Lecture 1:Structural Dynamics

Concepts, Design and Implementation

4th year Final Project

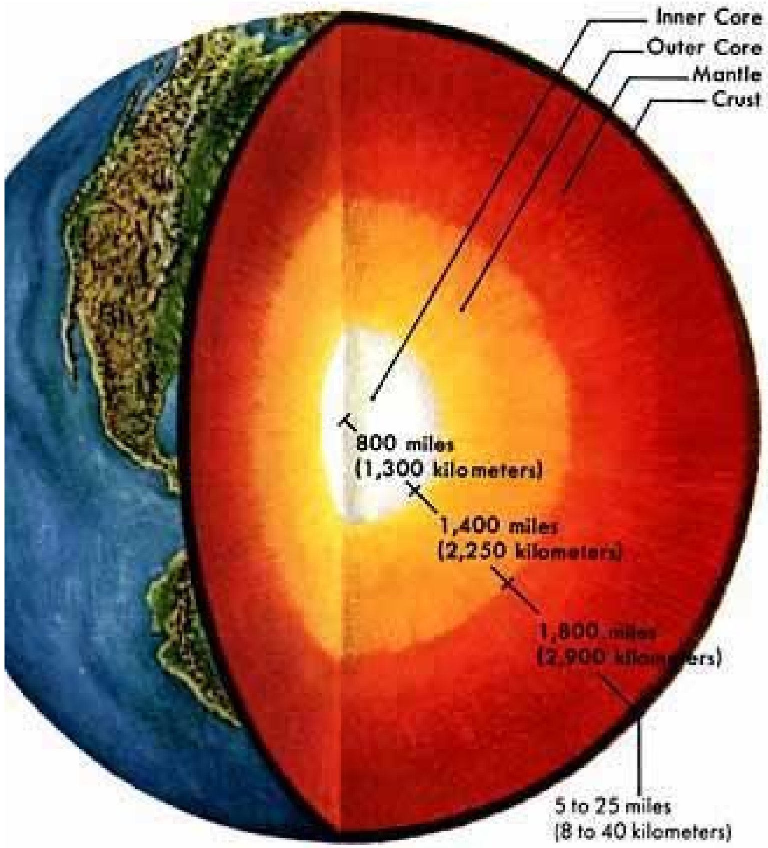
Structural Engineering Project

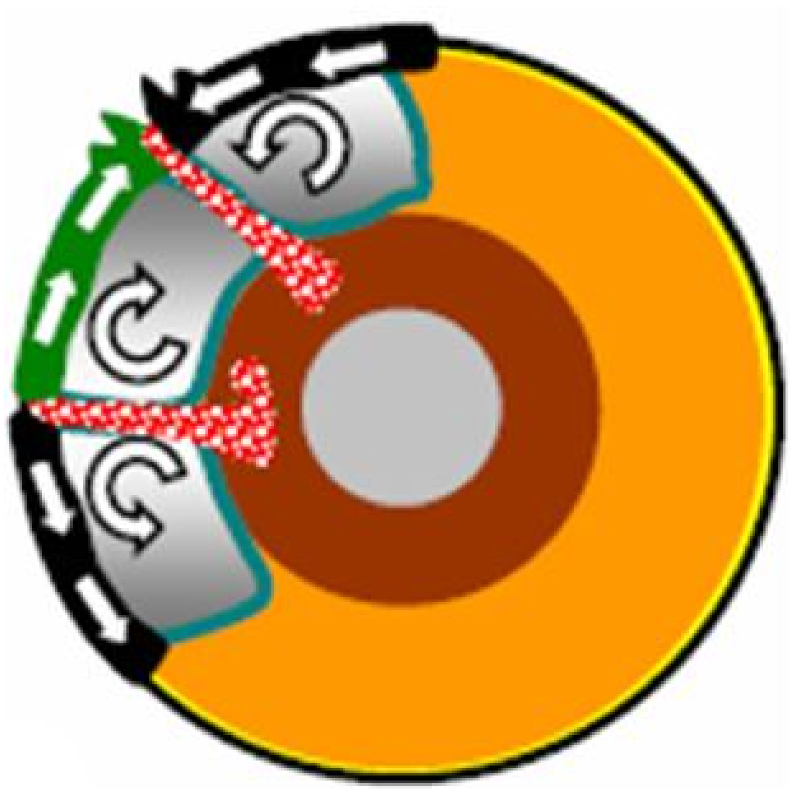
Dr. Said El-kholy

Structural Dynamics

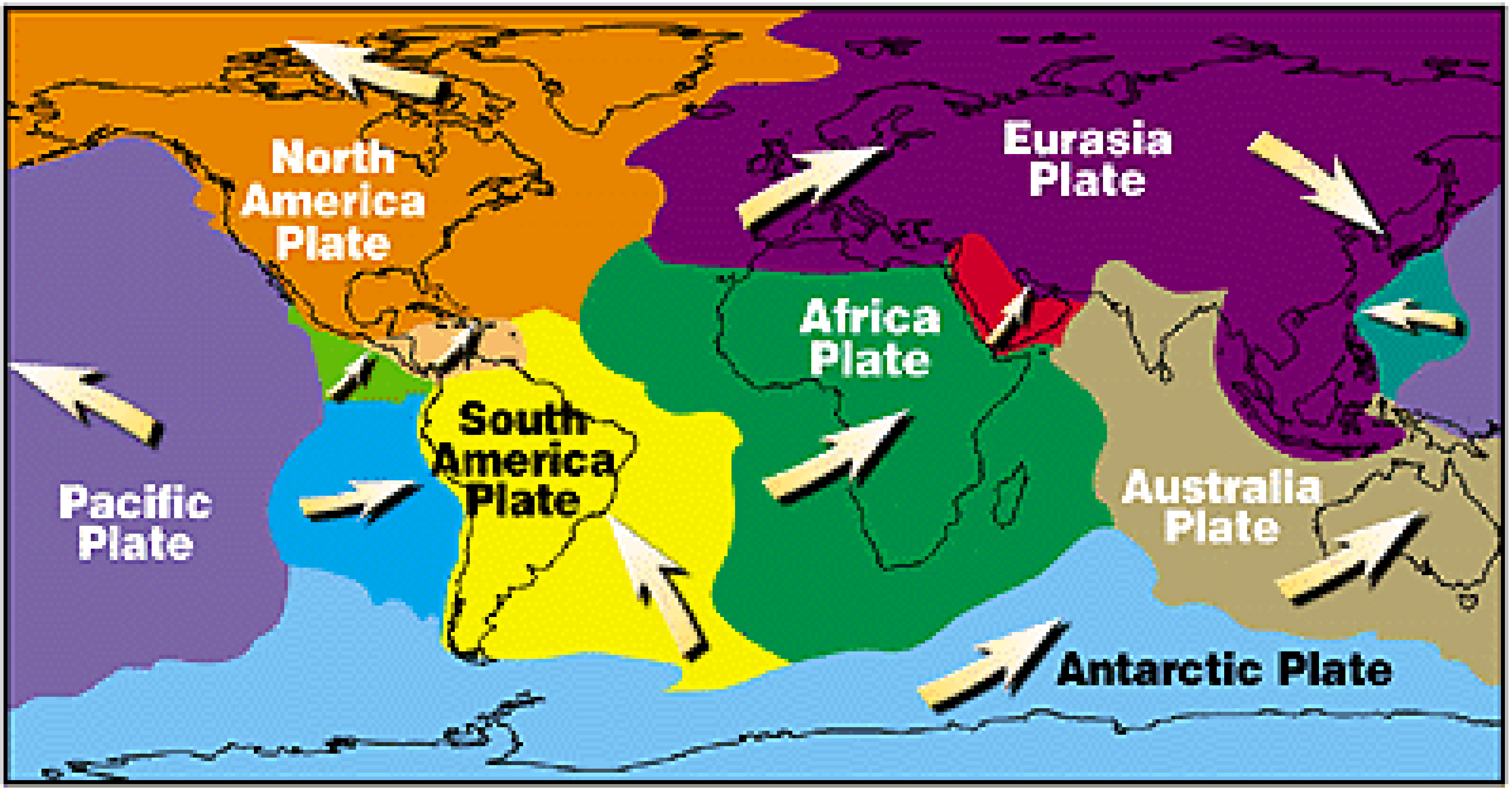
- Introduction
- What is Dynamic Loading?
- Structural Dynamics
- Concepts
- Seismic Loadings
- Method, Codes
- Prevention
- Advancements
- Responsibilities as Engineer, Architect
- Introduction to TMD

Inside Earth



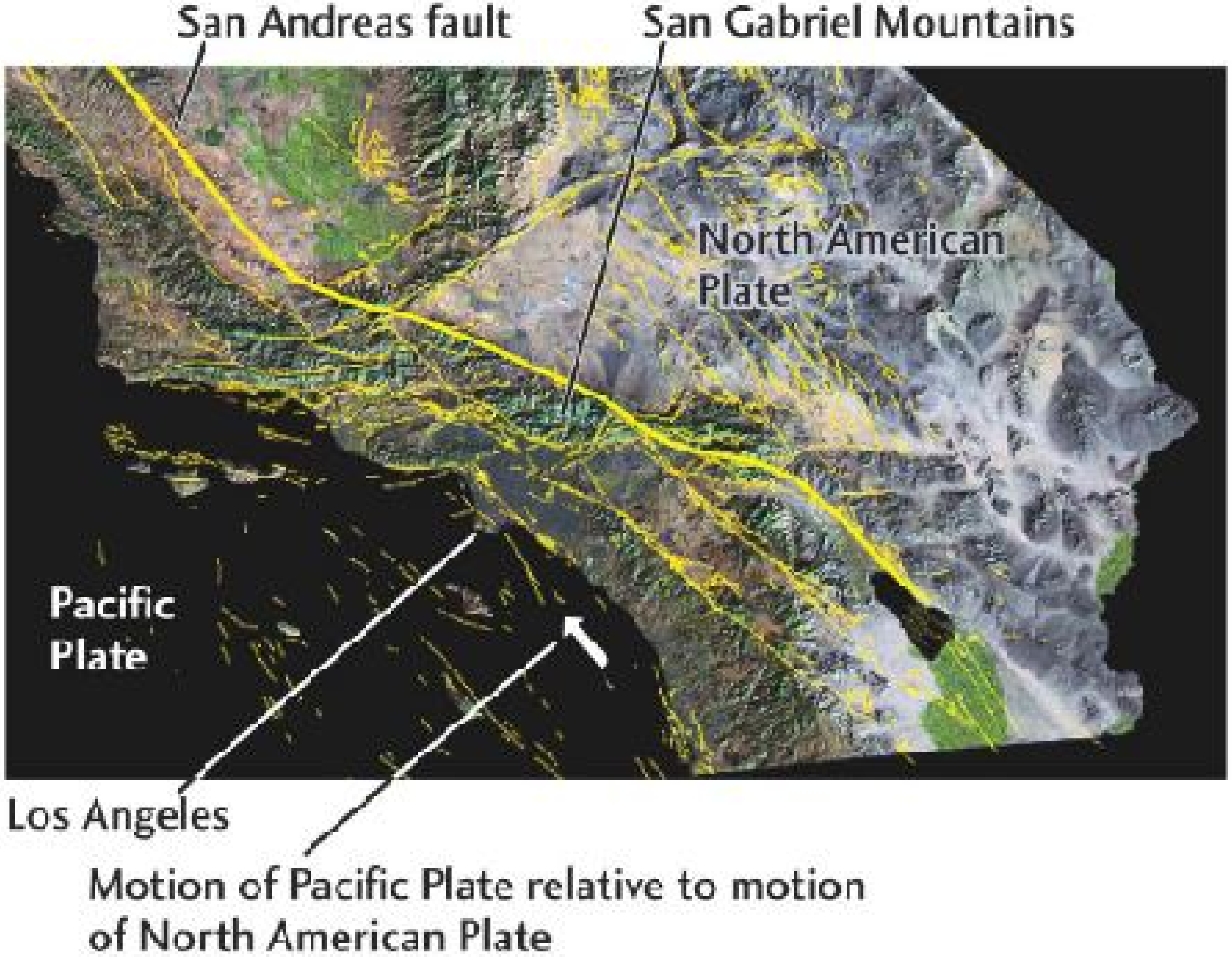


Geographical Plates Location



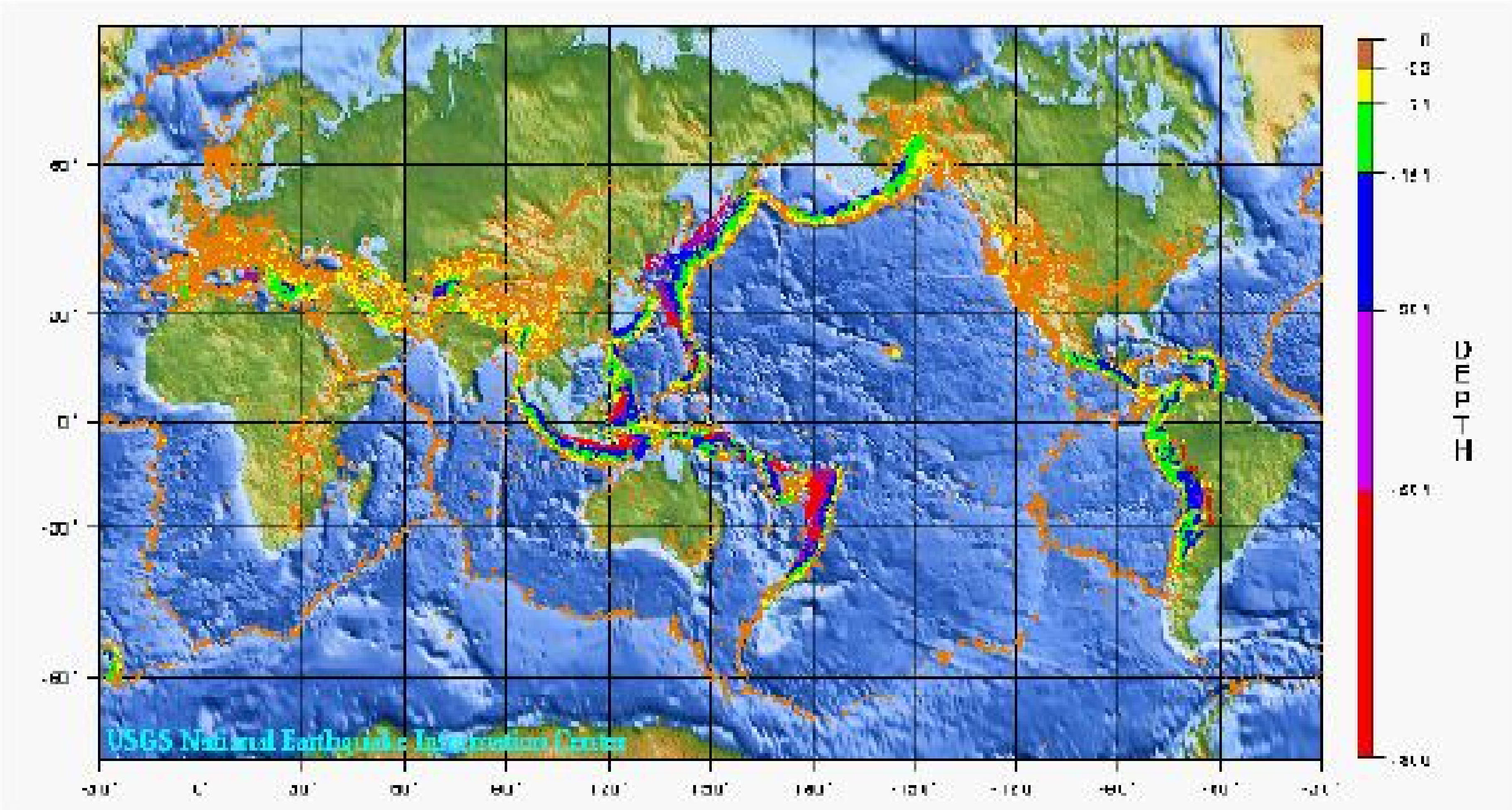
Types of Earthquake Faults

Southern California fault traces



Where Do Earthquakes Occur?

