Building Vulnerability

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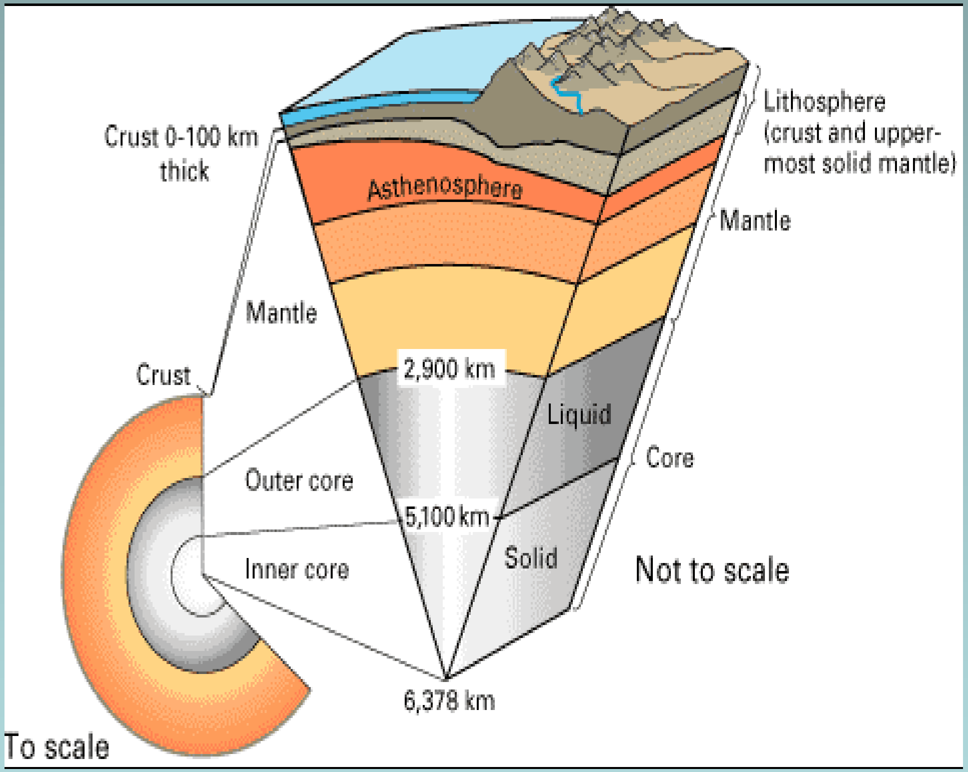
Definition of an Earthquake

An earthquake is the sudden, sometimes violent movement of the earth's surface from the release of energy in the earth's crust.

How Deep Do Earthquakes Occur in the World?

Earthquakes occur in the crust or upper mantle which ranges from the surface to about 800 kilometers deep (about 500 miles).



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Modified Mercalli Intensity Scale

I. Not felt. Marginal and long period effects of large earthquakes.

II. Felt by persons at rest, on upper floors, or favorably placed.

III. Felt indoors. Hanging objects swing. Vibration like passing of light trucks. Duration estimated. May not be recognized as an earthquake.

IV. Hanging objects swing. Vibration like passing of heavy trucks; or sensation of a jolt like a heavy ball striking the walls. Standing motor cars rock. Windows, dishes, doors rattle. Glasses clink. Crockery clashes. In the upper range of IV, wooden walls and frame creak.

V. Felt outdoors; direction estimated. Sleepers wakened. Liquids disturbed, some spilled. Small unstable objects displaced or upset. Doors swing, close, open. Shutters, pictures move. Pendulum clocks stop, start, change rate.

VI. Felt by all. Many frightened and run outdoors. Persons walk unsteadily. Windows, dishes, glassware broken. Knickknacks, books, etc., off shelves. Pictures off walls.

Furniture moved or overturned. Weak plaster and masonry D cracked. Small bells ring (church, school). Trees, bushes shaken (visibly, or heard to rustle).

