

STRUCTURAL HEALTH MONITORING AND DEVELOPMENT OF ANALYTICAL MODELS

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WHY DO WE MONITOR STRUCTURES?

- **To determine the in-situ dynamic characteristics of the structure**
- **To check the design and analysis methods used.**
- **To improve structural design codes.**
- **To develop new retrofit and strengthening techniques.**
- **To predict behavior for future extreme loads.**
- **To detect and locate damage after an extreme event.**
- **To develop instantaneous damage distribution and loss maps.**



İSTANBUL BÜYÜKŞEHİR BELEDİYESİ
İMAR MÜDÜRLÜĞÜ

İSTANBUL YÜKSEK BİNALAR DEPREM YÖNETMELİĞİ



Deprem Mühendisliği Anabilim Dalı
Kandilli Rasathanesi ve Deprem Araştırma Enstitüsü
Boğaziçi Üniversitesi
Çengelköy, İstanbul

Versiyon – IV

Mayıs 2008



SEISMIC ANALYSIS AND DESIGN REQUIREMENTS FOR BUILDINGS IN DUBAI, THE UNITED ARAB EMIRATES

prepared for

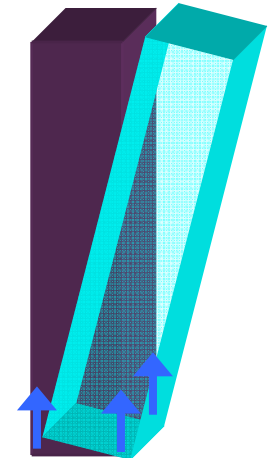
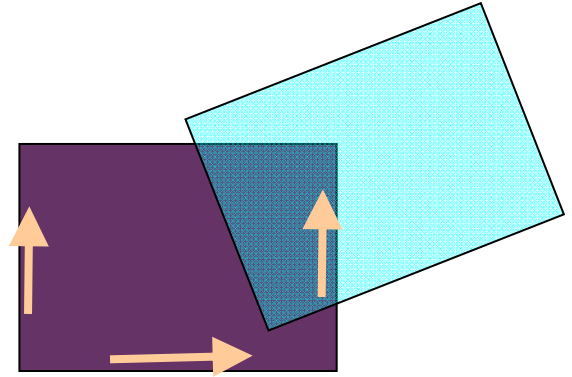
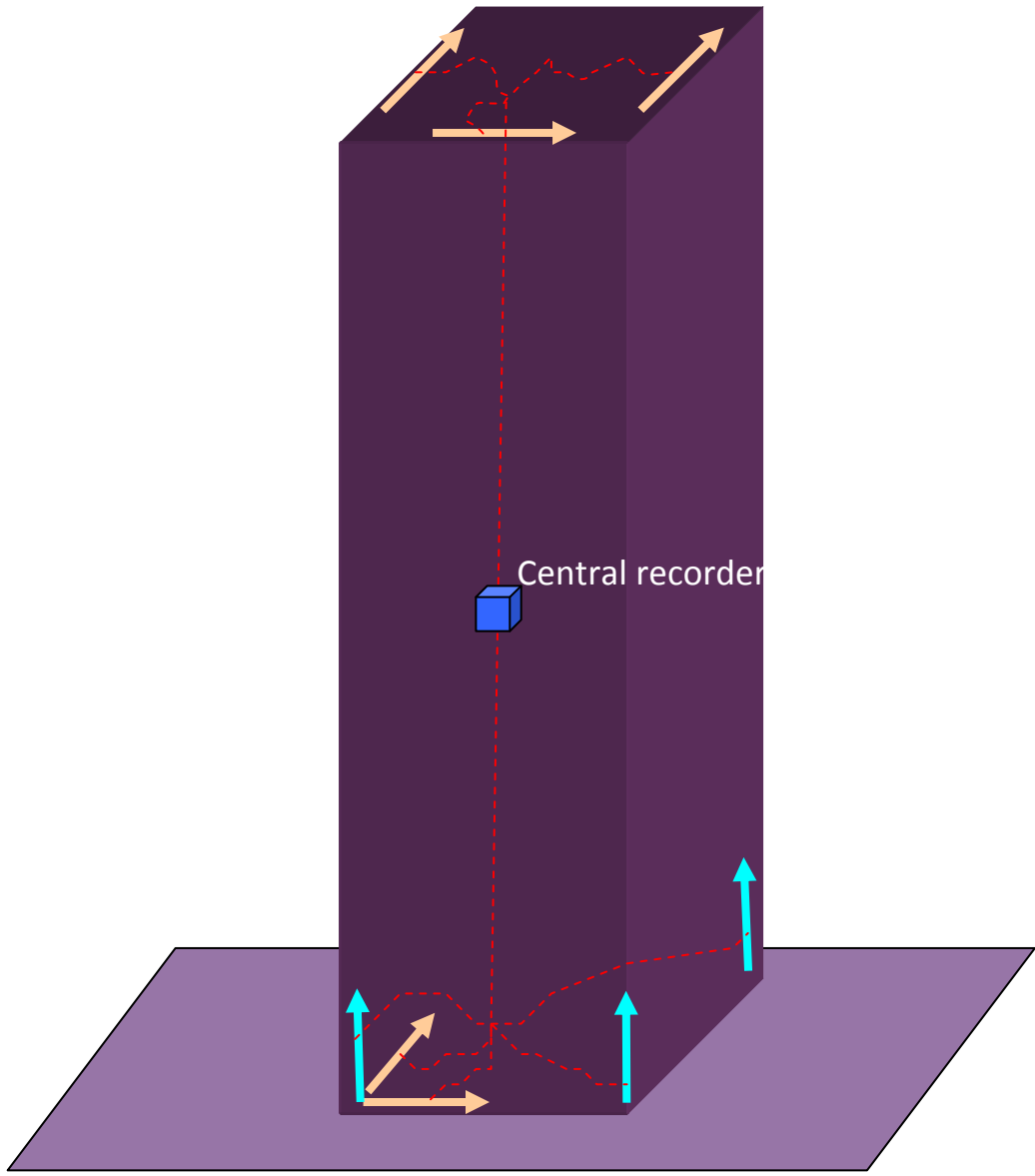
Dubai Municipality

by

Department of Earthquake Engineering
Kandilli Observatory and Earthquake Research Institute
Bogazici University, Istanbul, Turkey

April 2009

MINIMUM MONITORING SYSTEM FOR A TALL BUILDING





AN ALTERNATIVE PROCEDURE FOR SEISMIC ANALYSIS AND DESIGN OF TALL BUILDINGS LOCATED IN THE LOS ANGELES REGION

2008 Edition

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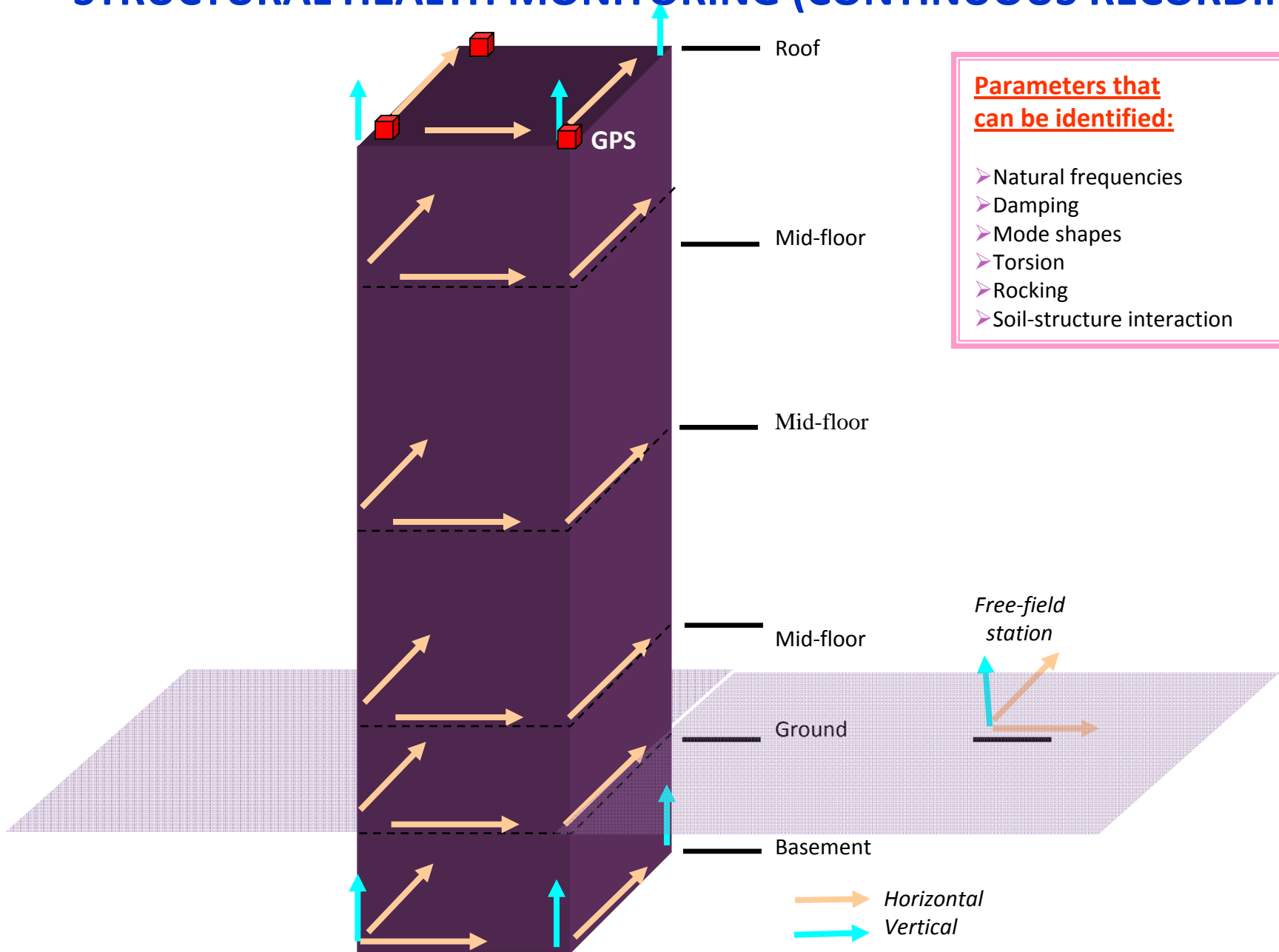
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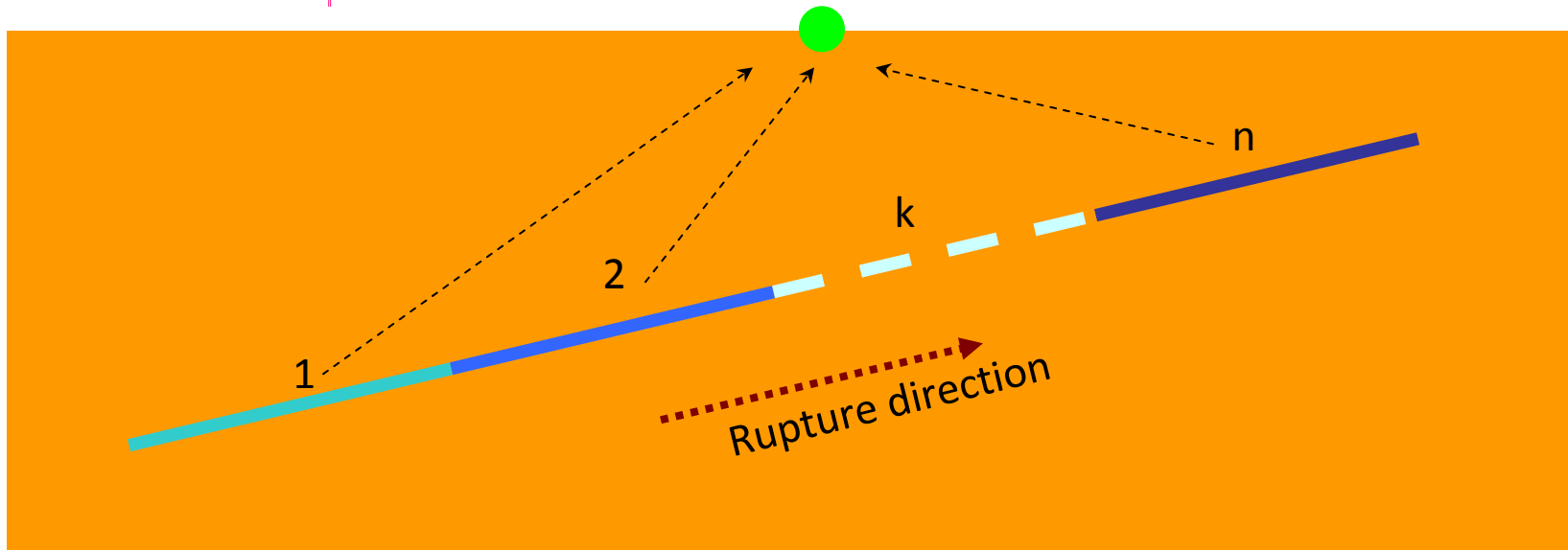
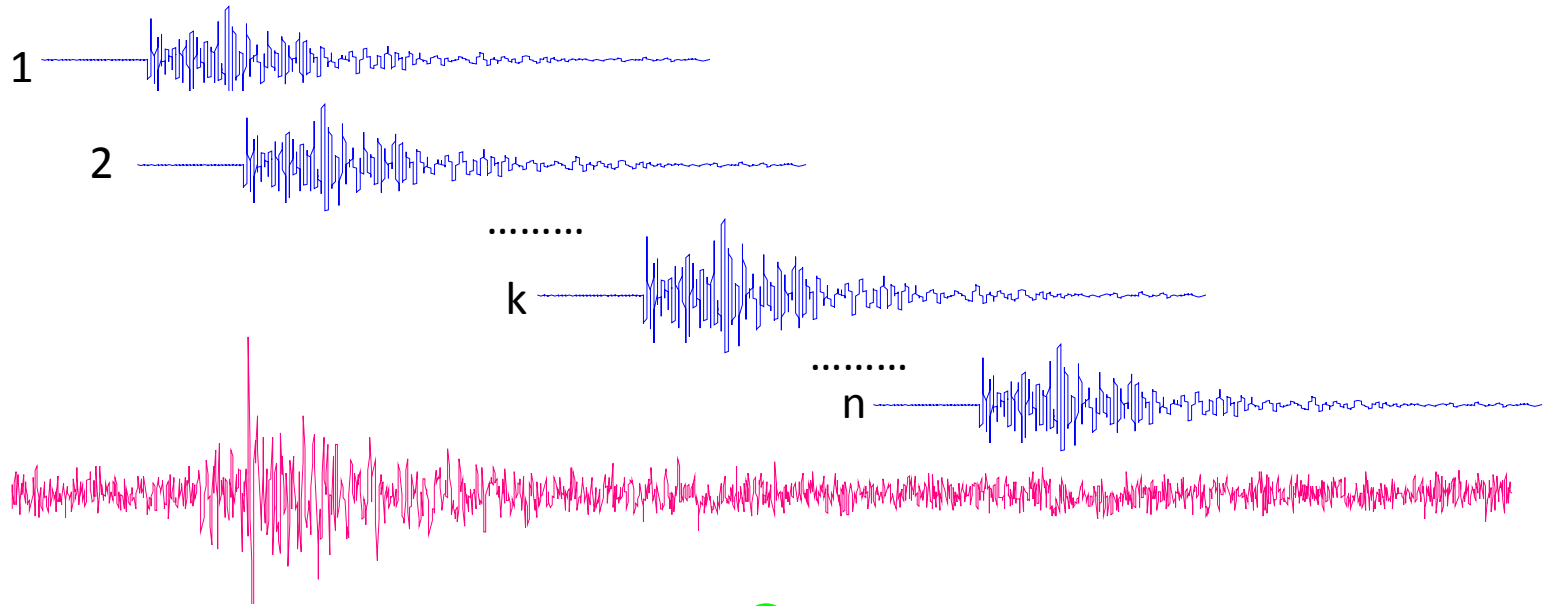
Table 3. Minimum Number of Channels of Instrumentation

