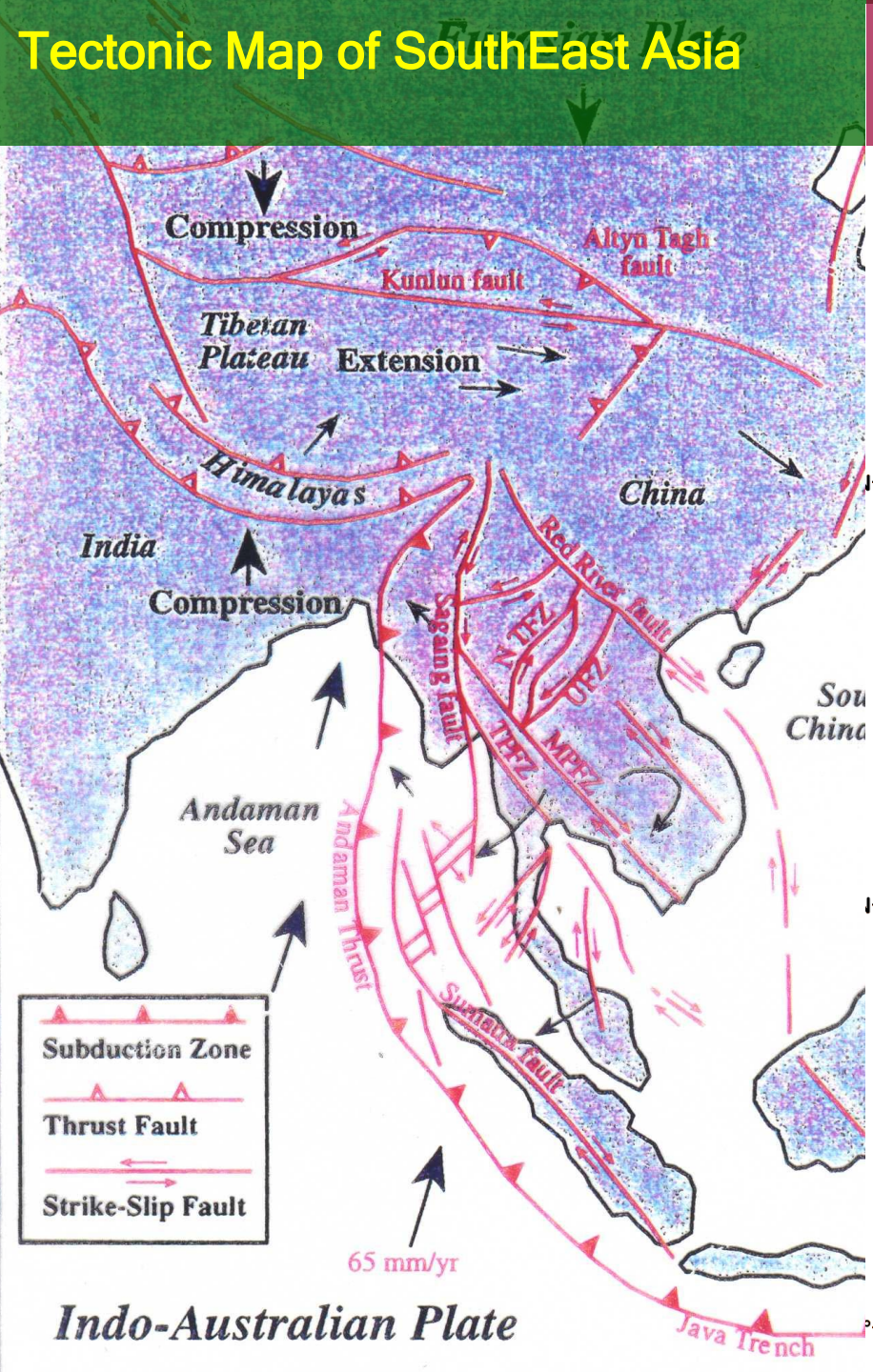
New Challenges in Earthquake and Wind Engineering in Thailand

Pennung Warnitchai

Professor of Structural Engineering

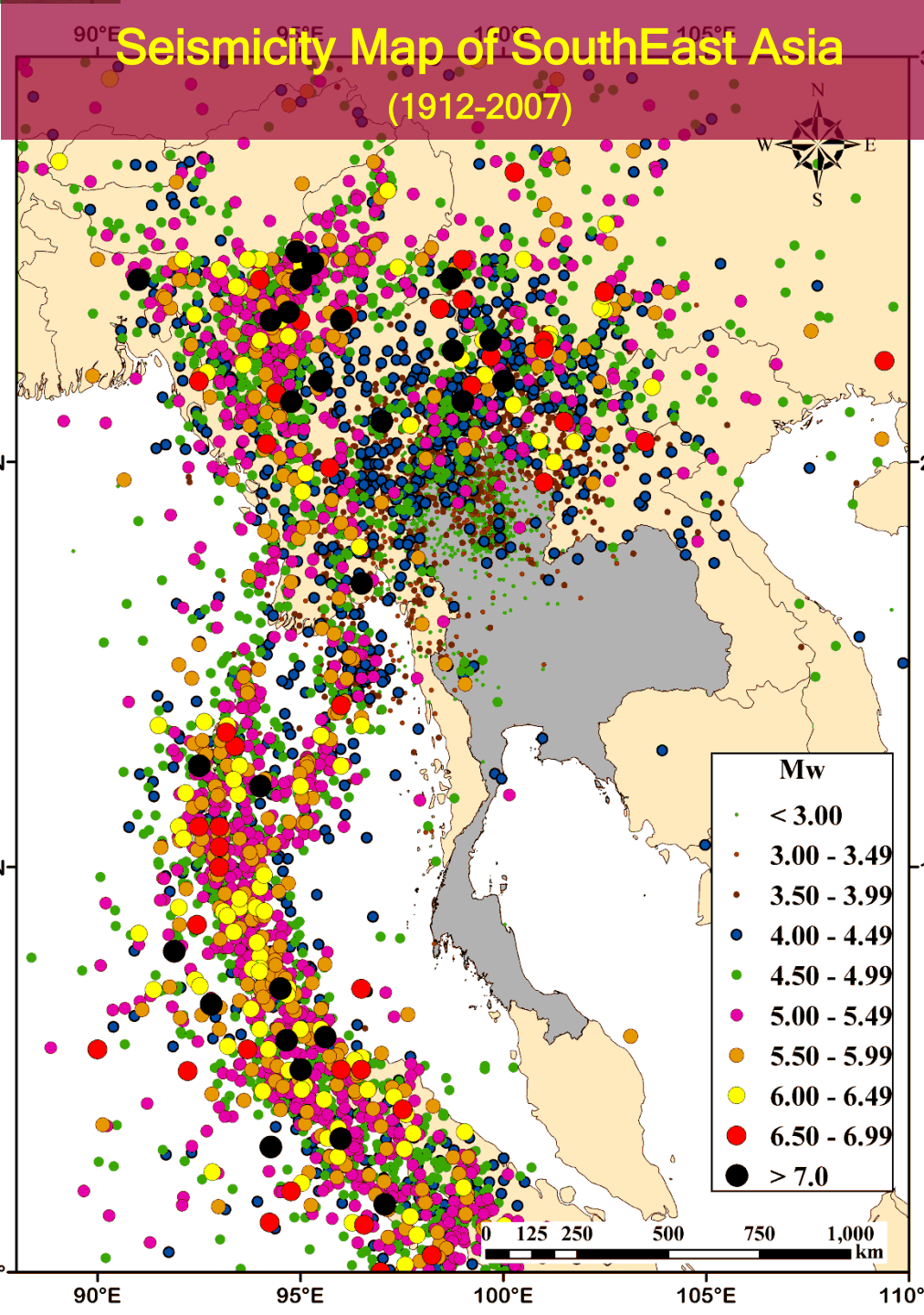
Asian Institute of Technology (AIT)

Tectonic Map of SouthEast Asia



Seismicity Map of SouthEast Asia

(1912-2007)

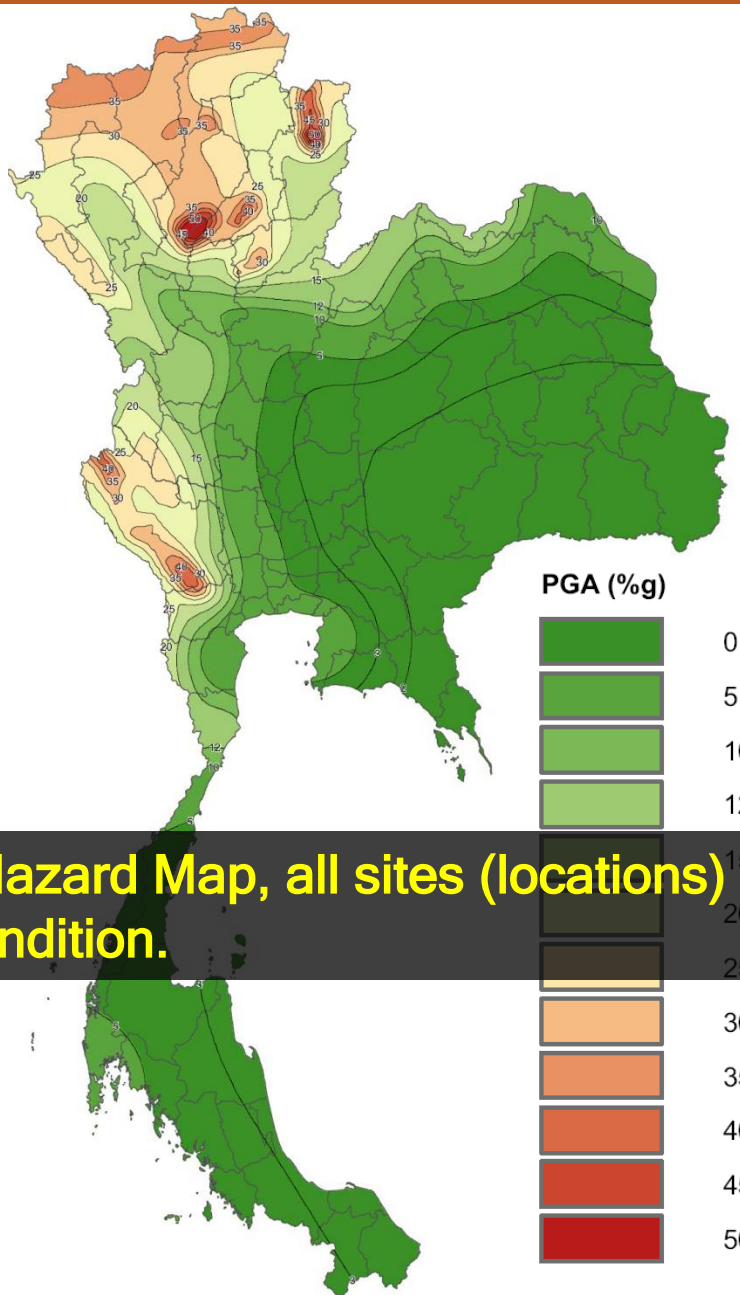


Crustal Faults in and near Thailand

1. Mae Chan Fault (SS
2. Central Phayao Fau
3. Mae Kuang Fault (S
4. Pua Fault (N)
5. Thoen Fault (N)
6. Long Fault (N)
7. Phrae Fault (N)
8. Phrae basin Fault (
9. Nam Pat Fault (N)
10. Moei Fault(SS)
11. Sri Sawat Fault (S
12. Chao Phraya Basi
13. Three Pagoda Fau
14. Bong Ti Fault (SS)
15. Tavoy Fault (SS)
16. Kungyaungale Fau
17. Tenasserim Fault
18. Ranong Fault (SS)
20. Khlong Marui Fau
21. Sagaing Fault (S

SS= Strike-Slip Fault
N = Normal Fault

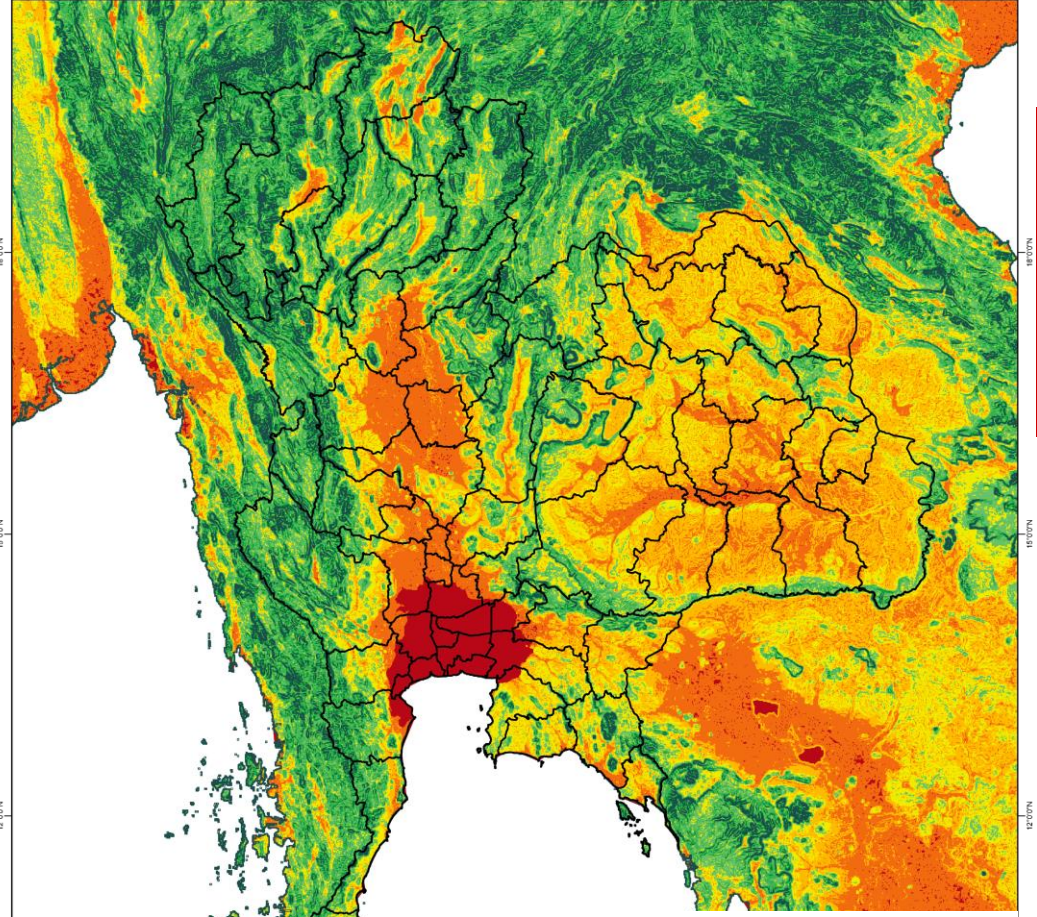
Peak Ground Acceleration with 2% Probability of Exceedance in 50 years



In the process of making this Seismic Hazard Map, all sites (locations) are assumed to be a standard 'rock-like' condition.

Map showing Soil (Site) Conditions in Thailand

(derived from digital elevation data—SRTM30 and boreholes data)



Seismic Risk of Tall buildings in Bangkok from Distant Earthquakes due to 'Basin Amplification of Ground Motions'

Rock (No Amplification)

Very Stiff Soil

Stiff Soil (Moderate Amplification)

Moderately Soft Soil

Very Soft Soil (High Amplification)

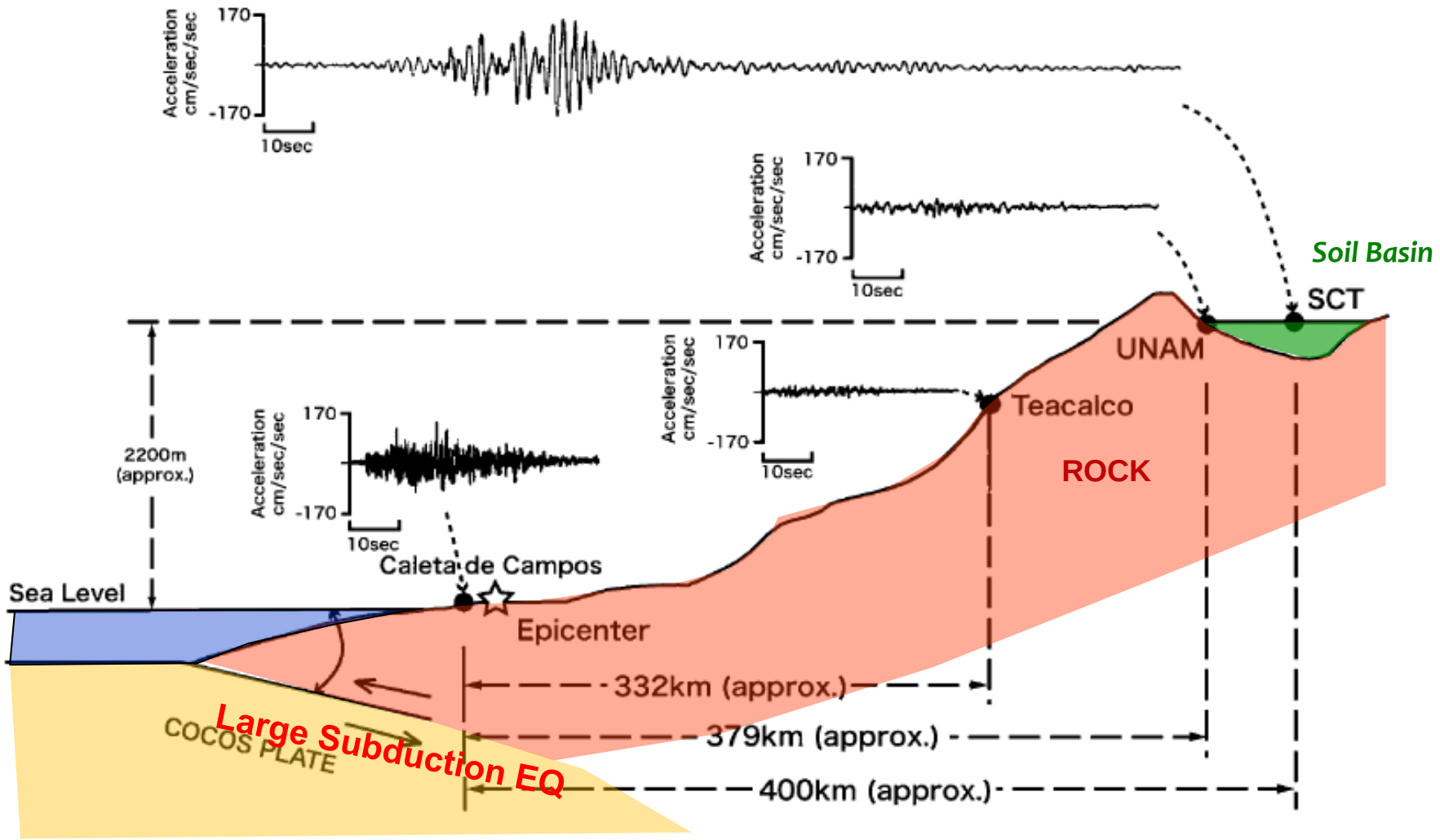
The 1985 Michoacan Earthquake (M_s = 8.1)

The earthquake caused considerable destruction and loss of life in Mexico City, about 350 km from the EQ epicenter. The number of deaths was more than 10,000.

