University College London
Civil & Environmental Engineering

Earthquake Engineering

Dr Tiziana Rossetto

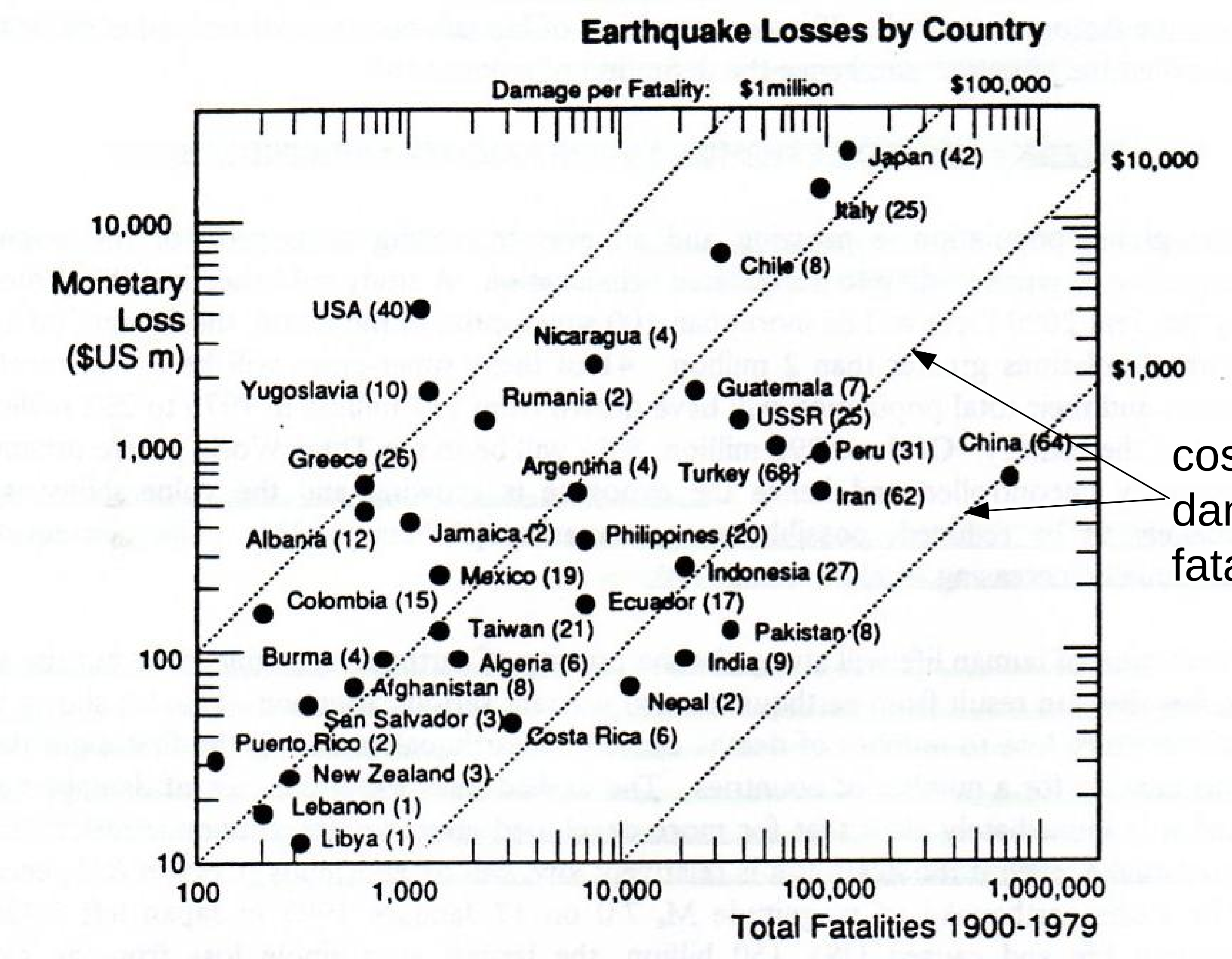
Introduction

- In the past 3 centuries over 3 million people have died due to earthquakes and earthquake related disasters.
- The economic losses estimated for the period 1929-1950 are in excess of US$10 billion.
- 2/3 of the earths crust is seismically active, which means that about 1,000,000,000 people are living in areas of the world that are prone to earthquakes.

Introduction

For more developed countries the economic loss due to an earthquake can be enormous even if the death toll is fairly low (Coburn and Spence 1992):

e.g. Kobe Earthquake (Ms 7.0, Japan, 1995) killed 5,420 people but caused US$ 150 billion economic loss



cost of damage per fatality

Introduction

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But cost is relative:

e.g. Managua earthquake (Ms 6.1, Nicaragua, 1972), caused 10,000 deaths and US$ 2 billion economic loss.

…..but This loss = 40% of GNP

Introduction

What do we know?

- Earthquakes cannot be prevented nor accurately predicted.
- It is not ground shaking itself that causes life and economic loss but the collapse or damage of buildings and infrastructure that are too “weak” to resist the ground shaking.

What is Earthquake Engineering?

The application of civil engineering to reduce life and economic losses due to earthquakes,

(i.e to mitigate *seismic risk)*

What is Seismic Risk from the engineers' perspective?

the probability of losses occurring due to earthquakes within the lifetime of a structure; these losses can include human lives, social and economic disruption as well as material damage.

What is Seismic Risk?

RISK = SEISMIC HAZARD x VULNERABILITY

What is Seismic Risk?

RISK = SEISMIC HAZARD x VULNERABILITY

Probability of a potentially damaging earthquake effect occurring at the site of planned construction within its design life.

What earthquake effects cause damage?

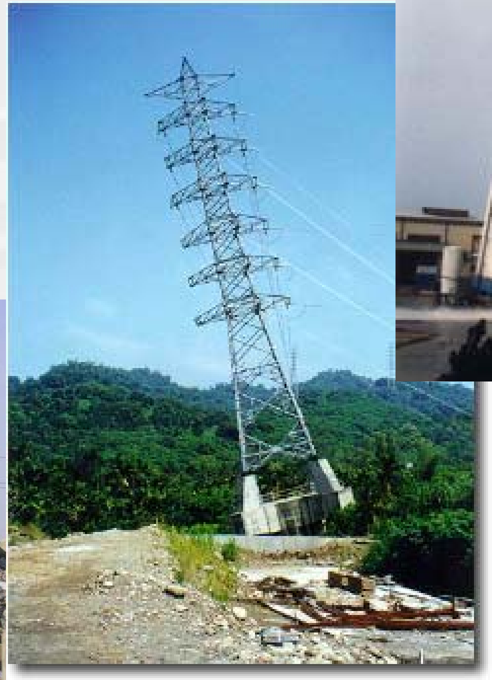
- Ground shaking

Loma Prieta, CA 1989

Bhuj E/q, India 2001

What earthquake effects cause damage?

- Ground shaking

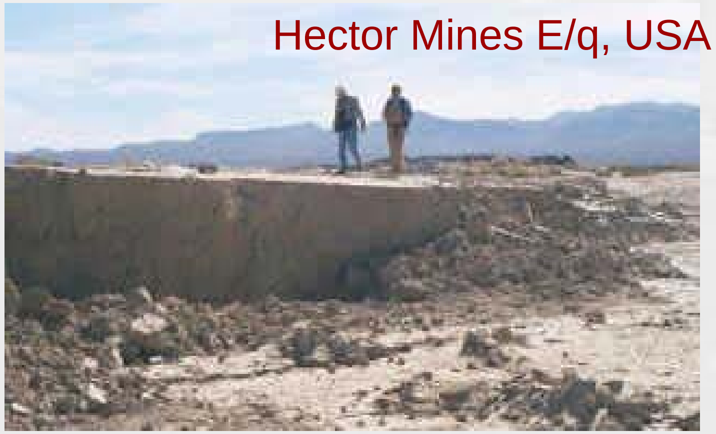


What earthquake effects cause damage?

- Ground shaking
- Surface rupture

Chi Chi E/q, Taiwan

Hector Mines E/q, USA



What earthquake effects cause damage?

- Ground shaking
- Surface rupture
- Landslides

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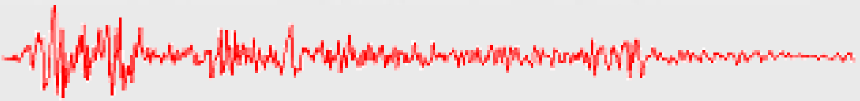
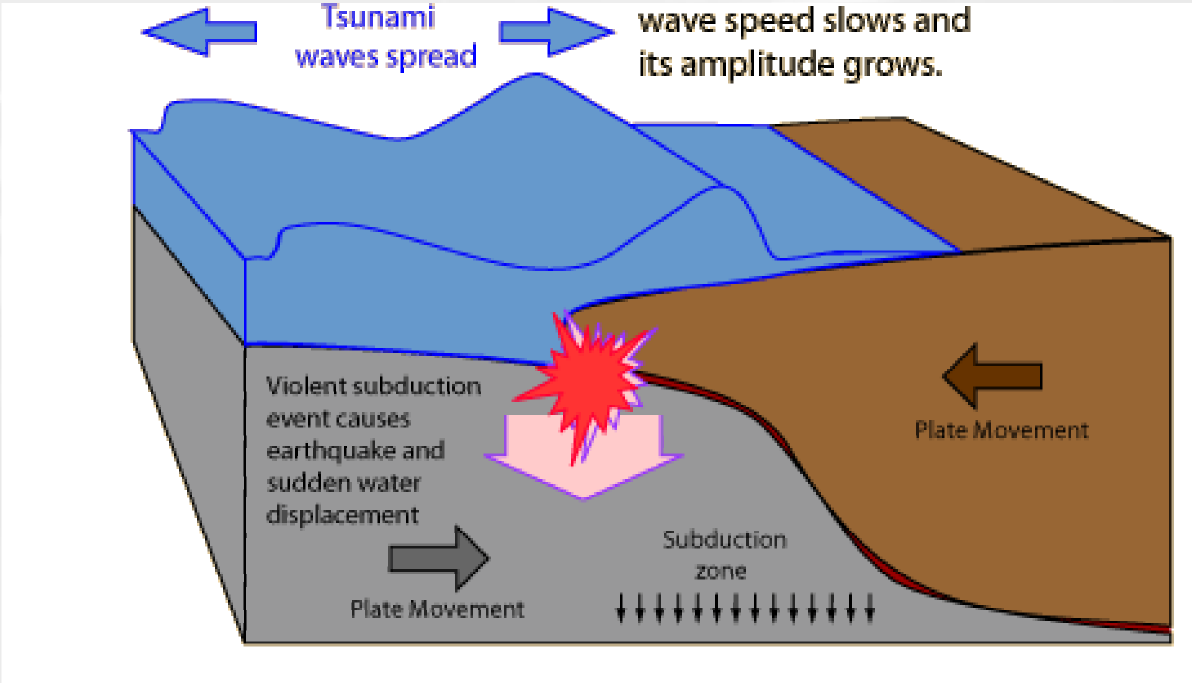


What earthquake effects cause damage?

