6-10 NOVEMBER 2023

ANTALYA, TÜRKİYE

7 ICEES | 18 WCSI

7th International Conference on Earthquake Engineering and Seismology

18th World Conference on Seismic Isolation, Energy Dissipation and Active Vibration Control of Structures

URBAN-SCALE EARTHQUAKE RISK MANAGEMENT UTILIZING STRUCTURAL HEALTH MONITORING TECHNOLOGY

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1. Roadmap to Achieve Earthquake-Resilient Cities

Sendai Framework
for Disaster Risk Reduction
2015 - 2030

UNDRR
UN Office for Disaster Risk Reduction

Managing the Risk vs. Managing the Crisis *critical interaction*

Pre-Earthquake: Understanding the risk, taking precautions before the earthquake

Time of Earthquake: Well-Targeted Management of First 48 Critical Hours

Post-Earthquake: Recovery / Rapid comeback to the normal flow of live

Problem lack of data
How can we achieve these? Using recent technological developments

1/A. Earthquake-Resilient Cities – Investigating Deeper

Pre-Earthquake (Precautions)	Well-Targeted Management of First 48 Critical Hours	Post-Earthquake: Recovery
WHAT WE HAVE Better Earthquake Building Codes Urban Transformation Strengthening Seismic Isolation	WHAT WE HAVE Rescue Teams Rescue Equipment & Machinery Limited Coordination	WHAT WE HAVE Tents & Temporary Shelters Examination by Observations Time Taking Classification of Buildings as Safe or Light, Mid, Heavily Damaged
WHAT WE SHOULD HAVE Prioritization Accurate & Rapid Scanning Micro-Zoning (Response Spectrums) Monitoring the Condition in Real-Time Behavior during Mid-Intensity Shakings Aging & Fatigue	WHAT WE SHOULD HAVE Real-Time / Data-Driven Approach Well-Targeted Management Prioritization Damage Status Information Especially for the Critical Infrastructure & Pass ways	WHAT WE SHOULD HAVE Data-Driven Approach Rapid Analysis of Risk Status of the Buildings Decreasing the Negative Psychological Outcomes & Economic Losses Rapid Comeback to Normal Flow of Life

Not easy!
Time & Finance

1/B. Technological Approach to Increase Seismic Resilience

Besides urban transformation, better construction and strengthening efforts;

it is possible to develop a quite effective earthquake risk management methodology utilizing the recent technologies.

We propose a holistic approach utilizing

the real-time structural health monitoring technology,

depending on dynamic analysis & identification, mainly.

But, who are we?

TDG
Seismic and Structural Health Monitoring Systems

R & D Company specialized in developing
Seismic & Structural Health Monitoring (SHM) solutions.

For last 15 years, we are closely following the recent technological developments & analysis methods, best practices in this field.

We are developing the sensors, digitizers, methods & software to increase effectiveness of monitoring.

We delivered many real-time SHM projects, including :

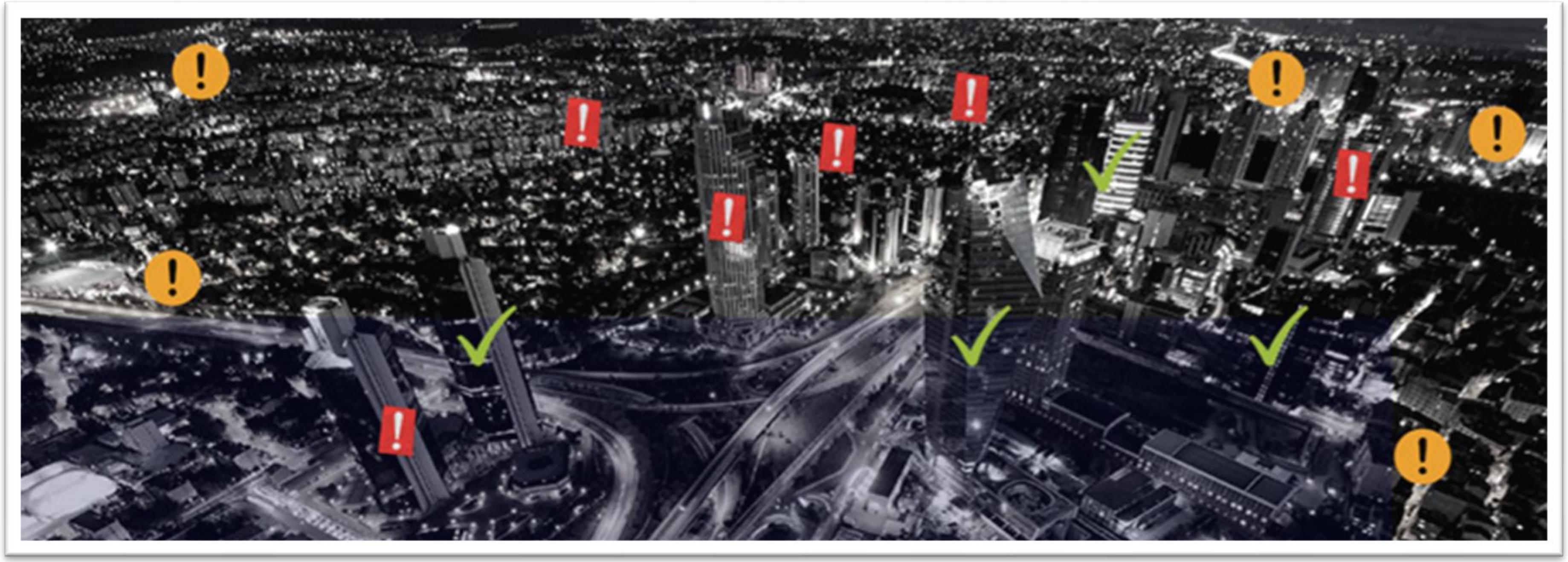
High-Rise Buildings	Hospitals	Historical Structures	Bridges
Industrial Plants	Schools	Airports	Tunnels
Wind Turbines	Mid-Rise Buildings		Towers

