementary School (萬安國小)

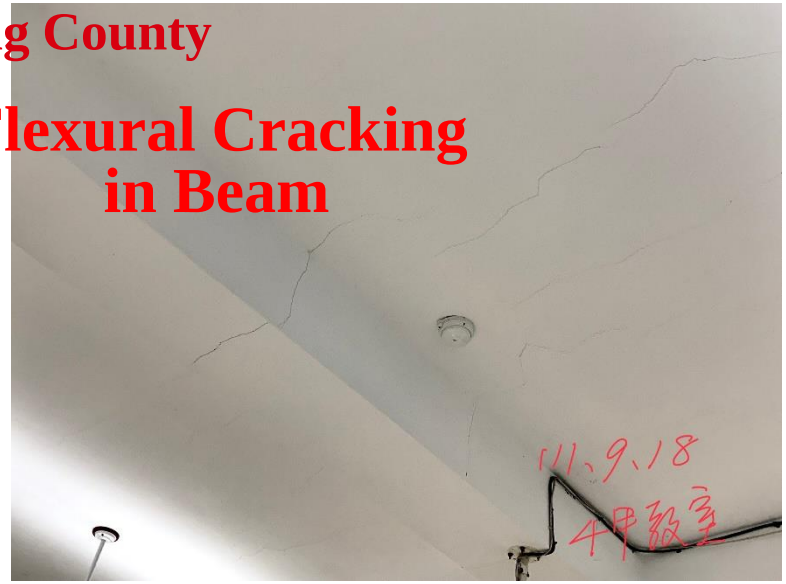
No. 36, Chihshang Township, Taitung County

GPS : (23.315711214952866, 121.45235635031123)

Zhangbin Elementary School (長濱國小)

No. 11, Changbin, Changbin Township, Taitung County

Flexural Cracking
in Beam



Outline of Disaster Investigation Report

- Ground Motion Characteristics
- Damage of Buildings
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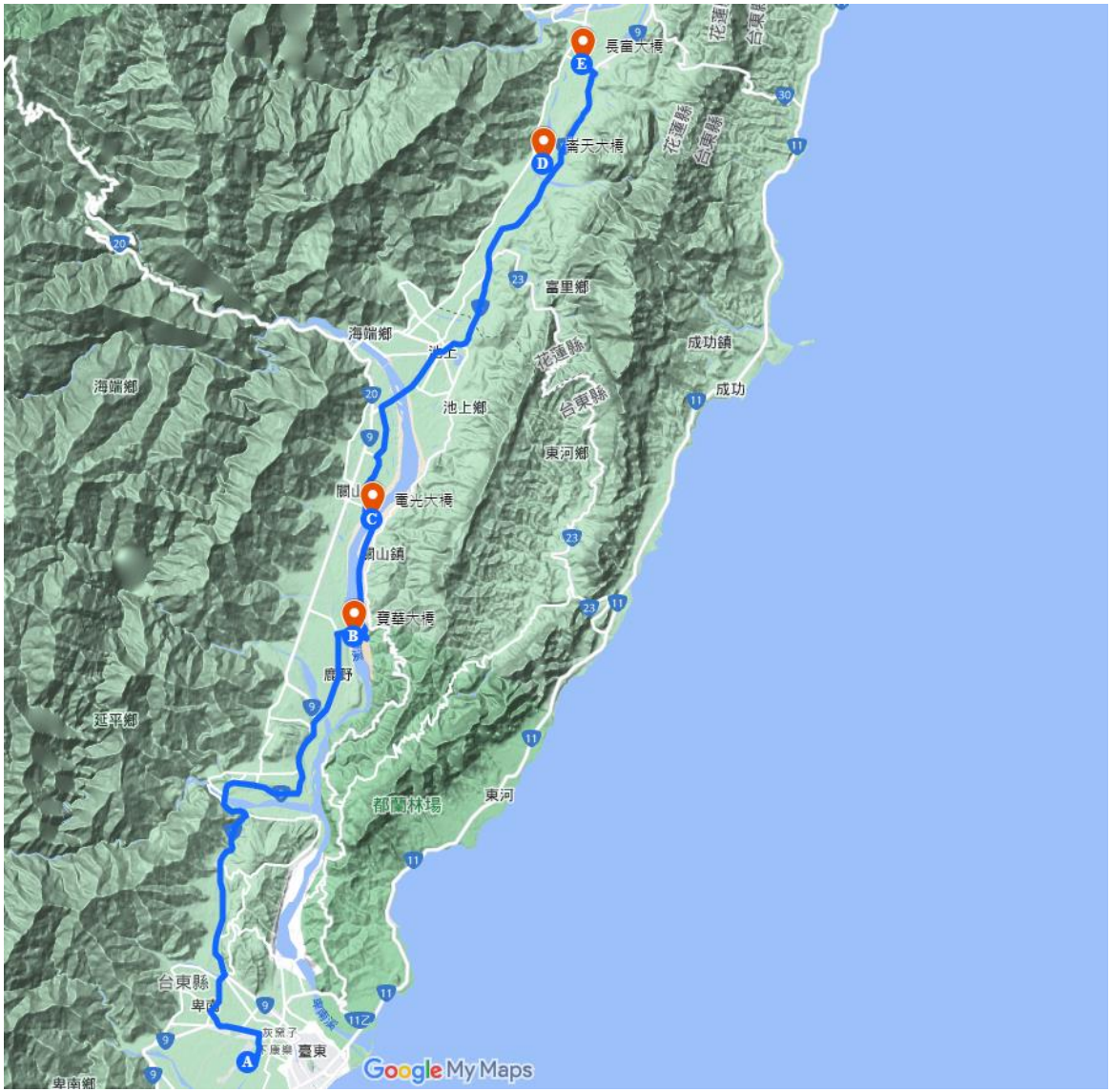
- Geotechnical Damage
- Damage of Nonstructural Components and Nonbuilding Structures
- Information for Earthquake Early Warning, Structural Monitoring and Control

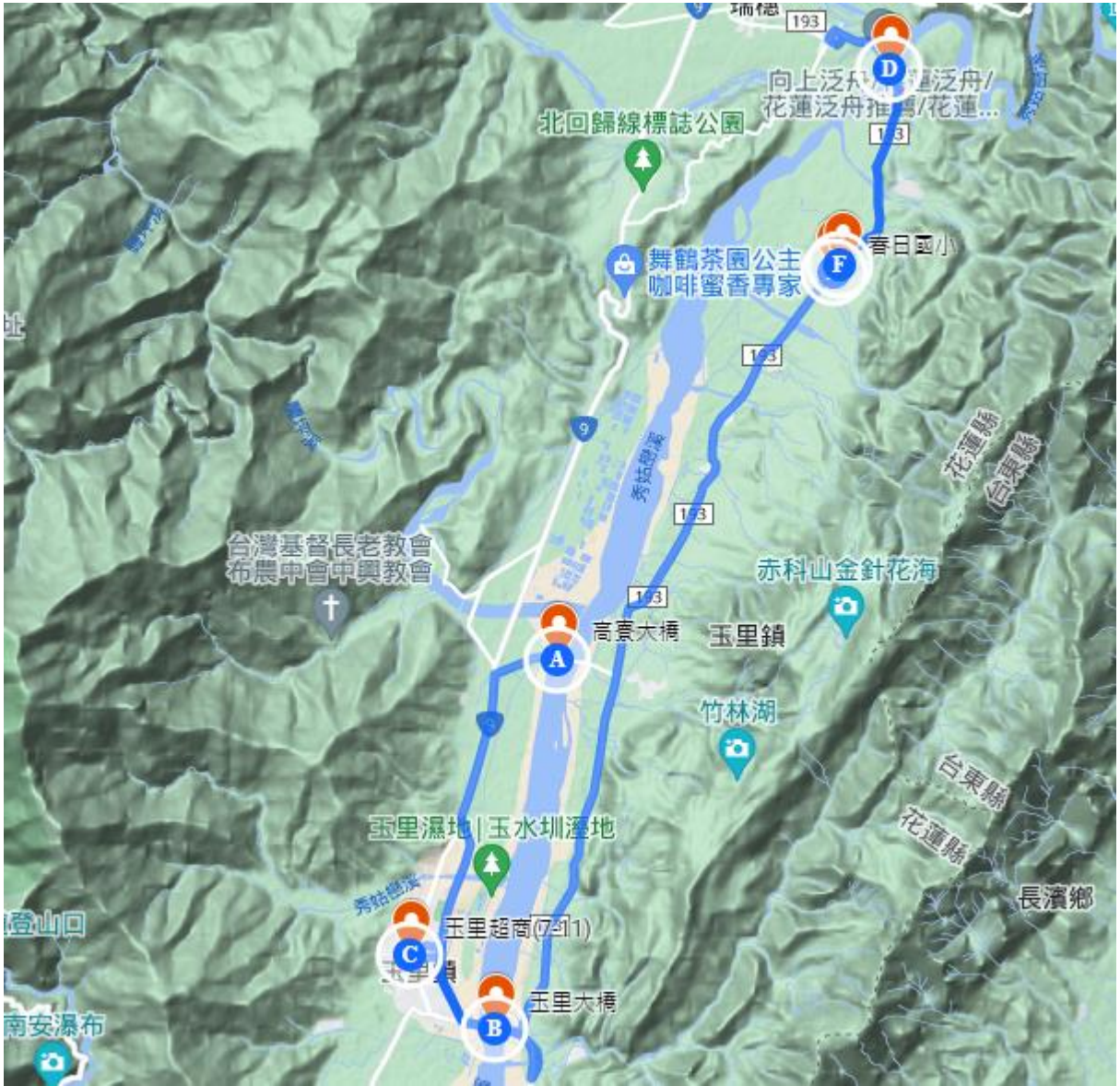
Members of Reconnaissance Team

2022/9/19 (MON)



A	台東機場	Taitung Airport
B	賓華橋	Baohua Bridge
C	電光大橋	Dianguang Bridge
D	嵩天大橋	Luntian Bridge
E	長富大橋	Changfu Bridge

2022/9/20 (TUE)

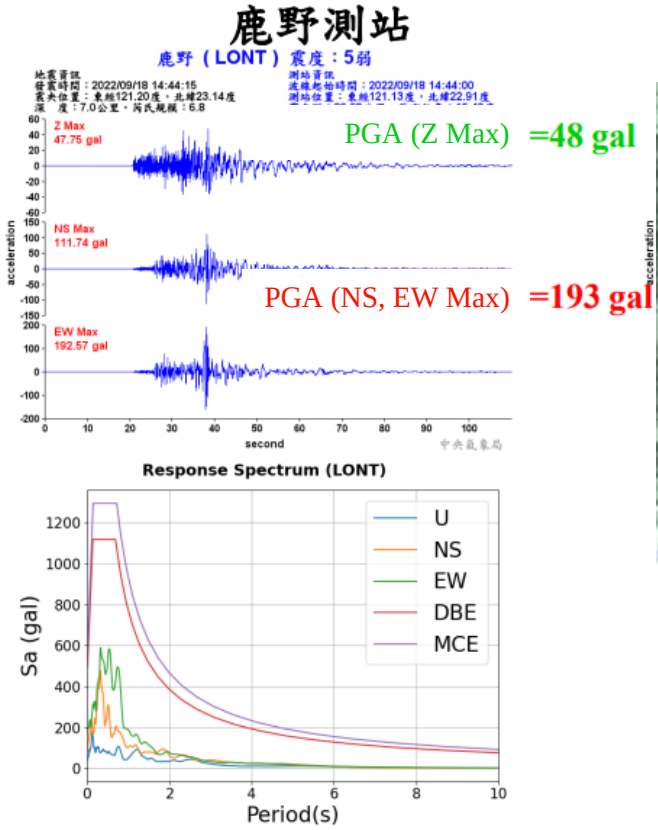


A	高寮大橋	Gaoliao Bridge
B	玉里大橋	Yuli Bridge
C	玉里超商(7-11)	Yuli (7-Eleven)
D	瑞穗大橋	Ruisui Bridge
E	春日國小	Chunrih Elementary School
F	天宣道院	Tianxuan Temple

Location of damaged bridges

1. Baohua Bridge(1/2)

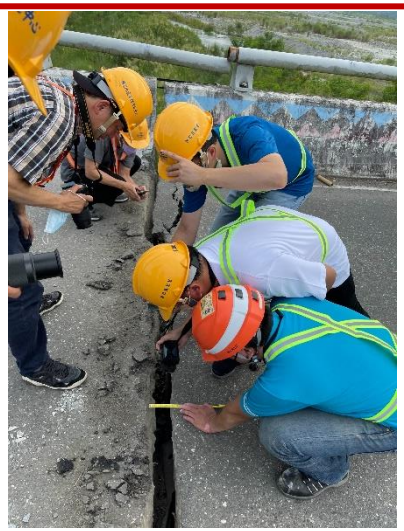
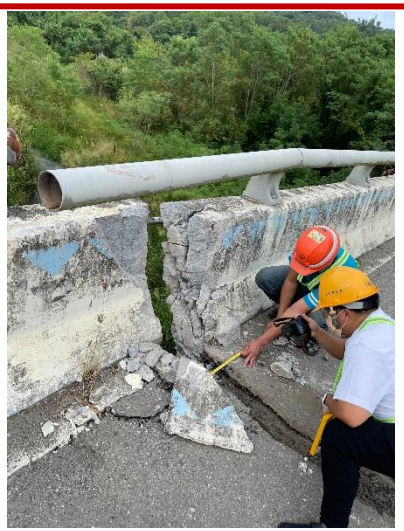
Construct Year	**1984/4 (39y)**
Length	**680m**
Structure Type	**Plate girder bridge**



PGA (Z Max) =48 gal

PGA (NS, EW Max) =193 gal

1. Baohua Bridge(2/2)

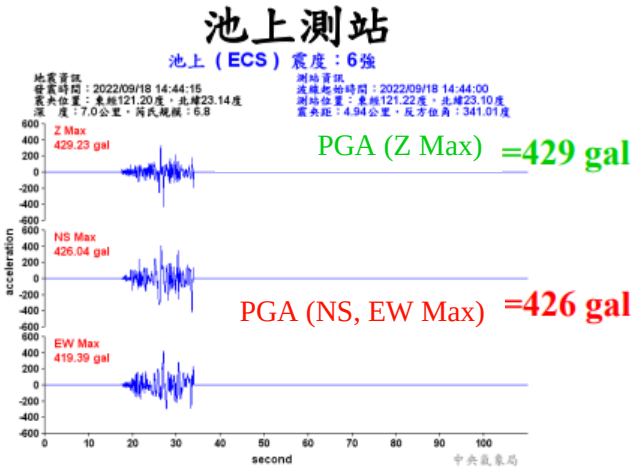




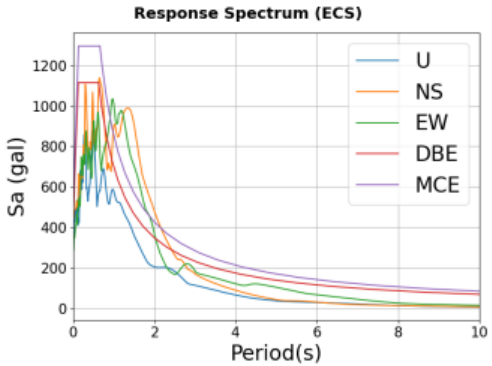

large displacement at expansion joint, support serious damage


Deck displacement, guardrail and attached pipe broken

2. Dianguang Bridge

Construct Year	**1988/11 (34y)**
Length	**720m**
Structure Type	**Plate girder bridge**

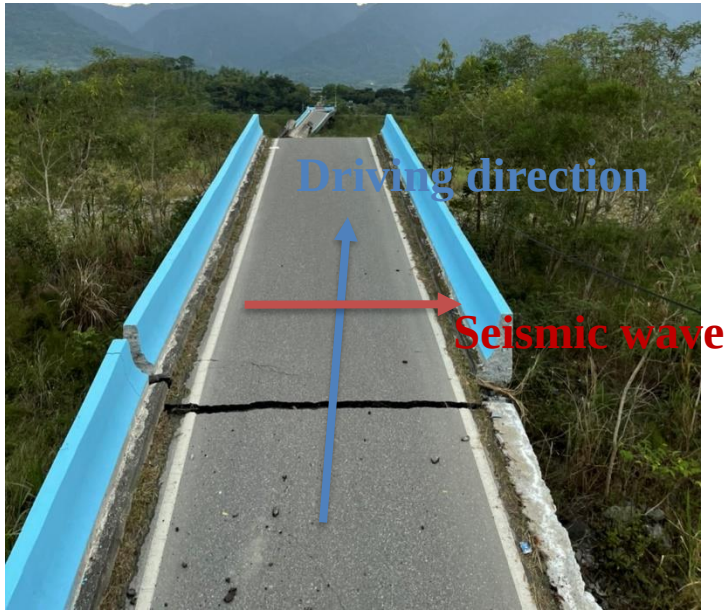


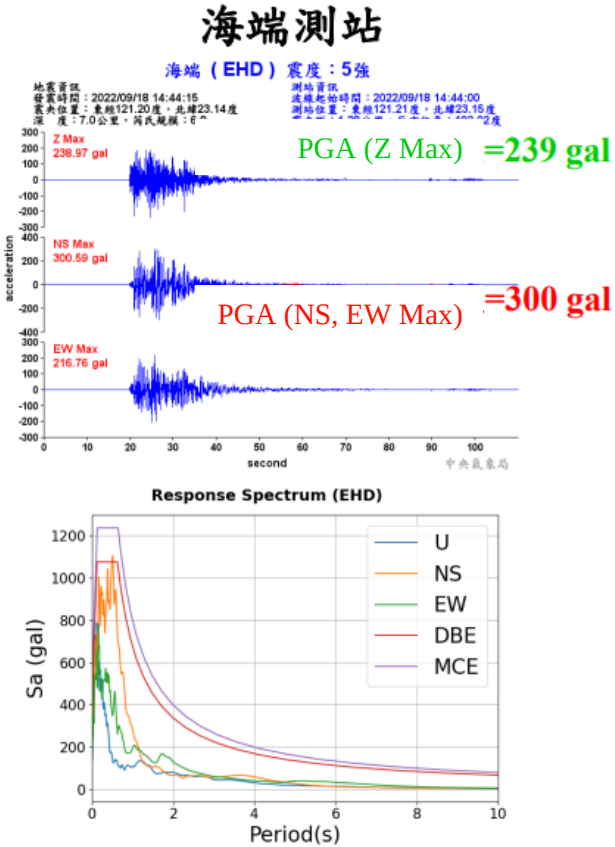


Guardrail damage

3. Luntian Bridge(1/3)

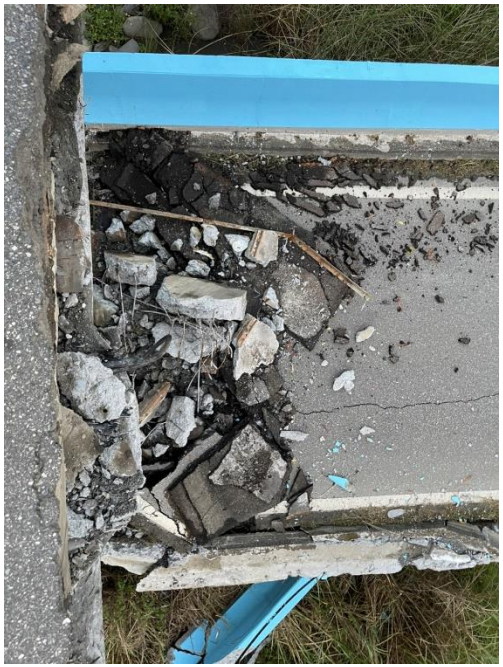
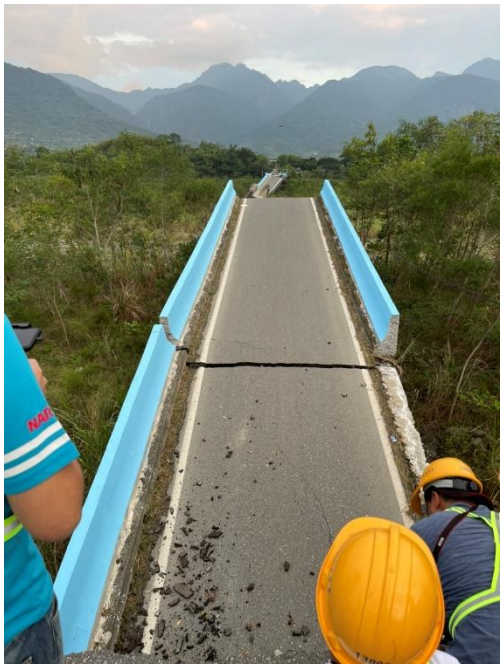
Construct Year	**1982/6 (41y)**
Length	**450m**
Structure Type	**Plate girder bridge**