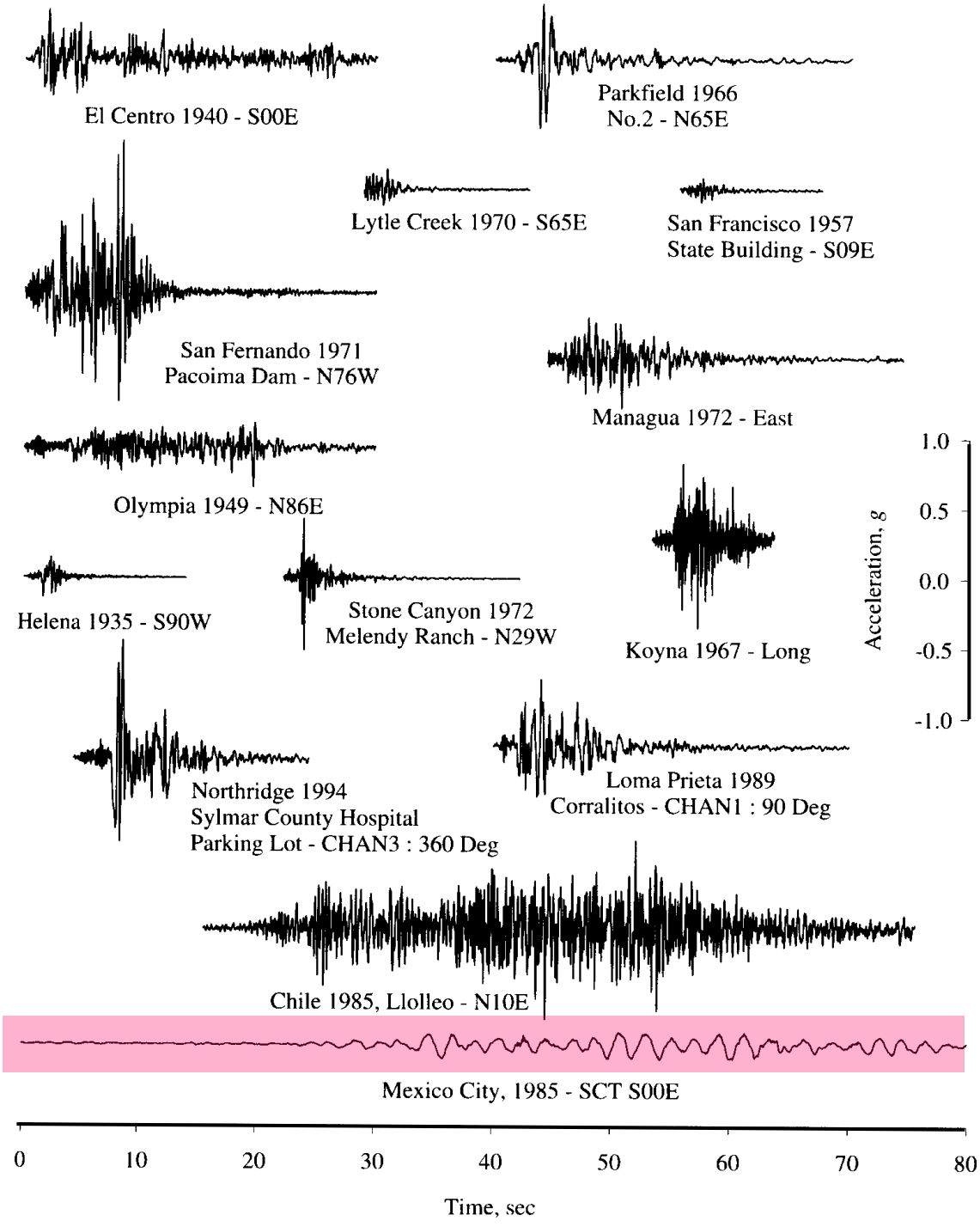
Earthquake Disaster in Mexico City (1985)

Much of the destruction was due to significant amplification of EQ ground motions by thick soft soil deposits/basins.

Large Amplification of Ground Motion by Soil Basin



Source: Celebi et al. 1987



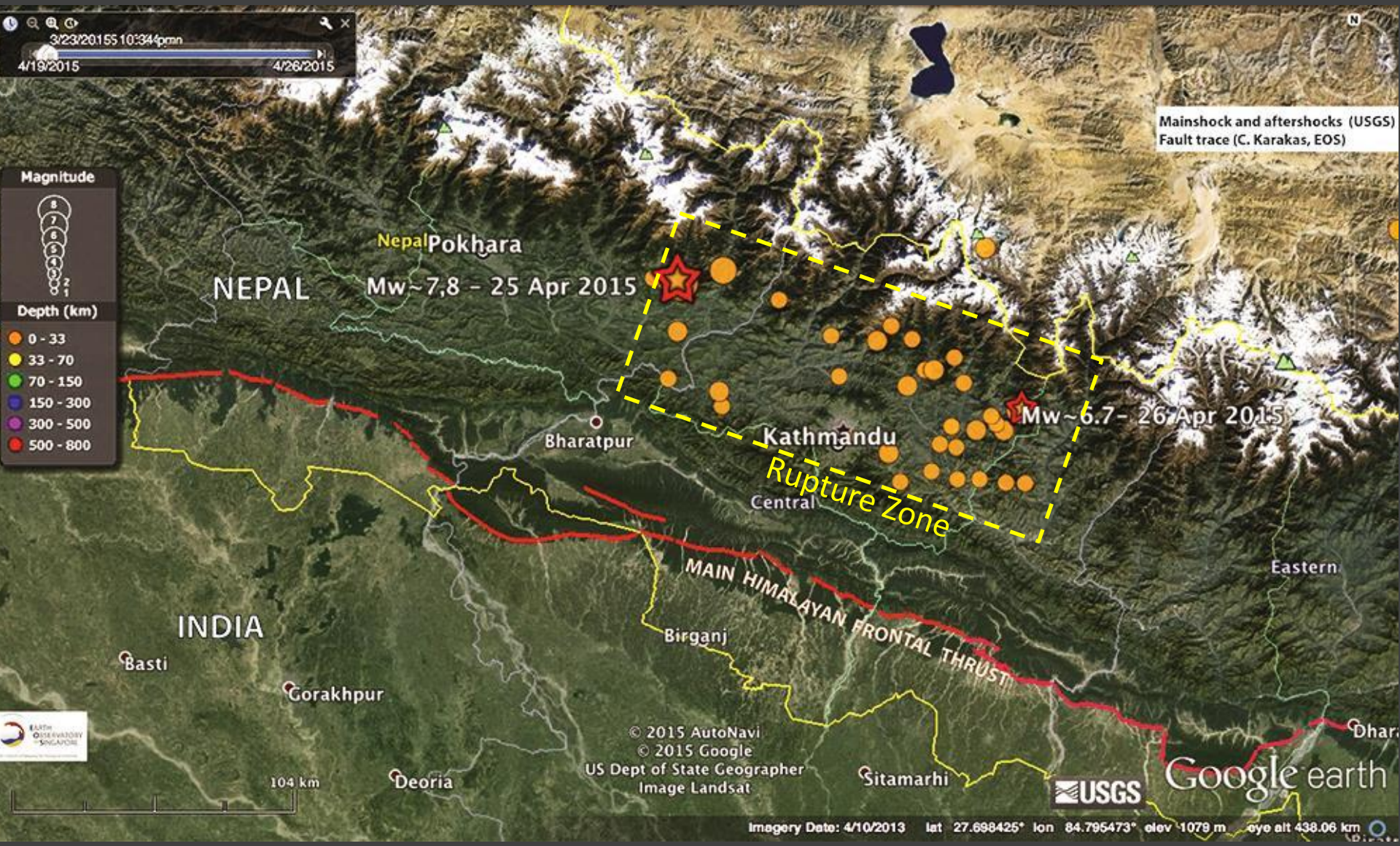
Time Histories of Ground Accelerations

Compared to other damaging ground motions, the Mexico City's SCT motion is:

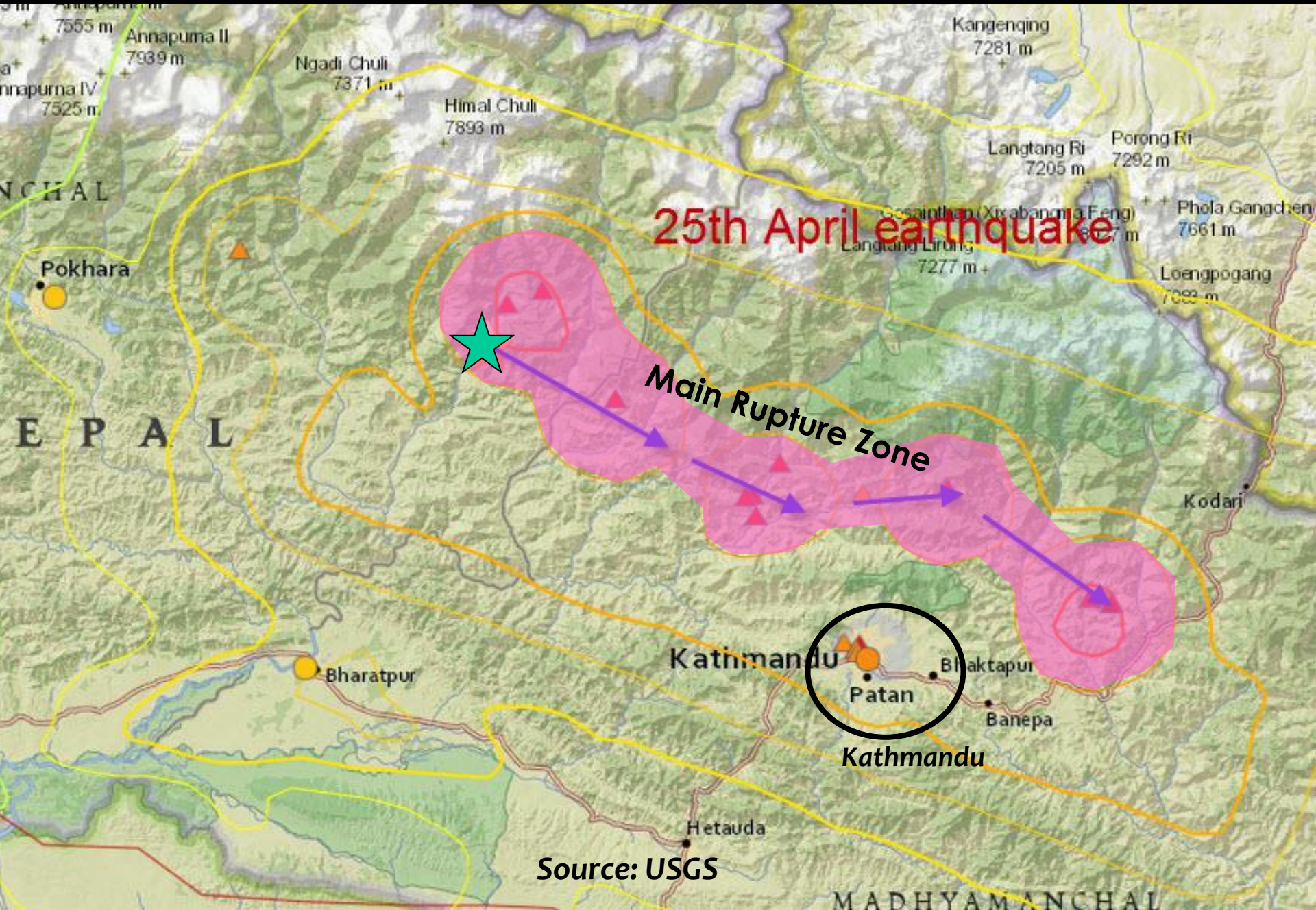
- *Long-period motion*
- *Long duration*
- *Low shaking intensity (low acceleration)*

Shake Table Experiment

Nepal Earthquake: M 7.8, 25 April 2015



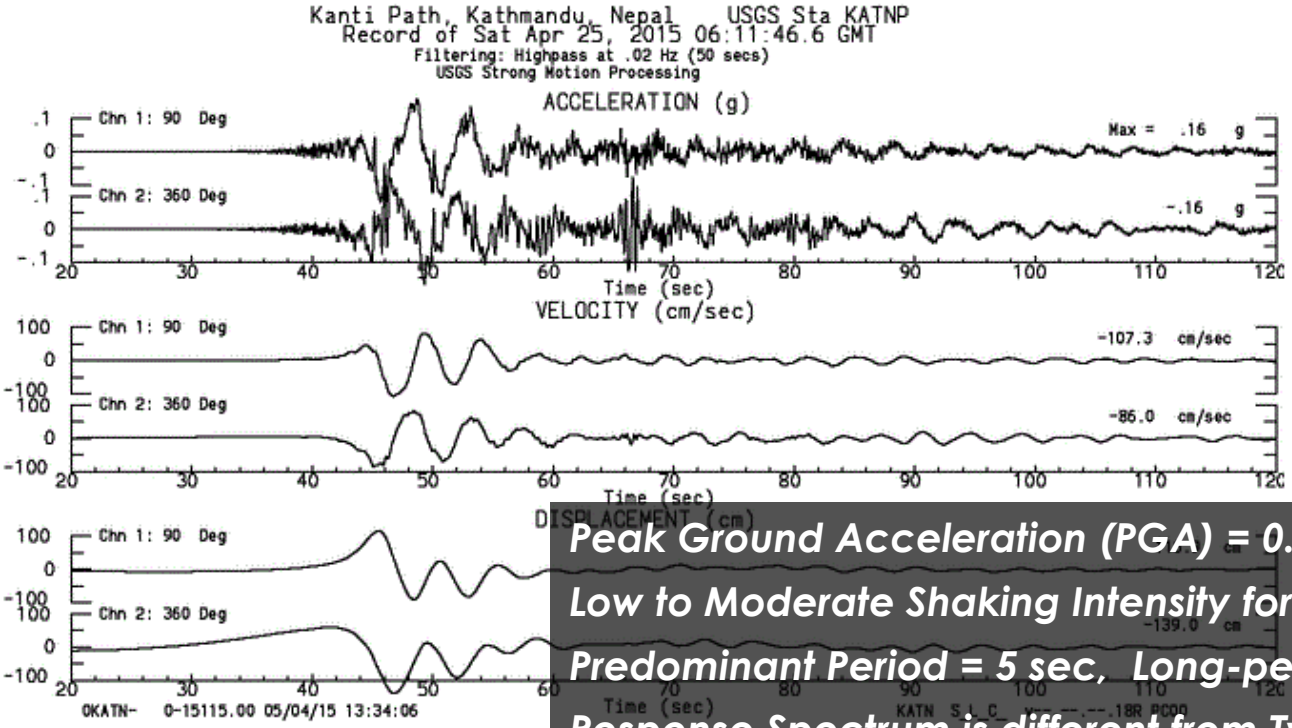
Rupture Mechanism



Kathmandu Valley

View from Swayambhu Hill Top

Ground Motion Records in Kathmandu: The 25th April 2015 Earthquake (M_w 7.8)



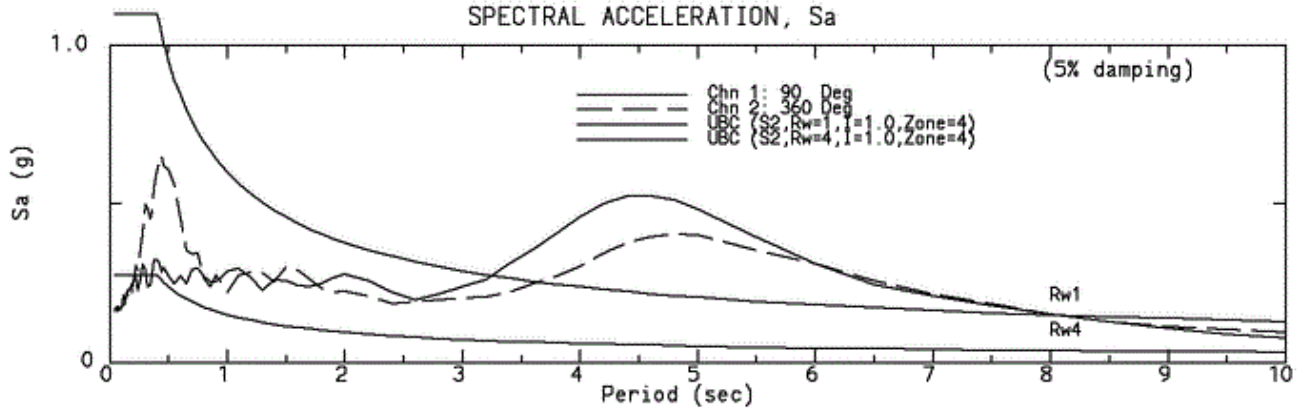
Peak Ground Acceleration (PGA) = 0.16 g

Low to Moderate Shaking Intensity for Low-rise Buildings

Predominant Period = 5 sec, Long-period Ground Motion!

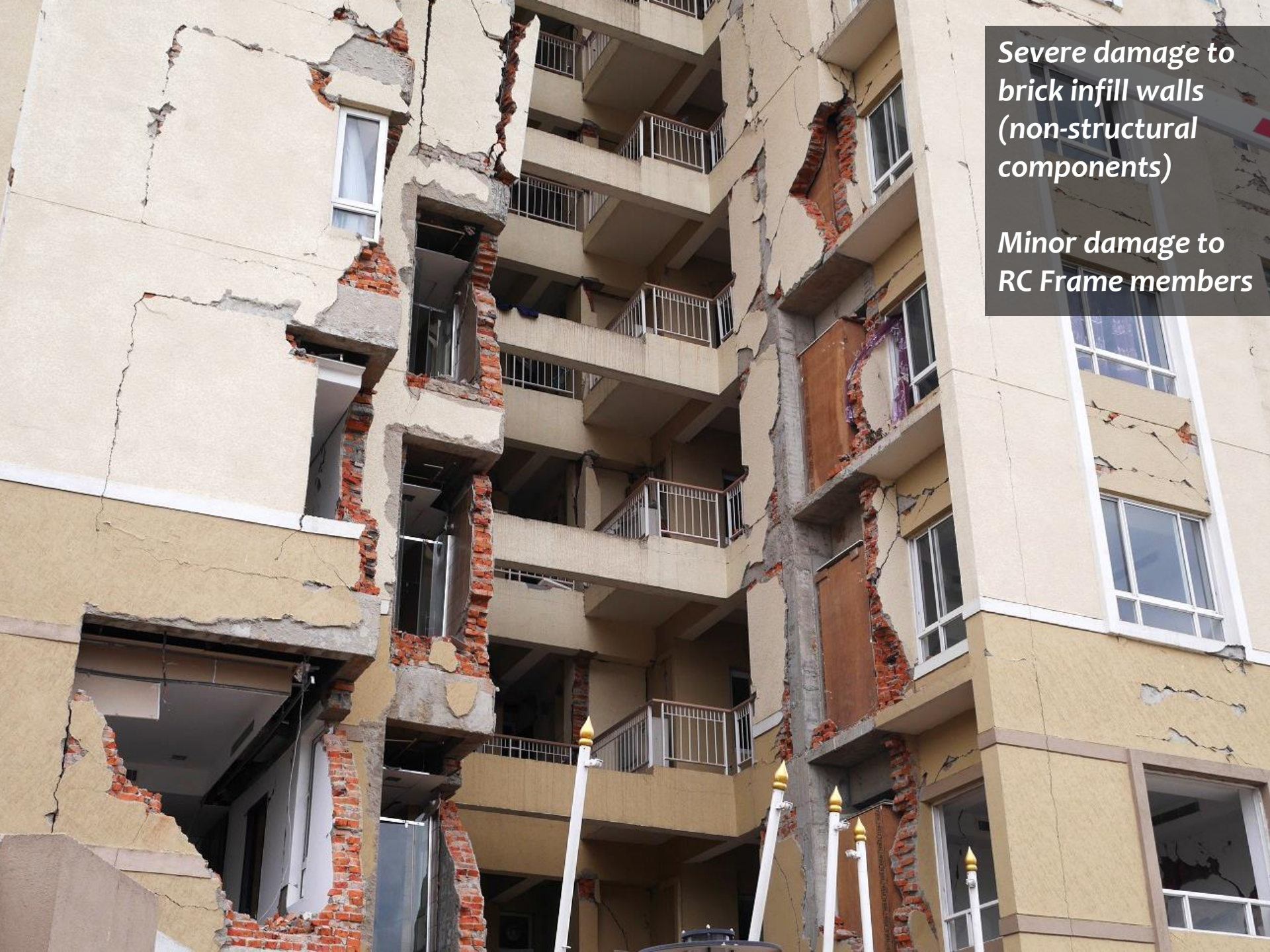
Response Spectrum is different from Typical Design Spectrum

More Damaging Effect to Tall Buildings (Long-period Structures)



Park View Horizon Apartment
Kathmandu, Nepal

Damaged by long-period ground motion in Kathmandu Basin (Nepal EQ, M7.8, 25 April 2015)



Severe damage to brick infill walls (non-structural components)

Minor damage to RC Frame members

All building occupants were evacuated from these buildings.