- Ground shaking
- Surface rupture
- Landslides
- Liquefaction
- Tsunamis

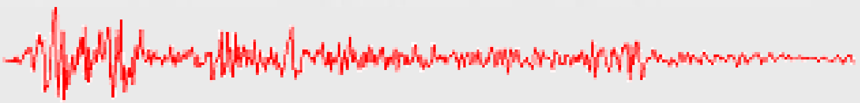


What is Seismic Risk?

is the probability of the occurrence of damage in a building when exposed to a particular earthquake effect.

RISK = SEISMIC HAZARD x VULNERABILITY

Probability of a potentially damaging earthquake effect occurring at the site of planned construction within its design life.



What is Seismic Risk?

DETERMINED BY MAN: CAN BE REDUCED THROUGH SEISMIC DESIGN

RISK = SEISMIC HAZARD x VULNERABILITY

DETERMINED BY NATURE: CANNOT BE REDUCED

Seismic Hazard and Seismic Design

Design Problem: An earthquake usually constitutes the most severe loading to which most civil engineering structures might possibly be subjected, and yet in most parts of the world, even those that are highly seismic, there is a possibility that an earthquake may not occur during the life of the structure.

Note: Lateral loads imposed by winds = 1-3% of building weight.
Lateral loads due to earthquakes = 25-30% of building weight.

Seismic Hazard and Seismic Design

Design Problem: An earthquake usually constitutes the most severe loading to which most civil engineering structures might possibly be subjected, and yet in most parts of the world, even those that are highly seismic, there is a possibility that an earthquake may not occur during the life of the structure.

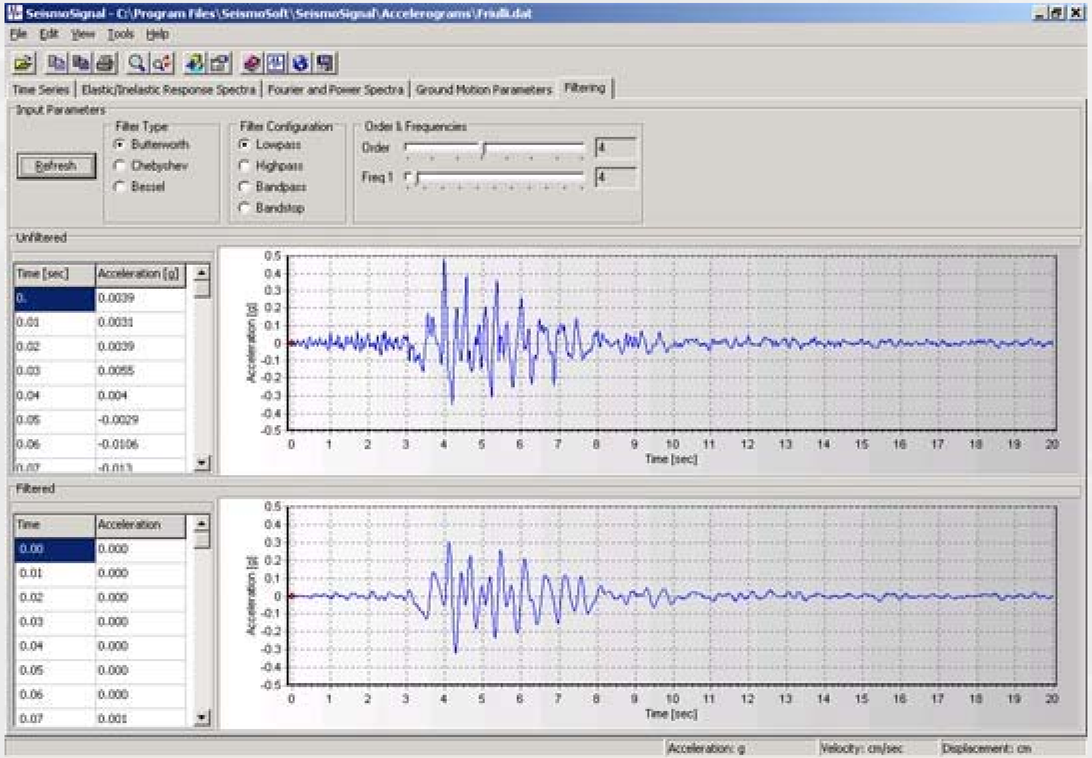
Assessment Problem: Most buildings that exist have not been designed to seismic codes. Can they withstand the type of earthquake that might happen in their location? What will be the damage incurred if an earthquake does occur?

Seismic Hazard and Seismic Design

Hence, engineers require seismic hazard assessments to provide not only a description of the likely seismic loads (ground shaking) to be experienced by an engineering structure, but also to attach probabilities of occurrence to these earthquake loads.

How do earthquake measurements translate into earthquake design loads?

•Seismograms can be used directly as input to complicated dynamic inelastic time history finite element analyses of important buildings.



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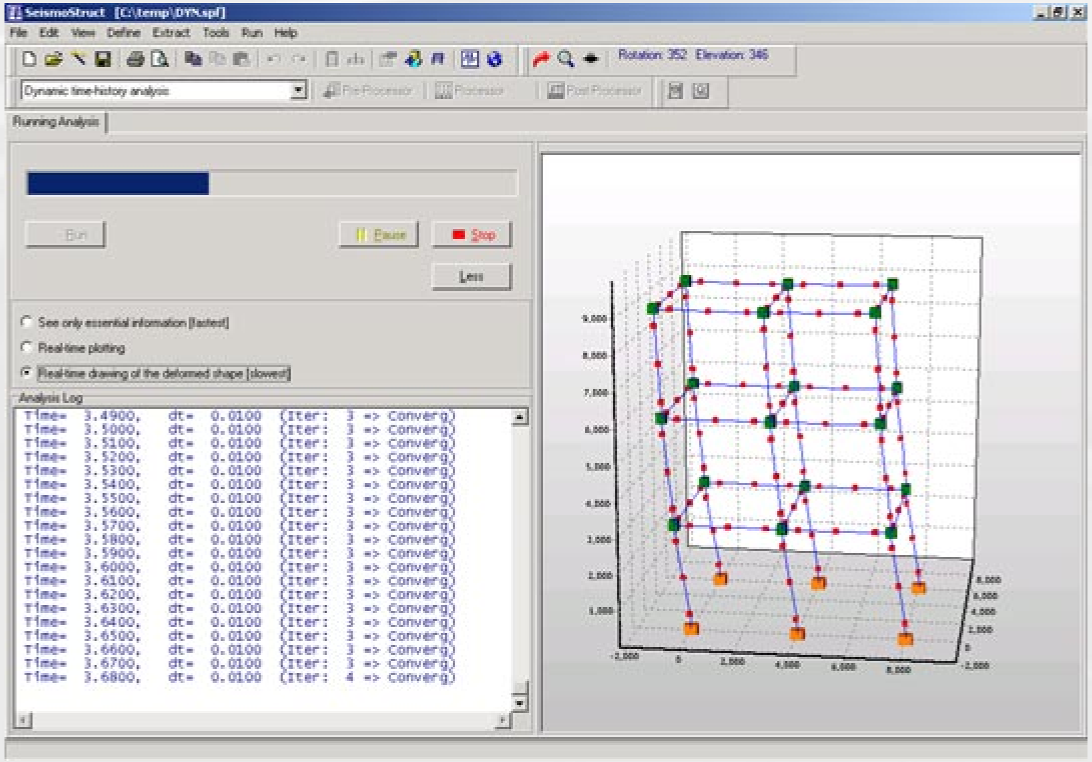
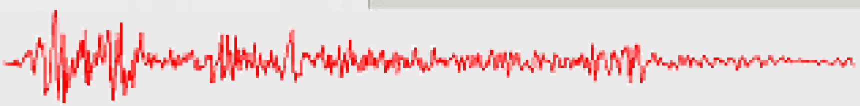


