Seismic Isolation and Structural Health Monitoring Technologies

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Ankara – June 4th, 2013
Seismic Isolation Technologies
- The basics – How it works?
- Design related issues

Structural Health Monitoring Technology (SHM)
- The basics – What is SHM?
- SHM for Buildings as a market
Seismic Isolation
Seismic Performance Goals

Our goals are to **Preserve Life Safety and Prevent Collapse**

If collapse can be prevented, which **level of damage is acceptable**?

- **Local Failure**
  - L’Aquila Earthquake 2009 - Italy
  - Total collapse

- **Permanent Failure**
  - Van Earthquake 2011 - Turkey
Seismic Performance Goals

In Earthquake Engineering the challenge is to build structures for different performance levels (e.g.,):

- **Life safety** for strong earthquakes (rare events),
- **Limited damage** for design based earthquakes.

RESILIENT STRUCTURES
Challenges in “ductile design” strategy:

- **Strong column – weak beam** mechanism may not form due to existence of wall,
- **Shear failure of columns** may occur due to wrong proportioning or short-column effect,
- **Construction difficulty at beam-column joints** due to complexity of steel reinforcement,

**So, why not control the inertial forces attracted to the structure?**
Seismic Isolation – Controlling Forces

How It Works?

- The structure is **decoupled** from the ground by isolators with **low horizontal stiffness**, resulting in a fundamental frequency that is **much lower** than the fixed-base frequency.
- The first **dynamic mode** of the isolated structure involves deformation only in the isolation system.
Seismic Isolation and Structural Health Monitoring Technologies

Seismic Isolation – Controlling Forces
How It Works?

- These higher modes do not participate in the motion, reducing drift (orthogonality),
- The isolation system does not absorb the earthquake energy, but rather deflects it through the dynamics of the system.

Seismic Isolation and Structural Health Monitoring Technologies
With a seismically isolated structure, the seismic forces are reduced, this leads to:

- Smaller structural members
- Smaller foundations
- Smaller accelerations
Seismic Isolation
How It Works? – A Demonstration!

TESTING OF NEW LINE OF SEISMIC BASE ISOLATORS
STEP 3
CSUN - UCSD
DECEMBER 5 - 6, 2006
Seismic Isolation

Requirements of a Base Isolated Device

1. Isolating the building from the ground,

2. Supporting the weight of the structure,
Seismic Isolation
Requirements of a Base Isolated Device

3. Damping of response amplitude,

4. Restoring to the original position after an earthquake,
Seismic Isolation

Increasing the period will reduce the acceleration
Seismic Isolation

Increase in period will increase the displacements, therefore high damping is needed!
Seismic Isolation

Types of Isolators

- Laminated elastomeric bearings,
- Pendulums (low friction sliders – stainless steel/PTFE)
- Elastoplastic devices,
Application of anti-seismic system

Over 10,000 new and existing structures:

- Bridge and viaduct
- Industrial plants and components
- Buildings including cultural heritage
Design of isolated structures

- Equivalent Lateral Force Procedure *(effect. stiffness and damping)*
  - N/A: near-field effect, soft soil conditions, irregular structure
- Response Spectrum Analysis *(effect. stifness and damping)*
  - N/A: nonlinear superstructure
- Nonlinear time history analysis
  - Applicable for all cases
    - Mandatory if it is not possible to model the Isolation System with an equivalent linear system,
    - The superstructure may be modeled elastically,
    - The constitutive model of the devices shall represent its actual behavior in the range of deformations and velocities associated with the seismic design situation.
Validation Tests

Engineering parameters (design properties) of isolators are determined by validation tests:

- **Effective stiffness and damping values must be determined,**
- **These values are amplitude dependent (both displacement and velocity)!**
Structural Health Monitoring (SHM)
Why Structural Health Monitoring

- **Structures face**
  - **Man-induced damaging events**
    - Fires, impacts, explosions, biochemical hazards
  - **Natural phenomena**
    - Floods, earthquakes, strong winds, temperature fluctuations
  - **Age**
    - General fatigue and design life limits

Damage occurs — some obvious as shown above — but how about what visual inspection and modeling miss?
Why Structural Health Monitoring

*In minutes following a damaging event – such as earthquakes - the clock starts ticking...*
It is relatively easy to say that a building is in bad condition, but to conclude that it is safe is a challenging task!

