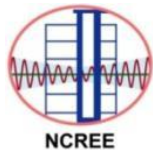# Advancement of Earthquake Mitigation in Taiwan

Shyh-Jiann Hwang

Director
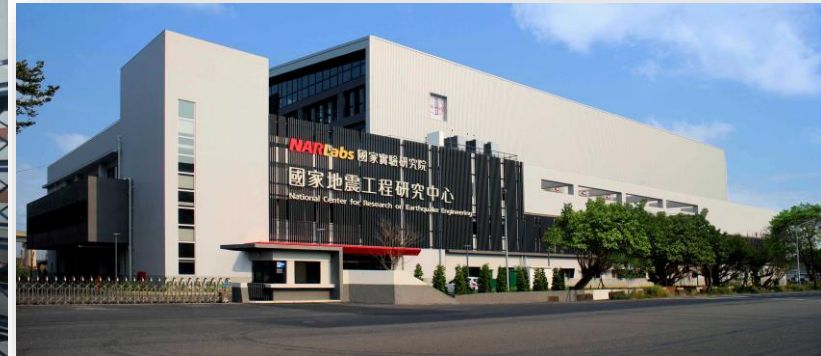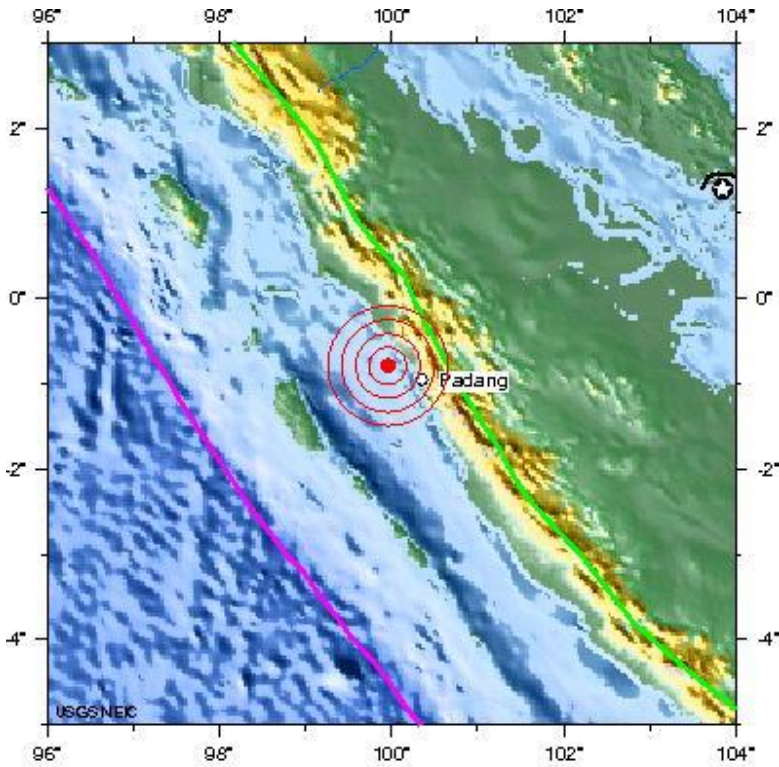National Center for Research on Earthquake Engineering

Professor
National Taiwan University

Introduction of NCREE

- Established at National Taiwan University in 1990

- Mission:

  - Pre-quake preparation – Disaster prevention
  - Emergency response   – Disaster reduction
  - Post-quake recovery   – Disaster relief
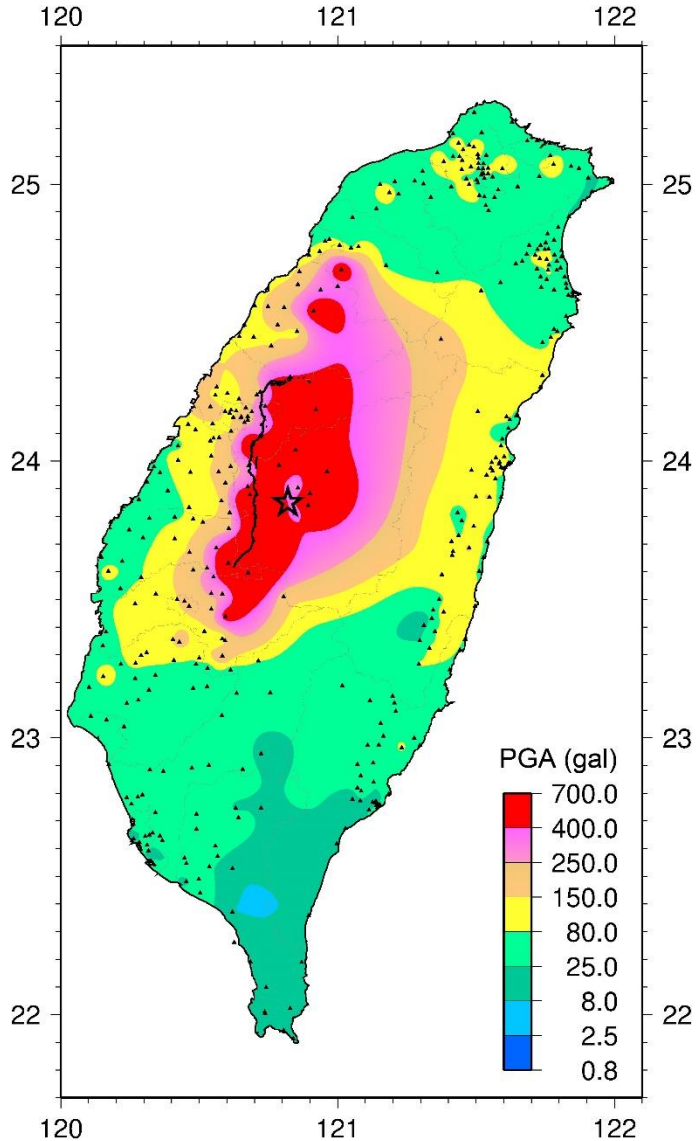
Padang Earthquake (10th Anniversary)

SOUTHERN SUMATRA, INDONESIA

2009 09 30 10:16:09 UTC 0.79S 99.96E Depth: 80.0 km, Magnitude: 7.6

Earthquake Location

Date	2009/9/30 (local)
Time	10:16:10 (local)
Magnitude	Mw 7.6
Depth	87 km
Epicenter	1.4° S, 99.9° E (Padang)
Casualties	1,115 killed 2,902 injured

Chichi Earthquake (20th Anniversary)

Date	1999/9/21 (local)
Time	01:47:12.2 (local)
Duration	**102 seconds**
Magnitude	M_w **7.6-7.7** (M_L 7.3)
Depth	**8 km**
Epicenter	ChiChi, Taiwan
Max. PGA	**1.01 g**
Casualties	2,415 killed 11,305 injured 51,711 buildings collapsed 53,768 buildings damaged

PGA (gal)
700.0
400.0
250.0
150.0
80.0
25.0
8.0
2.5
0.8

Outlines

- **Chichi Earthquake Disaster**
- **Probability Seismic Hazard Analysis**
- **Geotechnical Engineering**
- **Buildings**
- **Bridges**
- **Lifeline Systems**
- **Resilient and Sustainable Communities**
- **Conclusions**

Chichi Earthquake Disaster

Probability Seismic Hazard Analysis
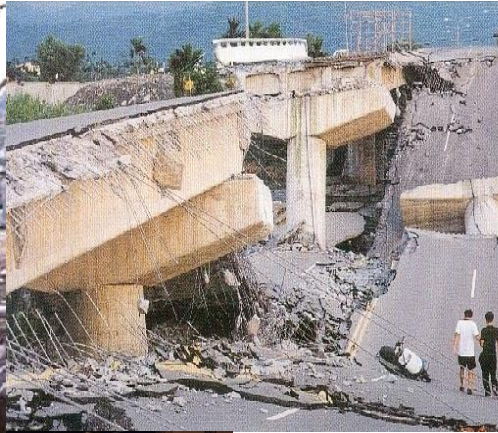
Geotechnical Engineering

