Current State of Infrastructure Maintenance and Monitoring in Taiwan

(ACECC TC-28, CECAR9, 22nd of Sep 2022)

Prof. Tzu-Kang Lin, Chair

Department of Civil Enginering

National Yang Ming Chiao Tung University

國立陽明交通大學
NATIONAL YANG MING CHIAO TUNG UNIVERSITY

For a Better Quality of Life

http://www.acecc-world.org/

Outline

1. The TSMIP System
2. Case 1: Dexin residential building (RC)
3. Case 2: CTSPB Building and IC Building (Steel)
4. Summary and Conclusion

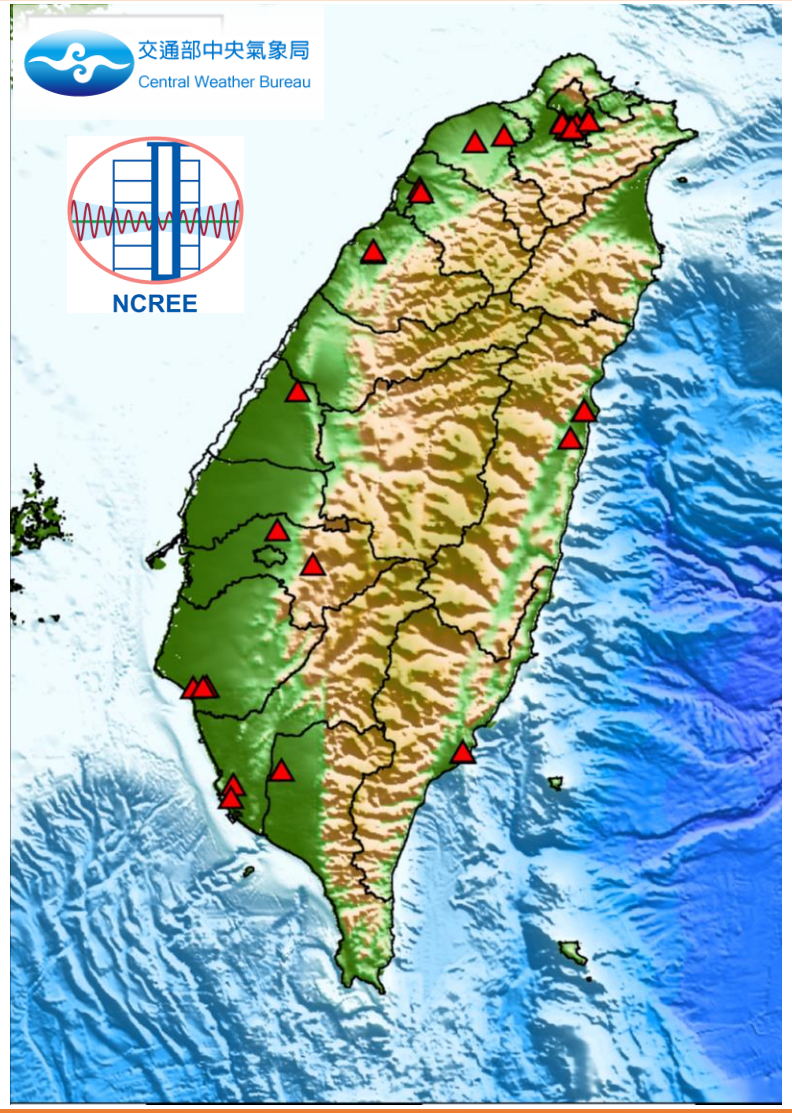
1 The TSMIP System

The TSMIP System

- More than 40 infrastructures (building and bridge) are monitored by the Central Weather Bureau supported by the Taiwan government
- Basic information: structure introduction、sensor layout and description
- Monitoring database: seismic event(before^{2min}、earthquake^{2min}、after^{2min})、whole duration (local/30days)

Taiwan Seismic Building Array

國立陽明交通大學
NATIONAL YANG MING CHIAO TUNG UNIVERSITY



Monitoring layout example

Site information

新光三越站前大樓

結構物強震監測系統裝設計畫

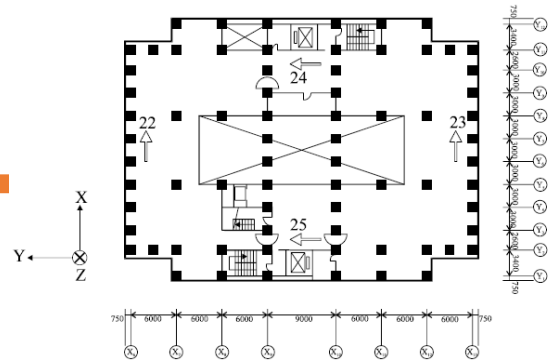
二、強震儀位置與頻道數摘要

強震儀裝設位置	頻道數
地下室七樓樓地板上	4
地下室一樓樓地板下	6
三樓樓地板下	4
十八樓樓地板下	3
三十二樓樓地板下	4
四十七樓樓地板下	4
五十樓樓地板下	4
頻道總數	29

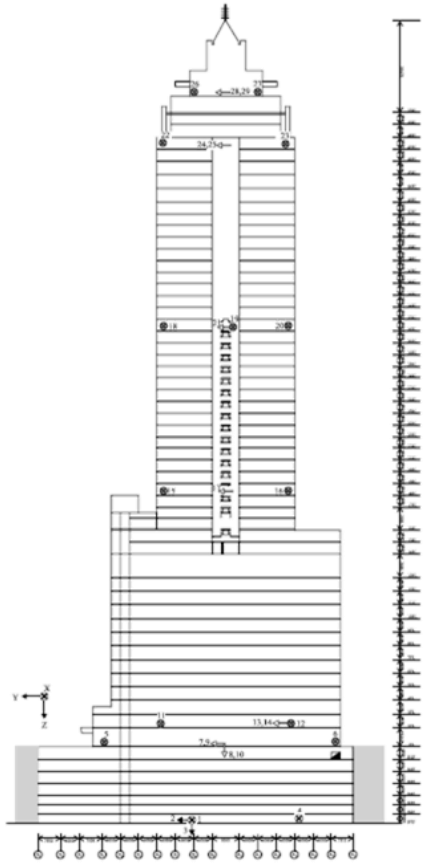
三、強震儀安裝位置座標明細表（單位:公分）

編號	軸向	位置描述	參考點	與參考點相對座標		參考點與點A1相對座標		
				X	Y	X	Y	Z
CH01	X	B7F中間地坪上	X8,Y5	440	5	16350	-5100	3000
CH02	Y	B7F中間地坪上	X8,Y5	432	19	16350	-5100	3000
CH03	Z	B7F中間地坪上	X8,Y5	422	5	16350	-5100	3000
CH04	X	B7F中間地坪上	X14,Y5	34	35	16350	-90000	3000
CH05	X	B2F北側樓地板下	X3,Y5	-62	-5	16350	-5100	6240
CH06	X	B2F南側樓地板下	X15,Y5	41	97	16350	-96000	6240
CH07	Y	B2F東側樓地板下	X10Y11	-34	25	33950	-66000	6240
CH08	Z	B2F東側樓地板下	X10,Y8	-31	39	33950	-6600	6240
CH09	Y	B2F西側樓地板下	X10,Y2	112	-173	7750	-6600	6240
CH10	Z	B2F西側樓地板下	X10,Y2	110	-159	7750	-6600	6240
CH11	X	3F東北側樓地板下	X6,Y2	56	-39	7750	-3900	4480
CH12	X	3F西南側樓地板下	X12,Y2	45	-320	7750	-7800	4480
CH13	Y	3F西南側樓地板下	X12,Y2	58	-323	7750	-7800	4480
CH14	Y	3F東南側樓地板下	X12Y11	-51	-311	7750	-6600	4480
CH15	X	18F東北側樓地板下	X7,Y11	-14	14	33950	-4500	3840
CH16	X	18F東南側樓地板下	X13Y11	-16	37	33950	-84000	3840
CH17	Y	18F西側樓地板下	X9,Y2	96	-225	7750	-5700	3840
CH18	X	32F北側樓地板下	X6,Y6	98	-62	15750	-3900	3840
CH19	X	32F中間樓地板下	X10,Y7	-87	287	18750	-5700	3840
CH20	X	32F南側樓地板下	X13,Y6	78	65	15750	-7500	3840
CH21	Y	32F西側樓地板下	X10,Y2	87	376	4150	-5700	3840
CH22	X	47F北側樓地板下	X6,Y6	83	-151	15750	-3900	3840
CH23	X	47F南側樓地板下	X13,Y6	109	148	15750	-7500	3840
CH24	Y	47F東側樓地板下	X9,Y10	104	-127	27750	-5700	3840
CH25	Y	47F西側樓地板下	X9,Y3	-110	-63	6750	-5700	3840
CH26	X	50F北側樓地板上	X8,Y7	-37	222	18750	-5100	3840
CH27	X	50F南側樓地板上	X11,Y7	-29	-222	18750	-66000	3840
CH28	Y	50F東側樓地板上	X10,Y11	210	36	24750	-43500	3840
CH29	Y	50F西側樓地板上	X10,Y3	-220	-37	6750	-43500	3840