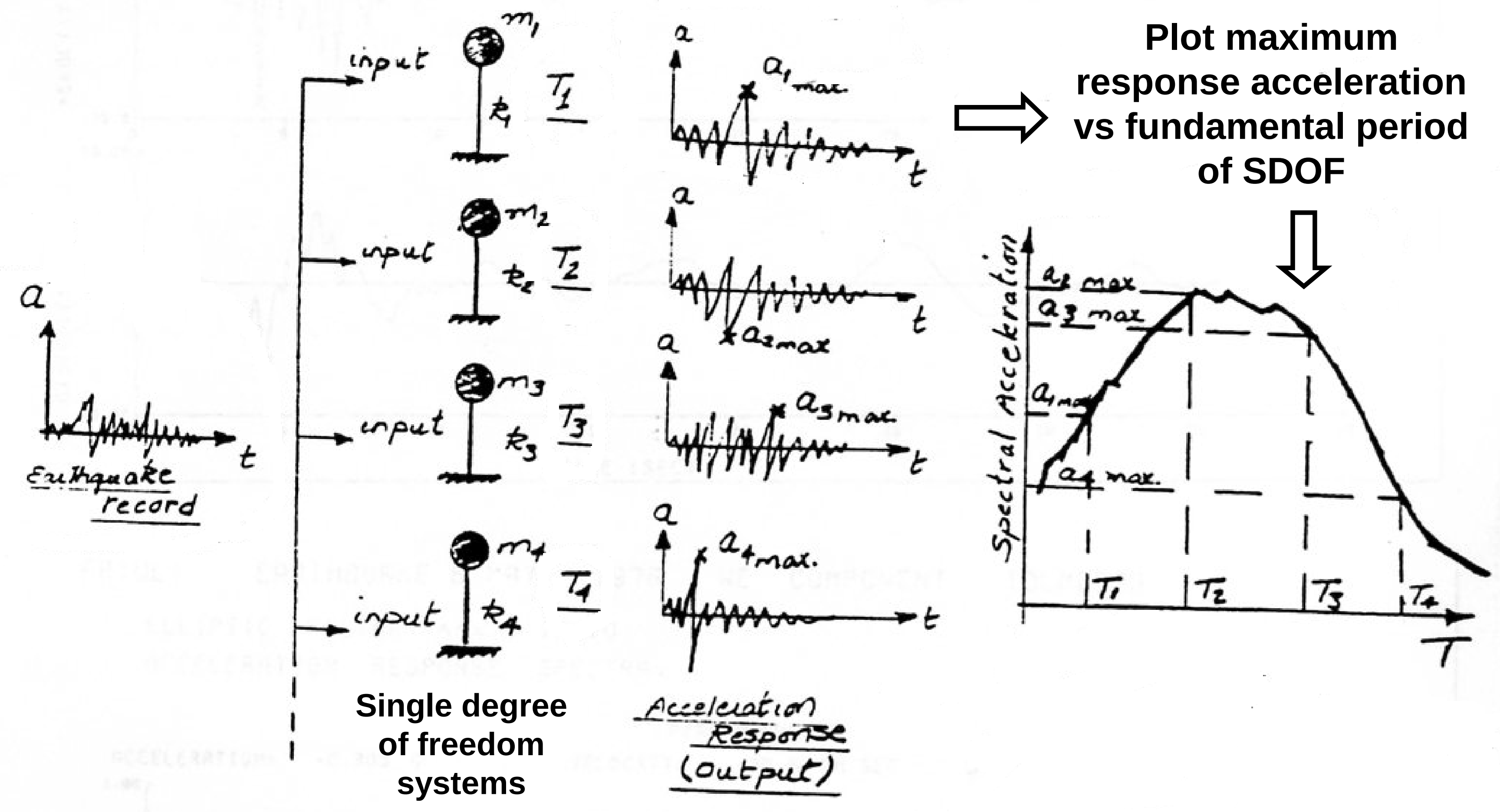


How do earthquake measurements translate into earthquake design loads?

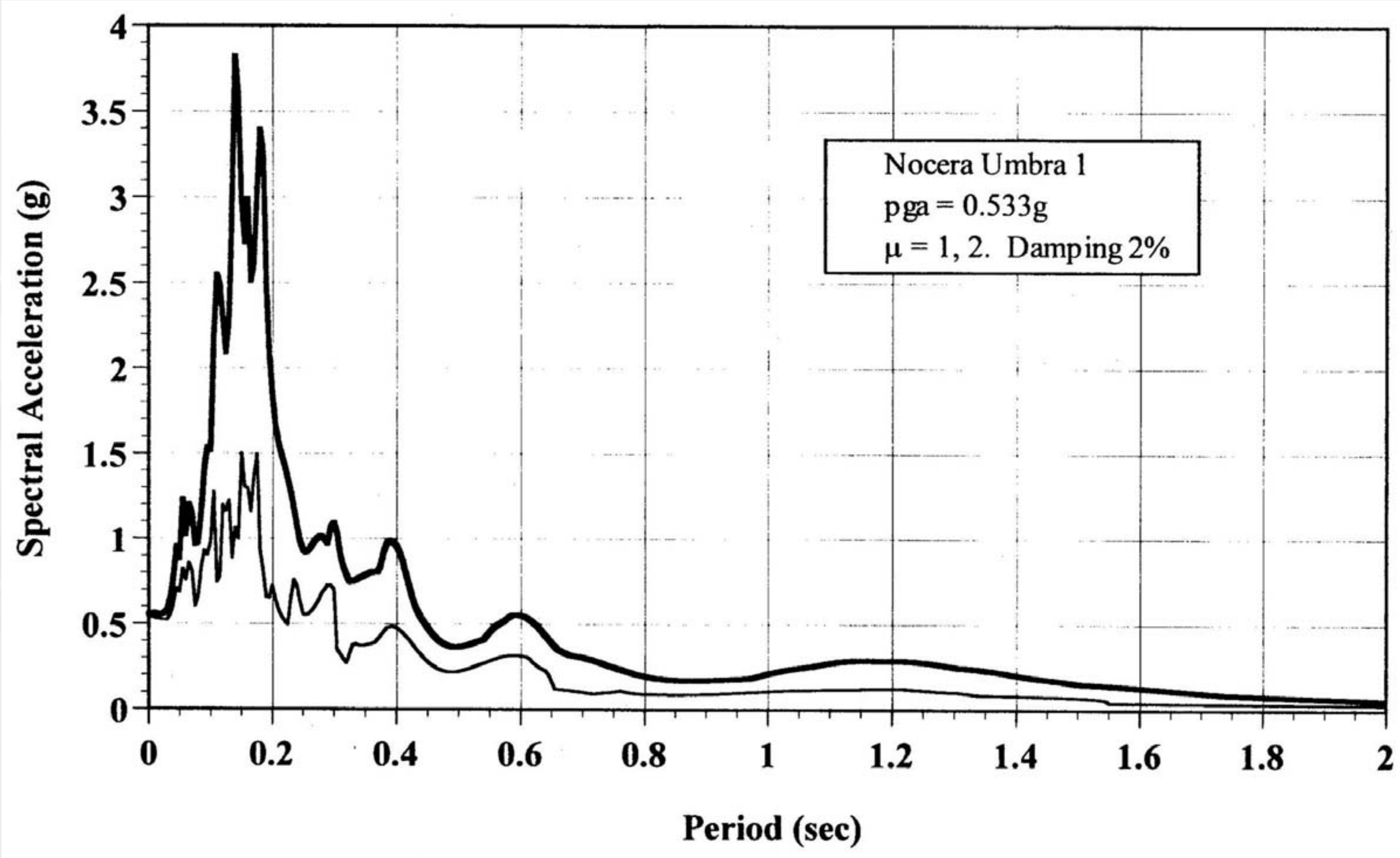
- Seismograms used directly as input to complicated dynamic inelastic time history finite element analyses of important buildings.

- Earthquake Acceleration Spectra and Peak Ground Acceleration.
    - Spectral modal analysis methods
    - Equivalent lateral force methods

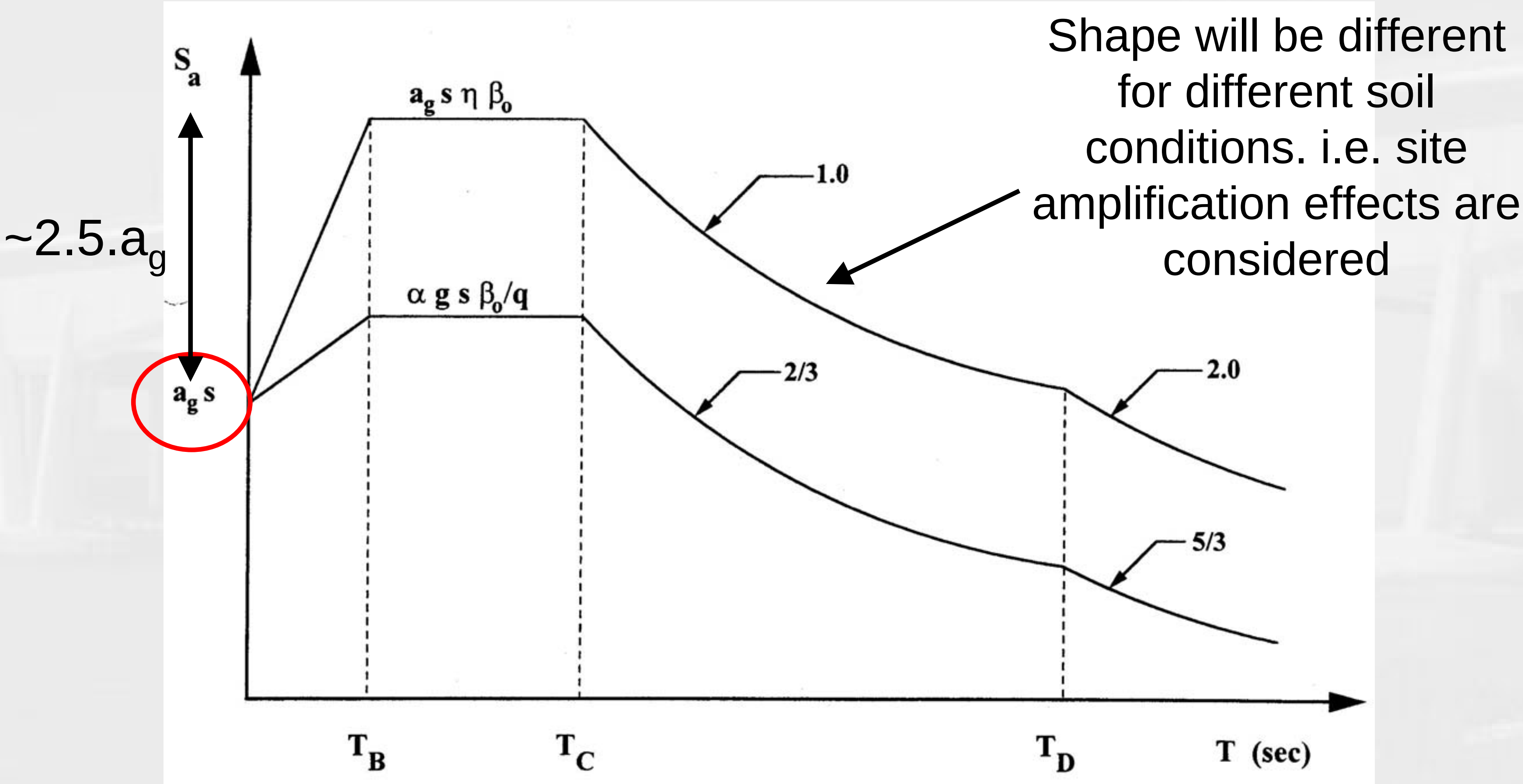
Computation of Elastic Response Spectrum