3. Luntian Bridge(2/3)




Bridge falling and large residual displacement

3. Luntian Bridge(3/3)

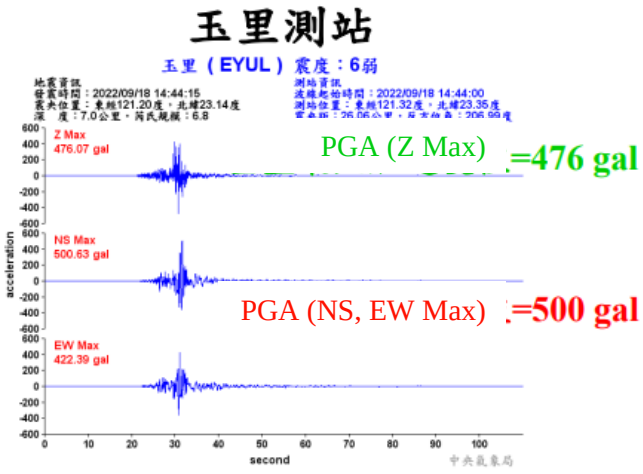


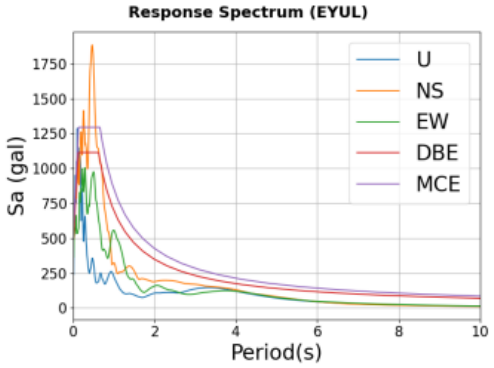



Bridge falling and bridge column fracture

4. Changfu Bridge

Construct Year	**1997/11 (25y)**
Length	**450m**
Structure Type	**Plate girder bridge**

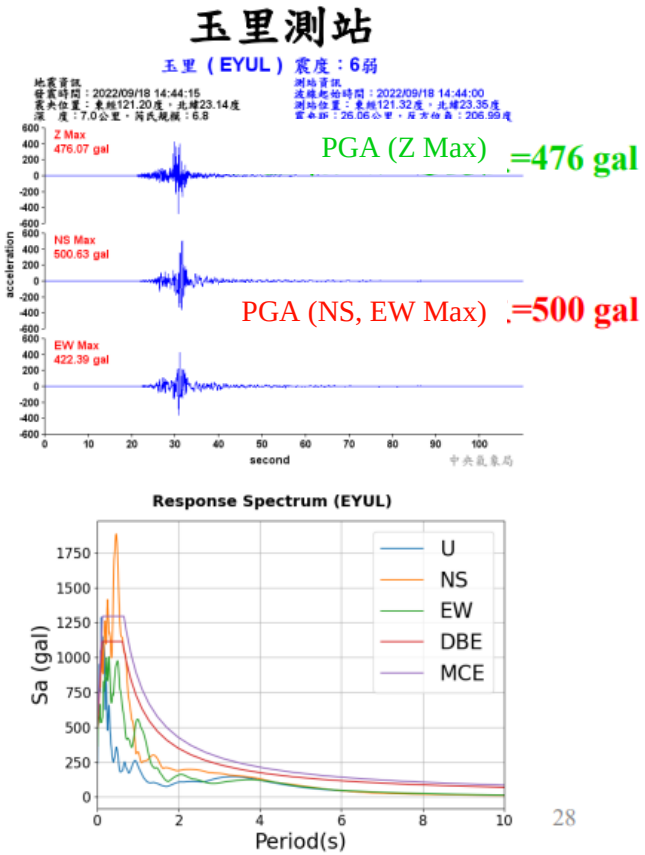




Large displacement at expansion joint

5. Yuli Bridge

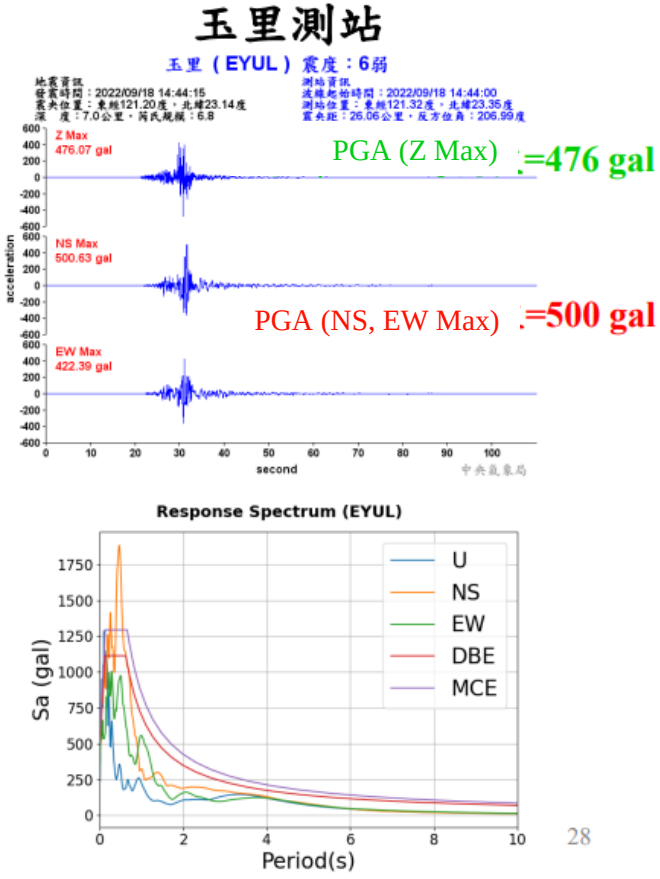
Construct Year	**1977(North)、1994(South)**
Length	**575m**
Structure Type	**Girder bridge**



Damage at expansion joint

6. Gaoliao Bridge(1/4)

Construct Year	**1991 (32y)**
Length	**879.1m**
Structure Type	**PCI girder bridge**



PGA (Z Max) =476 gal

PGA (NS, EW Max) =500 gal

Original

Broken

6. Gaoliao Bridge(2/4)

On bridge side

Off bridge side

East Abutment：pavement and retaining wall collapse

6. Gaoliao Bridge(3/4)

Upstream direction

Column and Base：**Collapse**、**Fracture**

6. Gaoliao Bridge(4/4)

Bridge falling

PCI girder

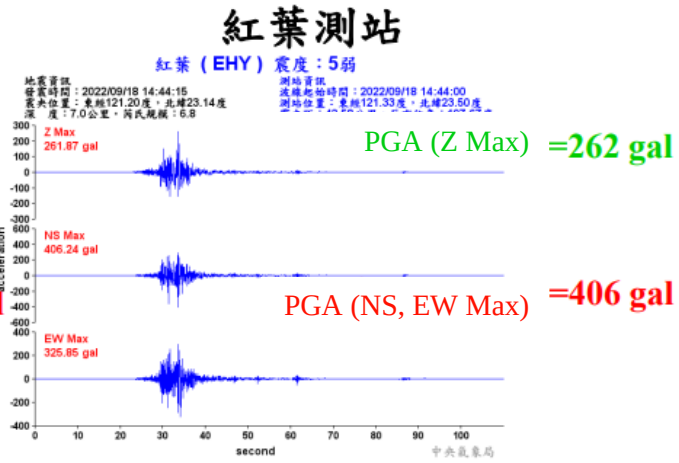
Shear key

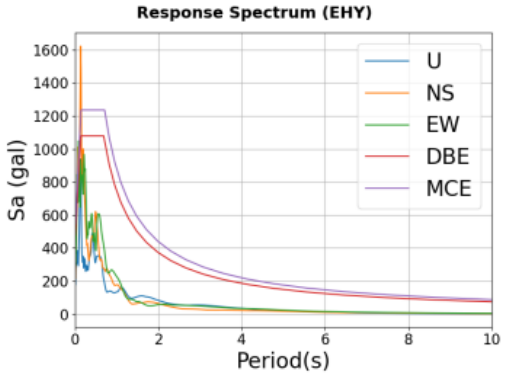
Superstructure：**Bridge falling, collapse**

7. Ruisui Bridge

Construct Year	**1975(North)、1990(South)**
Length	**700m**
Structure Type	**Girder bridge**

pavement, guardrail slight damage





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- Ground Motion Characteristics
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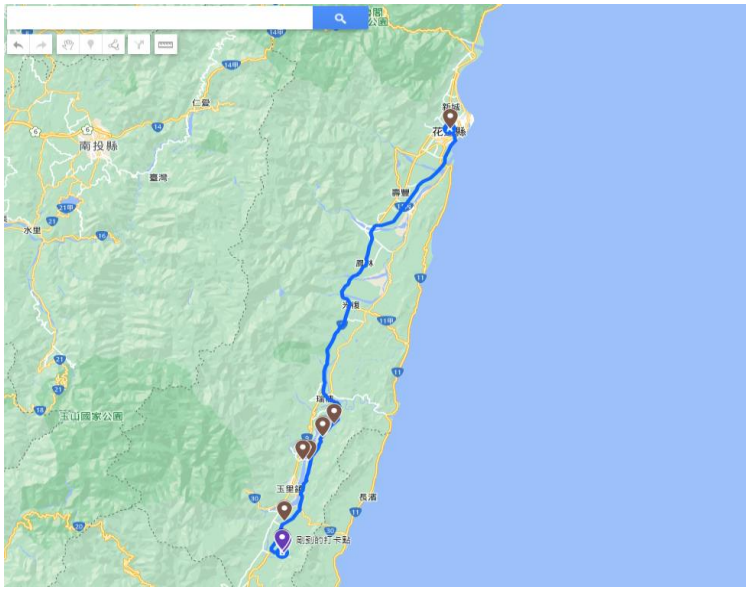
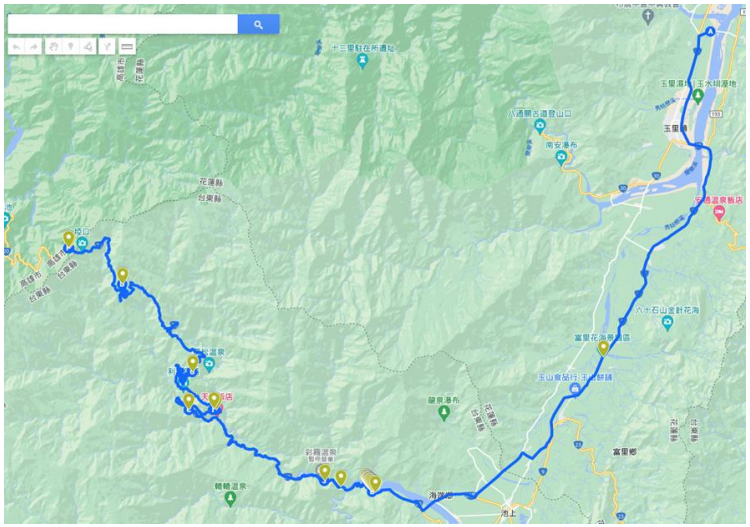
Itinerary

- 9/19 (Hualien)
  - Chun-Rih Elementary School
  - Song-Pu Elementary School
  - Gao-Liao Bridge (East side)
  - Sixty Stone Mountain
  - Gao-Liao Bridge (West side)
- 9/20 (Taitung)
  - Southern Cross-Island Highway (141K+500, 164K, 174K, 192K, 191K, 195K)
  - Fu-Li





Location coordinates of 9/19

Date	Location	Focus	Coordinates
9/19	Chun-Rih Elementary School	Building, Foundation	23.452321, 121.392933
	Song-Pu Elementary School	Building, Foundation	23.428478, 121.373582
	Structure near the Song-Pu Elementary School	Building, Foundation	23.428064, 121.373257
	Gao-Liao Bridge (East side)	Bridge, Foundation	23.384818, 121.348445
	Sixty Stone Mountain	Slop, Landslide, Geology	23.219629, 121.299467 23.215441, 121.301890 23.215177, 121.302079 23.214465, 121.303679 23.214369, 121.302778 23.219573, 121.300230 23.218935, 121.300123 23.219659, 121.300083
	Dong-Li Station	Building, Foundation, Railway	23.272492, 121.304144
	Gao-Liao Bridge (West side)	Bridge, Foundation	23.385727, 121.337124

Location coordinates of 9/20

Date	Location	Focus	Coordinates
9/20	Southern Cross-Island Highway	Slop, Landslide, Geology	23.132383,121.134640 23.177604,121.024732 23.266750,120.952960 23.138576,121.106105 23.135566,121.130808 23.135134,121.131437 23.134602,121.131717 23.134324,121.132225 23.133864,121.132833 23.133276,121.133574 23.132732,121.134341 23.132370,121.135324 23.132174,121.136219
	Fu-Li	Soil Liquefaction	23.206597,121.272588

Chun-Rih Elementary School

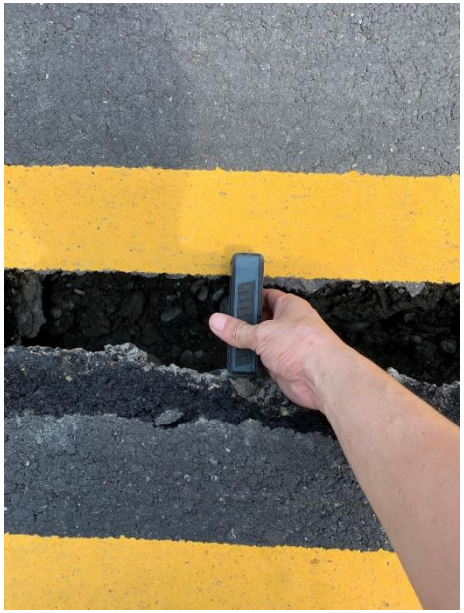
- The building did not collapse when the M_L6.4 earthquake occurred on 9/17.
- The M_L6.8 earthquake on 9/18 caused the collapse of the connecting corridor, and the entire wall was tilted.
- There are many cracks in the kindergarten classrooms, toilets, and kitchens adjacent to the collapsed corridor.

Song-Pu Elementary School

- The buildings and roads opposite to the elementary school were pushed towards Song-Pu elementary school, and the pushing direction was from southeast to northwest.
- Opposite to the elementary school, the concrete floor was squeezed and raised by about 40 cm.

Gao-Liao Bridge (East side)

- Abutment damage camber, bridge deck subsidence.
- The water pipeline is damaged resulting in water service outage to the downstream residents.
- Retaining wall is without reinforcements.



Gao-Liao Bridge (East side)

- Soil loss due to the collapse of the second retaining wall on the east entrance of the bridge.
- The retaining walls were pushed out by the earthquake (mainly pushed toward north).
- The maximum subsidence of the subgrade elevation of the entry wall is about 1 meter.

Gao-Liao Bridge (East side)

- Compared with the south and north retaining walls on the outside of the culvert under the abutment, there is an inward shrinkage.
- The difference between the south retaining wall and the culvert is about 15 cm. The difference between the north retaining wall and the culvert is about 45 cm.

Gao-Liao Bridge (East side)

- Three piers from the east abutment were completely destroyed.
  - The first pier is located at the border of the bridge deck and is covered with steel plates. The pier is completely collapsed, but there is no obvious structural damage.
  - The second pier was located in the middle of the deck and was damaged by shear force.
  - The third pier was not clad with steel plates, and the damage was similar to the first pier.

Gao-Liao Bridge (West side)

- The spacing between the main rebar is about 13-20cm.
- Stirrup spacing is about 12-15cm.
- Caisson foundation under the pier.

Sixty Stone Mountain

- The mountain road is damaged by many rock falls and there are signs of continuity of such.
- It is estimated that the largest area may be 100 meters long and 30 meters wide, and the largest diameter of the rock block may be up to 5 meters.

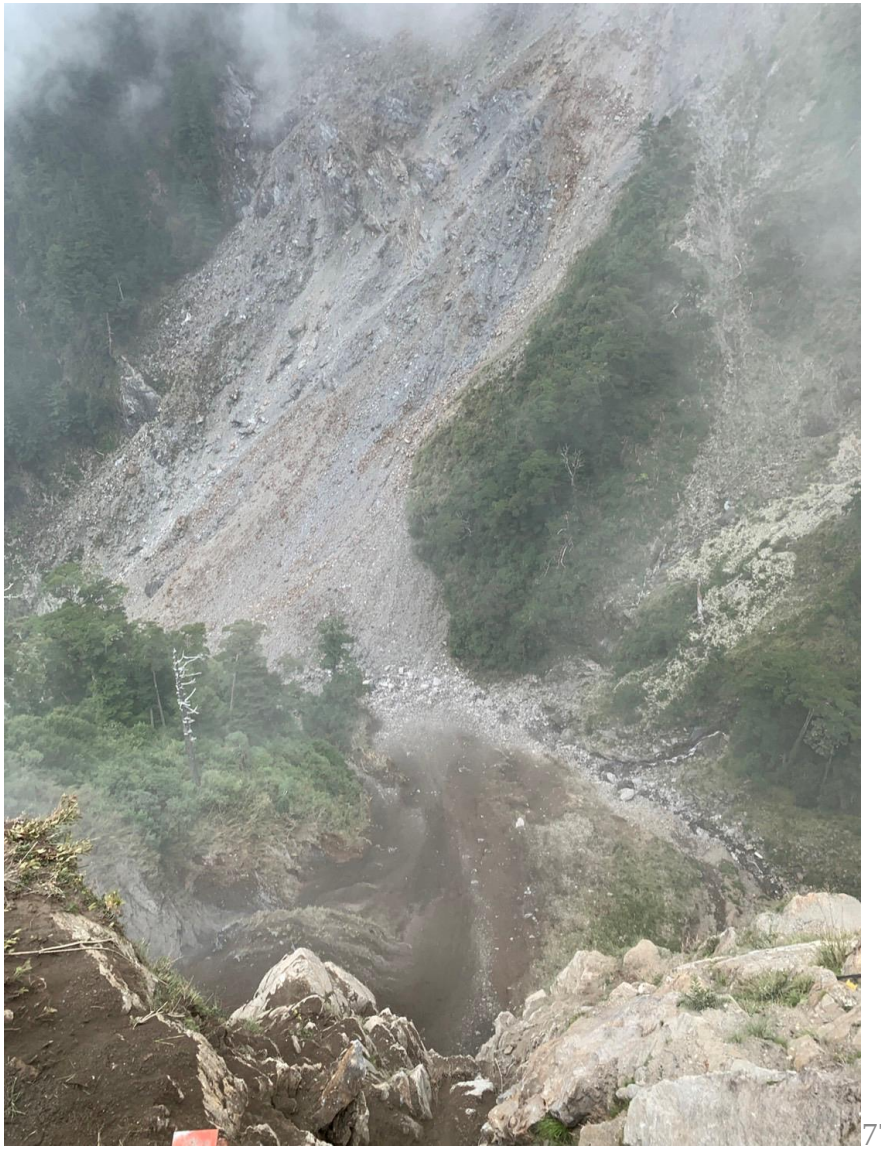
Dong-Li Train Station

- The roof of the train station platform fell and the train derailed.
- The railway is seriously deformed.
- The base unit carrying the ballast is separated, resulting in the loss of ballast.

Railway deformed

Southern Cross-Island Highway

Landslide



Southern Cross-Island Highway

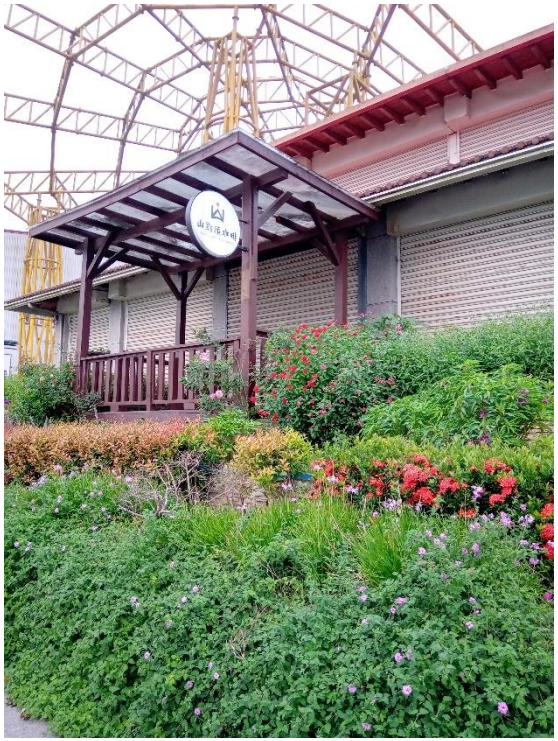
- The rockfall materials can be roughly categorized into rocks (metamorphic sandstone, schist) and river grade gravel.

141K+500

195K

Fu-Li

- A suspected liquefaction phenomenon found in Fu-Li.
- No building damage due to soil liquefaction was observed.