Number of Stories Above Ground	Minimum Number of Channels
10 – 20	15
20 – 30	21
30 – 50	24
> 50	30

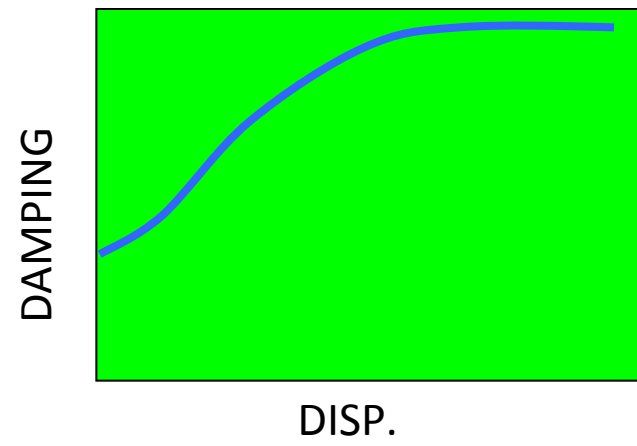
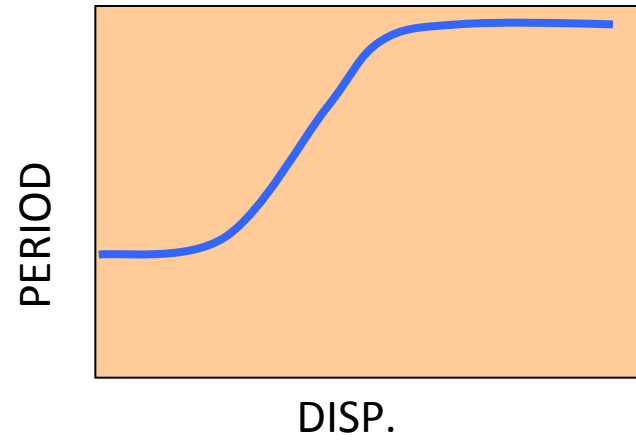
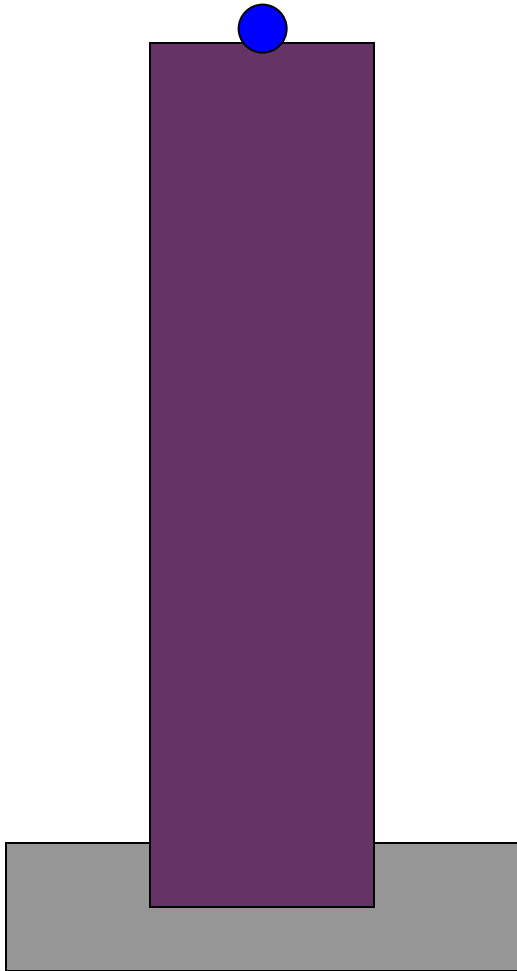
STRUCTURAL HEALTH MONITORING (CONTINUOUS RECORDING)



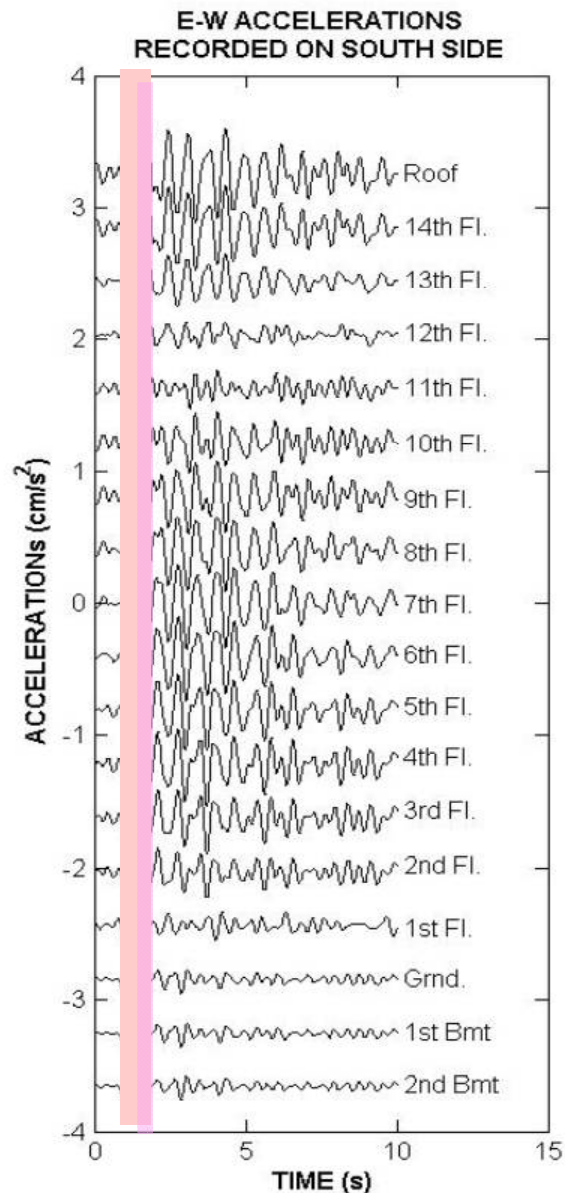
PREDICTION OF LARGE EARTHQUAKE MOTIONS FROM THE RECORDINGS OF SMALLER ONES



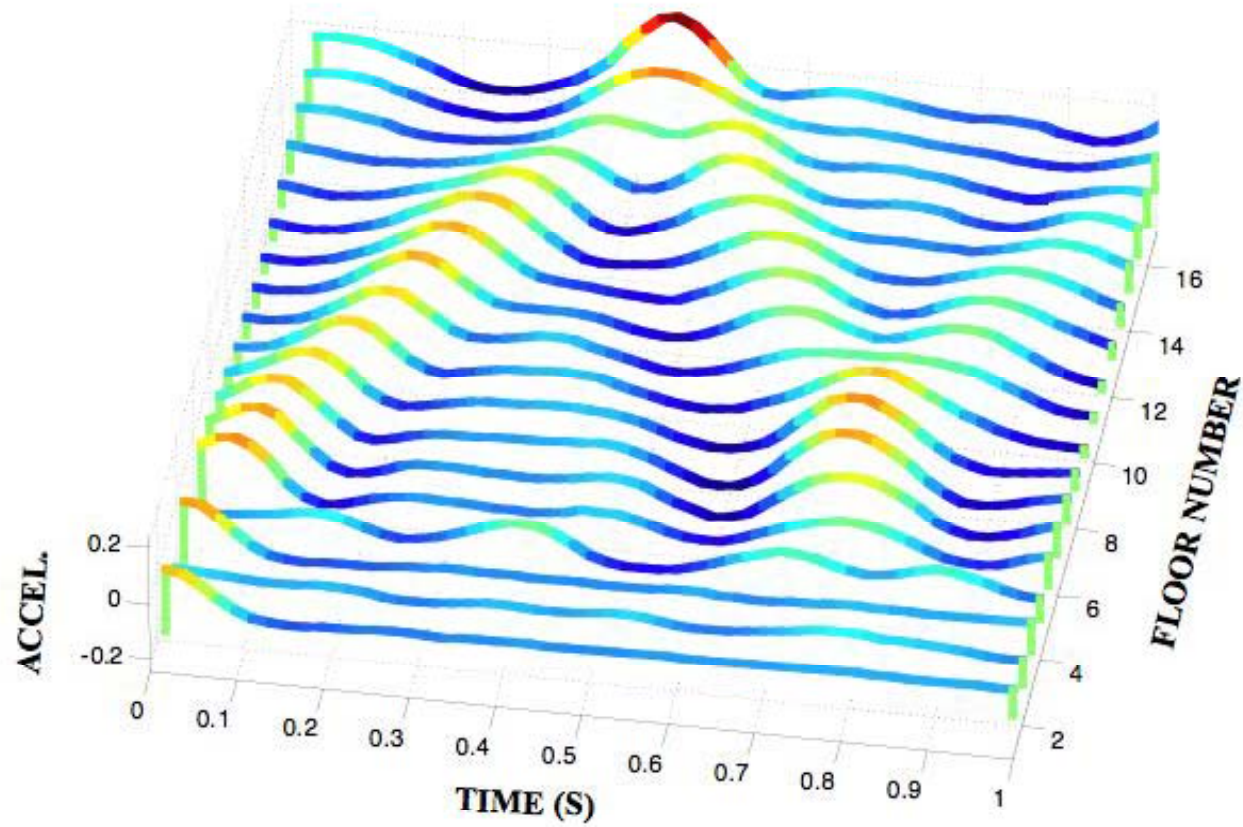
UTILIZATION OF SMALL-AMPLITUDE VIBRATIONS



WHAT DID WE HAVE LEARNED?