Buildings

Bridges

Lifeline Systems

Resilient and Sustainable Communities

Conclusions

Horrible Disaster

Chichi Earthquake Disaster

Probability Seismic Hazard Analysis

Geotechnical Engineering
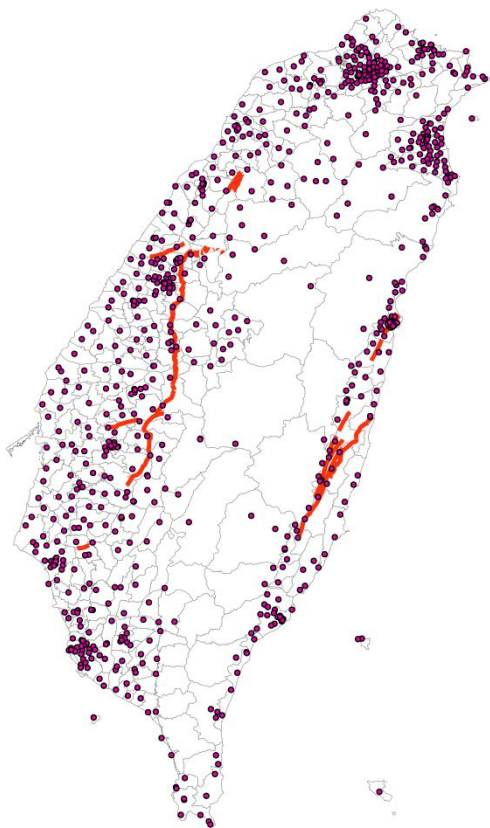
Buildings

Bridges

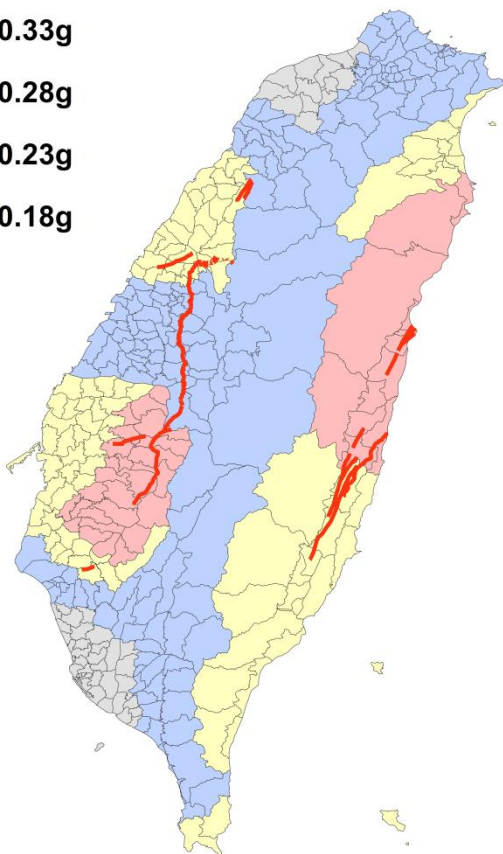Lifeline Systems

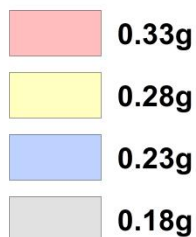Resilient and Sustainable Communities
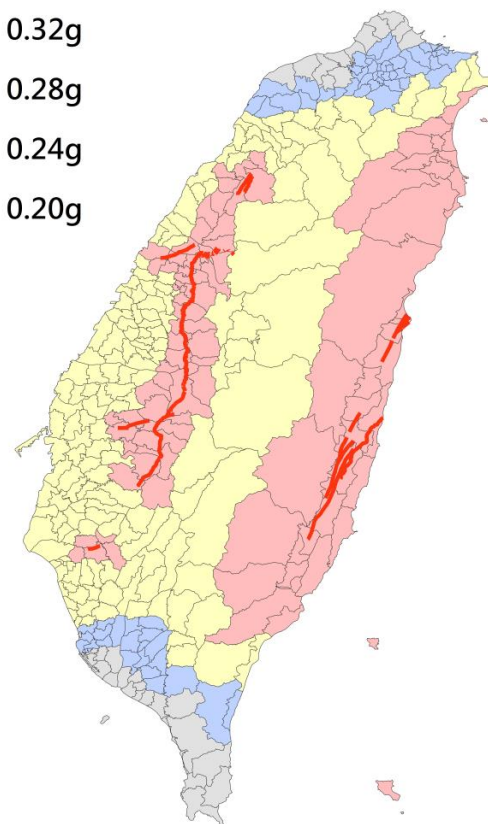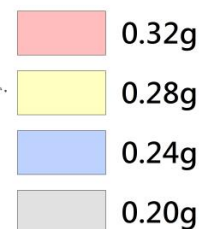
Conclusions
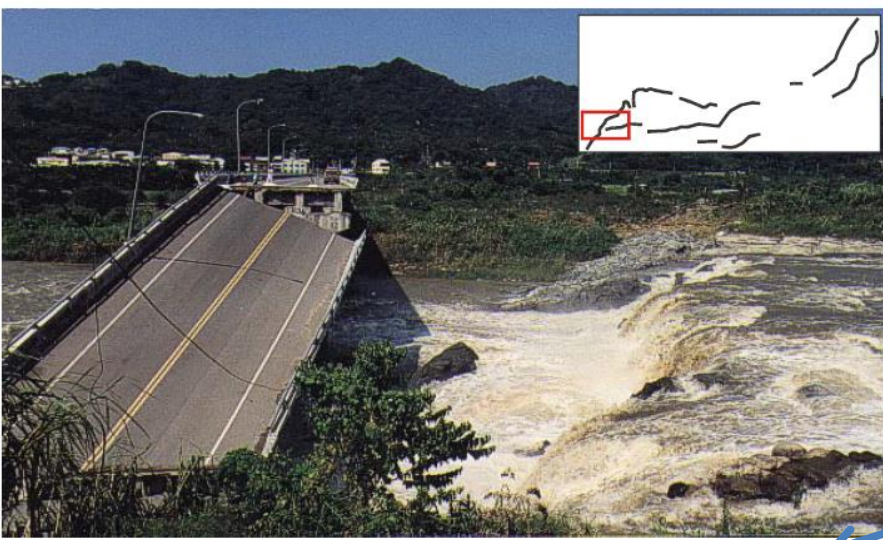
Updated Seismic Zonation