VII. Difficult to stand. Noticed by drivers of motor cars. Hanging objects quiver. Furniture broken. Damage to masonry D, including cracks. Weak chimneys broken at roof line. Fall of plaster, loose bricks, stones, tiles, cornices (also unbraced parapets and architectural ornaments). Some cracks in masonry C. Waves on ponds; water turbid with mud. Small slides and caving in along sand or gravel banks. Large bells ring. Concrete irrigation ditches damaged.

VIII. Steering of motor cars affected. Damage to masonry C; partial collapse. Some damage to masonry B; none to masonry A. Fall of stucco and some masonry walls. Twisting, fall of chimneys, factory stacks, monuments, towers, elevated tanks. Frame houses moved on foundations if not bolted down; loose panel walls thrown out. Decayed piling broken off. Branches broken from trees. Changes in flow or temperature of springs and wells. Cracks in wet ground and on steep slopes.

IX. General panic. Masonry D destroyed; masonry C heavily damaged, sometimes with complete collapse; masonry B seriously damaged. (General damage to foundations.) Frame structures, if not bolted, shifted off foundations. Frames racked. Serious damage to reservoirs. Underground pipes broken. Conspicuous cracks in ground. In alluvial areas sand and mud ejected, earthquake fountains, sand craters.

X. Most masonry and frame structures destroyed with their foundations. Some well-built wooden structures and bridges destroyed. Serious damage to dams, dikes, embankments. Large landslides. Water thrown on banks of canals, rivers, lakes, etc. Sand and mud shifted horizontally on beaches and flat land. Rails bent slightly. Rails bent greatly. Underground pipelines completely out of service. Damage nearly total. Large rock masses displaced. Lines of sight and level distorted. Objects thrown into the air.

What are Tsunamis?
`Tsunamis are ocean waves caused by large earthquakes and landslides that occur near or under the ocean. Scientists do not use the term "tidal wave" because these waves are not caused by tides. Tsunami waves are unlike typical ocean waves generated by wind and storms. When tsunamis approach shore, the behave like a very fast moving tide that extends far inland. A rule of thumb is that if you see the tsunami, it is too late to out run it. Most tsunamis do not "break" like the curling, wind-generated waves popular with surfers. Even "small" tsunamis (for example, 6 feet in height) are associated with extremely strong currents, capable of knocking someone off their feet.

Because of complex interactions with the coast, tsunami waves can persist for many hours. As with many natural phenomena, tsunamis can range in size from micro-tsunamis detectable only by sensitive instruments on the ocean floor to mega-tsunamis that can affect the coastlines of entire oceans, as with the Indian Ocean tsunami of 2004. If you hear a tsunami warning or if you feel strong shaking at the coast or very unusual wave activity (e.g., the sea withdrawing far from shore), it is important to move to high ground and stay away from the coast until wave activity has subsided (usually several hours to days). For more general information on tsunamis and what to do during a tsunami warning, please visit sites sponsored by FEMA, the National Weather Service, state agencies, NOAA, and the USGS.

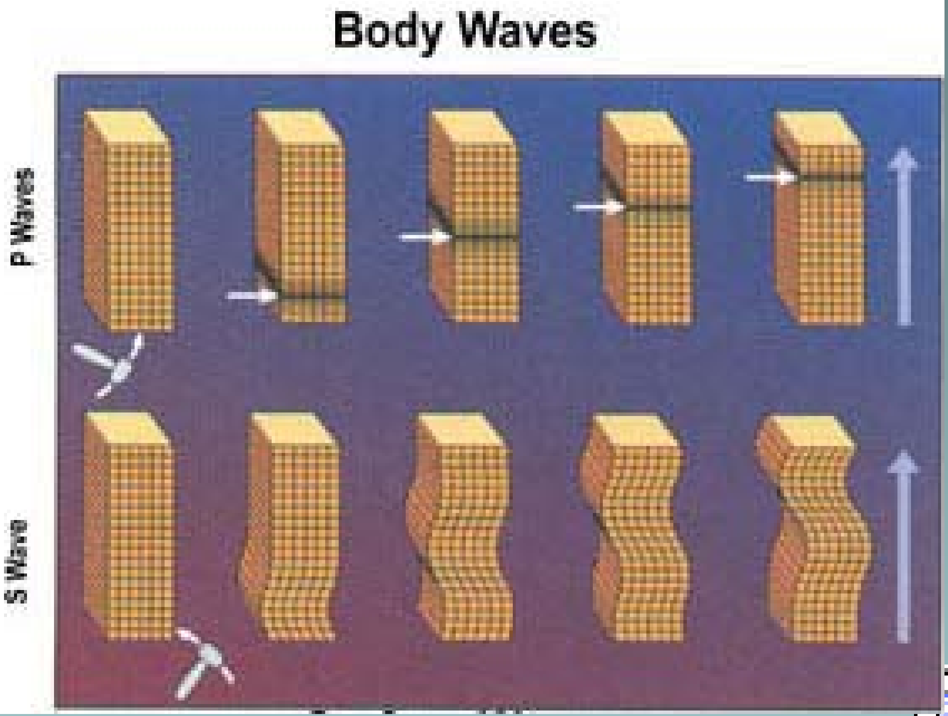
23. How Much Energy is Released in an Earthquake?