A plot of all earthquakes from 1975 to 1995



Where Earthquakes Occur

In summery:

Majority of earthquakes occur around tectonic plate boundaries and margins

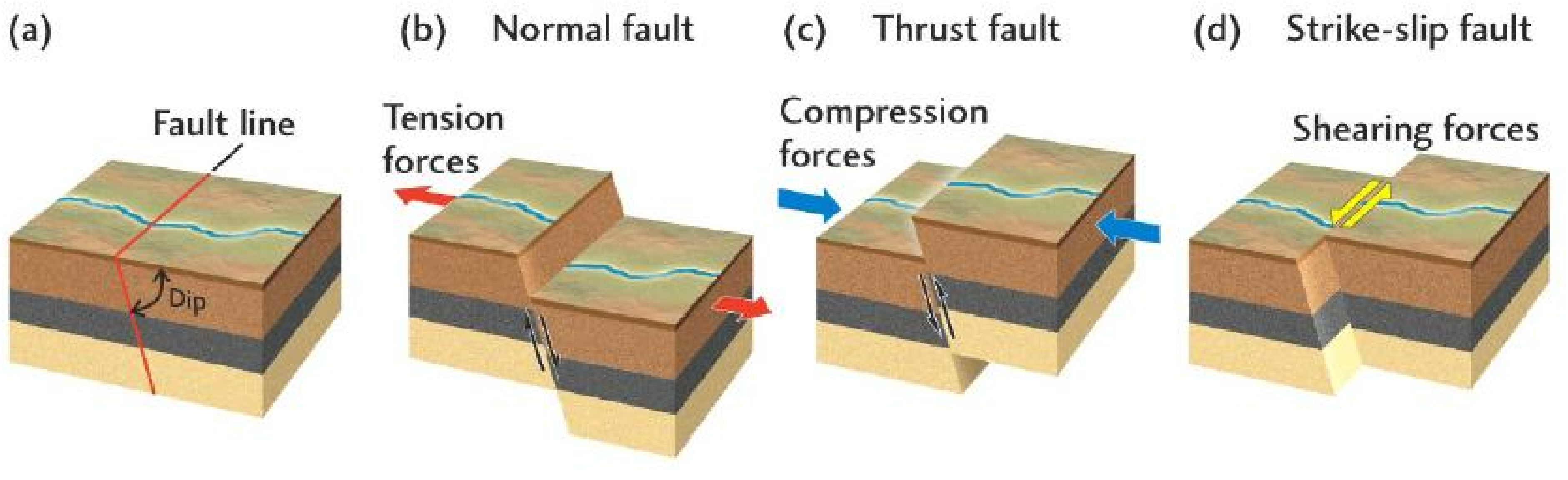
World’s strongest and most deadly earthquakes occur at convergent plate boundaries

Deepest earthquakes also occur at convergent plate boundaries

Types of Earthquake Faults

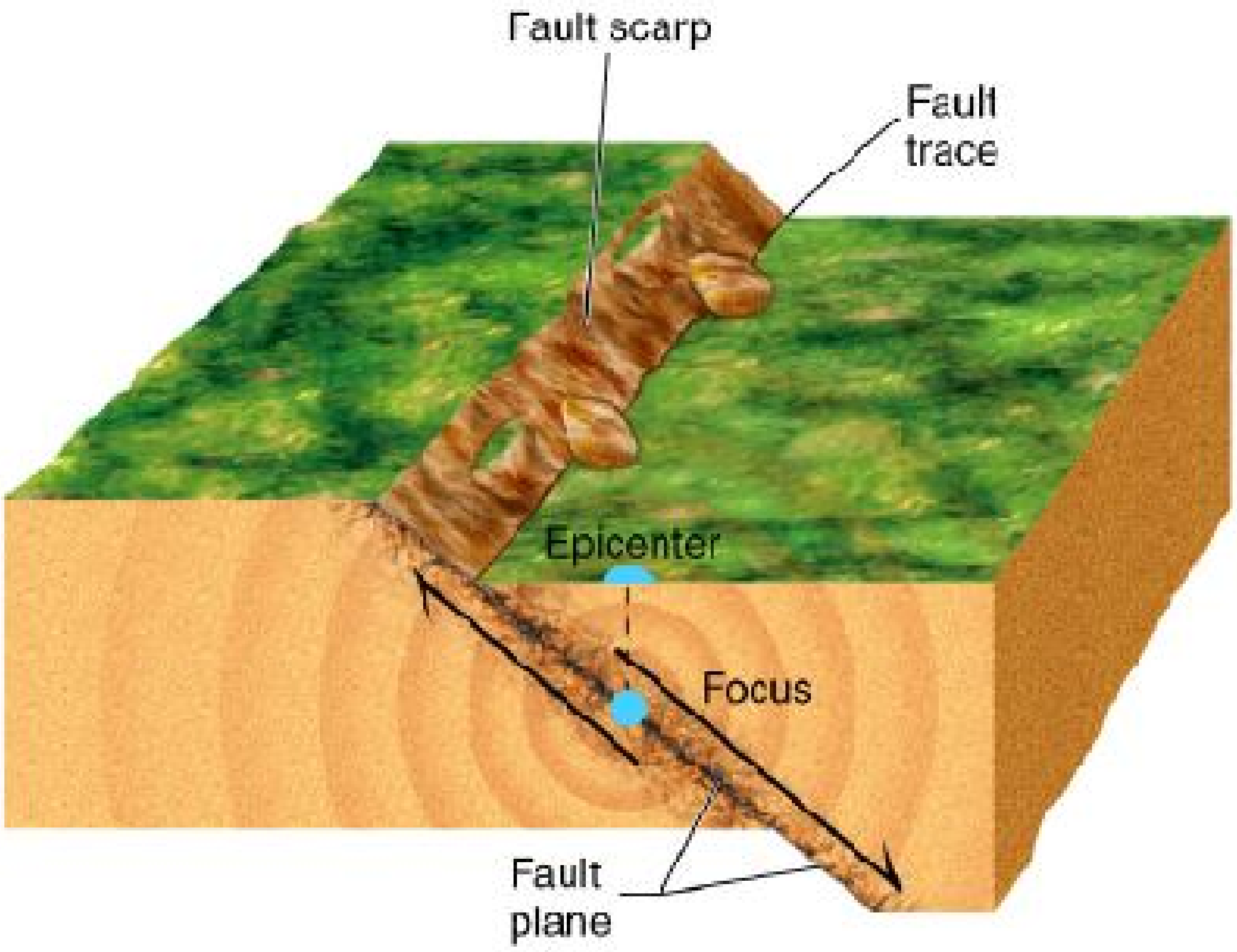
The fault movement can be caused by three main type of forces:

push (compression)
pull (tension)
shove (shear)

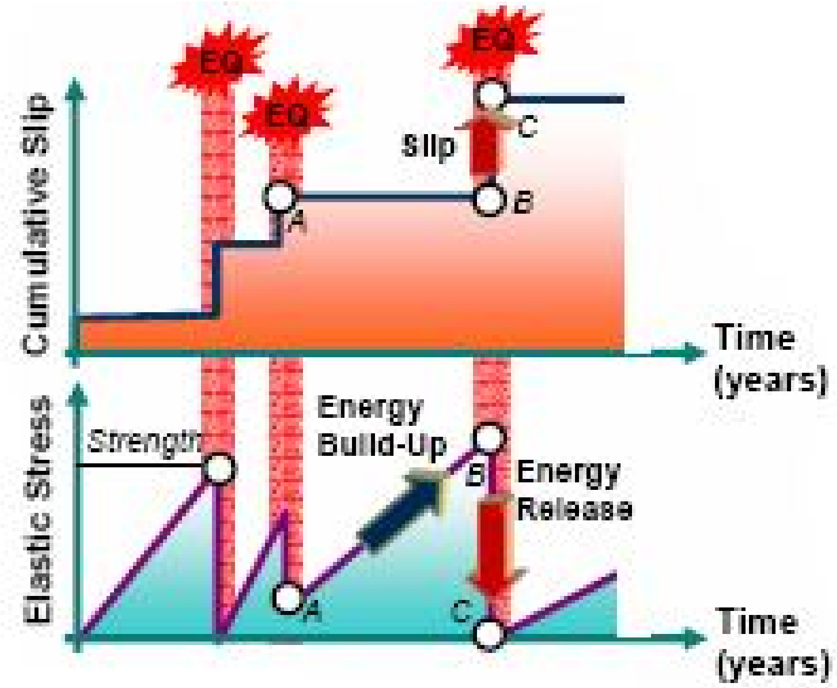


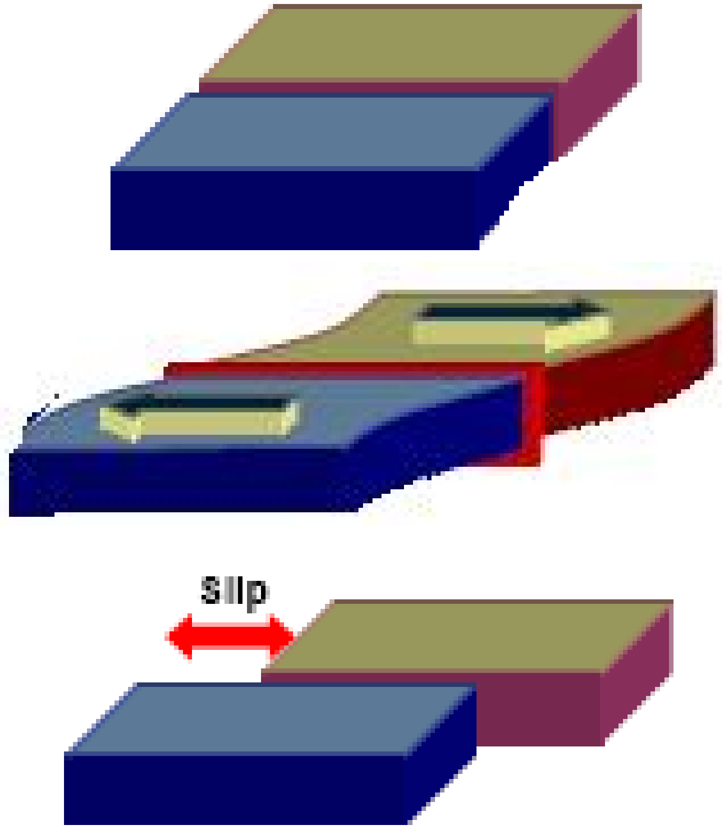
Focus

The focus, or hypocenter, is the point on a fault at which the first movement or break occurs