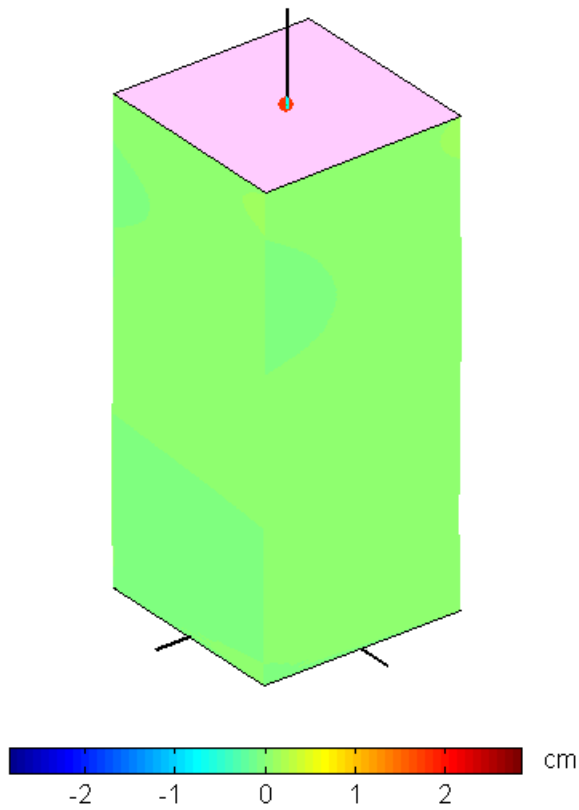
HORIZONTAL ACCELERATIONS AFTER DECONVOLUTION BY FOUNDATION ACCELERATIONS





ATWOOD BUILDING, ANCHORAGE, AK

M=3.7 Point MacKenzie Earthquake; Dec. 15, 2003 (Magnif.= x 1000)

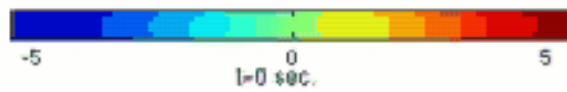
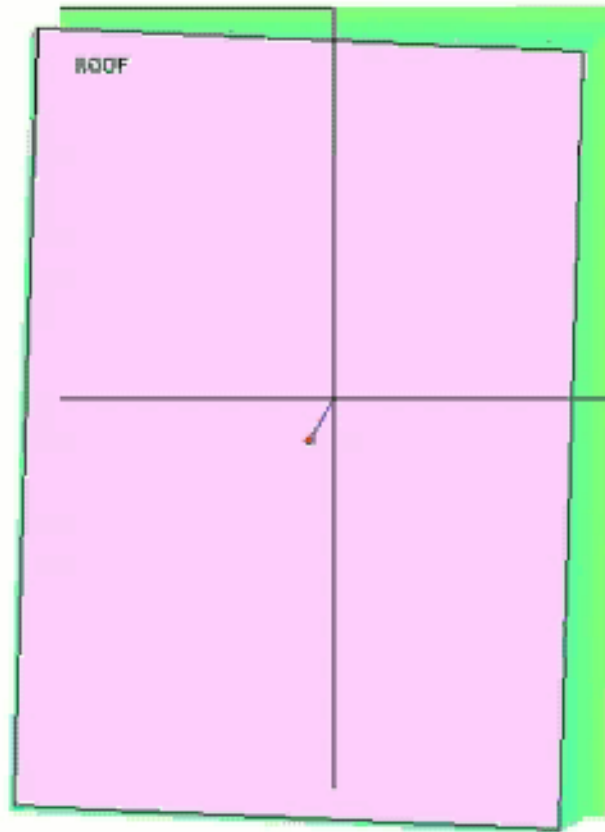


t=0 sec.

by E. Safak, USGS

FACTOR BUILDING AT UCLA CAMPUS

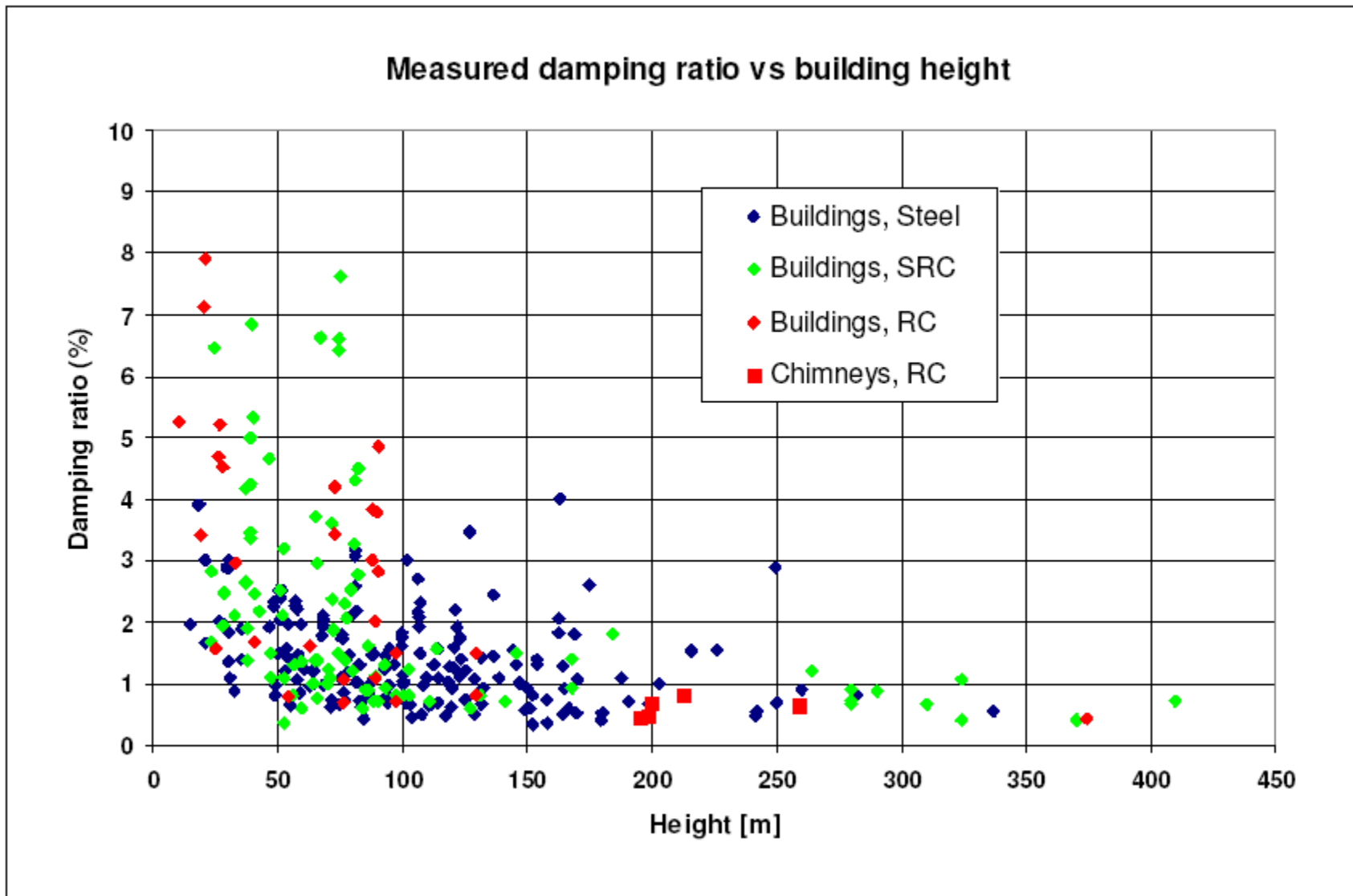
SANTA MONICA DAY EQ. - FIRST MODE at 0.5Hz (Magnif. = x 10000)