備註：1. 主機位置在地下室一樓行控中心。



四十七樓建築平面圖（長度單位：公分　原始比例尺：1/400）



南北向建築立面圖（長度單位:公分　原始比例尺：1/400）

2 Case 1: Dexin residential building (RC)

Dexin residential building

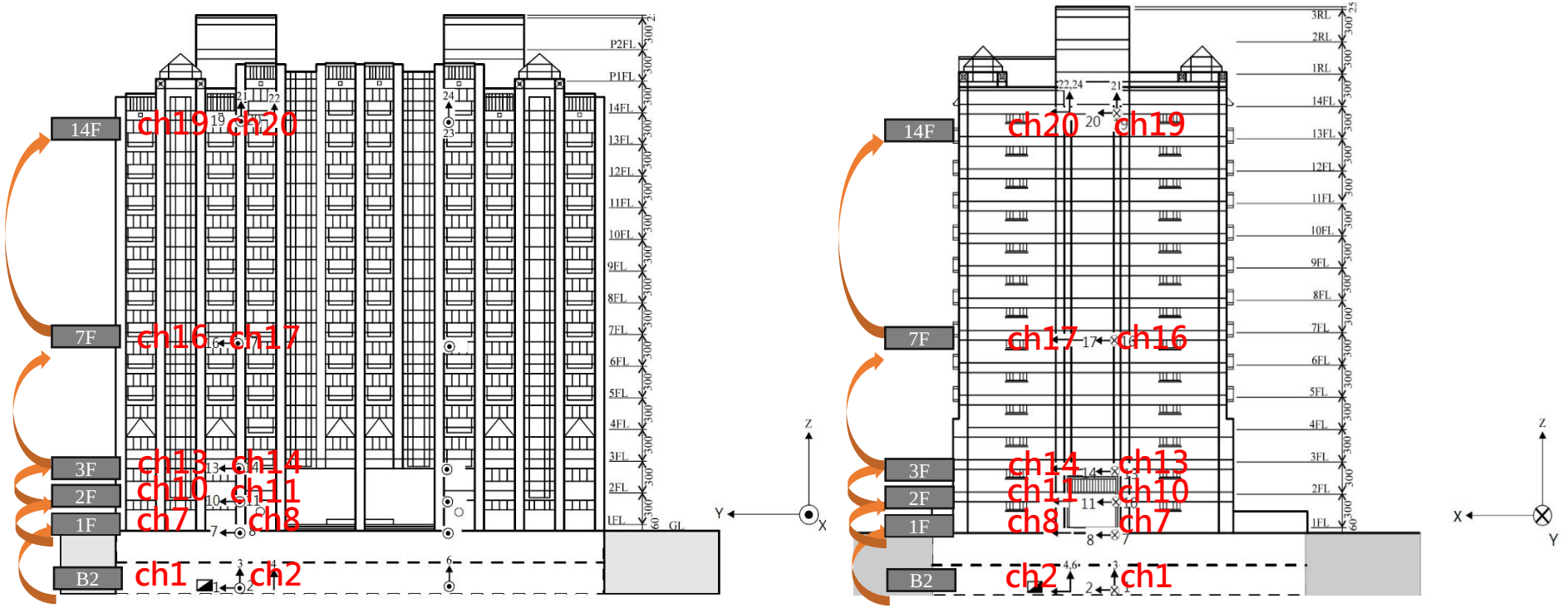
國立陽明交通大學
NATIONAL YANG MING CHIAO TUNG UNIVERSITY

- Dexin residential building located in Hsinchu City, Taiwan.
- Constructed in October 1991, a reinforced concrete structure with 14 aboveground floors and 2 underground floors.
- structure was designed in accordance with the ACI-318-77 and UBC.

Sensor Location (*cont'd*)

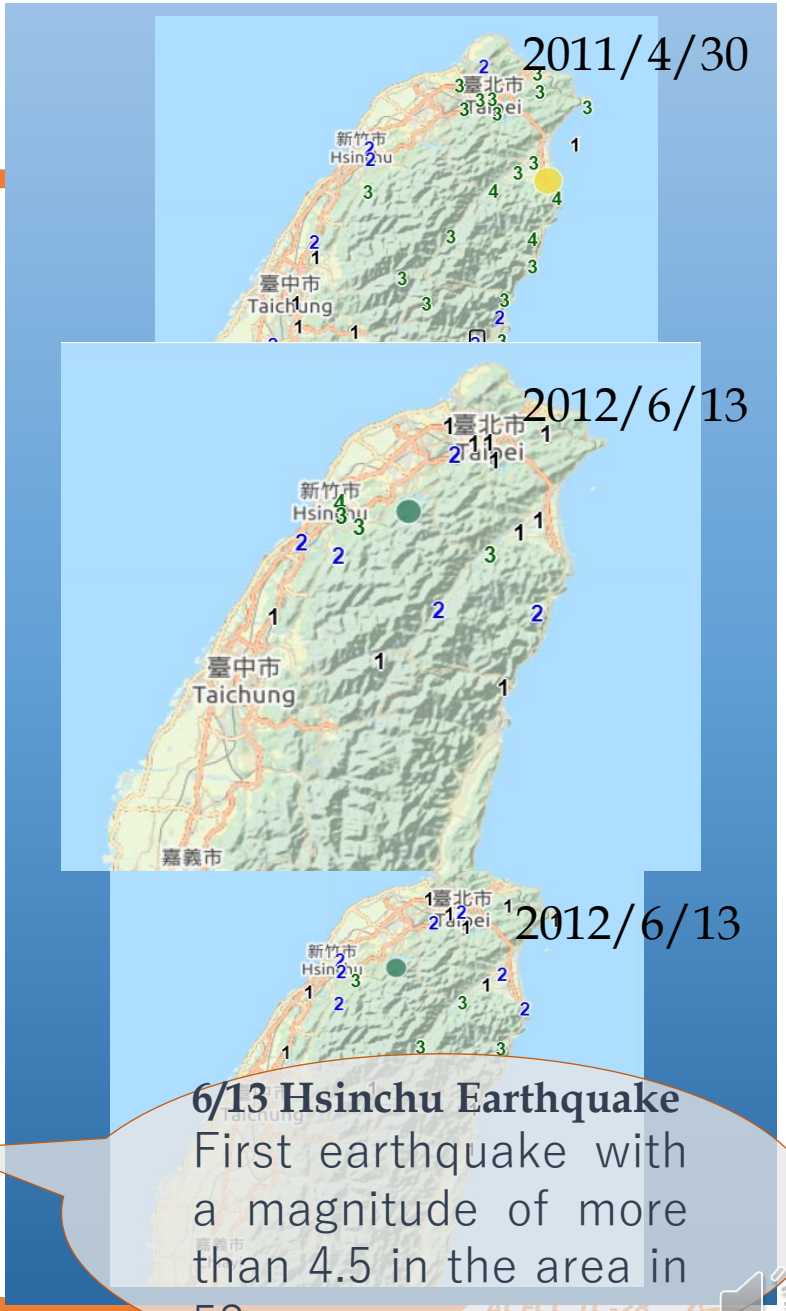
國立陽明交通大學
NATIONAL YANG MING CHIAO TUNG UNIVERSITY

Floor	B2	1F	2F	3F	7F	14F
X-axis Senor channel	2	8	11	14	17	20
Y-axis Senor channel	1	7	10	13	16	19