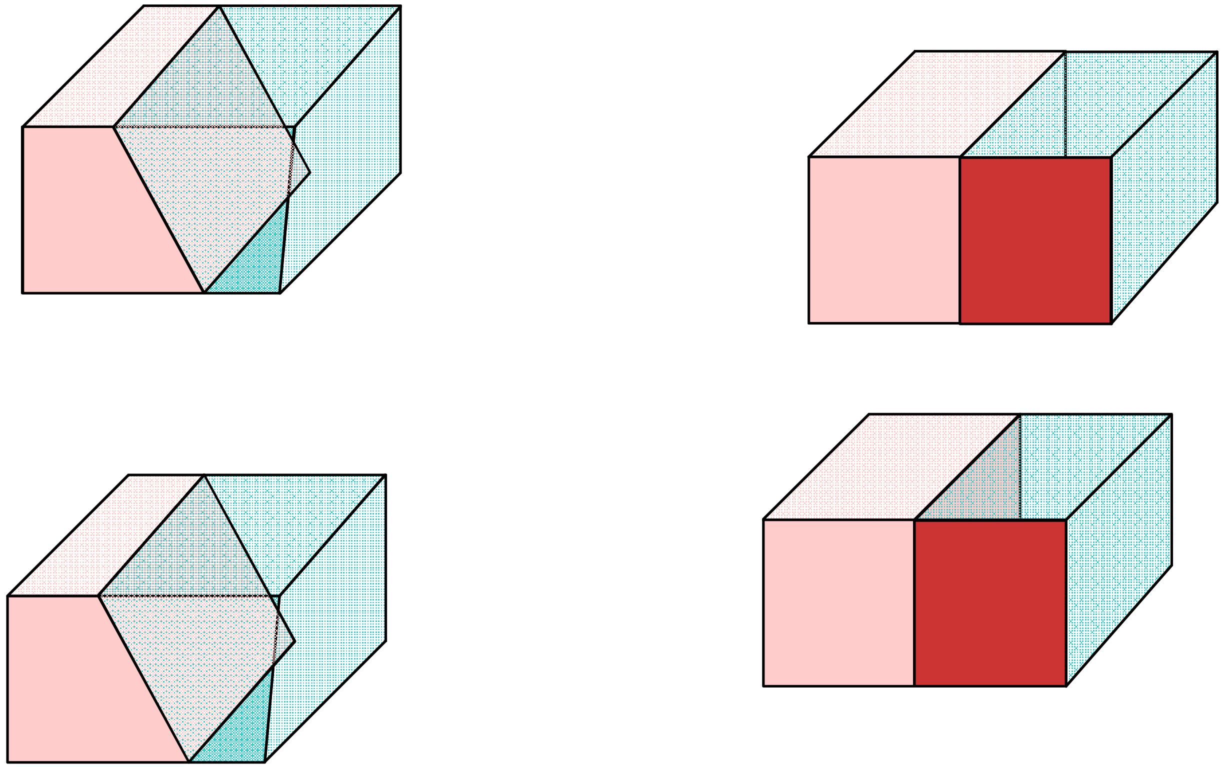


Slips and Faults

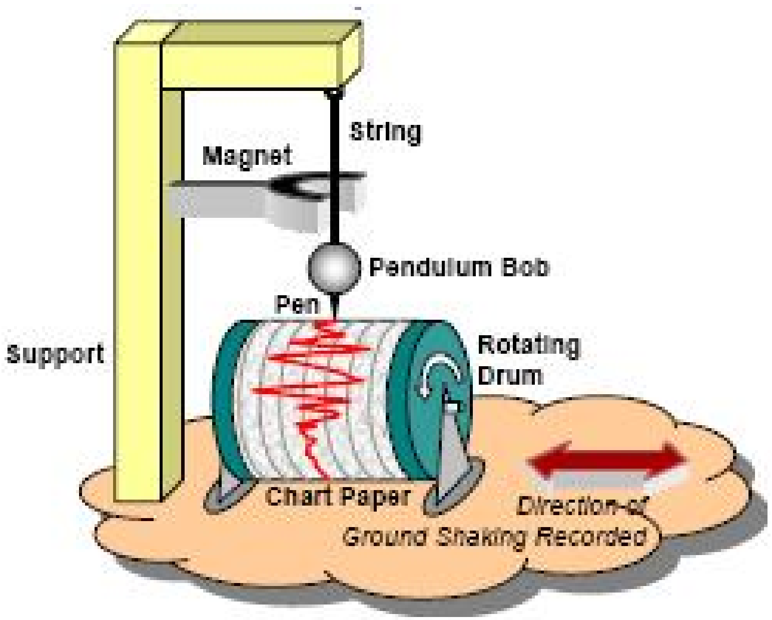


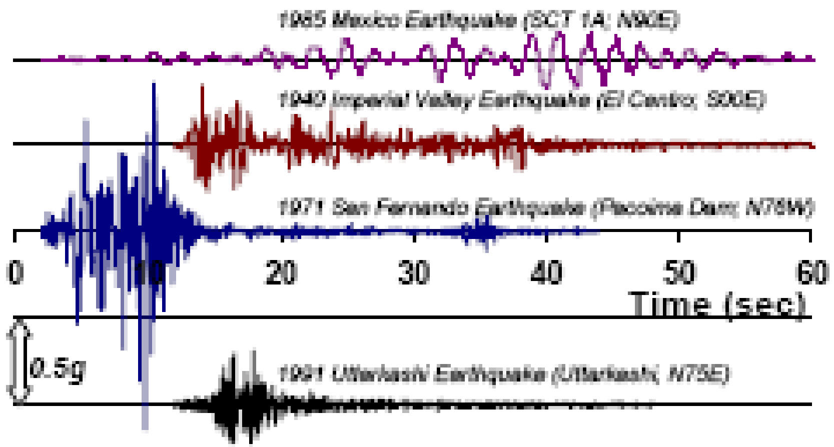


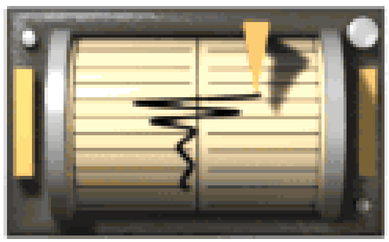
Slips and Faults



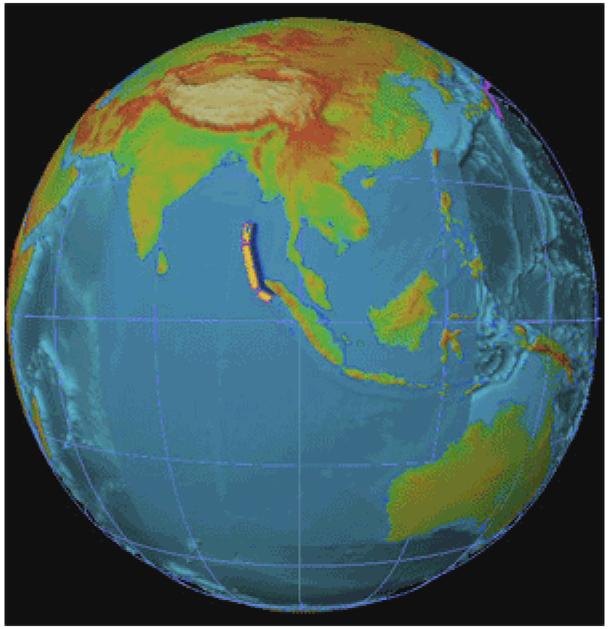
Intensity Measuring Instruments

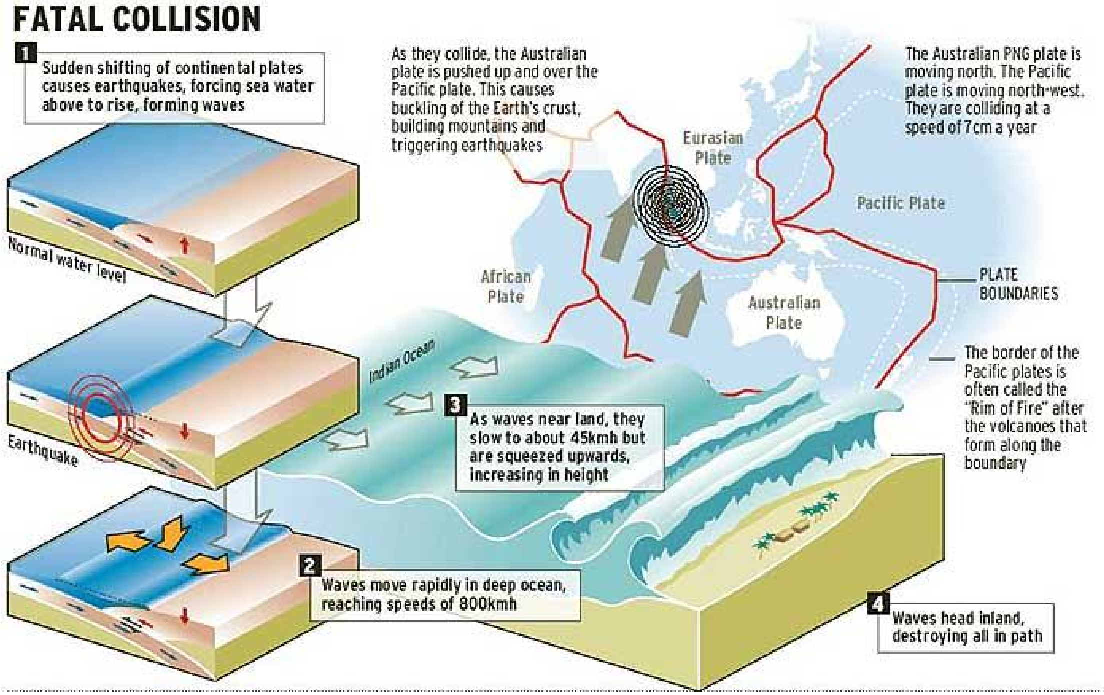






Tsunami Attack





Effect of Earth Quake

Collapse of reinforced concrete columns (and building) during 2001 Bhuj (India) earthquake

Resonance of Structure

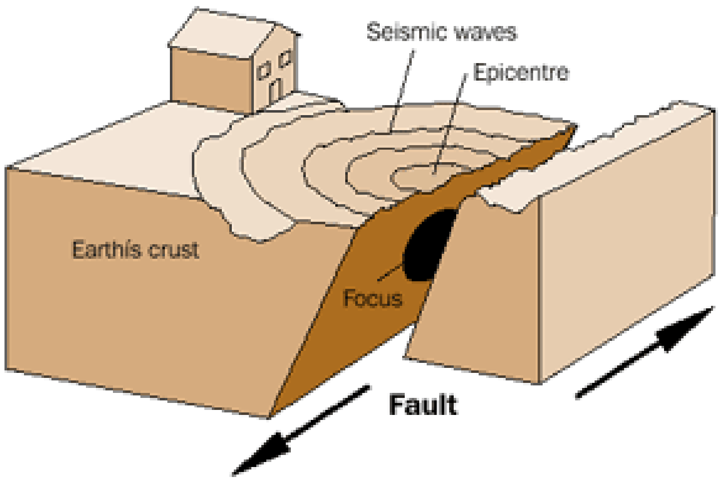
Soft Story

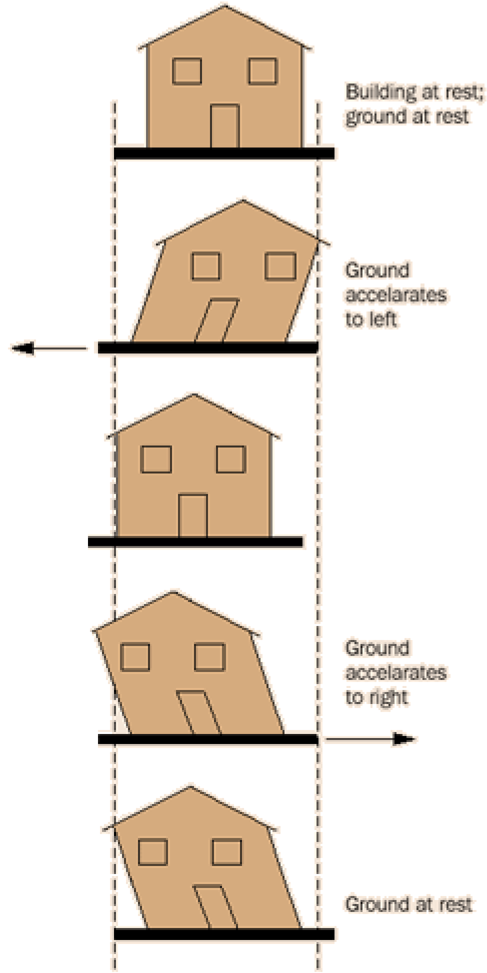
- A common building design flaw is to make the first story much more flexible than the upper stories. During an earthquake the upper floors tend to move as a unit while the first floor flexes a great deal. This can cause collapse of the first floor, as happened during to some apartment buildings during the 1994 Northridge earthquake in California

Earthquake Design Philosophy

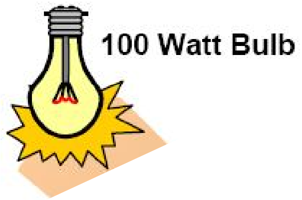
- Under minor but frequent shaking, the main members of the building that carry vertical and horizontal forces should not be damaged; however building parts that do not carry load may sustain repairable damage
- Under moderate but occasional shaking, the main members may sustain repairable damage, while the other parts of the building may be damaged such that they may even have to be replaced after the earthquake
- Under strong but rare shaking, the main members may sustain severe (even) irreparable damage, but the building should not collapse

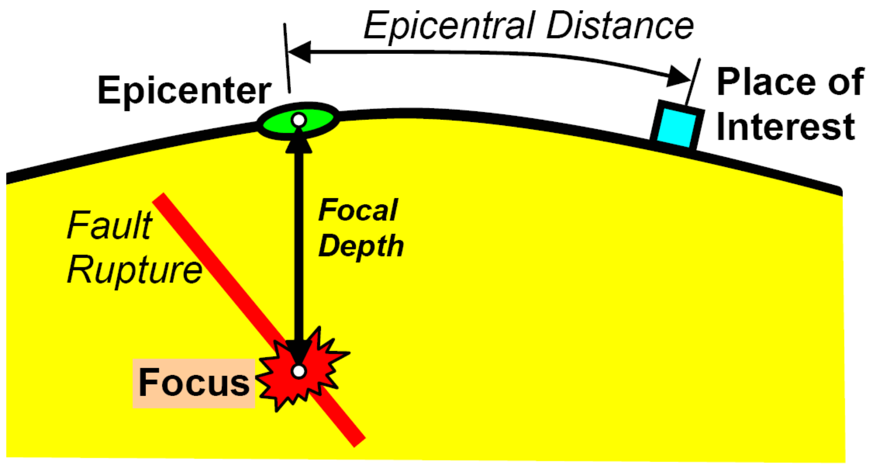
Seismic basics





Intensity of Earth Quake





Well Confined Column

Splice in Hinge Region

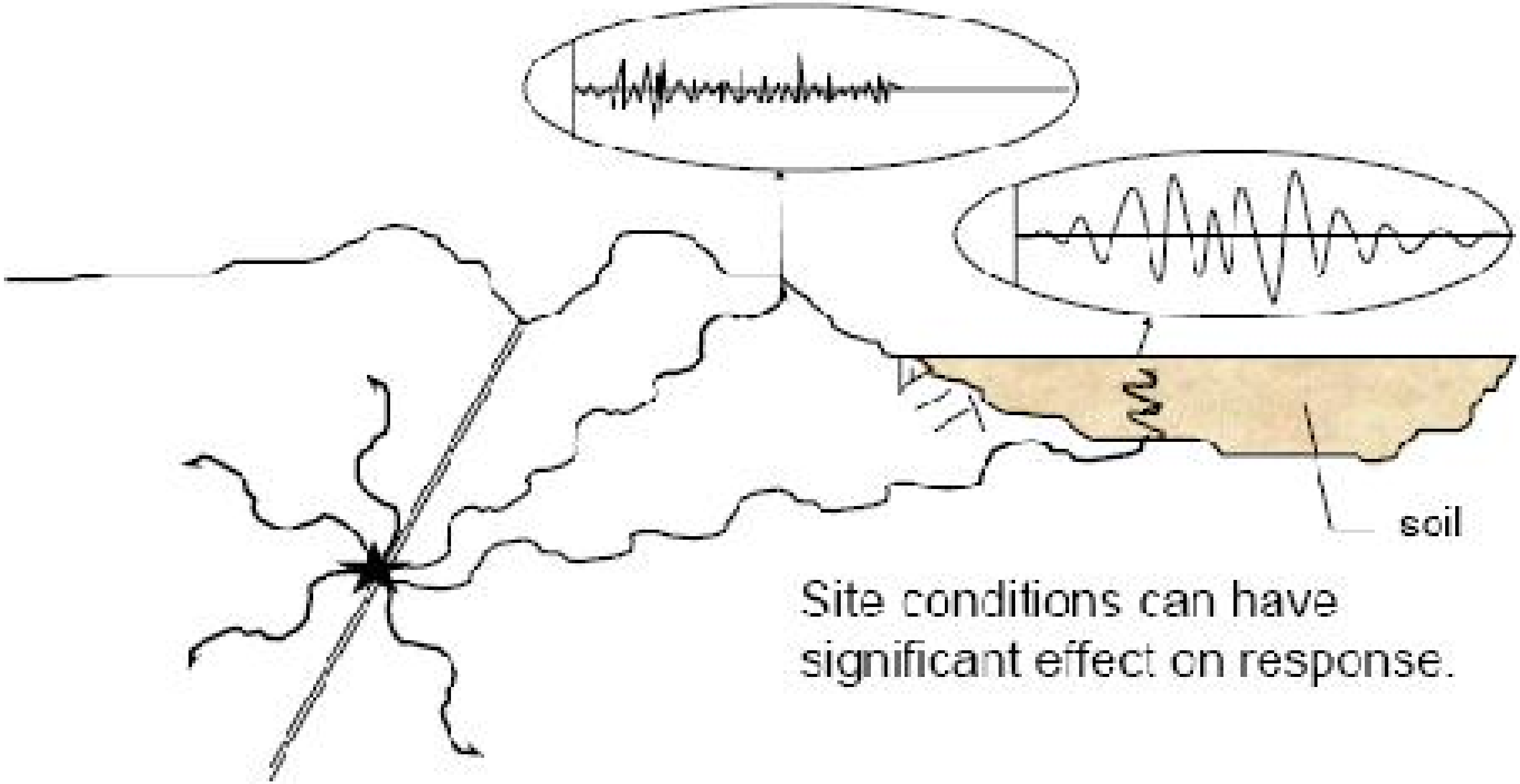
Terminating bars

Joint Failure – No Shear Reinforcing

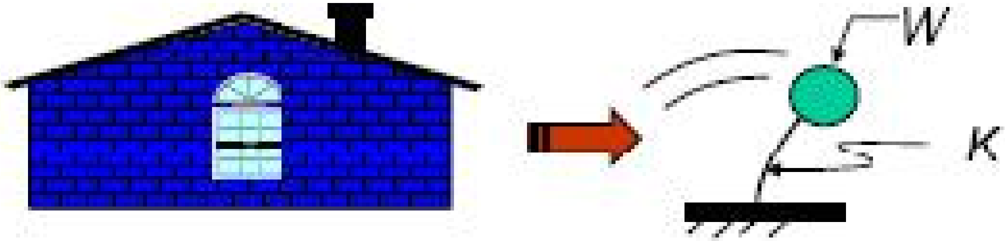
Column Shear Failure

Anchorage Failure in Column/Footing Joint

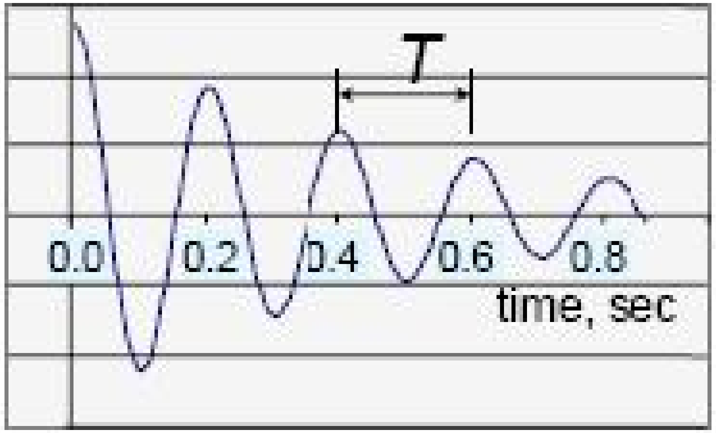
Seismic Hazard



Site conditions can have significant effect on response.