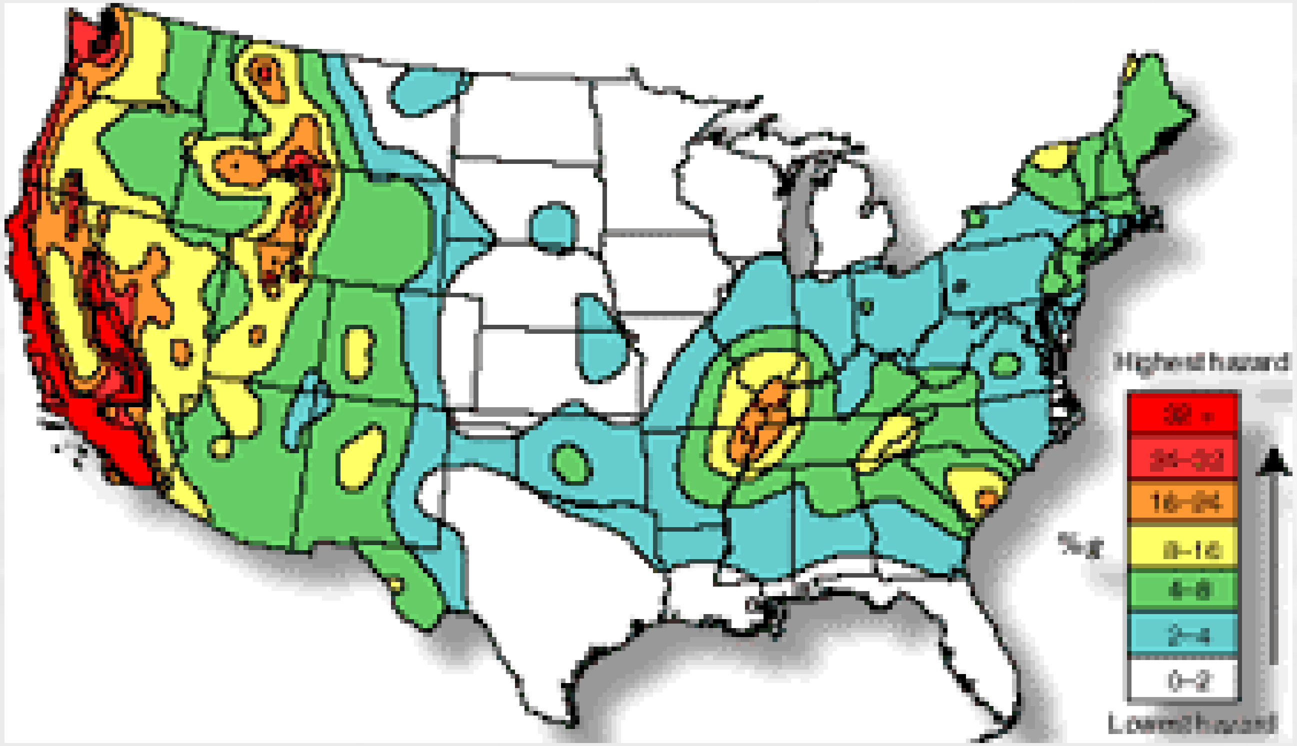
Elastic and Inelastic Spectra

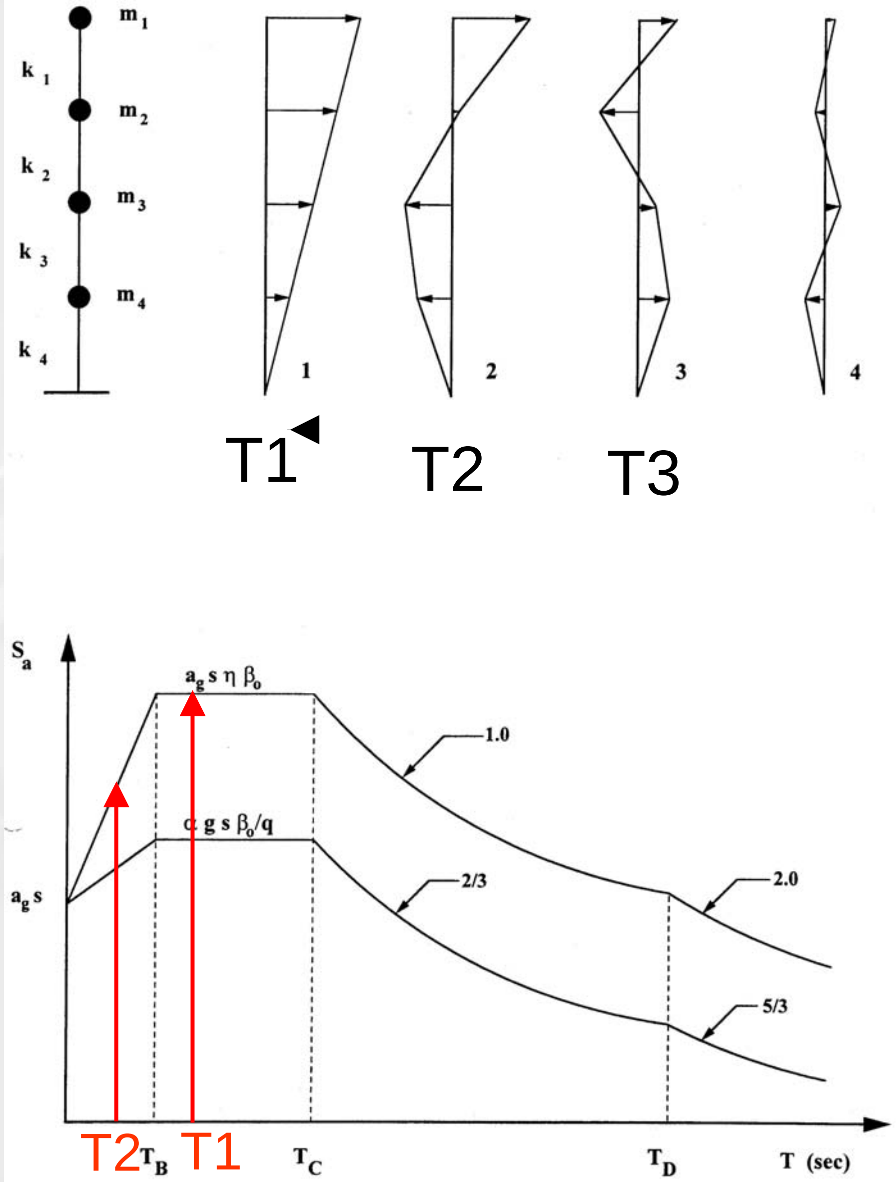


Design Spectra (EC8)



Code-type zonation map

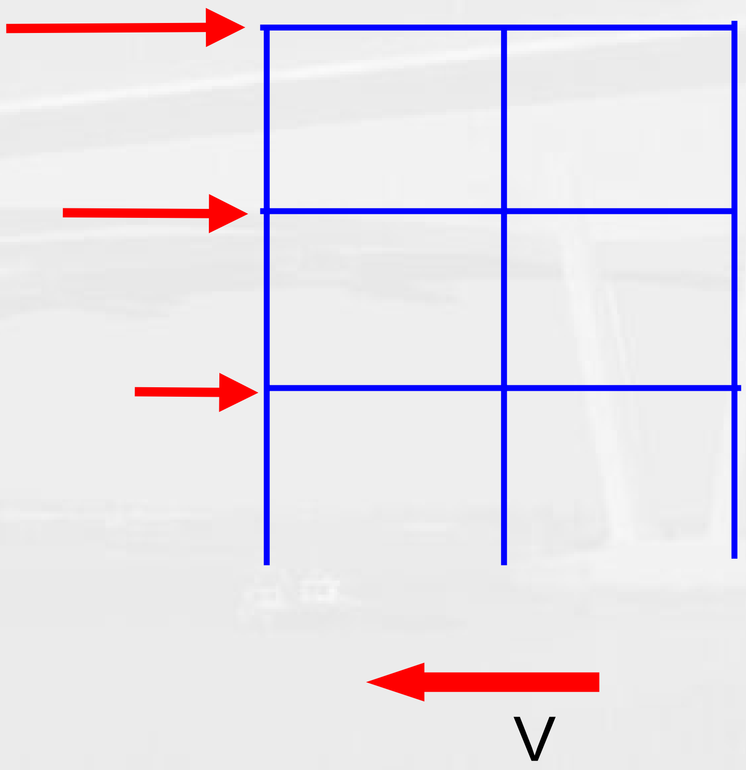



m1
m2
m3
m4
k1
k2
k3
k4
1
2
3
4
T1
T2
T3
Sa
ag s η β0
α g s β0/q
1.0
2/3
2.0
5/3
ag s
T2
TB
T1
TC
TD
T (sec)

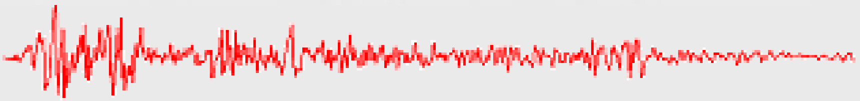
Equivalent Lateral Load

V = C.W (~ F=m.a)

$$C = \frac{Sa(T_1)}{g} . I . S . q$$



- I = Importance factor
- $Sa(T_1)$ = spectral acceleration for fundamental period, includes site effects
- q = behaviour factor, represents structure's ability to dissipate energy



Conventional Seismic Design

Normal building life assumed to = 50years

Ultimate limit state design: Design a building to resist an earthquake with a return period of 475yrs (i.e. the design loads will have a 10% probability of being exceeded in the structures life).

If a structure is very important (i.e. the consequences of its damage are severe) these loads will be increased: e.g. Nuclear structures designed to resist a 10,000 year return period event.