Long-term Minor Earthquakes Event

No.	Long-term CMSCE events			
	Data	PGA (gal)		Seismic intensity
		X-axis	Y-axis	
1	1994/11/26	3.91	6.35	2
2	1995/7/14	4.23	4.18	2
3	1995/12/18	3.77	5.99	2
4	1996/3/5	3.62	8	2
5	1996/11/26	6.48	8.61	2
6	1998/7/17	7.87	7.25	2
7	2001/1/11	6.52	7.12	2
8	2002/2/12	10.9	7.78	2
9	2003/8/3	5.62	7.02	2
10	2004/5/1	6.69	4.92	2
11	2004/11/11	12.19	9.4	3
12	2005/4/30	3.18	3.08	2
13	2005/7/26	4.69	8.3	2
14	2007/9/6	13.3	13.87	3
15	2008/9/9	4.57	8.69	2
16	2010/3/4	6.76	5.36	2
17	2011/4/30	5.7	8	2
18	2012/6/13 1st	25.2	36.84	4
19	2012/6/13 2nd	5.6	7.82	2
20	2013/3/7	12.69	8.86	3
21	2014/5/21	7.91	7.06	2

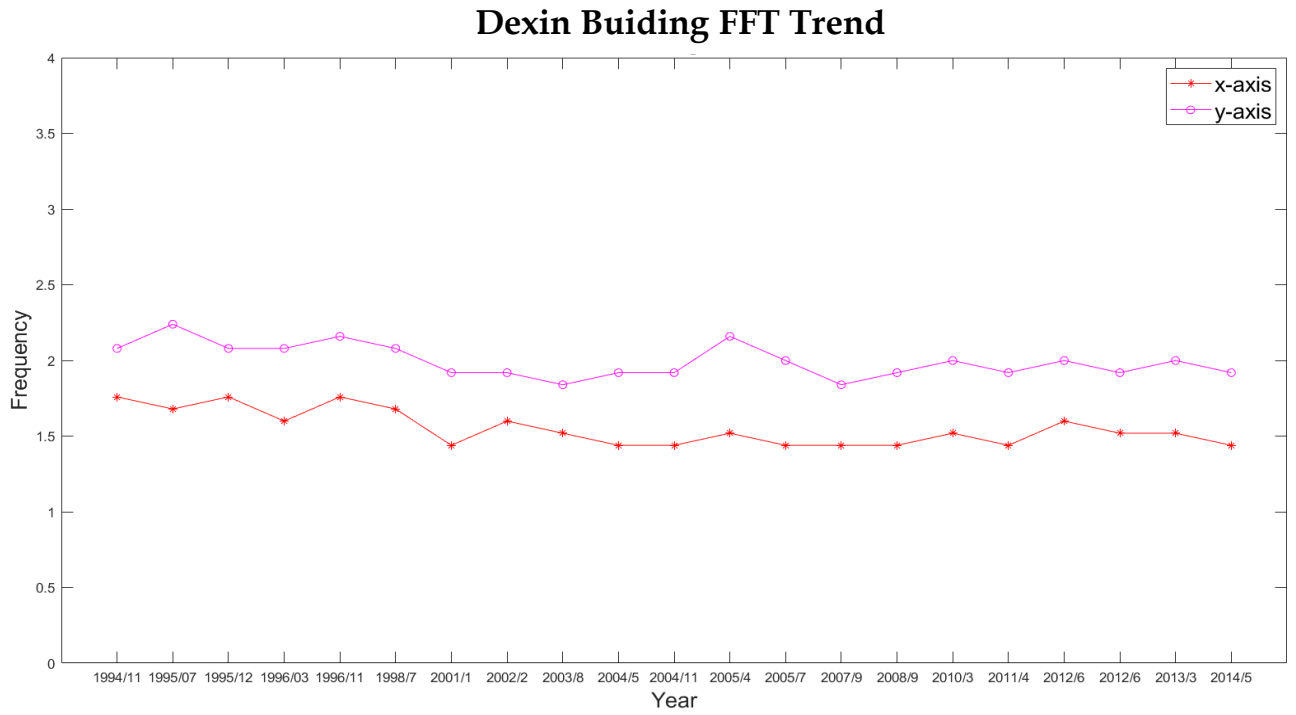


6/13 Hsinchu Earthquake
First earthquake with a magnitude of more than 4.5 in the area in 58 years

Long-term FFT Trend Chart

國立陽明交通大學
NATIONAL YANG MING CHIAO TUNG UNIVERSITY

Top Floor FFT Results		
Events data	Frequency(Hz)	
	X-axis	Y-axis
1994/11/26	1.759	2.079
1995/07/14	1.679	2.239
1995/12/18	1.759	2.079
1996/03/05	1.599	2.079
1996/11/26	1.759	2.159
1998/07/17	1.679	2.079
2001/01/11	1.439	1.919
2002/02/12	1.599	1.919
2003/08/03	1.519	1.839
2004/05/01	1.439	1.919
2004/11/11	1.439	1.919
2005/04/30	1.519	2.159
2005/07/26	1.439	1.999
2007/09/06	1.439	1.839
2008/09/09	1.439	1.919
2010/03/04	1.519	1.999
2011/04/30	1.439	1.919
2012/06/13	1.599	1.999
2012/06/13	1.519	1.919
2013/03/07	1.519	1.999
2014/05/21	1.439	1.919



$$2\pi f = \sqrt{\frac{k}{m}}$$

1994-2014 Structure Stiffness Reduction
X-axis:33%
Y-axis:15%

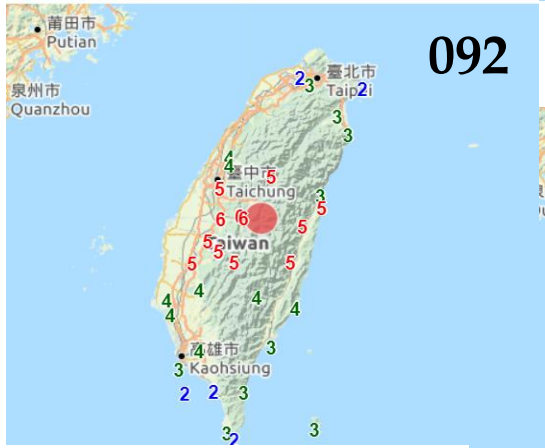
921 Major Earthquakes

- The 921 earthquake occurred on September 21,1999 in Jiji township, Nantou City.
- The earthquake intensity was recorded to be 7.3 on the Richter scale. The epicenter of the earthquake was at 23.85°N (latitude) and 120.82°E (longitude), with a depth of focus of approximately 8 km.
- According to the records of the Central Weather Bureau, 44 significant earthquakes occurred on September 21 and 18 occurred on September 22.