Vibration Period $T = 2\pi\sqrt{\dfrac{W/g}{K}}$



Base excitation

Using **u** to describe relative movement:

$$\mathbf{u} = \mathbf{x} - \mathbf{x_o}$$

We obtain:

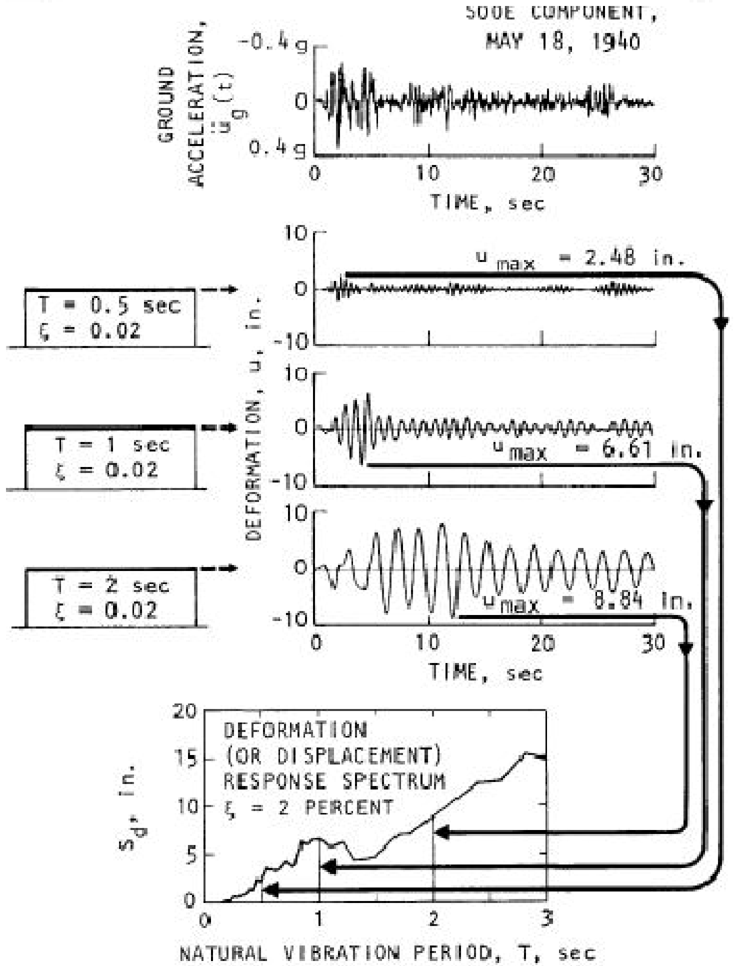
$$m\ddot{u} + c\dot{u} + ku = -m\ddot{x}_o$$

And dividing by **m**

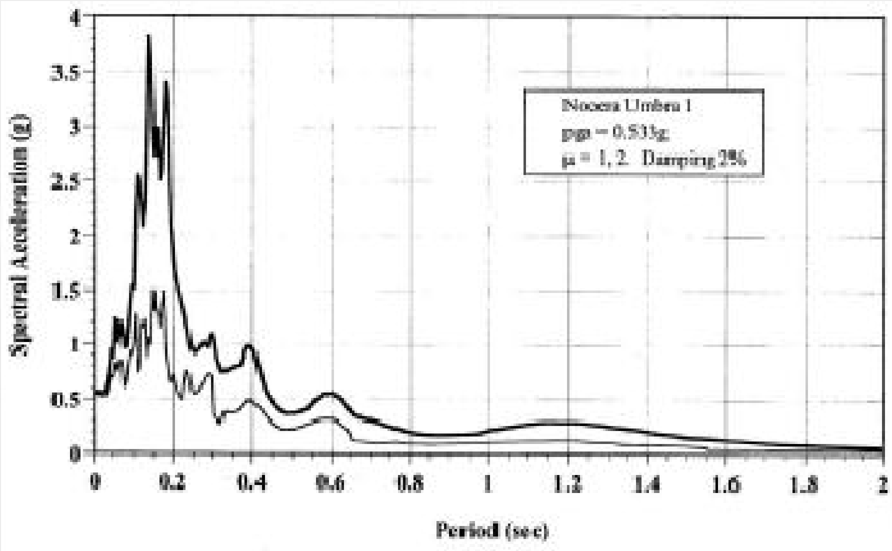
$$\ddot{u} + 2\xi\omega\dot{u} + \omega^2 u = -\ddot{x}_o$$

and

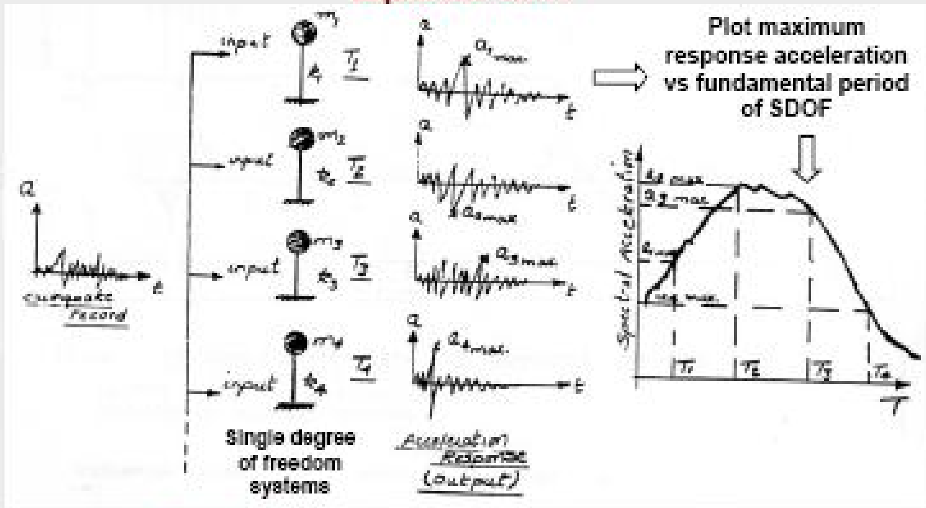
$$u(t) = \frac{-1}{\omega\sqrt{1-\xi^2}}\int_0^t \ddot{x}_o(\tau)\, e^{-\xi\omega(t-\tau)}\,\mathrm{sen}\left\{\sqrt{1-\xi^2}\,\omega(t-\tau)\right\}d\tau$$



Elastic and Inelastic Spectra

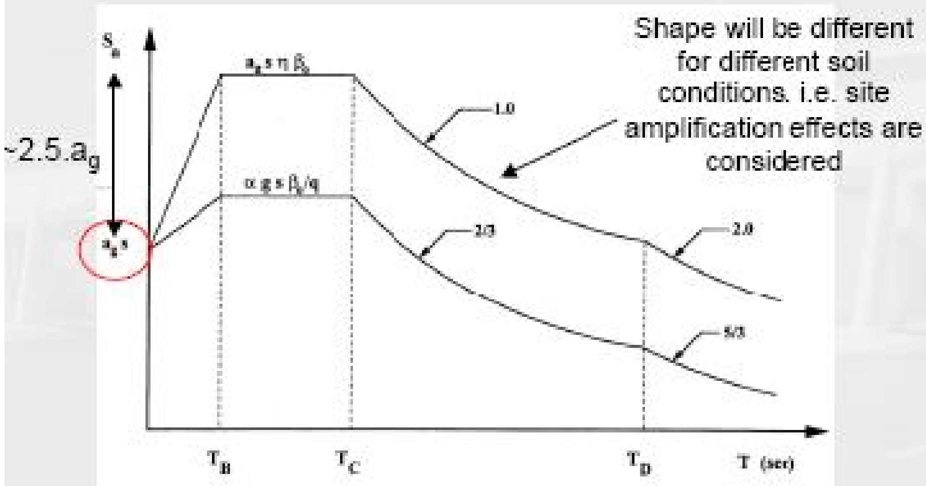


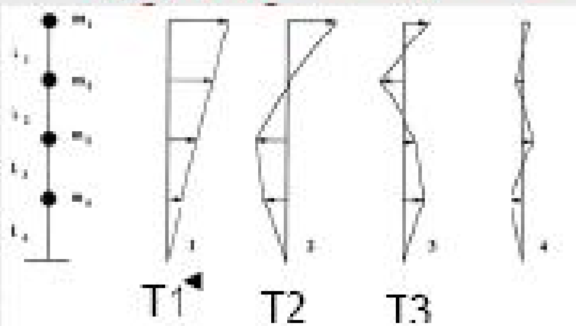
Computation of Elastic Response Spectrum

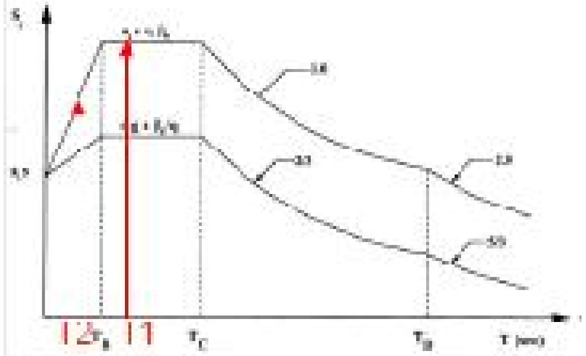


Earthquake Engineering

Design Spectra (EC8)







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

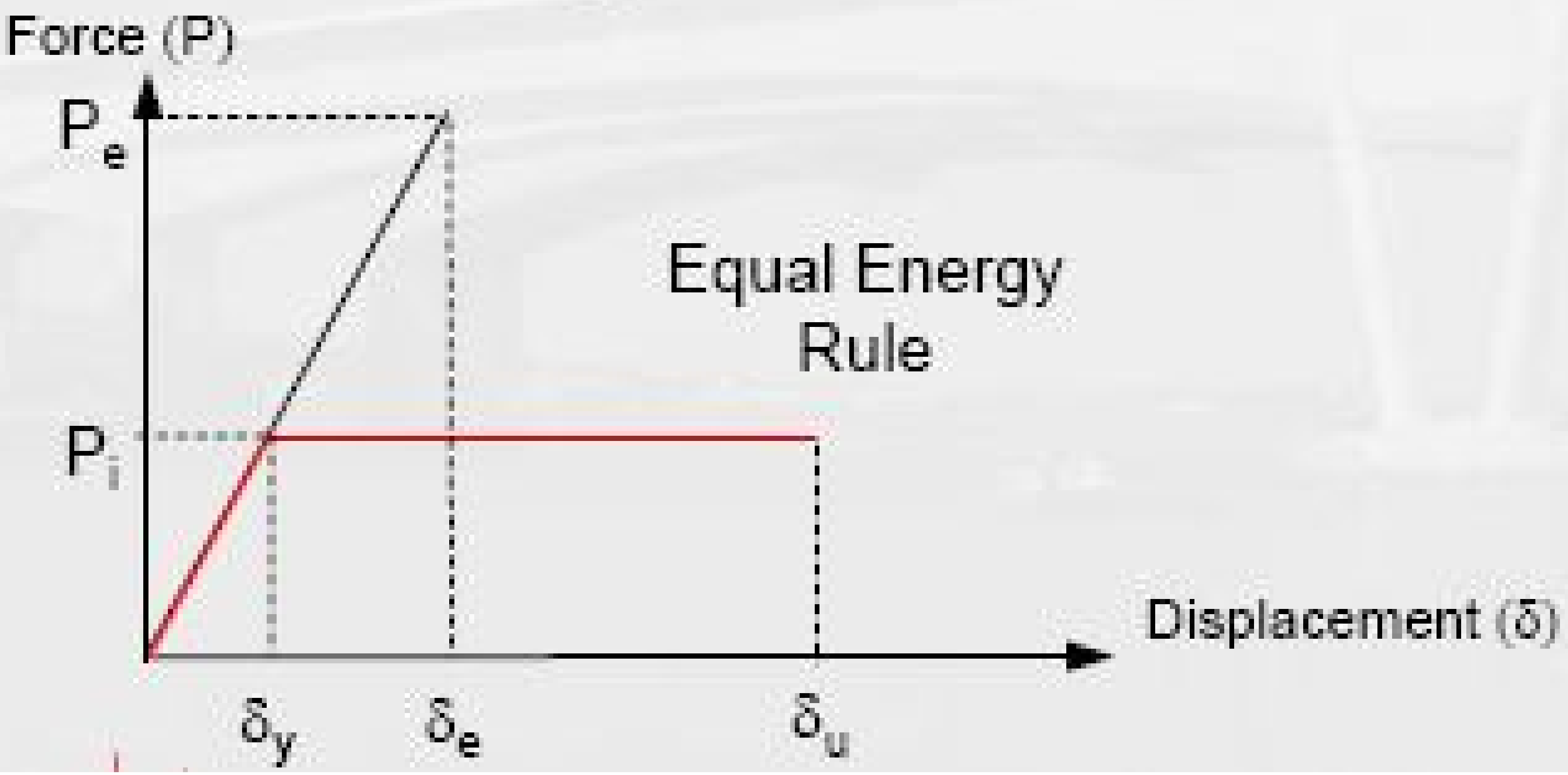
Ultimate limit state design: Design a building to resist an earthquake with a return period of 475yrs (i.e. the design loads will have a 10% probability of being exceeded in the structures life).