Outline of Disaster Investigation Report

- Ground Motion Characteristics
- Damage of Buildings
- Damage of Bridges
- Geotechnical Damage
- Damage of Nonstructural Components and Nonbuilding Structures
- Information for Earthquake Early Warning, Structural Monitoring and Control

Earthquake Reconnaissance Locations

Nonstructural Components and Equipment

Hospital

Kuanshan Tzu Chi Hospital
(關山慈濟醫院)

Taitung Hospital Chenggong Branch
(台東醫院成功分院)

Taitung Christian Hospital
(台東基督教醫院)

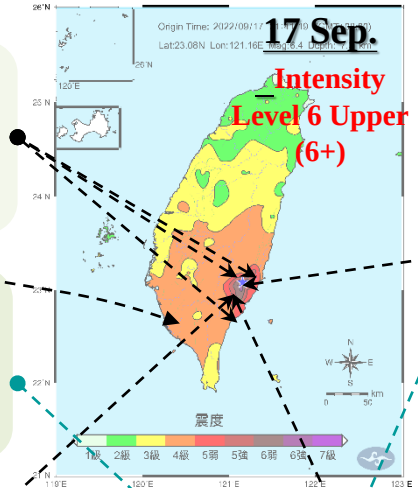
Shopping mall

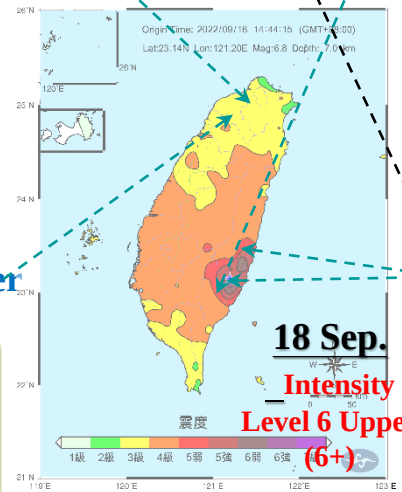
Dream mall(高雄夢時代)

IKEA Hsin Chuang Store
(新莊IKEA)

Hou-Hu Columbarium Pagoda
(鹿野后湖納骨塔)

Taoyuan City Bade Civil Sports Center
(八德運動中心)





Nonbuilding Structures

Rice mill

Xin-Qian-Kun rice mill
(關山新乾坤碾米廠)

Guan-Shan township Farmers' association rice mill
(關山鎮農會碾米加工廠)

Gravel factory

Lei-Xin ready mixed plant
(玉里磊信水泥廠)

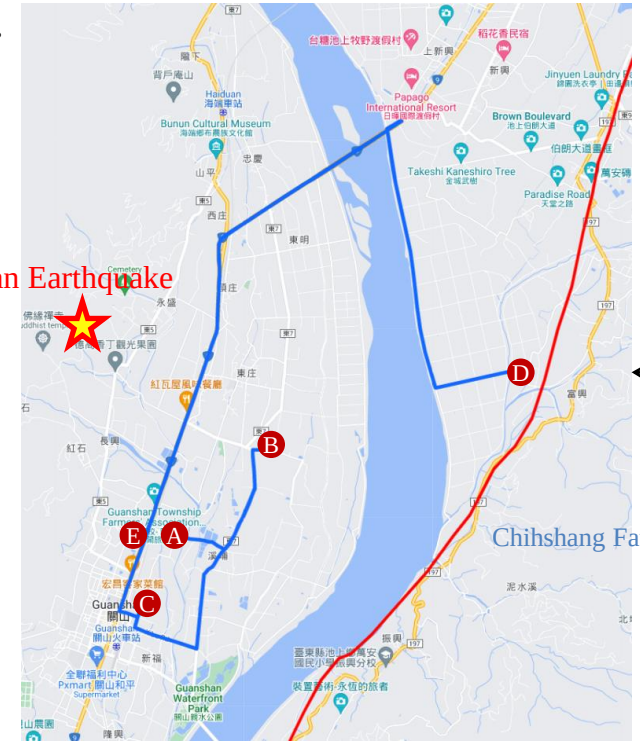
Hao-Ye ready mixed plant
(池上灝業採石場)

Zhi-Sheng ready mixed plant
(關山志昇預拌廠)

Reconnaissance Route (East Taiwan)

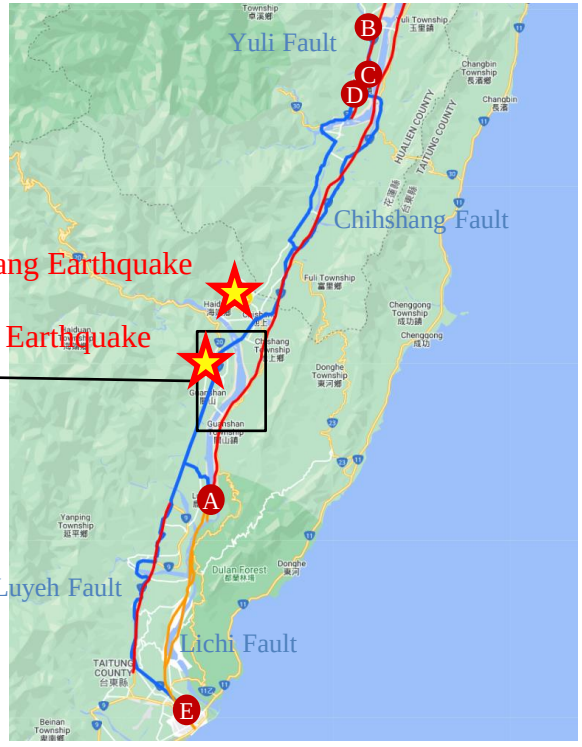
A	Zhi-Sheng ready mixed plant, Guan-Shan township, Taitung	關山/志昇預拌混凝土廠
B	Xin-Qian-Kun rice mill, Guan-Shan township, Taitung	關山/新乾坤碾米廠
C	Farmers' association rice mill, Guan-Shan township, Taitung	關山/農會碾米加工廠
D	Hao-Ye ready mixed plant, ChihShang township, Taitung	池上/灝業採石場
E	Kuanshan Tzu Chi Hospital, Guan-Shan township, Taitung	關山/慈濟醫院

19 Sep.



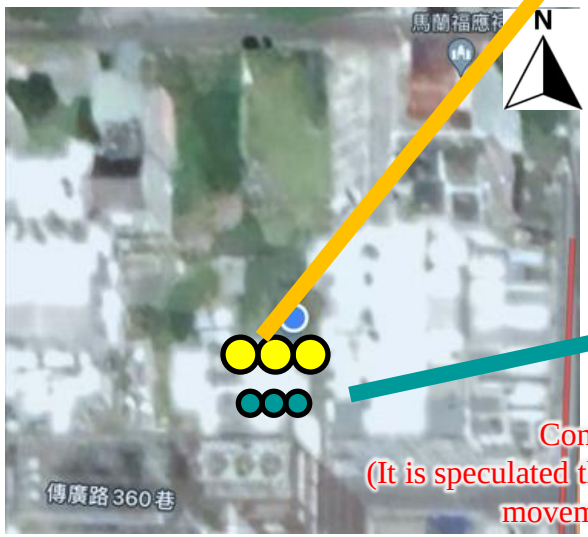
A	Hou-Hu Columbarium Pagoda, Lu-Ye township, Taitung	鹿野/后湖納骨塔
B	Lei-Xin ready mixed plant, Yu-Li township, Hua-Lien	玉里/磊信混凝土預拌廠
C	Nian-Chang rice mill , Yu-Li township, Hua-Lien	玉里/年昌碾米廠
D	Xie-Tian Temple, Yu-Li township, Hua-Lien	玉里/協天宮
E	Taitung Christian Hospital, Taitung	台東/基督教醫院

20 Sep.



Taitung Christian Hospital (台東基督教醫院), Taitung County

- **RO water system was damaged in Guan-Shan Earthquake (17 Sep.)**



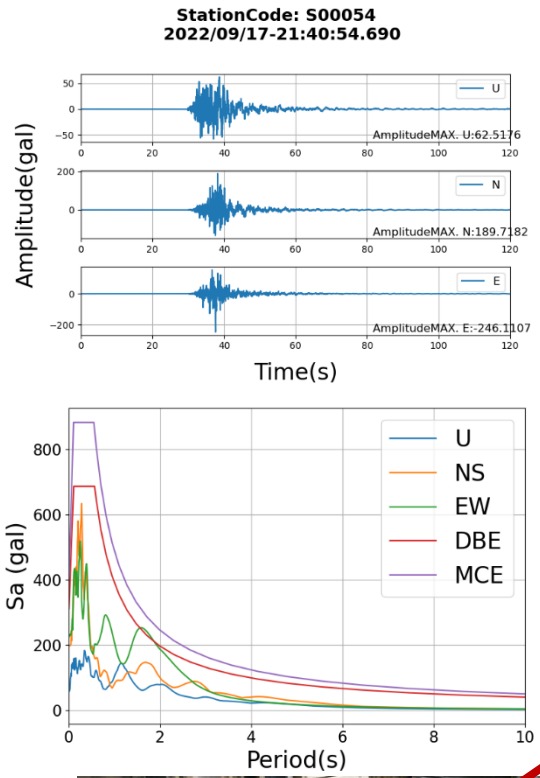
RO water filters are girdled and fixed by metal rings
(No damage to filters and connected pipes)

Comparing to the freestanding RO water filters in Taitung Hospital Chenggong Branch, the connection pipe was damaged during 0323, 2022 Hualien Earthquake.

Connection pipe damage
(It is speculated that the filters are inconsistent with movement of adjacent motors)

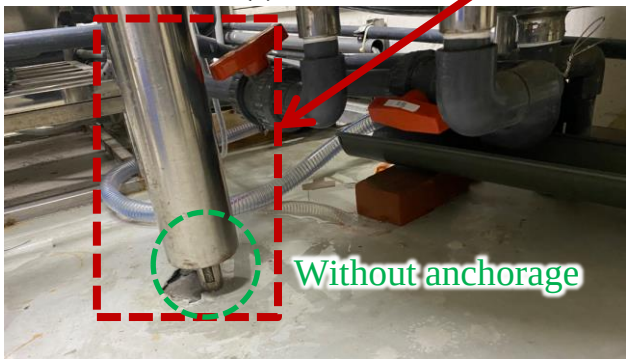
RO water filters are girdled and fixed by metal rings
(Connection pipe damage)

Taitung Christian Hospital (台東基督教醫院), Taitung County

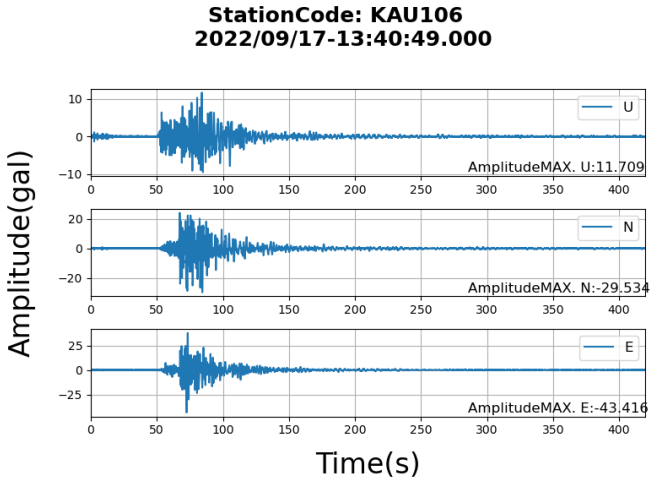


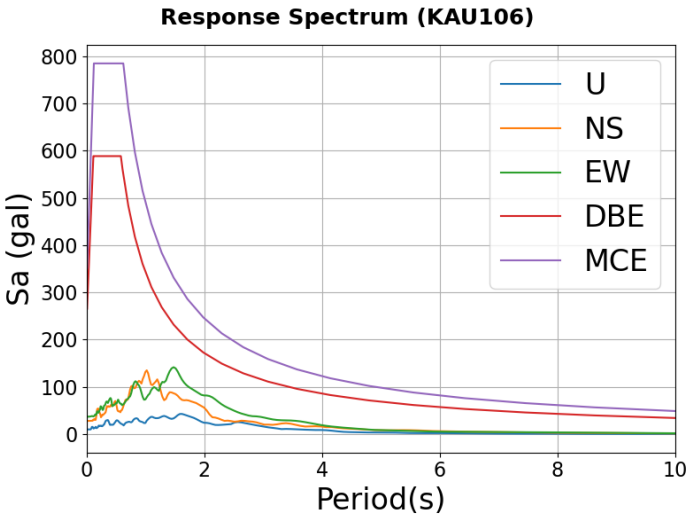
Freestanding RO water tank (without any anchorage)

Originally, the two ends marked with green circles were connected to each other with a pipe. After earthquake, the pipe was broken and a transparent hose connection was temporarily used to keep its functionality.

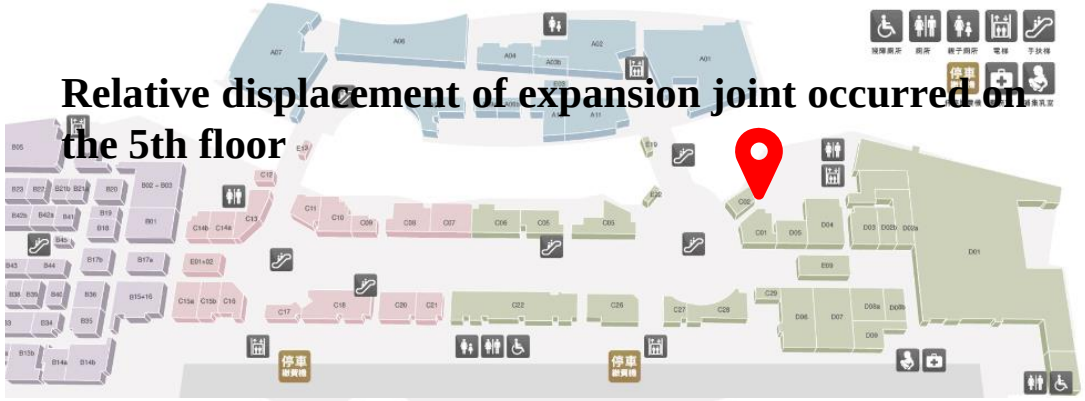


Kaohsiung/Dream Mall

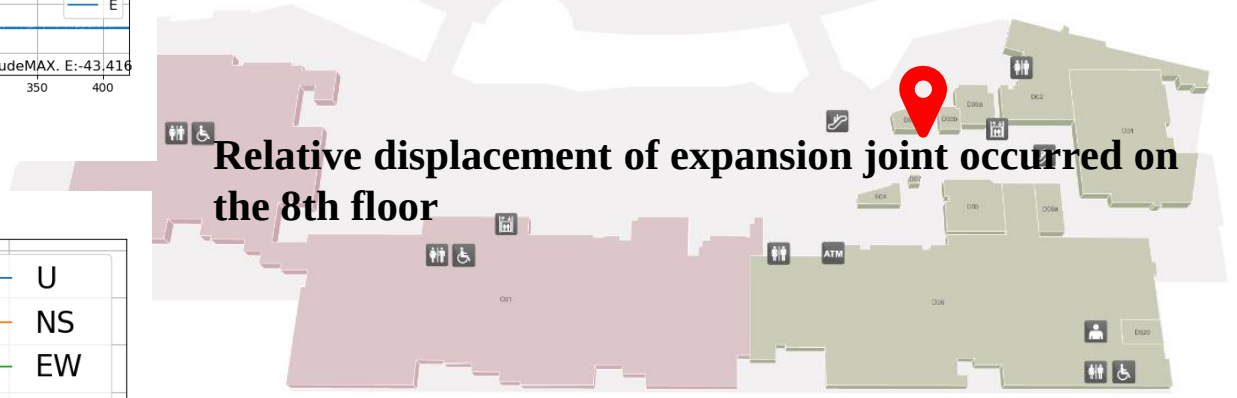




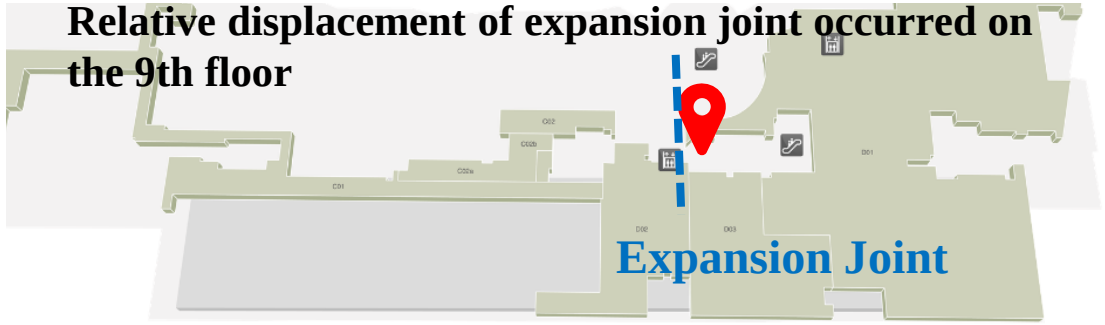
Relative displacement of expansion joint occurred on the 5th floor



Relative displacement of expansion joint occurred on the 8th floor



Relative displacement of expansion joint occurred on the 9th floor



Kaohsiung/Dream Mall

Architectural Component：
interior veneer and ornamentations

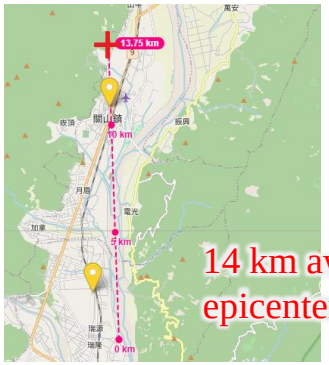
Damage to the interior veneer and ornamentations was investigated due to the relative displacement of expansion joint on 5th, 8th and 9th floor.

Kaohsiung/Dream Mall

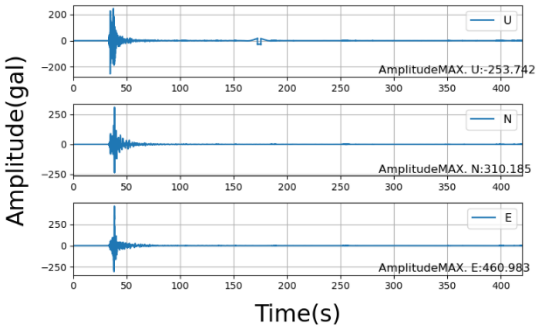
Architectural Component：Suspended Ceilings

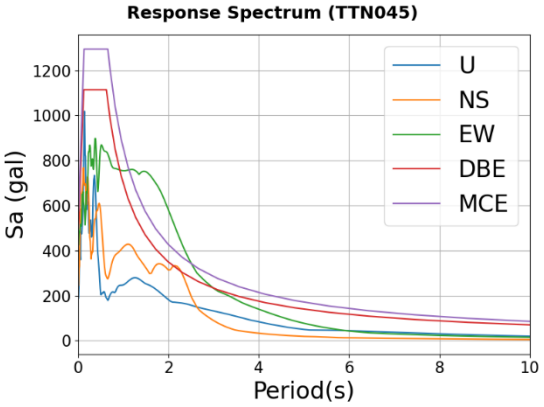
- The boundary, an unbraced gypsum board, on the side of the ceiling is adjacent to the expansion joint, which was damaged during the earthquake.
- Damage to the unbraced gypsum panel led to fallen ceiling panels and deformed ceiling runners.
- Rods are used as the suspension system. The suspension length of the ceiling is approximately 2.5 m to 3.0 m.

Hou-Hu (后湖) Columbarium Pagoda
Lu-Ye township, Taitung County



14 km away from epicenter





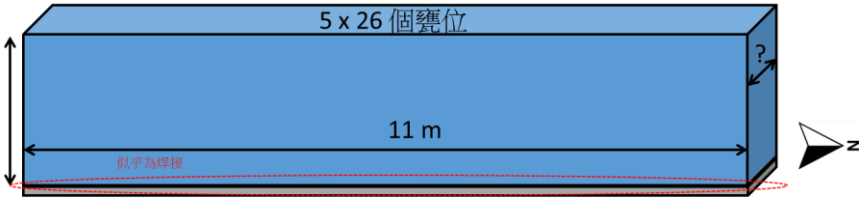
Ossuary cabinets in 1st to 3rd floor are collapsed

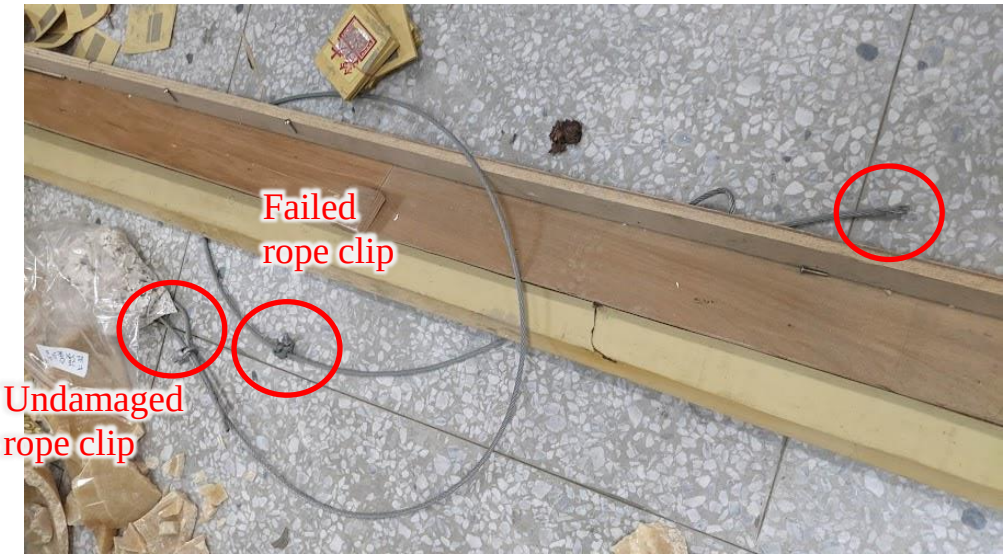
Water tank of outdoor public toilet fell from the roof

Hou-Hu (后湖) Columbarium Pagoda Lu-Ye township, Taitung County

Nonstructural Component：Contents

- **On the first floor**, one of the ossuary cabinets, not attached to any other structural components, was collapsed westward.
- **No anchorage observed** at the bottom of the cabinet.
- The steel wires connecting to the top of the cabinet and the above slab failed during Guan-Shan Earthquake.