Should tall buildings be designed for long-period ground motions?

Should the seismic performance of non-structural components be considered in the seismic design of tall buildings?

set to show their grace.
TALK OF THE TOWN, 12A

award and Bt100,000.
LOCAL, 4A

five-hour record tie.
SPORTS, 16B

SHAKEN

- Tremor spreads panic among Bangkok office workers
- 2,000 vocational students flee college in Phuket
- Epicentre of earthquake located off Sumatra island

■ *The Nation*

OFFICE WORKERS and people living in skyscrapers in Bangkok and several major southern cities were in a panic for more than an hour yesterday morning after feeling the vibrations of an earthquake originating off the Indonesian island of Sumatra.

The higher the building, the stronger the effect of the quake. Residents of skyscrapers flocked to their building's elevators. Those who reached the ground floor found crowds of people rushing to get outside.

Many of them rang friends and family while some rang the public service FM 100 radio station seeking information, or to express their feelings or opinions.

The panic subsided after the authorities announced the source of the tremors, saying the situation was not a crisis.

In Bangkok, the panic occurred in the centre of the city in prime commercial areas like Siam Square, Silom and Sukhumvit. Slightly less serious panics were reported in Phuket, Songkhla, Trang and Satun.

"A quake measuring 7.0 on the Richter scale originating from Sumatra Island, 1,200km from Bangkok and 300km from Phuket, was felt yesterday. By the time the tremors reached Bangkok, we experienced it at 2 merculli," said Dr Prapansak Rattana director-general of the Meteorological Depar (MET).

Although Thai media initially reported that the quake measured an 8 on the Richter scale, the MET's official figure is 7. International news services have said the quake measured 8.6-8.5 on the Richter scale.

"Don't panic. The quake is over. It was not enough to cause damage and was not centred Kingdom," the MET chief said.

"In fact, by the time the quake reached Ban was of a low magnitude but we felt it because th ogy of the area is of the 'soft soil' type, which fied the effects of the quake by three to four t Department of Mineral Resources (DMR) dir general Somsak Bhodisat said.

Natural Resources and Environment Mi Prapat Panyachatraksa offered the following for coping with tremors: "Hide behind a strong ture that will not collapse on you, avoid standin mirrors or windows, do not use the elevator an your car until the vibrations are over."

The public's main concern was over the sa living in skyscrapers, especially in Bangkok, there are some 700 buildings that are more tha metres tall. Experts went to great lengths yes to allay these fears.

"Bangkok does not lie on an active fault zone

and residents gather outside the Pacific Place building on Sukhumvit Road after a mild n Bangkok late yesterday morning.

Rattled city

Note: Richter is a magnitude scale to express the seismic energy released by an earthquake.
Mercalli is a measure of the intensity of the effect of an earthquake, its significance concerning a location's social or physical structure.
No information is available from the seismographic stations.

most high buildings were designed to resist high forc from very strong winds, which can be more powerf than a quake," Engineering Institute of Thailand pre ident Dr Karoon Chandrangsu said.

"Buildings in Bangkok need no special design t resist possible earthquakes. However, buildings

the 20th floor of the tower said he saw the venetian blind and the partition in his work area shaking. He said he and his colleagues were

Chaweewan Wanthit, who was working on the same floor when the vibrations were felt, said that at first she thought there was something

Quake leaves Phuket r

■ *The Nation, Phuket Gazette*

TREMORS FROM AN earthquake centred off the Indonesian island of Sumatra yesterday morning frightened people in tall buildings in Bangkok and triggered a stampede from the Phuket Vocational College at Saphan Hin, Phuket Town.

About 2,000 vocational students in Phuket's Muang District were told to make a hurried exit from the college buildings, which were rocked by an earthquake with a

10am. "I felt nausea from the shaking but I did not realise that it was due to an earthquake," she said.

Tuanjai Pannakit, a college librarian, said at first when she saw a chair moving she thought it was because it was on wheels, until she saw bookshelves shaking too.

When students in the library told her they thought it was an earthquake,

■ "I felt r
from the sh
I did not re
it was
an earth

ORACHORN

ell: Bangkok trembles

After the crash of 1997, nothing scares us, says capital's 'Wall St'

■ *Montira Narkwichien*
THE NATION

A MILD EARTHQUAKE struck the heart of Bangkok yesterday, but downtown workers said half-jokingly it wasn't as bad as when their businesses were hit by the 1997 economic debacle.

Staffers of KGI Securities, on the 45th floor of the United Building on Silom Road, the capital's "Wall Street", noticed their computer screens were shaking and said their morning coffee spilled from their cups, according to one employee, who requested anonymity.

SHOPPERS SEEK *safety outside the Tokyu Department Store in Bangkok.*

Building were immediately emptied, leaving some staffers on the higher floors in confusion.

Rangsit Road, 10 kilometres north of just south of Don Muang

เดลินิวส์
ฉบับที่ 19,460 วันพฤหัสบดีที่ 23 มกราคม พ.ศ. 2546 ราคา 8 บาท DAILY NEWS
http://www.dailynews.co.th

ผวาตึกระฟ้าถล่ม แผ่นดินไหว หนีตายอลหม่าน

'ใบหยก-มาบุญครอง'โกลาหลไปทั่ว 'ใต้'สะเทือนหนัก-เม็กซิโก'ตายอื้อ!

แผ่นดินไหวที่เม็กซิโกเมื่อวันอังคารที่ผ่านมาคร่าชีวิตแล้วกว่าร้อยละ 23 ศพ บาดเจ็บ 40 ส่วนเมืองอื่นหนา "สมาตรา" กรมมีฟิโรตาม กระเทือนถึง เพชบุรี ทั่วไทยรู้สึกสะเทือนและแจ้งเตือนแล้วหลายจังหวัด ◆ อ่านต่อหน้า 20

▲ ดูช่องล่าง...แผนที่ปักหมุดสีแดงแสดงจุดที่เกิดแผ่นดินไหวในเอเชีย และแสดงให้เห็นจุดศูนย์กลางของแผ่นดินไหวในช่วงเวลาต่างๆ ที่เกิดแผ่นดินไหวครั้งนี้ด้วย

'ประพัฒน์'รอดถูกถอดถอน

รุกหนักม็อบปากมูล กดดัน'ตัดน้ำตัดไฟ'

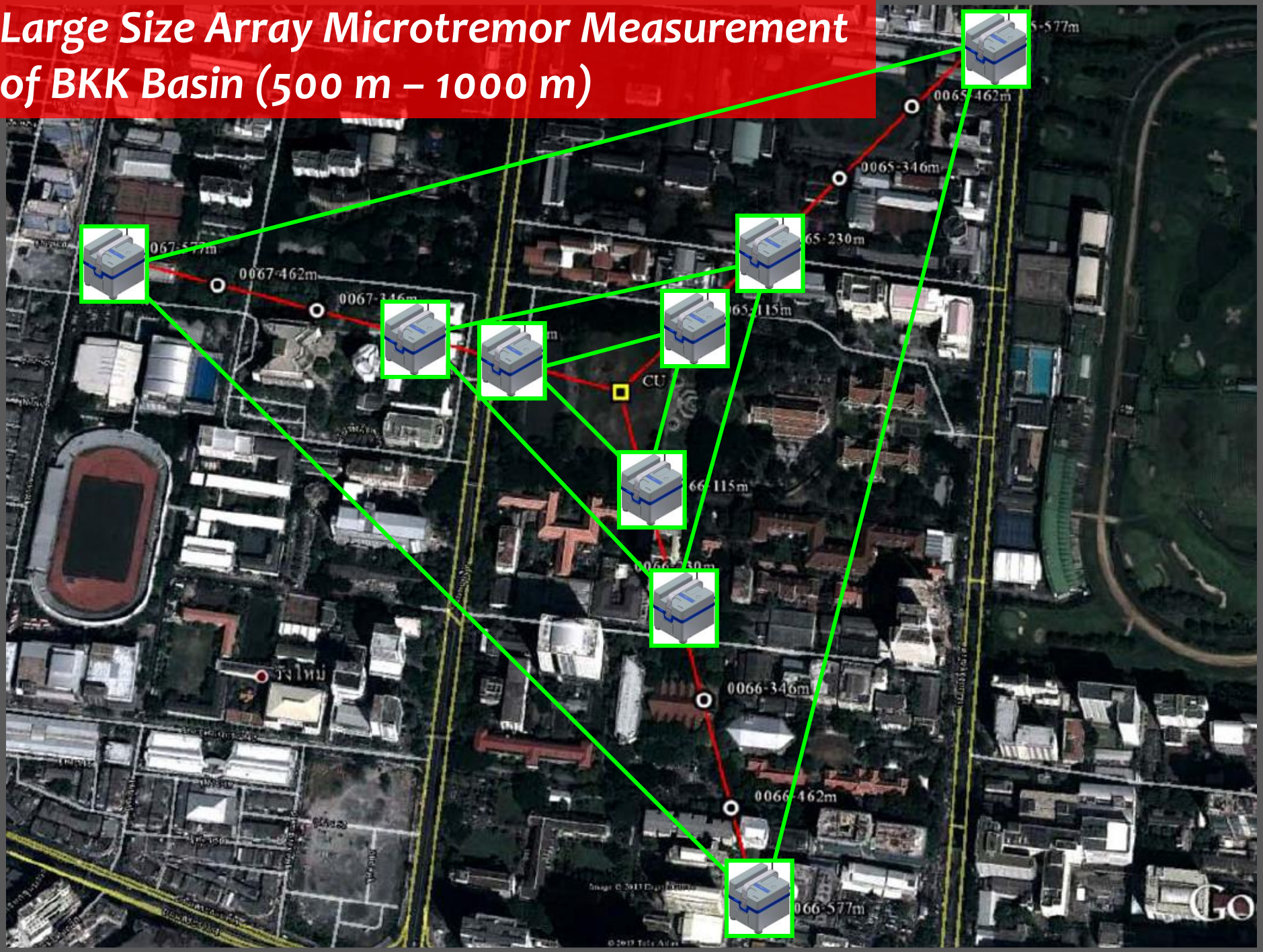
เมื่อปากมูลระทมหนัก ถูกตัดน้ำ ตัดไฟ ต้องทิ้งมาจุดเที่ยนก่อนออกแถลงการณ์ตอบโต้นายกฯ ค่ำสนใจเพียงชื่อ "แม่มูนมั่นยืน" ควรหาวิธีแก้ไขปัญหา ด้าน ส.ว.ที่รากสูงร้อง ◆ อ่านต่อหน้า 2

Array Microtremor Measurement

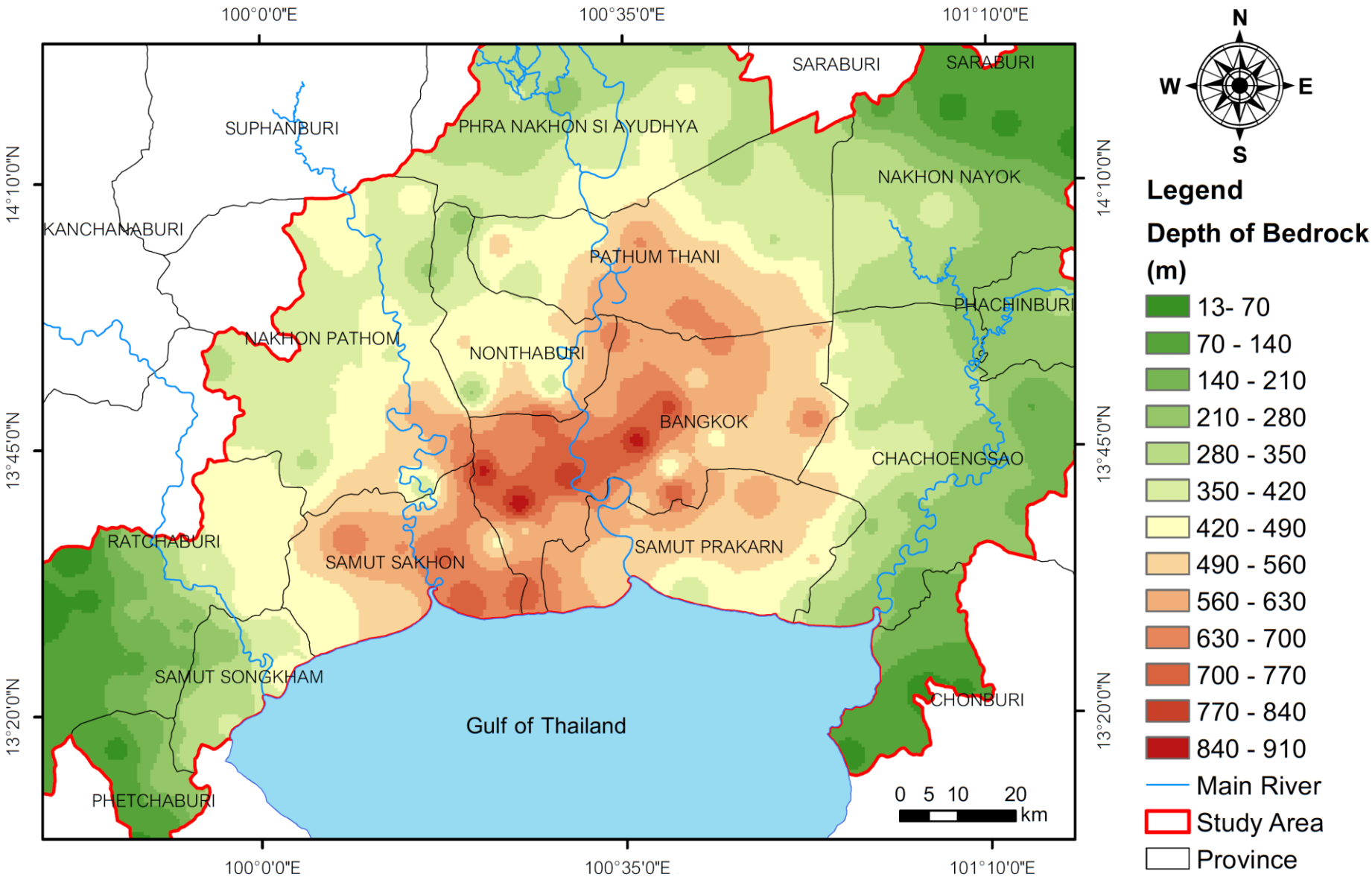
To identify the dynamic properties of soil basin (depth to bedrock, shear wave velocity profile, etc.)

Source: Dr. Nakhorn Poovarodom

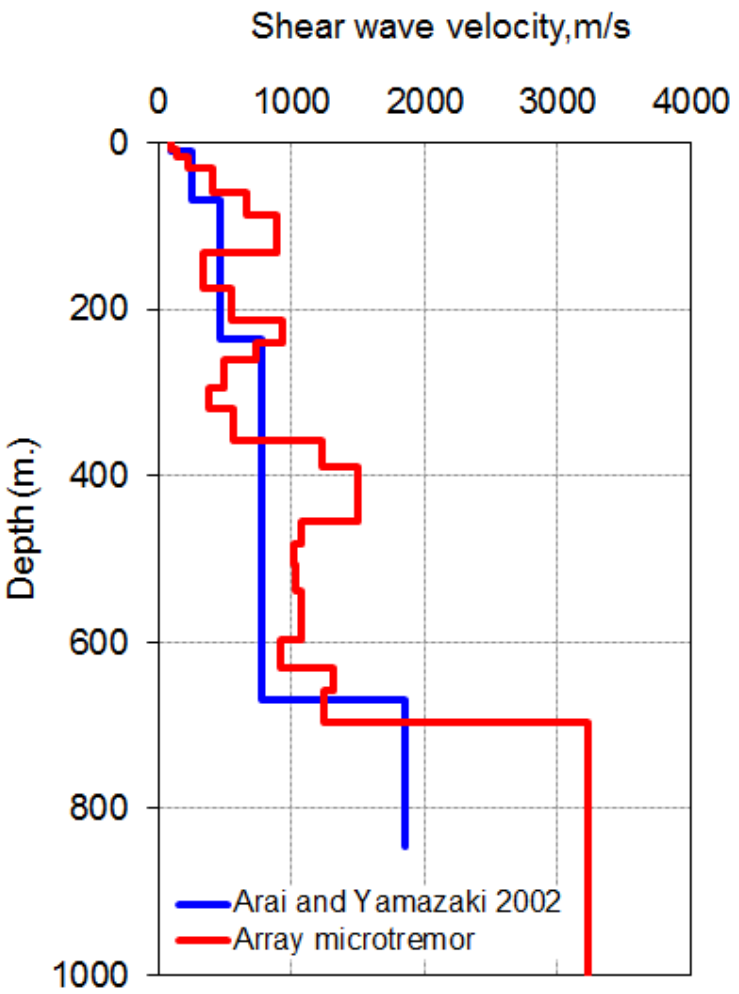
Large Size Array Microtremor Measurement of BKK Basin (500 m – 1000 m)



