Earthquake Hazards and Effects

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Course Objectives

Participants will be able to:

- Understand the nature of earthquakes and seismic hazard
- Understand earthquake effects on buildings and types of building damage
Introduction

A great earthquake can, in a few seconds, create a level of death and destruction equaled only by the most extreme weapons of war.

Tangshan, China, 1976 ; 250,000 deaths

Introduction

The U.S. has few deadly earthquakes compared to other countries, and its design and construction standards are higher.

In U.S. history there have been only about 3,100 deaths of which 1906 San Francisco was responsible for about 2,000
Recent California Earthquakes

Although life loss has been low, increasing economic earthquake losses are a concern in the U.S.

<table>
<thead>
<tr>
<th>Earthquake</th>
<th>Date</th>
<th>Richter Magnitude</th>
<th>Total Loss ($ million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>San Fernando (Los Angeles)</td>
<td>2/9/1971</td>
<td>6.7</td>
<td>2,240</td>
</tr>
<tr>
<td>Imperial Valley (Mexico border)</td>
<td>10/15/1979</td>
<td>6.5</td>
<td>70</td>
</tr>
<tr>
<td>Coalinga (Central California)</td>
<td>5/2/1983</td>
<td>6.4</td>
<td>18</td>
</tr>
<tr>
<td>Lone Pine (San Francisco Bay)</td>
<td>9/18/1989</td>
<td>7.0</td>
<td>8,000</td>
</tr>
<tr>
<td>Northridge (Los Angeles)</td>
<td>1/17/1994</td>
<td>6.7</td>
<td>46,000</td>
</tr>
</tbody>
</table>

The Kobe Lesson

However, the 1995 earthquake centered in downtown Kobe, Japan, showed that a modern city can be severely damaged.

Over 5,000 deaths occurred, 300,000 people were homeless and the regional economy crippled.

Before this earthquake, Kobe was regarded as a low-risk area and was lacking in preparedness measures.
Seismicity of the United States

Map shows relative seismicity by Counties

SOURCE: USGS

What Earthquakes are:

THE ORIGIN OF EARTHQUAKES

Earthquakes begin when a fault – a break in the underground structure – slips
What Earthquakes are:

Fault slippage starts at one point but spreads rapidly along the fault. Loma Prieta 1989

Fault Types

3 MAIN TYPES:
- Strike-Slip
- Normal
- Reverse (Thrust and Blind thrust)

Fault rupture causes seismic waves to travel through the earth.
The Subduction Zone

The oceanic plate is sliding to the right under the continental plate

Waves
Near the Ground Surface
A: PRIMARY (P)  B: SHEAR (S)  C: LOVE WAVE  D: RAYLEIGH

They combine to produce motion in all directions
Random Ground Motion

Waves

Seismic waves travel very fast: their speed varies depending on the type of ground and the nature of the initial fault rupture:

- **P WAVES IN ROCK**: 7,000-18,000 MPH
- **S WAVES IN ROCK**: 5,000-11,000 MPH.
Earthquake Magnitude

Measured as a Richter Magnitude \( (M_r) \)

- Proportional to size of the seismic waves at a given distance
- Open ended but maximum is about \( R = 9.0 \)
- Significant damage begins at about \( R = 5.5 \)
- Scale is Logarithmic: tenfold increase in each value, thus \( R = 7.0 \) is one hundred times the energy release of \( R = 6.0 \)

Inertial Forces

Seismic waves create movements of the base of the building that are resisted by inertial forces within the building

\[ F = MA \]

Newton’s Second Law of Motion, which governs earthquake generated forces within the building.
Acceleration

Acceleration is the RATE OF CHANGE of velocity

It is Measured in “G’s” : One G is a Velocity of 32 Feet per Second, per Second, which is the Acceleration of Gravity (on a Free Body Falling in Space)

Building Damage Begins at about 0.10 G in Poor Construction. Short duration Accelerations may Exceed 1.0 G

Typical Acceleration Values

1 "g" parachute team
4 "g" roller coaster
9 "g" air force display team
0.001 "g" human perception
Earthquake Related Hazards

- SURFACE FAULTING

- LIQUEFACTION

- GROUND FAILURE, LANDSLIDES

- TSUNAMI AND COASTAL SURGE

Ground Amplification

A site with soft soils may have certain characteristics of the ground motion amplified by between 1.5 to 6.0 times compared to rock.