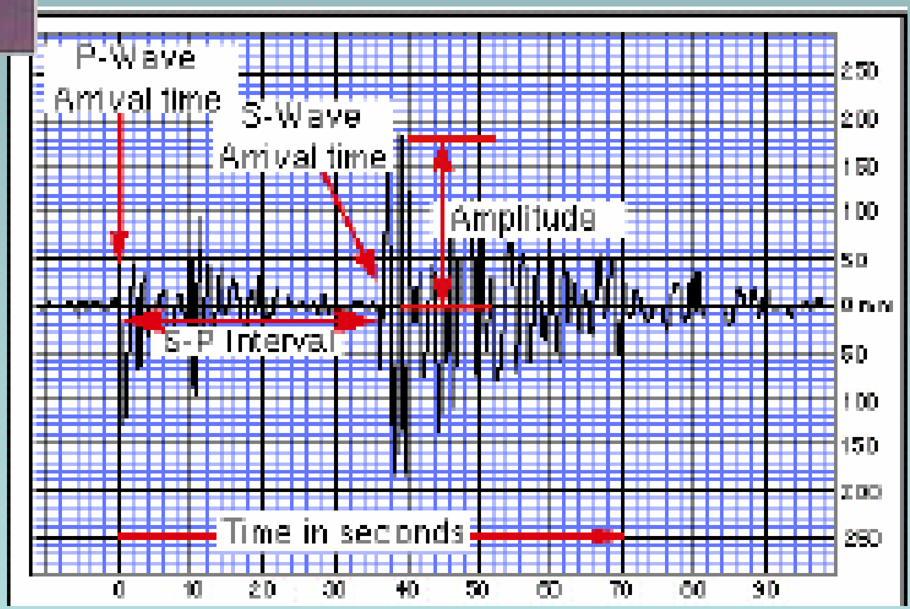
Earthquakes release a tremendous amount of energy, which is why they can be so destructive. The table below shows magnitudes with the approximate amount of TNT needed to release the same amount of energy.

Magnitude	Approximate TNT Energy
4.0	6 tons
5.0	199 tons
6.0	6,270 tons
7.0	199,000 tons
8.0	6,270,000 tons
9.0	99,000,000 tons

- **Primary waves**, also called **P waves** or **compressional waves**, travel about 1 to 5 miles per second (1.6 to 8 kps), depending on the material they're moving through. This speed is greater than the speed of other waves, so P waves arrive first at any surface location. They can travel through solid, liquid and gas, and so will pass completely through the body of the earth. As they travel through rock, the waves move tiny rock particles back and forth -- pushing them apart and then back together -- in line with the direction the wave is traveling. These waves typically arrive at the surface as an abrupt thud.

- **Secondary waves**, also called **S waves** or **shear waves**, lag a little behind the P waves. As these waves move, they displace rock particles outward, pushing them perpendicular to the path of the waves. This results in the first period of rolling associated with earthquakes. Unlike P waves, S waves don't move straight through the earth. They only travel through solid material, and so are stopped at the liquid layer in the earth's core.
- Both sorts of body waves do travel around the earth, however, and can be detected on the opposite side of the planet from the point where the earthquake began. At any given moment, there are a number of very faint seismic waves moving all around the planet.
- Surface waves are something like the waves in a body of water -- they move the surface of the earth up and down. This generally causes the worst damage because the wave motion rocks the foundations of manmade structures. L waves are the slowest moving of all waves, so the most intense shaking usually comes at the end of an earthquake.