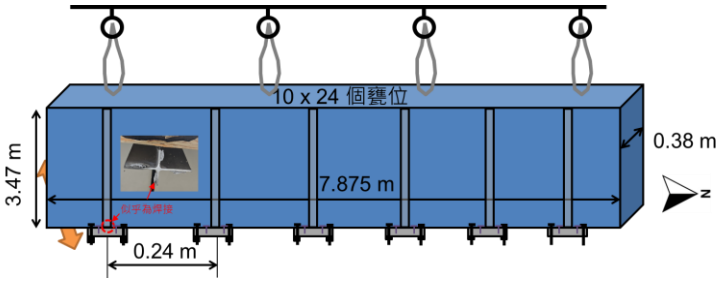


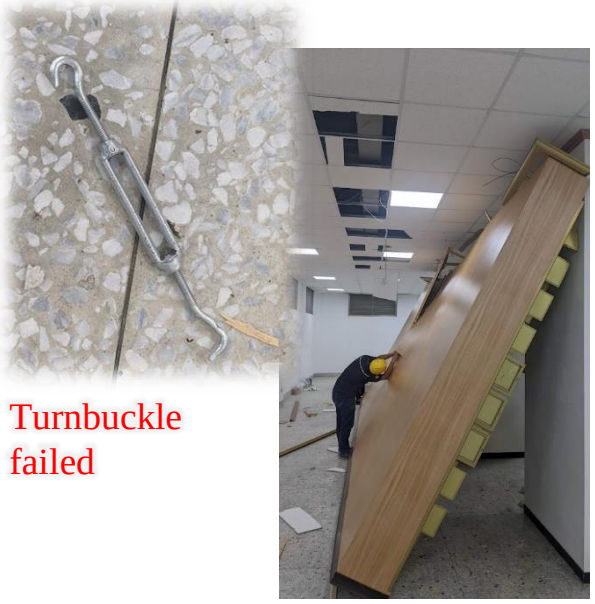
Hou-Hu (后湖) Columbarium Pagoda
Lu-Ye township, Taitung County

- **On the second floor**, one of the ossuary cabinets, which was not attached to any other structural components, **was collapsed westward**.
- The **bottom steel supporting frame** secured to the floor by **thin L-shaped sheet metals and plastic nylon anchors** failed.
- The **steel wires** connecting the above slab and the top of the cabinet failed.
- **Doors opened** and the **urns dropped**.

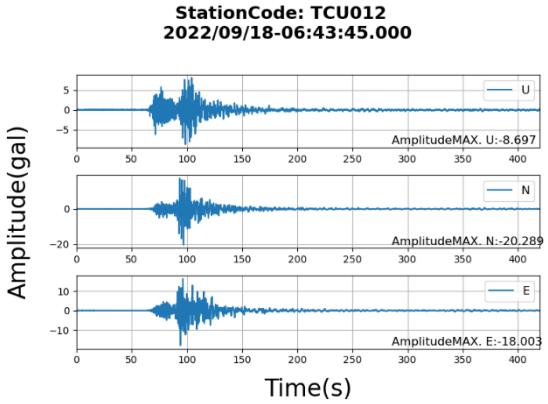
Hou-Hu (后湖) Columbarium Pagoda
Lu-Ye township, Taitung County

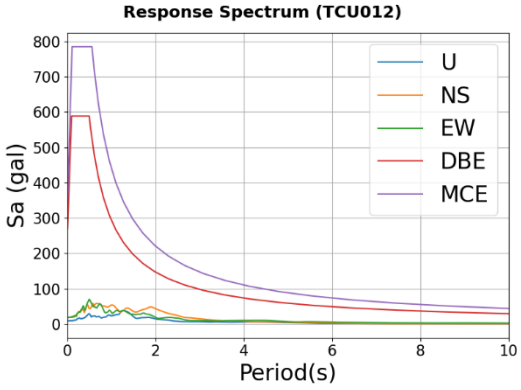
- The cabinets **on the third floor** were built recently.
- One of the ossuary cabinets, which was not attached to any other structure components, **was collapsed eastward**.
- **Failure of the hook of a turnbuckle** was observed. This may lead to the failure of the cable system above the cabinet.
- **Aluminum skeletons with cross section behind the cabinet ruptured** from the aluminum bottom plate, which was supposed to be fixed on the floor.

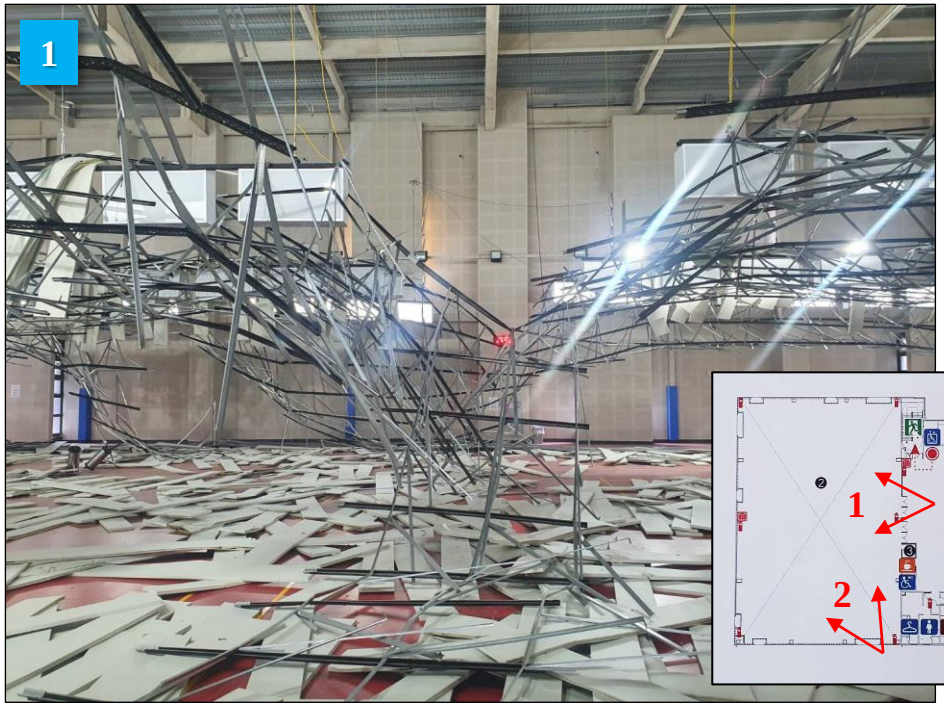


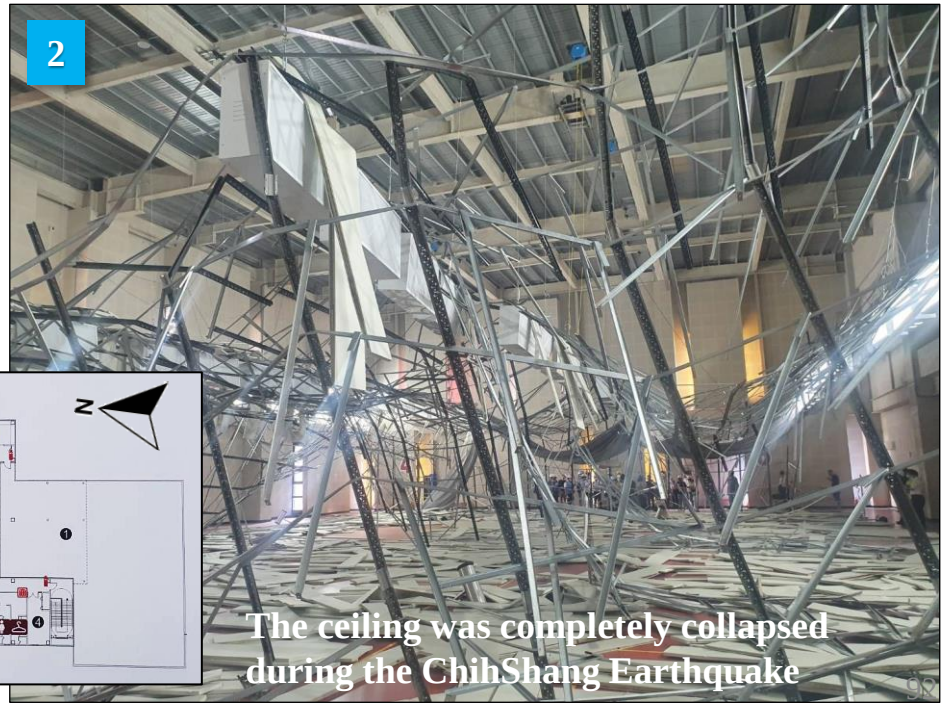


Taoyuan/Bade (八德) Civil Sports Center

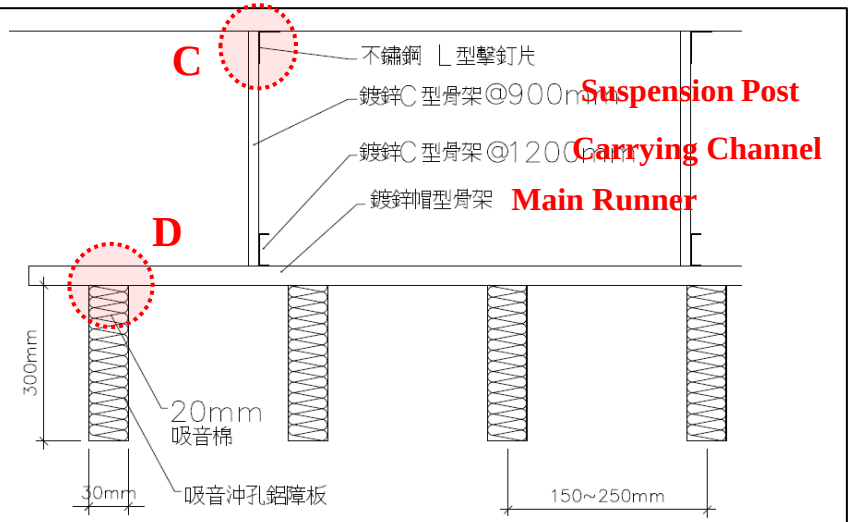




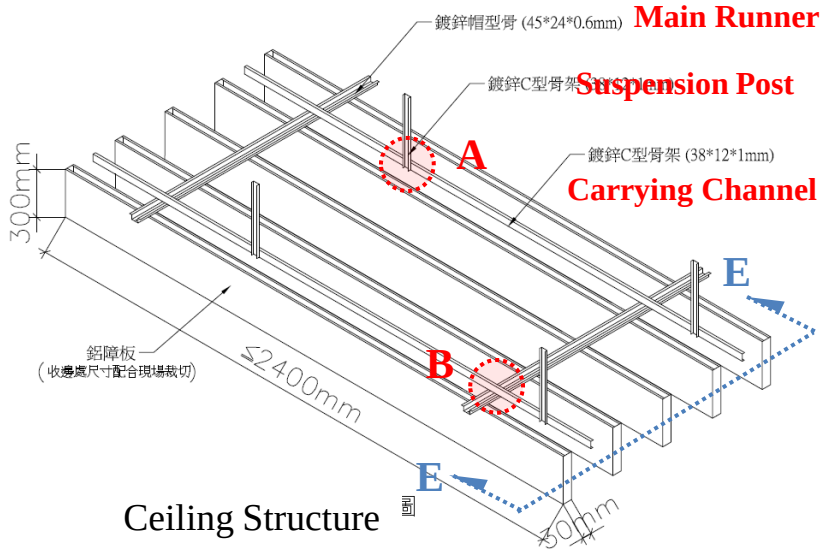




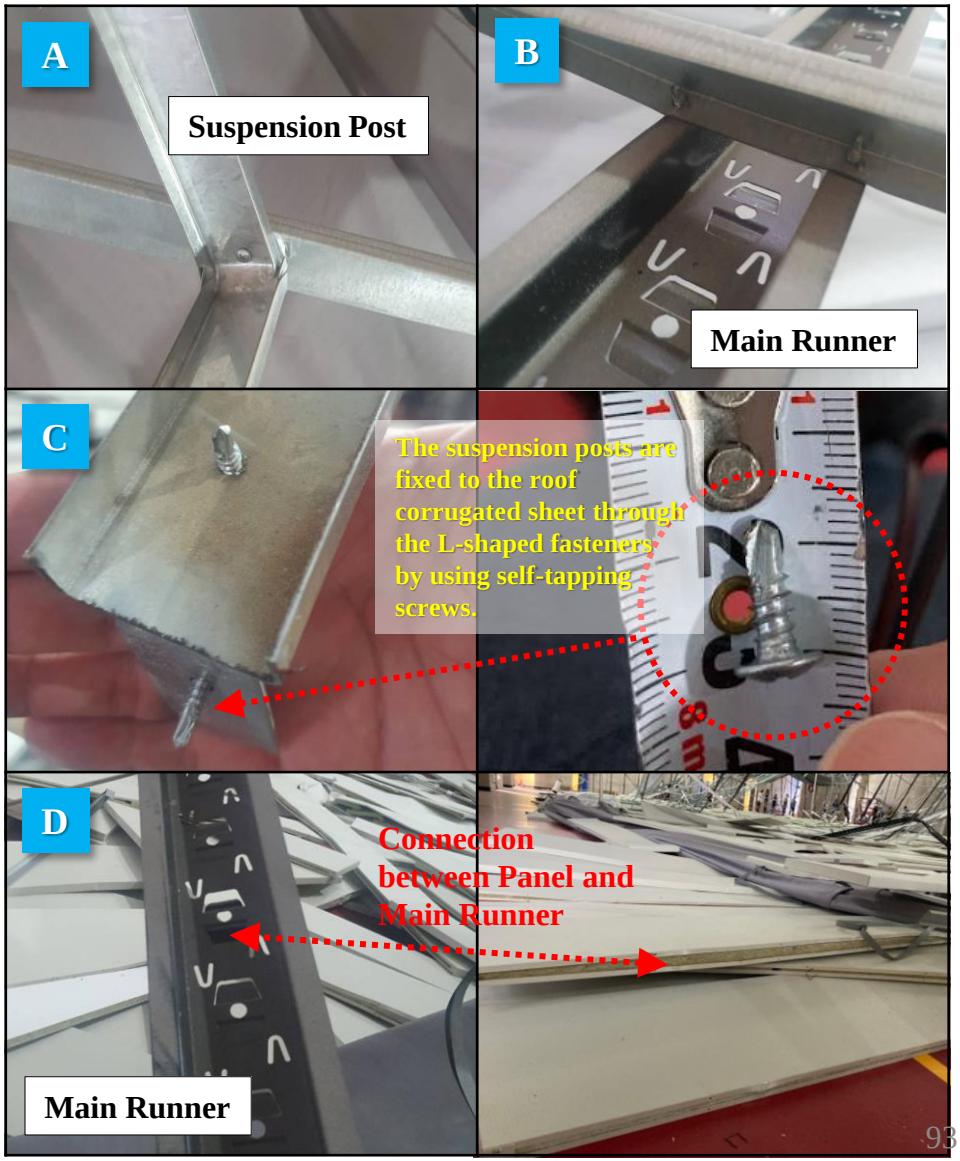
Taoyuan/Bade (八德) Civil Sports Center



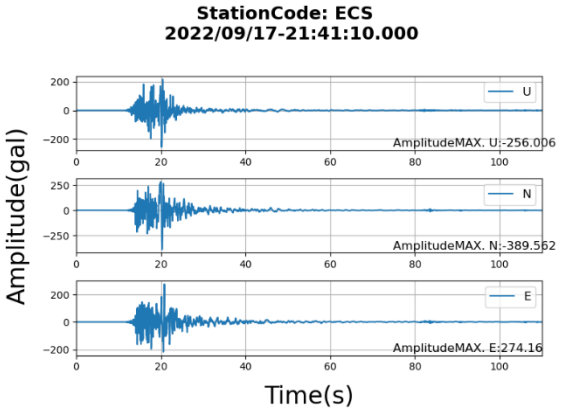
E-E Sectional View

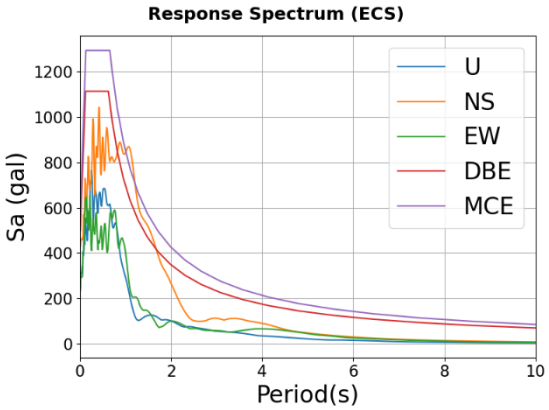


Ceiling Structure



Xin-Qian-Kun (新乾坤) rice mill
Guan-Shan township, Taitung County

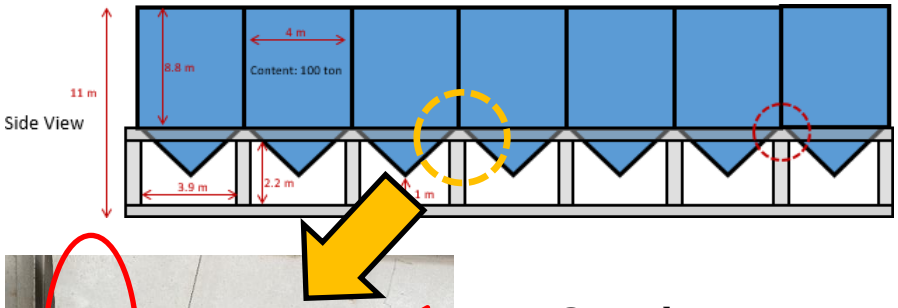




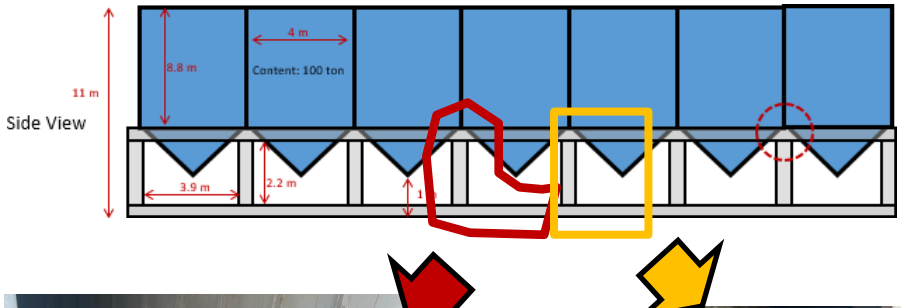
The failure of the supporting frame underneath the tanks led to the grain tanks collapsed toward southwest in 9/17 event.

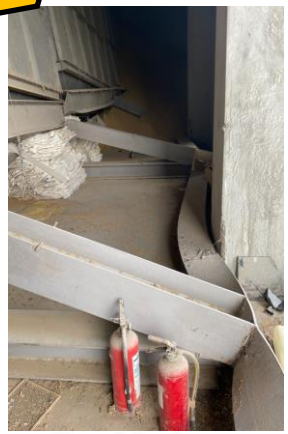
South side of the tanks

Xin-Qian-Kun (新乾坤) rice mill
Guan-Shan township, Taitung County



- The inner beams were secured on a tiny steel plate, which were simply welded to the outer beam, with 4 bolts.
- The welding strength was not sufficient, and the beams fell during the earthquake.

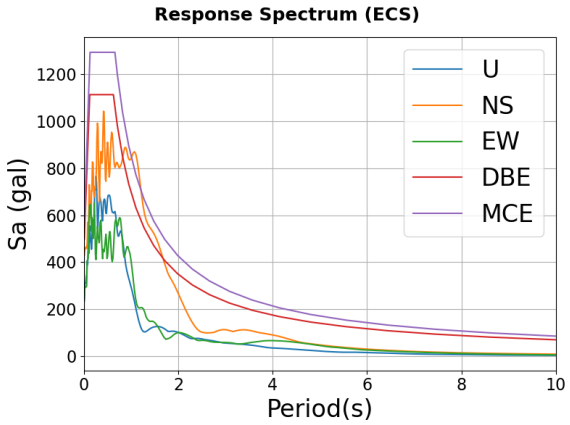


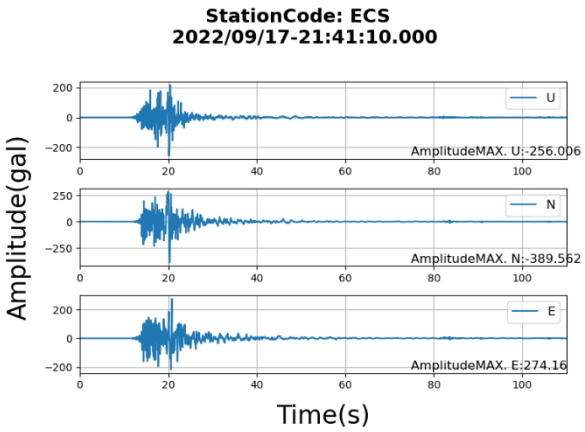


- Some of the bolts used to secure the columns and beams were sheared.
- The lower beams were just placed on the floor without any anchorage.

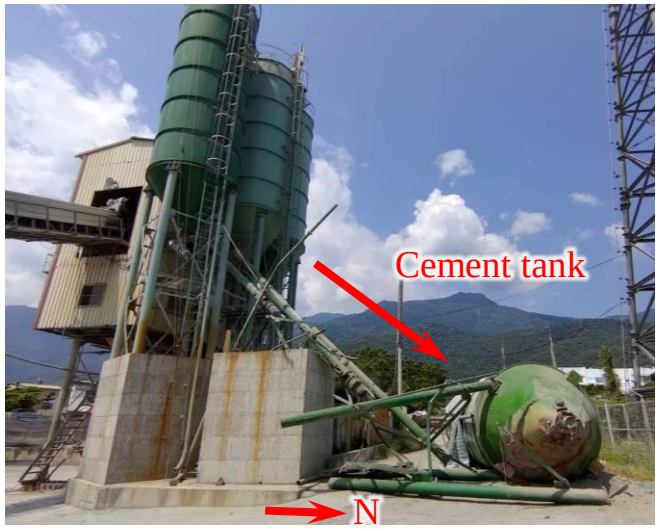
Zhi-Sheng (志昇) ready mixed plant Guan-Shan township, Taitung County

Before earthquake (from Google map)





- Storage tanks of gravel and cement collapsed.