We are publishing articles based on our experience & results we have observed.

2. What is Structural Health Monitoring(SHM) ?

SHM is the technological decision support system that helps to monitor, analyze and report the structural integrity and the damage condition of civil engineering structures by the help of sensors against earthquakes and other destructive causes.

Provides rapid results such as **Before & After Comparison** just after the earthquake

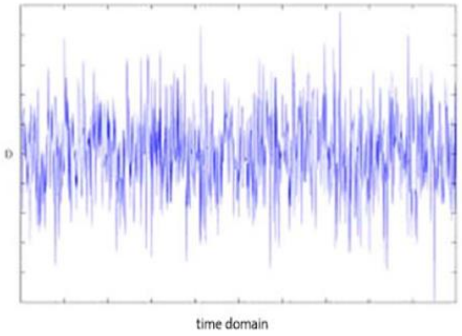


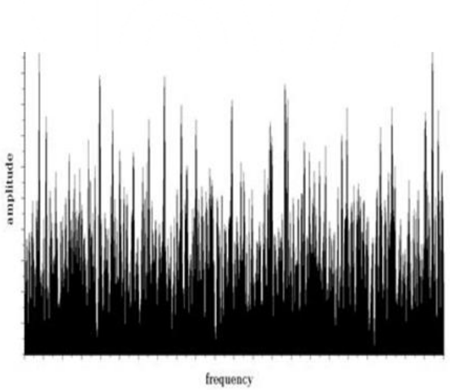
2/A. SHM under Ambient Vibration

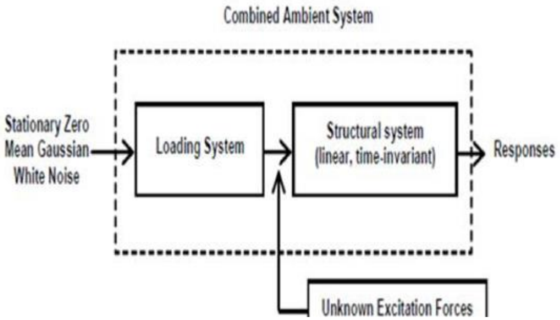
Operational Modal Analysis, Dynamic Identification,