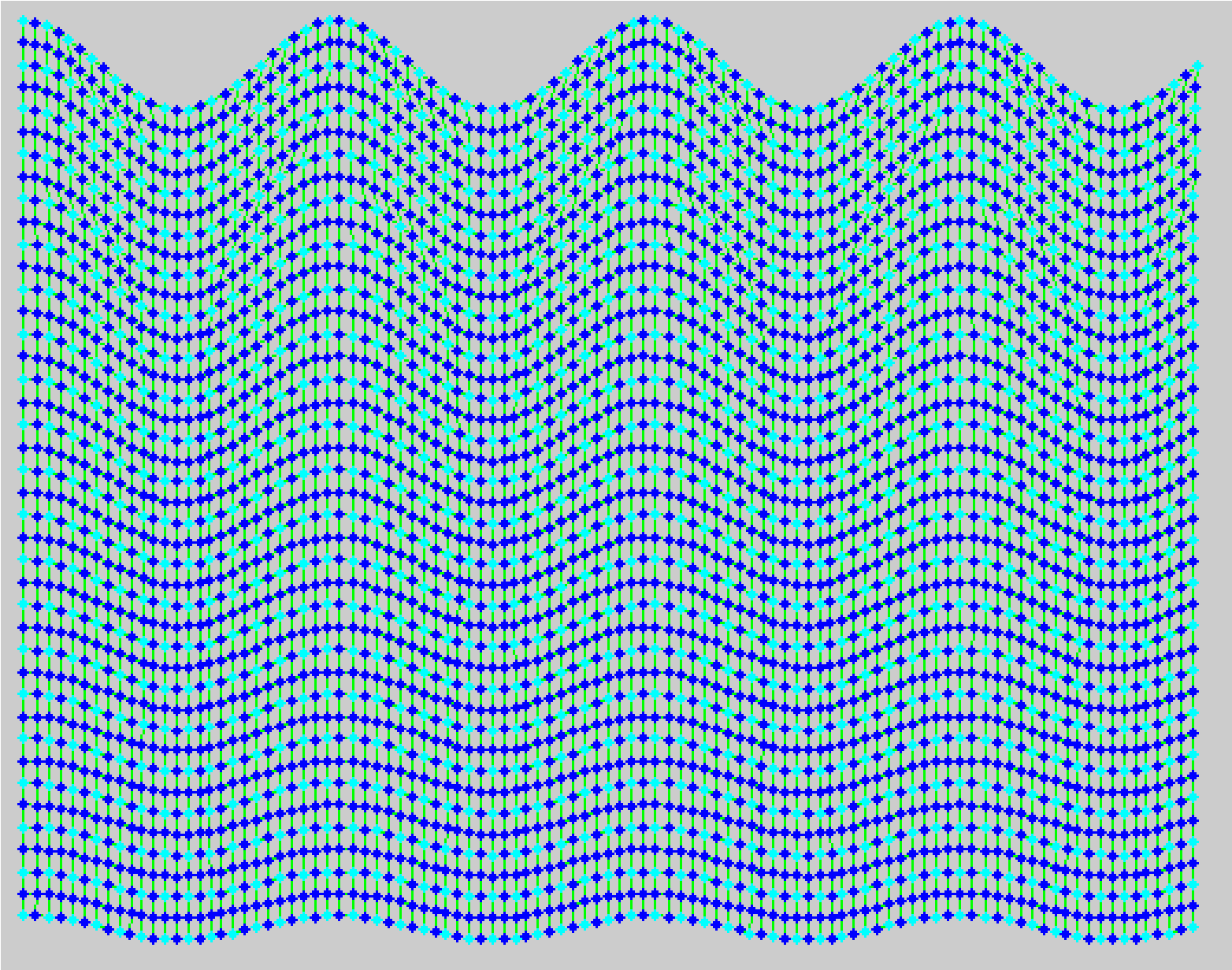
cm

by E. Sakak, 1995

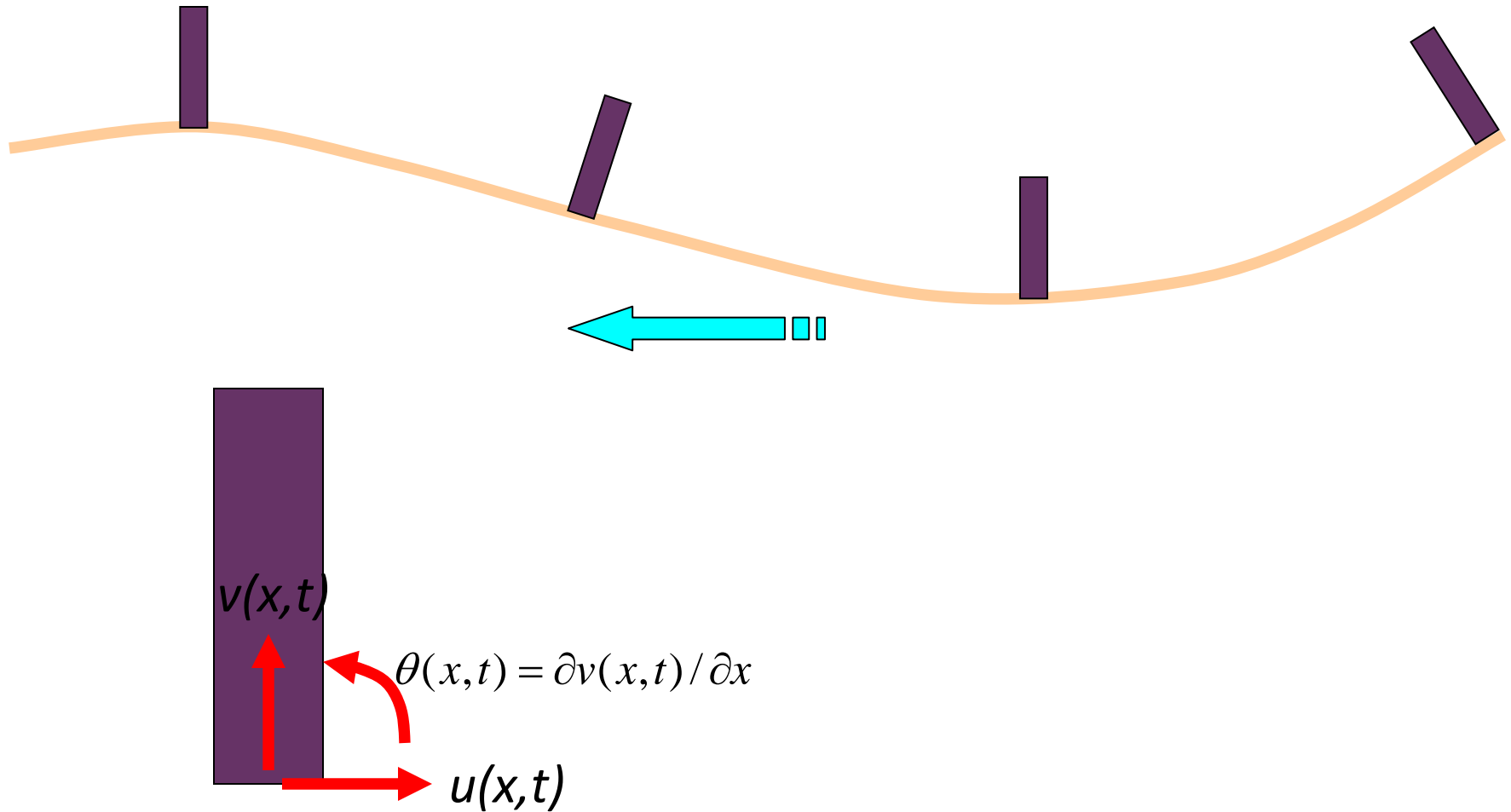




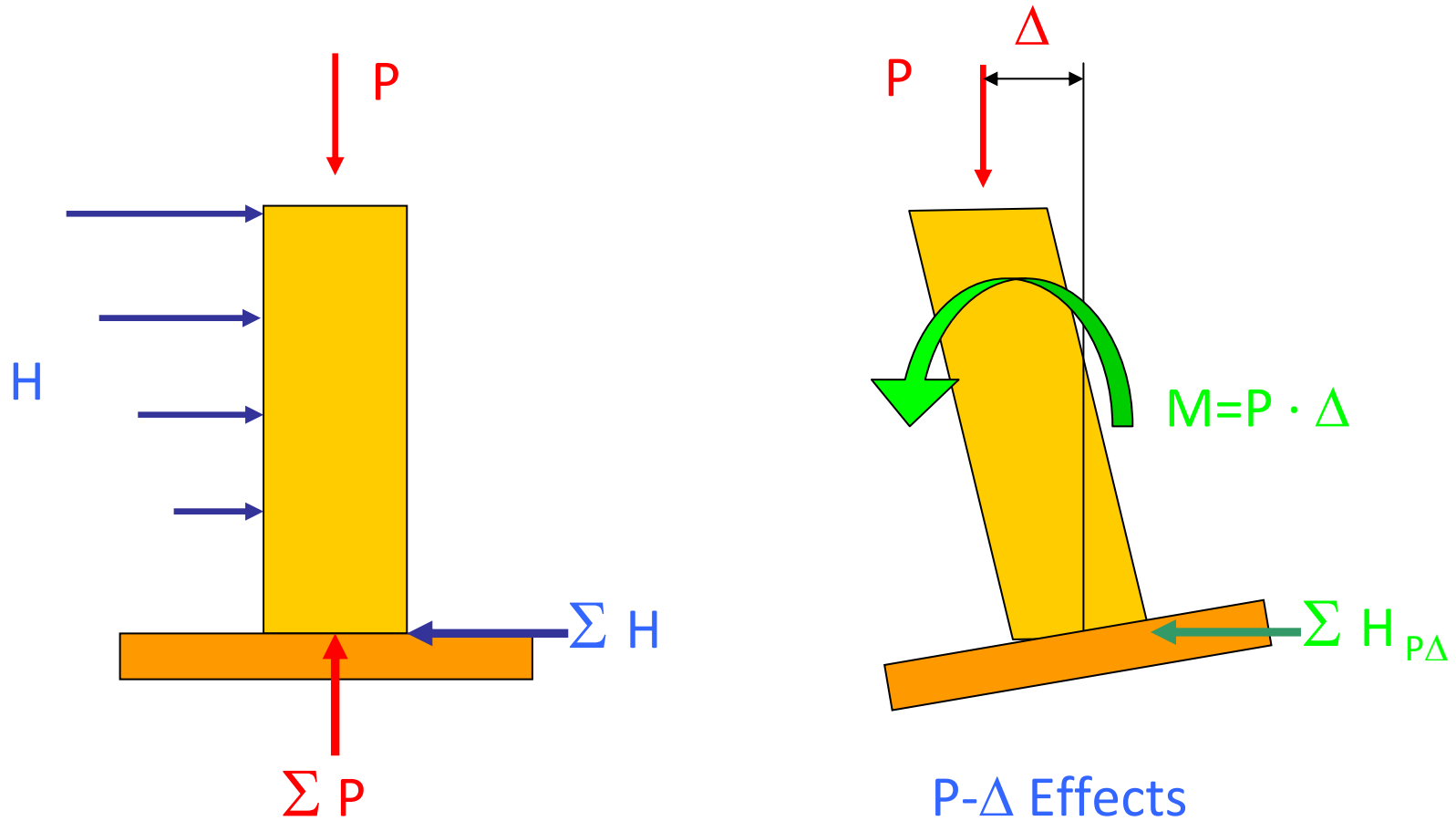
After Satake at.al, 2003



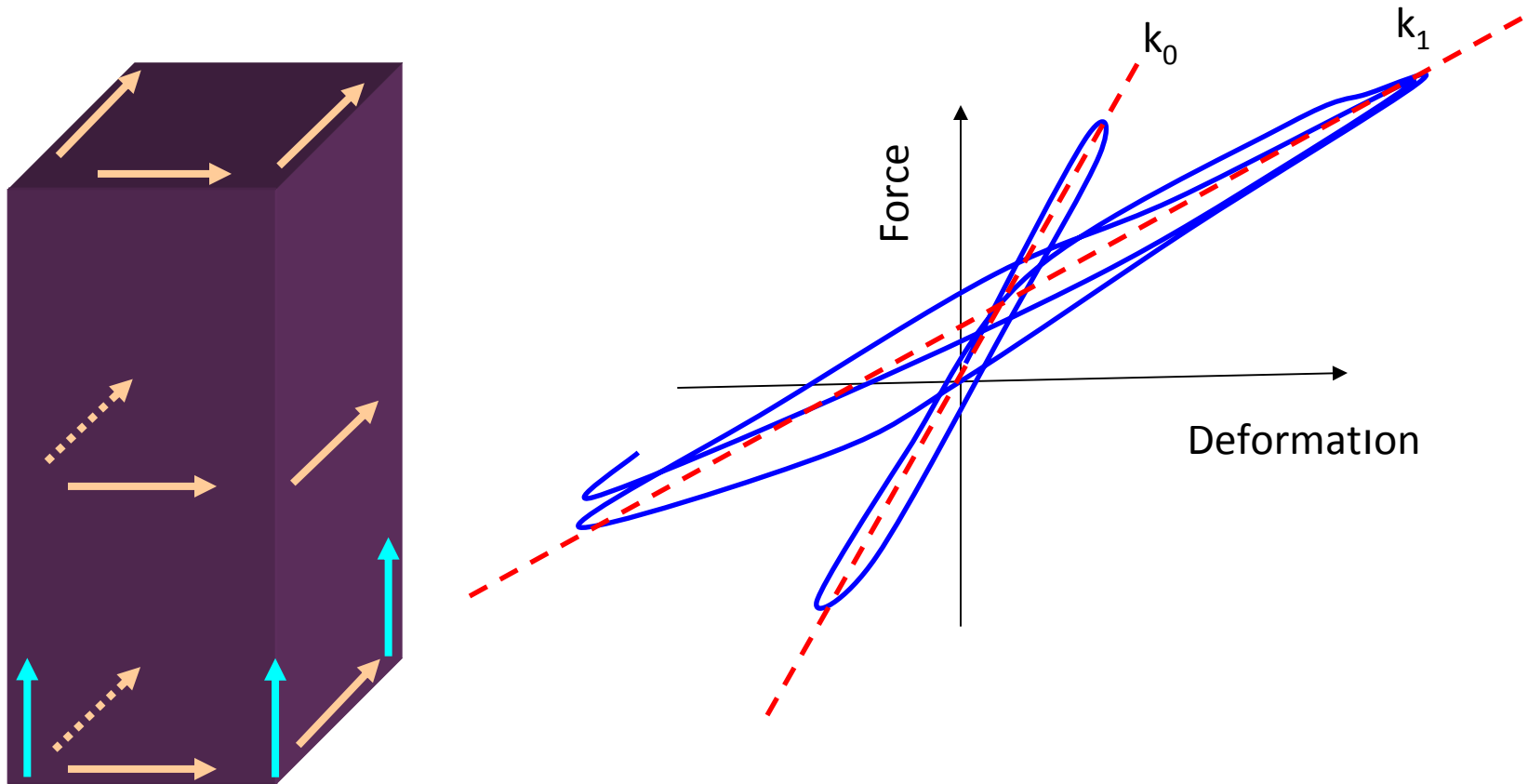
SURFACE WAVES FROM DISTANT LARGE EARTHQUAKES