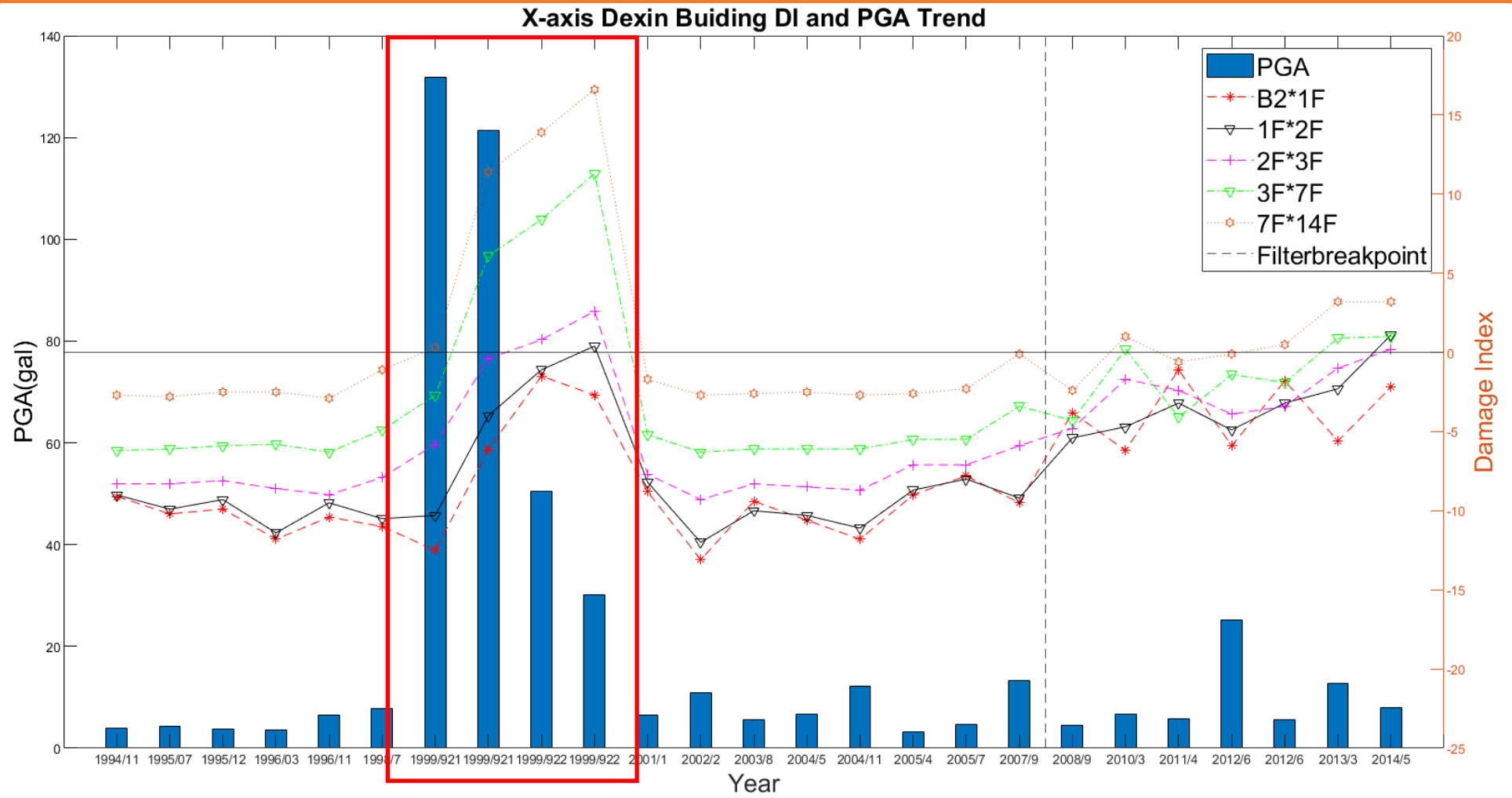
921 Major Earthquakes Dexin Event

1999/9/21 Dexin Earthquake Events				
CWB no.	Time	PGA(gal)		Seismic intensity
		X-axis	Y-axis	
043	**01:47**	**131.77**	**94.14**	**5**
	01:49	3.18	5.05	2
	01:51	9.46	10.39	3
044	01:57	17.95	18.4	3
	01:59	4.22	5.79	2
047	02:03	11.53	15.15	3
	02:05	9.07	12.51	3
	02:11	77.4	60.86	4
048	**02:16**	**121.49**	**65.81**	**5**

1999/9/22 Dexin Earthquake Events				
CWB no.	Time	PGA(gal)		Seismic intensity
		X-axis	Y-axis	
092	**08:14**	**50.56**	**41.45**	**4**
094	**08:49**	**30.17**	**32.42**	**4**

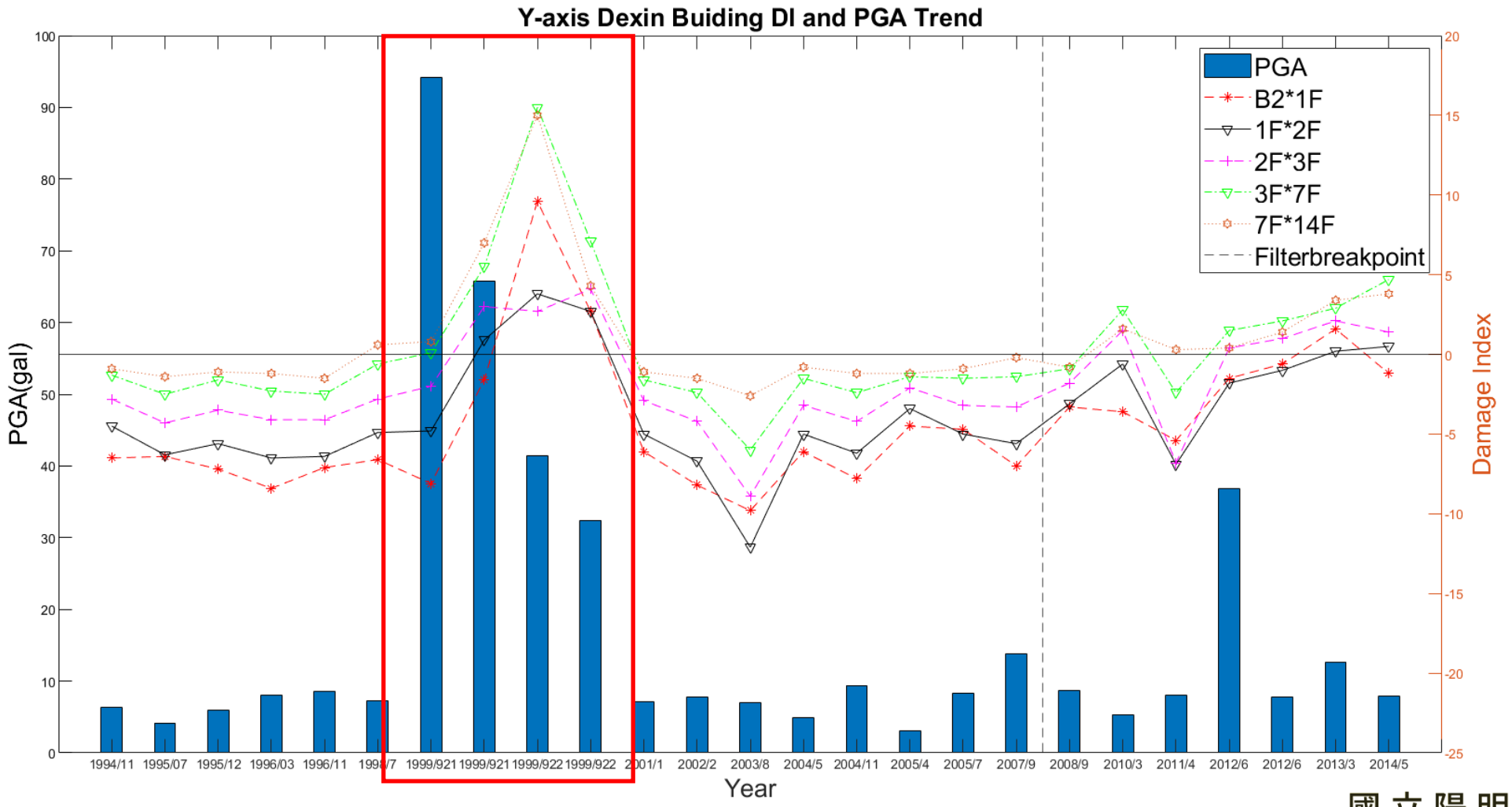


X-axis Damage Index and PGA Chart



major earthquake in 921 and 922

Y-axis Damage Index and PGA Chart



major earthquake in 921 and 922

Relationship between Major Earthquake and DI

The trend of abnormal increase DI coincides with the protrusion of the PGA histogram in continuous violent earthquakes. Based on the analysis results, the inference is as follows:

- In the short time, intensive and frequent earthquakes occur in the same monitoring building, which will increase the signal complexity and then increase the entropy value.