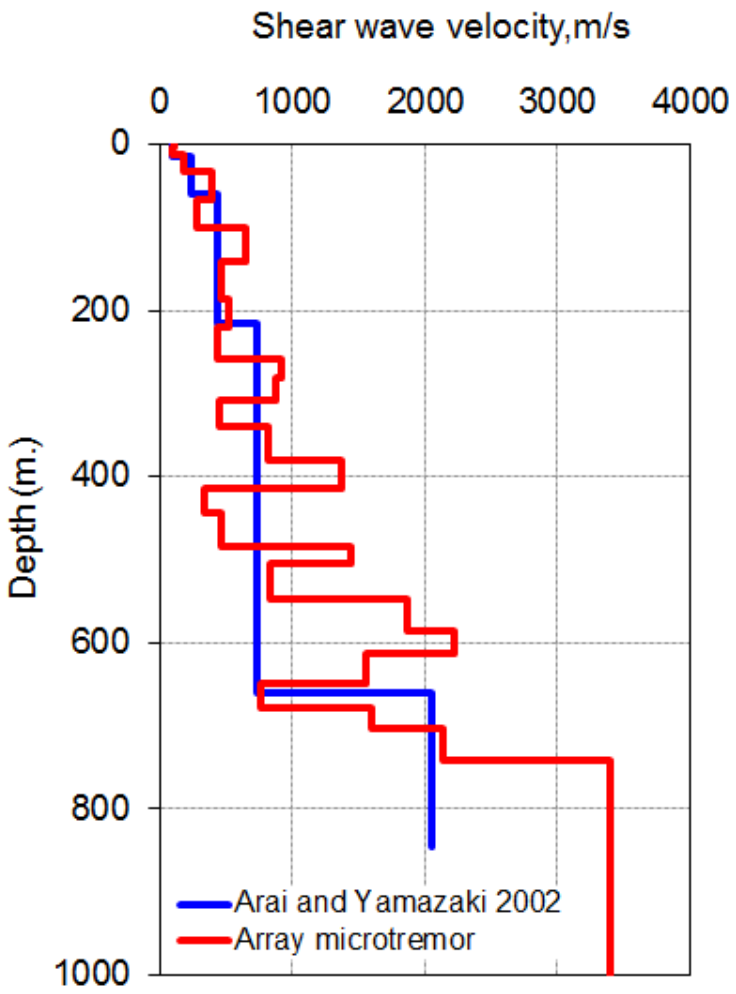
Depth to Basement Rock in Bangkok Basin



Shear Wave Velocity Profile of Bangkok Basin

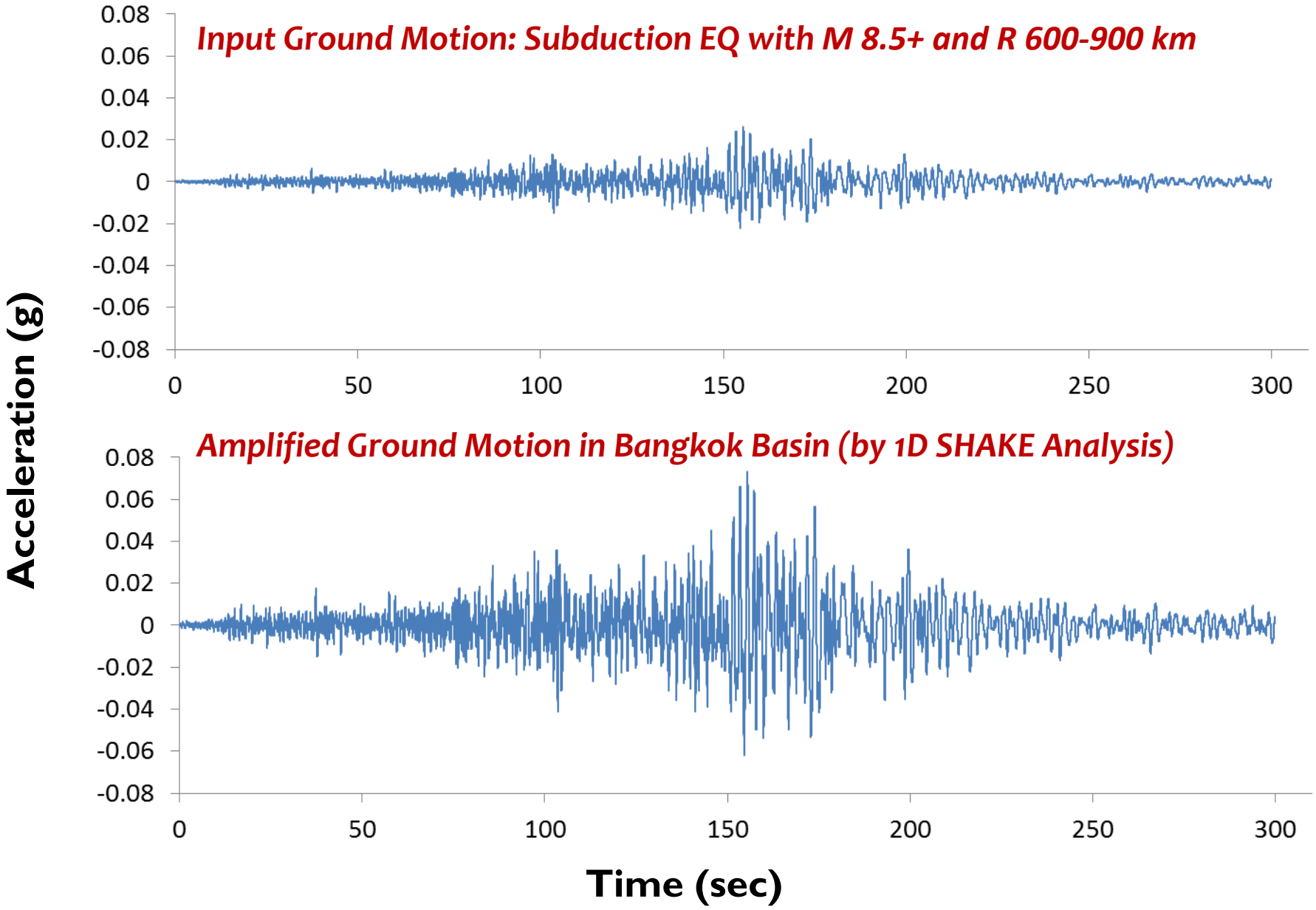


At Asian Institute of Technology (North of Bangkok)

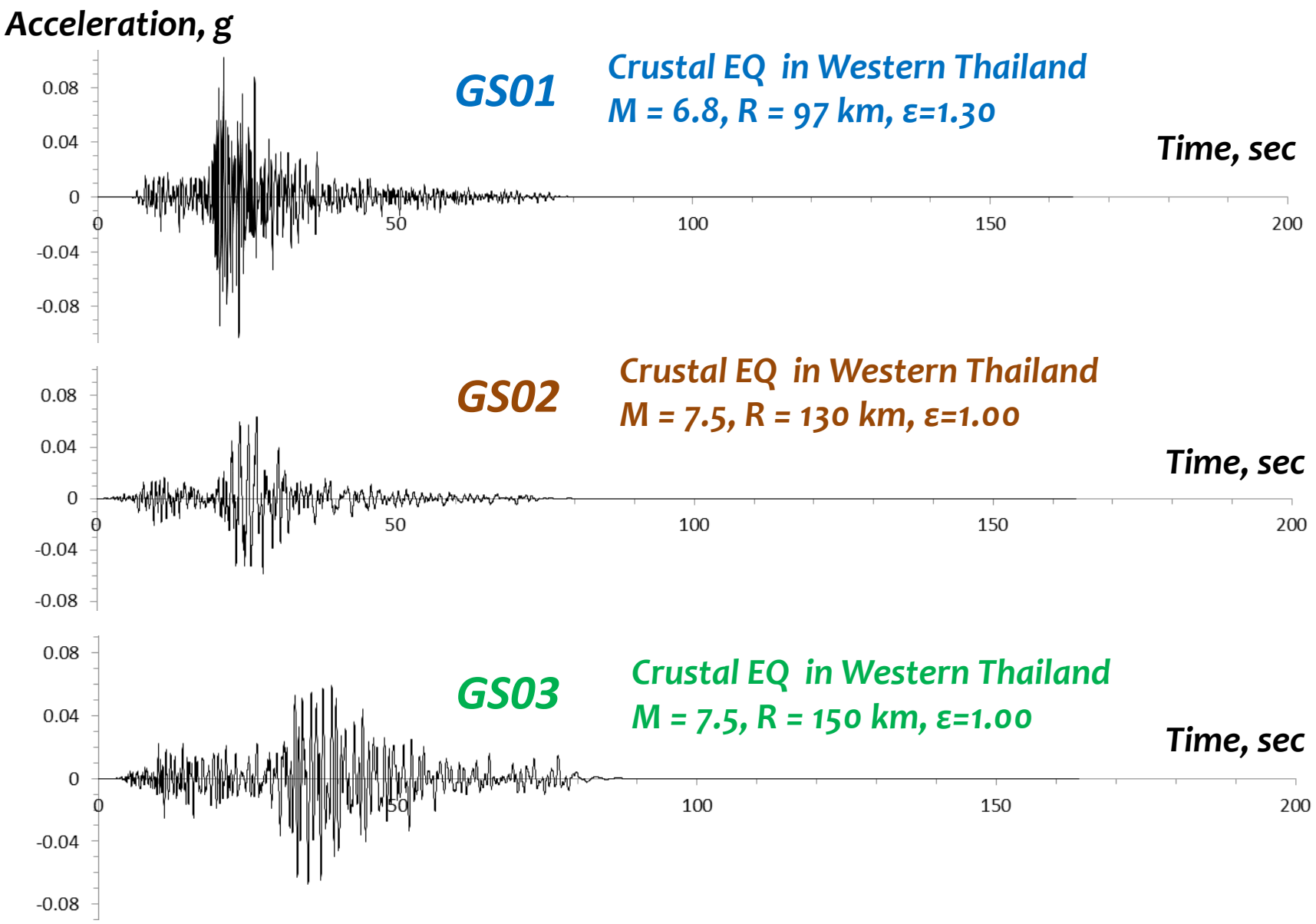


At Chulalongkorn University (Center of Bangkok)

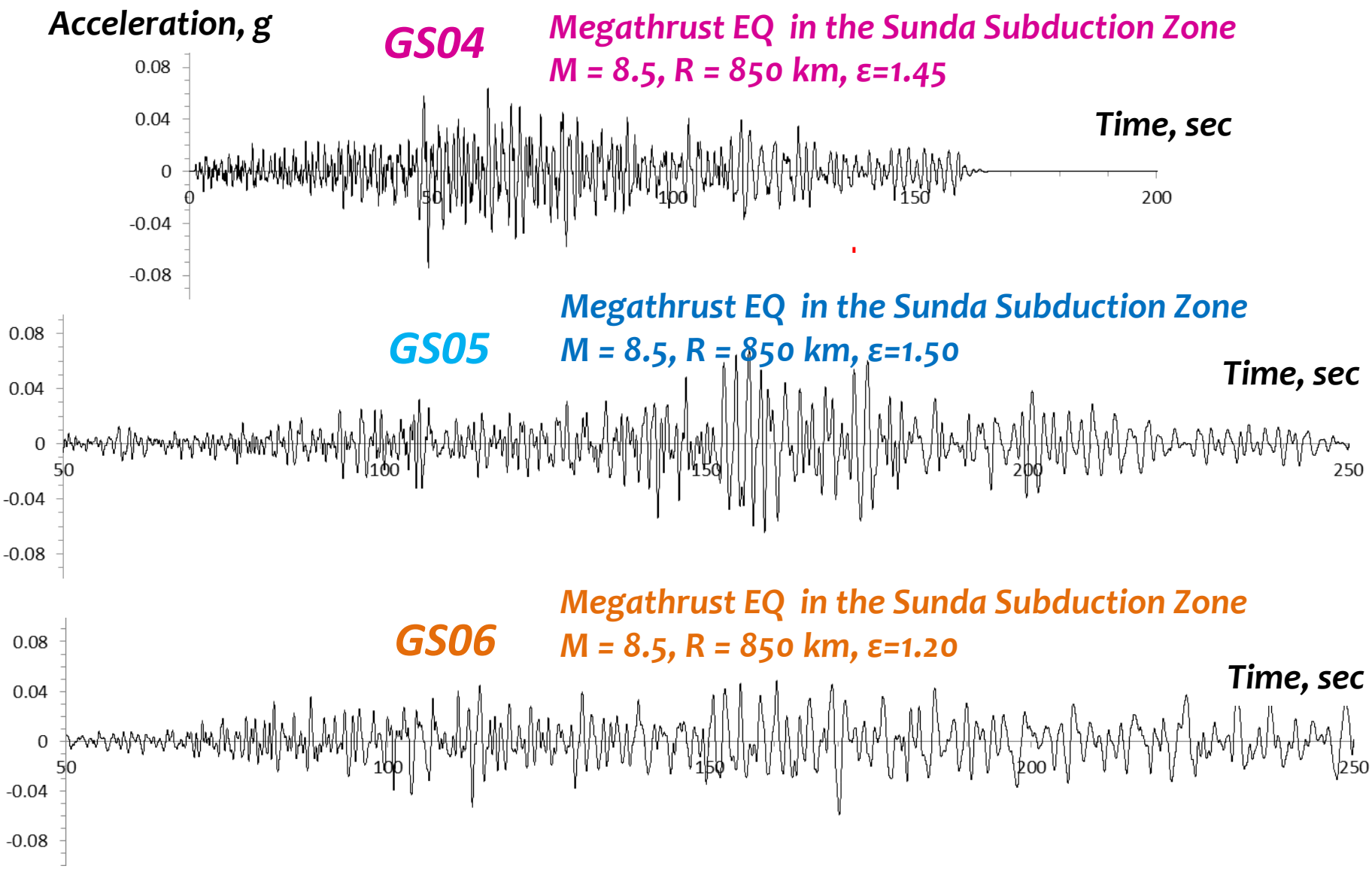
Basin Amplification of Ground Motion



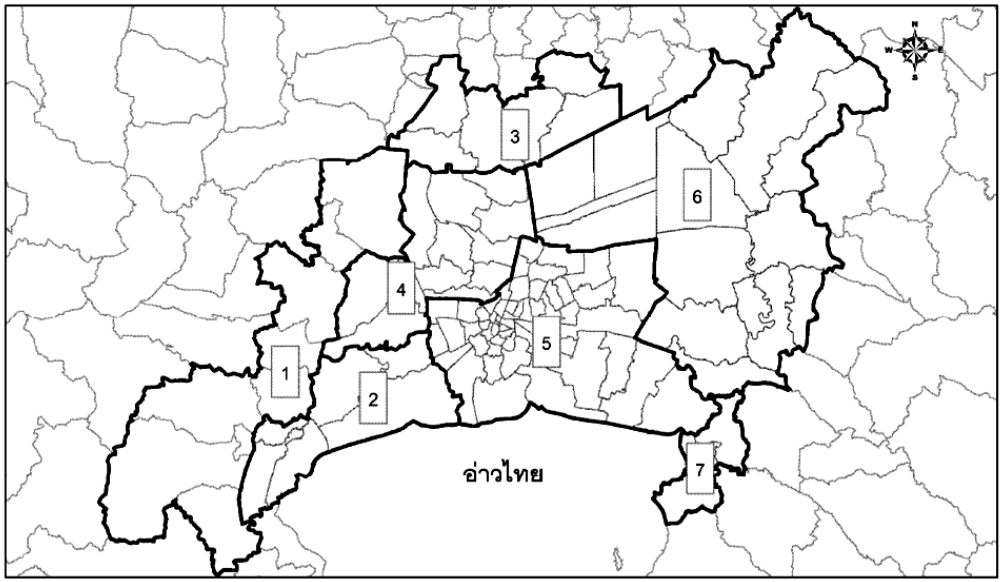
Bangkok's Earthquake Ground Motions with 2,500 yr Return Period

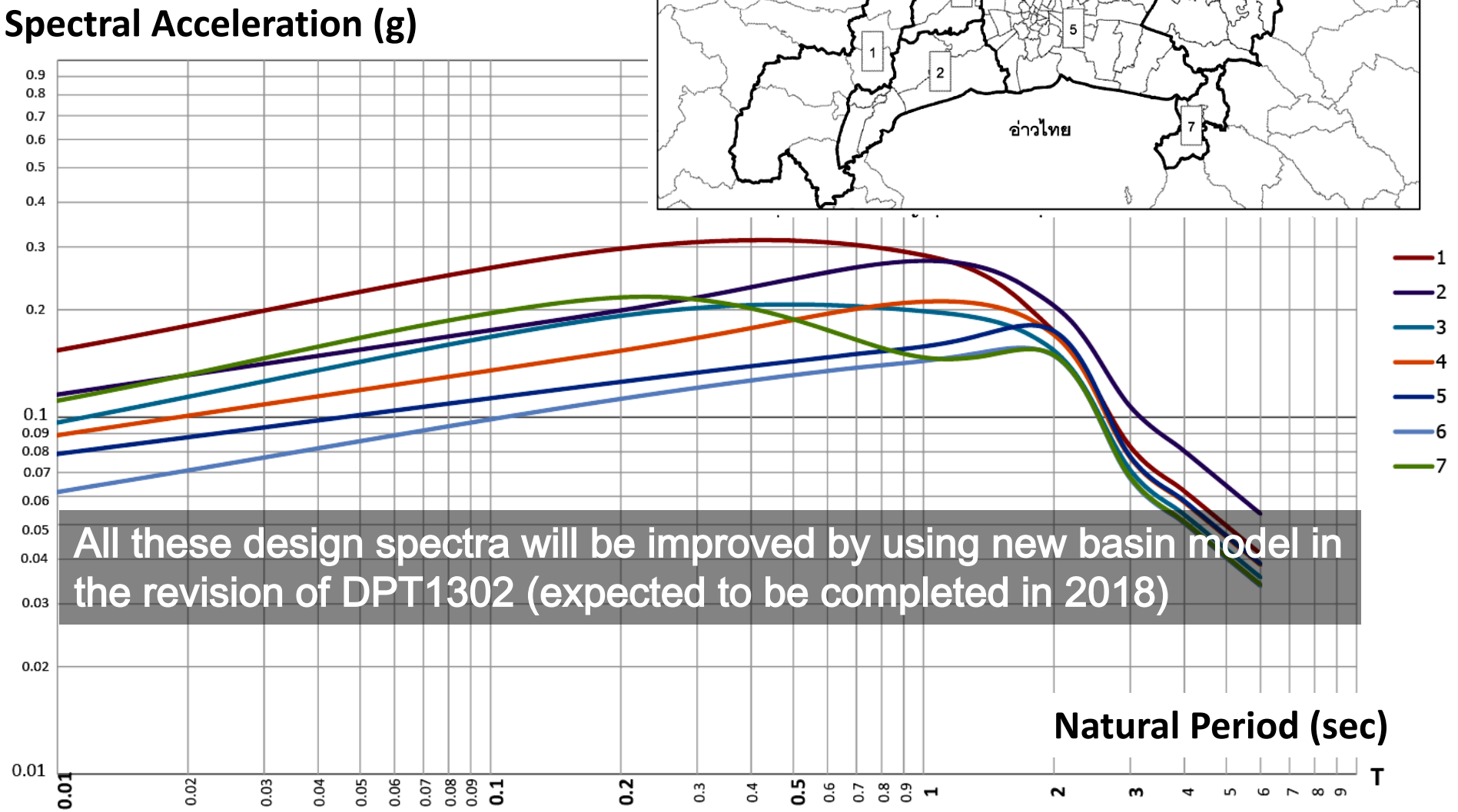


Bangkok's Earthquake Ground Motions with 2,500 yr Return Period



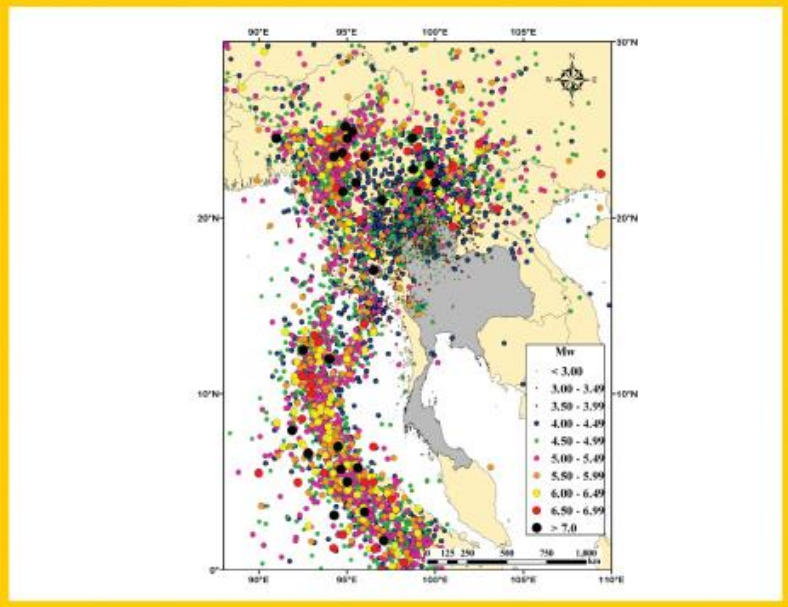
Design Spectrum for Bangkok and surrounding provinces





มยผ. 1302

มาตรฐานการออกแบบอาคารต้านทาน
การสั่นสะเทือนของแผ่นดินไหว



กรมโยธาธิการและผังเมือง
กระทรวงมหาดไทย
พ.ศ. 2552

National Standard DPT 1302: Seismic Resistant Design of Buildings and Structures

Issued by Department of Public Works and Town & Country Planning,Ministry of Interior (2009)

Model Code: ASCE 7-05

Require the values of Spectral Acceleration at 0.2 sec and 1.0 sec with 2 % probability of exceedance in 50 yr for defining Maximum Considered Earthquake (MCE) ground motion