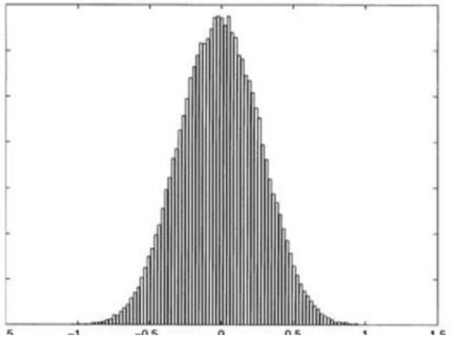
Real-Time Monitoring

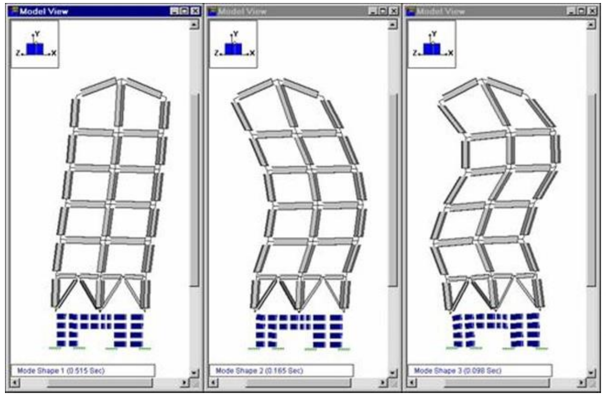
Most innovative part











Natural frequencies

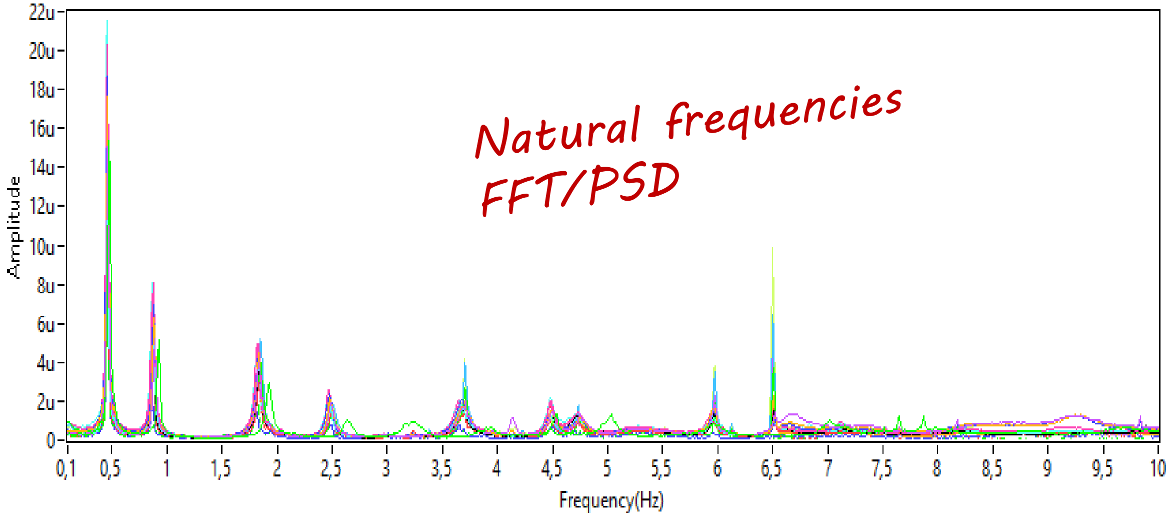
Damping ratios

Mode shapes

Top Displacement

Inter-storey drift ratios

Soil-structure interaction



2/B. Natural Frequency Shift / Case Study 1

A special experimental program in Kartal, Istanbul, in 2013, Demolishing Site

To observe the natural frequency shift of a building induced by damage

2 identical buildings The second was controllably weakened by hammering of selected columns and in-fill walls, before demolishing of the building by implosion.

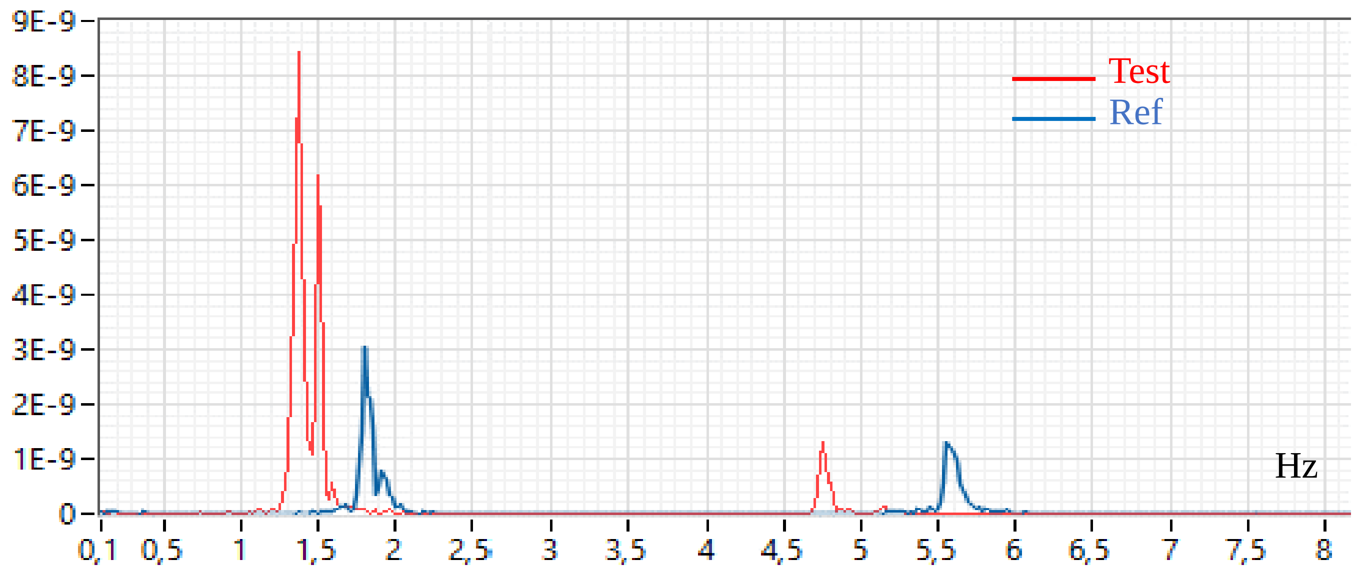
Reference Building-
Undamaged or Minor
Damage