NARLabs

Zhi-Sheng (志昇) ready mixed plant Guan-Shan township, Taitung County

Sand and gravel tank

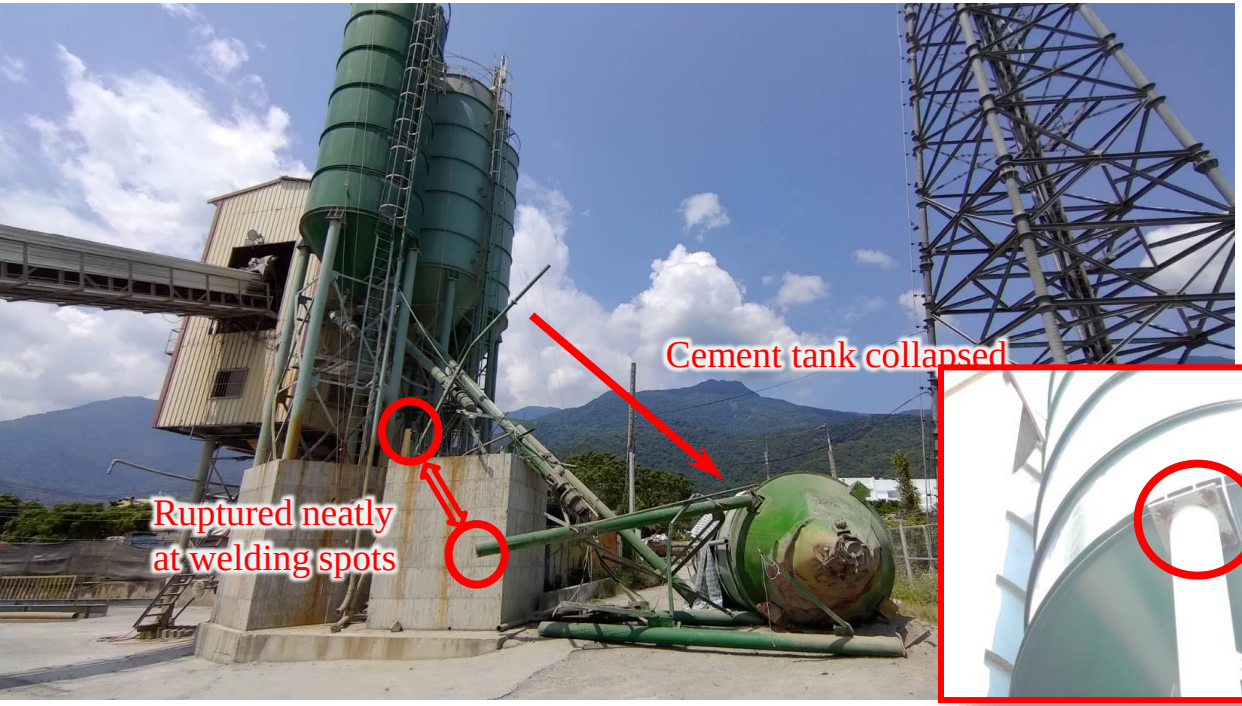
- The tank was supported by a steel frame, and there were 12 steel posts underneath it.
- The bolts pulled off due to the tensile force.
- The posts ruptured at the welding spots.

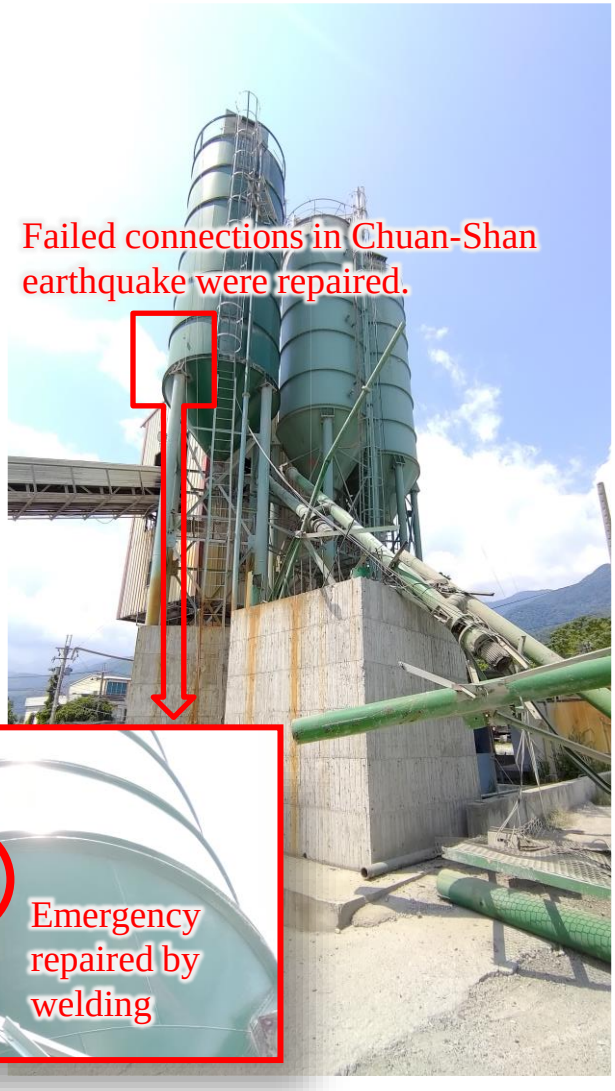
NARLabs

Zhi-Sheng (志昇) ready mixed plant Guan-Shan township, Taitung County

Cement tank

- One of the cement tanks collapsed in the Guan-Shan Earthquake. Shear failure of bolts of another tank occurred as well.
- The tank was emergency repaired by welding and survived in ChihShang Earthquake.

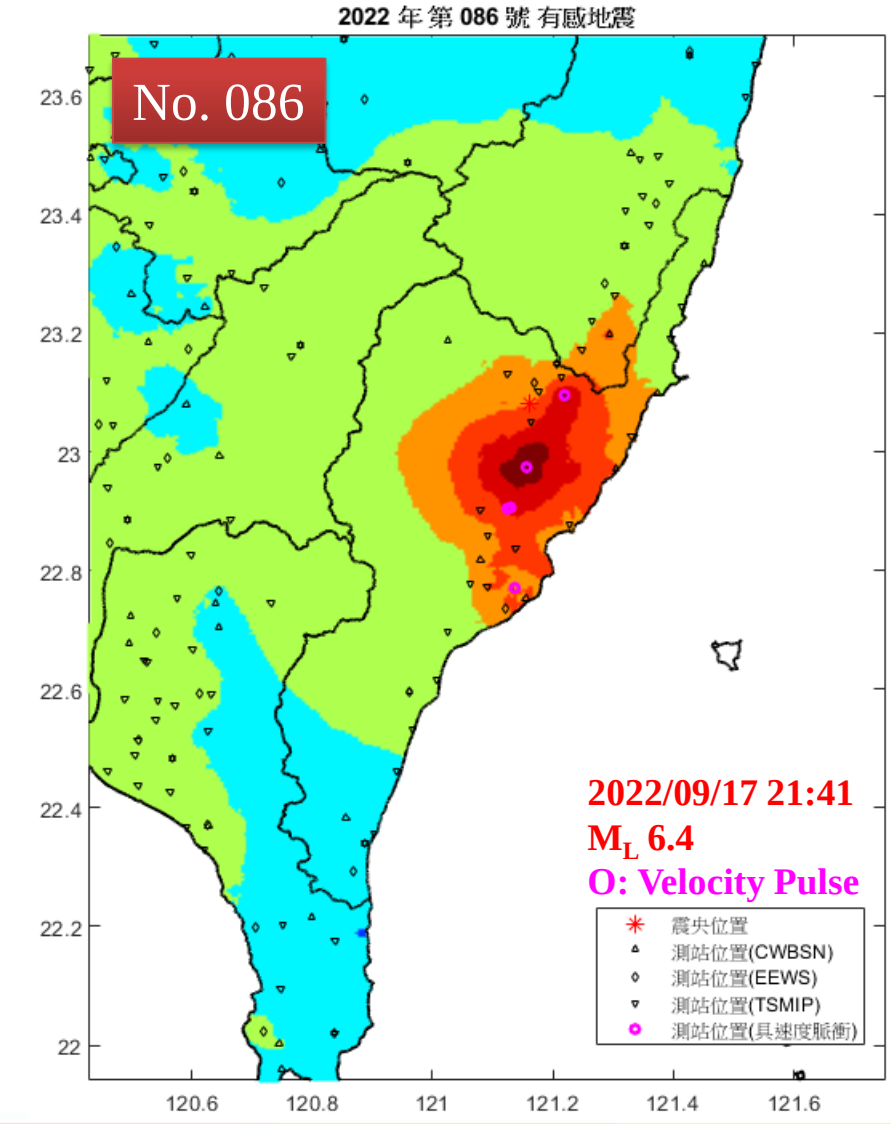


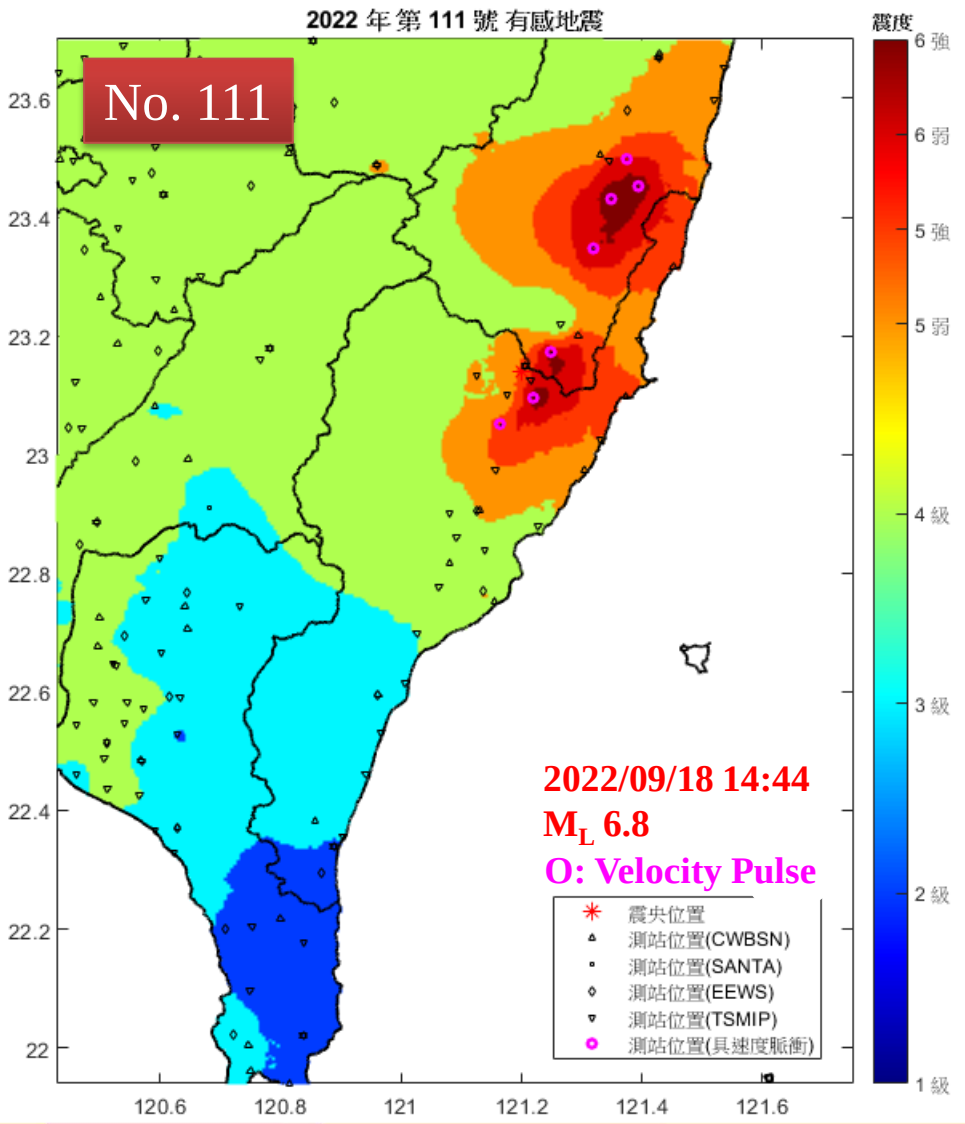


Outline of Disaster Investigation Report

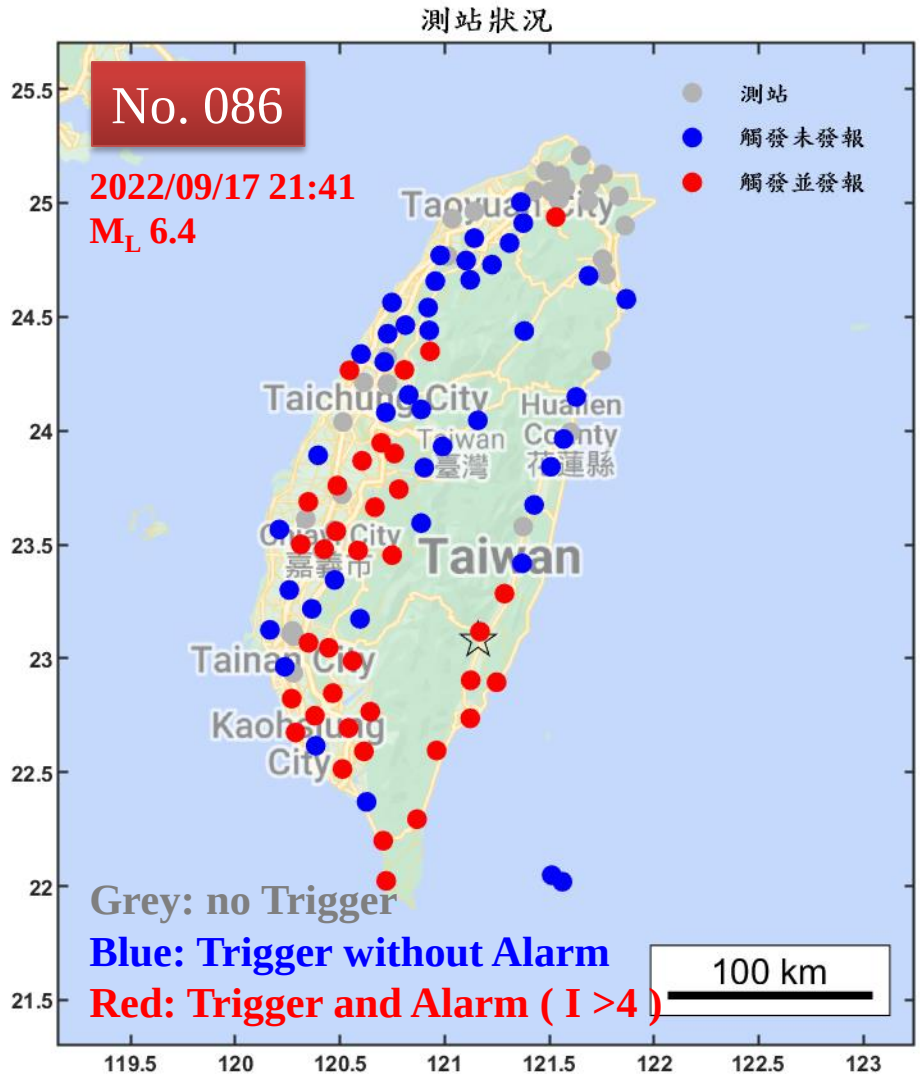
- Ground Motion Characteristics
- Damage of Buildings
- Damage of Bridges
- Geotechnical Damage
- Damage of Nonstructural Components and Nonbuilding Structures
- Information for Earthquake Early Warning, Structural Monitoring and Control