- 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

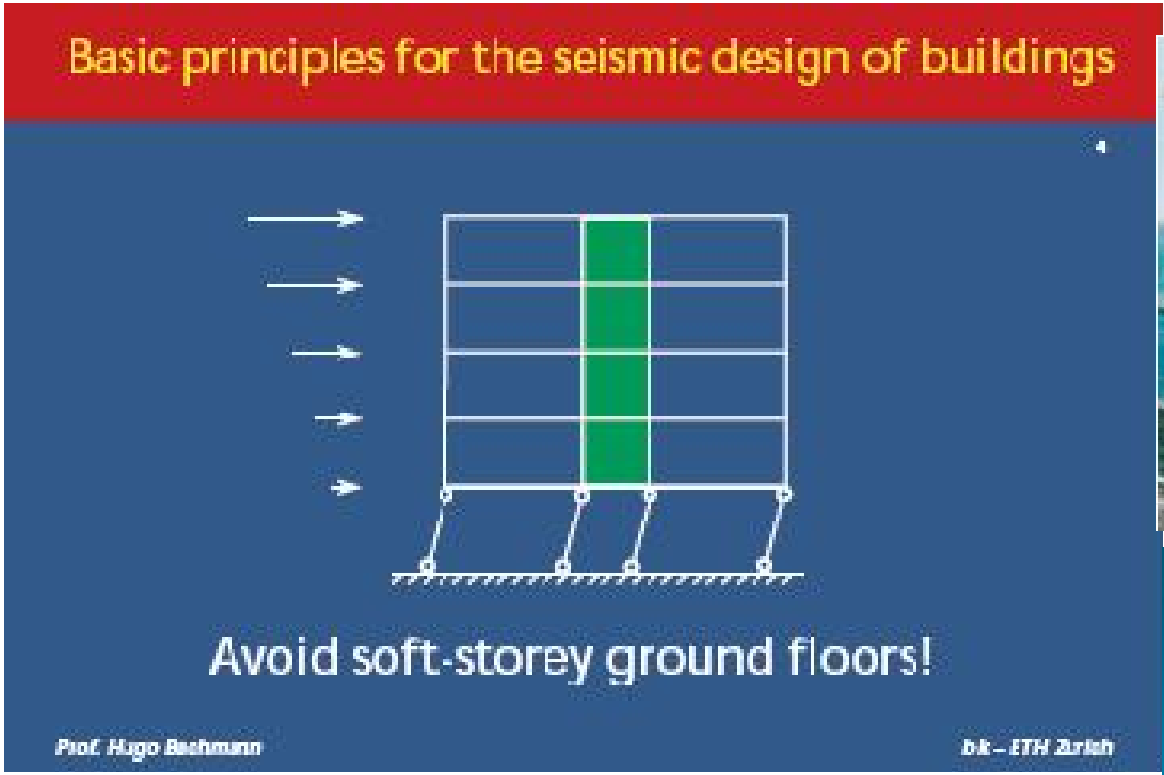


Designing for Controlled Damage

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.

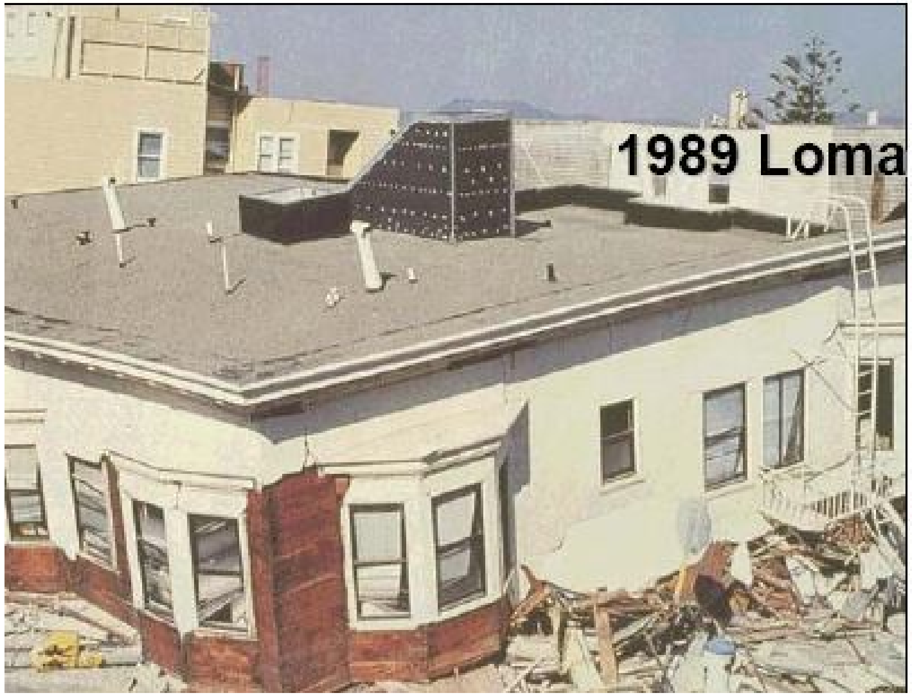
→ Simple design rules and capacity design

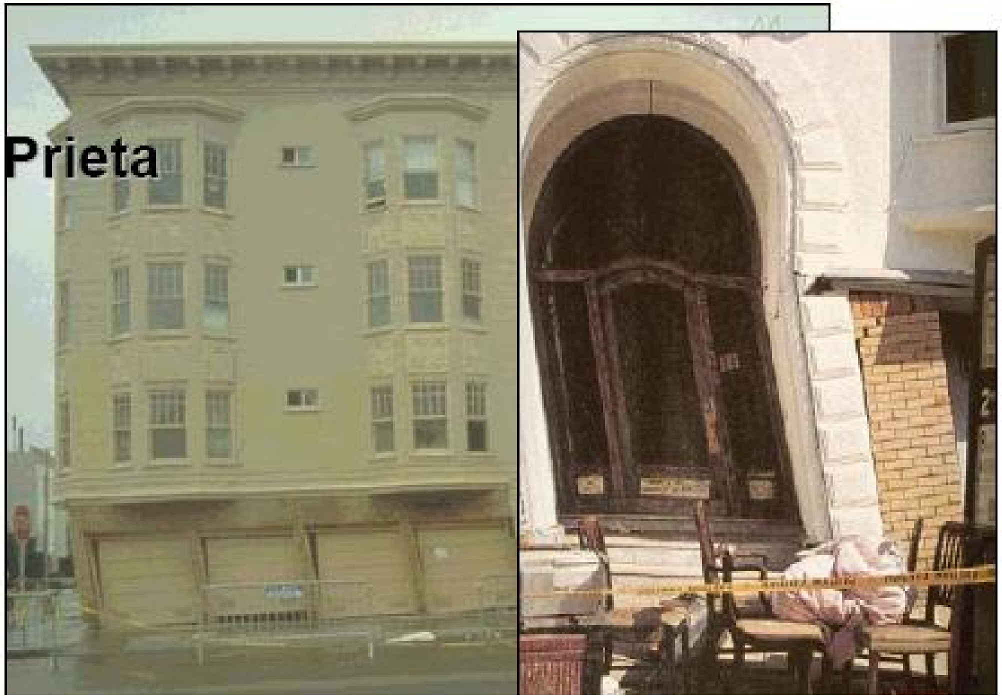


Many building collapses during earthquakes may be attributed to the fact that the bracing elements, e.g. walls, which are available in the upper floors, are omitted in the ground floor and substituted by columns. Thus a ground floor that is soft in the horizontal direction is developed (soft storey). Often the columns are damaged by the cyclic displacements between the moving soil and the upper part of the building. The plastic deformations (plastic hinges) at the top and bottom end of the columns lead to a dangerous sway mechanism (storey mechanism) with a large concentration of the plastic deformations at the column ends.


ypical soft story
tuckunder"
uilding


1971 San
Fernando


1989 Loma Prieta



(a) 1971 San Fernando Earthquake

(b) 2001 Bhuj Earthquake

Figure 3: Consequences of open ground storeys in RC frame buildings – *severe damage to ground storey columns and building collapses.*

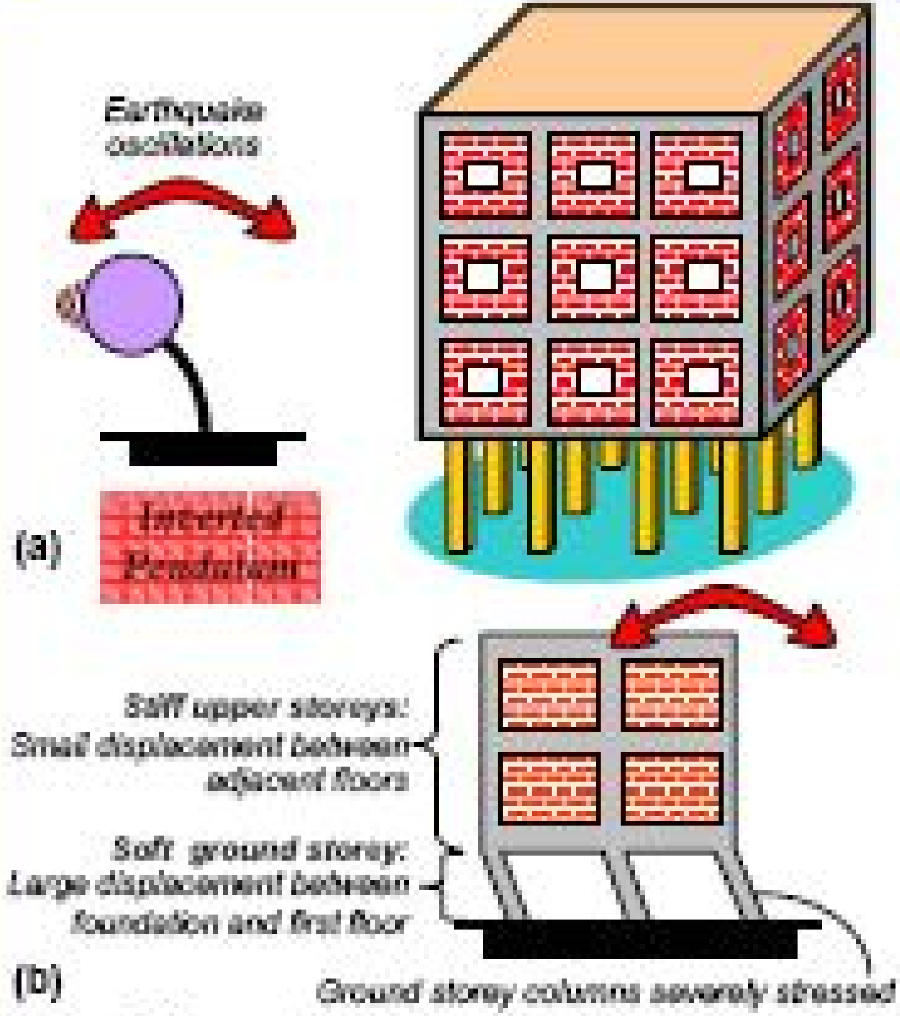
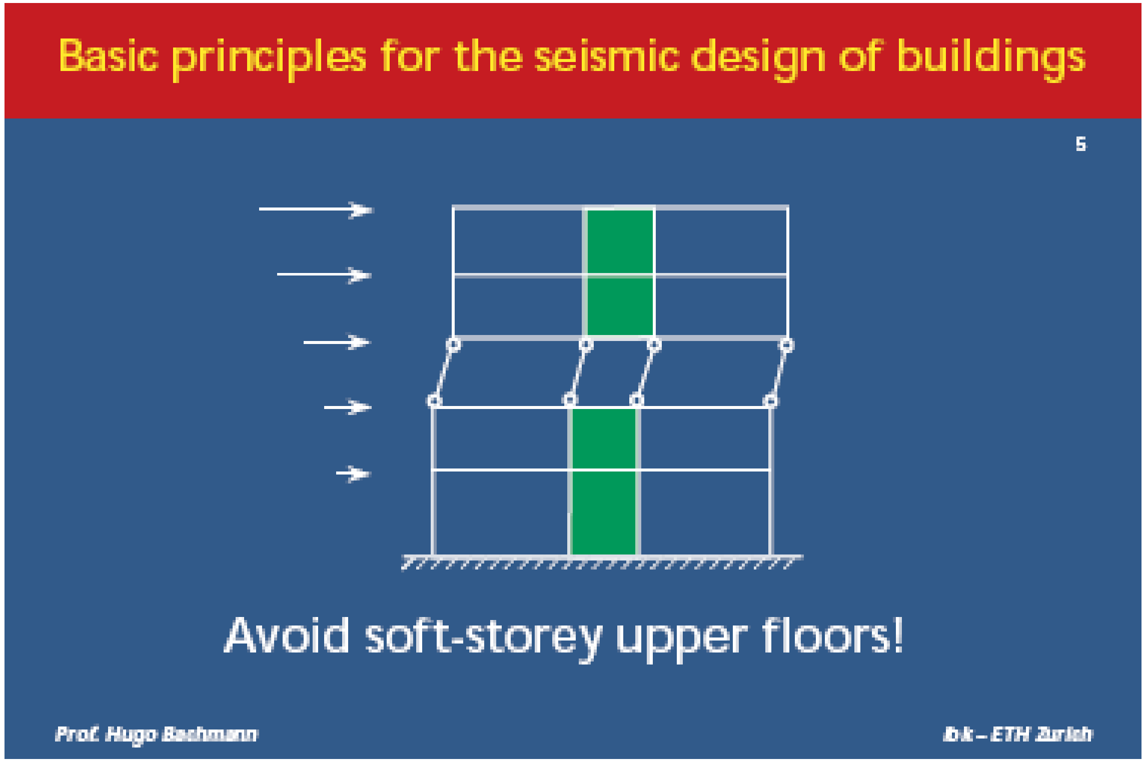


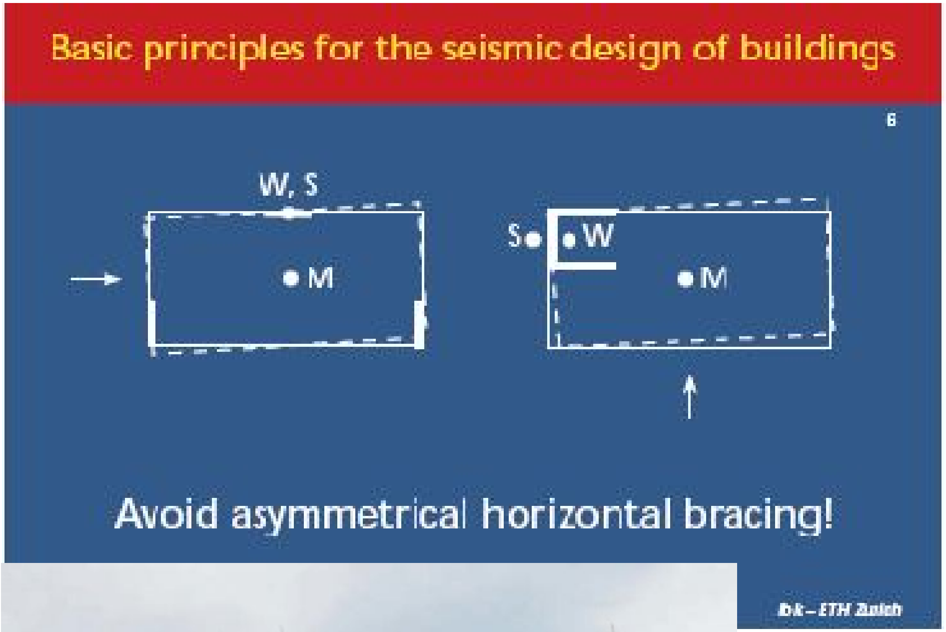
Figure 2: Upper storeys of open ground storey buildings move together as a single block – *such buildings are like inverted pendulums.*