วิศวกรรมสถานแห่งประเทศไทย ในพระบรมราชูปถัมภ์

THE ENGINEERING INSTITUTE OF THAILAND
UNDER H.M. THE KING'S PATRONAGE

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มกราคม 254
ราคา 120 บา

มยผ. 1311-50

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และการตอบสนองของอาคาร

Wind Resistant Design Standards of Thailand

The Engineering Institute of Thailand's Standard

The Public Work Department's Standard

กรมโยธาธิการและผังเมือง
กระทรวงมหาดไทย
พ.ศ. 2550

TU-AIT Boundary Layer Wind Tunnel Laboratory

Large Billboards—Highly Vulnerable to Wind Loads

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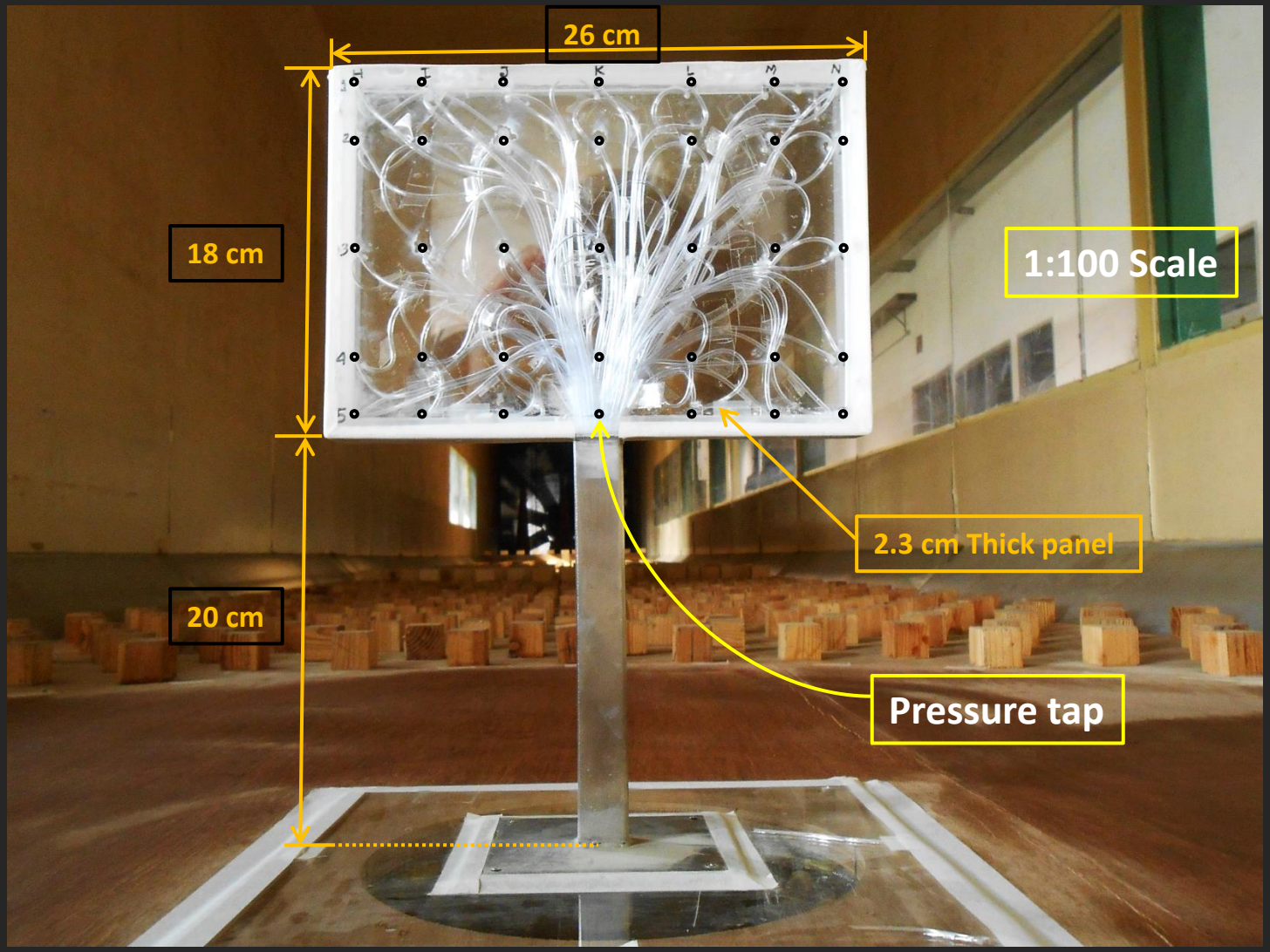
tongtumstudio tongtumstudio tongtumdesign

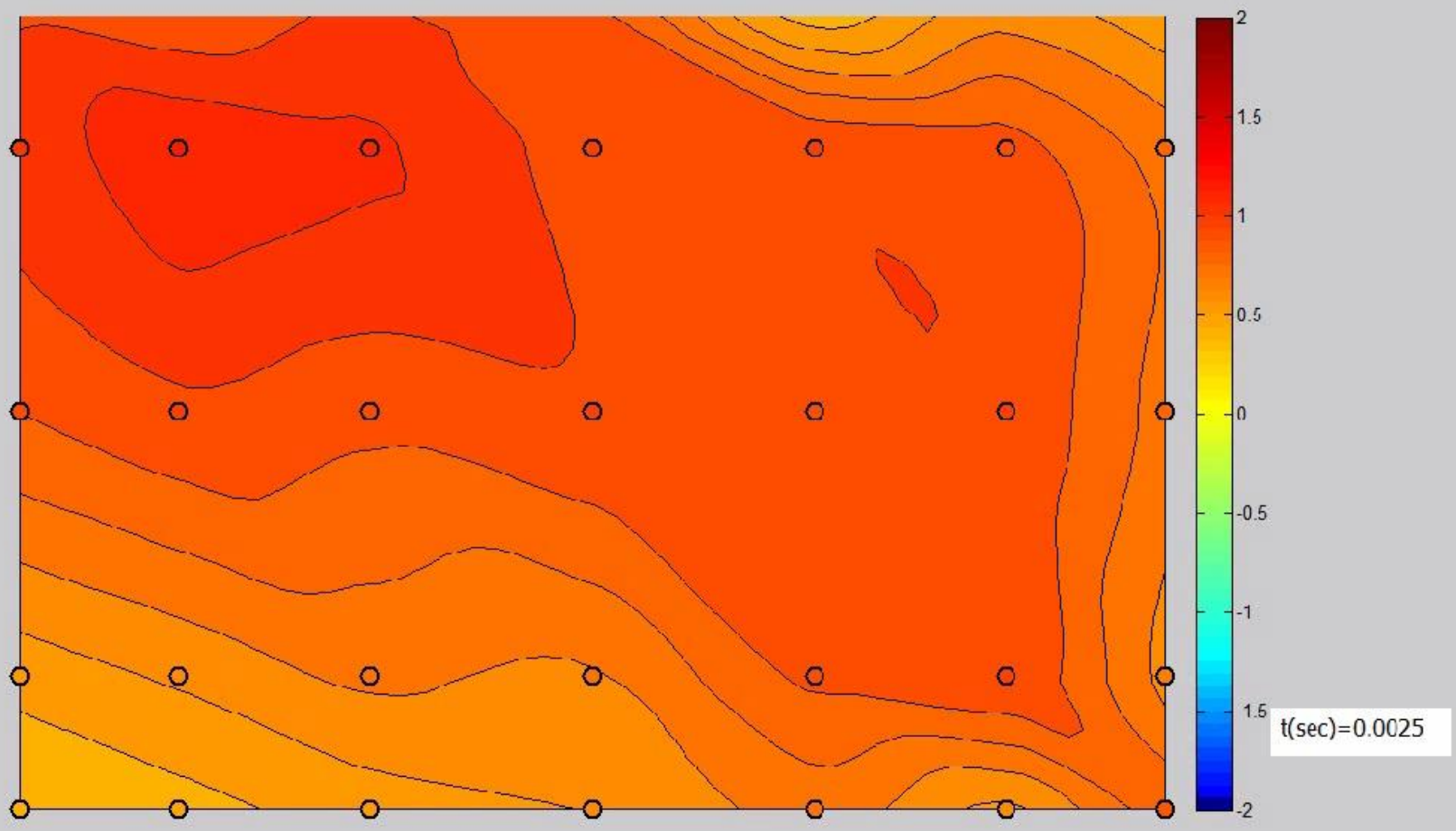
Several large billboards in Bangkok were completely destroyed by severe thunderstorms on 28th June 2007

High Frequency Pressure Integration (HFPI) Technique

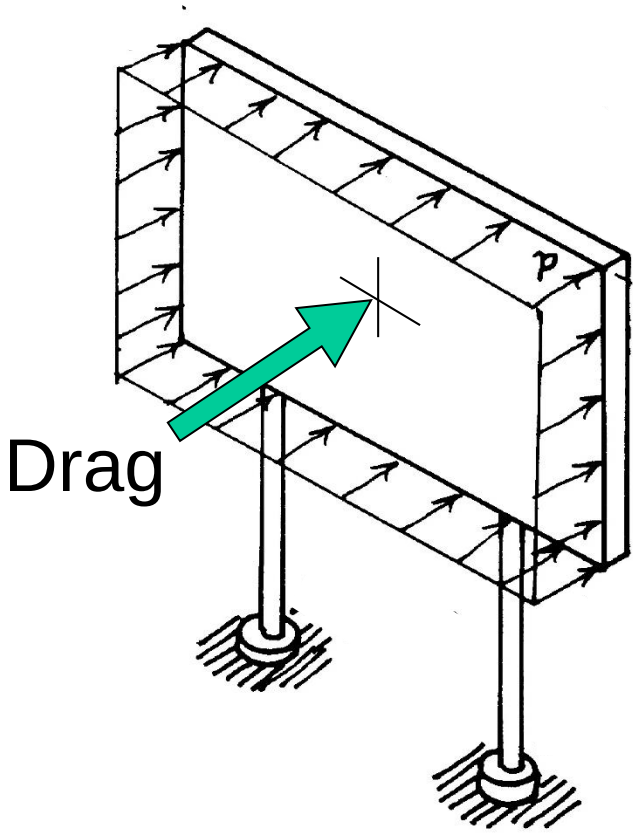


Net Wind Pressure Coefficient

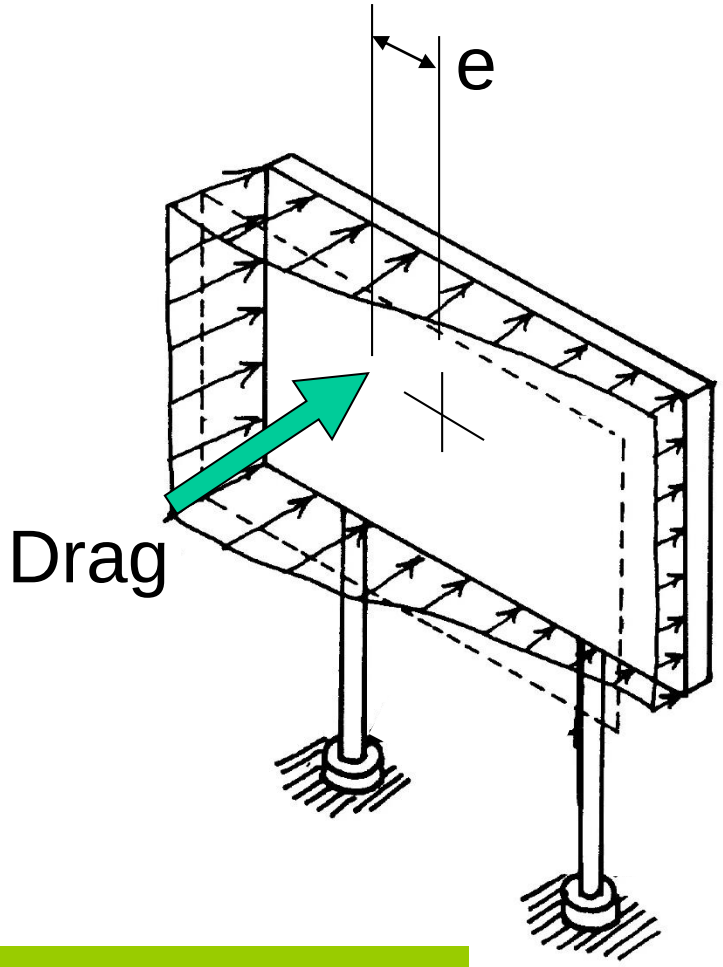
(Wind direction is normal to the Billboard Panel)