Conventional Seismic Design

Normal building life assumed to = 50years

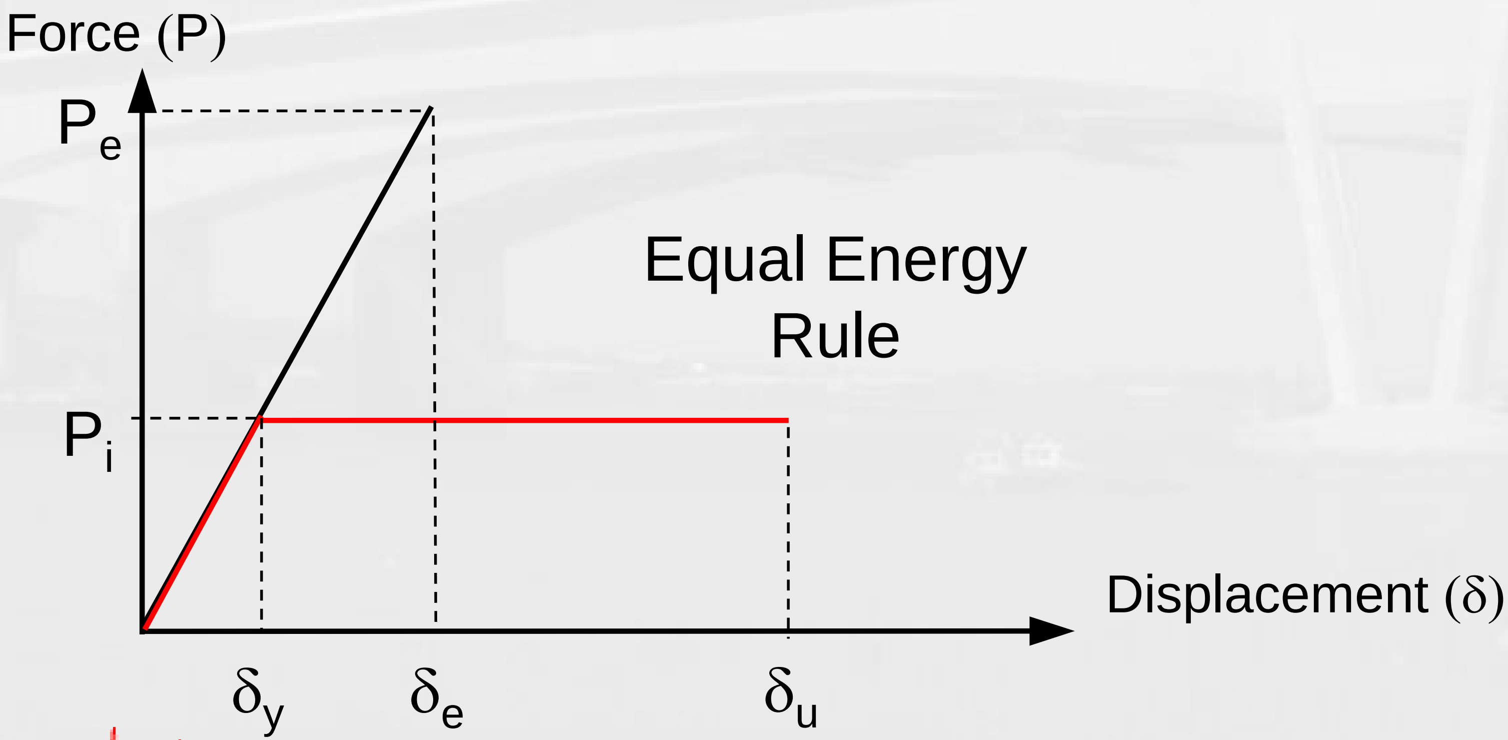
Ultimate limit state design: Design a building to resist an earthquake with a return period of 475yrs (i.e. the design loads will have a 10% probability of being exceeded in the structures life).

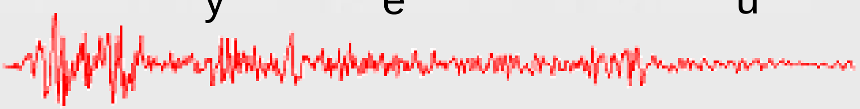
→ If we design for the seismic loads to be resisted by the building without damage (i.e. for the building to react elastically) the cost of construction would be prohibitive

→ So we design buildings to be damaged under earthquake loading

Designing for Controlled Damage

We design buildings to be damaged and react inelastically: meaning they dissipate the same energy, but will undergo greater deformation during the event



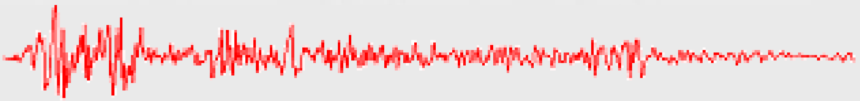


Designing for Controlled Damage

We design buildings to be damaged and react inelastically: meaning they dissipate the same energy, but will undergo greater deformation during the event

The location of the damaged areas is controlled to avoid catastrophic failure.

→ Simple design rules and capacity design



Simple Design Criteria

- Choose an adequate lateral load resisting system

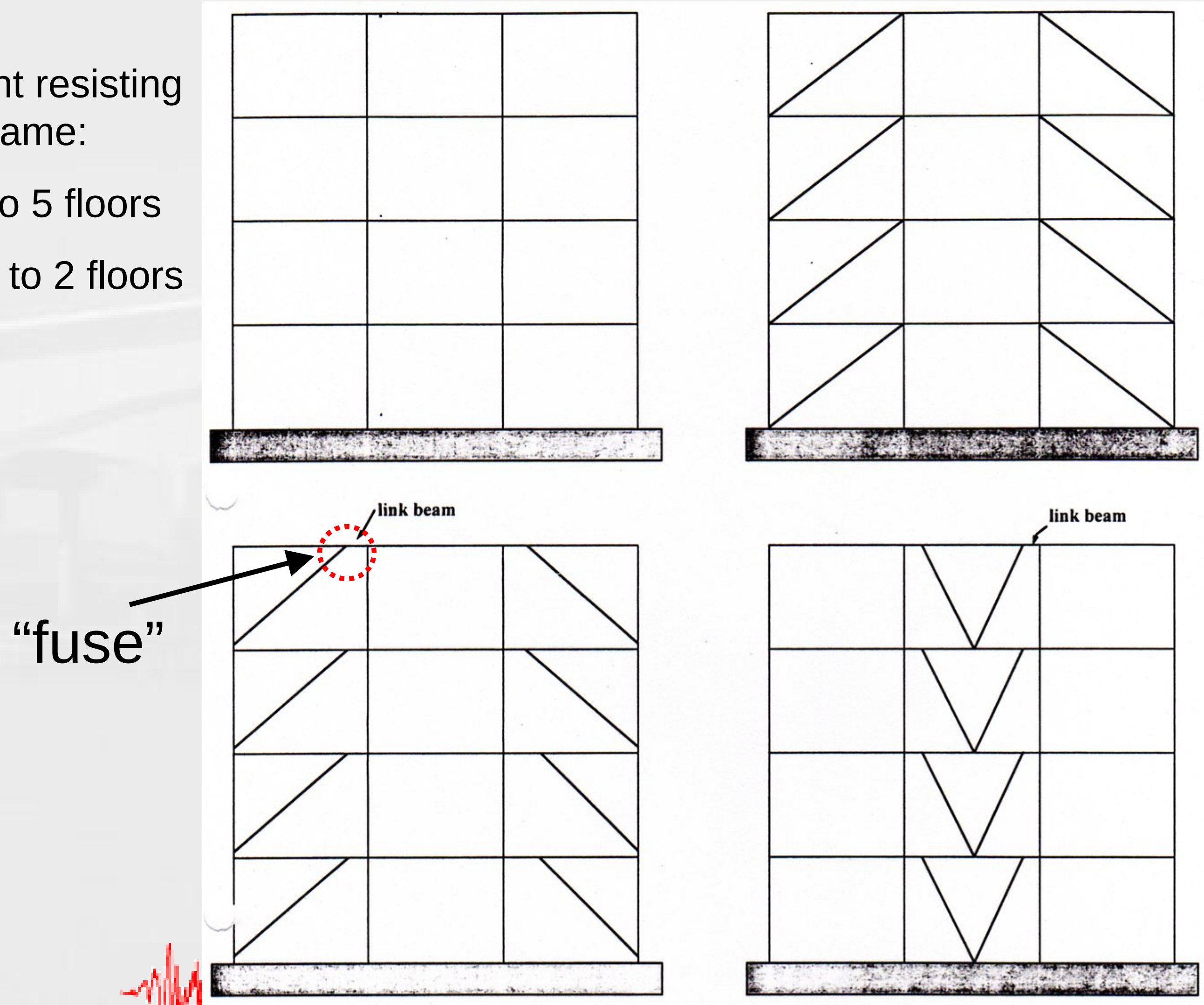
Adequate Lateral Load Resisting Systems

Moment resisting frame:

- RC up to 5 floors
- Steel up to 2 floors

Concentrically braced frame

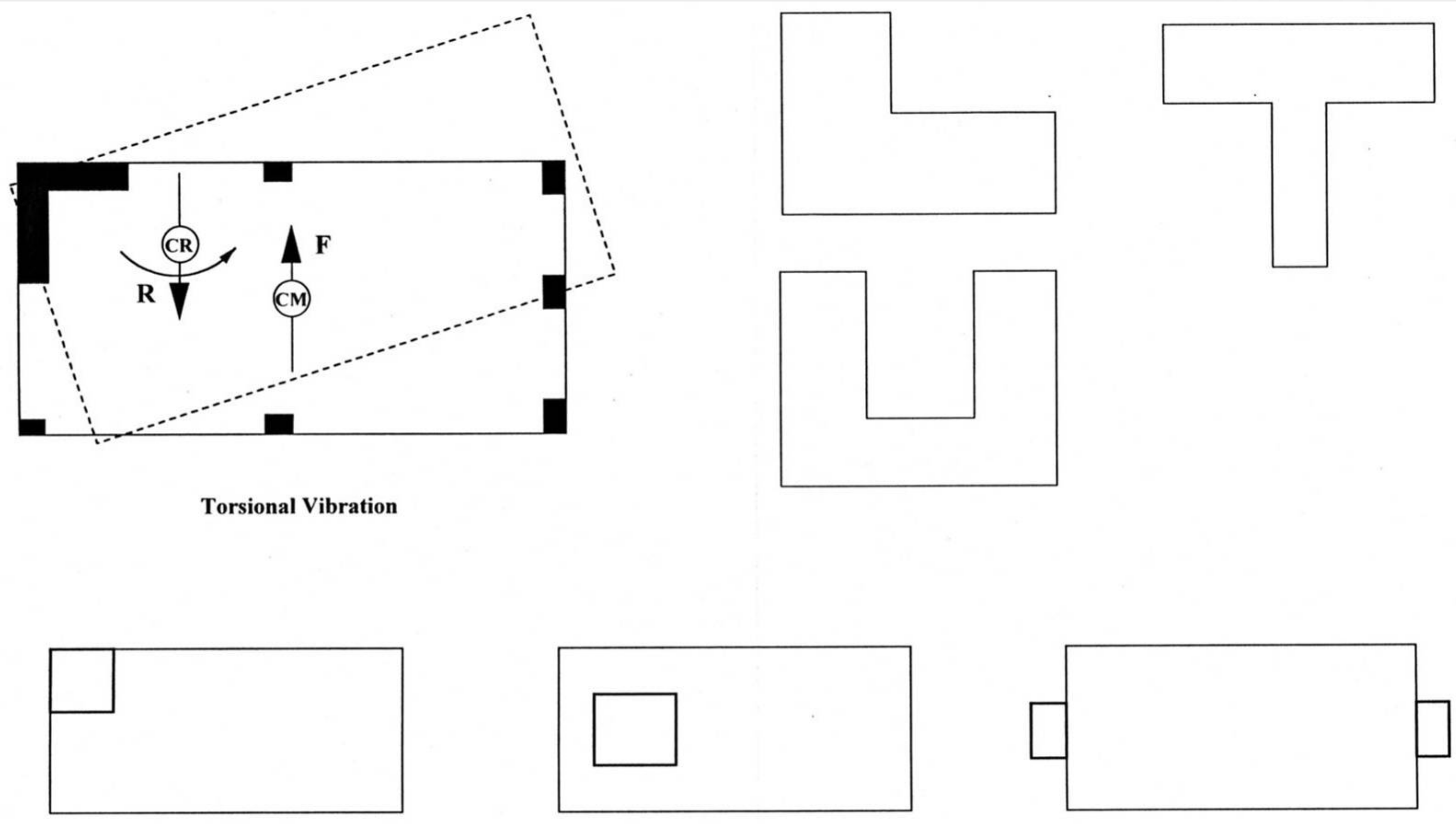
Eccentrically braced frames



Simple Design Criteria

- Choose an adequate lateral load resisting system
- Maintain regularity in plan and elevation (of stiffness and mass distribution)