The CWB ground-motion array

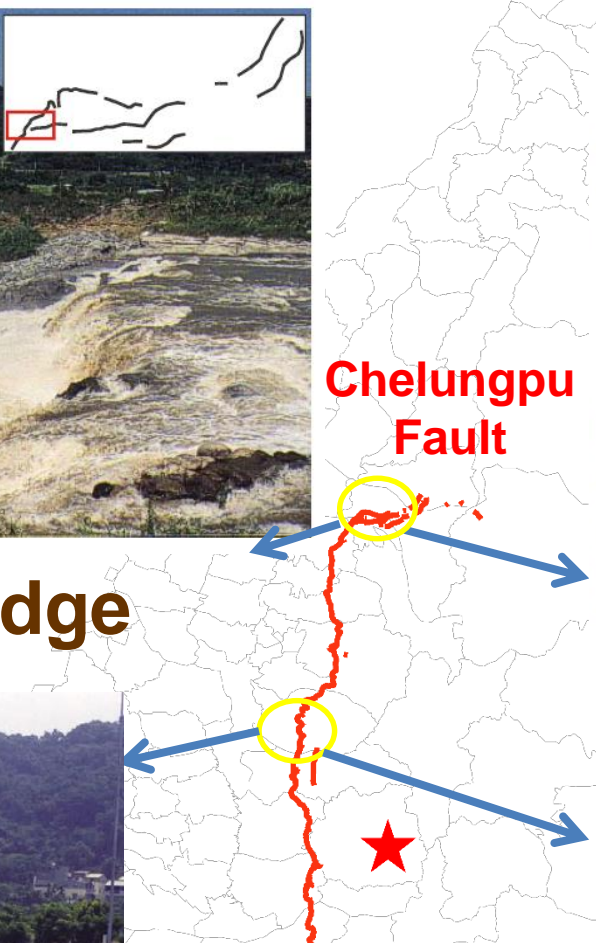**Before 921 Earthquake**

After 921 Earthquake

0.33g	
0.28g	
0.23g	
0.18g	

0.32g	
0.28g	
0.24g	
0.20g	

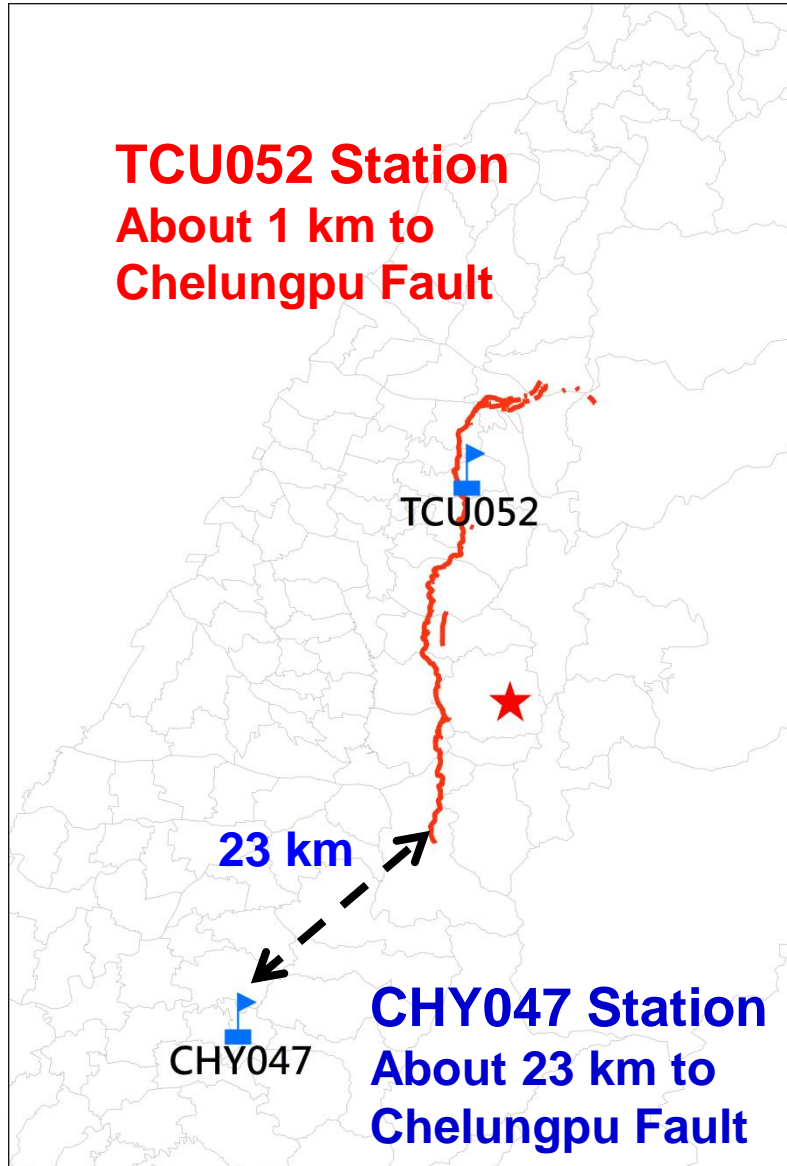**Bei-Feng Bridge**

Chelungpu Fault

Shih-Kang Dam

Kuang-Fu Junior High School

Railway

Near-Fault Effect

TCU052 Station
About 1 km to Chelungpu Fault

TCU052

23 km

CHY047

CHY047 Station
About 23 km to Chelungpu Fault

Force

Energy

Displacement

921 Chi-Chi Earthquake, Mw 7.6

348.6544

177.7129

CHY047-NS
TCU052-EW

26.6315

183.8071

CHY047-NS
TCU052-EW

16.4109

515.3473

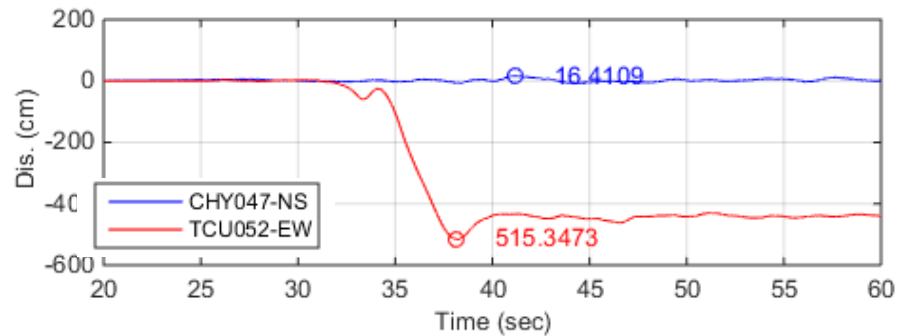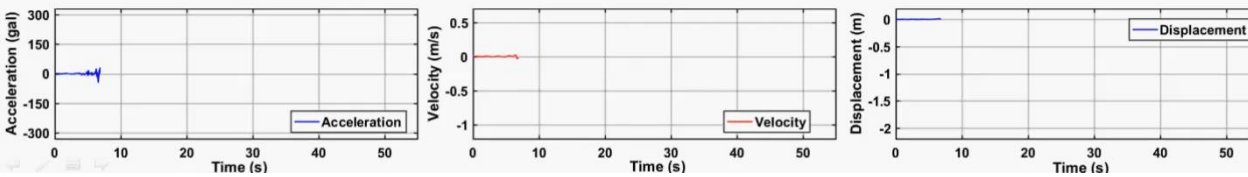CHY047-NS
TCU052-EW
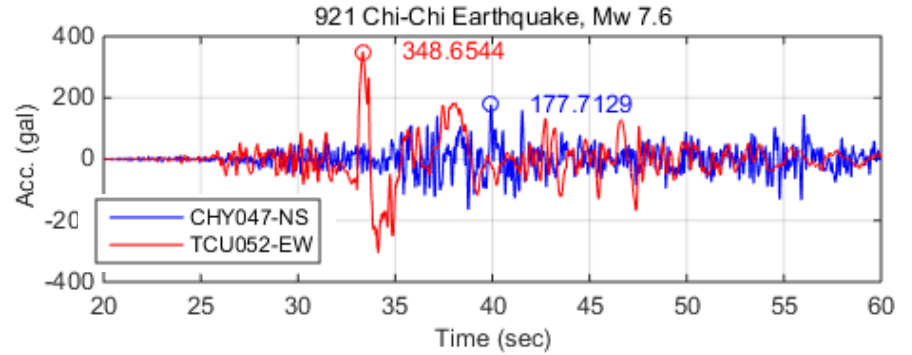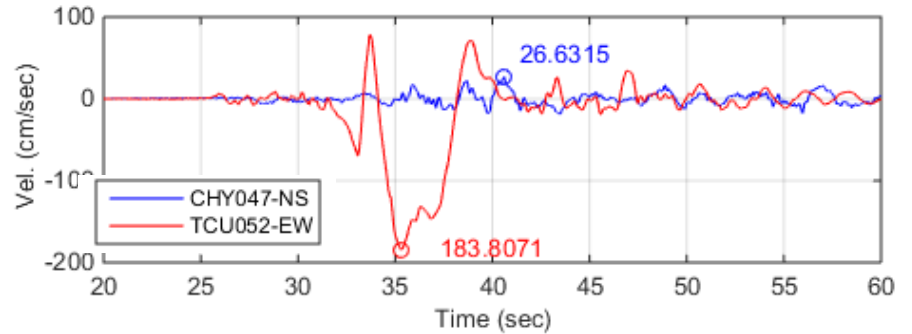
Long Stroke / High Velocity Earthquake Simulator
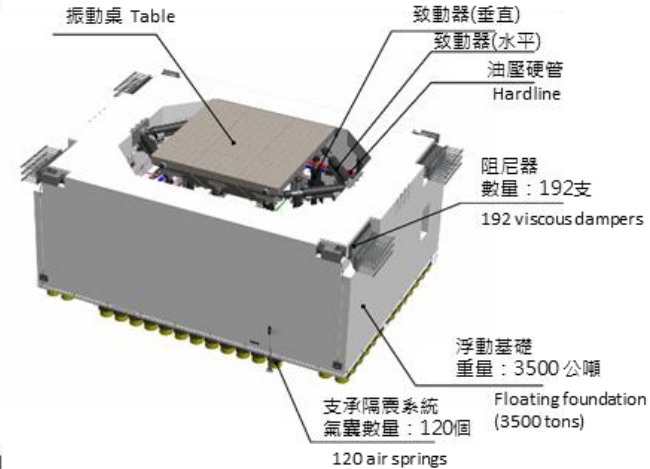
Site	Specifications of the earthquake simulators				
	Size (m)	Max Stroke (m)	Max Velocity (m/s)	Max Acceleration (g)	Max payload (tf)
Tainan Lab	**8 x 8**	**± 1**	**± 2**	**± 2.5**	**250**
Taipei Lab	**5 x 5**	**± 0.25**	**± 1**	**± 1.5**	**50**

Chichi Earthquake Disaster

Upgraded Seismic Zonation

Geotechnical Engineering

Buildings

Bridges

Lifeline Systems

Resilient and Sustainable Communities

Conclusions

Geotechnical Earthquake Disaster

Soil liquefaction

Liquefaction and settlement

Damaged wharf
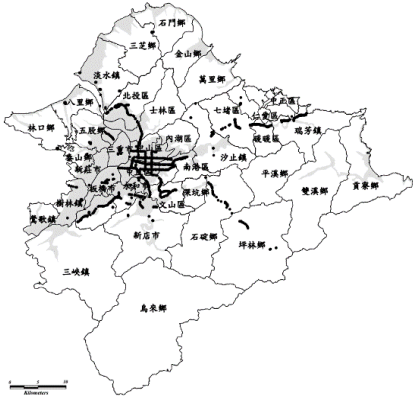
Landslide & slope failure
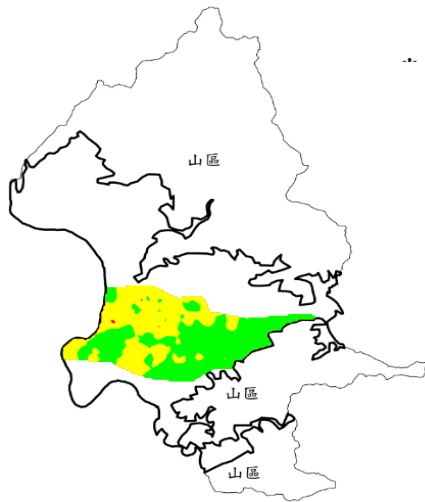