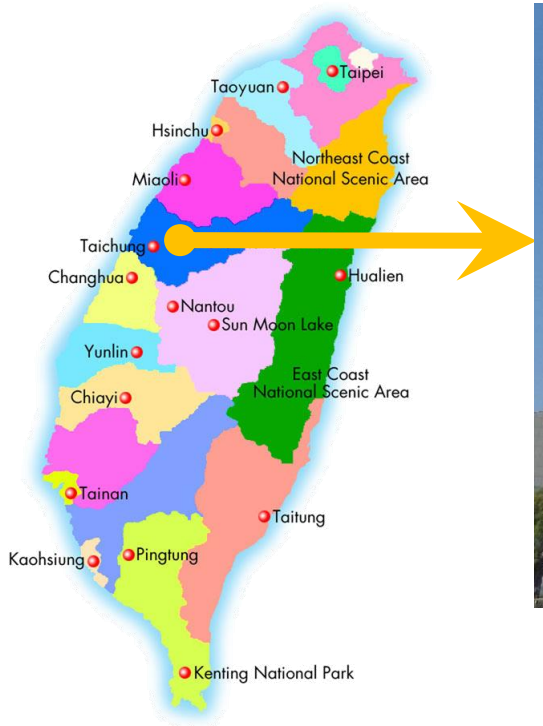
CWB no.	043			044		047		092	094
Time	01:47	01:49	01:51	01:57	01:59	02:03	02:05	08:14	08:49
Seismic intensity	5	2	3	3	2	3	3	4	4

- When experiencing a very strong earthquake to make the structure unstable, the DI value will rise sharply.

3 Case 2: CTSPB Building and IC Building (Steel)

Curtesy: Prof. Wen-Hwa Wu
Department of Civil and Construction Engineering,
YunTech

CTSPB Building and IC Building



Industrial & Commercial (IC) Building

41 m in height (9F)

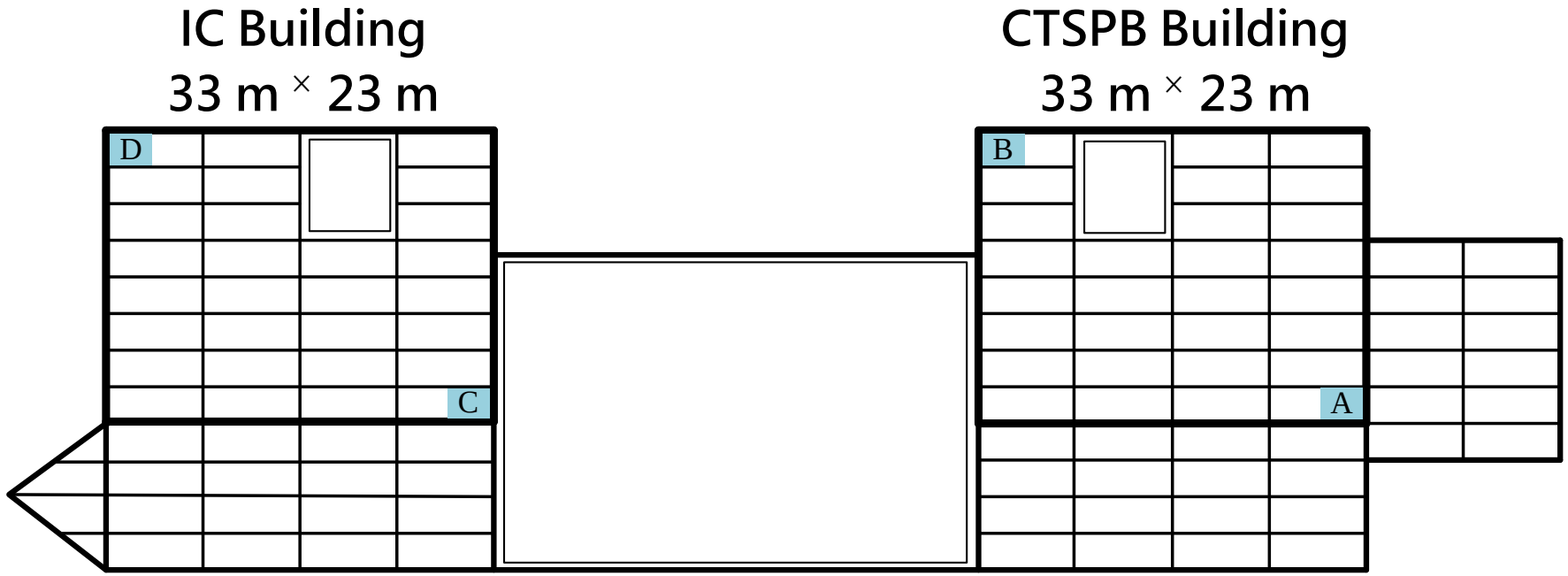
Central Taiwan Science Park Bureau (CTSPB) Building

58 m in height (13F)

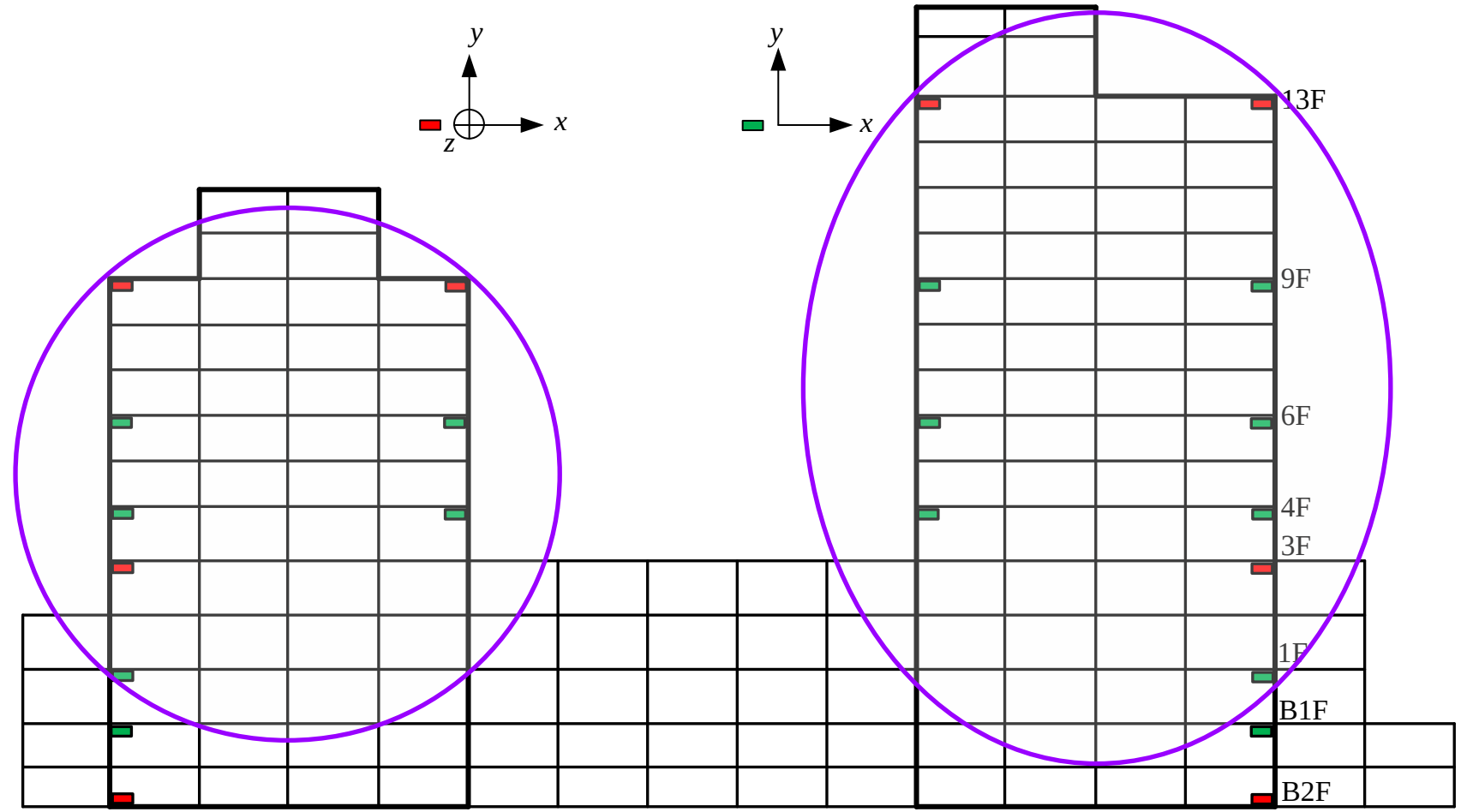
2 underground stories and the lowest 3 overground stories are connected by a common RC structure

- **Both office buildings locate in Central Taiwan Science Park at Taichung and are steel framed structures.**