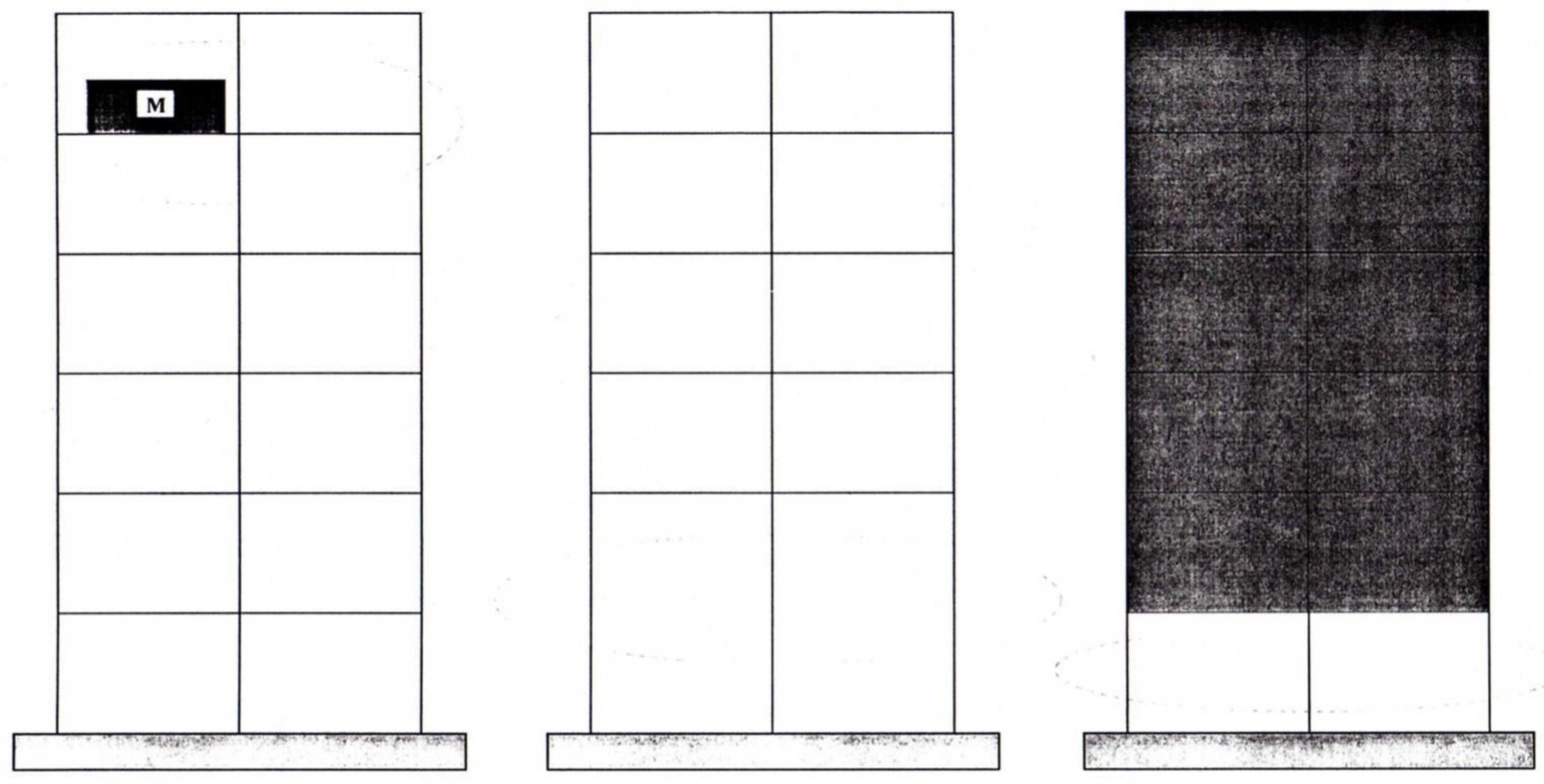
Regularity in Plan



Regularity in Elevation

Regularity in Elevation

Regularity in Elevation



Mass Irregularity

Stiffness Irregularity

"Soft-storey" Failure

“Soft-storey” Failure

“Soft-storey” Failure

Simple Design Criteria

- Choose an adequate lateral load resisting system
- Maintain regularity in plan and elevation (of stiffness and mass distribution)
- Ensure connection between structural elements
  - Connecting and anchoring of reinforcement
  - Using appropriate materials