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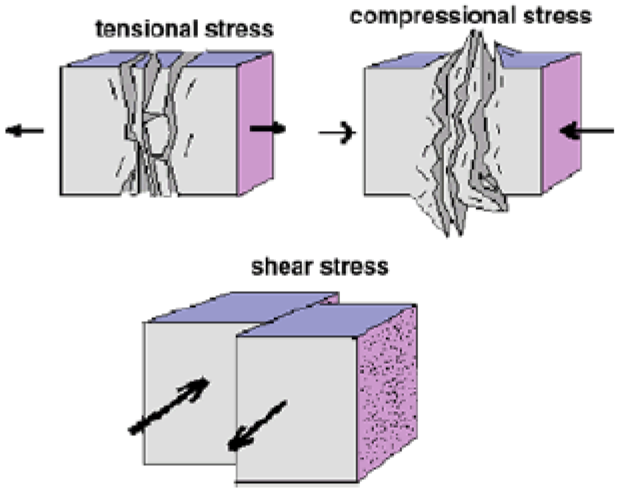
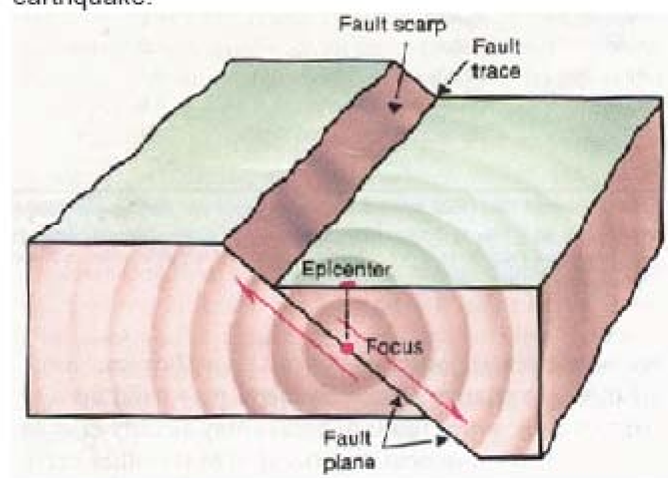
Liquefaction

In some areas, severe earthquake damage is the result of **liquefaction** of soil. In the right conditions, the violent shaking from an earthquake will make loosely packed sediments and soil behave like a liquid. When a building or house is built on this type of sediment, liquefaction will cause the structure to collapse more easily. Highly developed areas built on loose ground material can suffer severe damage from even a relatively mild earthquake. Liquefaction can also cause severe mudslides, like the ones that took so many lives in the recent earthquake that shook Central America. In this case, in fact, mudslides were the most significant destructive force, claiming hundreds of lives.