Test Building-
Controllably Damaged in
one Direction

140 dB
Triaxial Accelerometer &
Recorder
In order to sense the
response under ambient
vibration
Nano-micro G Level
Vibrations

2/B. Natural Frequency Shift / Case Study 1

DIRECTION	EAST-WEST		NORTH-SOUTH	
	1st MODE FREQUENCY (Hz)	NATUAL PERIOD (sn)	1st MODE FREQUENCY (Hz)	NATUAL PERIOD (sn)
REF BUILDING	1,80	0,55	1,56	0,64
TEST BUILDING	1,38	0,73	1,48	0,68
RATE OF CHANGE(%)	33		6	



REF

TEST

2/C. Effectiveness of Long-Term Monitoring (Fatigue-Aging) / Case Study 2

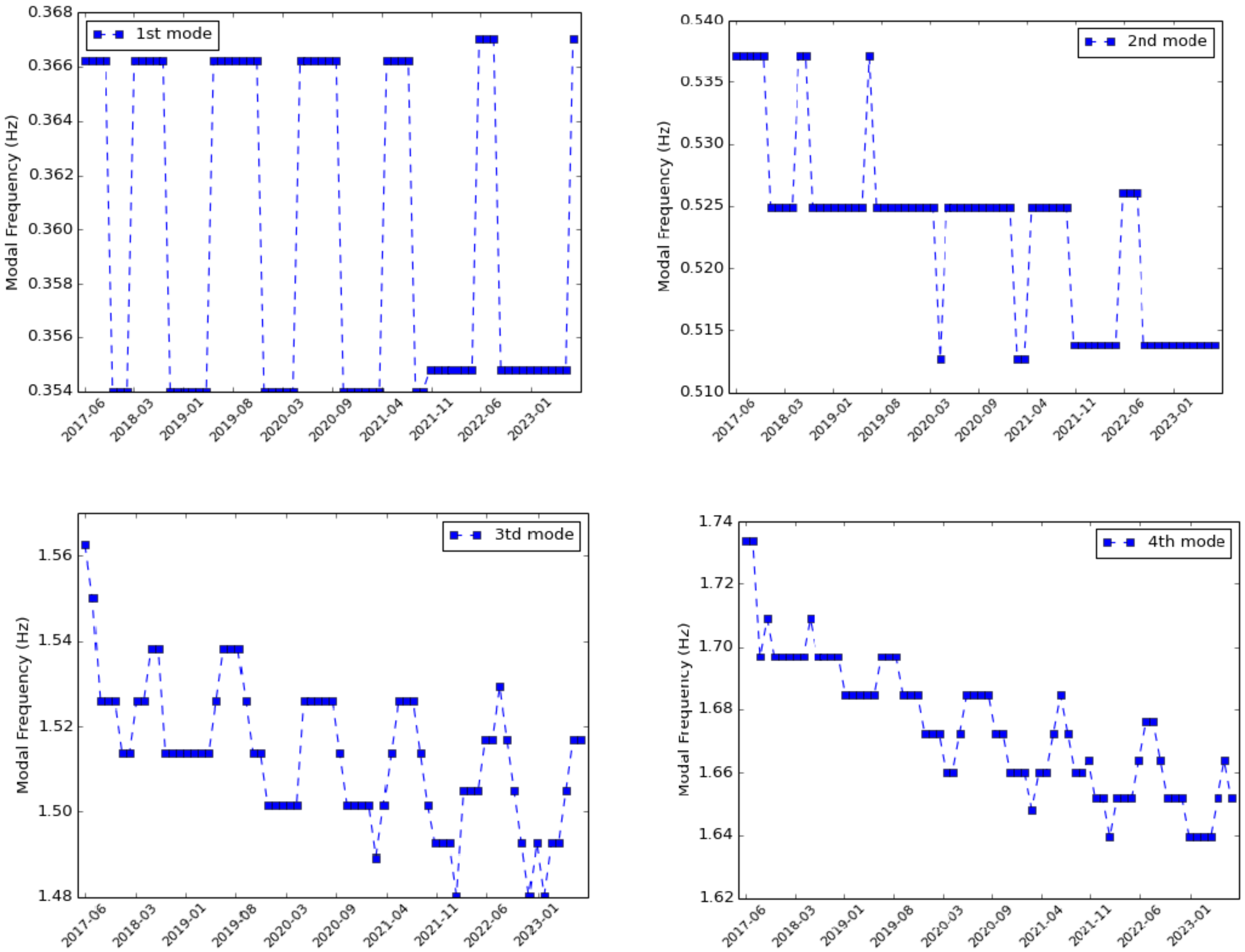
High Rise Building

First 4 modes – 66 Months

Each point represents the monthly average natural frequency

Seasonal Changes – Ups and Downs

Long-Term Trend will contribute to analyze the level of degradation or loss in stiffness related to time, early-identification of risk & possible need for strengthening