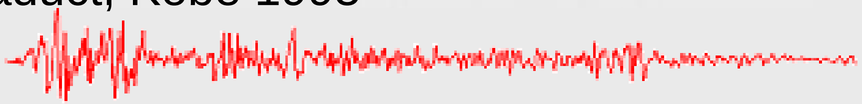
Poor Connection

Premature shear failure through inappropriate detailing

Fukae Viaduct, Kobe 1995

Premature shear failure through inappropriate detailing

Fukae Viaduct, Kobe 1995



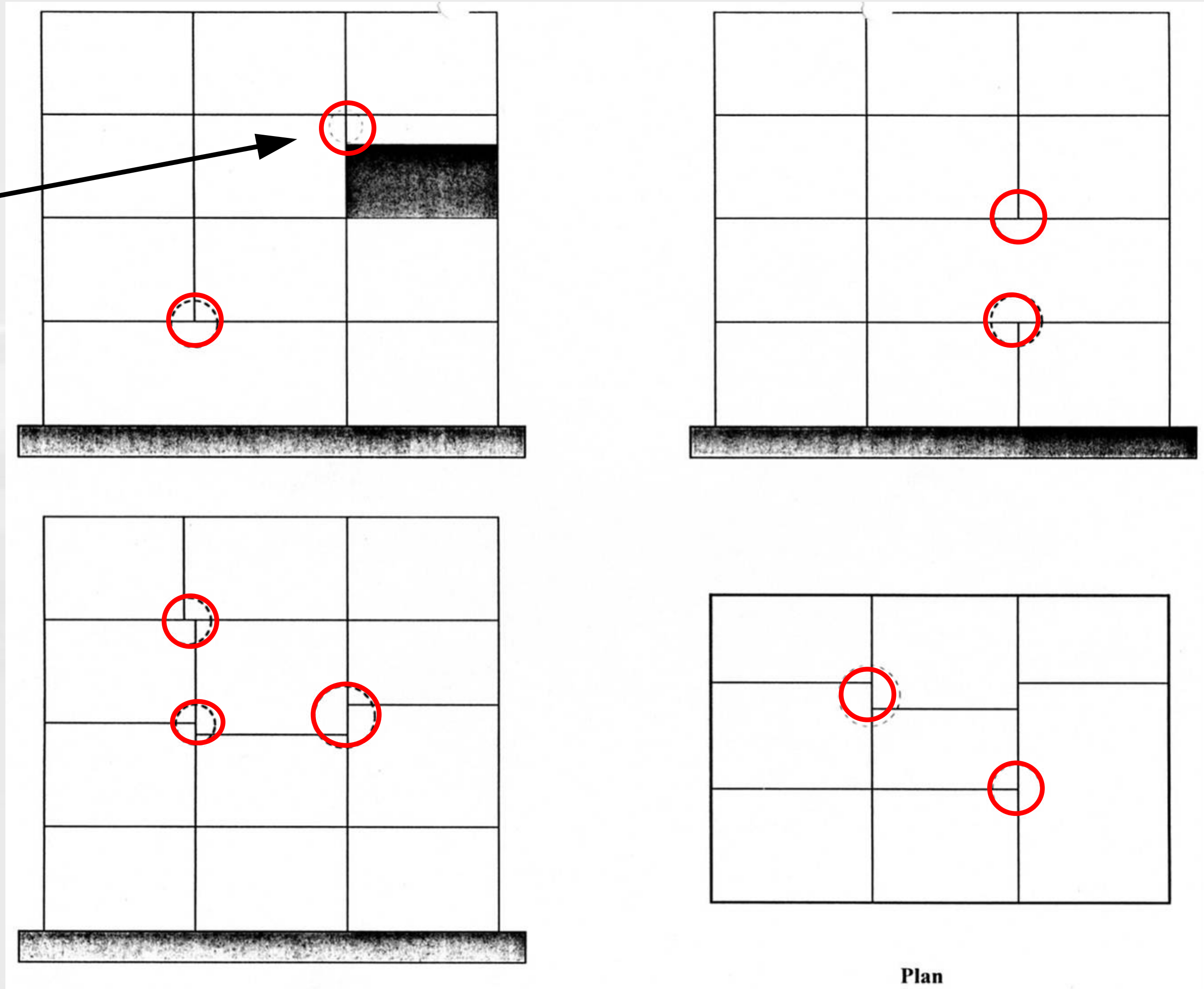
Poor Connection

Simple Design Criteria

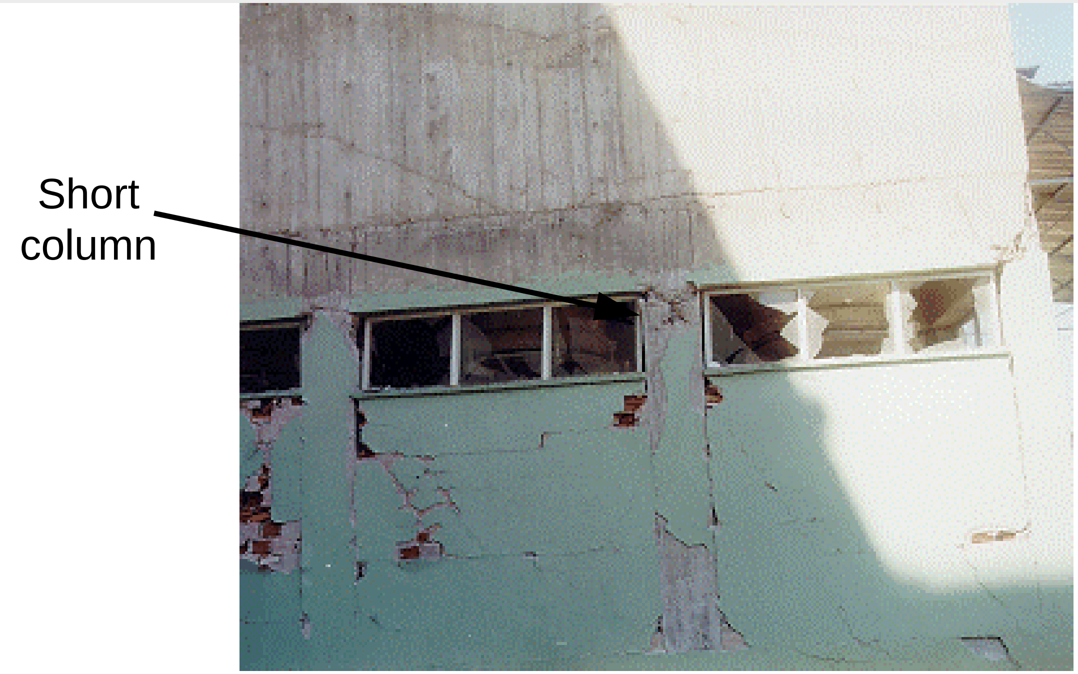
- Choose an adequate lateral load resisting system
- Maintain regularity in plan and elevation (of stiffness and mass distribution)
- Ensure connection between structural elements
- Avoid designing in locations of stress concentration

Local Stress Points

Short column



Short Column Failure



Resim-35 Zemin Katta Perdeden Kolona Geçişte Kısa Kolon Hasarı
Picture-35 Short Column Failure At The Ground Floor Where Shear Wall Is Supported By Columns

Simple Design Criteria

- Choose an adequate lateral load resisting system
- Maintain regularity in plan and elevation (of stiffness and mass distribution)
- Ensure connection between structural elements
- Avoid designing in locations of stress concentration
- Consider dynamic response in determining spacing between buildings, so as to avoid pounding

Pounding

Pounding

Simple Design Criteria

- Choose an adequate lateral load resisting system
- Maintain regularity in plan and elevation (of stiffness and mass distribution)
- Ensure connection between structural elements
- Avoid designing in locations of stress concentration
- Consider dynamic response in determining spacing between buildings, so as to avoid pounding
- Adopt capacity design concepts to control the failure mode

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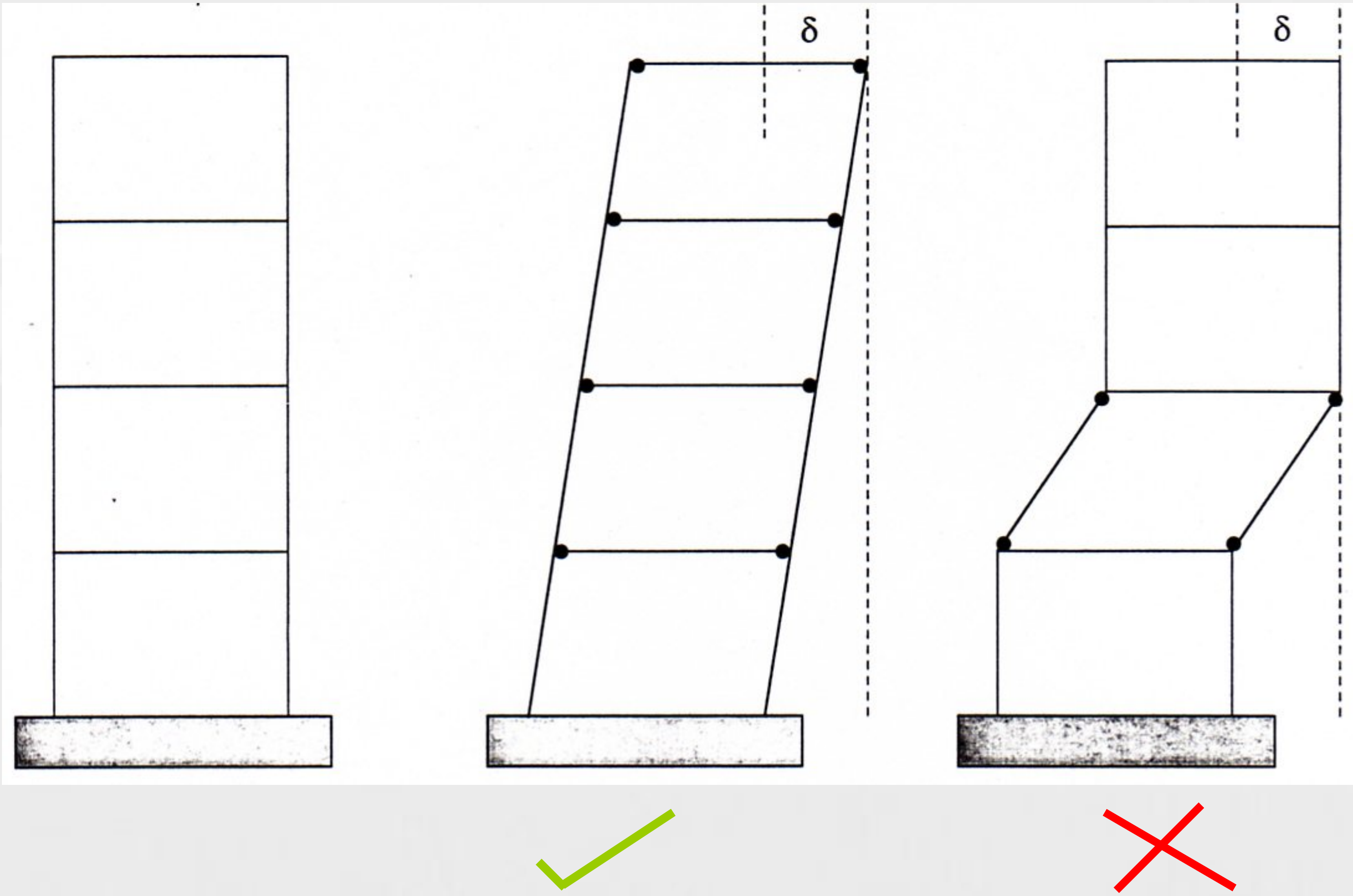
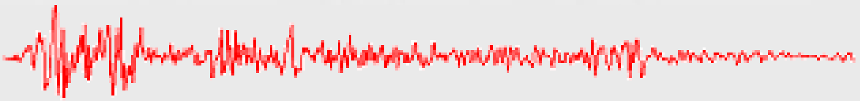
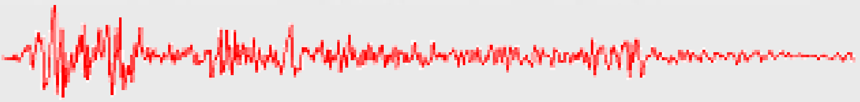
Capacity Design