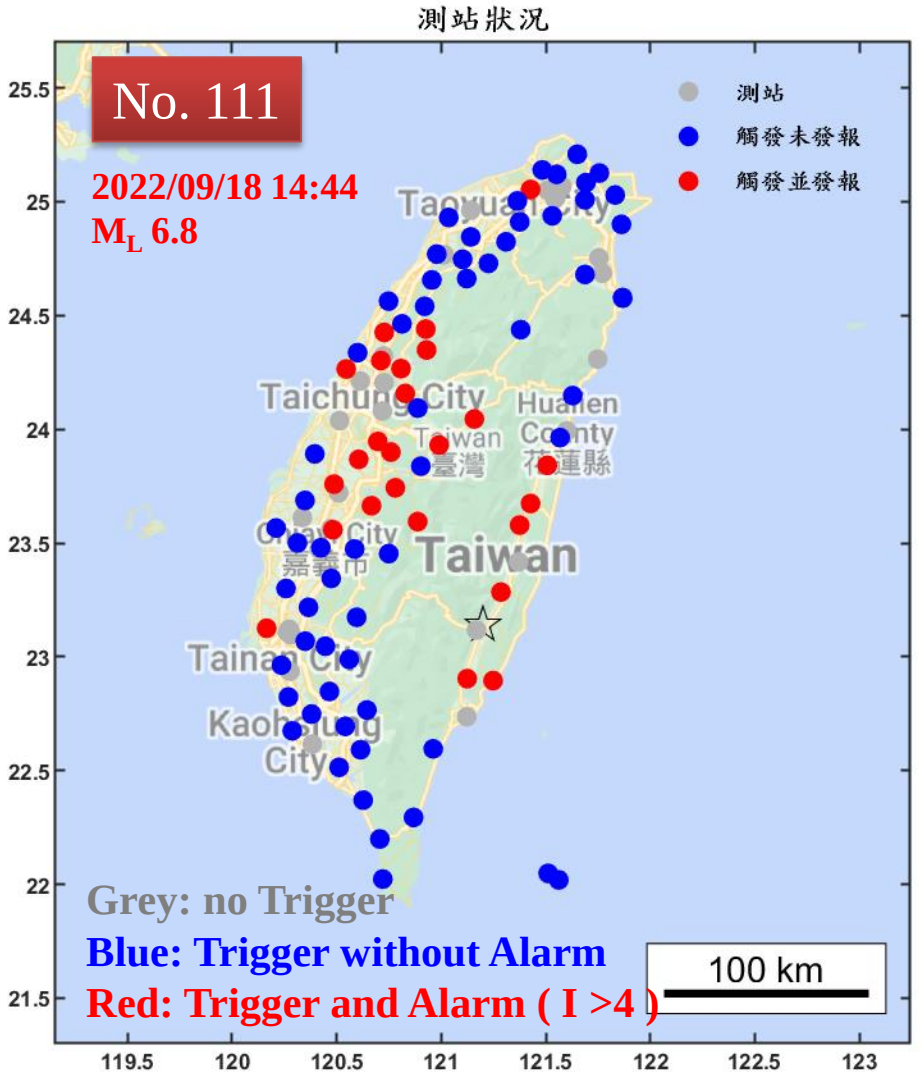
Intensity Maps of Two Earthquakes



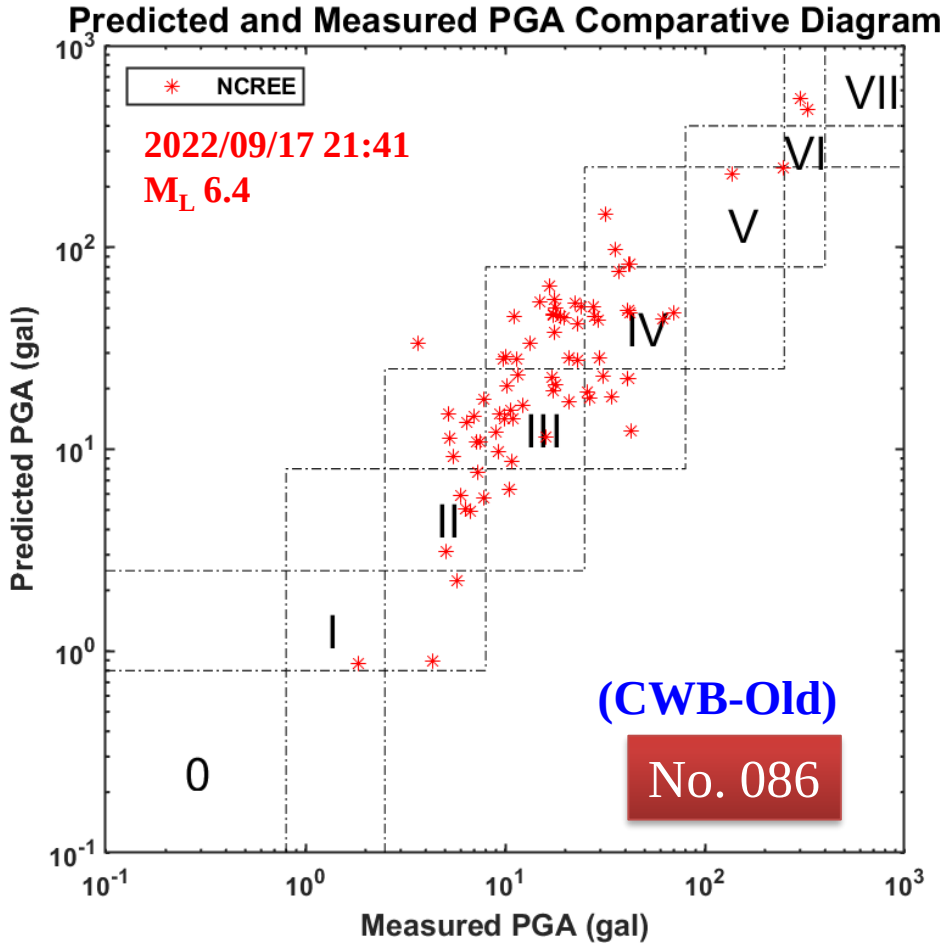


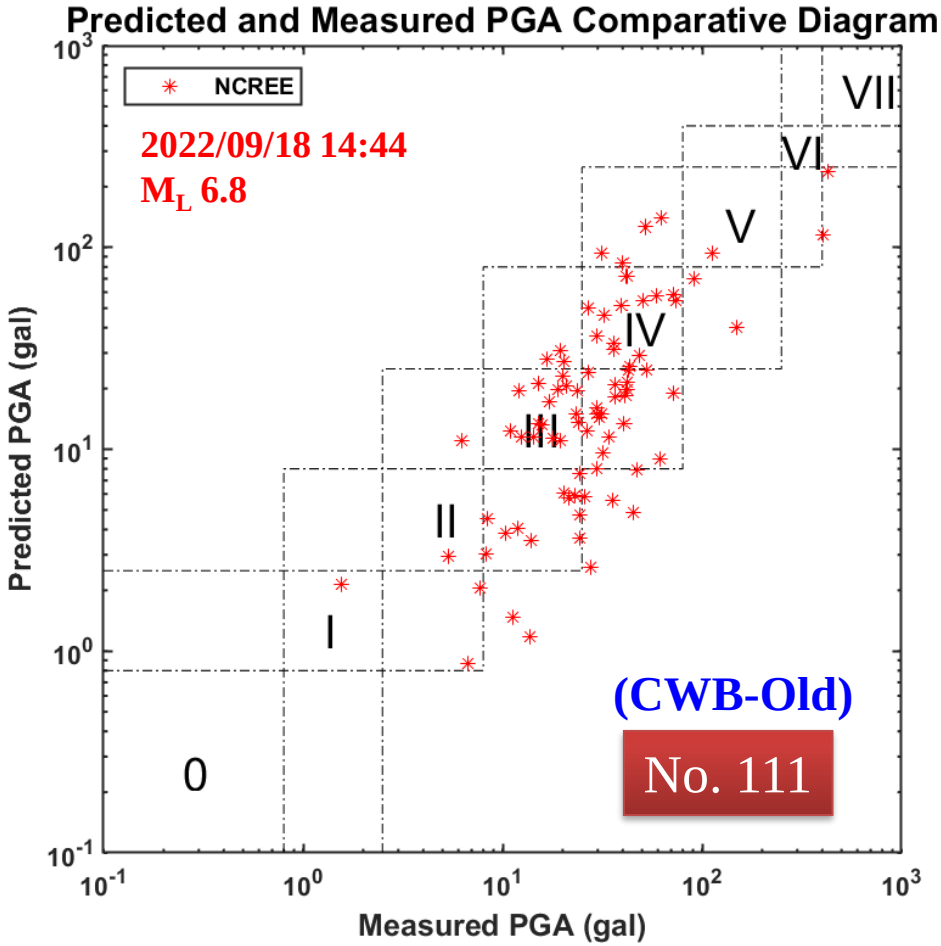
NCREE EEWS Trigger and Alarm





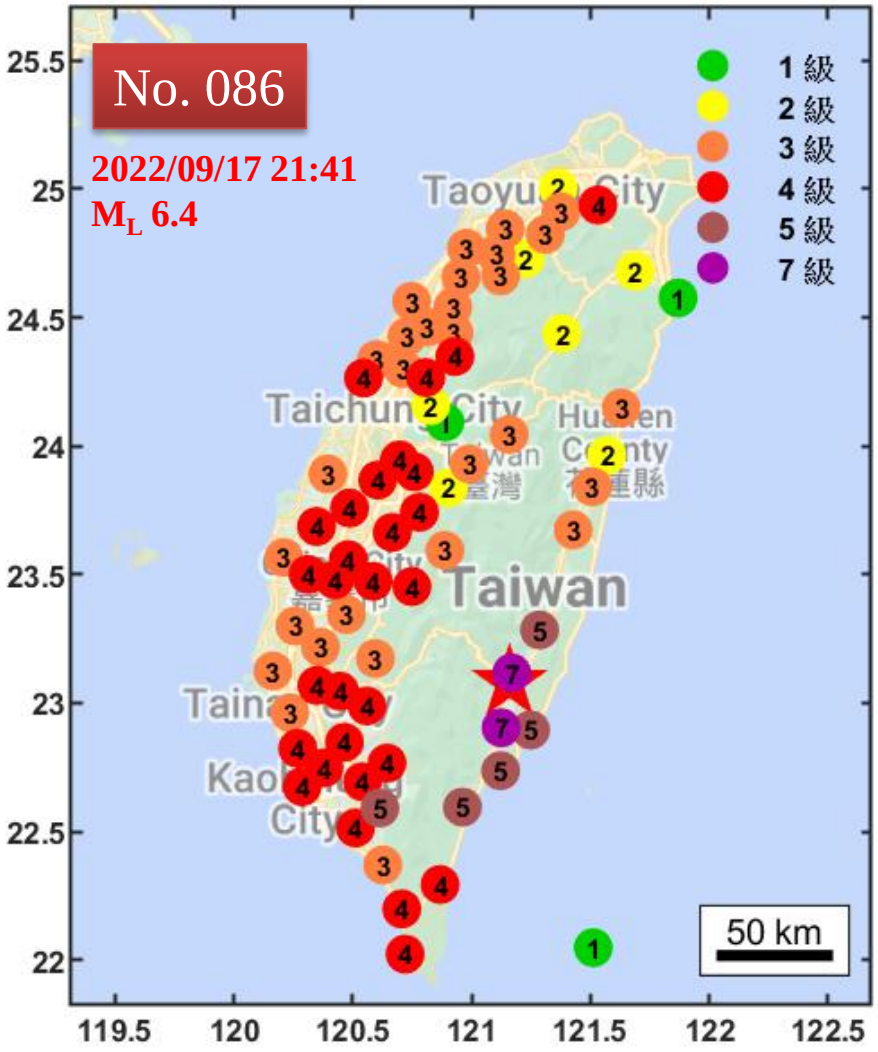
NCREE EEWS Predicted and Measured PGA



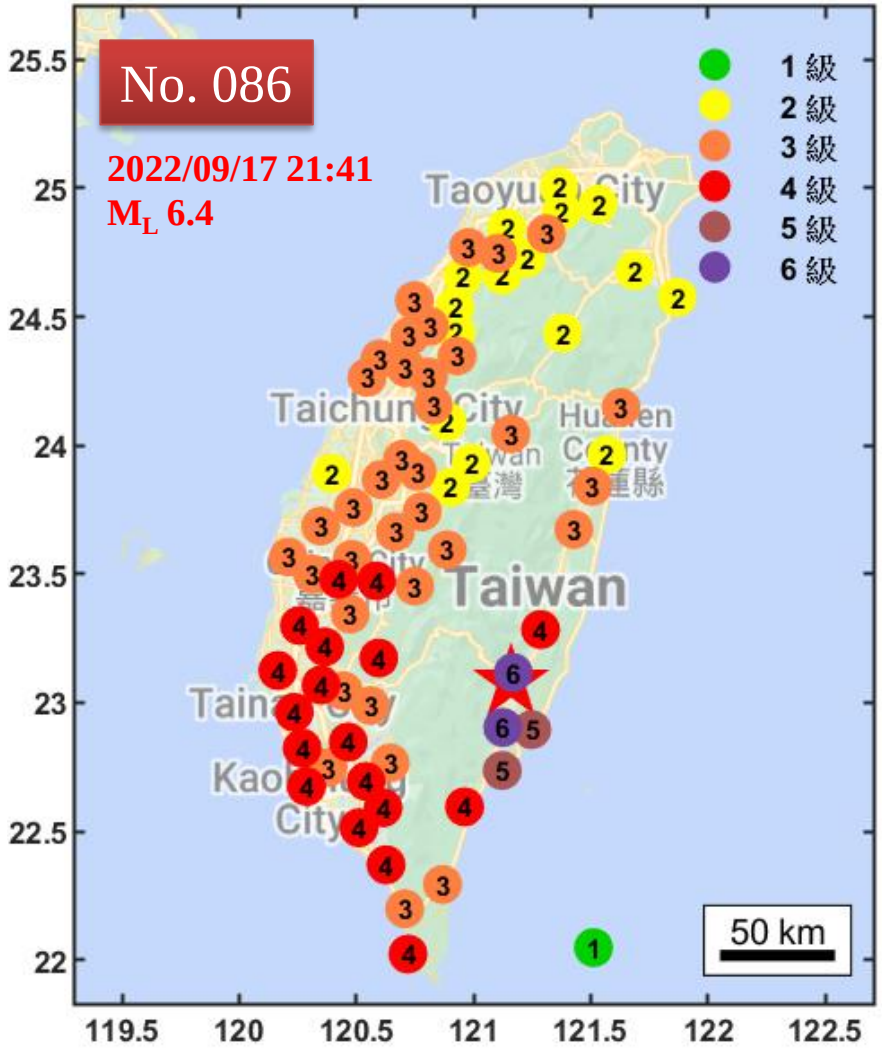


2022/09/17 21:41 M_L 6.4

Predicted Intensities (CWB-Old)

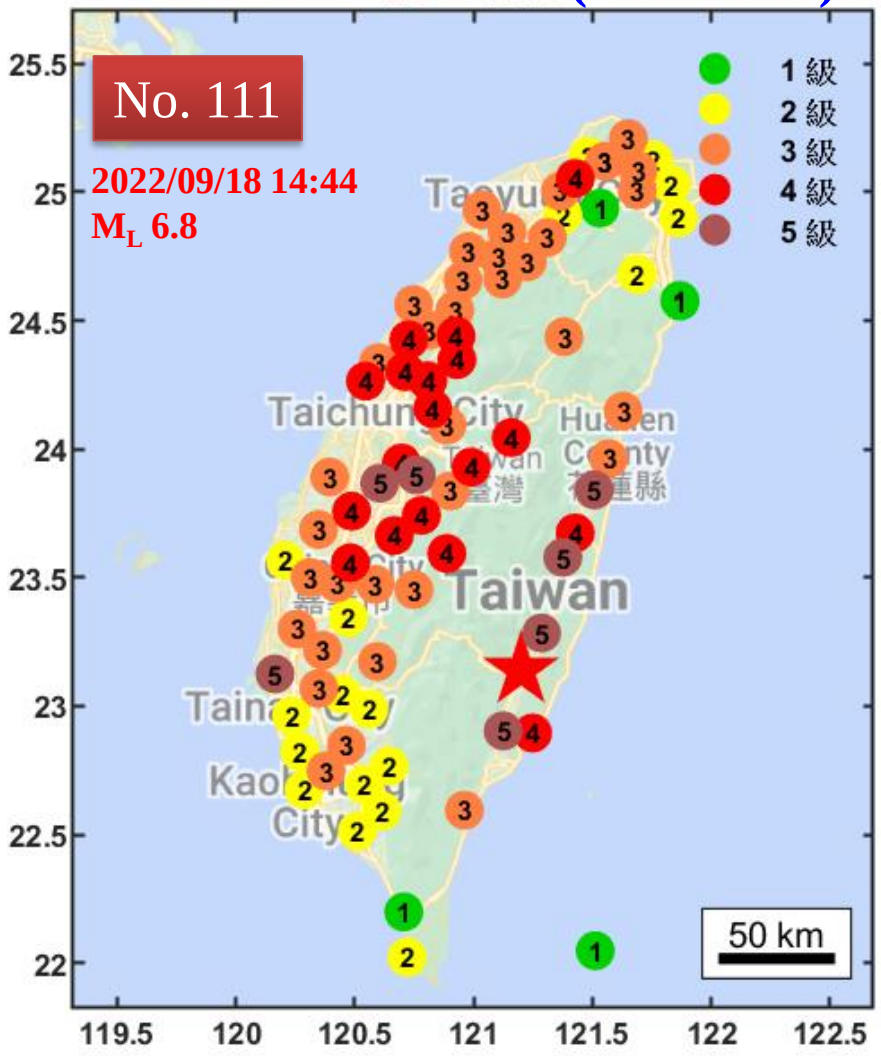


Measured Intensities (CWB-Old)

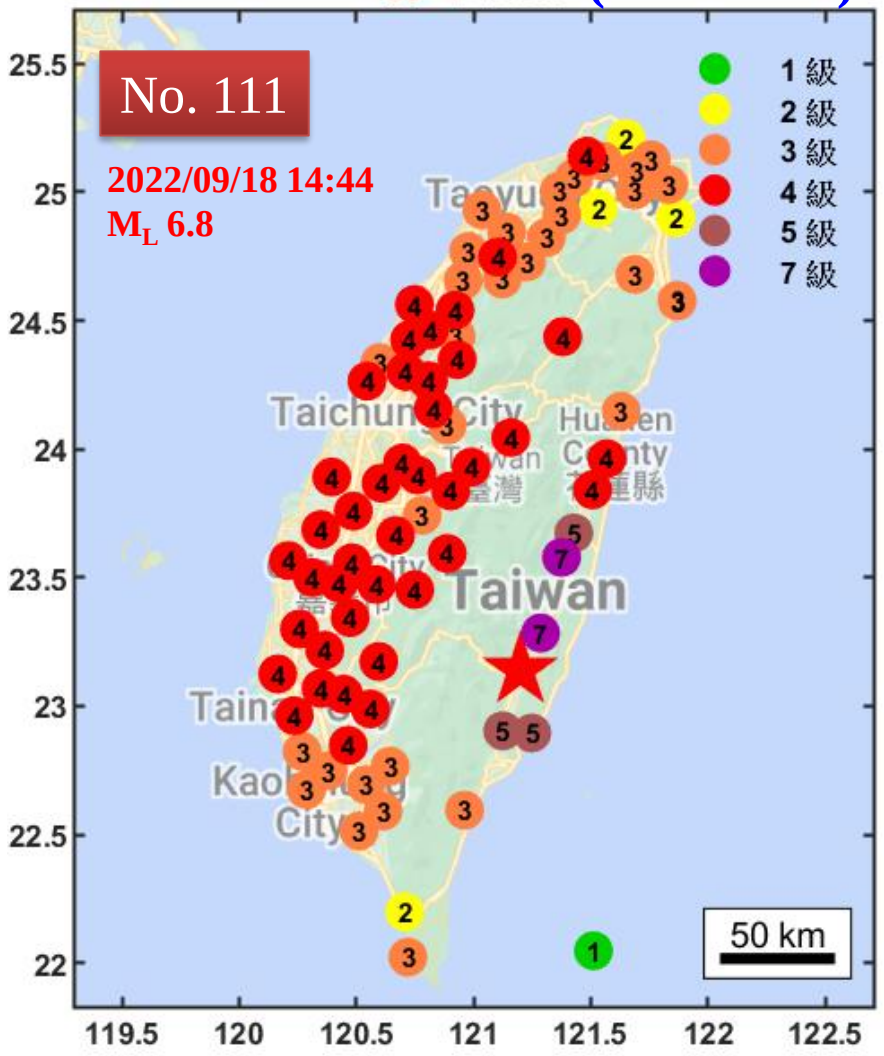


2022/09/18 14:44 M_L 6.8

Predicted Intensities (CWB-Old)

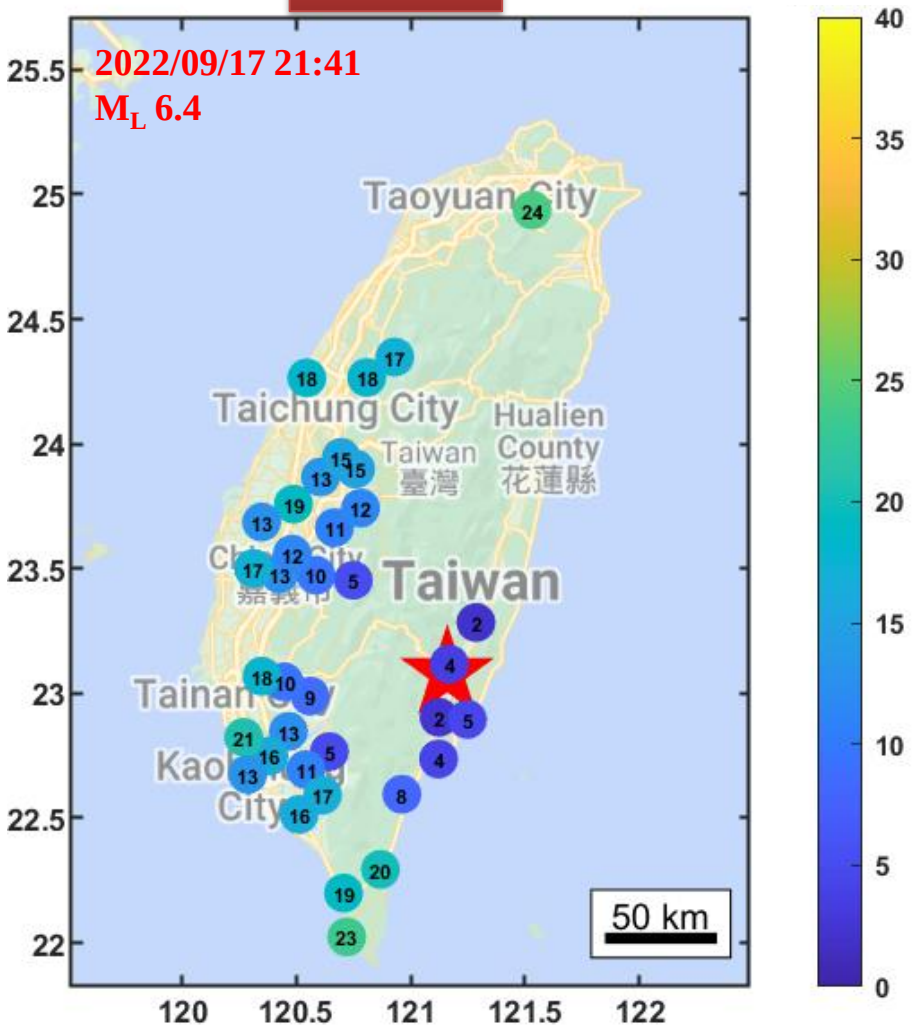


Measured Intensities (CWB-Old)



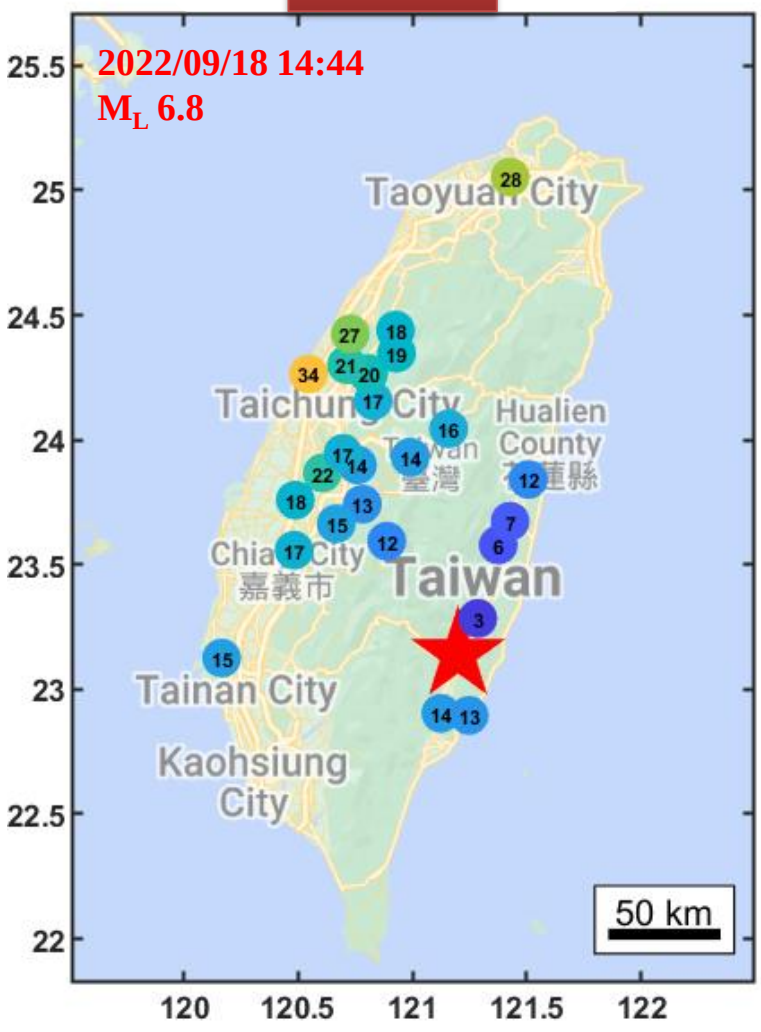
NCREE EEWS Advanced Warning Time

No. 086

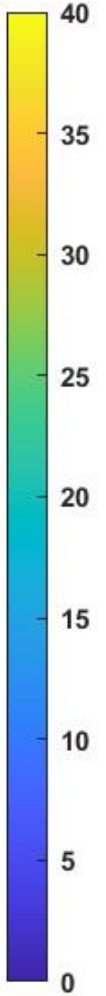


Time (sec)