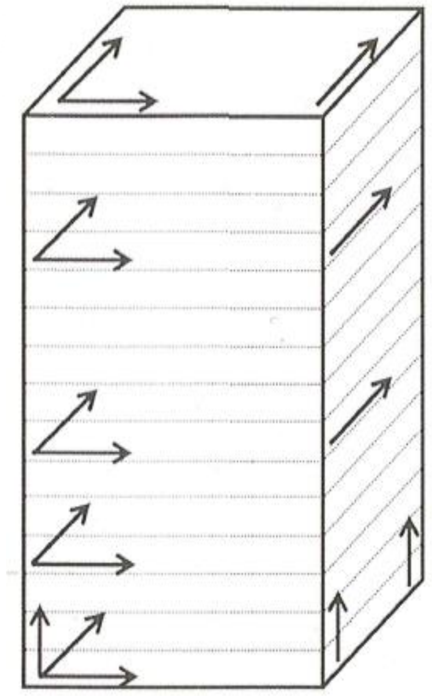


2/D. SHM in Current Codes and Regulations

Turkish National Earthquake Building Code (2018)

According to Article-13.8 Turkish National Earthquake Build Code installation of a Structural Health Monitoring System is compulsory for buildings H>105m in regions with Seismic Risk Class 1,1a,2,2a.

Height Above Ground Level	Number of Accelerometer Axes
105-155	16
156-205	24
>205	32



Turkey - AFAD Structural Health Monitoring Directive (2020)

Disaster & Emergency Management Presidency(AFAD) defines the detailed requirements of the compulsory structural health monitoring system instrumentation for buildings over 105 meters high and the establishment of the Monitoring Center according to Article-13.8 of Turkish National Earthquake Building Code.

Problem: Even though SHM solution is currently being adopted for high-rise buildings mostly in recent building codes, generally the greater number of low to mid-rise older buildings in higher risk group.

How can SHM can be adapted to mid-rise buildings, so that it should be possible to increase the effectiveness of the technology in risk & crisis management?