Damage to Cypress Freeway, San Francisco, partially caused by soft soil conditions, Loma Prieta, 1989.
**Fundamental (Natural) Period**

Period is one complete back and forth motion defined in seconds
- The swing oscillates at its fundamental period

**Building Periods**

- Each building has its own fundamental period.
- Height is the main determinant but also proportional to mass and stiffness.
Earthquake Probability & the Code

Based on the NEHRP Provisions the IBC provides Maps that gave Potential Probabilities of Exceedance in specified years, such as:

10% probability in 50 years 10%/% which corresponds to a return period of about 475 years

2% probability in 50 years, a return period of about 2500 years.

Code Maps (IBC, UBC)

Code maps are based on the Maximum Considered Earthquake (MCE) which is the 2%/50 earthquake

The Design Earthquake (DE), which the engineer uses to establish forces on the structure, is 2/3 the MCE value

Near active faults, the MCE shaking is determined using the characteristic earthquake for each particular fault.

Maps show acceleration values for short and long period structures
I.B.C Probability Maps

IBC Map for the USA: the code provides 22 maps that are 0.2 sec and 1.0 sec blow ups of various locations

Building Damage in Earthquakes

Extent of building damage is influenced by:
- Nature and intensity of shaking
- Building age and seismic code used (if any)
- Nature of structural design
- Nature of structural system
- Architectural/Structural configuration
- Quality of construction
Age and Structural System

GOOD

BAD

BUILDING SCIENCES SEMINAR  MULTIHAZARD DESIGN CONSIDERATIONS

MODERN STEELFRAME WITH ENERGY DISSIPATING BRACING
UNREINFORCED MASONRY, PRE-CODE

Earthquake Damage

SAN FERNANDO, 1971 Olive View Hospital, soft first floor

BUILDING SCIENCES SEMINAR  MULTIHAZARD DESIGN CONSIDERATIONS
Earthquake Damage

Loma Prieta, 1989: Soft soil and soft first floor

Earthquake Damage

NORTHRIDGE 1994

Soft story apartment houses: open parking at first floor
Earthquake Damage

NORTHRIDGE, 1994: Collapsed parking garage: inadequate interior columns

Earthquake Damage

NORTHRIDGE, 1994
Tilt-up reinforced concrete structure:
Inadequate roof/wall connections
Earthquake Damage

VINA DEL MAR, CHILE, 1985  Soft soil and unbalanced lateral system.

KOBE, 1995  City Hall, collapsed intermediate floor due to change in structure system at this floor
Structural and Nonstructural Damage

- Occurs even if structure has little or no damage
- Can cause injury or even death
- Can render building non-functional
- Difficult to prevent
- Costly to repair: typical building cost is 20% structural / 80% nonstructural
Nonstructural Damage

Ceiling damage, school, Northridge, 1994

Nonstructural Damage

Typical interior damage, Northridge, 1994
Nonstructural Damage

Light Fixture fallen over teacher’s desk, Northridge, 1994

Nonstructural Damage

Exit corridor, Olive View Hospital, San Fernando, 1971
Nonstructural Damage

Broken sprinkler pipe, new Olive View Hospital, Northridge, 1994

Nonstructural Damage

Upset equipment in a school shop: Northridge 1994
Conclusions

THIS PRESENTATION HAS OUTLINED THE NATURE OF EARTHQUAKES AND THEIR EFFECTS ON BUILDINGS.

SOME OF THE BUILDING CHARACTERISTICS THAT AFFECT SEISMIC PERFORMANCE HAVE BEEN IDENTIFIED.

EXAMPLES HAVE BEEN SHOWN OF THE KINDS OF STRUCTURAL AND NONSTRUCTURAL DAMAGE THAT MAY BE EXPECTED.