P- Δ EFFECTS DUE TO BASE ROTATION

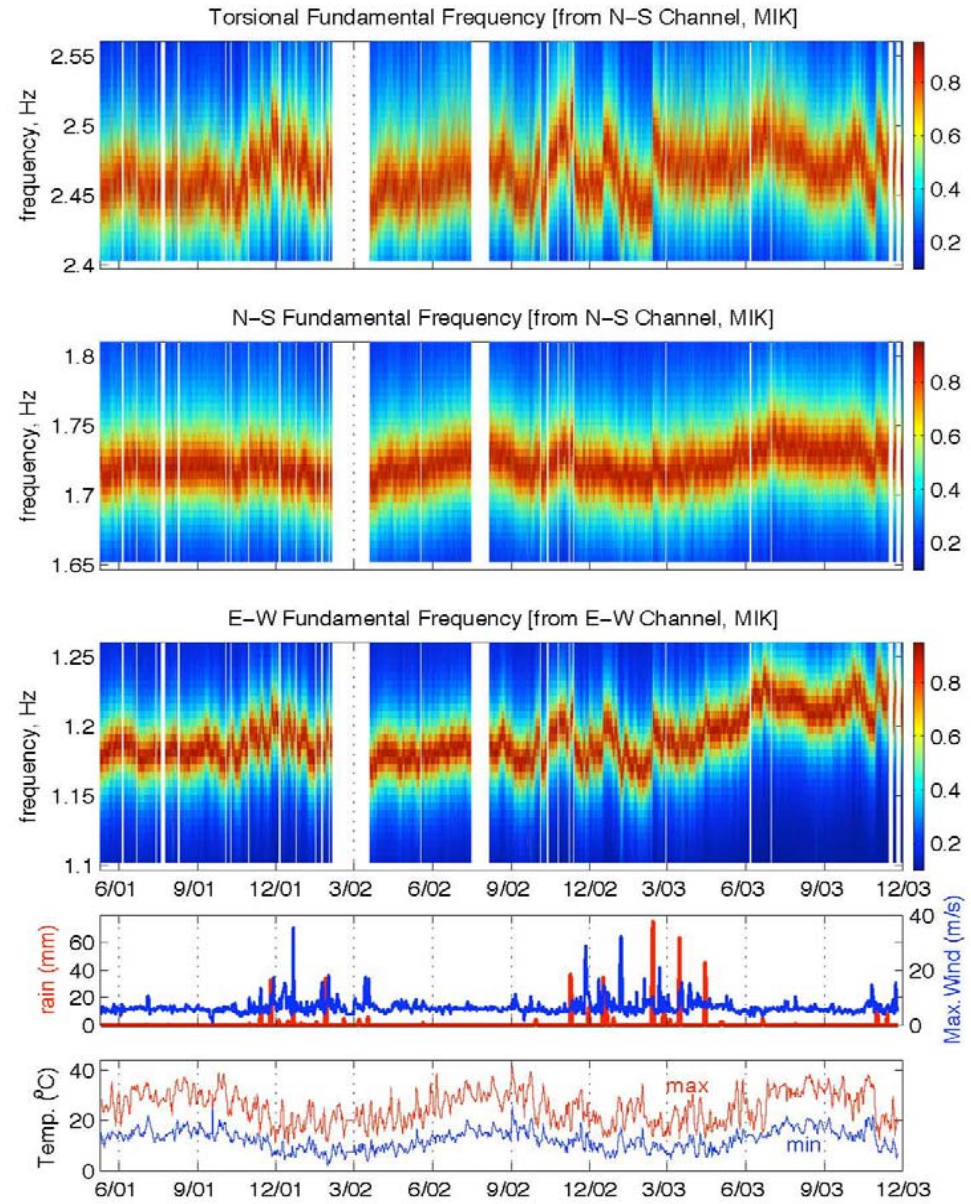


CHANGE IN THE NATURAL FREQUENCY vs. DAMAGE

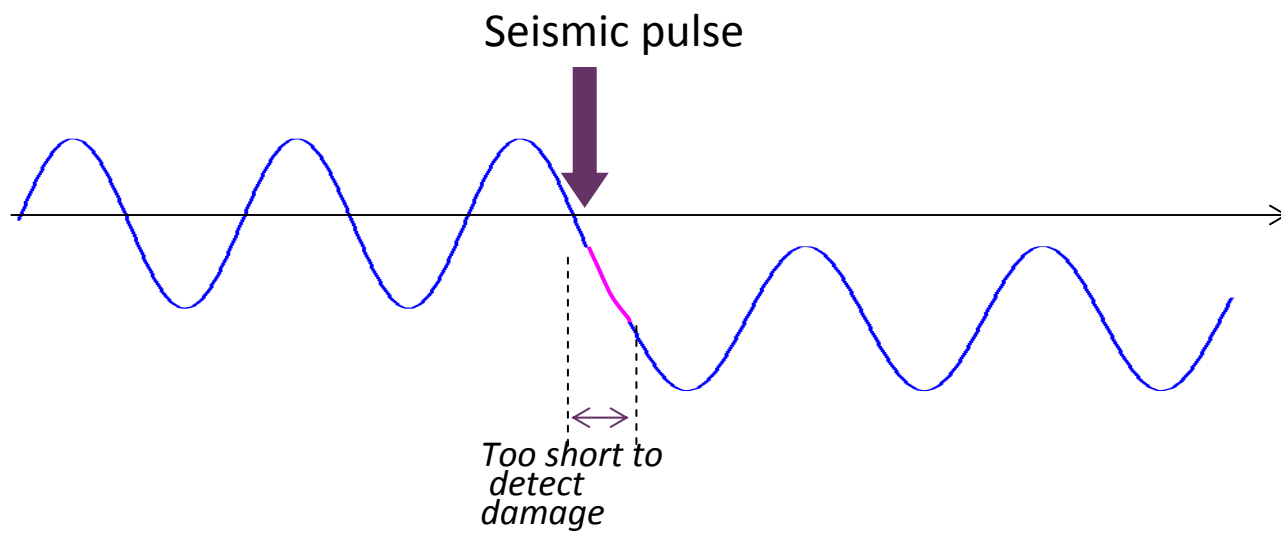
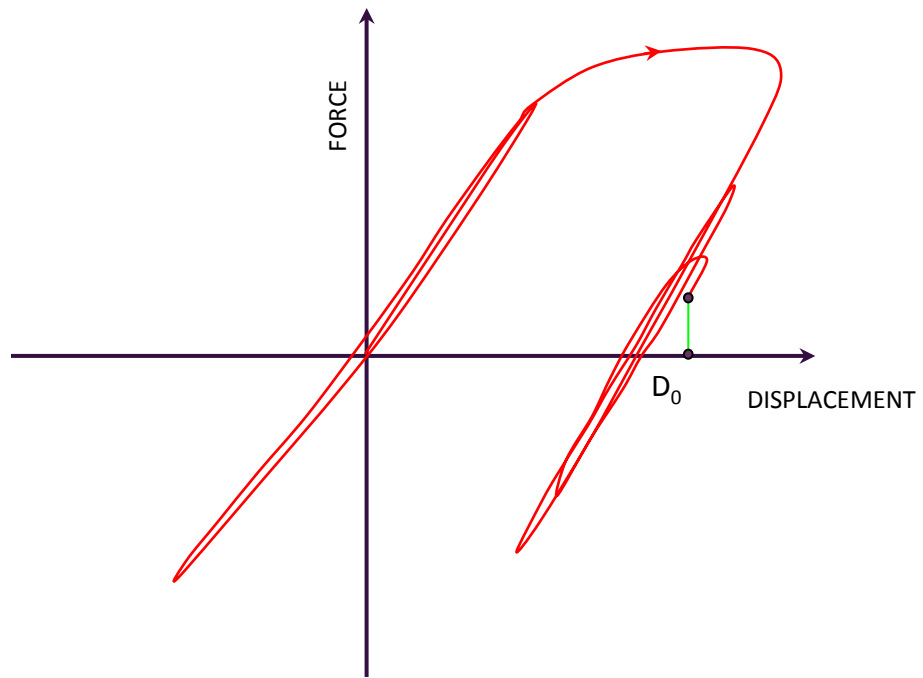


Assumption: Damage reduces the stiffness, and consequently the natural frequency.

$$k_1 < k_0 \Rightarrow f_1 = \sqrt{k_1/m} < f_0 = \sqrt{k_0/m}$$

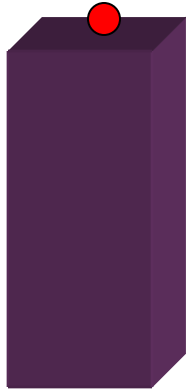


(From www.ce.caltech.edu/~jclinton/thesis.html)



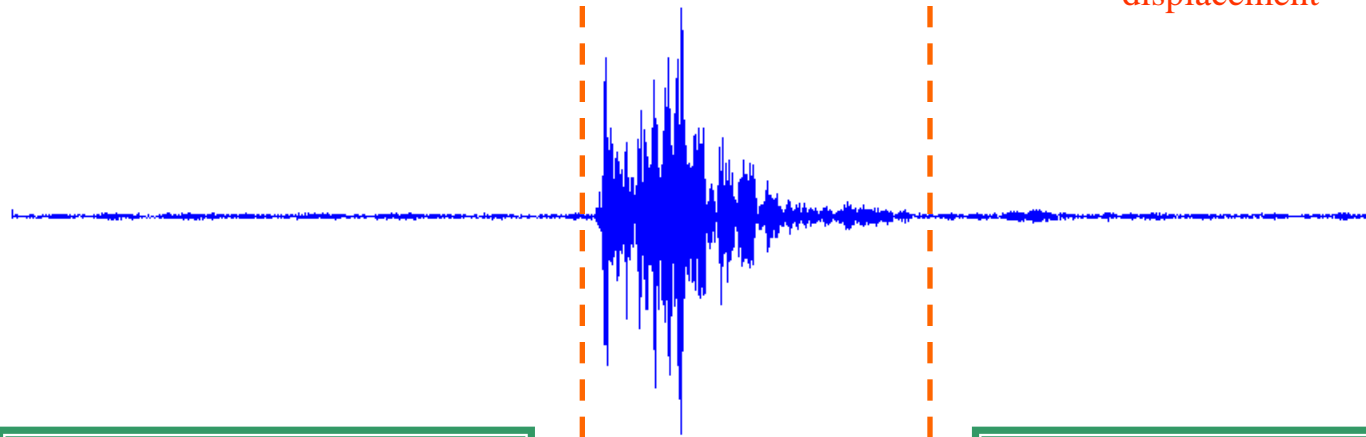
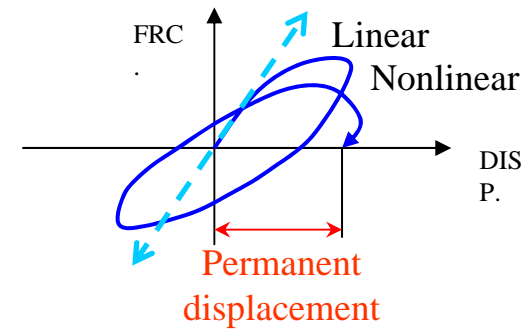
**NEW APPROACHES
AND
DEVELOPMENT OF ANALYTICAL
MODELS**

DAMAGE DETECTION BY REAL-TIME MONITORING



Multiple sensor package:

- Acceleration / Velocity
- Displacement (GPS)
- Rotation (tilt-meter)



Pre-earthquake:

GPS & Rot.
sensors

- Reference static displacement
- Reference static rotation
- Mean and variance of dynamic characteristics

During earthquake:

Acceleration
sensors

- Changes in dynamic characteristics
- Hysteretic behavior
- Damage initiation

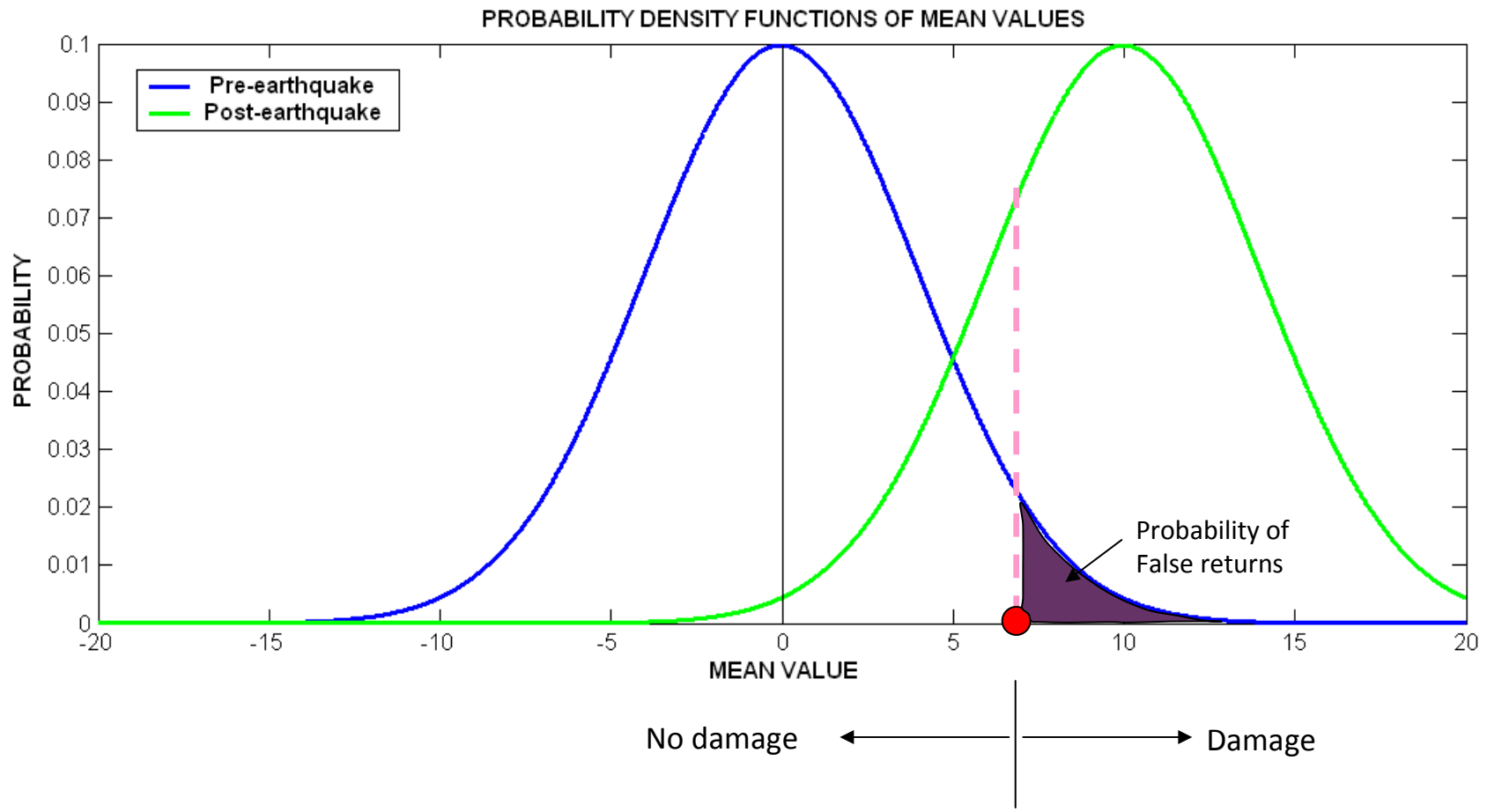
Post-earthquake:

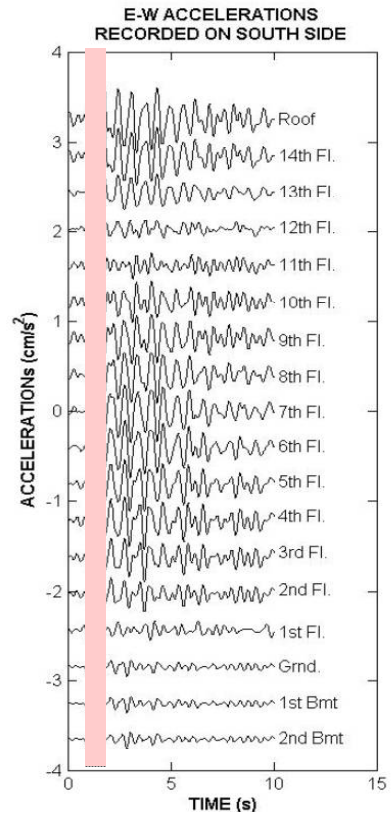
GPS & Rot.
sensors

- Permanent static displacement
- Permanent static rotation
- Mean and variance of dynamic characteristics

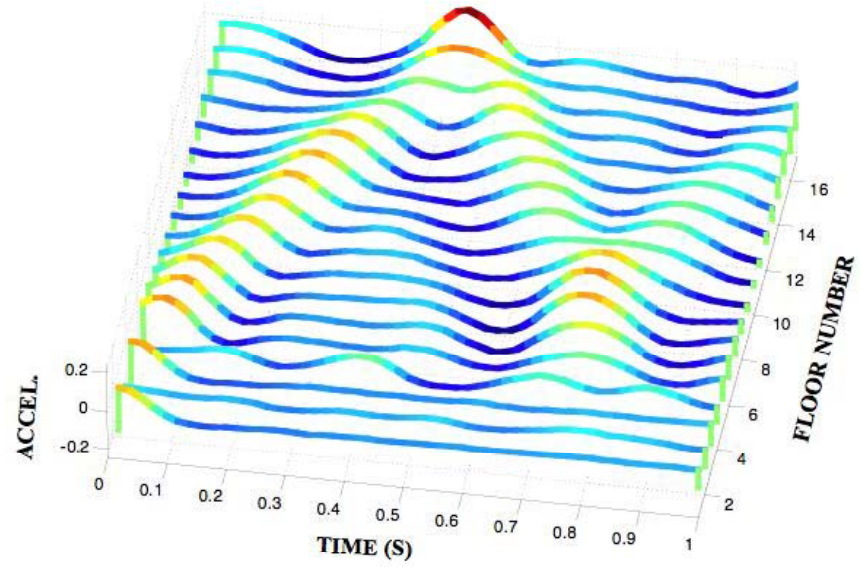
CHANGE IN MEAN VALUE vs. DAMAGE

Use statistical hypothesis tests (e.g., Neyman-Pearson test)