Dip slope

Landslide

Soil Liquefaction Potential (SLP) Map

1997

Borehole distribution

SLP map
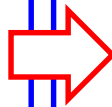
2019
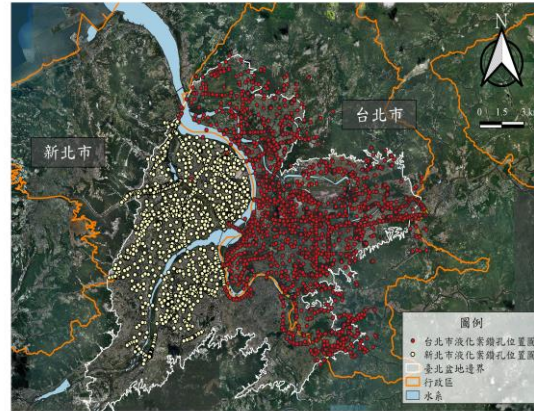
Borehole distribution
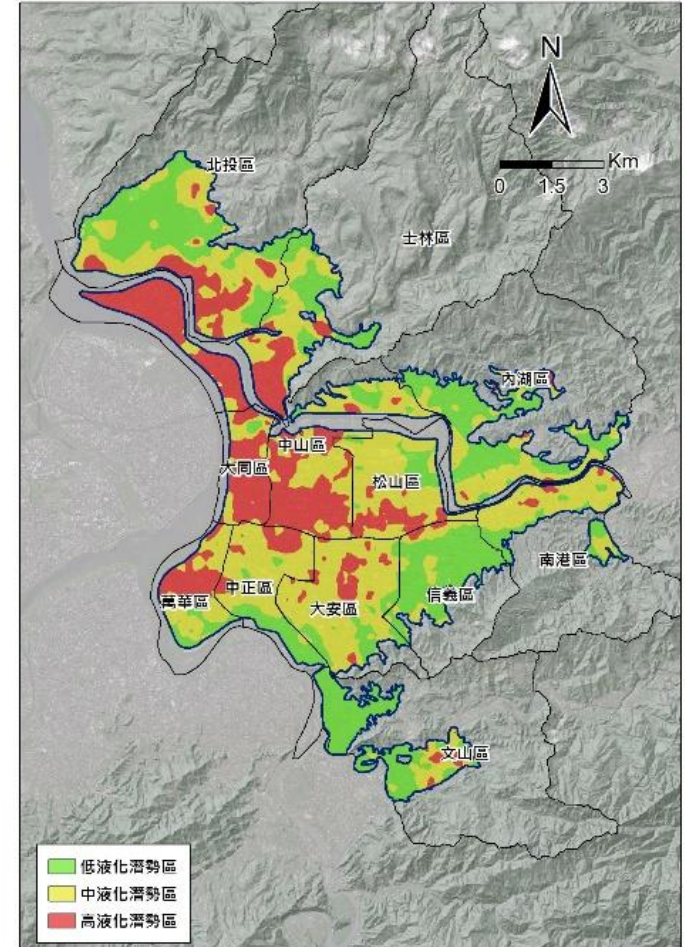
Current SLP map

Seismic Performance Study of Geotechnical Structures

NARLabs

Shaking table test of offshore wind turbine (1/25) with jacket foundation
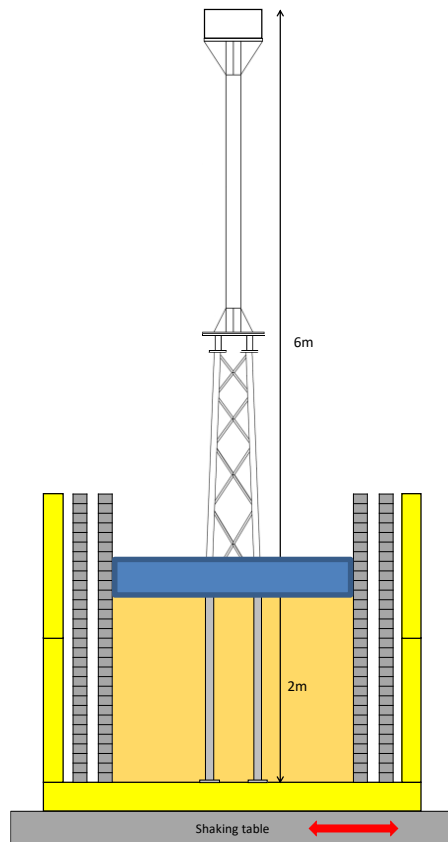
Chichi Earthquake Disaster

Probability Seismic Hazard Analysis

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Building's Earthquake Damage

Xinzhuang Dr.'s home

Dong-Xing Buildings

Building Seismic Retrofitting

NAR Labs

Earthquake energy

地震能量

建築物耐震力不良
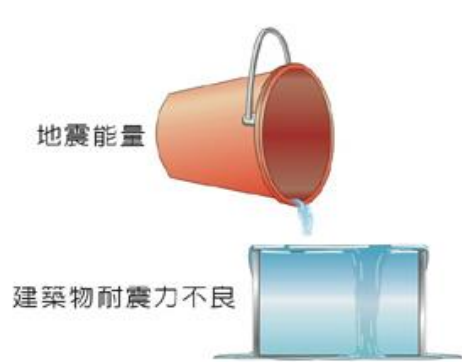
Water overflows the water tank.

地震能量

加高水族箱
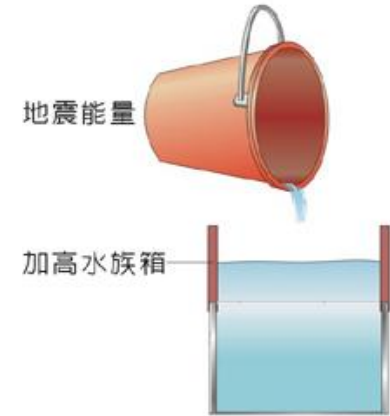
Improving the seismic capacity

Seismic capacity of the building

Building collapsed

老舊不耐震建築

提升柱子強度或增加壁量
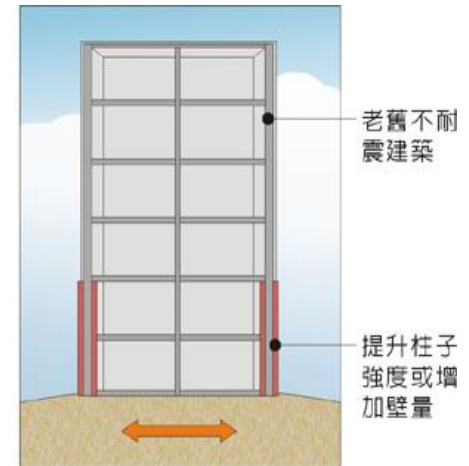
Safe building

School Building Seismic Retrofit Methods
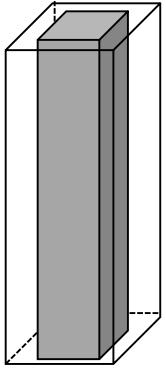
Enlarged column

Shear wall
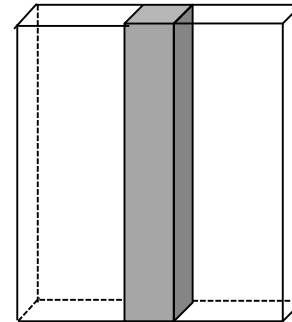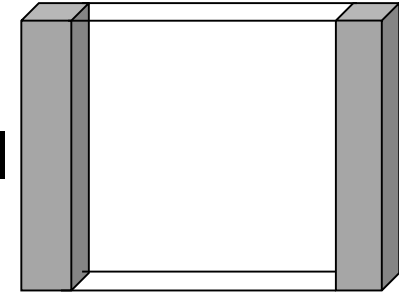
Wing wall

Research on Seismic Capacity of Buildings

Static Test
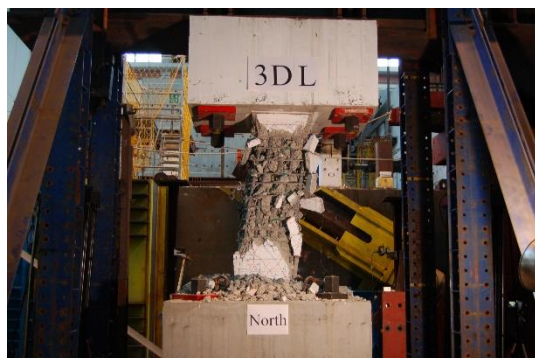
Column

Shaking Table Test

Columns

In situ test of school buildings

Elementary school
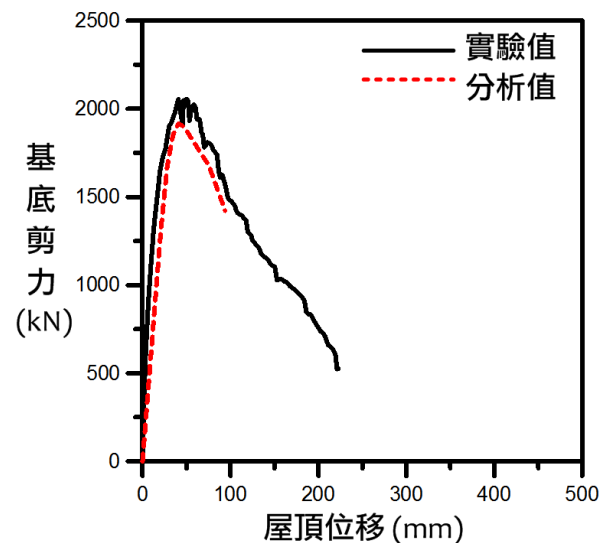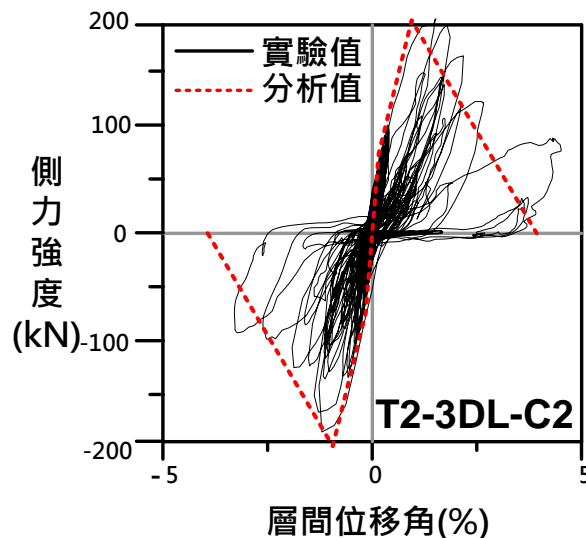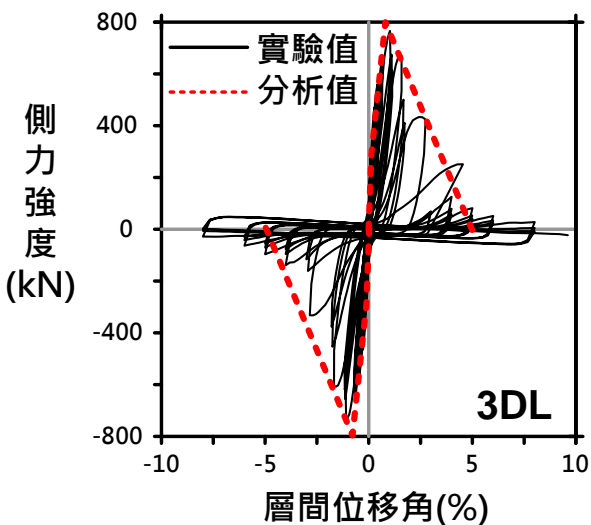
School Buildings Upgrading Projects