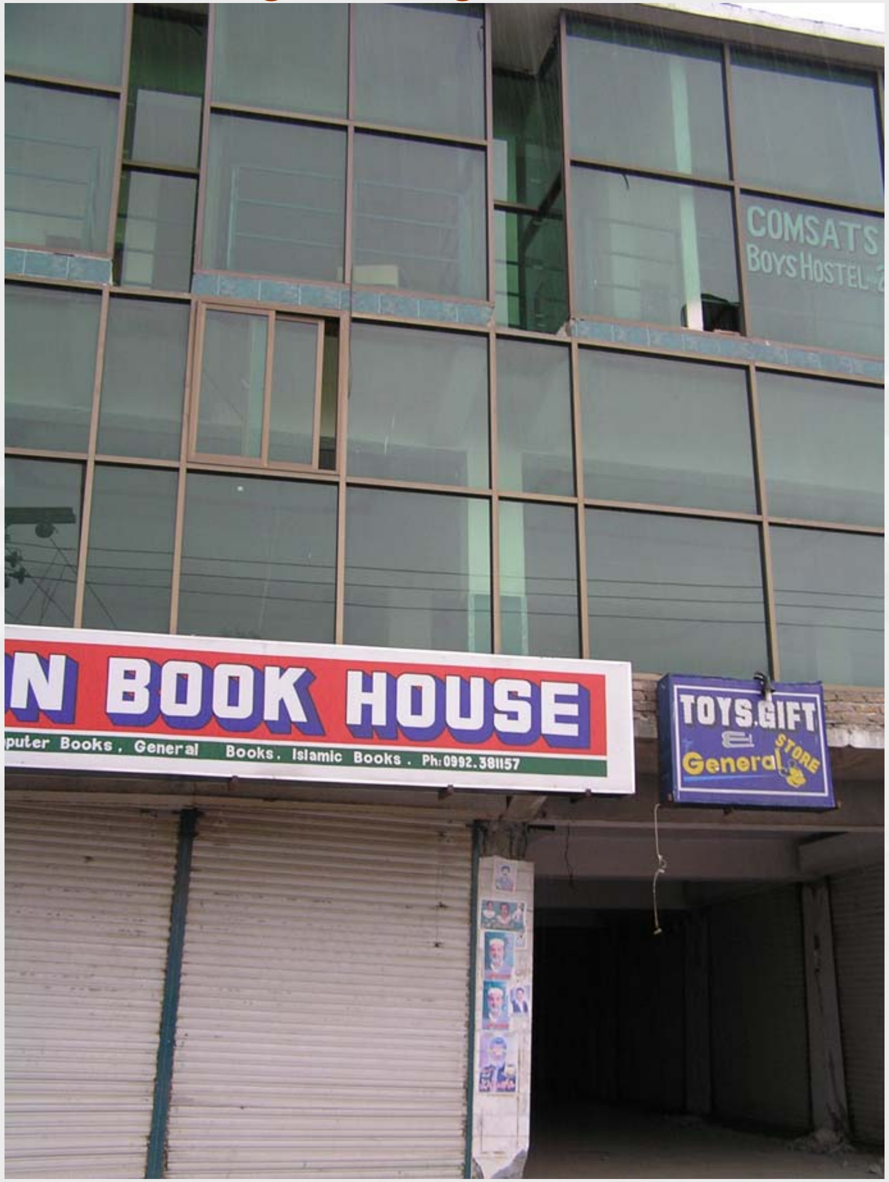


Earthquake Engineering

Bad Design



Bad Design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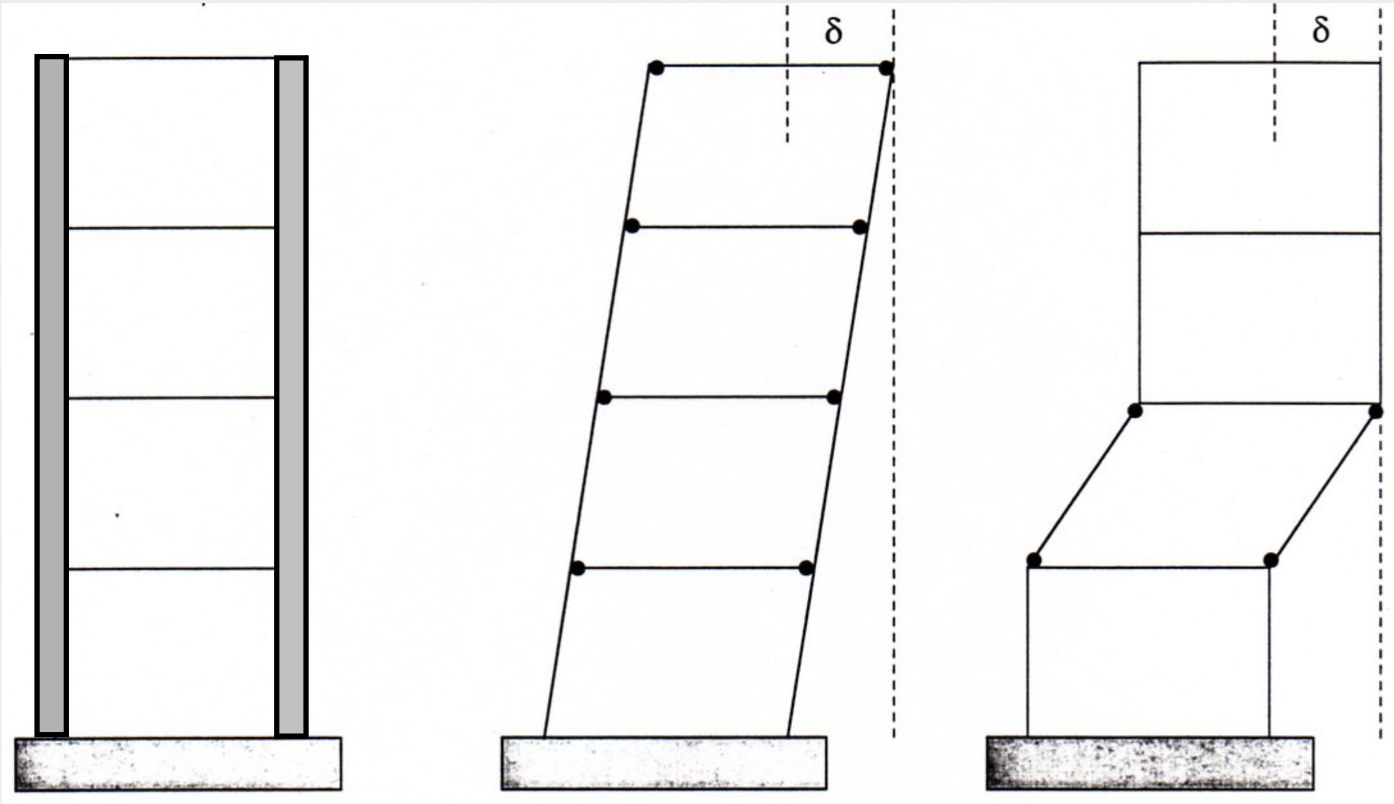
&
General
STORE

Capacity Design

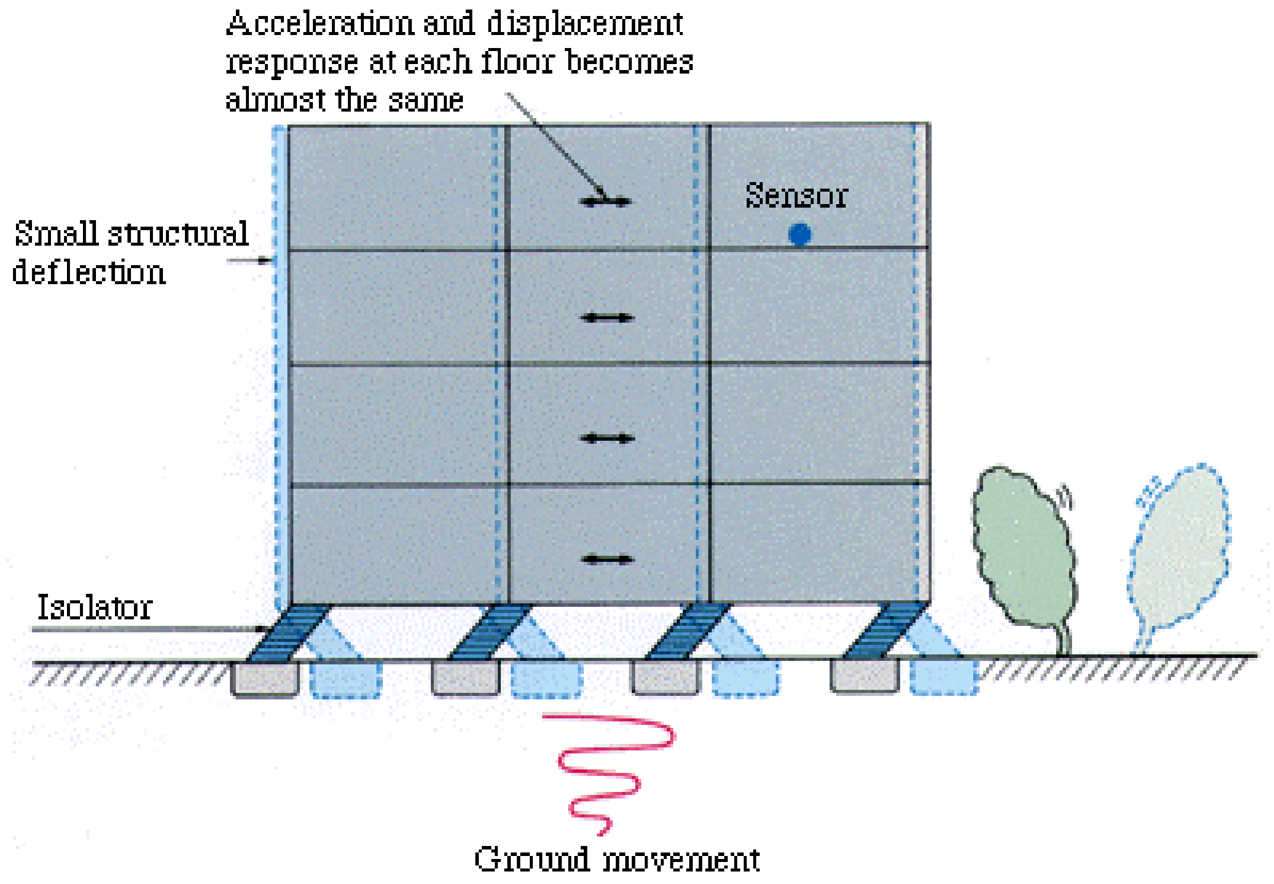


Simple Design Criteria

- Choose an adequate lateral load resisting system
- Maintain regularity in plan and elevation (of stiffness and mass distribution)
- Ensure connection between structural elements
- Avoid designing in locations of stress concentration
- Consider dynamic response in determining spacing between buildings, so as to avoid pounding
- Adopt capacity design concepts to control the failure mode
- Be aware of damage potential on non-structural elements

Damage due to Non-Structural Elements

Base-Isolation

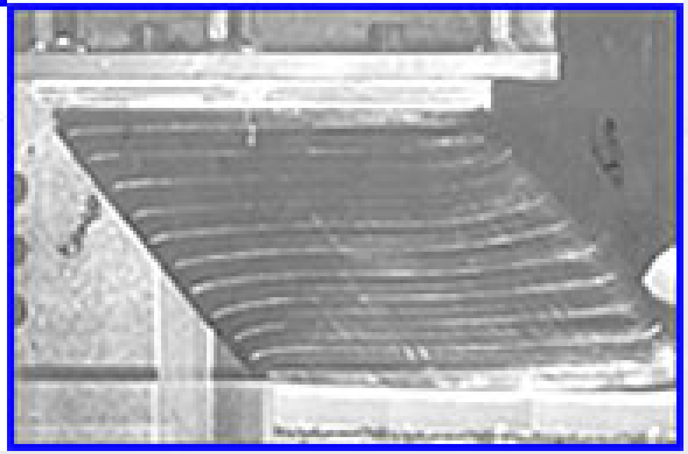


Base-Isolation


Construction of hospital in earthquake zone

◀ Base isolation of structure using laminated metal-rubber bearings

Testing of bearings under compression and shear loading - prior to installation ▶



Final Remarks

Damage to buildings is the greatest cause of life loss, direct damage and business interruption in an earthquake.

New buildings should be designed considering earthquake loading with the consequence of their damage in mind during the design process.

Assess our existing structures for their earthquake resistance

Predict the likely loss and intervene with structural strengthening if the risk is too high.

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Evening Seminar

7th February 2006 at 6pm

The October 8, Pakistan Earthquake: Effects and Relief

Presentation by EEFIT Team and Oxfam

Venue: Chadwick Lecture Theatre, Dept of Civil and Environmental Engineering, UCL

Open to All

Register your interest with me: t.rossetto@ucl.ac.uk