No. 111

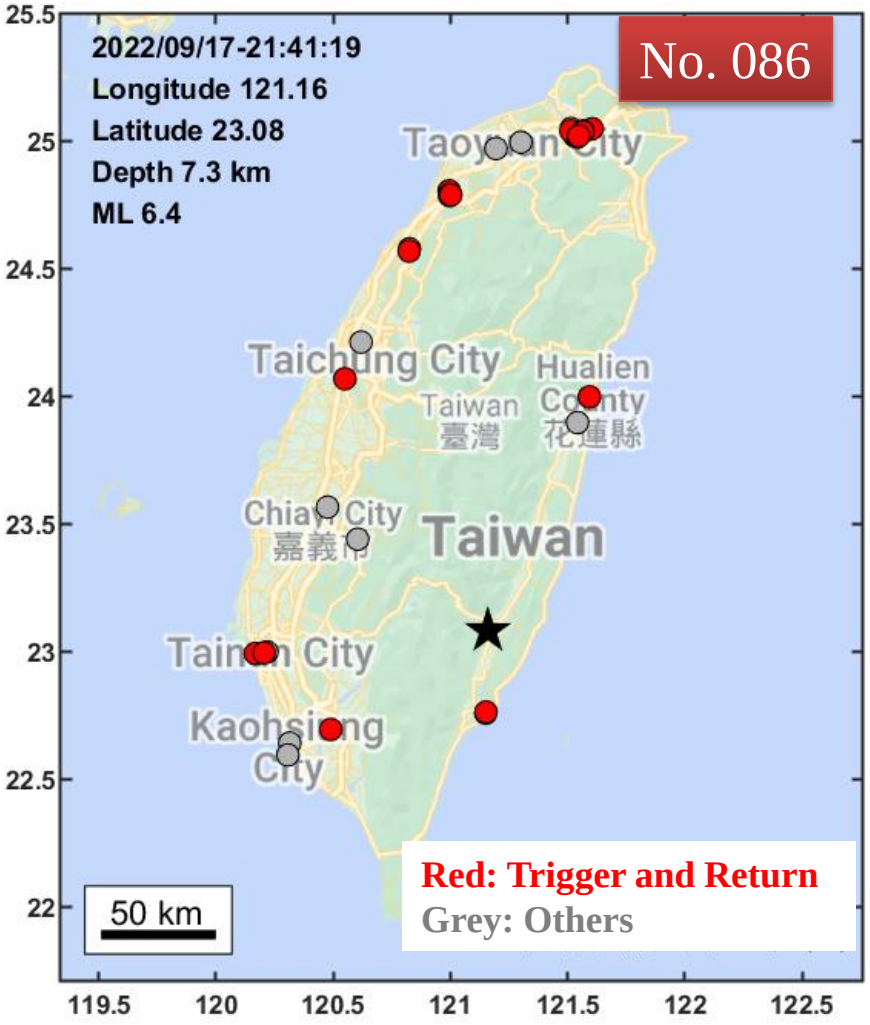


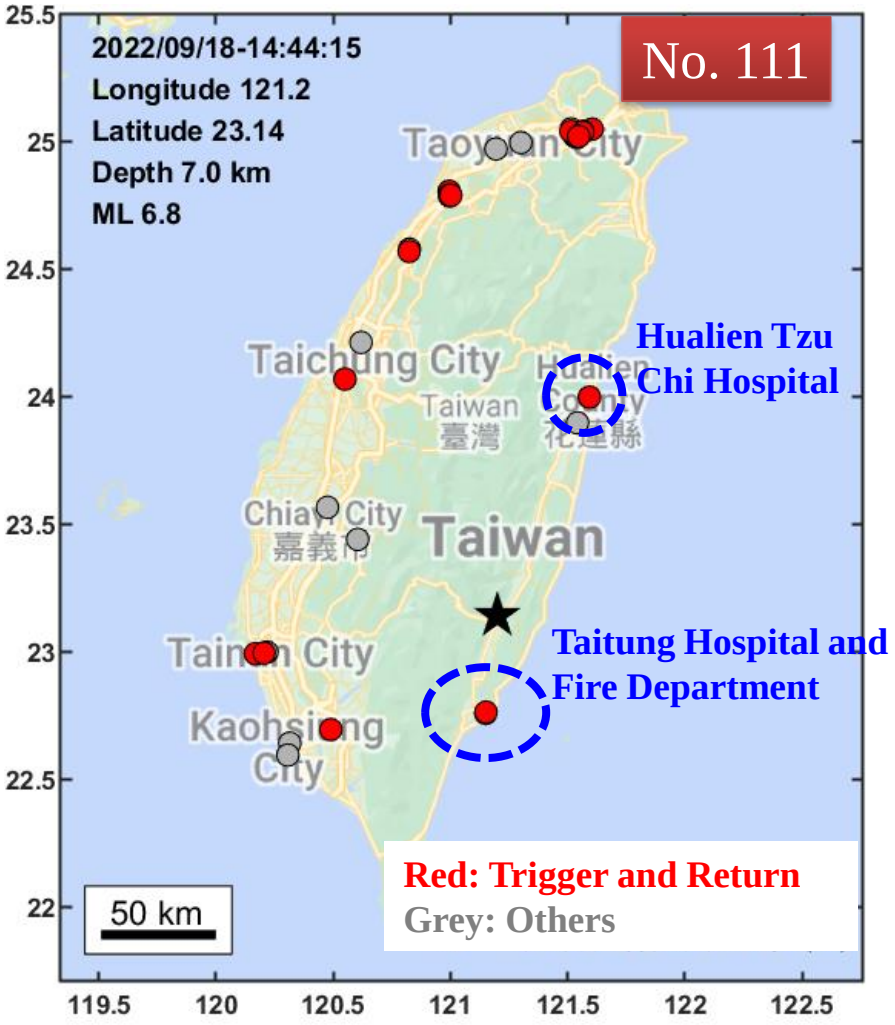
Time (sec)