- Project span from 2009 to 2019
- Upgrading rate by construction up to 32%
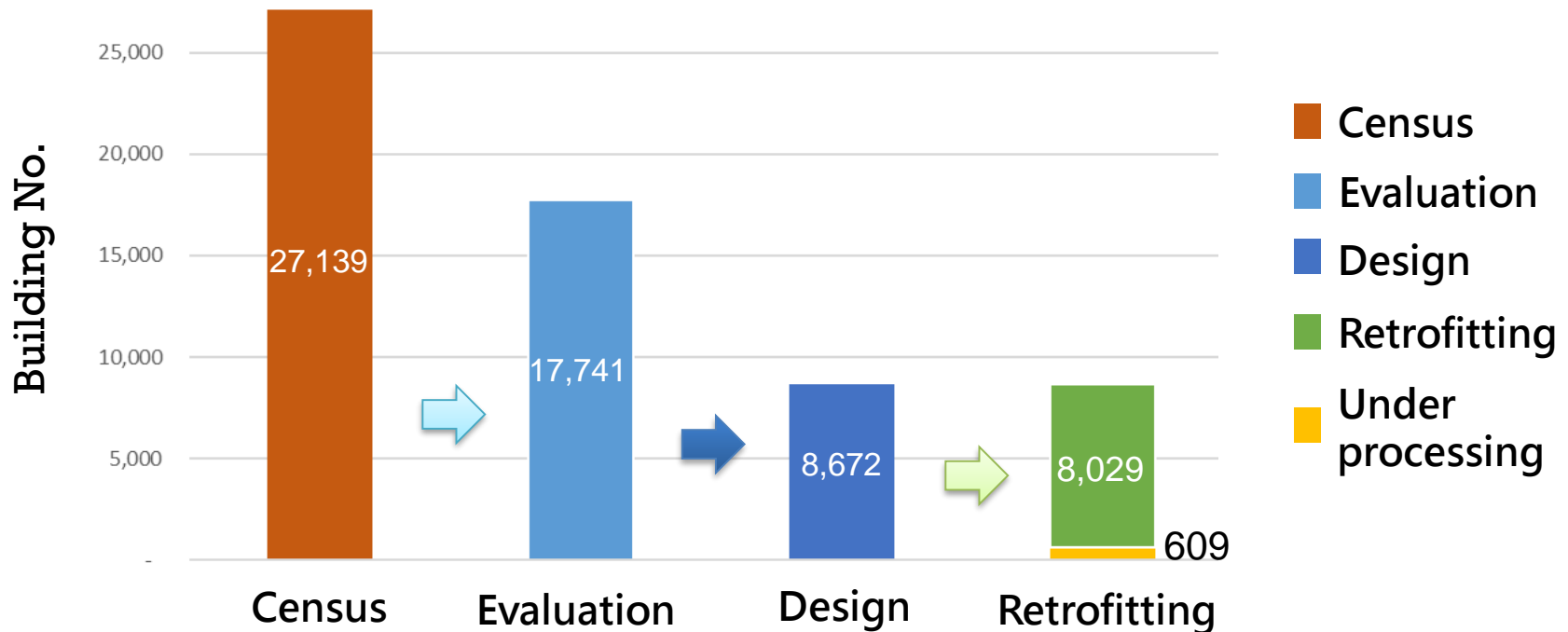
Data deadline：2019.6.30

Retrofitting Effectiveness

Kaohsiung Jia-Xian EQ
$M_L = 6.4$, March 4, 2010

Junior High S.
No retrofitting
30km from epicenter

Vocational S.
Retrofitted
31km from epicenter

Wing Wall

RC Wall
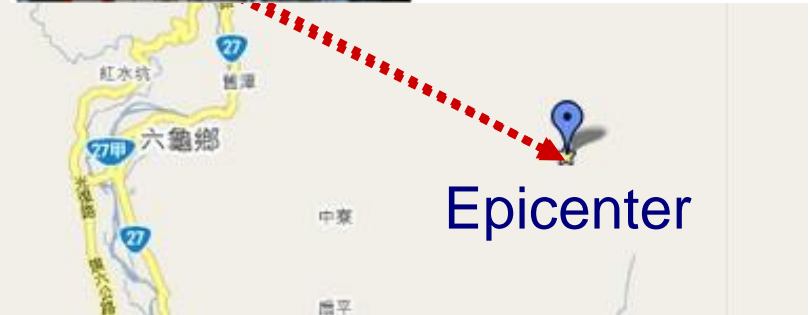
Epicenter

Concept of Structural Isolation and Energy Dissipation

Earthquake energy

Seismic capacity of building

Funnel

Faucet

Most of the water is drained by the funnel.

Some of the water is drained by the faucet.
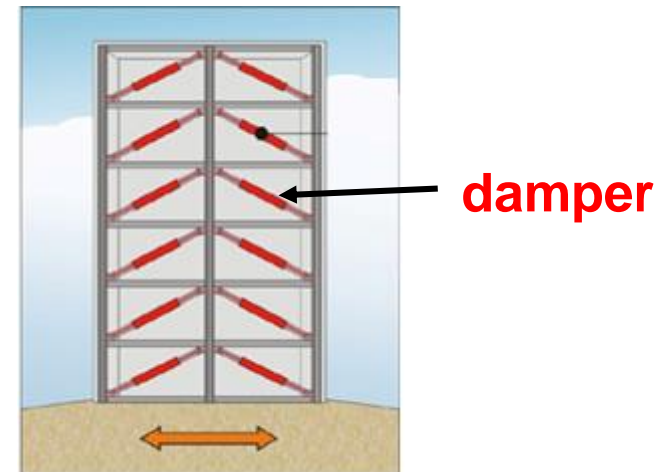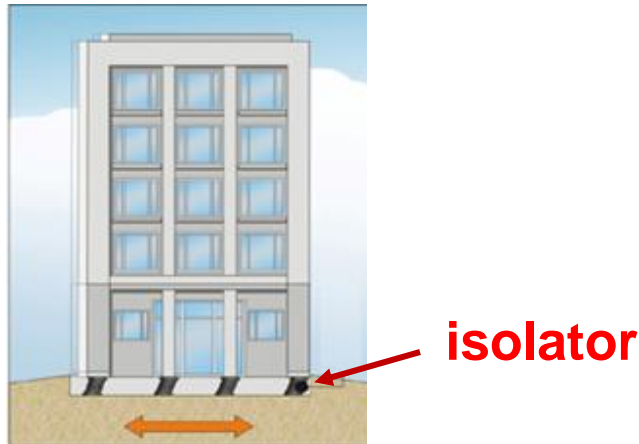
damper

isolator

Energy is isolated by isolators.

Energy is dissipated by dampers.