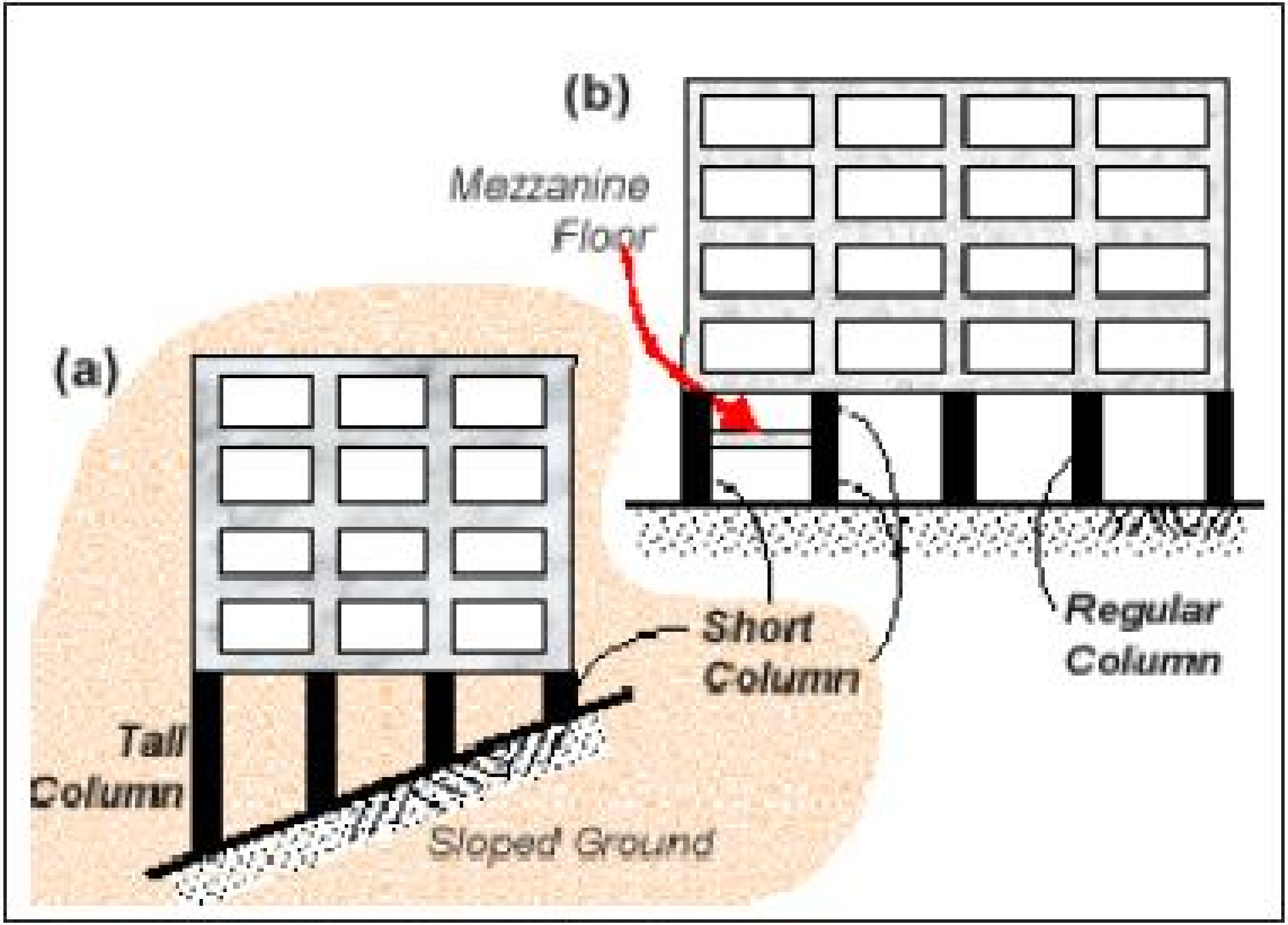
An upper storey can also be soft in comparison to the others if the lateral bracing is weakened or omitted, or if the horizontal resistance is strongly reduced above a certain floor. The consequence may again be a dangerous sway mechanism.

5/1 In this commercial building the third floor has disappeared and the floors above have collapsed onto it (Kobe, Japan 1995).

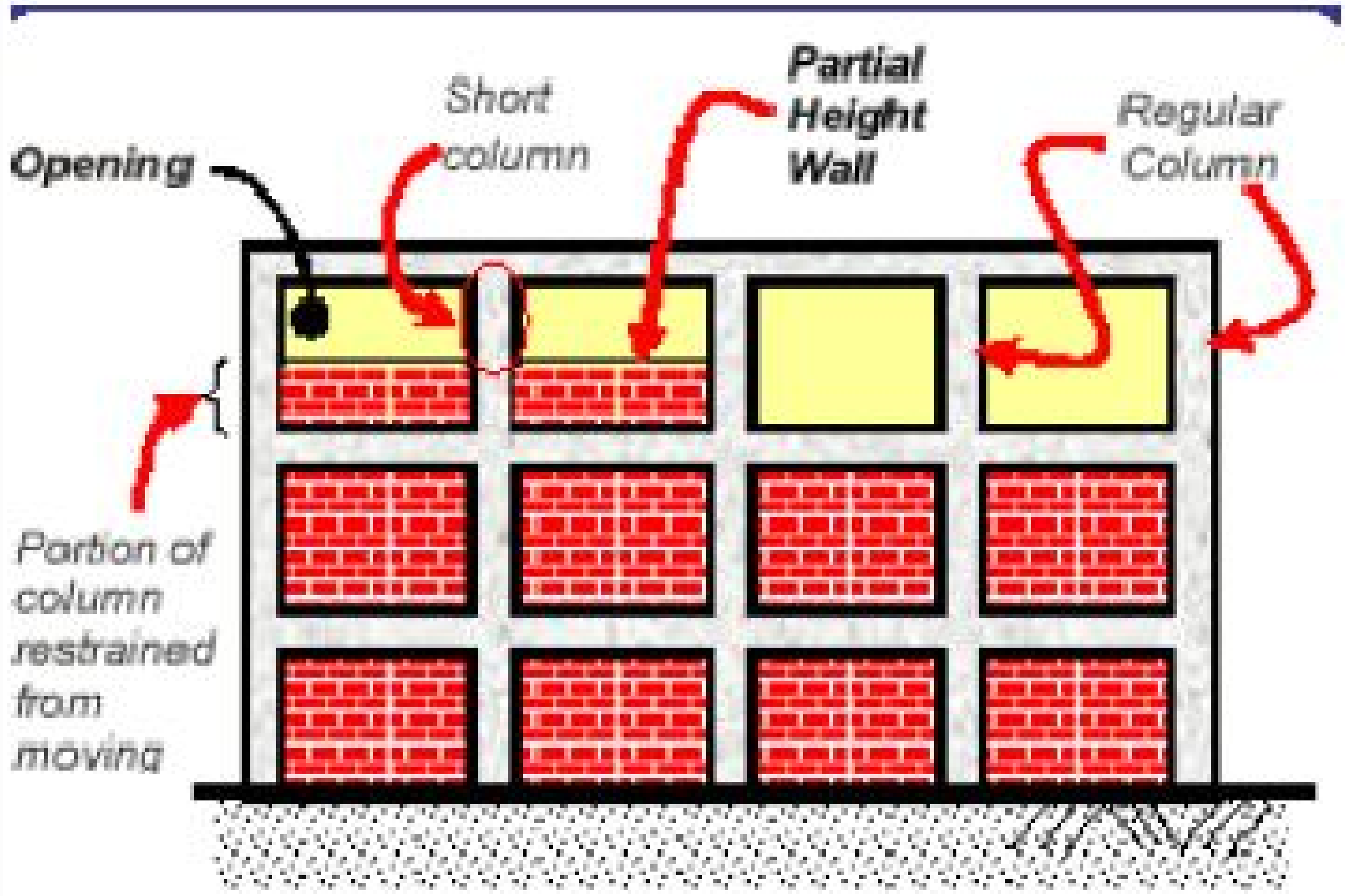
5/2 In this office building also, an upper storey failed. The top of the building has collapsed onto the floor below, the whole building rotated and leaned forwards.

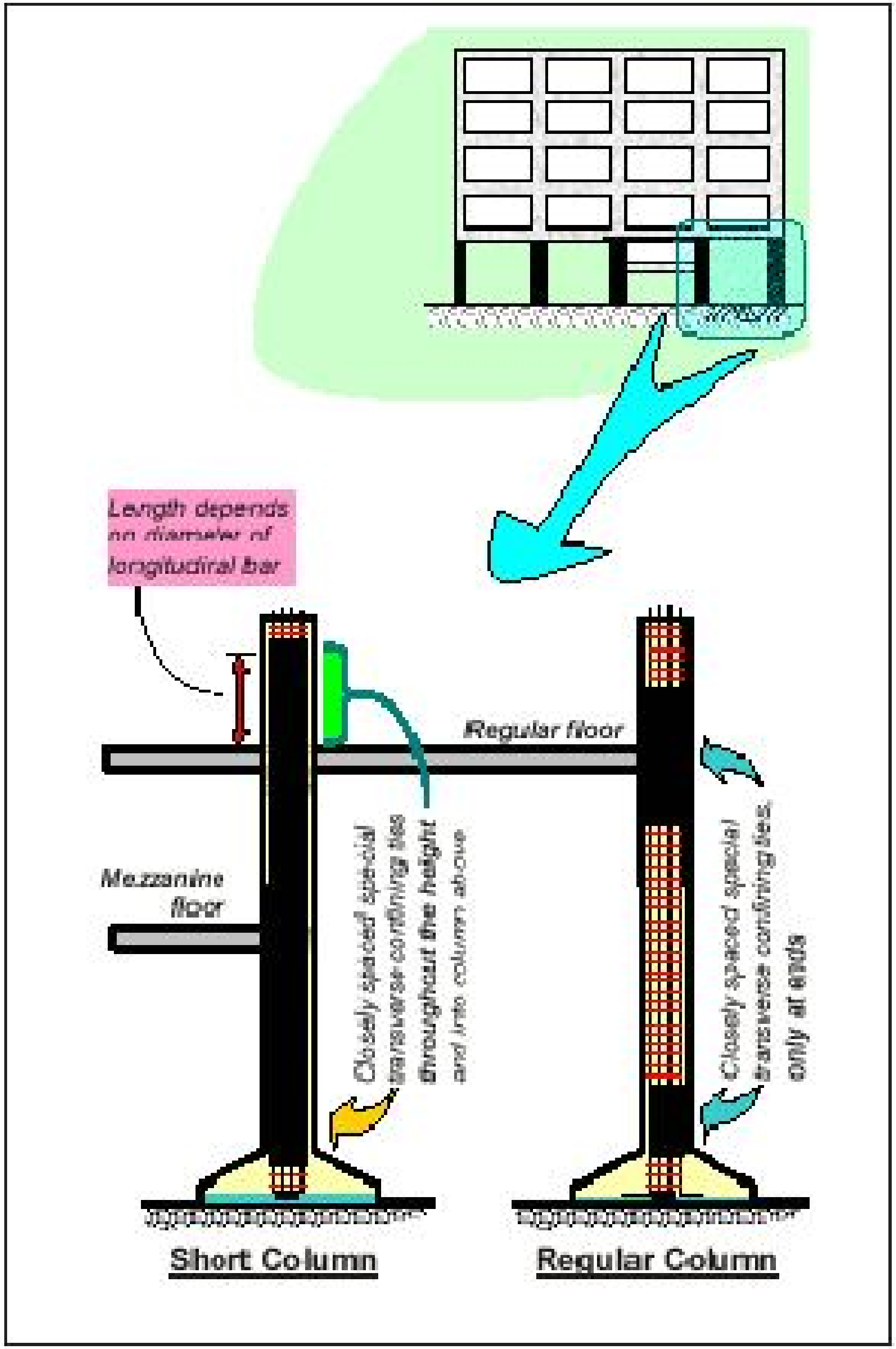


Asymmetric bracing is a frequent cause of building collapses during earthquakes. In the two above sketches only the lateral bracing elements are represented (walls and trusses). The columns are not drawn because their frame action to resist horizontal forces and displacements is small. The columns, which «only» have to carry the gravity loads, should however be able to follow the horizontal displacements of the structure without loosing their load bearing capacity.

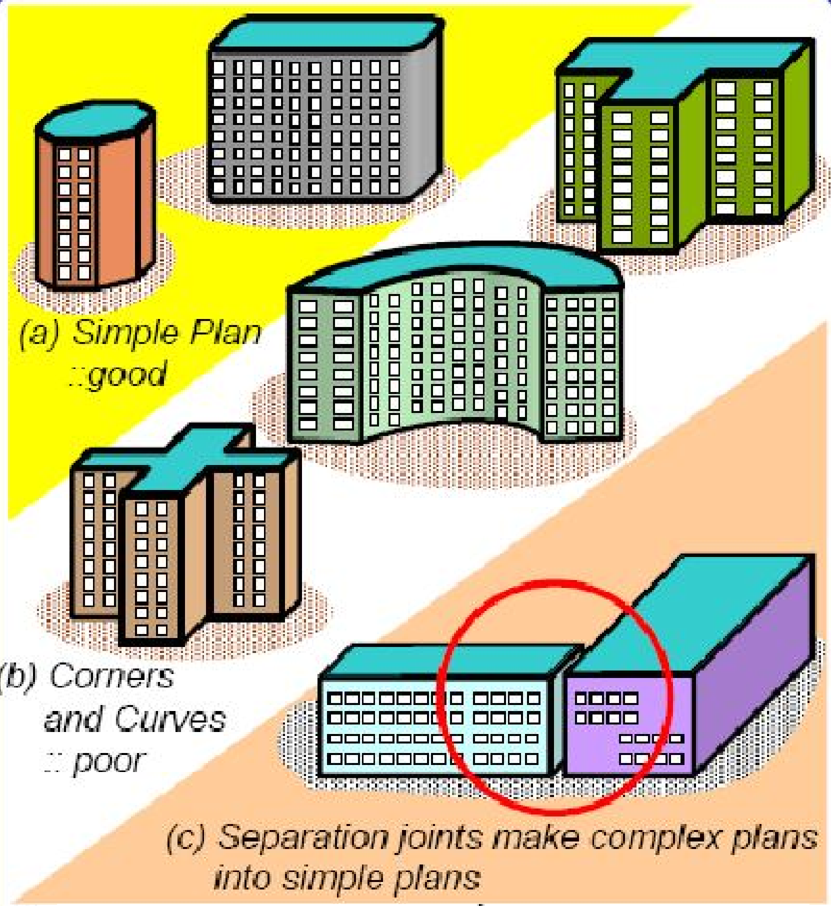


(b)
Mezzanine
Floor
(a)
Short
Column
Regular
Column
Tall
Column
Sloped Ground


Opening
Short column
Partial Height Wall
Regular Column
Portion of column restrained from moving


Length depends
on diameter of
longitudinal bar
Regular floor
Mezzanine
floor
Closely spaced special
transverse confining ties
throughout the height
and into column above
Closely spaced special
transverse confining ties
only at ends
Short Column
Regular Column


Short column
between lintel
and sill of
window
Source:
Wakabayashi M.,
Design of Earthquake-Resistant Buildings,
McGraw Hill Book Company, New York,