NCREE Building Seismic Array TSMOD

Taiwan Structural Monitoring Data Hub http://bas.ncree.org/





Hualien Tzu Chi Hospital

Photo is from internet

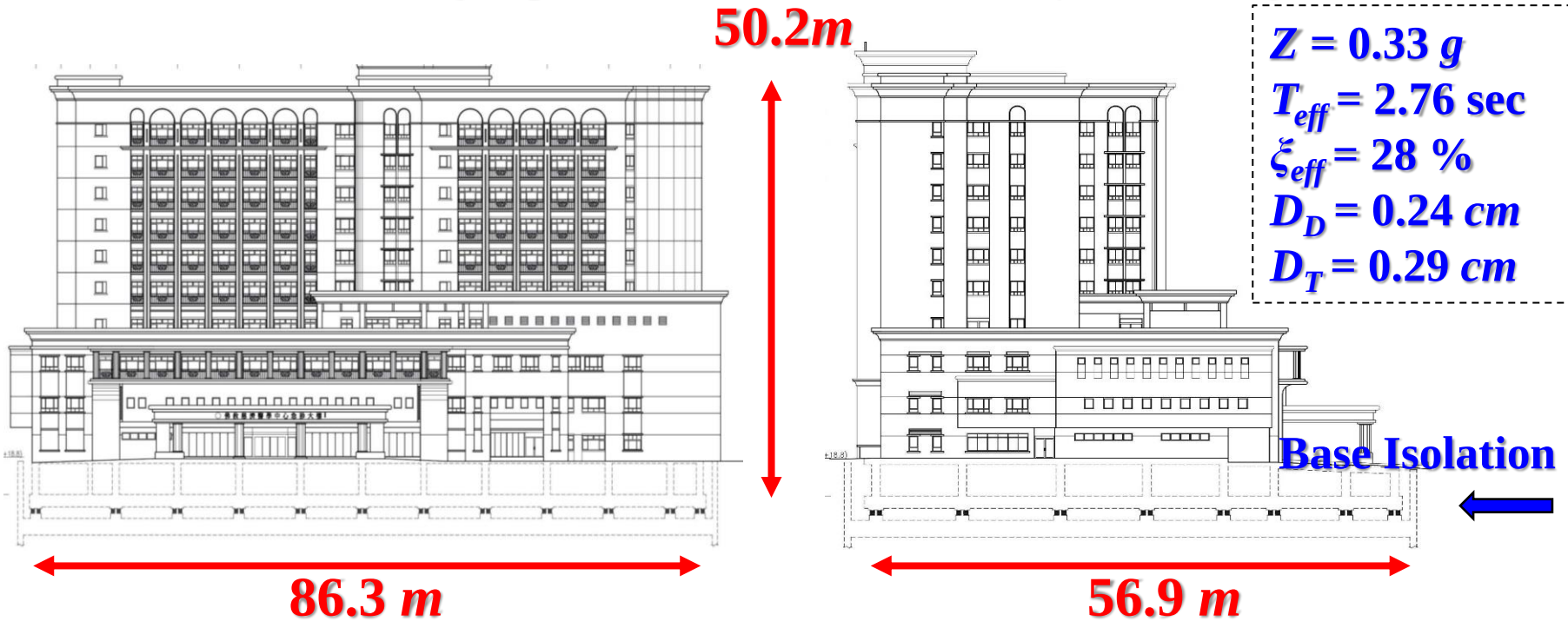
Completed in 2005.02

Hualien Tzu Chi Hospital

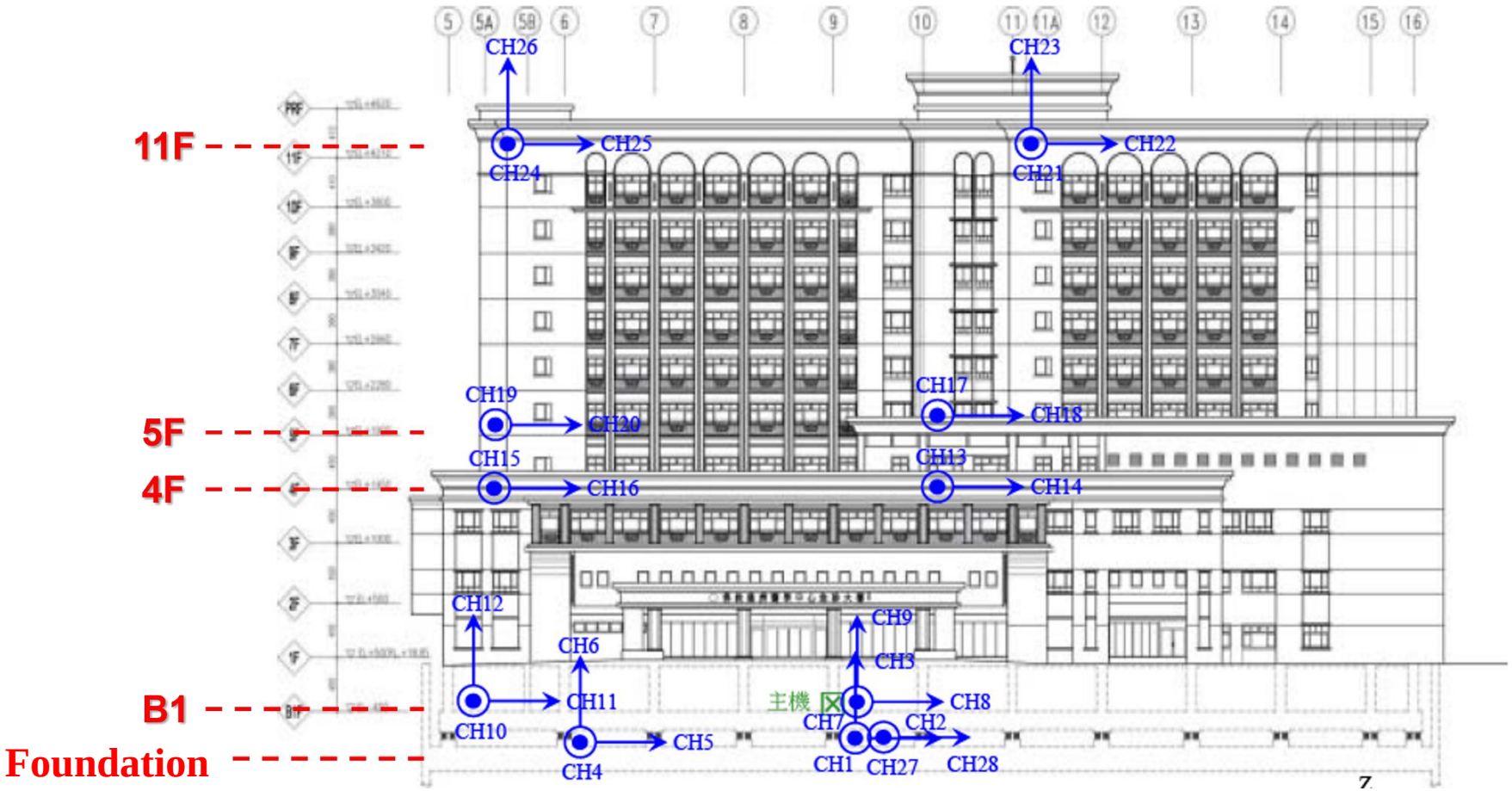
Base Isolation System

B2~1F SRC Structure，1F ~ 11F RC Structure

Use Seismic Design Specifications and Commentary of Buildings in 1997

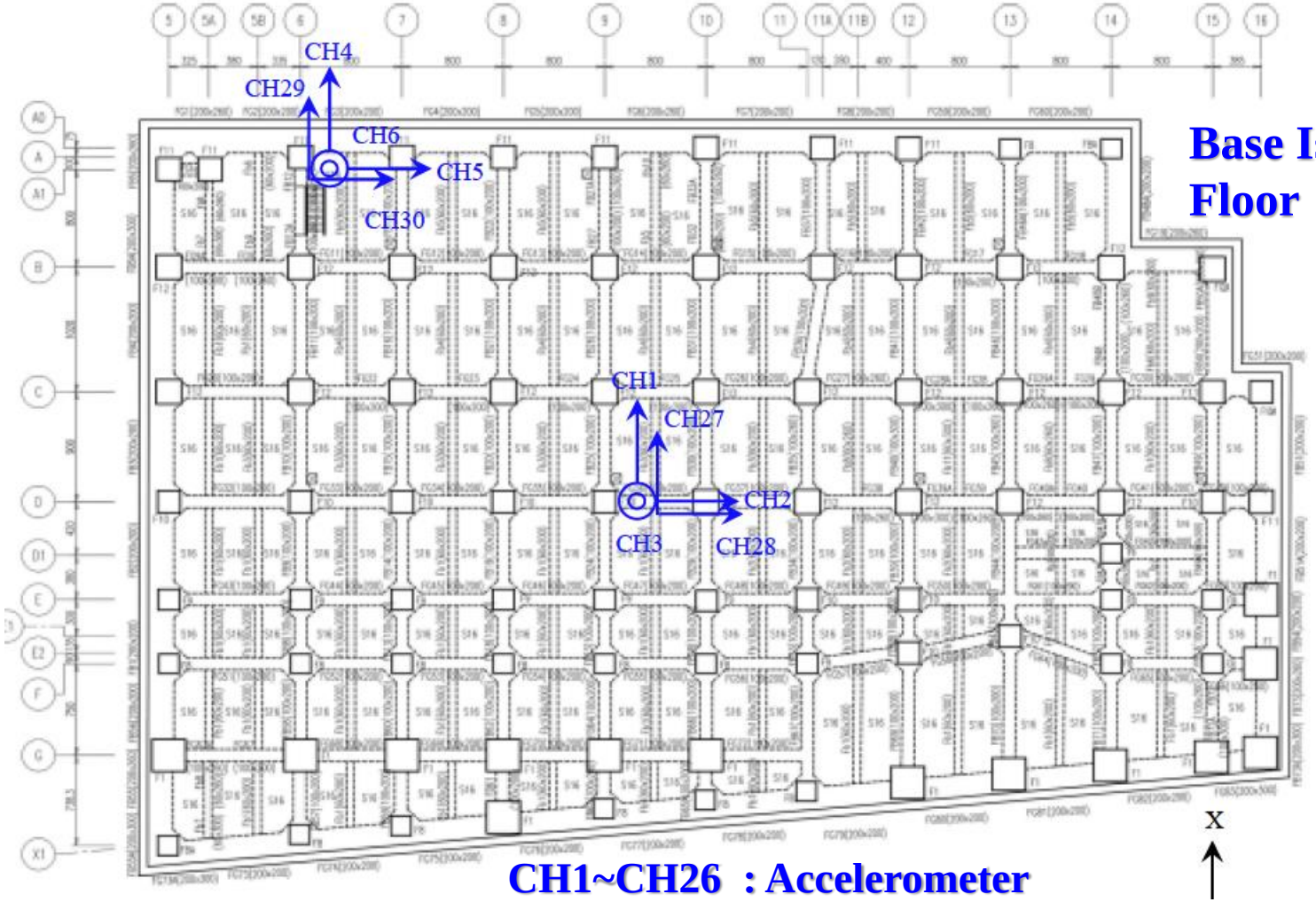


Strong Motion Instrument



CH1~CH26 : Accelerometer
CH27~CH30: Displacement meter

Strong Motion Instrument



Base Isolation Floor

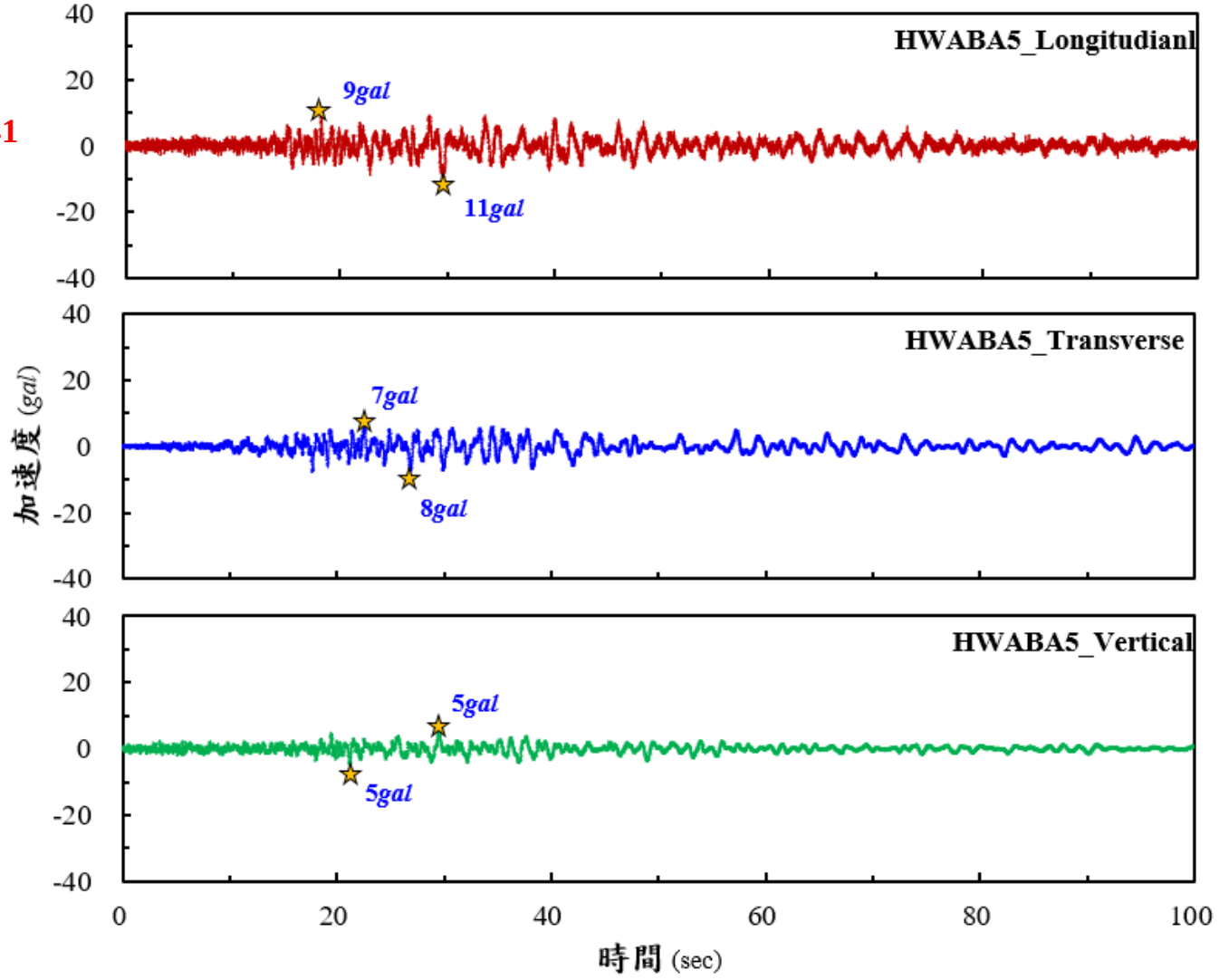
CH1~CH26 : Accelerometer

CH27~CH30: Displacement meter

2022/09/17 21:41 Accelerations of CH1~CH3

No. 086

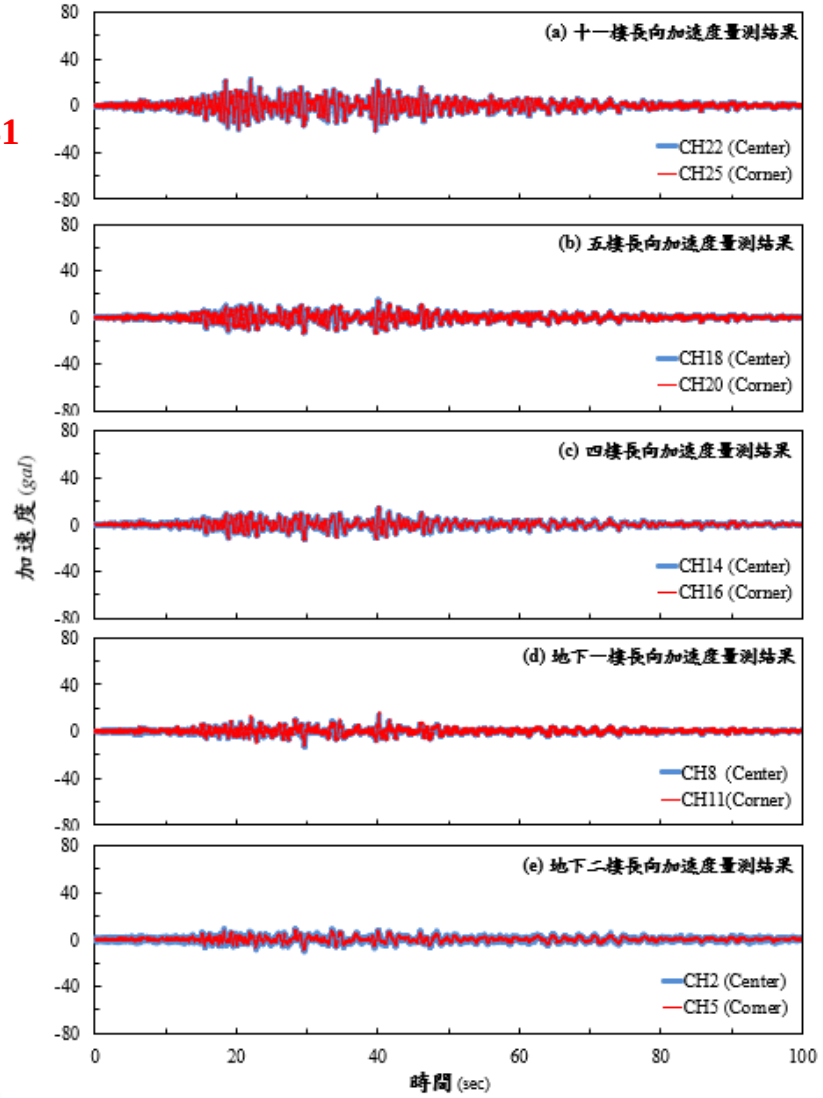
2022/09/17 21:41
M_L 6.4

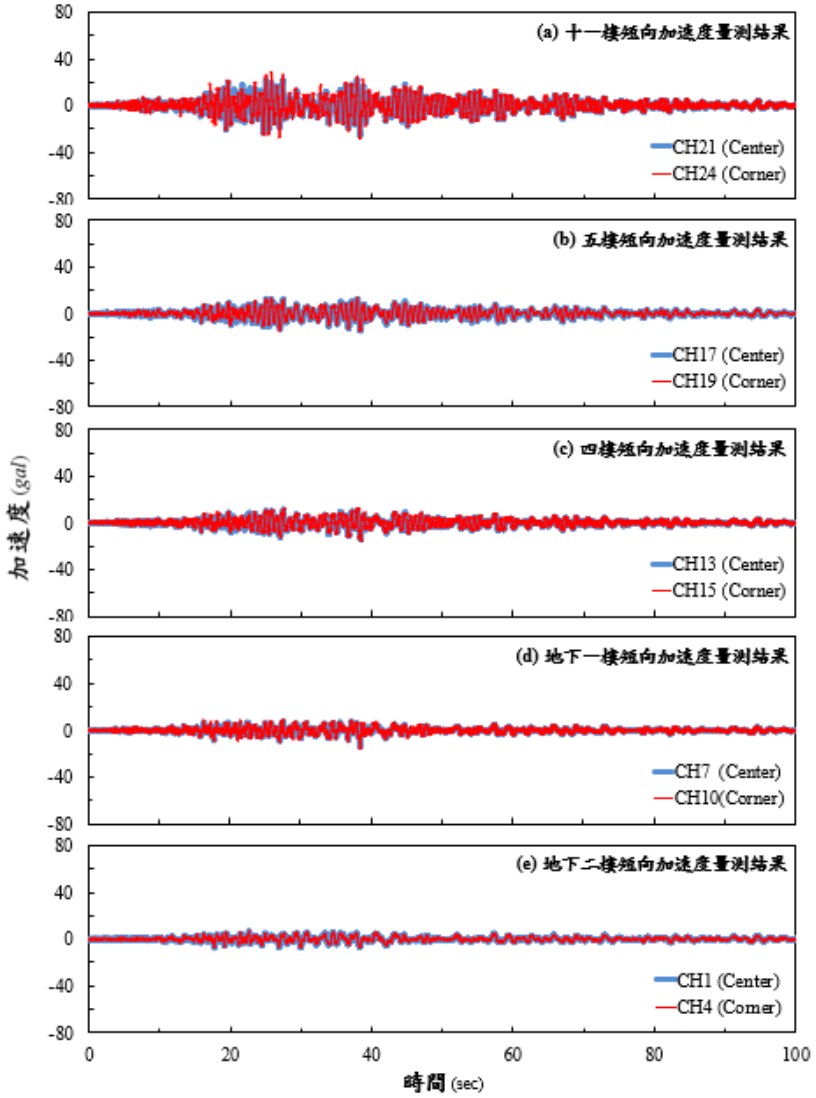


2022/09/17 21:41 Acceleration of Others

No. 086

2022/09/17 21:41
M_L 6.4

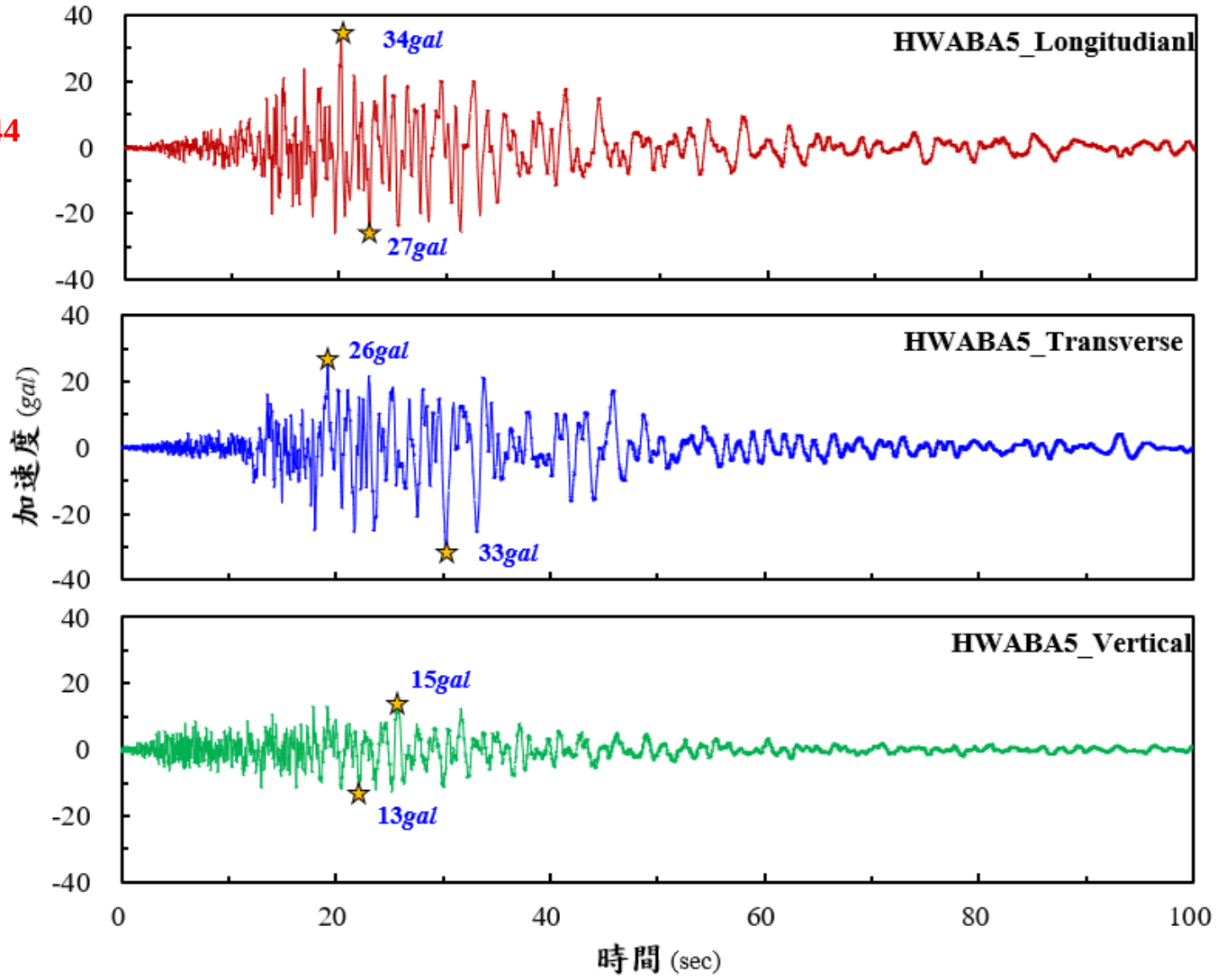




2022/09/18 14:44 Accelerations of CH1~CH3

No. 111

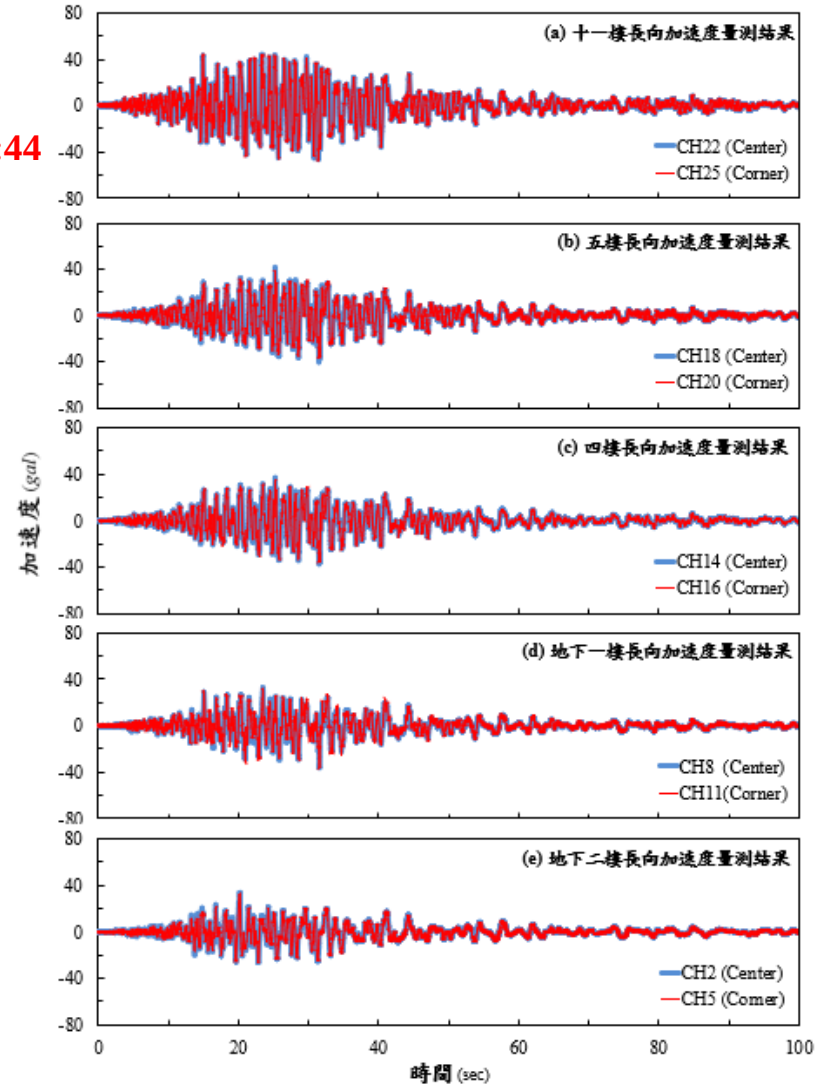
2022/09/18 14:44
M_L 6.8

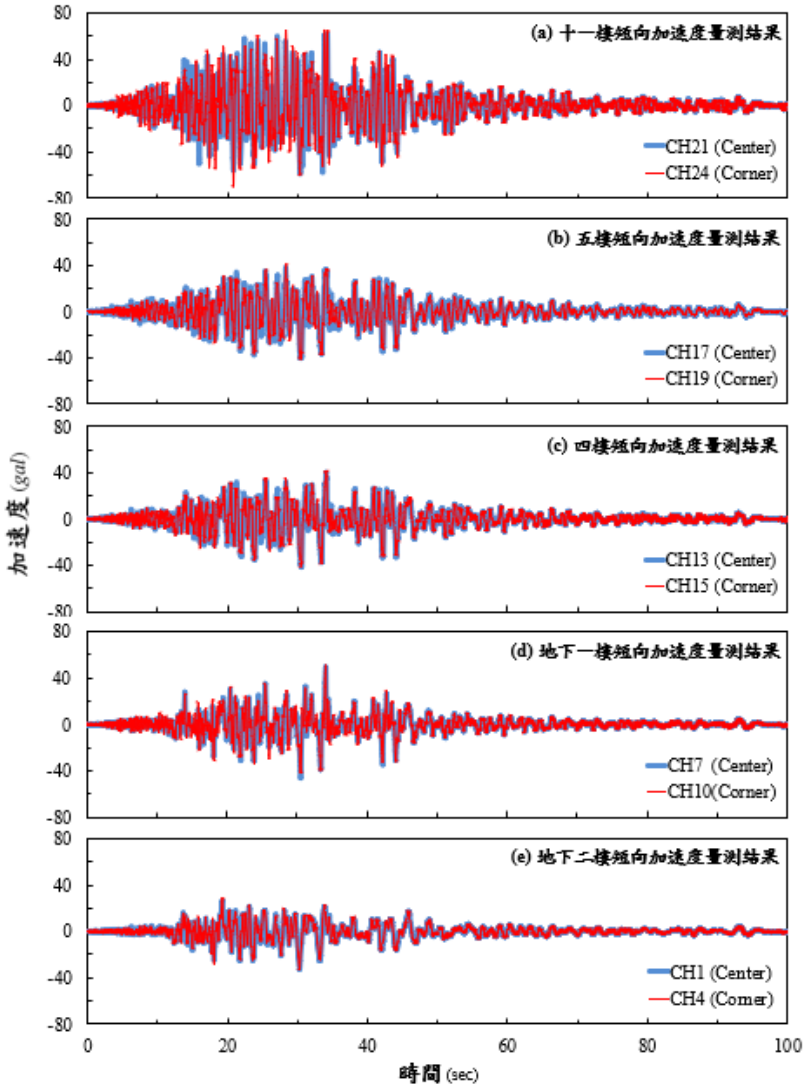


2022/09/18 14:44 Acceleration of Others

No. 111

2022/09/18 14:44
M_L 6.8





Maximum Acceleration of Each Floor

No. 086

20220917 unit: gal

Floor	Longitudinal	Transversal	Virtical
11F	23	26	6
5F	15	15	
4F	15	15	
B1F	14	15	5
B2F	11	8	5
11F / B2F	213.71%	339.04%	116.15%
5F / B2F	144.71%	194.64%	
4F / B2F	137.90%	192.06%	
B1F /B2F	132.89%	190.43%	97.90%

No. 111

20220918 unit: gal

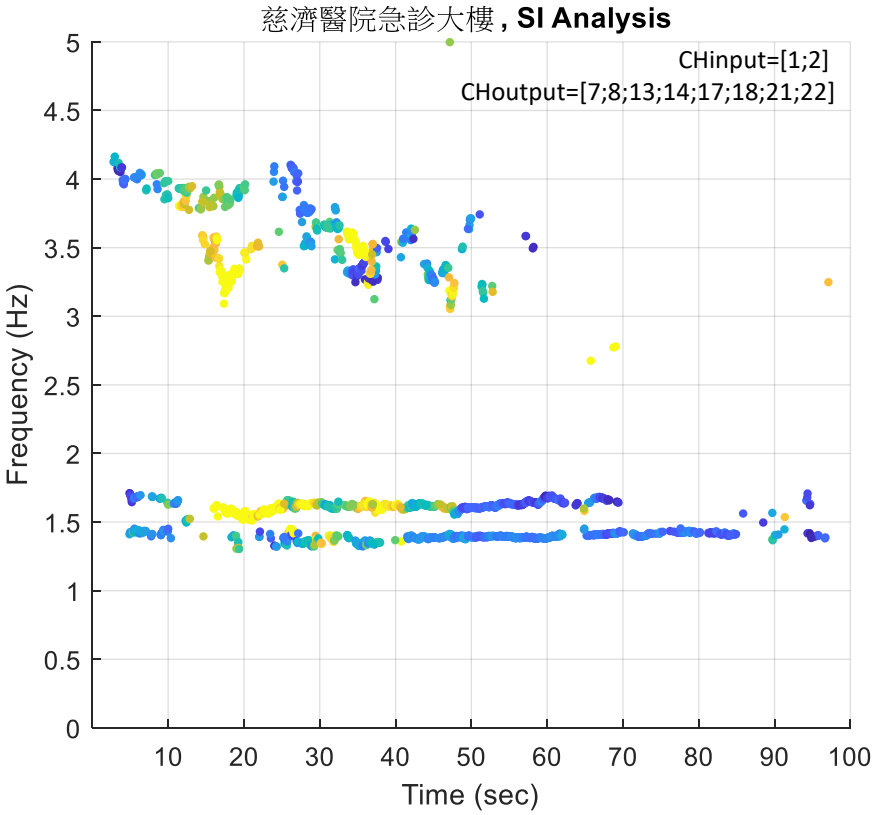
Floor	Longitudinal	Transversal	Virtical
11F	47	62	22
5F	42	40	
4F	37	42	
B1F	36	49	15
B2F	34	33	15
11F / B2F	138.01%	190.22%	152.35%
5F / B2F	123.51%	123.69%	
4F / B2F	110.57%	127.36%	
B1F /B2F	107.68%	151.16%	101.76%

Horizontal acceleration ratios are significantly lower for 09/18 earthquake.

Subspace Identification Results

No. 086

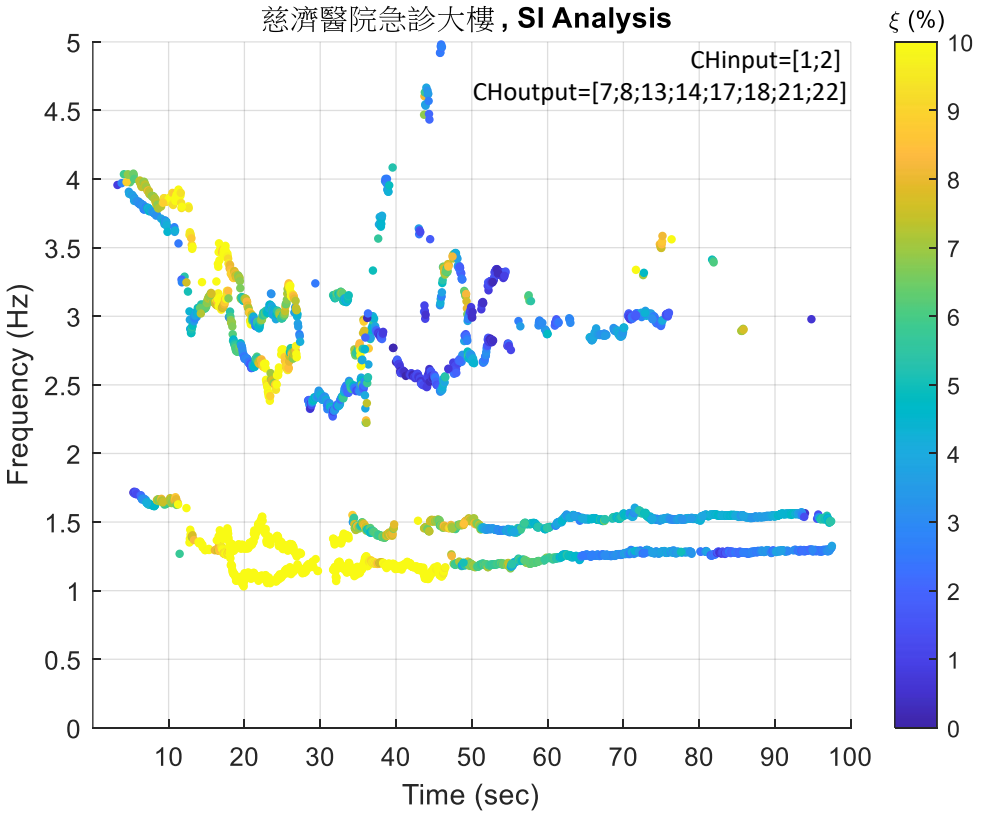
2022/09/17 M_L 6.4



No significant variation of fundamental period
Base isolation remained elastic stage

No. 111

2022/09/18 M_L 6.8



Significant variation of fundamental period
Damping ratios increase
Base isolation went through inelastic stage

Future Work

- **NCREE will continue to collaborate with local and central governments, the engineering industry and the academic community to investigate the severely impacted area and to study and propose measures for improvement, aiming to reduce losses induced by future earthquakes.**

NARLabs
國家實驗研究院

The End