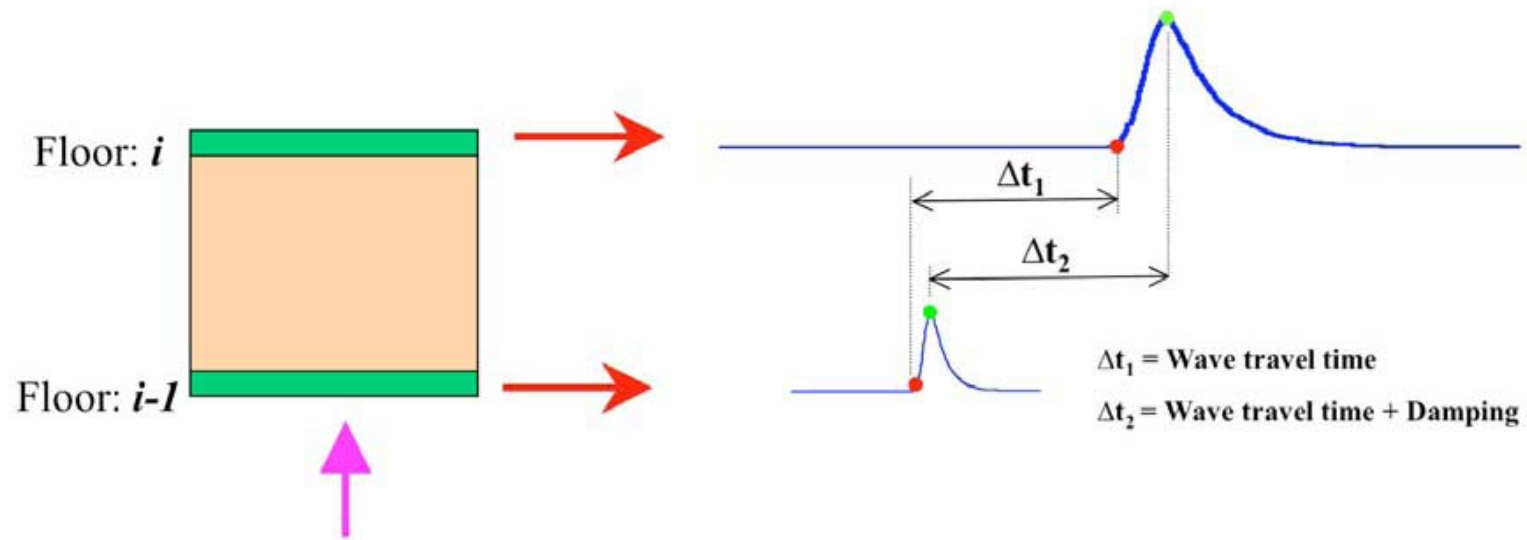




HORIZONTAL ACCELERATIONS AFTER DECONVOLUTION BY FOUNDATION ACCELERATIONS

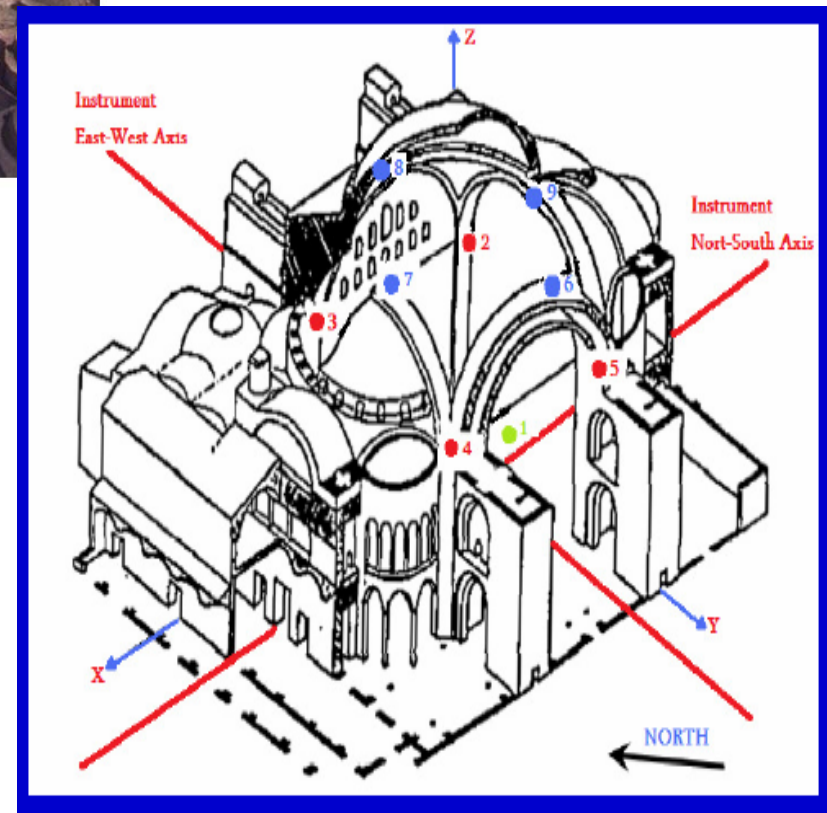


ATTENUATION DUE TO DAMPING

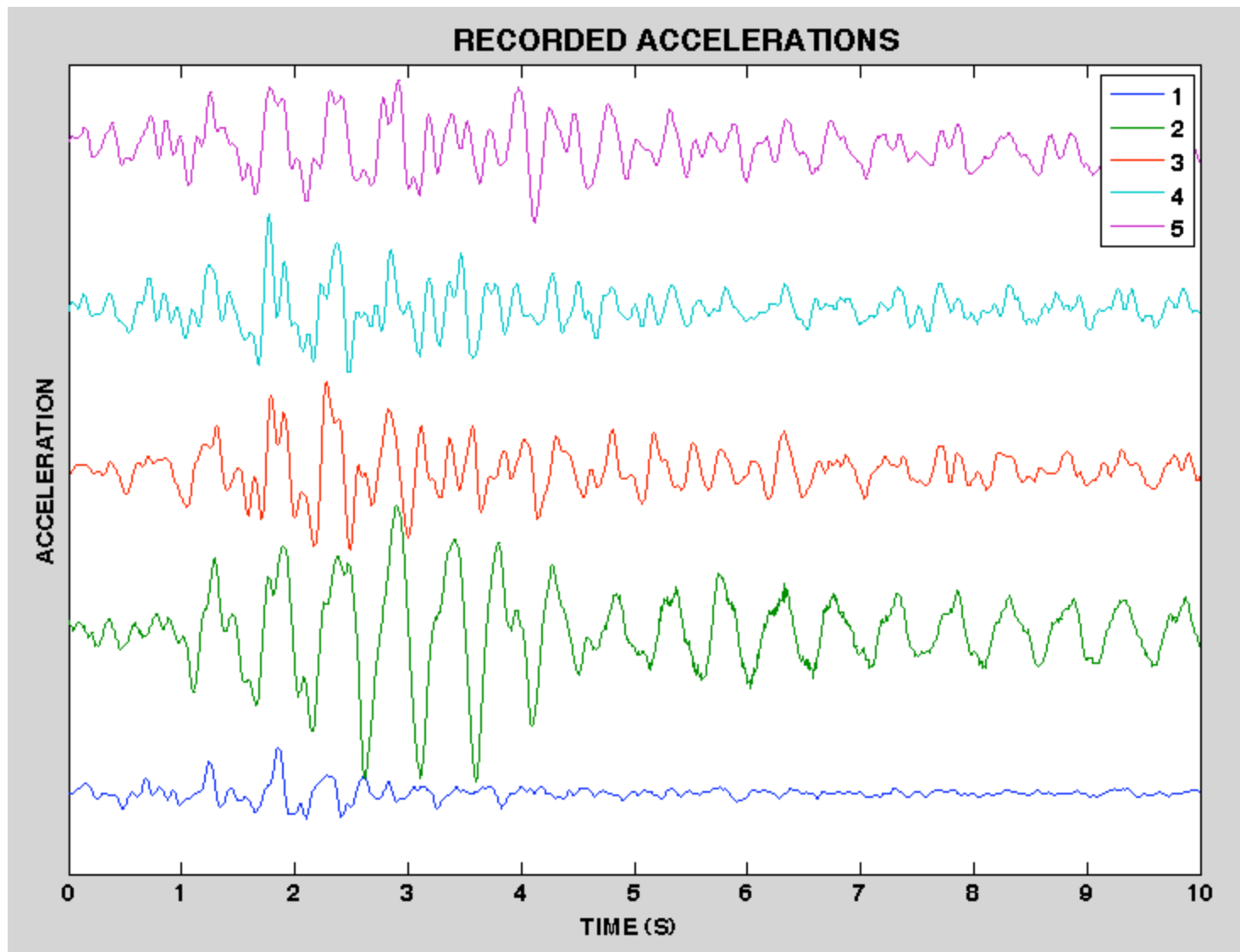


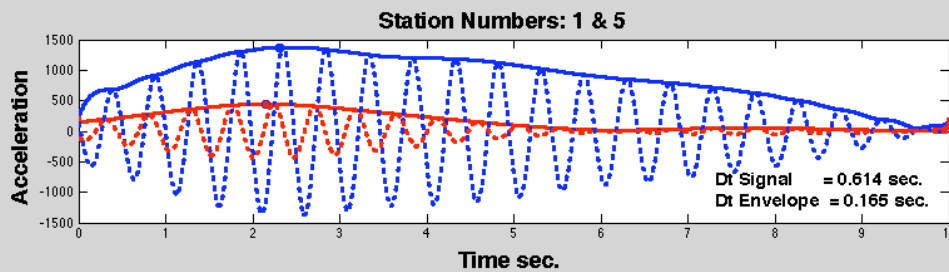
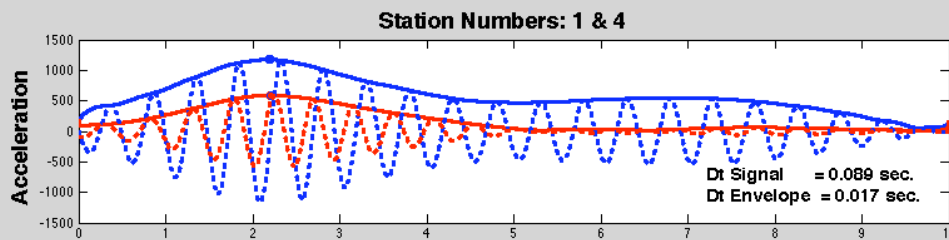
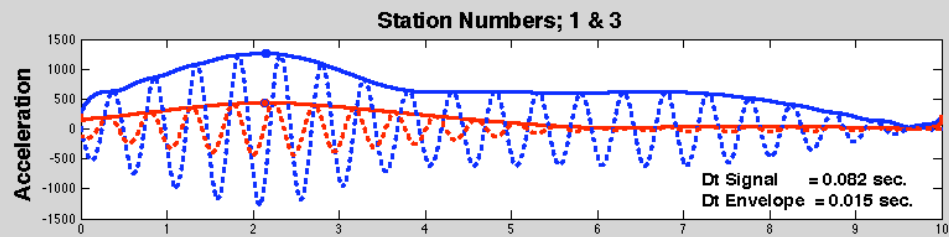
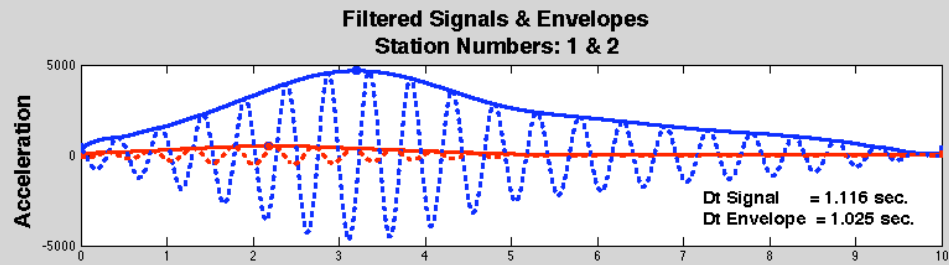