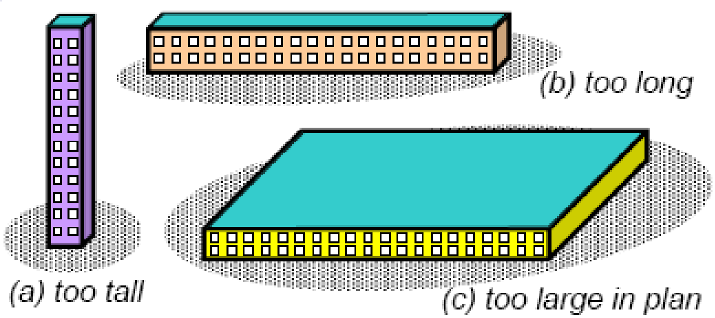
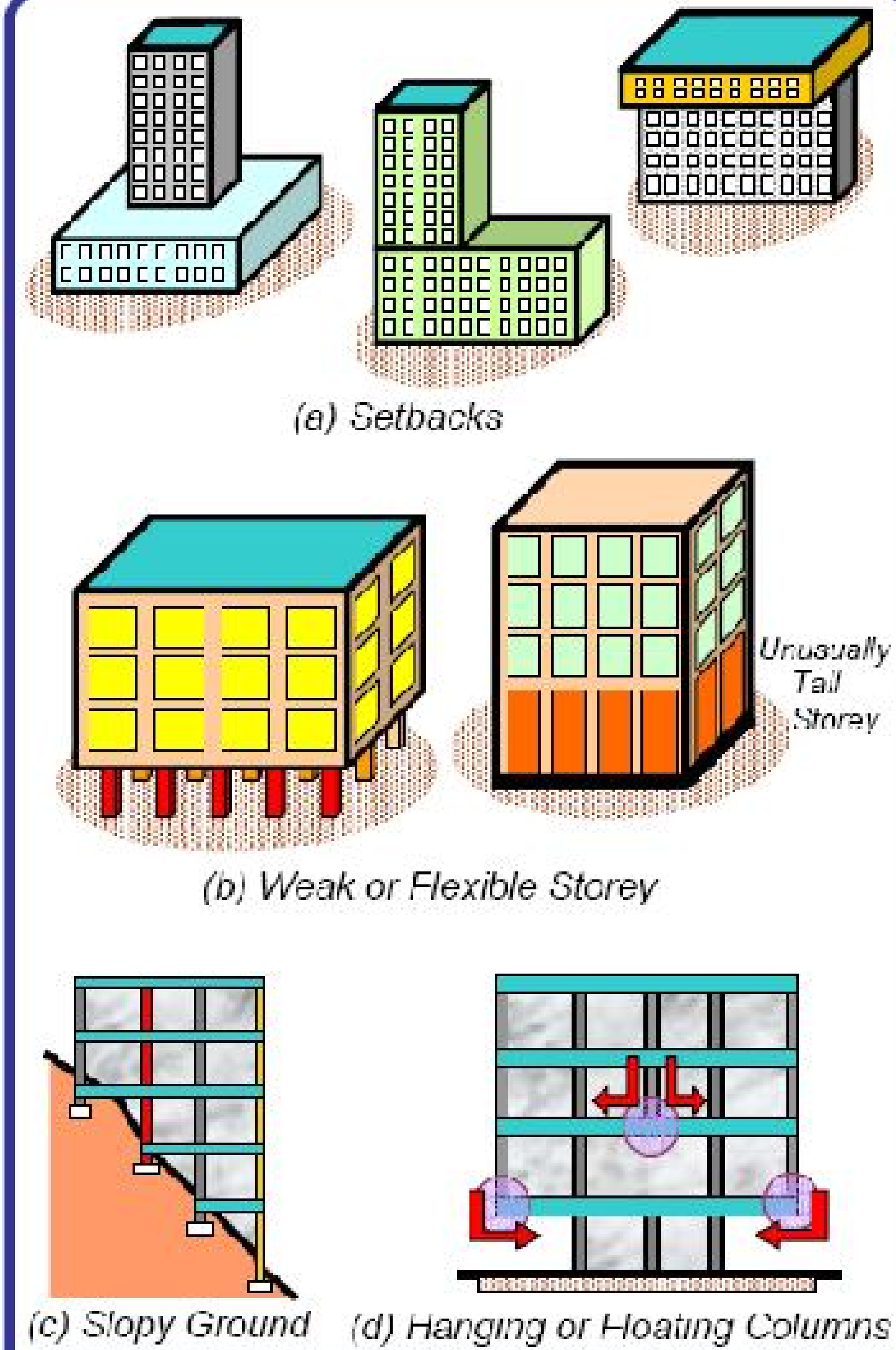
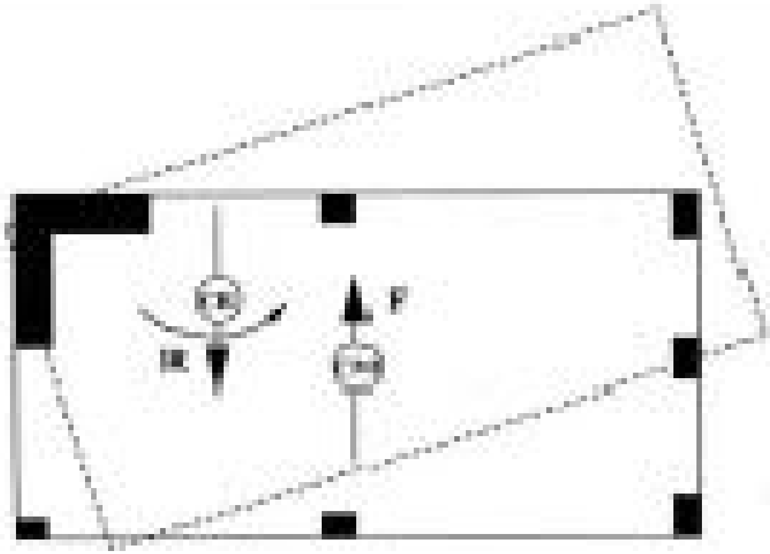


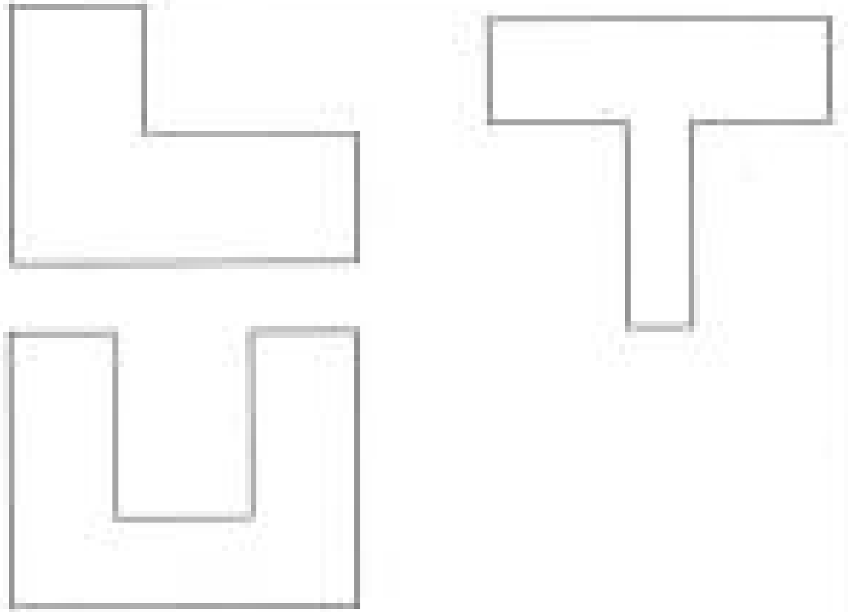
Figure 1: Buildings with one of their overall sizes much larger or much smaller than the other two, do not perform well during earthquakes.