3. Compact & Optimum Solution for More Extensive Utilization of SHM in Mid-Rise Buildings

RIGIDITY ↑ NO OF MODES ↓

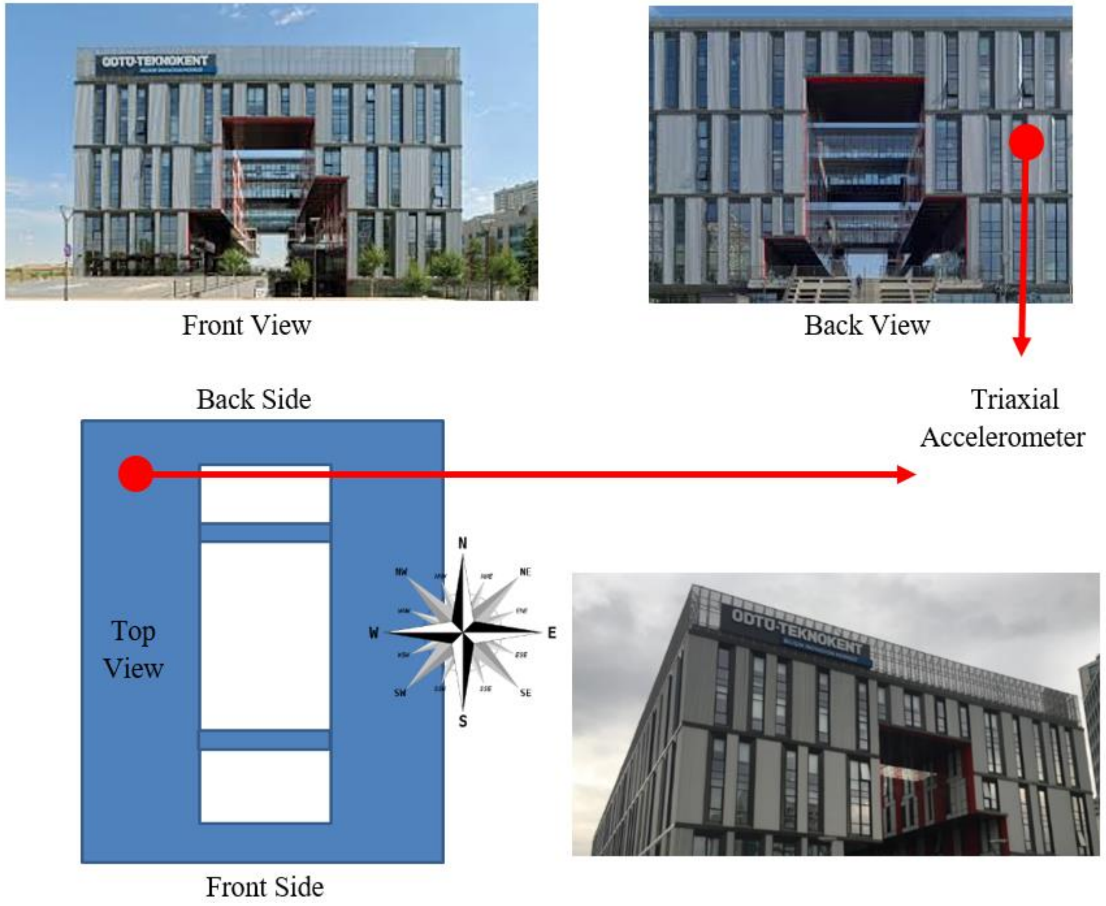
SENSITIVITY ↑ NO OF SENSORS ↓

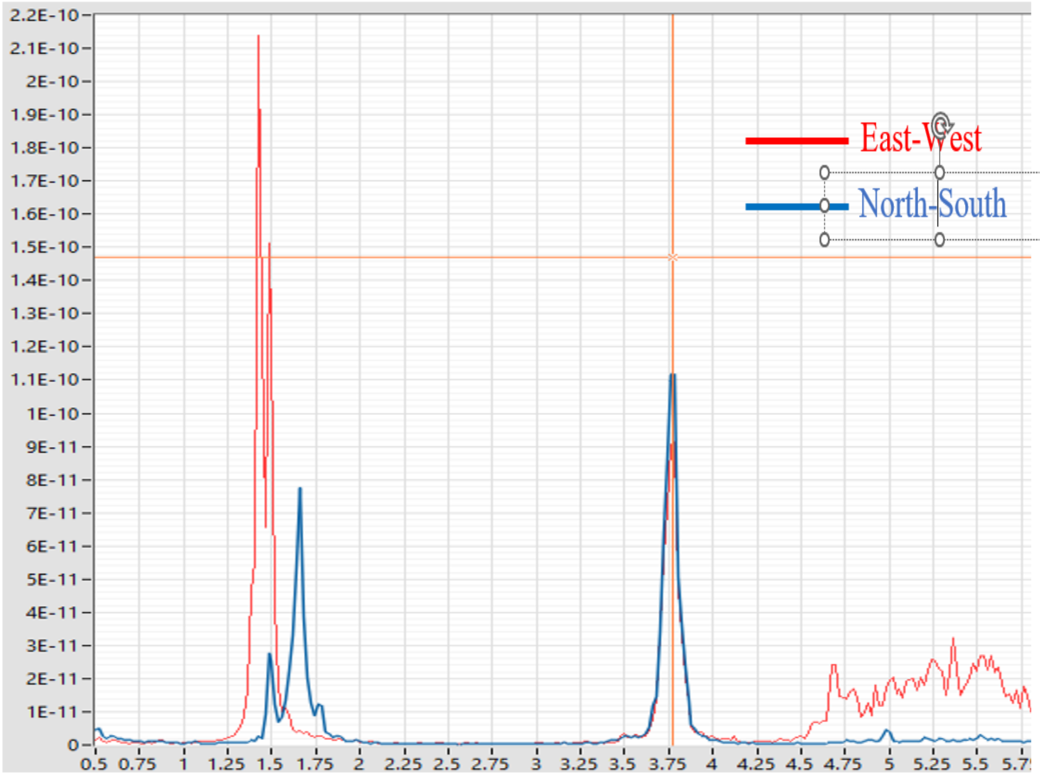
These buildings have lower number of significant mode shapes and the first 3 modes (x,y bending & torsion) generally dominate the dynamic behavior.

It is possible to monitor these mid-rise buildings even by a few (1-3 units of) tri-axial ultra-sensitive accelerometer(s), installed to the top and the foundation of the building. This gives the great opportunity to monitor greater number of buildings under high risk, **in the most cost-effective way**.