Buildings with Energy Dissipation Devices

Number of Buildings

50 with isolators
30 with dampers

150 with isolators
800 with dampers

1999 Chi Chi EQ   2009   2019   year
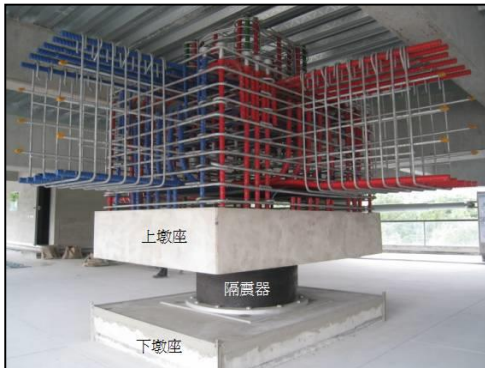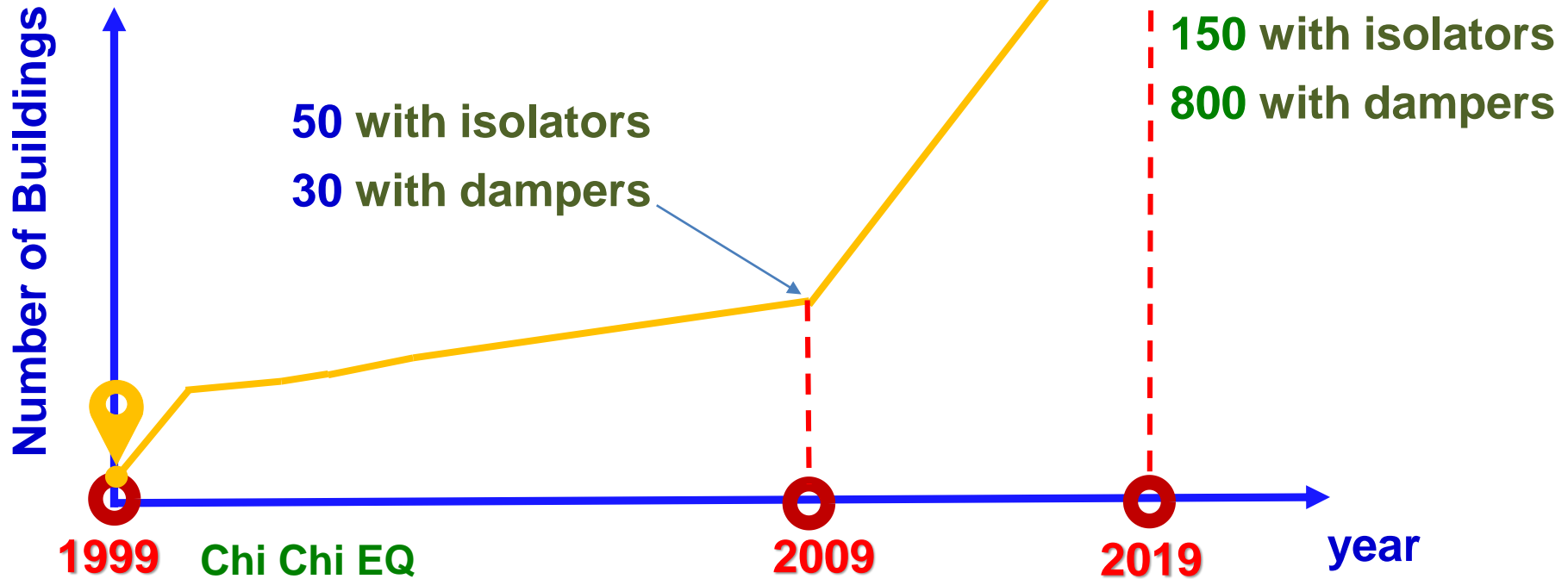
Mid-Story Isolation   Viscous damper   BRB

High-rise Building using Super High Strength Materials

NARLabs

Taiwan New RC Project

Japan highest **59** story RC building

Taiwan highest **27** story RC building

Conventional RC

New RC

$F_{y\ (MPa)}$

685

F_y 490

420

280

提升約 1.6倍

現行規範

New RC

提升約2.4倍

f'_c (MPa)

28 42 70 100

f'c
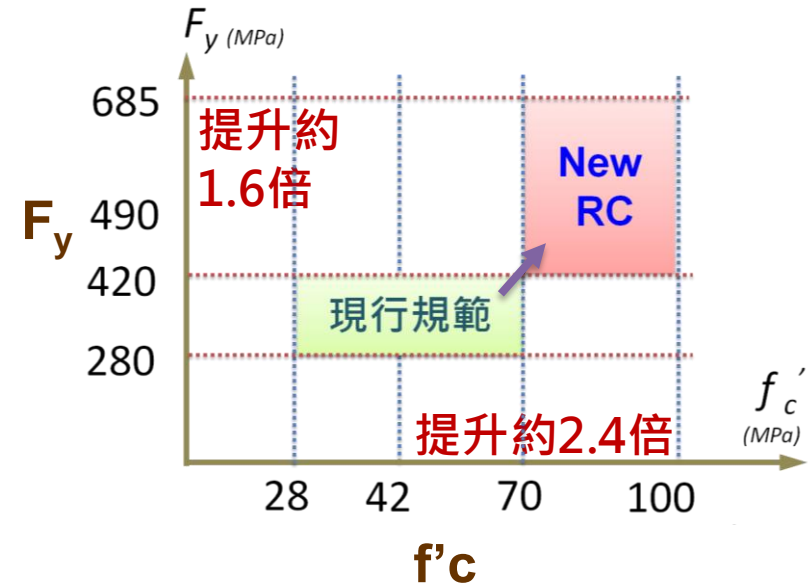
- **Material conservation**
- **Increase of urban green space**

Chichi Earthquake Disaster

Probability Seismic Hazard Analysis

Geotechnical Engineering

Buildings

Bridges

Lifeline Systems

Resilient and Sustainable Communities

Conclusions

Seismic Damage of Bridges

Beifeng Bridge

Shiwei Bridge
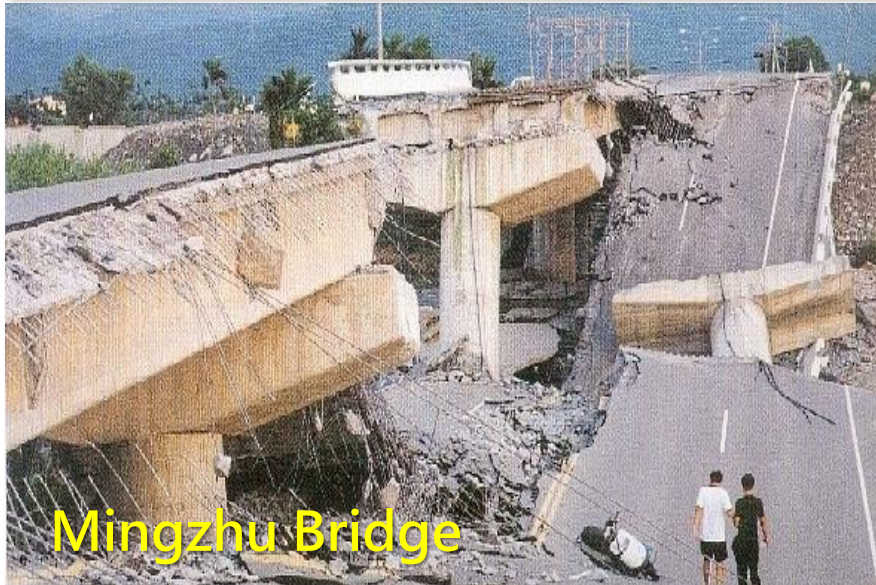
Mingzhu Bridge

Changgeng Bridge

Research on Seismic Performance of Bridges

RC piers retrofitted with steel jackets
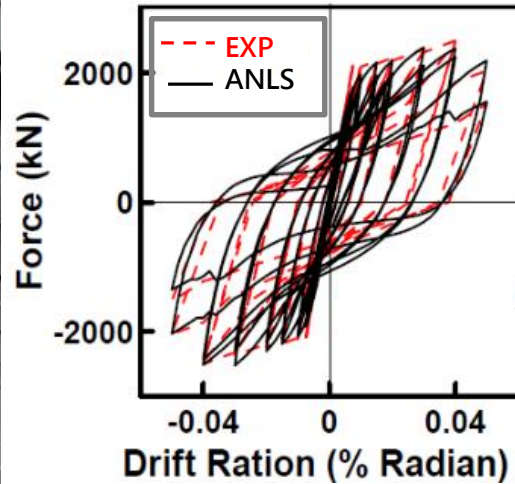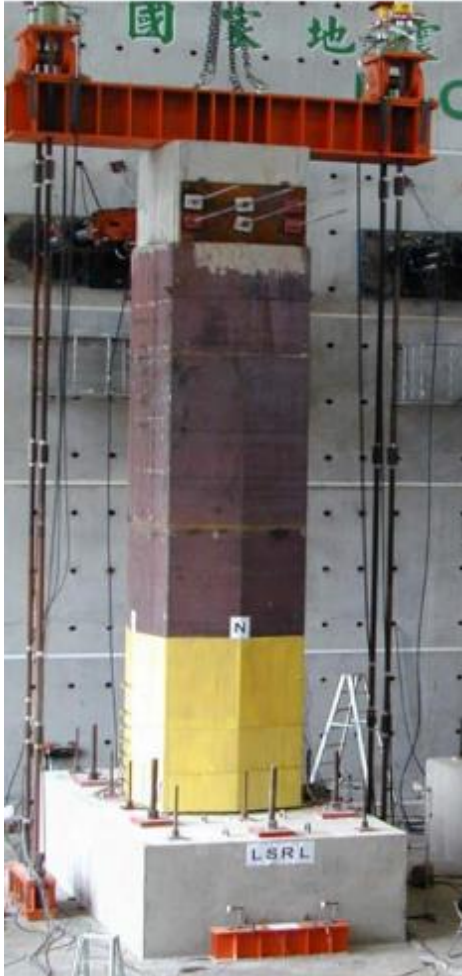
In-situ Seismic Test of Bridge
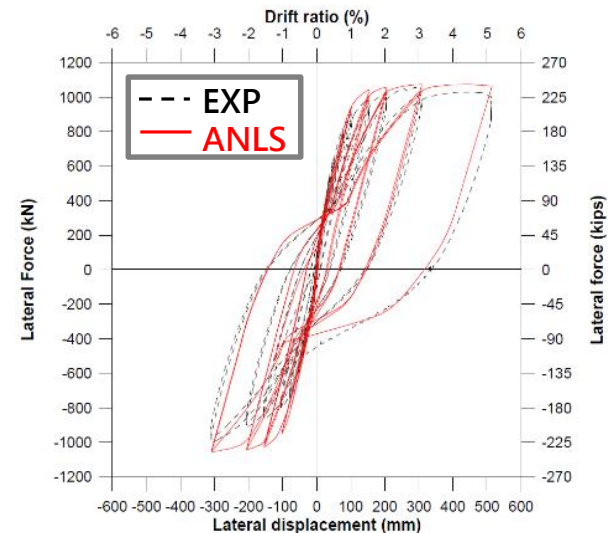
The Project of Taiwan Freeway Bridge Seismic Retrofit

Location	No. of bridges	Duration	Funds (NT$)
Freeway No. 1	353	2004/1-2009/12	10.0 bn
Freeway No. 3	542	2010/11-2020/8	12.54 bn
Freeway No. 4	1	2017/12-2020/8	1.1 bn
Freeway No. 8, Freeway No. 3	22	2018/12-2021/8	1.2 bn
Total	918	-	**24.84** bn

Pile   **Shear key**   **Concrete Jacketing**

Chichi Earthquake Disaster

Probability Seismic Hazard Analysis

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Conclusions

Damage in Lifeline Systems

Damages in water mains due to fault rupture.