Design Wind Pressure in Building Control Regulation



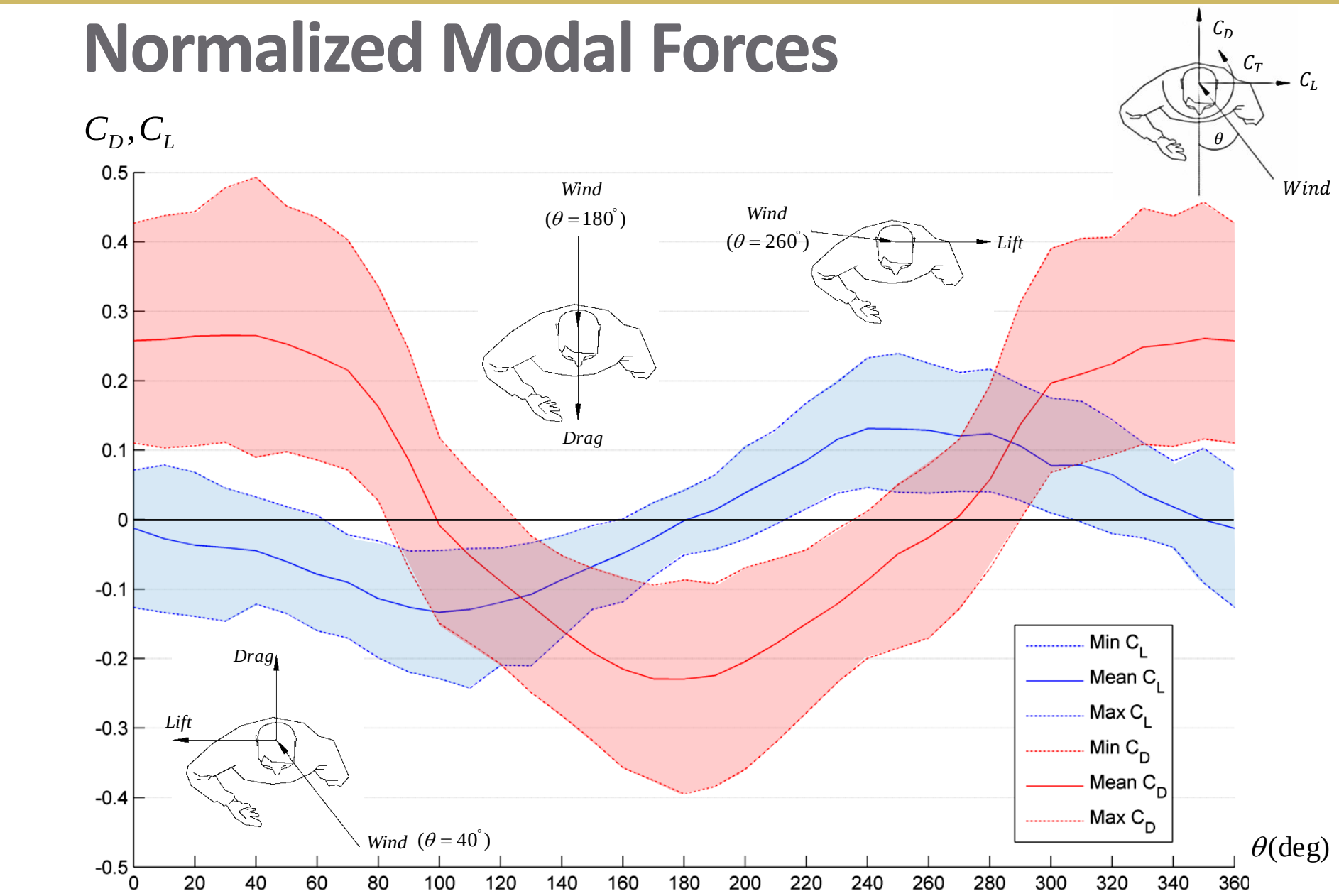
Actual Wind Pressure In Reality



Drag x e = Torsion

A 40-m Tall Buddha Statue
in Kanchanaburi Province

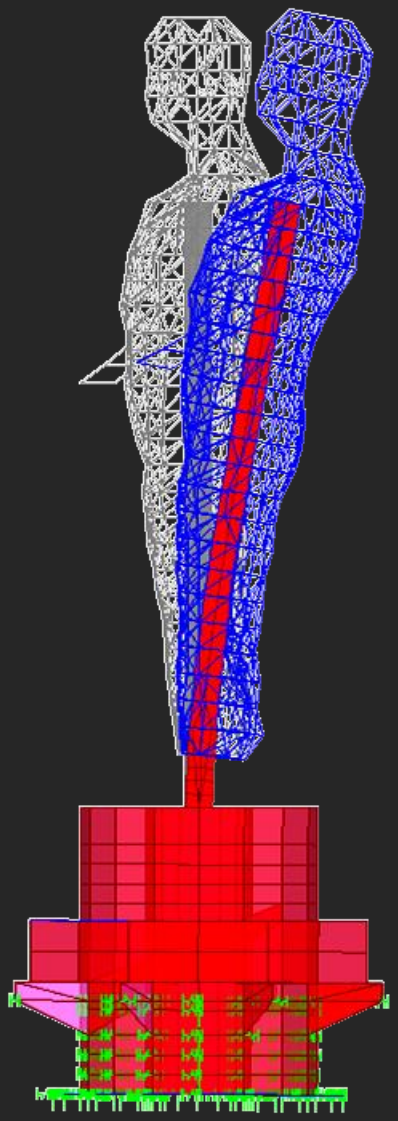
Normalized Modal Forces



Mode 1

T = 0.94 sec

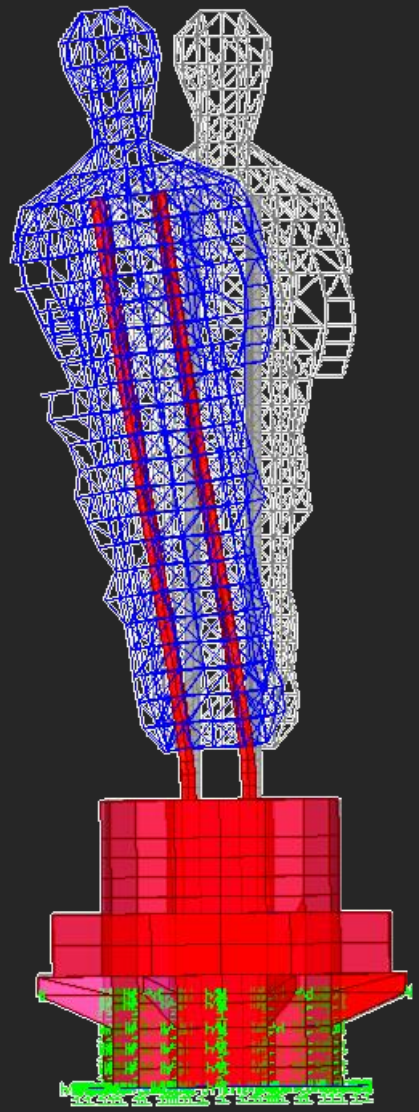
f = 1.06 Hz



Mode 2

T = 0.62 sec

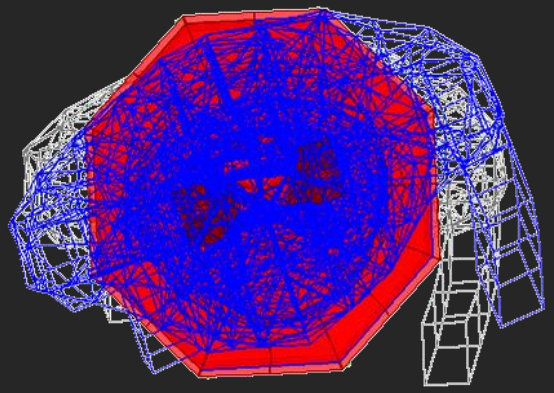
f = 1.62 Hz



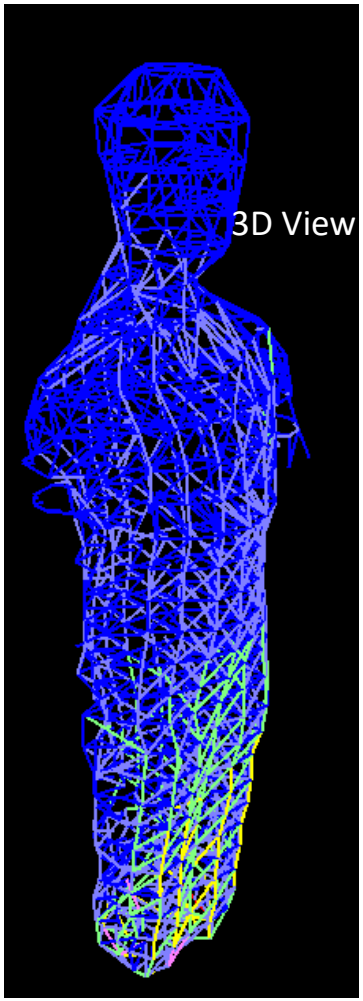
Mode 3

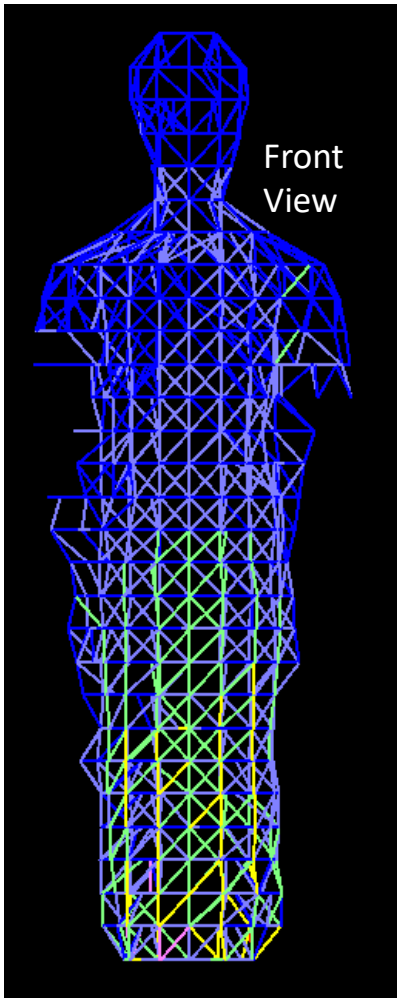
T = 0.30 sec

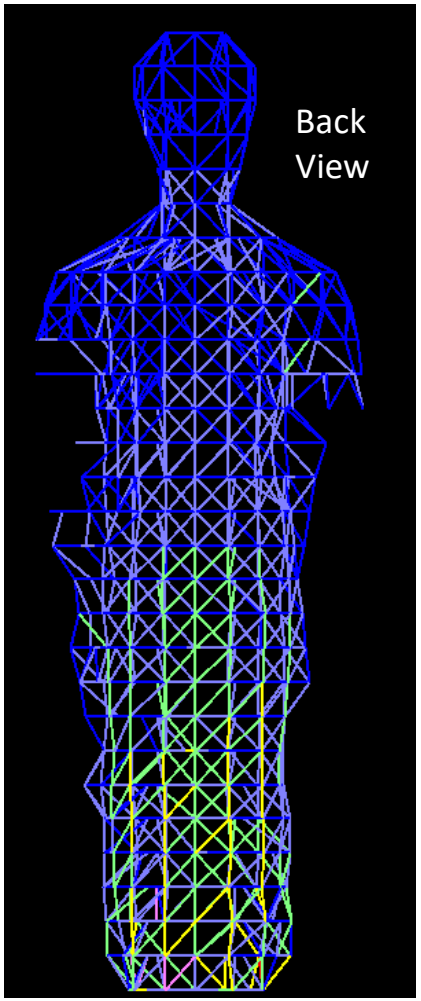
f = 3.40 Hz



Secondary members (Wind-1000 yrs)





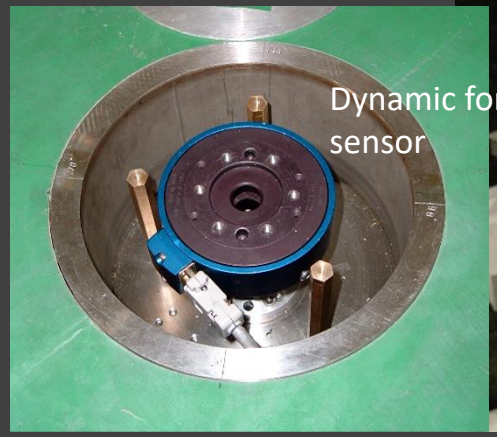


DC< 0.1	0.1<DC<0.3	0.3<DC<0.5	0.5<DC<0.8	0.8<DC<1	DC>1

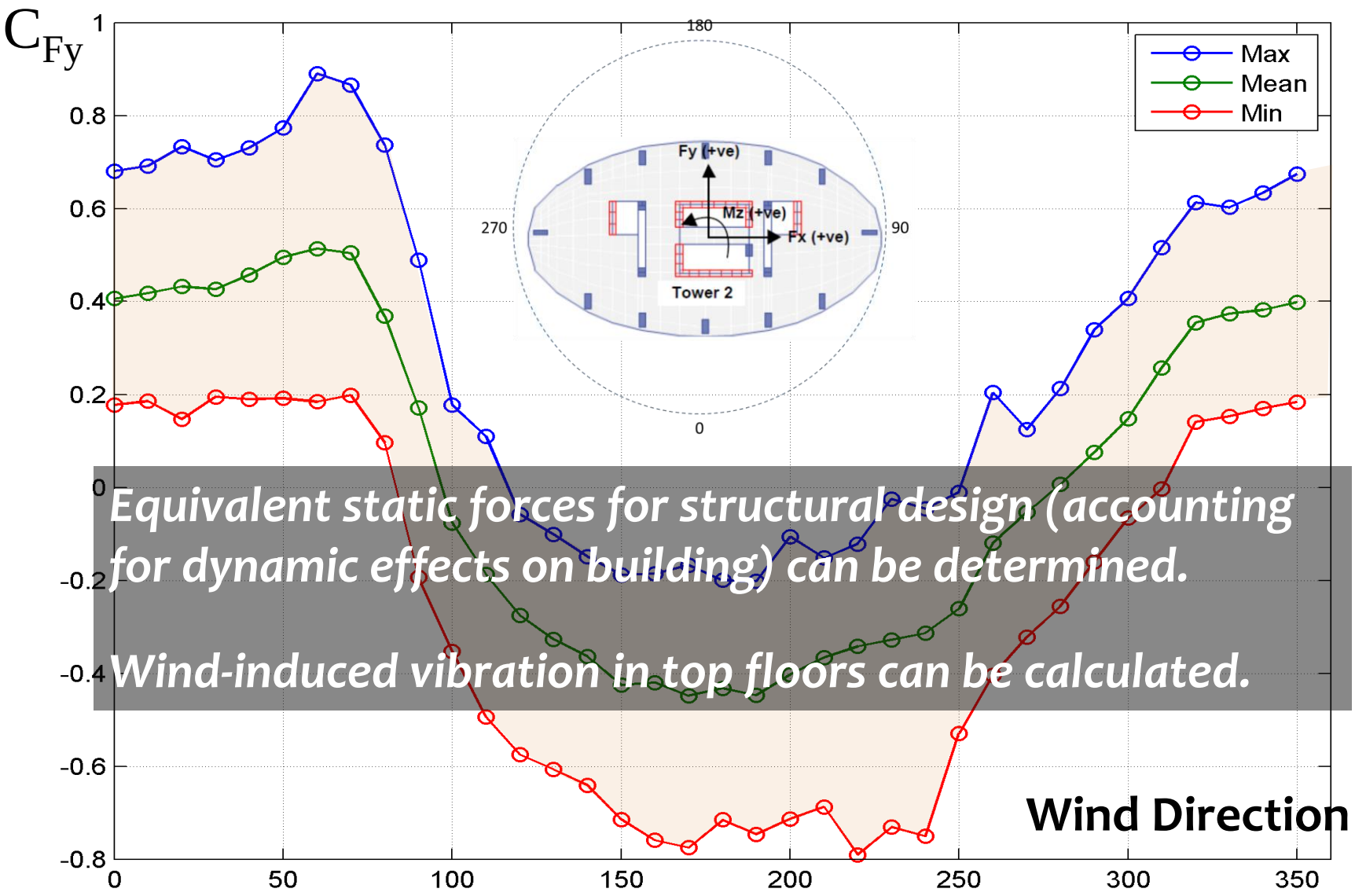
128 Nivel Hills, Cebu, Philippines

- *Tower1 (36-story, 118.9m high)*
- *Tower2 (44-story, 143.7m high)*
- *Garden residences (9-story,38.6m high)*

Measurement of Overall Wind Loading using High Frequency Force Balance (HFFB) Technique



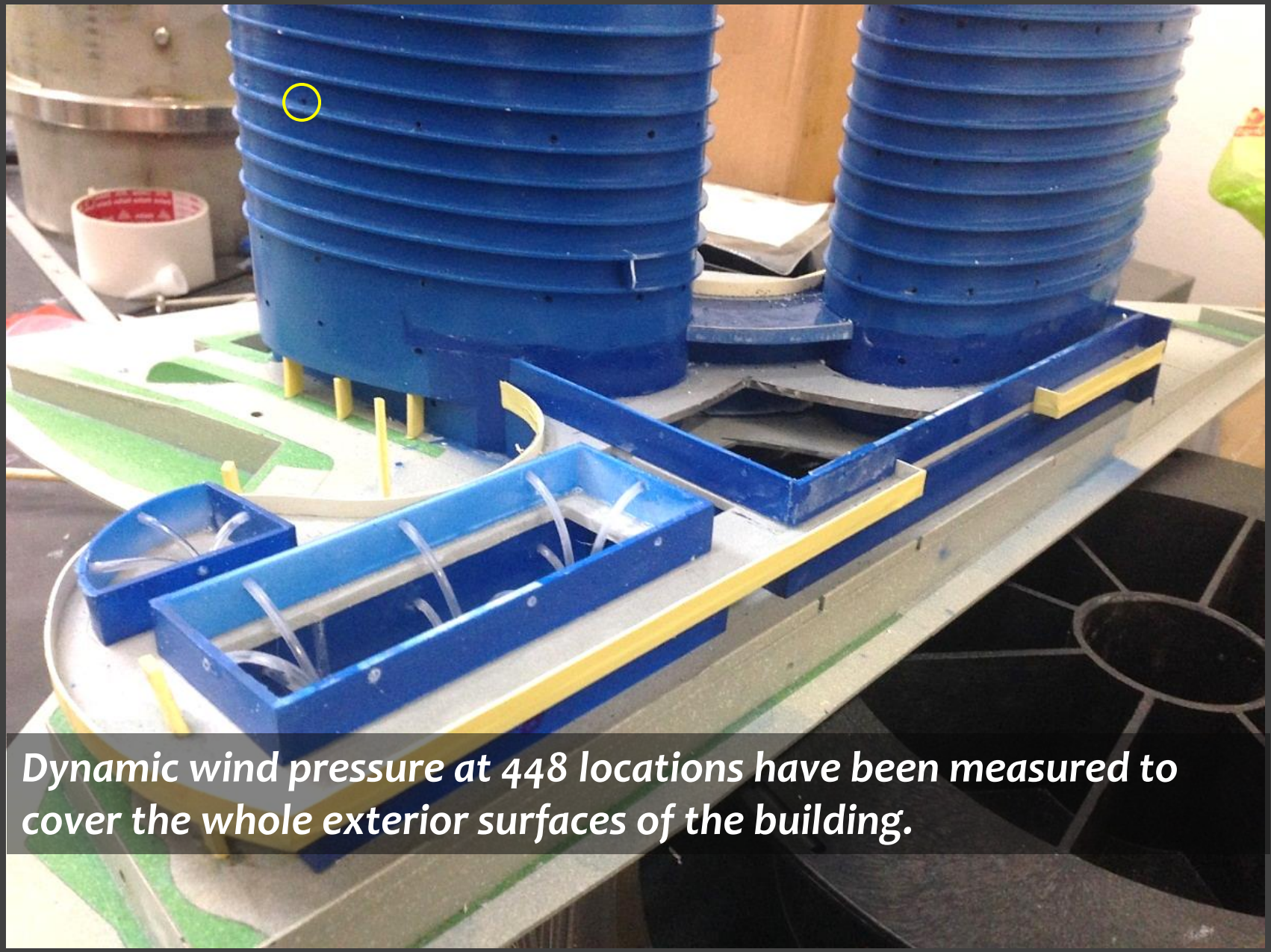
Wind Force Coefficients



Equivalent static forces for structural design (accounting for dynamic effects on building) can be determined.

Wind-induced vibration in top floors can be calculated.

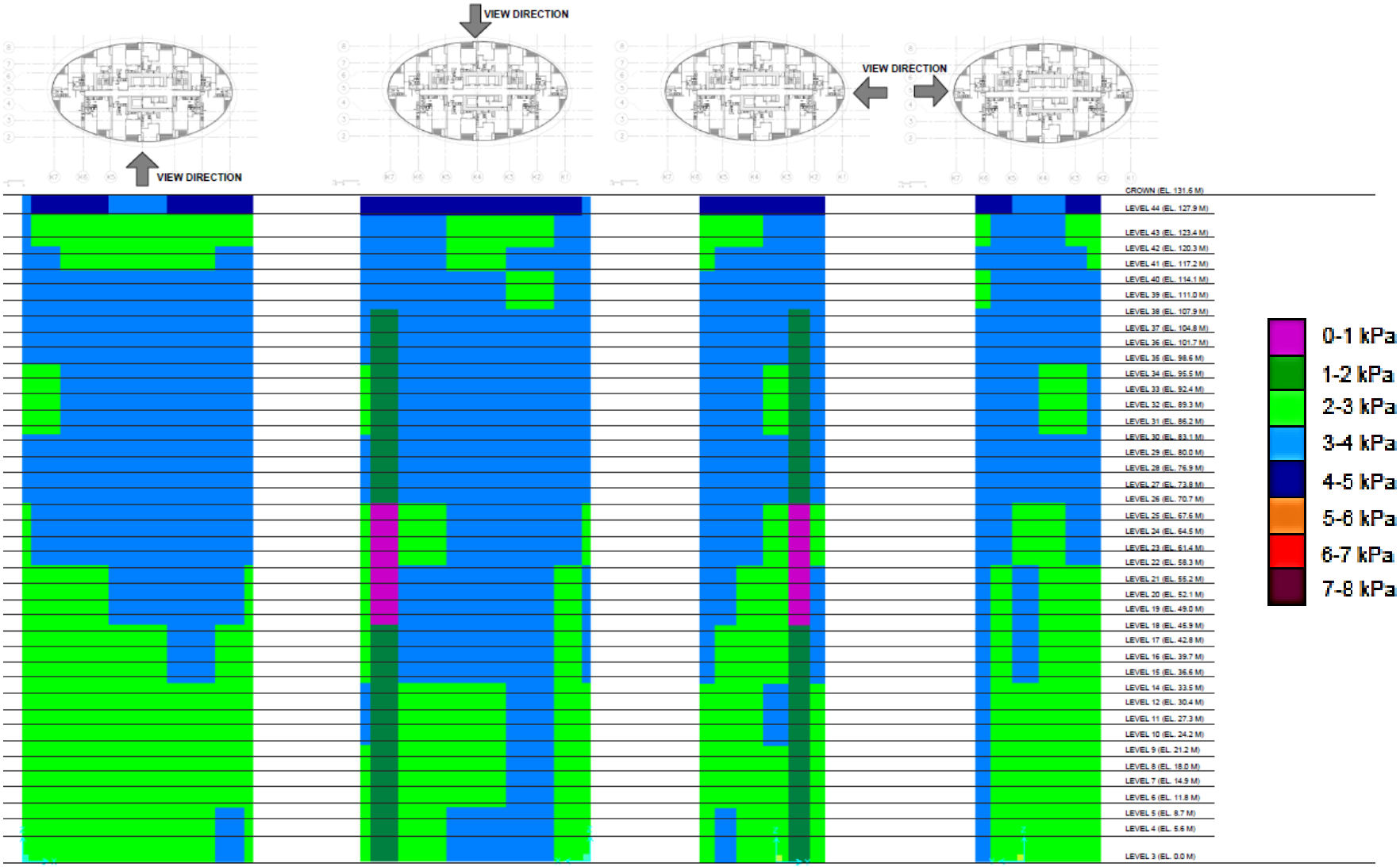
Measurement of Wind Pressure for Cladding Design



Dynamic wind pressure at 448 locations have been measured to cover the whole exterior surfaces of the building.

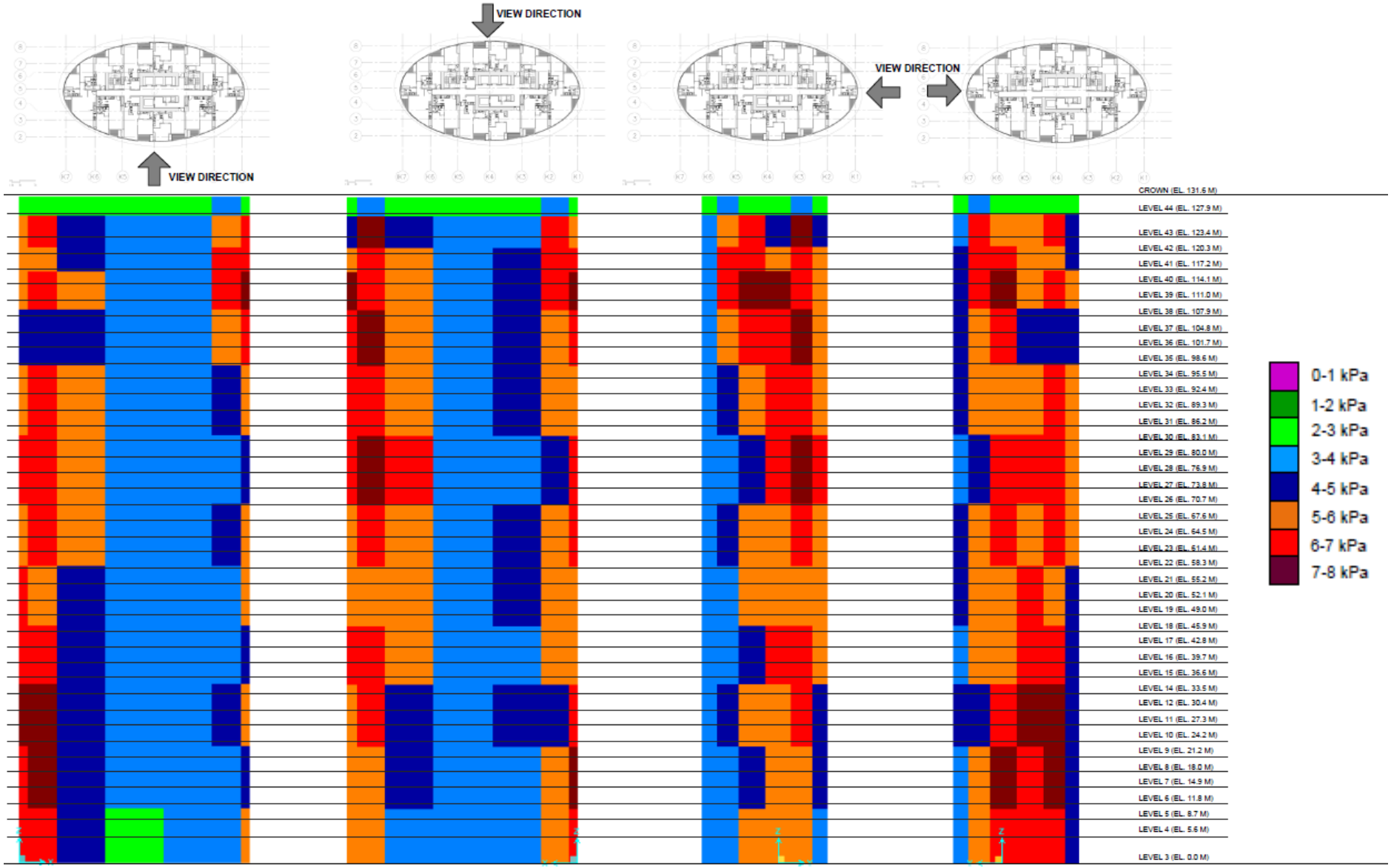
Recommended Positive Wind Pressure for Cladding Design