Sensor Deployment: Top View



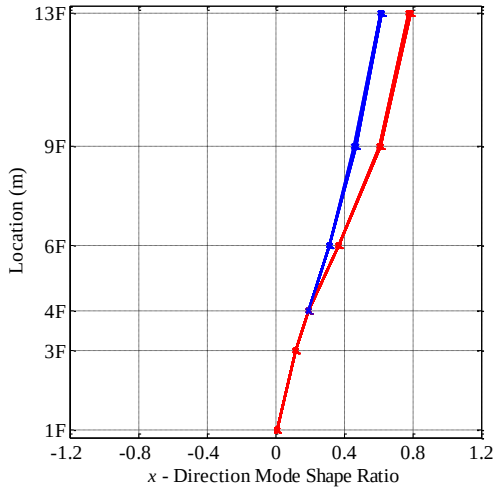
Sensor Deployment: Front View

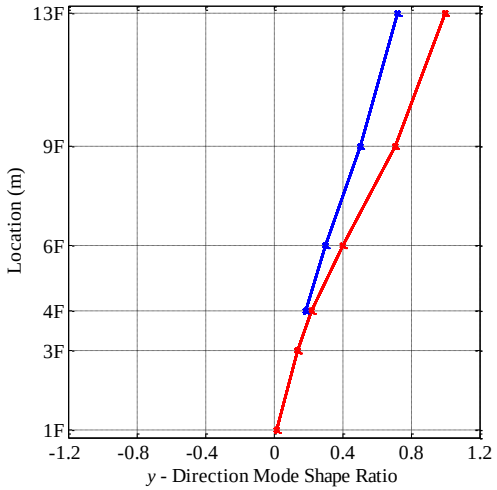


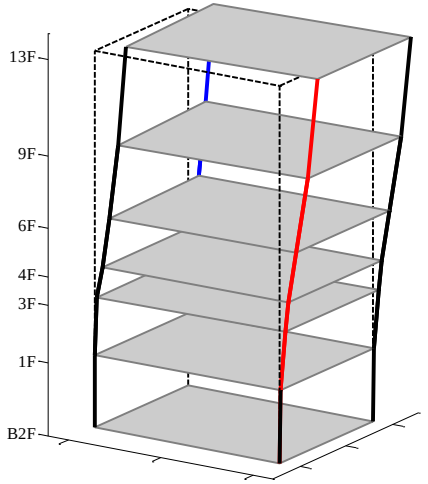
a total of 52 accelerometers in the monitoring system

Identified Modes of CTSPB Building (1)

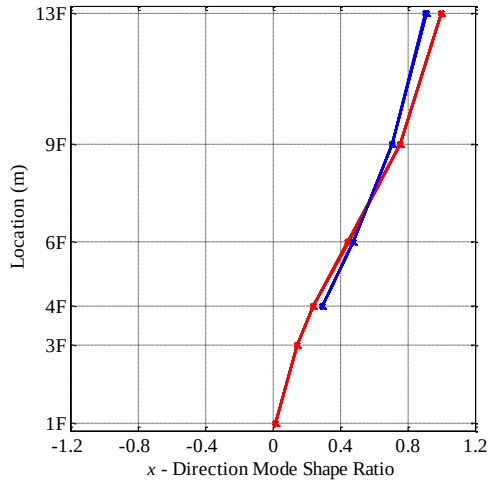
Mode B1-1:
0.733 Hz; 1.41%

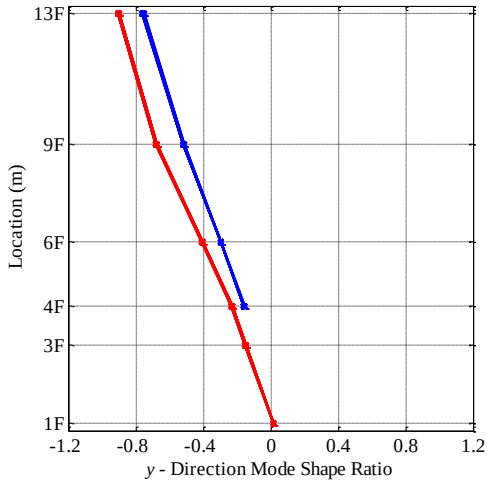


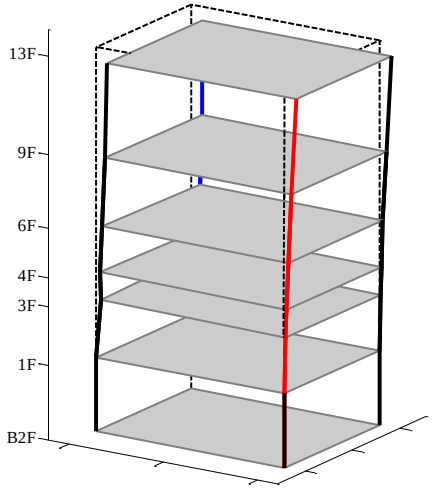




Mode B1-2:
0.734 Hz; 1.67%

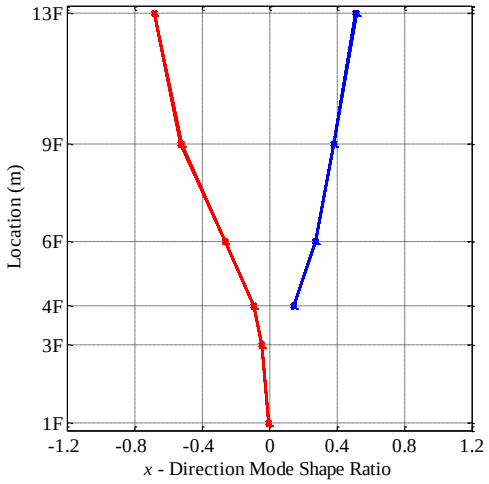


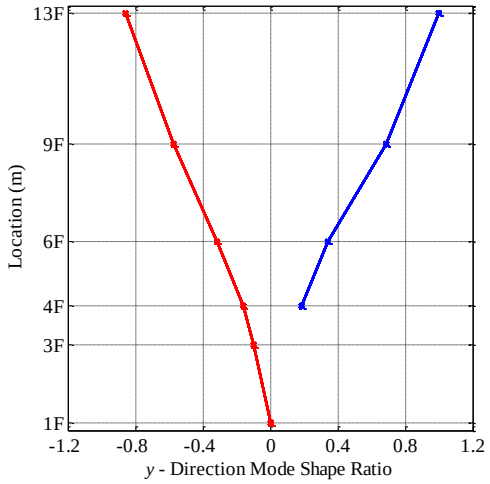


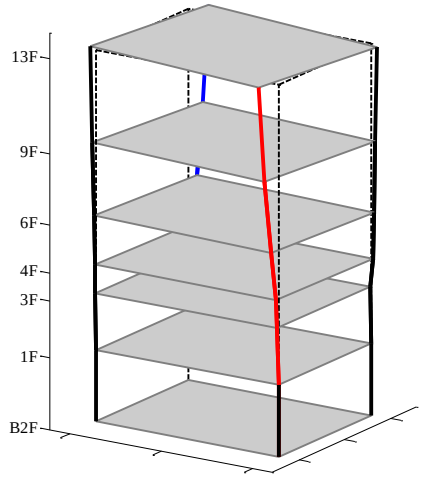


Identified Modes of CTSPB Building (2)