Affected areas without water for more than one month.

Pipe damages in the gas system in Taichung.

Blackout and rotation of power outage for 19 days.

Risk Assessment of Water Pipelines

- Seismic screening of water mains in Taiwan (2,300 km)
- Prioritization of seismic retrofit scheme for these pipes

Fault crossings

Liquefaction potential
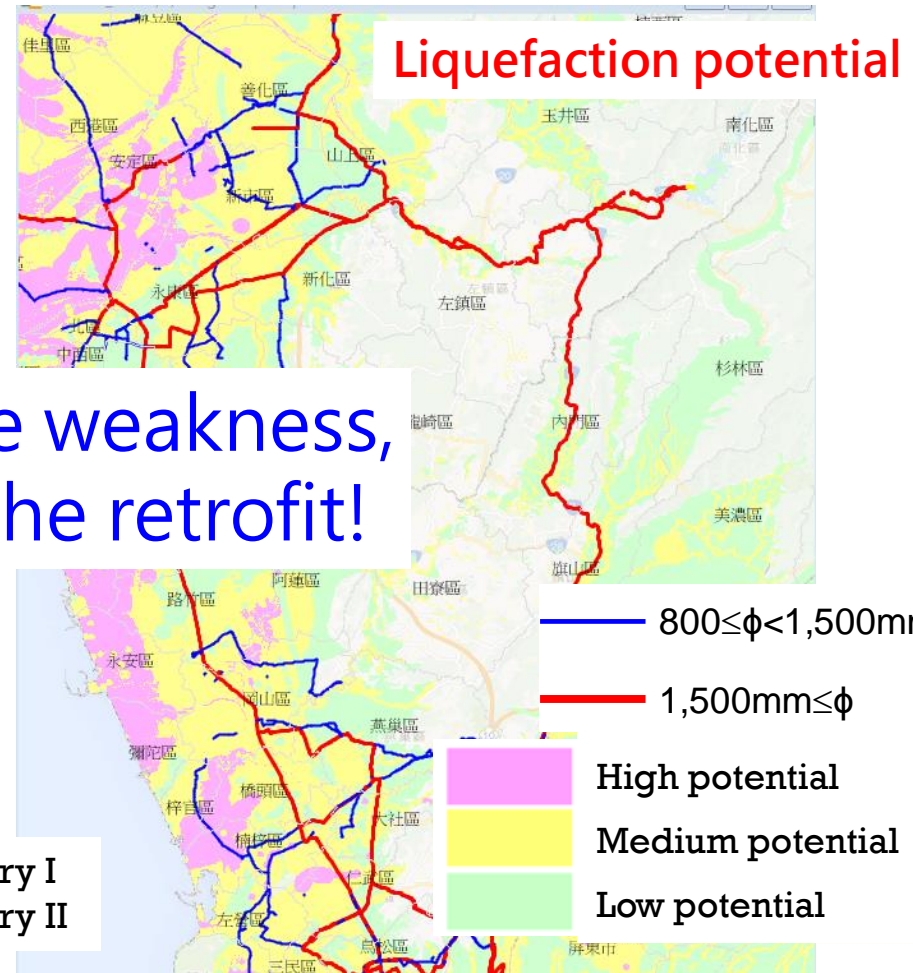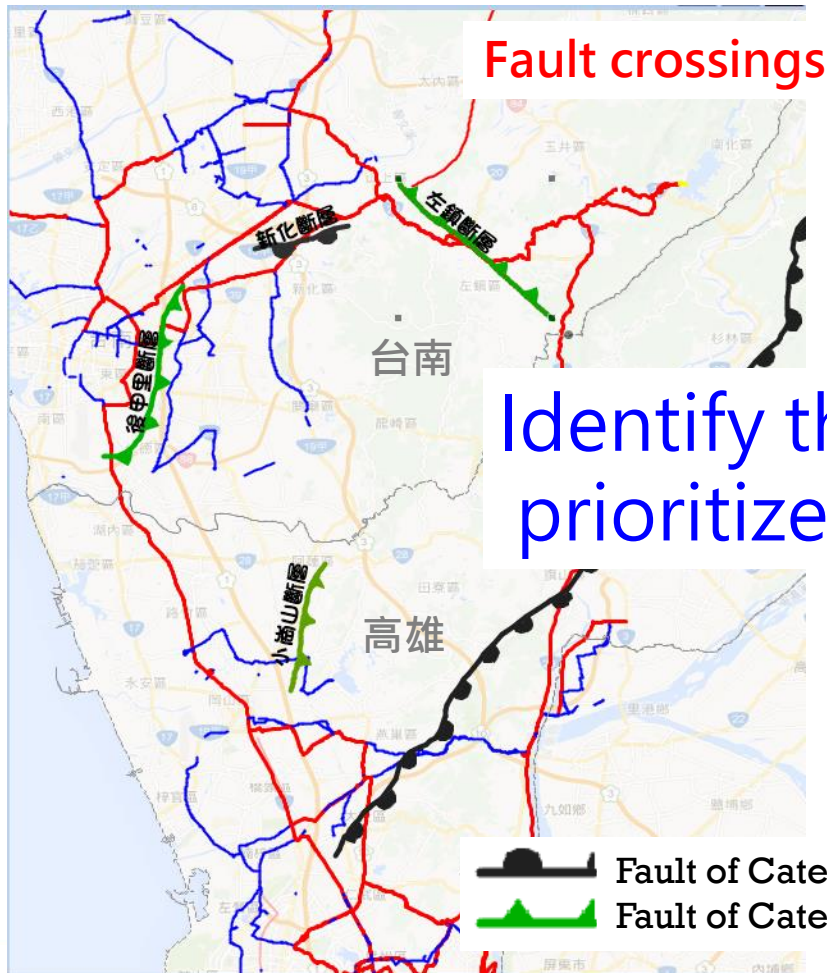
Identify the weakness, prioritize the retrofit!

800≤φ<1,500mm

1,500mm≤φ

High potential

Medium potential

Low potential

Fault of Category I

Fault of Category II

Chichi Earthquake Disaster

Probability Seismic Hazard Analysis

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Conclusions

Seismic Risk in Metropolitan Areas

Population concentration   **High building density**   **Complex infrastructures**

人口數(單位:人)
- 11,200 to 39,700
- 6,900 to 11,200
- 5,000 to 6,900
- 3,700 to 5,000
- 2,600 to 3,700
- 1,700 to 2,600
- 1,000 to 1,700
- 0 to 1,000

總樓地板面積(單位:平方公尺)
- 17,700,000 to 32,700,000
- 11,300,000 to 17,700,000
- 6,800,000 to 11,300,000
- 3,800,000 to 6,800,000
- 2,100,000 to 3,800,000
- 900,000 to 2,100,000
- 400,000 to 900,000
- 0 to 400,000