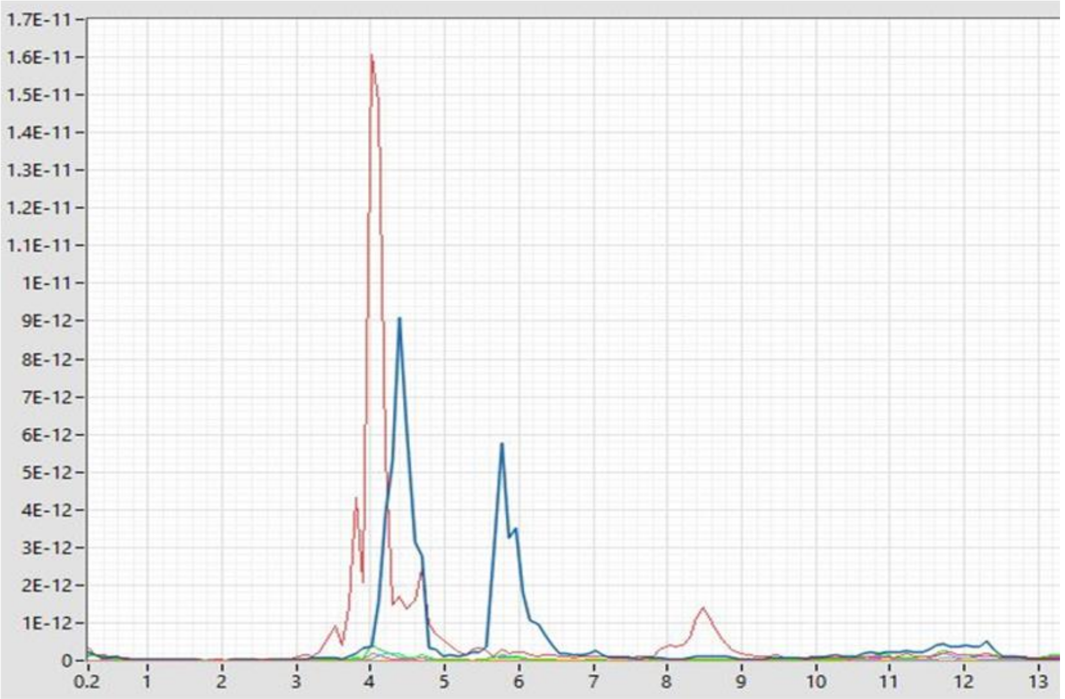
In this method, it is important to keep or even increase the sensitivity level of the accelerometer (>150-160 dB dynamic range), as lower buildings are even more rigid than the high-rise ones, and thus the excited acceleration levels under ambient vibration are even lower when compared to high-rise buildings.

3/A. Case Studies for Compact SHM - Monitoring of a 5-Story Office Building with A Single Triaxial Accelerometer





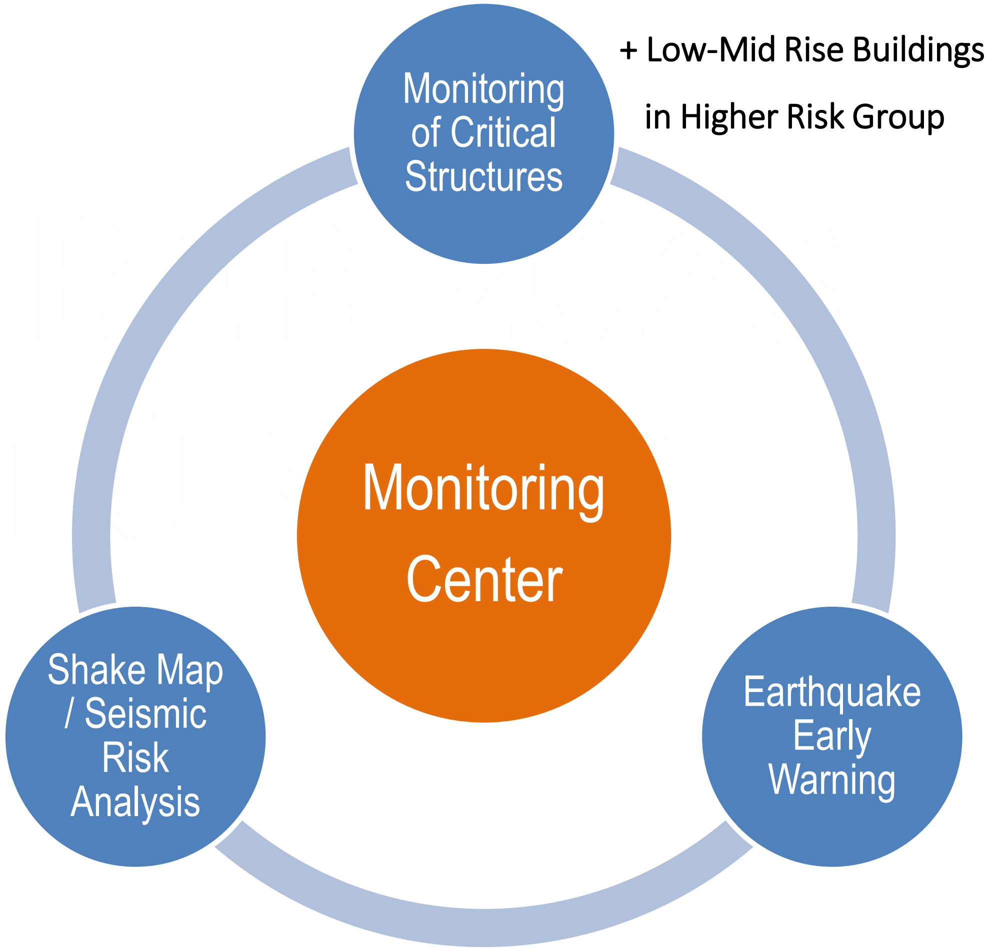
3/B. Case Studies for Compact SHM - Monitoring of a 3-Story School Building with Three Triaxial Accelerometers