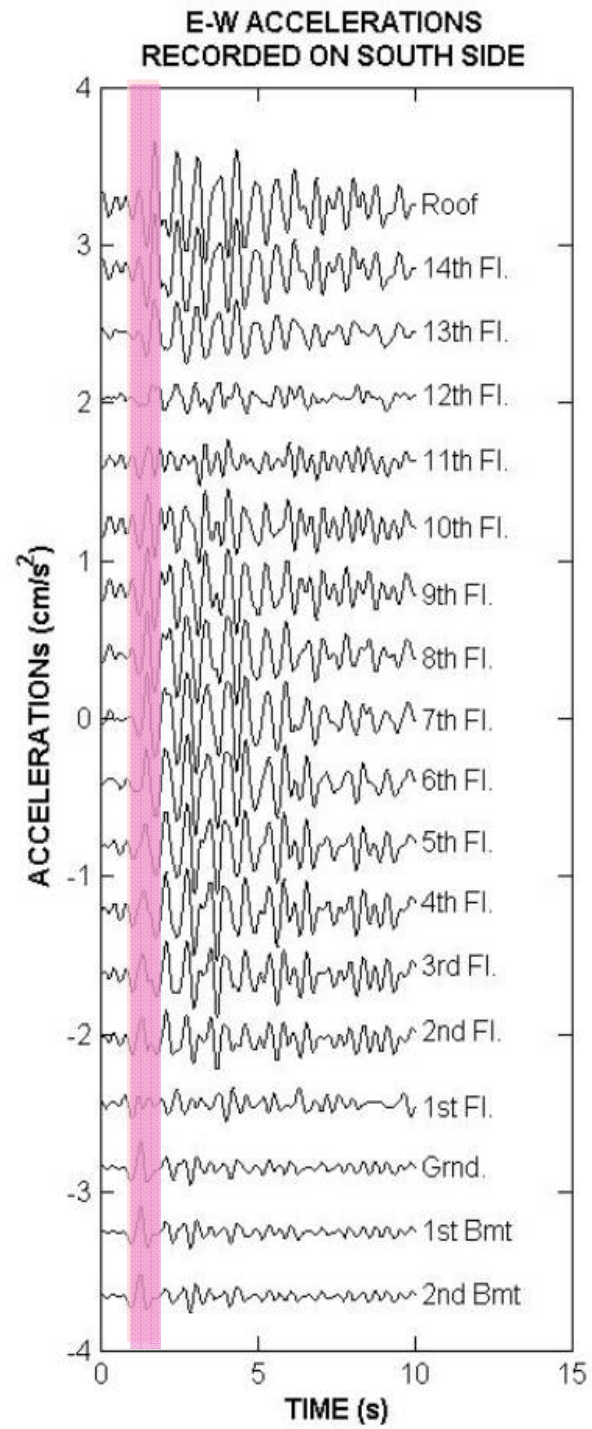
HAGIA SOPHIA MUSEUM MONITORING NETWORK



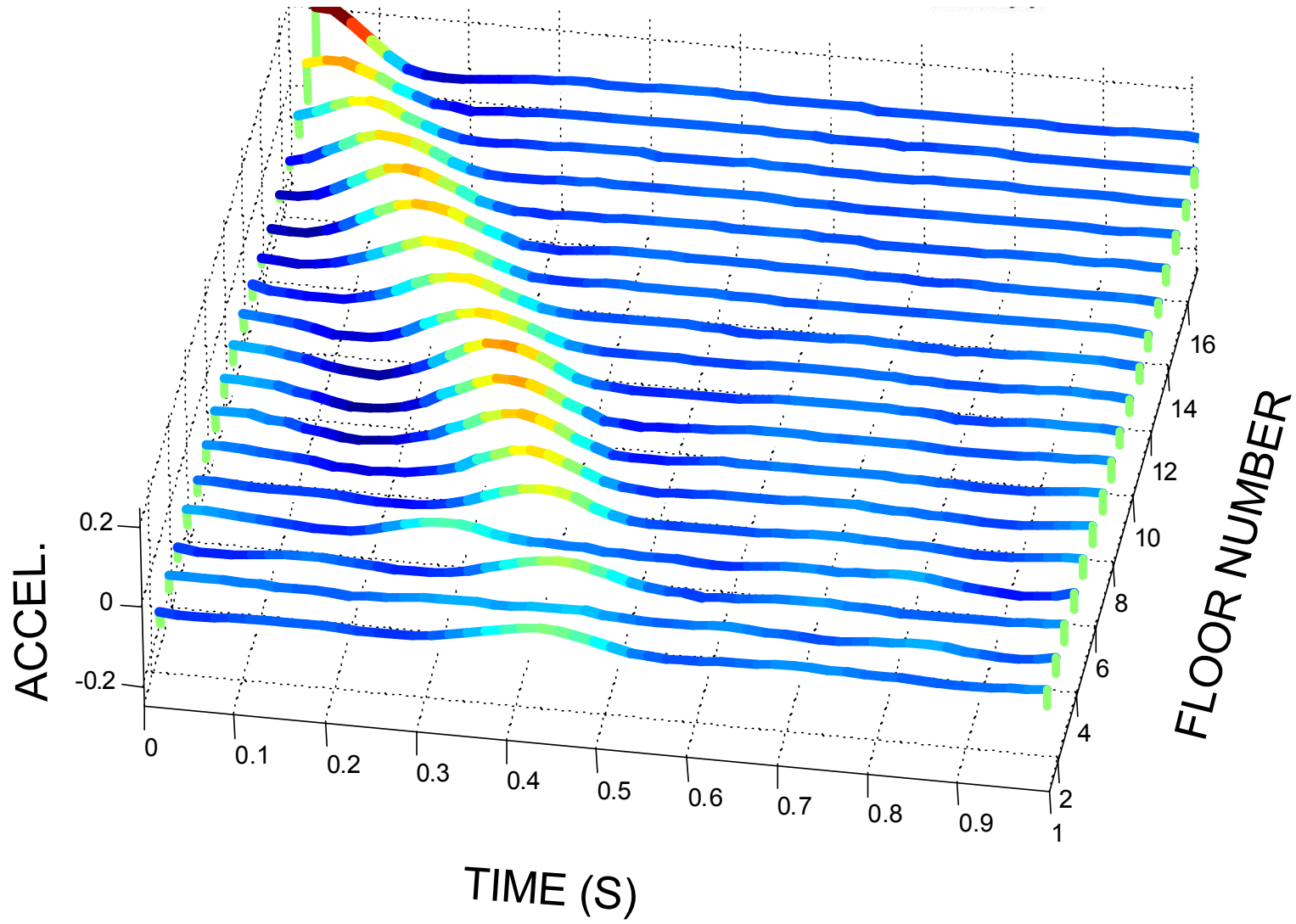




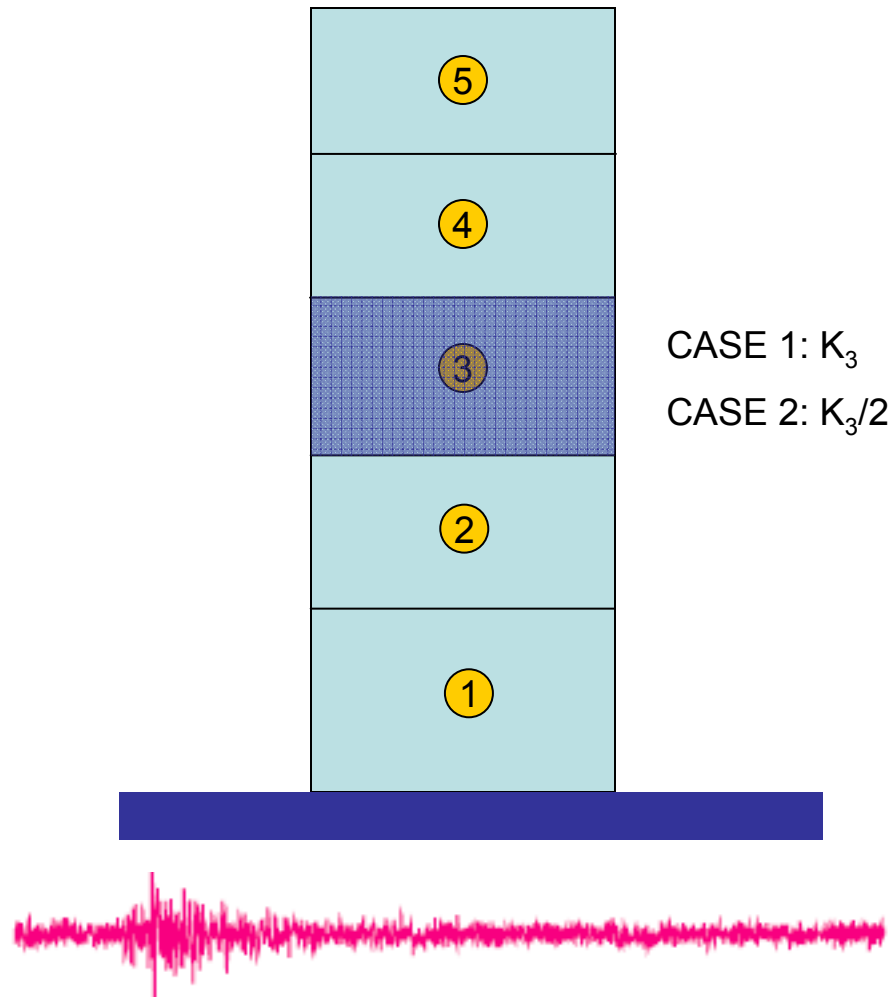




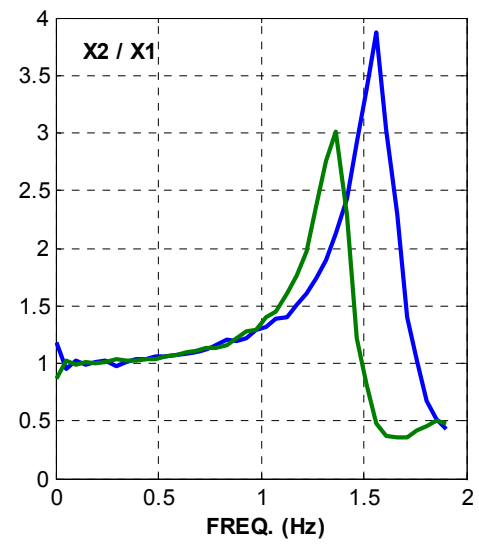
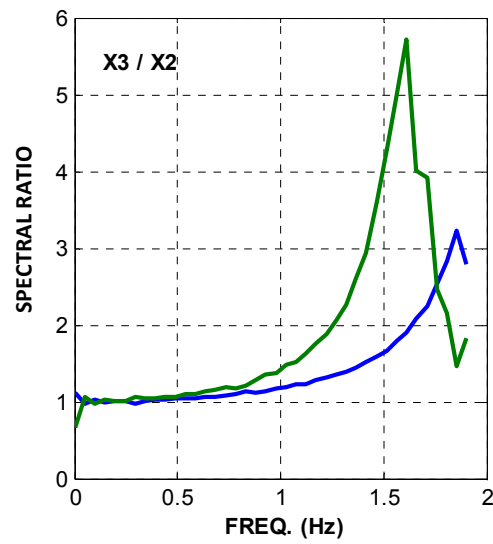
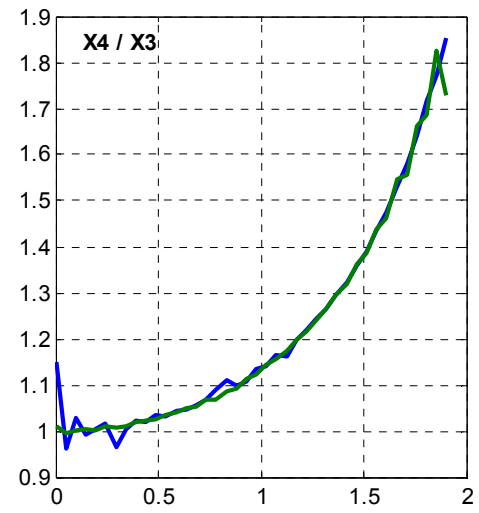
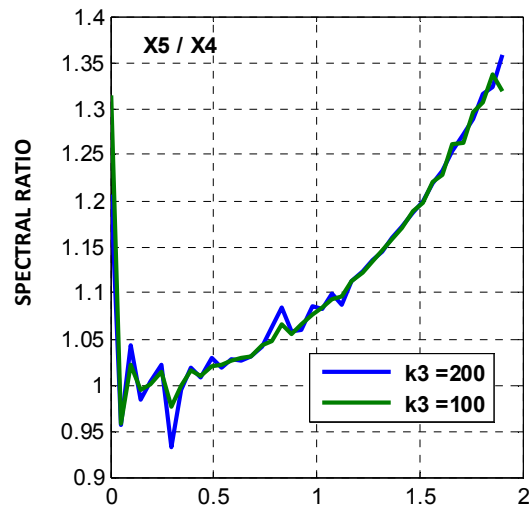
HORIZONTAL ACCELERATIONS AFTER DECONVOLUTION BY THE ROOF ACCELERATIONS