Considering all possible wind attack angles



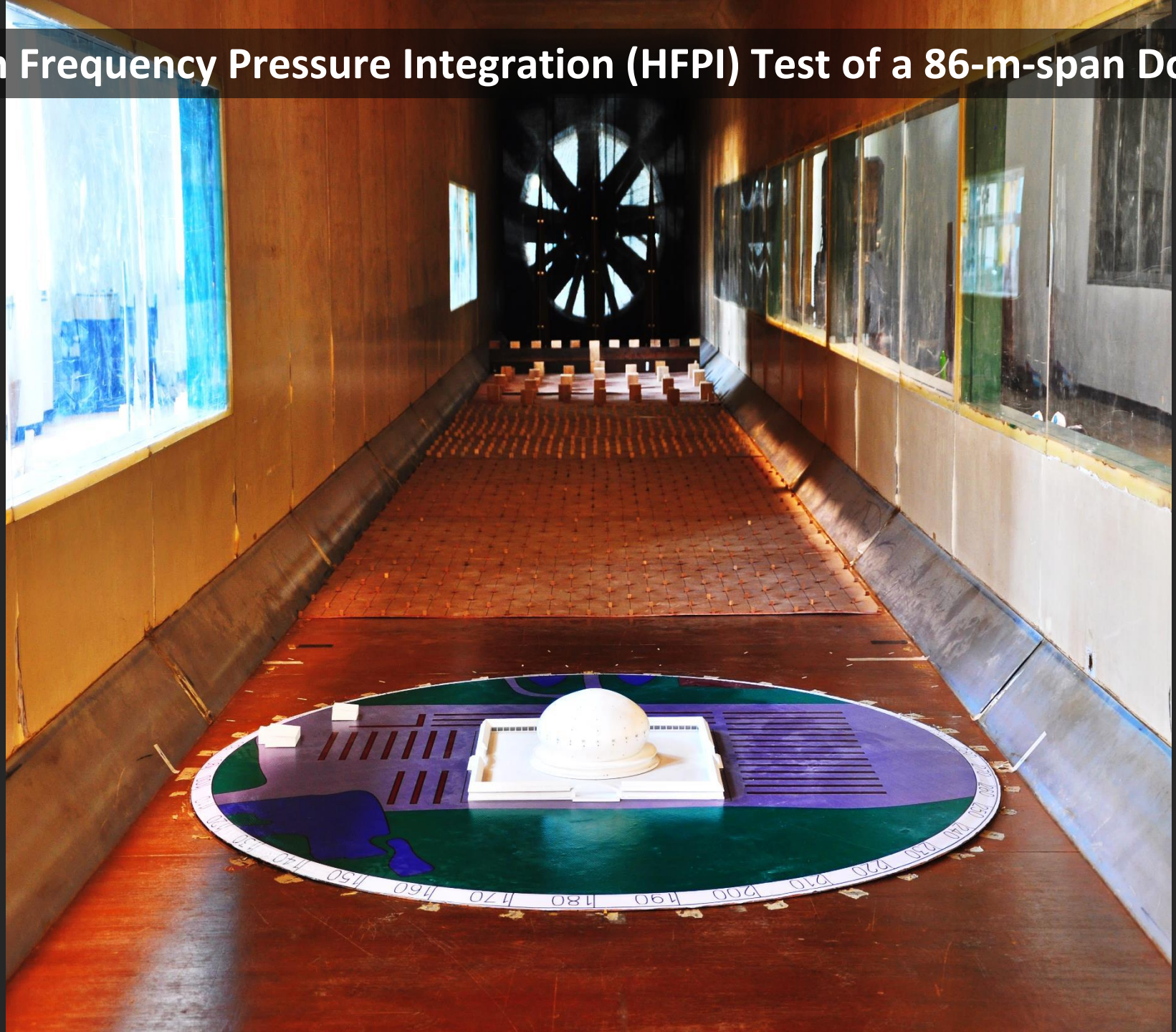
Recommended Negative Wind Pressure for Cladding Design

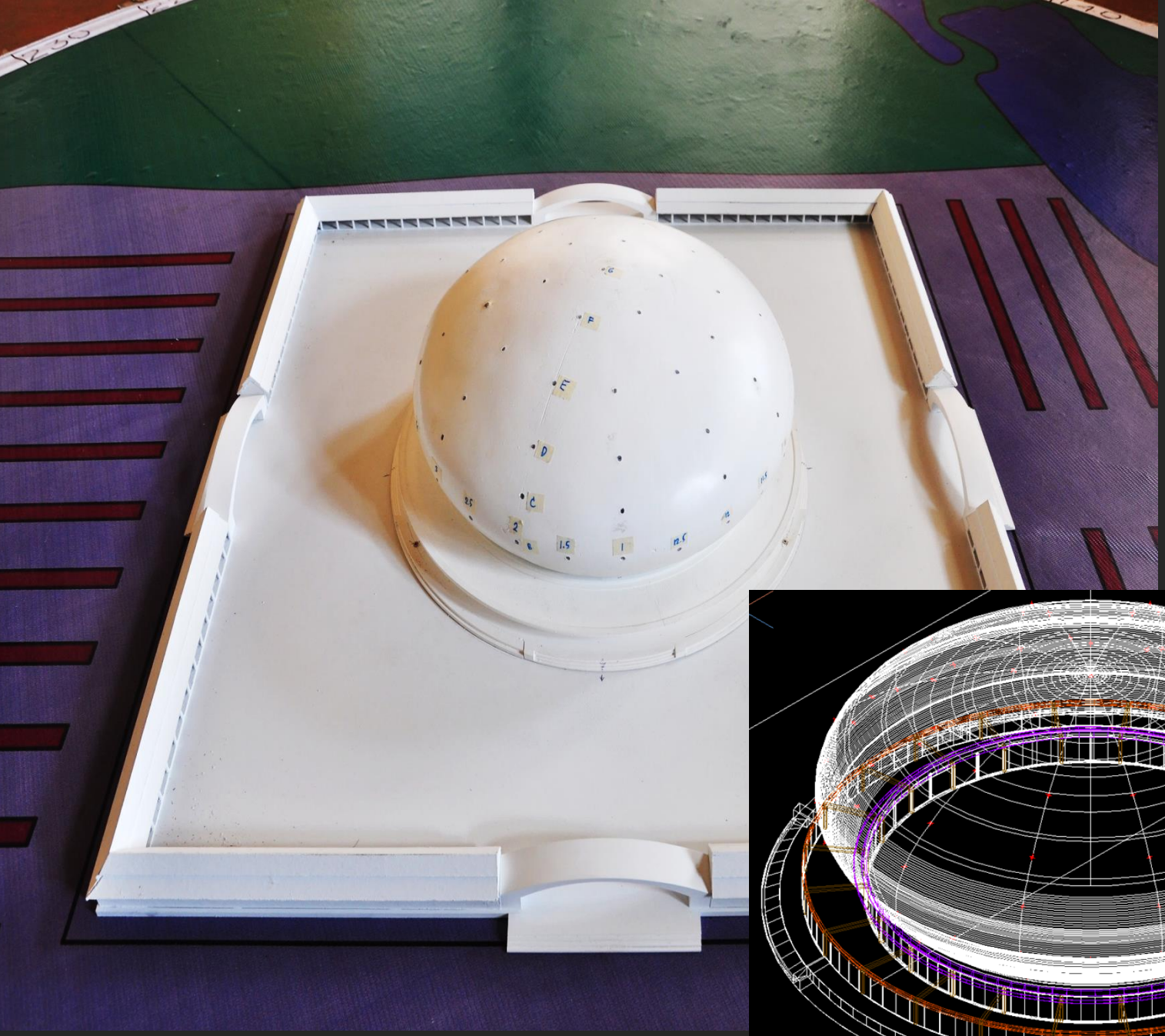
Considering all possible wind attack angles

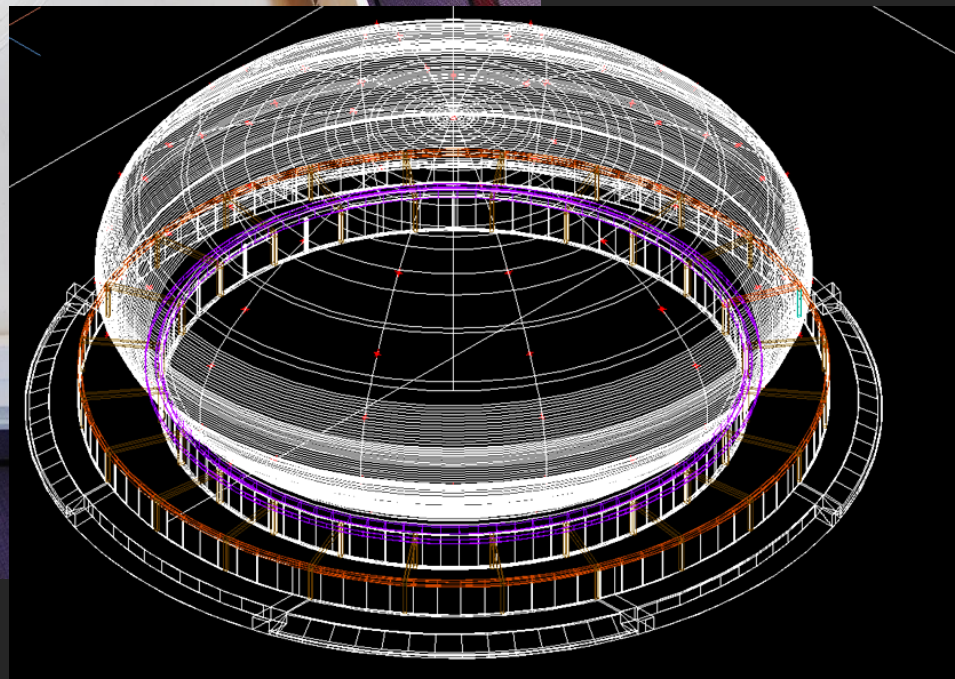


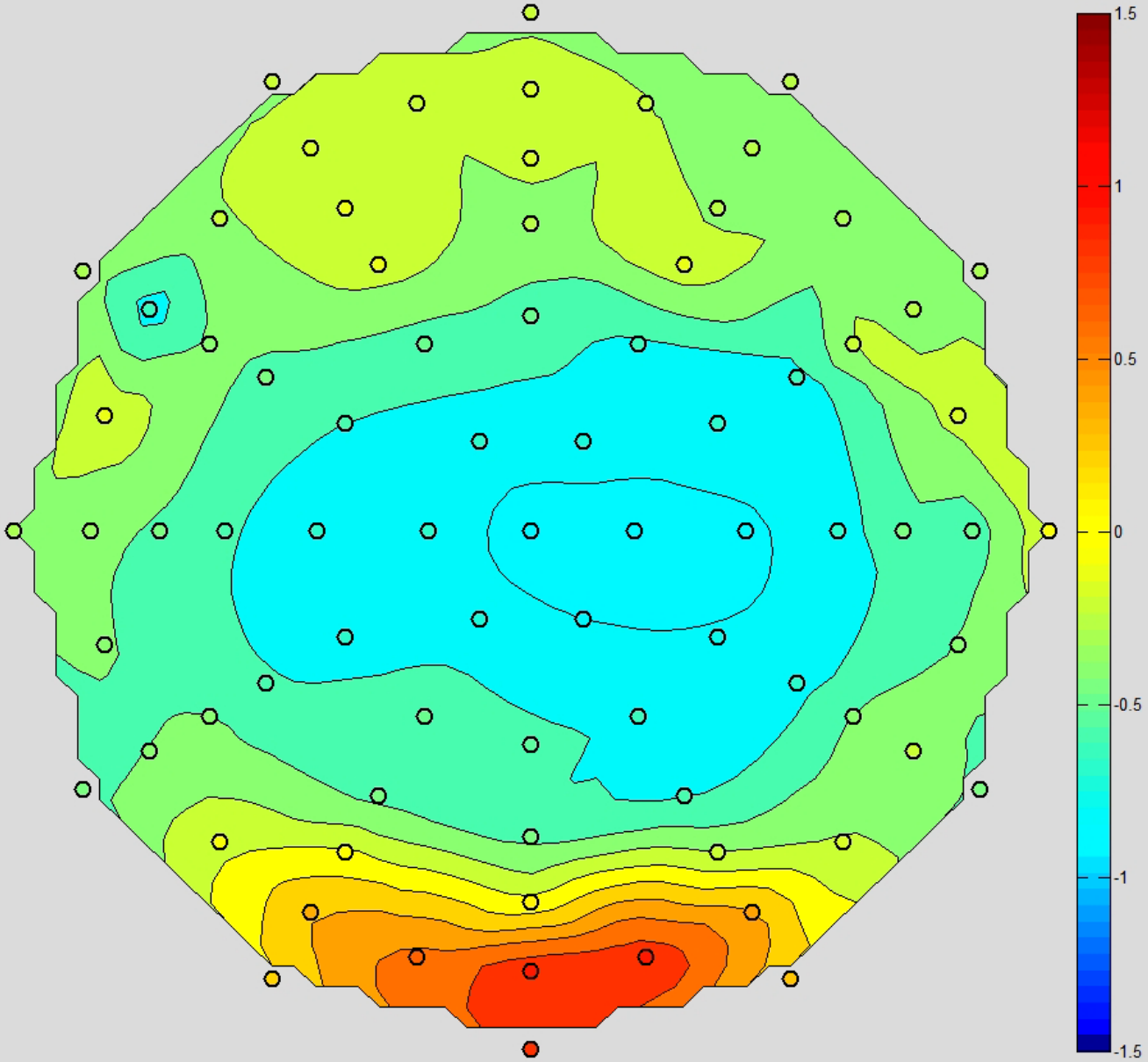
Measurement of Pedestrian Wind Velocity using Irwin Probe

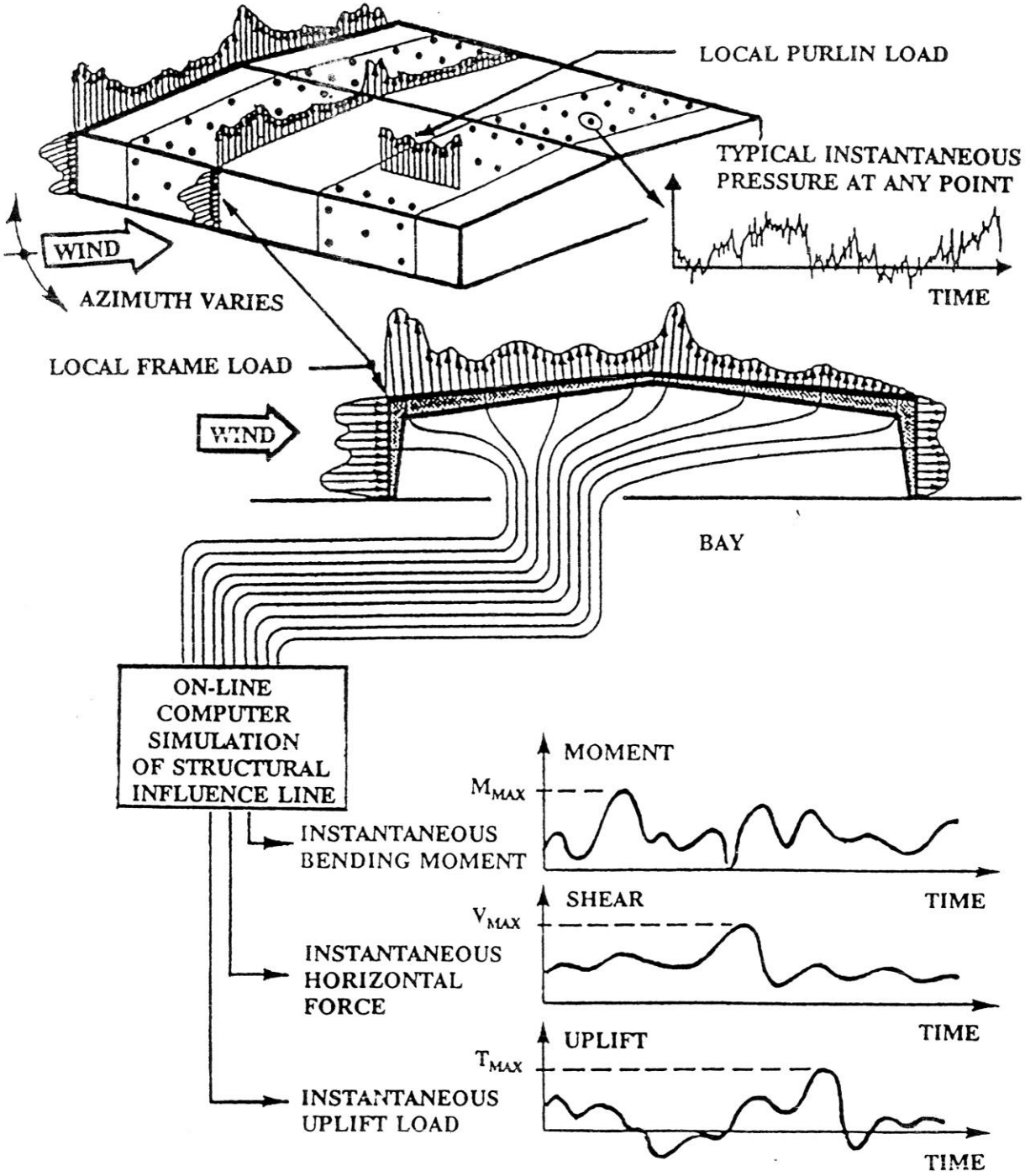
High Frequency Pressure Integration (HFPI) Test of a 86-m-span Dome