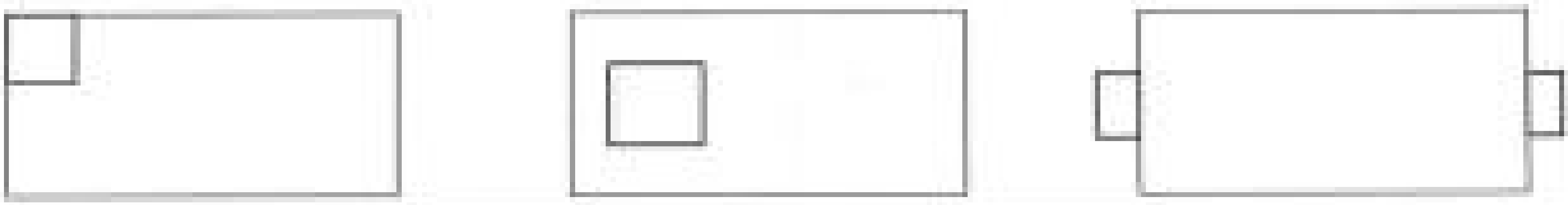


Regularity in Plan



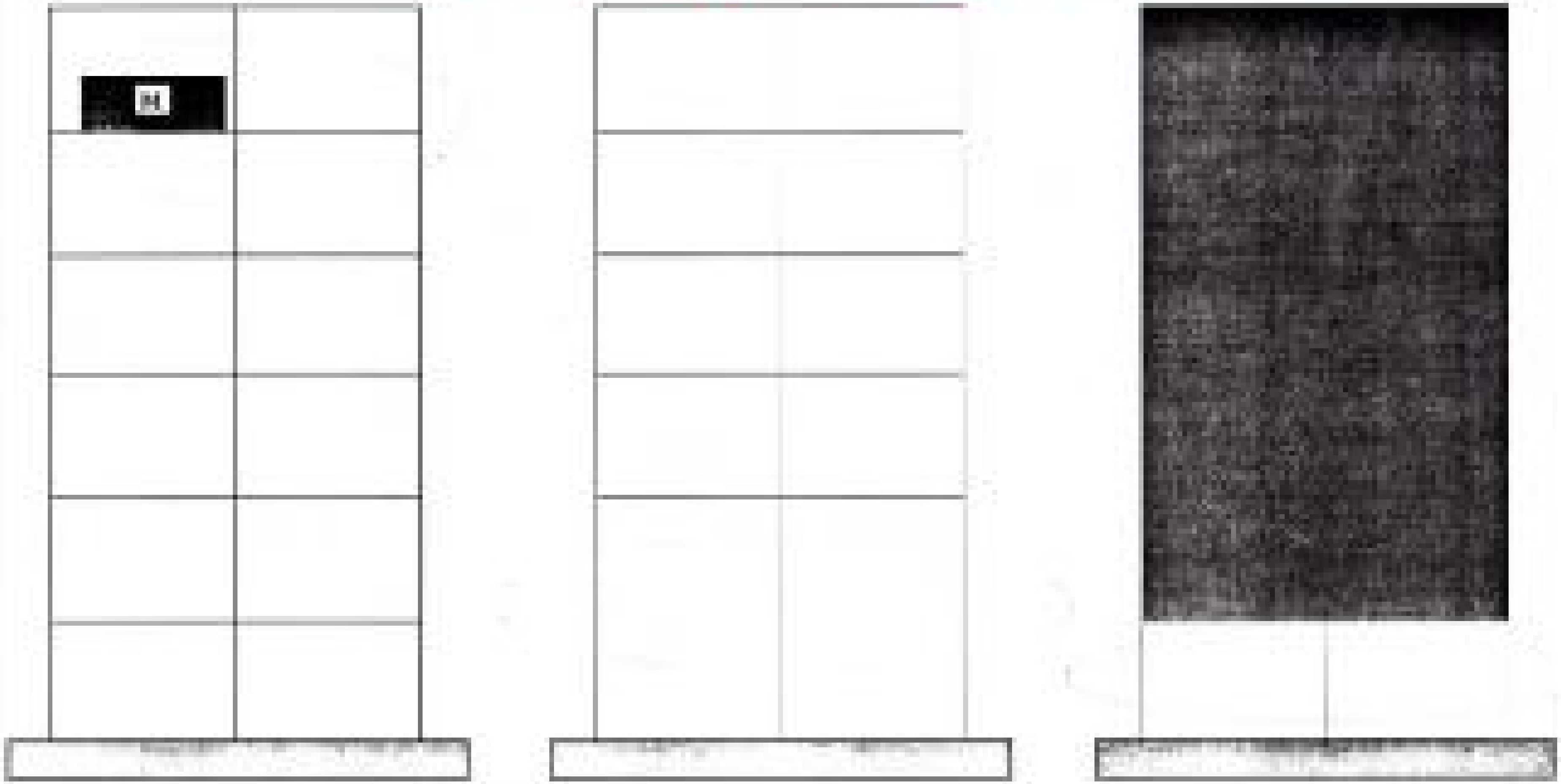
Torsional Vibration





Regularity in Elevation

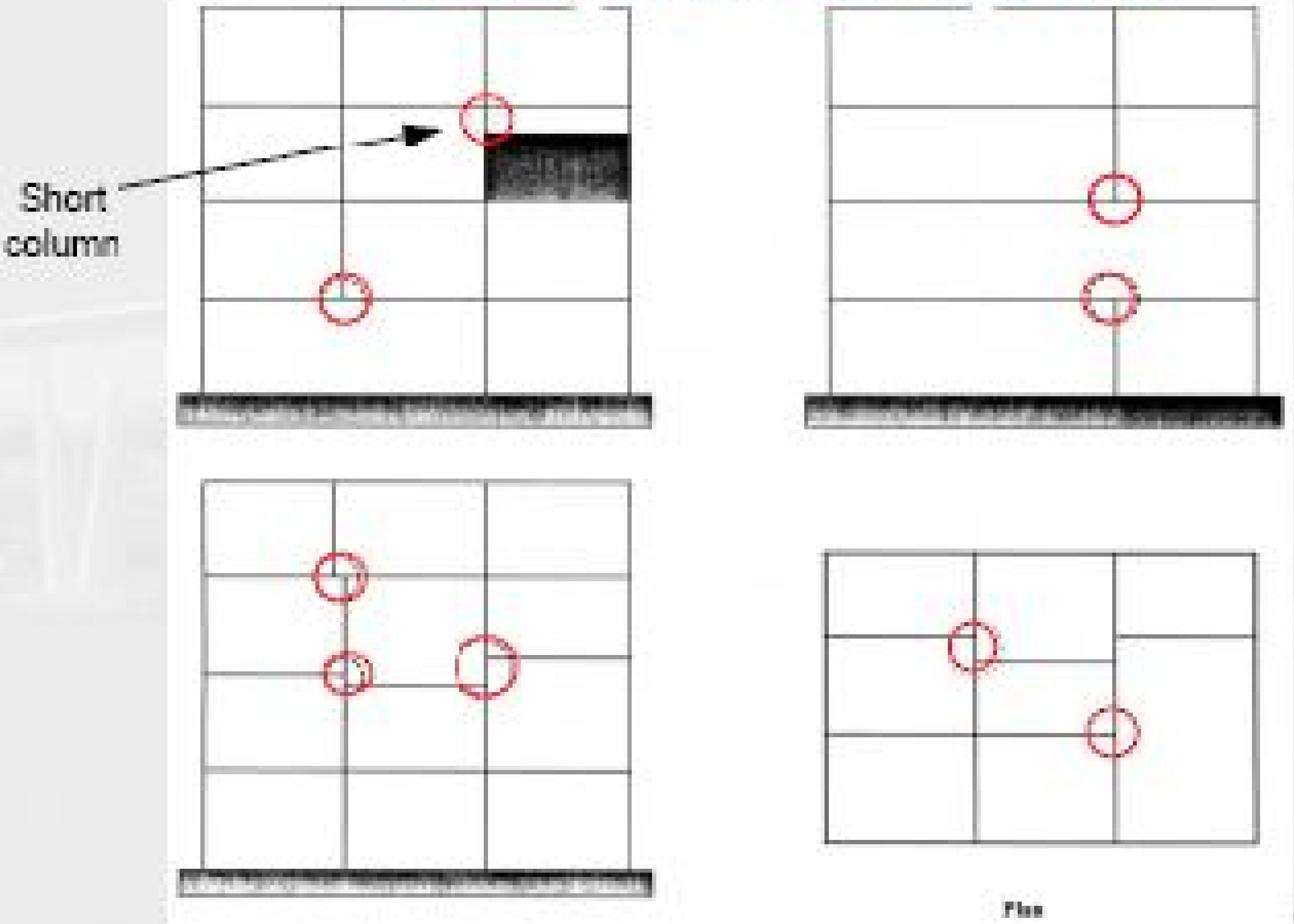
Regularity in Elevation



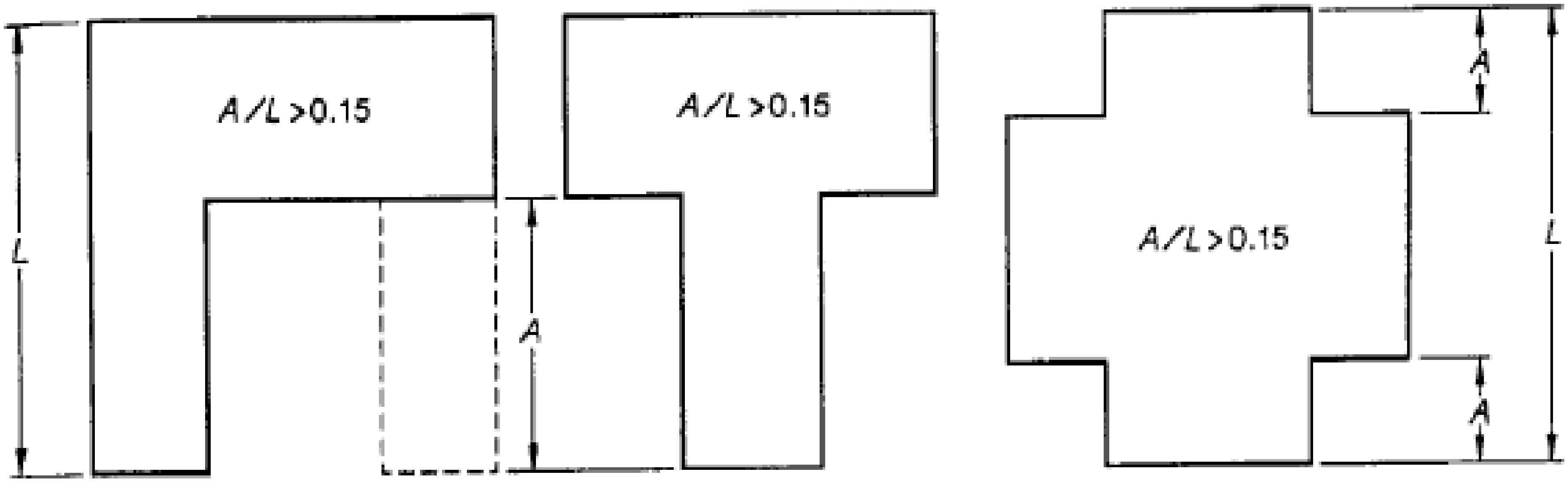
Mass Irregularity

Stiffness Irregularity

Local Stress Points



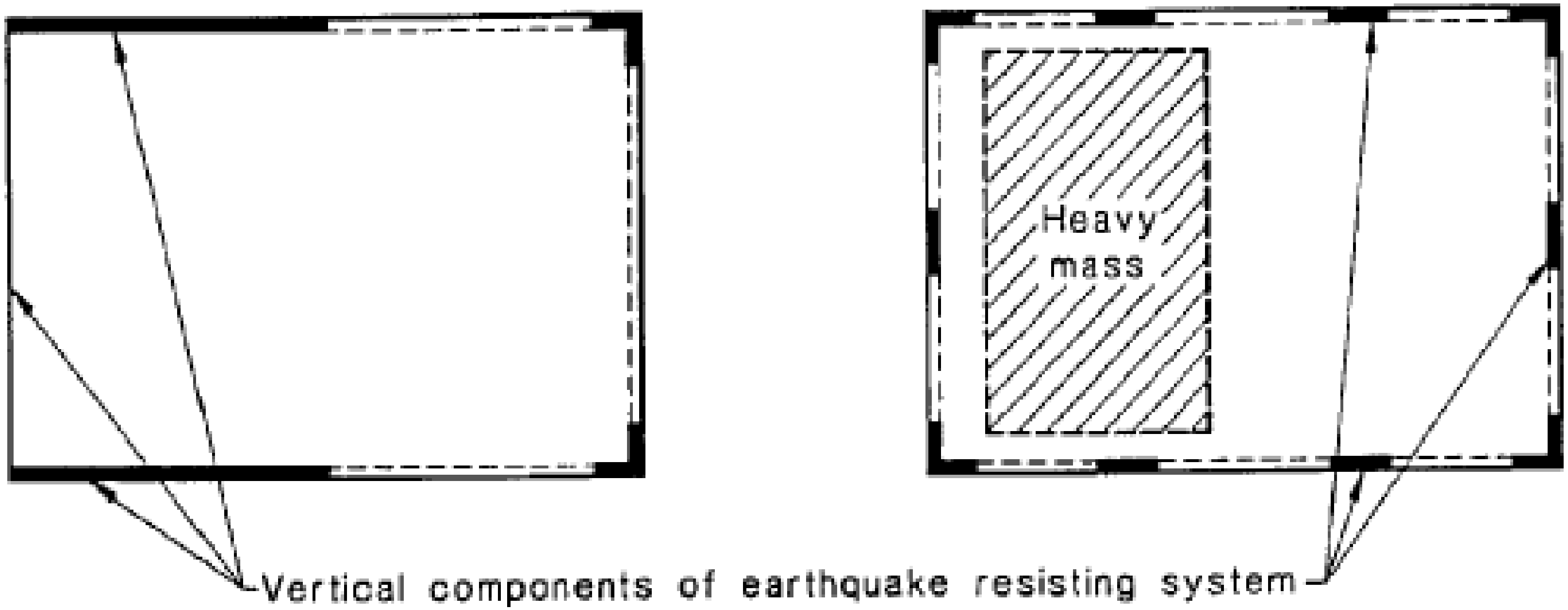
Large re-entrant corners creating a crucifix form would mean irregular configuration.



(a) Geometry

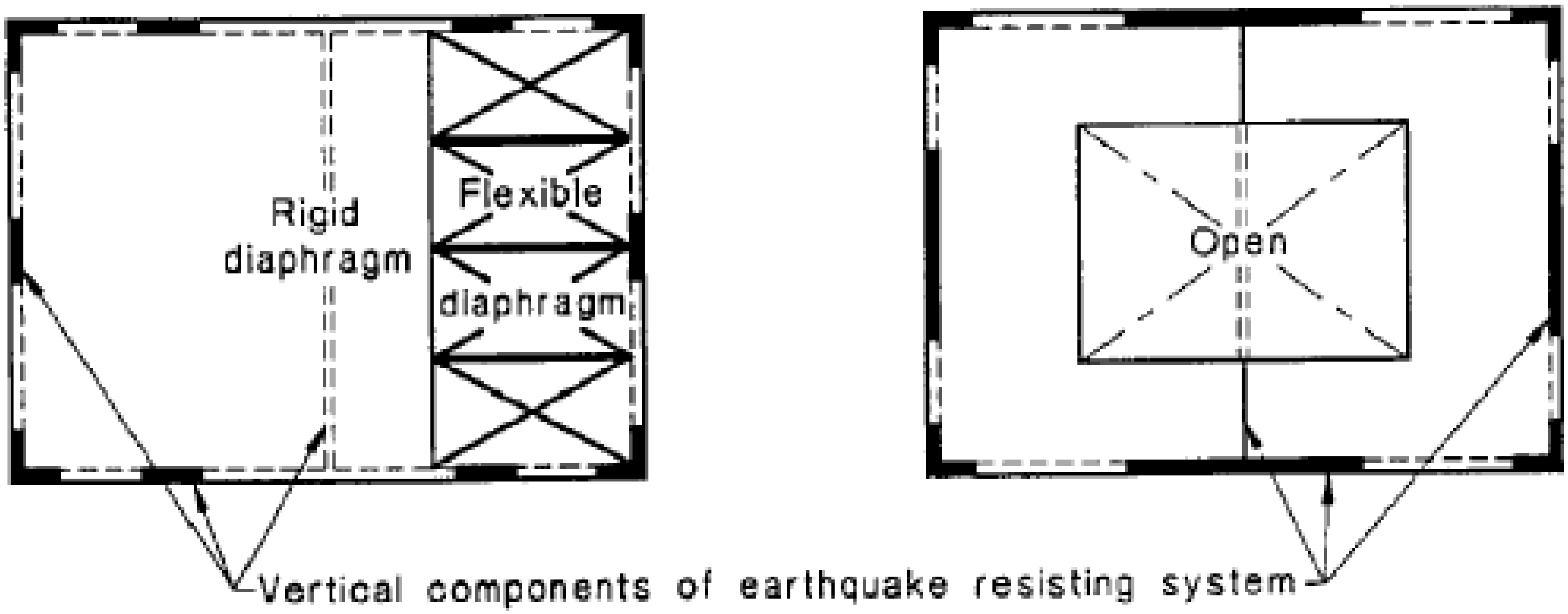
CENTRE OF MASS – CENTRE OF STIFFNESS

ECCENTRICITY



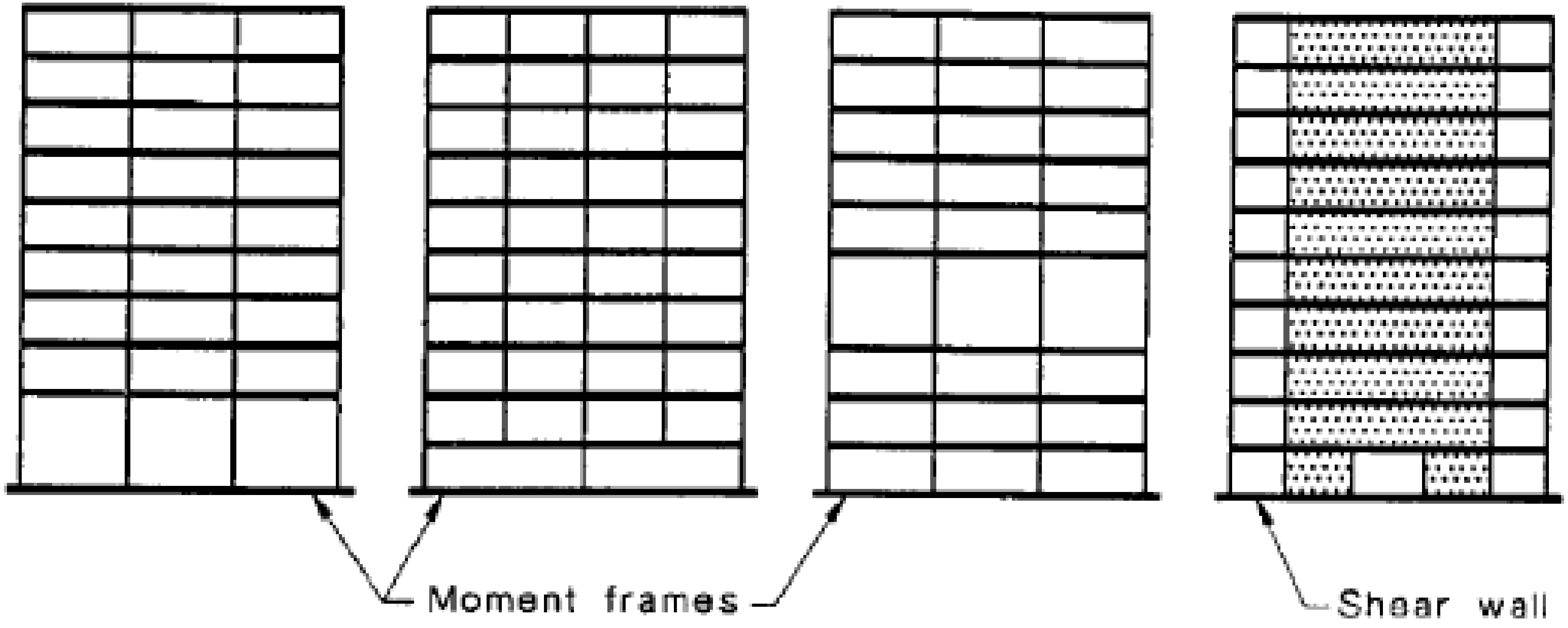
(b) Mass resistance eccentricity

PLAN IRREGULARITIES



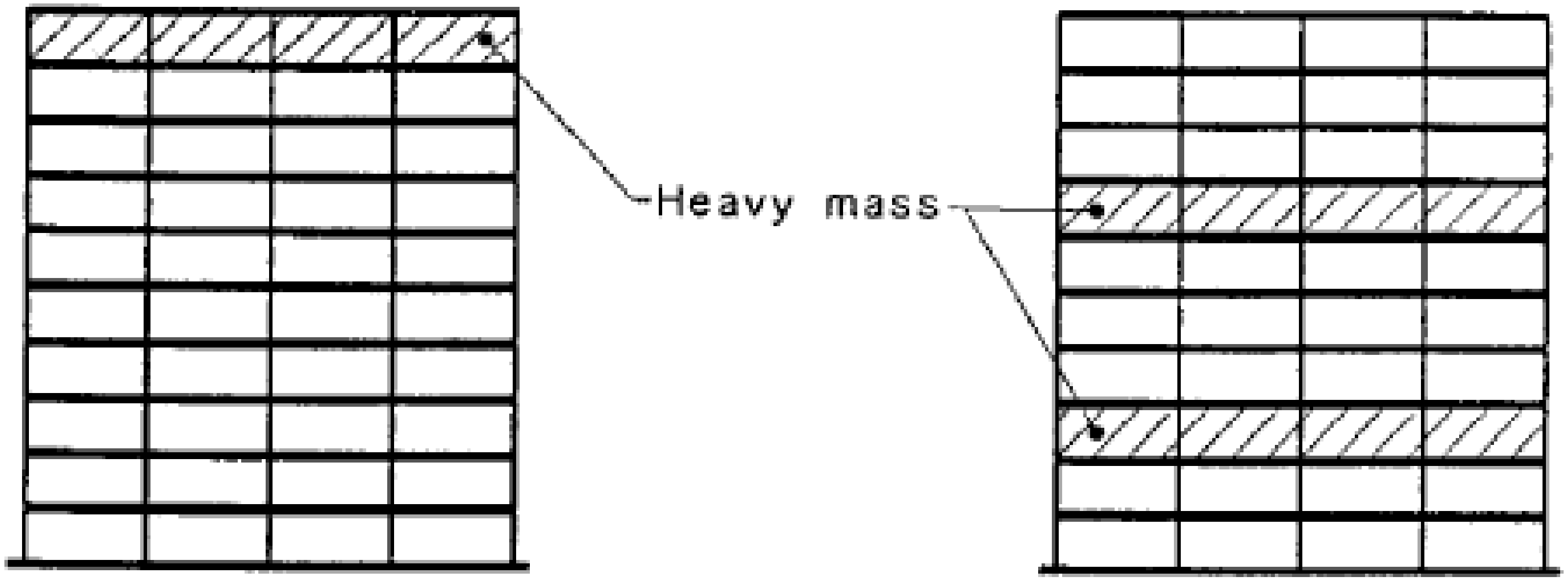
(c) Discontinuity in diaphragm stiffness

VERTICAL IRREGULARITIES - STIFFNESS



(a) Stiffness ratio

VERTICAL IRREGULARITIES - MASS



(b) Mass ratio