Valuable information, delivered quickly, is critical in order to react with the utmost efficiency to save lives and reduce cost impact.
What If the Damage Assessment can not be Done Properly after a Damaging Earthquake?
REAL-TIME STRUCTURAL HEALTH MONITORING (SHM)

• SHM is
  • the process of implementing a damage detection strategy for structures and civil infrastructure.

• SHM can answer the following questions
  • Is the system damaged?
  • Where is the damage located?
  • What type of damage present?
  • What is the extent of damage?
  • What is the remaining useful life (prognosis) of the system?
Sensors measure drift values between adjacent floors,
These values can be mapped with specific damage levels defined in codes, such as FEMA-356 and/or ASCE 41,
Damage can be estimated with certain confidence levels.
Powerful benefits of real-time SHM for Buildings:

- Enhances understanding of a building’s health through continuous monitoring and analysis,

- Provides a basis for rapid decision making regarding building safety and the possible need for evacuation following an extreme event,

- Allows more rapid identification of hidden structural damage
Most systems available today broadcast raw sensor data via the Internet in real-time or near real-time.
Real-Time Damage Identification

Design Based vs. Probabilistic Based Damage Detection

Imperial Valley Service Building
1979 Imperial Valley EQ
Real-Time Damage Identification

Probabilistic Methods

By measuring story drifts (indirectly from accelerometer measurements) damage can be estimated in near real-time.

Fragility Curves for a Column Element

Inter-story Drift Ratio

P(D>DS) Damage Level

P(DM | IDR)

No Damage  Slight Damage  Moderate Damage  Severe Damage

0.000  0.005  0.010  0.015  0.020

0.02

0.06

Seismic Isolation and Structural Health Monitoring Technologies
Damage Probability Reporting within Minutes Following an Earthquake:

- Provides detailed reporting within minutes following an event:
  - **Global Reporting** ("Get in or get out of the building")
  - **Floor by Floor Damage Probability Localization** ("Where is the damage")
Automated Email Report to Parties You Designate

Global Damage Assessment tells you:

- **Green**: No Damage (Continued Operation or “CO”).
- **Yellow**: Immediate Occupancy (IO).
- **Orange**: Life Safety (LS).
- **Red**: Collapse Prevention (CP).

Get an overall picture of the health of your building
Smart Building Systems
Floor by Floor Reporting

Understand where your highest likelihood of damage is with detailed floor-by-floor damage probability assessment.
Begin with one critical building and incorporate additional buildings for overall regional management.
Your Designated Structural Engineer will also have access to critical structural performance information to develop final building assessment and repair planning.
Local Codes Requiring SHM Systems

Highrise Building Codes of Istanbul and Izmir

**Istanbul**

Yüksek Binalar Deprem Yönetmeliği

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

Version - IV

Maası 2008

H >= 60 m
min. 8 sensors

**İzmir**

YENİ KENT MERKEZİNDE
(BAYRAKLI SALHANE/TURAN BÖLGESİ - KONAK ALSANCAK
LIMAN ARKASI KESİMİ VE SALHANE BÖLGESİ)

YAPILACAK YÜKSEK BİNALAR İÇİN

ZEMİN, GEOTEKNİK VE YAPI / DEPREM MÜHENDİSLİĞİ

PROJE VE RAPORLARINDA UYULMASI GEREKEN

TEKNİK ÖNERMELER

H >= 60 m
min. 14 sensors
Thank You for Your Attention!

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