4. Proposed Method for Urban Scale Earthquake Risk Management Utilizing SHM Technology

3- Component Solution coordinated by a city-based monitoring unit located at disaster coordination center

The effectiveness of this method comes from the utilization of an intersected set of instrumentation leading to an internet of things (IoT) ecosystem.



4.1 Monitoring of Critical Structures
+ Low-Mid Size Buildings in High Risk Group (Component-1)

Municipality Buildings

Govermental Buildings

Disaster Coordination Centers

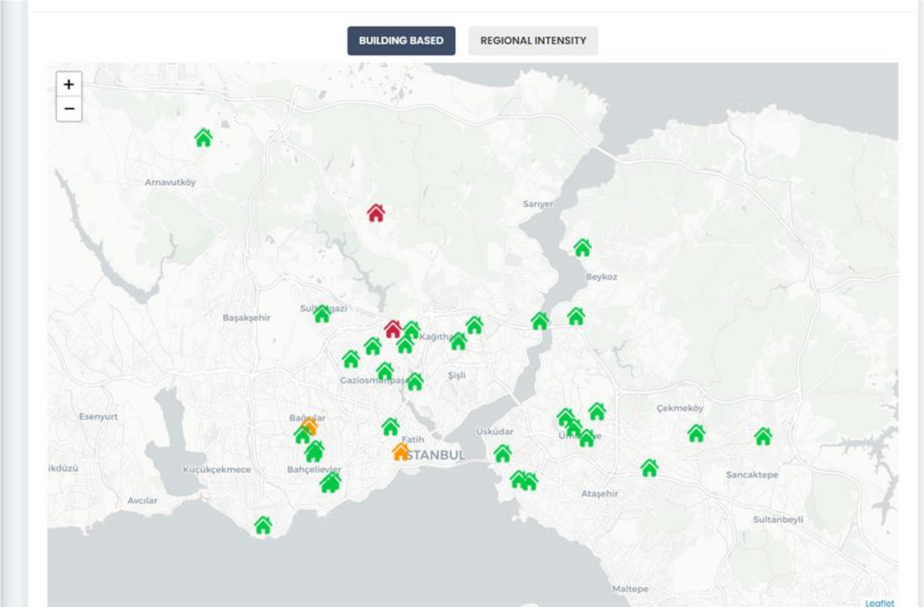
/ Fire Departments

Bridges & Viaducts

(Pass Ways)

Hospitals

High-Rise Buildings



Expected Outputs

4.2 Shake Maps, Micro Zoning, Seismic Risk Analysis (Component 2) + Earthquake Early Warning (Component 3)

Expected outcomes of shake/intensity maps

İn real-time and

in case of an earthquake

BEFORE THE EARTHQUAKE

High-Resolution micro-scale seismic risk maps

Micro zoning

Realistic & accurate design response risk spectrums

Urban transformation and planning

IN CASE OF AN EARTHQUAKE

High-resolution shake intensity maps

Most affected regions

Well-targeted disaster management

RELIABLE EARLY WARNING

Higher number of sensitive accelerometers installed to the foundations of the buildings in SHM systems

Conclusion

Effective use of recent technologies will contribute to establishment of a data driven real-time approach for seismic risk management.

SHM is an effective technological decision support system for both early identification of structural risks and rapid analysis tool just after an earthquake.

SHM solution is adopted in recent codes & regulations for real-time monitoring for high-rise buildings & other critical structures.

Furthermore it is possible to monitor higher number of low-mid rise buildings with 1-3 sensors in a cost-effective way.

Using SHM technology it is possible to achieve a 3 way earthquake risk management system with the use of shared instruments:-

-Managing the risk before the earthquake

-Well-targeted management of the first hours & days in case of an earthquake

-Achiving recovery / rapid comeback to the normal flow of live

This methodology has the potential to provide the valuable and unique data for future urban planning & transformation, regulations, and it will also support and accelerate academic research.

Thank you