Mode T1:
0.948 Hz; 1.25%

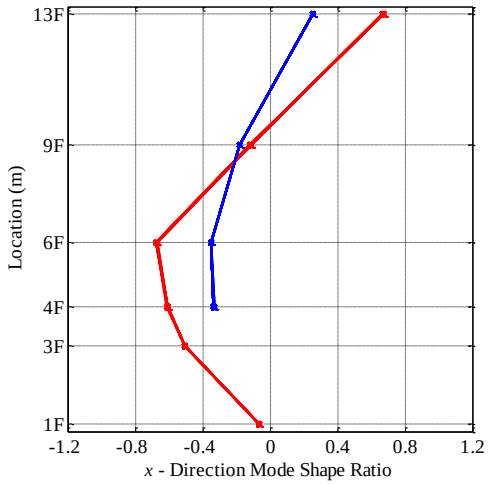


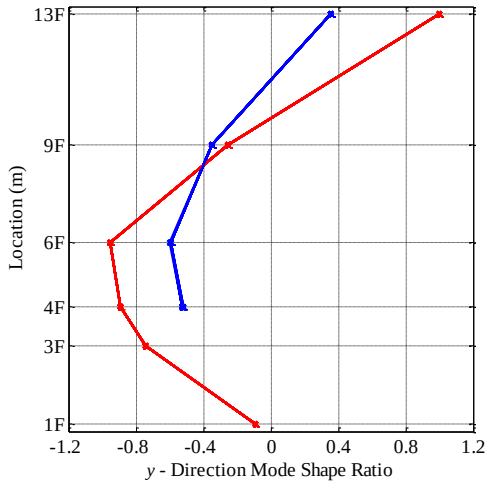


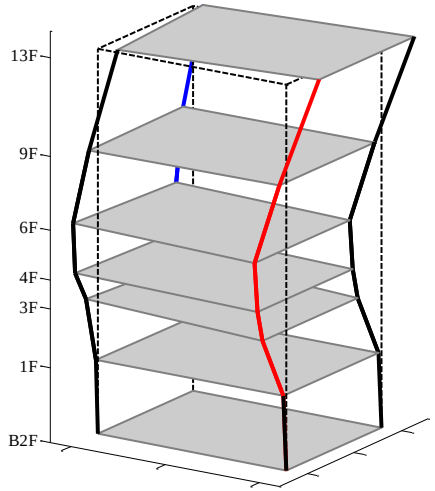


Identified Modes of CTSPB Building (3)

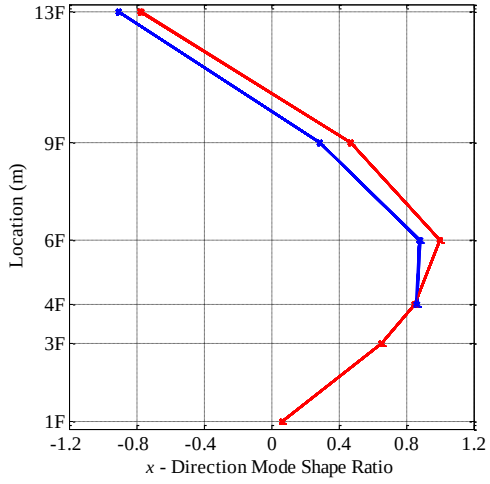
Mode B2-1:
1.966 Hz; 1.17%

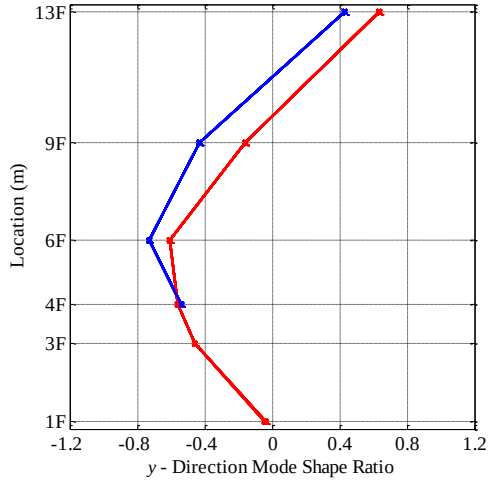


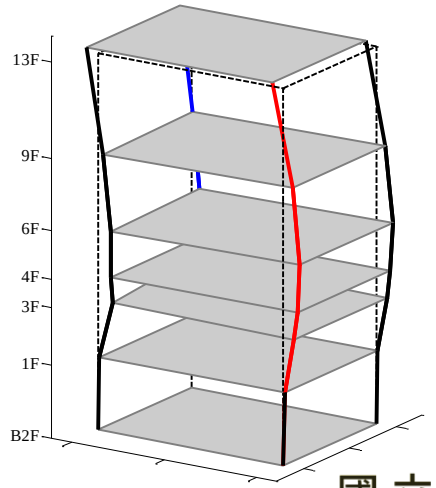




Mode B2-2:
2.022 Hz; 1.43%

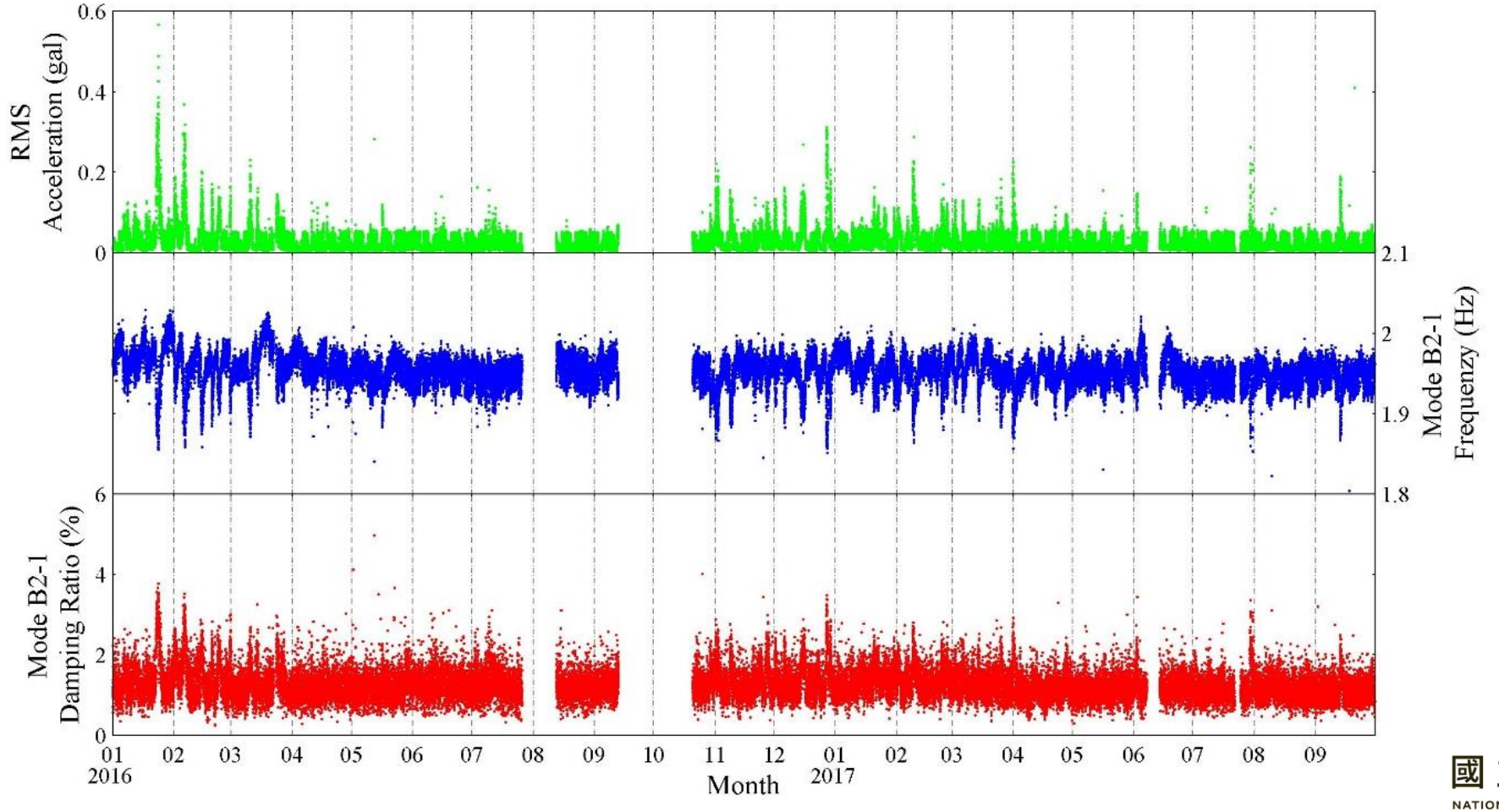






Comparison for Mode B2-1 of CTSPB Building

- The percentage of frequency variation in 21 months is 11.6%.