F
E
D
C
2.5
2
1.5
1
0.5



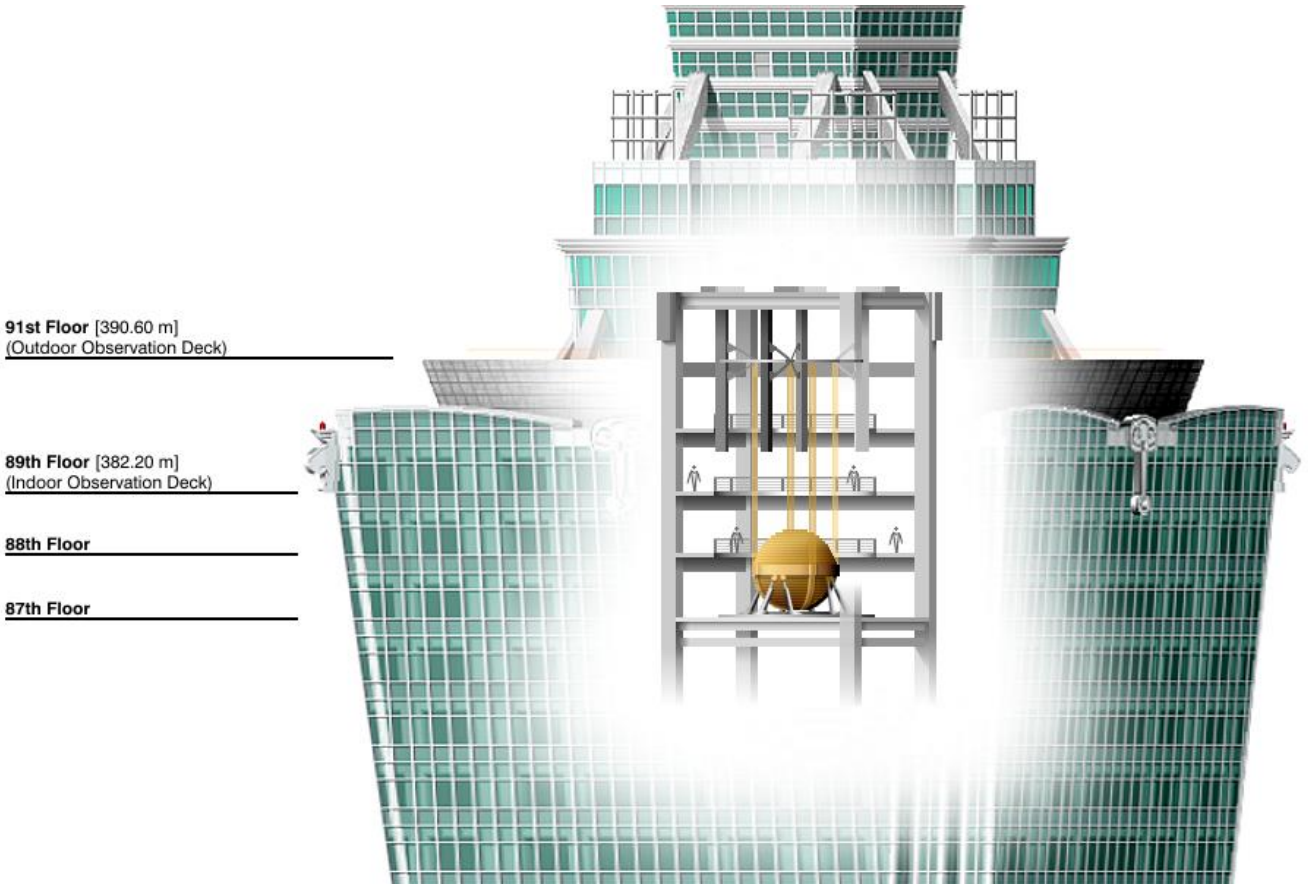

1.5
1
0.5
0
-0.5
-1
-1.5
t(sec)=0.0



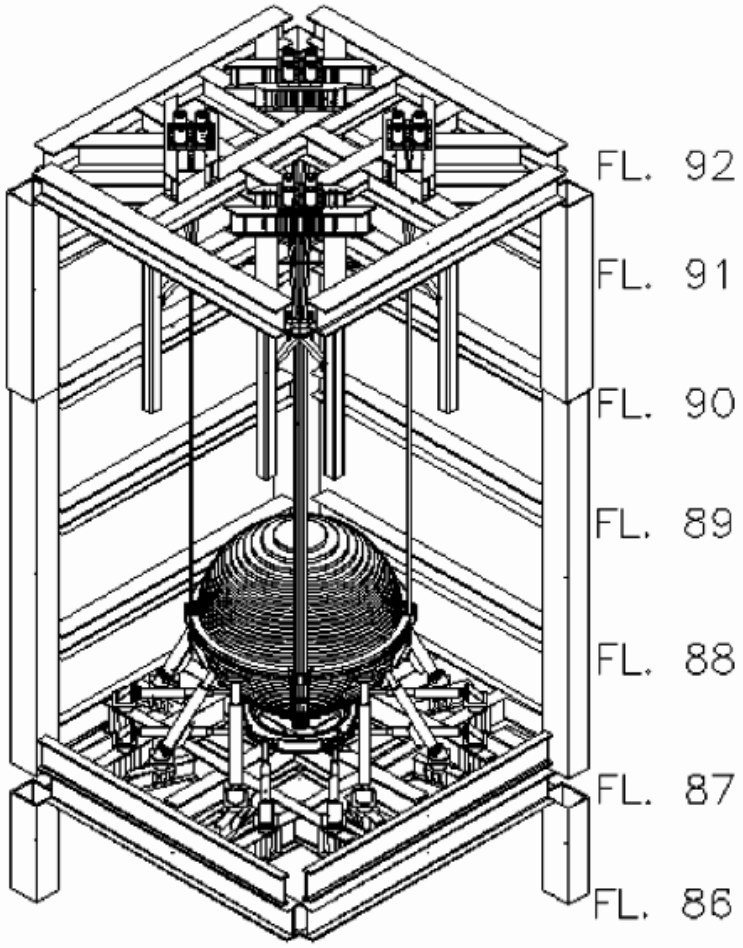
Computing wind forces and structural responses from records of distributed fluctuating pressures

Suppression of Wind-induced Vibration in Tall Buildings by using Tuned Mass Dampers

Pendulum TMD in Taipei 101, Taiwan



Pendulum-type TMD

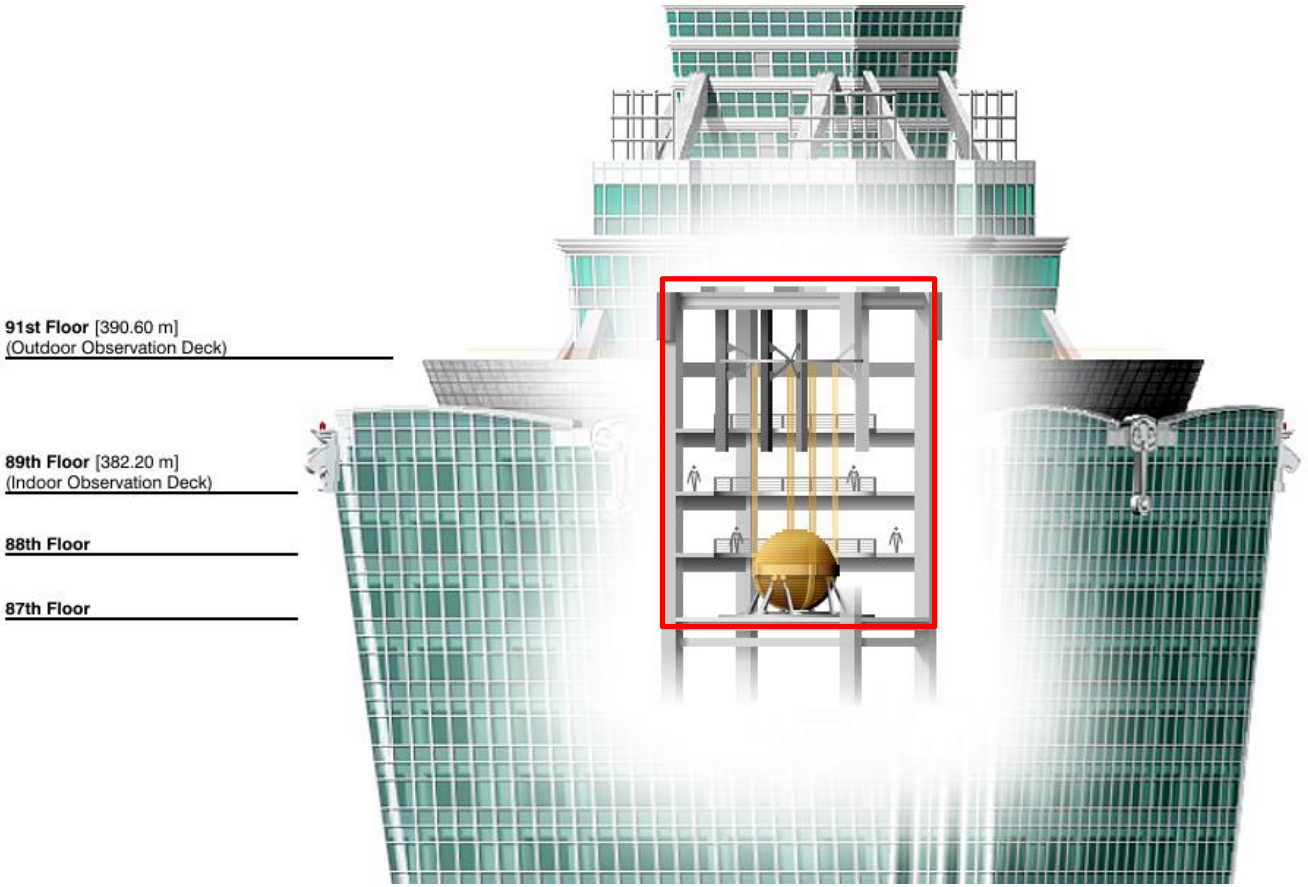


TMD made from Multi-stage Steel-laminated Rubber Bearings

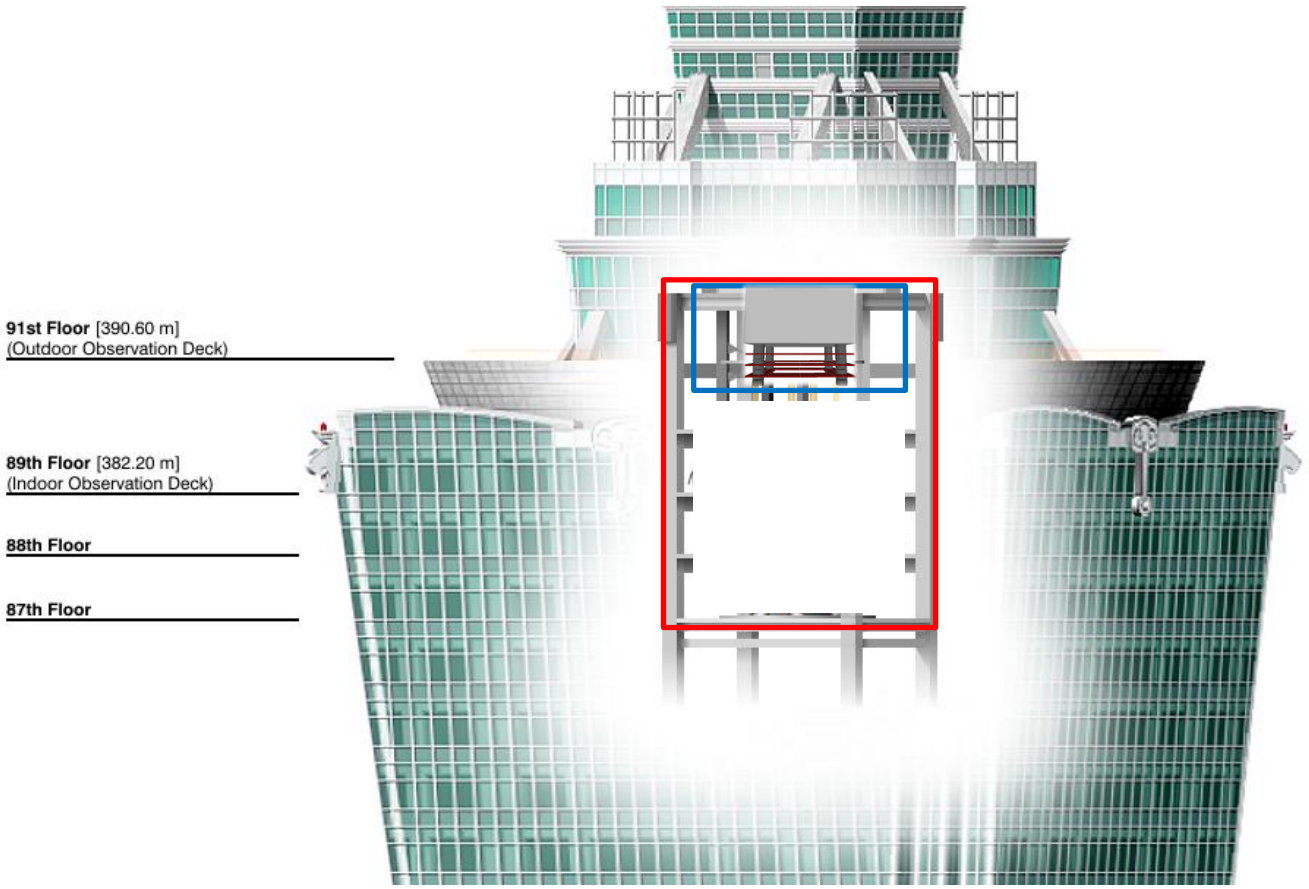
- *Occupy only small space*
- *Simple construction*
- *Low maintenance requirement*
- *Low cost !*

Suppression of Wind-induced Vibration in Tall Buildings by using Tuned Mass Dampers

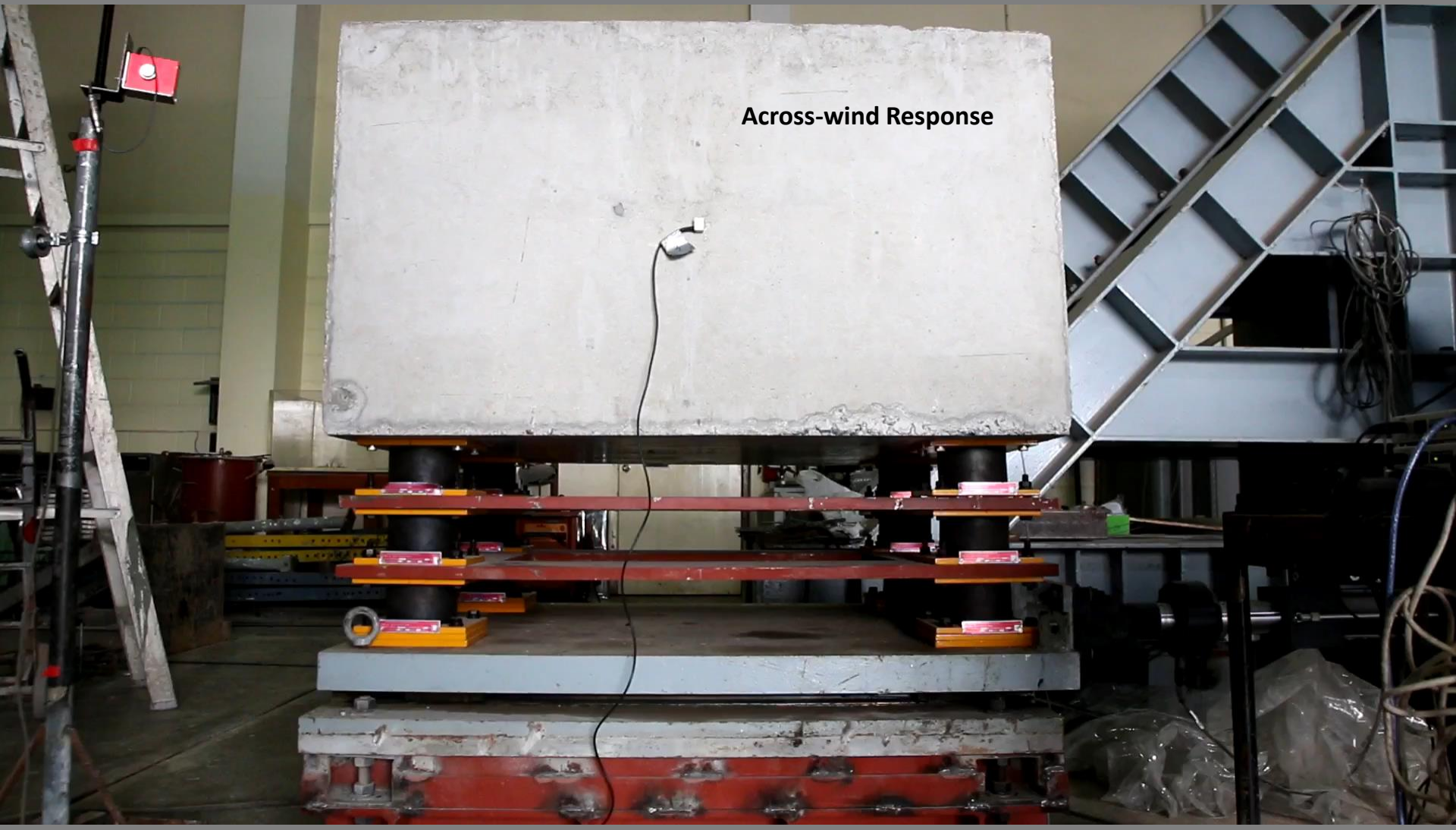
Pendulum TMD in Taipei 101, Taiwan

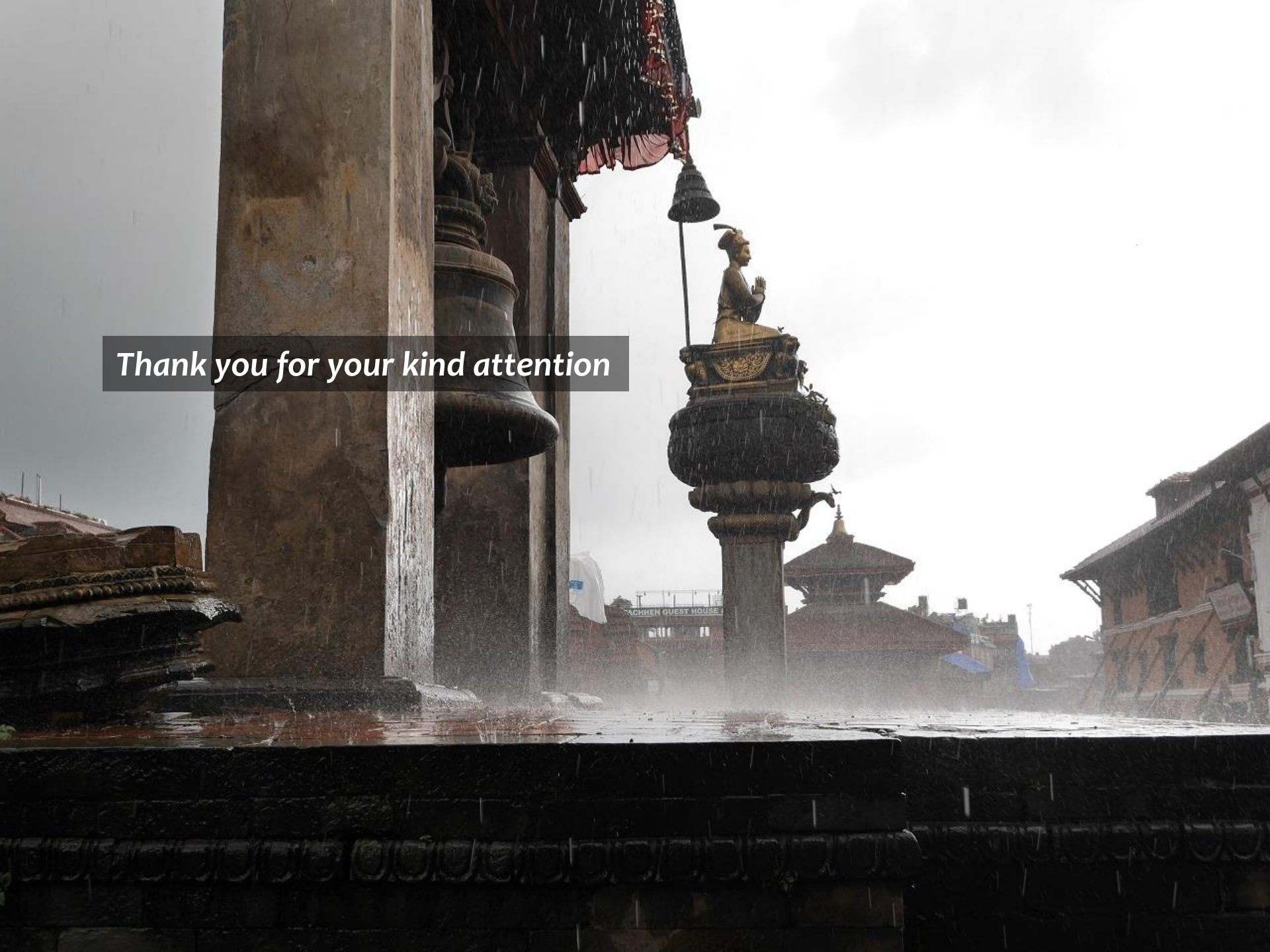


Suppression of Wind-induced Vibration in Tall Buildings by using Tuned Mass Dampers



Testing of TMD on Shake Table




Thank you for your kind attention