EXAMPLE



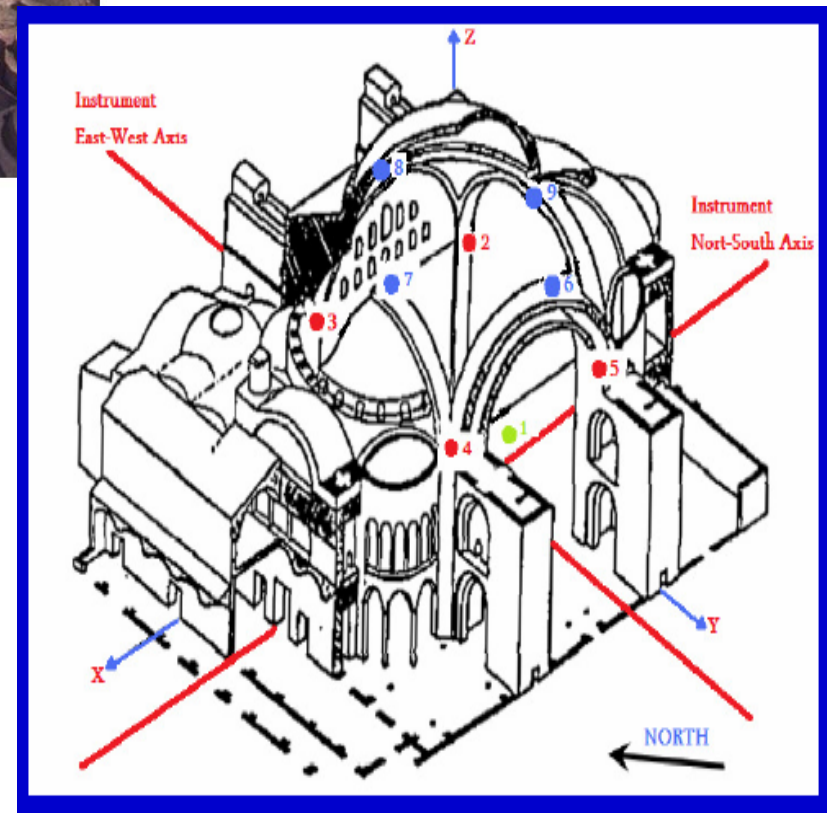
SPECTRAL RATIOS OF ACCELERATIONS AT ADJACENT FLOORS



EXAMPLES FROM ISTANBUL

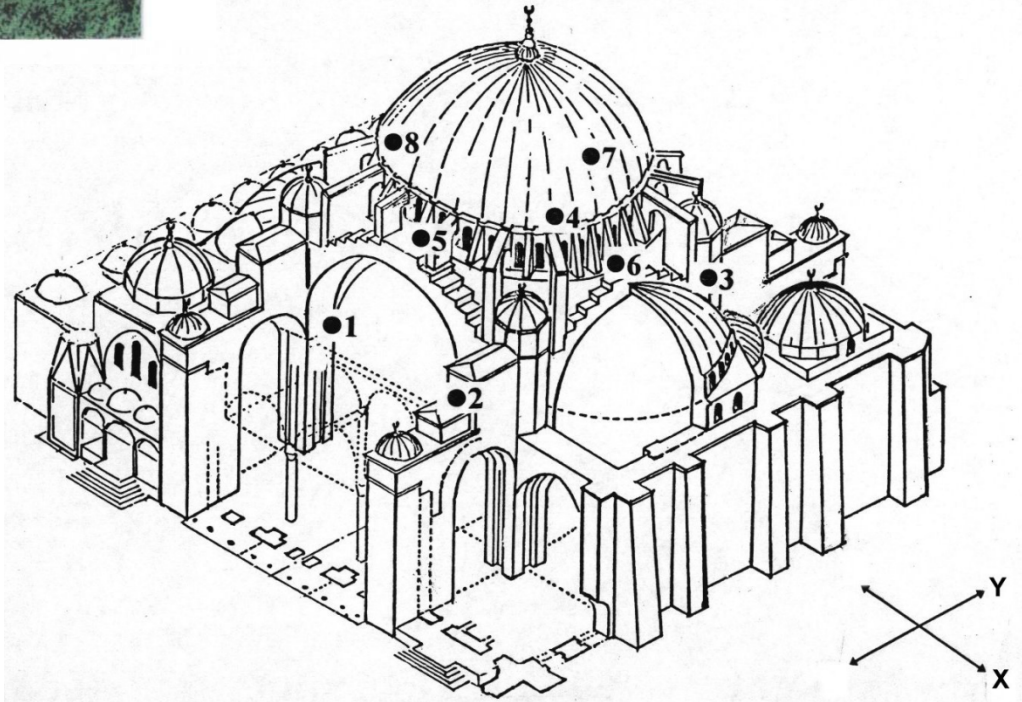


HAGIA SOPHIA MUSEUM MONITORING NETWORK





SÜLEYMANİYE MOSQUE MONITORING NETWORK



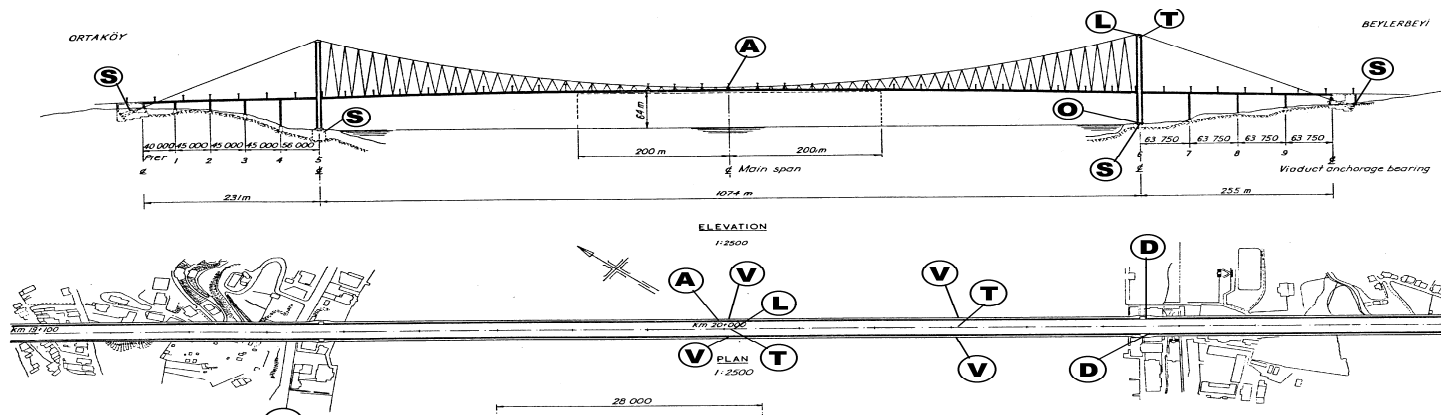


**FATIH MOSQUE
REAL-TIME MONITORING NETWORK**

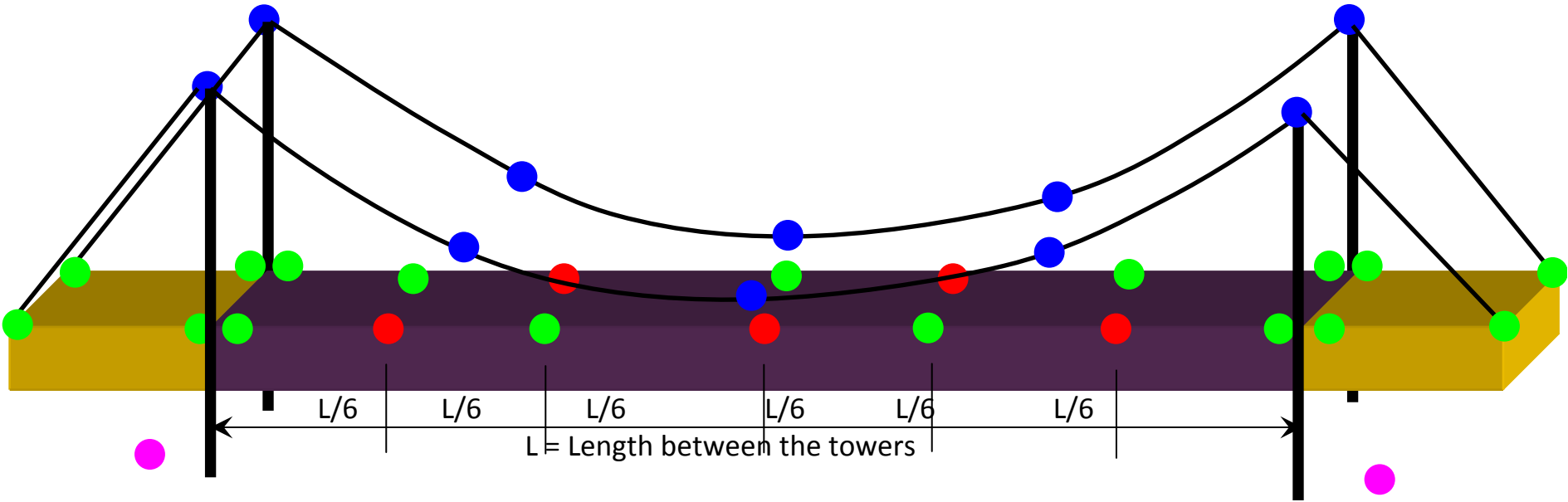




THE FIRST BOSPHORUS BRIDGE

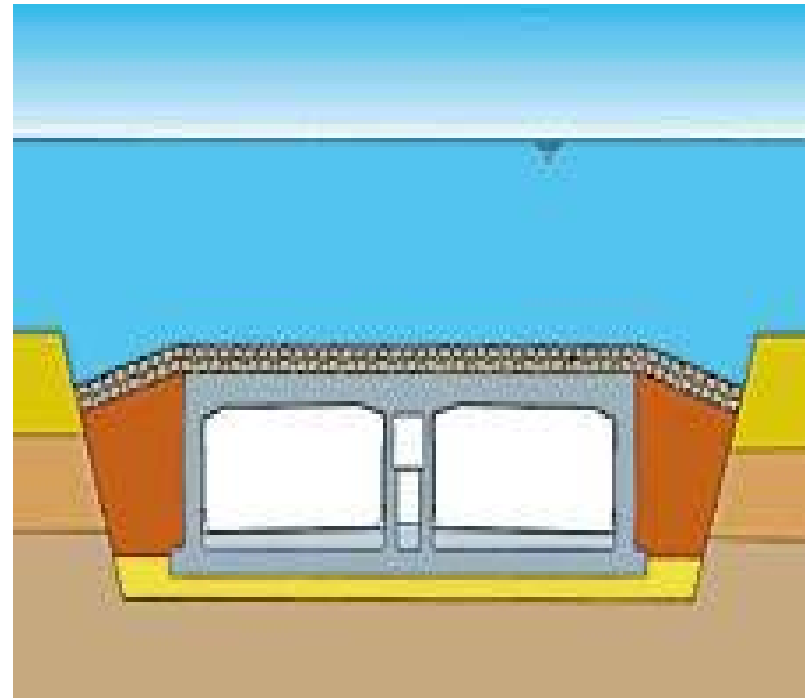


THE SECOND BOSPHORUS (FSM) BRIDGE



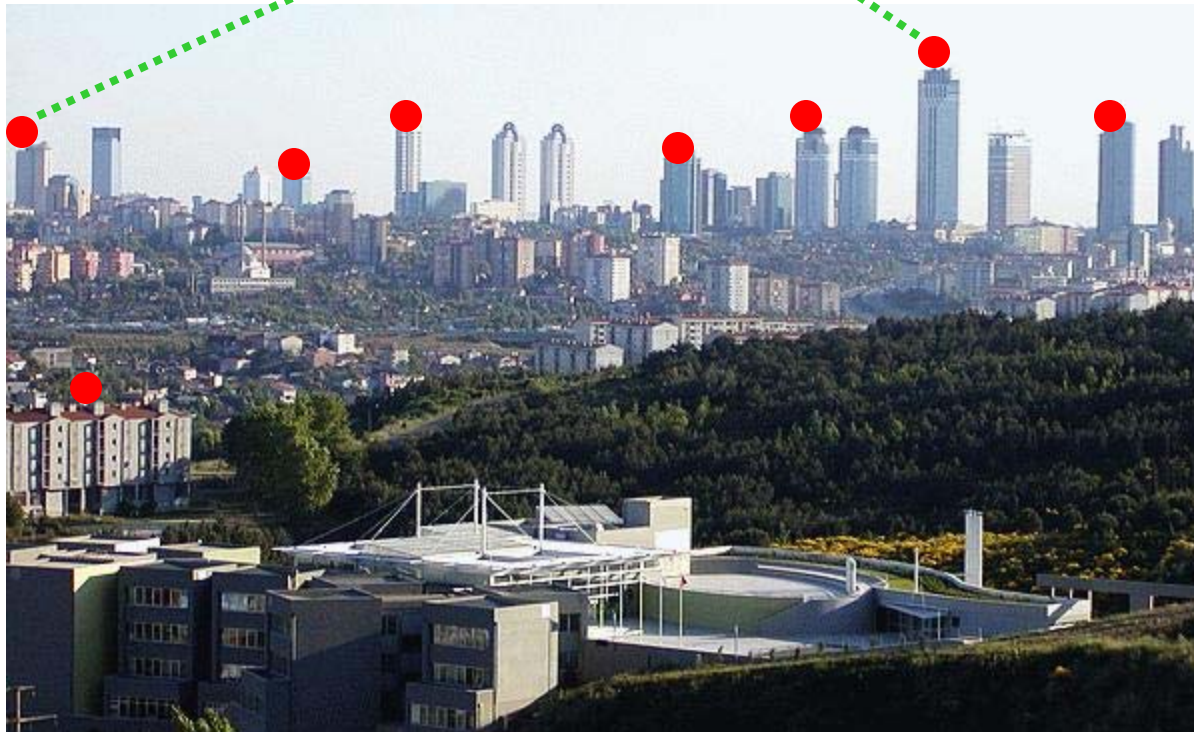
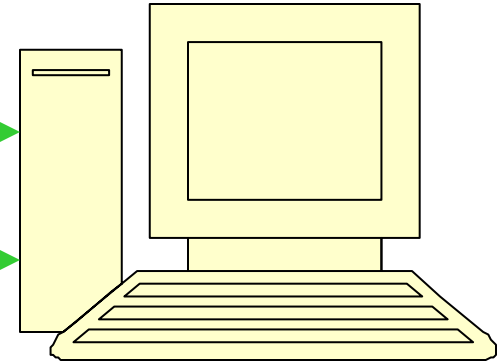
Location of deck sensors

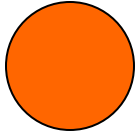
BOSPHORUS TUBE TUNNEL



REAL-TIME DAMAGE ASSESSMENT

- Satellite
- Telemetry
- Internet





SENSOR PACKAGE

- Accelerometer
- Tiltmeter
- GPS sensor

KOERI_MIS