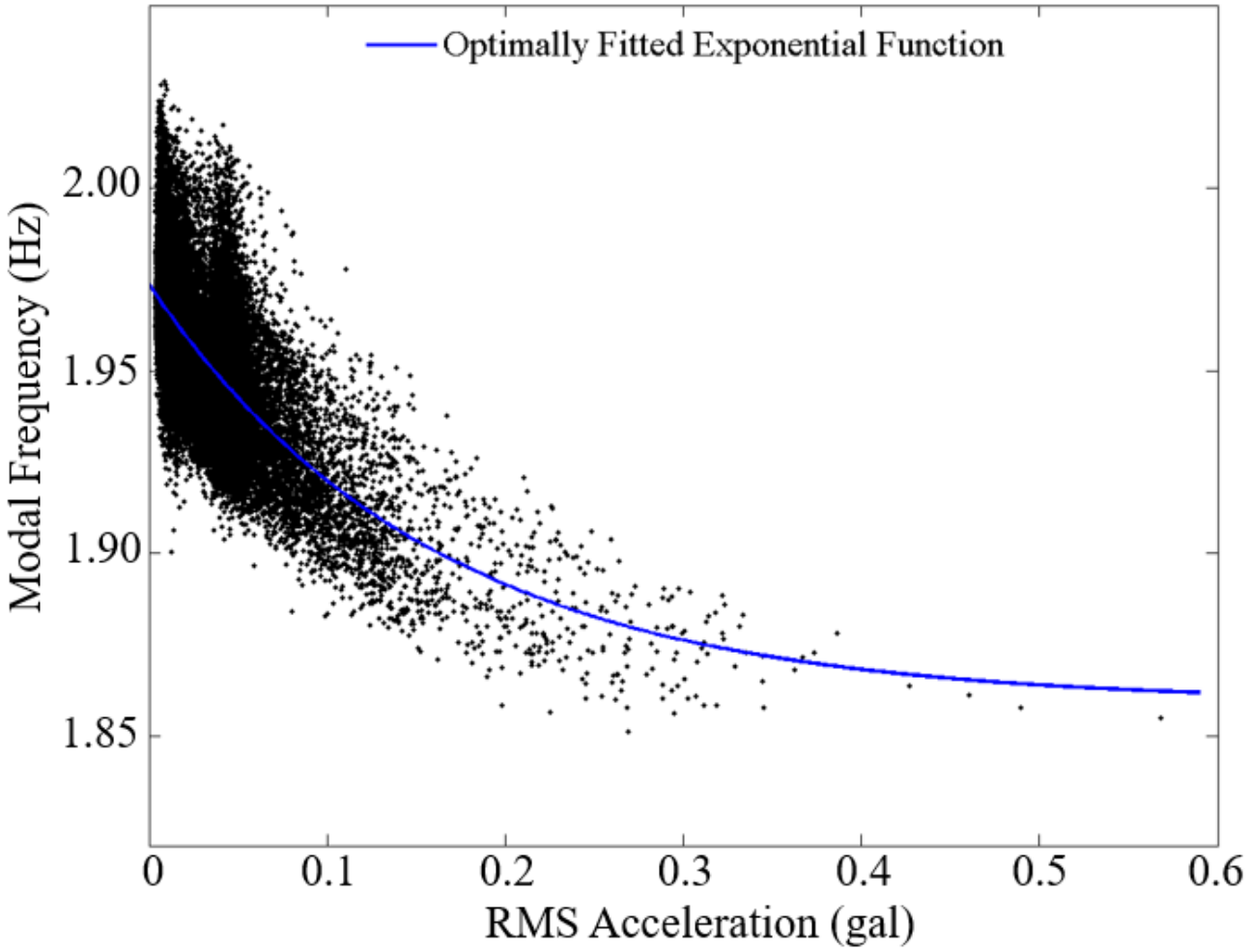
Observation and discussion

- The significant effect of the RMS response on the modal parameters can be reasonably explained by considering the possible relaxation of boundary conditions and contact conditions between structural members under large responses.

- The modal frequencies are decreased by the reduction in stiffness and increase the damping ratios by the enhanced energy dissipation.

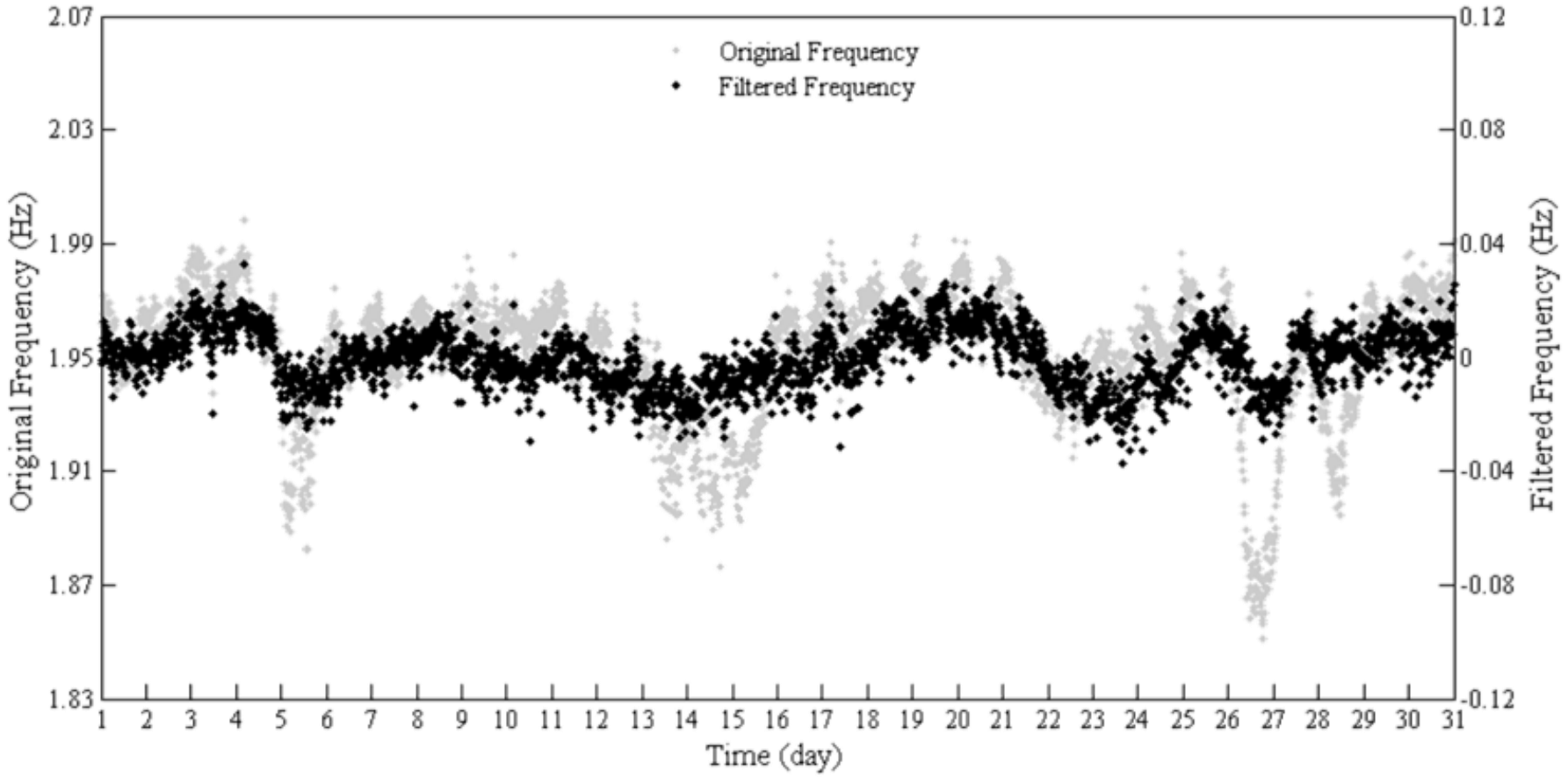
Mode B2-1 Frequency vs. RMS Acceleration

CTSPB Building



Elimination of Environmental Effects

Mode B2-1 of CTSPB Building (2016/12)



4 Summary and Conclusion

Summary and Conclusion

- For more than 30 years, Taiwan government has established the TSMIP system to monitor the long-term behavior of infrastructures.
- Data of different types of structure (low-rised, mid-rised, skyscraper, isolated, twin-towered, etc.) are periodically analyzed.
- Accompanying with this continuous TSMIP system, more and more private sectors (e.g. life insurance groups) are joining this field to guarantee the health condition of important infrastructures.

國立陽明交通大學
NATIONAL YANG MING CHIAO TUNG UNIVERSITY

THANKS FOR YOUR LISTENING!