- $\phi \geq 1,500$ mm
- $1,500 \leq \phi \leq 800$ mm
- $\phi < 800$ mm
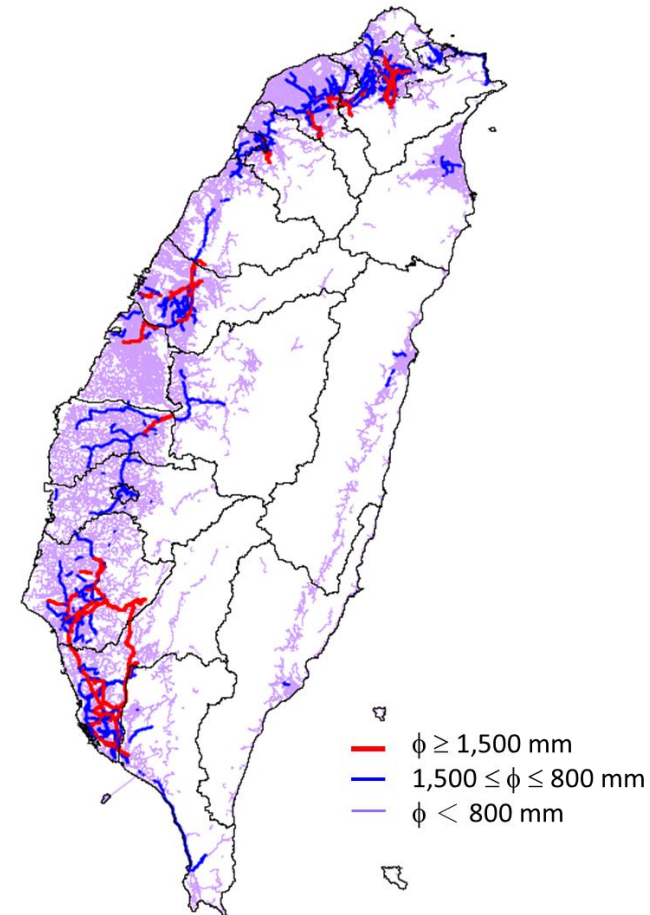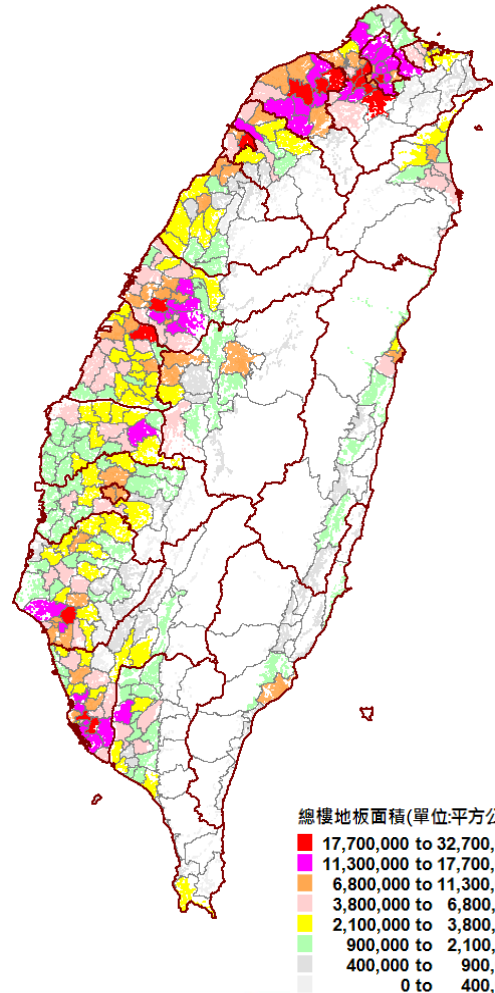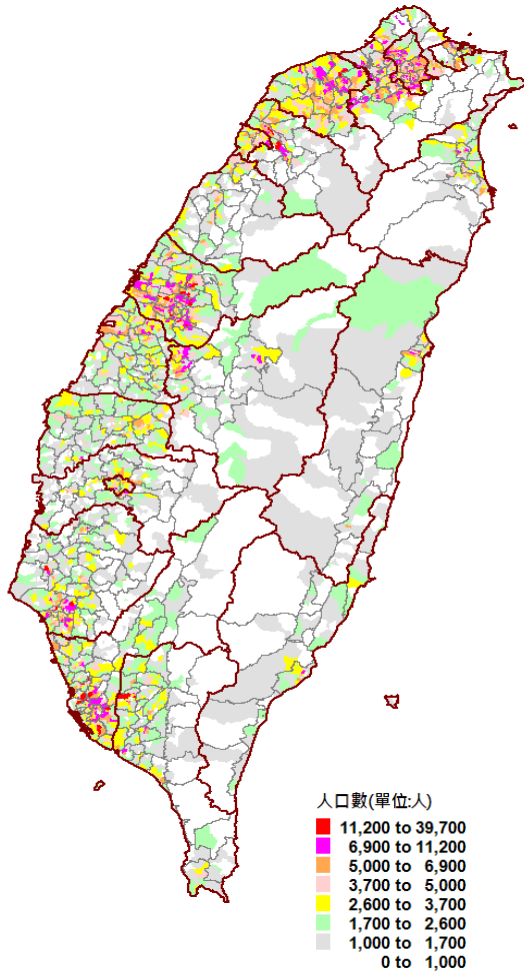
High Risk!!

Catastrophe Simulations in Mega-City

Scenario Earthquake

➢ **Shanchiao Fault rupture**

➢ **Epicenter in Sanchong, New Taipei**

➢ **Magnitude 6.6, Focal Depth 8 km**

➢ **Rupture length 22 km, Dip angle 60**

Distr. of Casualties (seriously injured + death)

- **Scenario Source Parameters**

- **Earthquake Loss Estimation**
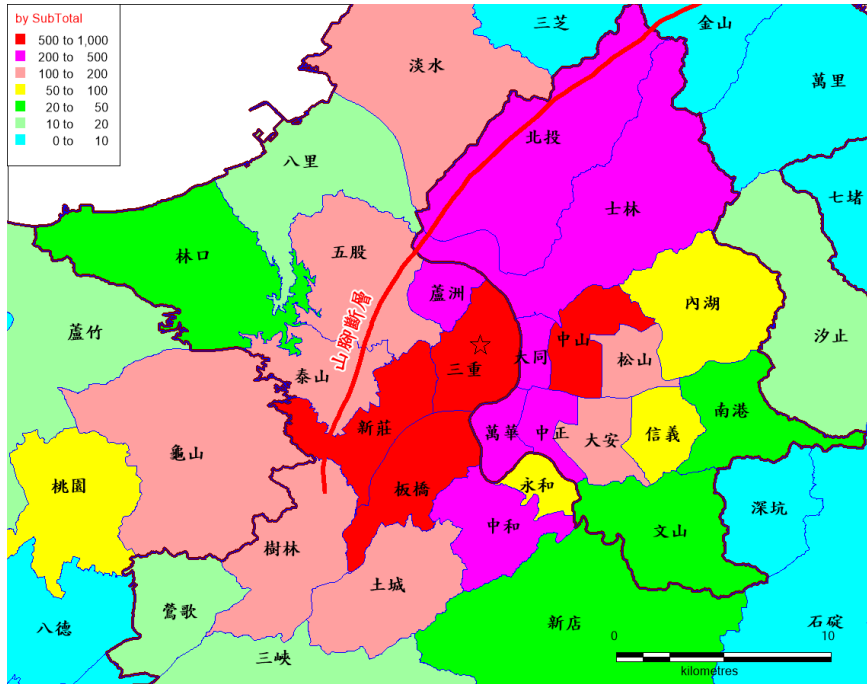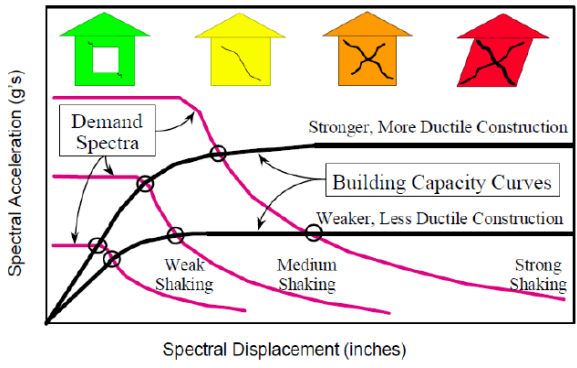 - Damages of general building stocks
  - Human casualties
  - Fires following earthquake (firefighting demands)
  - Resource needs of rescue, medical care, transportation, shelters, livelihood supplies, etc.
  - Damages of transportation systems (highway and railway systems, bridges, and network analysis)
  - Damages of potable water systems (restoration time and cost, number of households without water, etc.)
  - …

- **Countermeasures**

3D Seismic Simulation

0206 Hualien earthquake

At February 6th 2018, an earthquake of magnitude 6.4 on the moment magnitude scale hit Taiwan

Demand Spectra

Building Capacity Curves

Stronger, More Ductile Construction

Weaker, Less Ductile Construction

Spectral Acceleration (g's)

Weak Shaking | Medium Shaking | Strong Shaking

Spectral Displacement (inches)
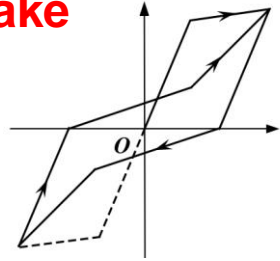
Damage State
0 No Damage
1 Minor Damage
2 Moderate Damage
3 Serious Damage
4 Collapse

Retrofitting Policy for Residential Building

Retrofit soft and weak first story

Vulnerable soft and weak first story

Earthquake Early Warning System

Structural Safety Monitoring System

Health examination   **Medical examination**   **Medical report**
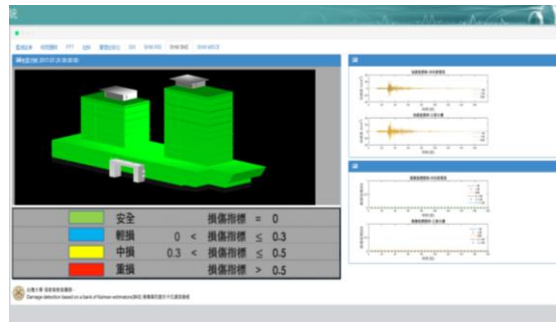
Human

Structural response data (Event / full time)   **Seismic event data**   **Structural safety report**

Building

Monitoring the structural responses, automatically output the structural safety report quickly after shake, speed up the recovery.

Chichi Earthquake Disaster

Probability Seismic Hazard Analysis

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Conclusions

- **Disaster reduction of earthquake needs constant efforts.**

- **Indonesia and Taiwan share the same earthquake threat.**

- **Collaboration between Indonesia and Taiwan is highly expected.**

Thanks for Your Kind Attention

Commitment · Passion · Innovation

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