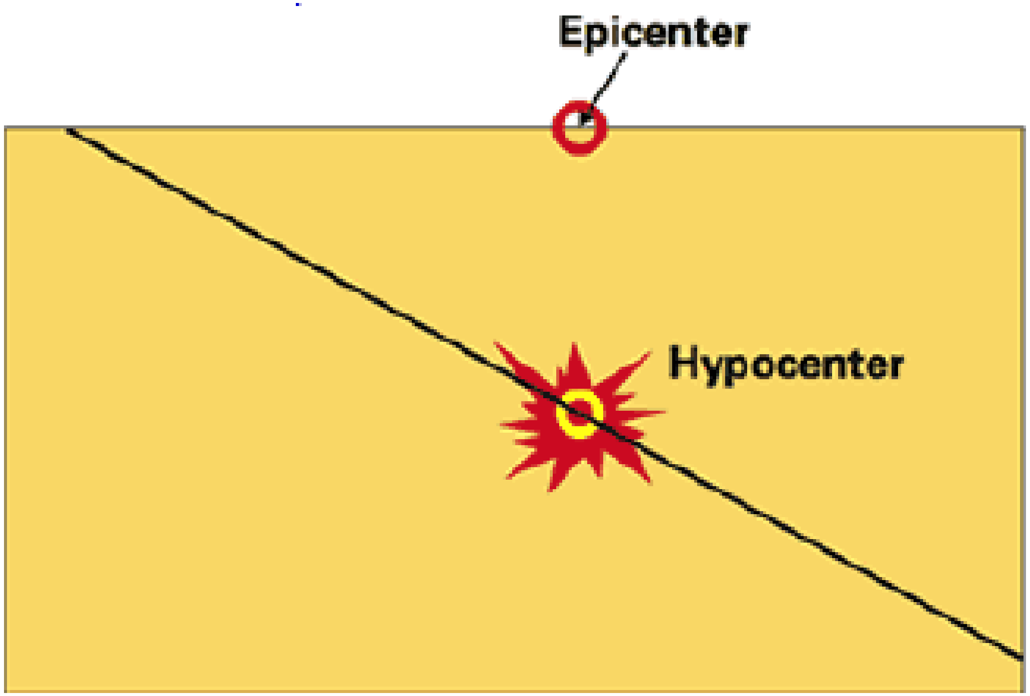


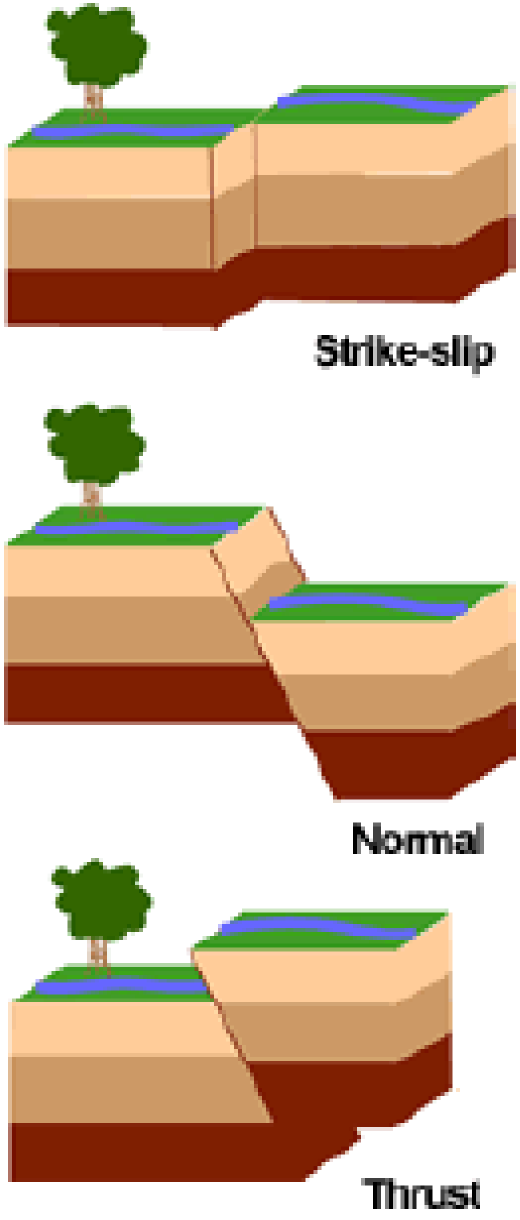
- **fault plane**

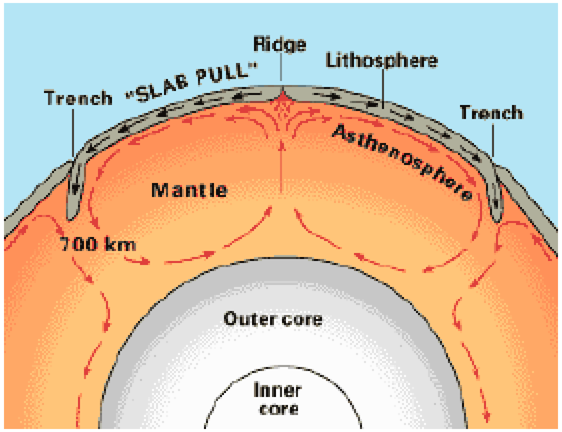
The fault plane is the planar (flat) surface along which there is slip during an earthquake.

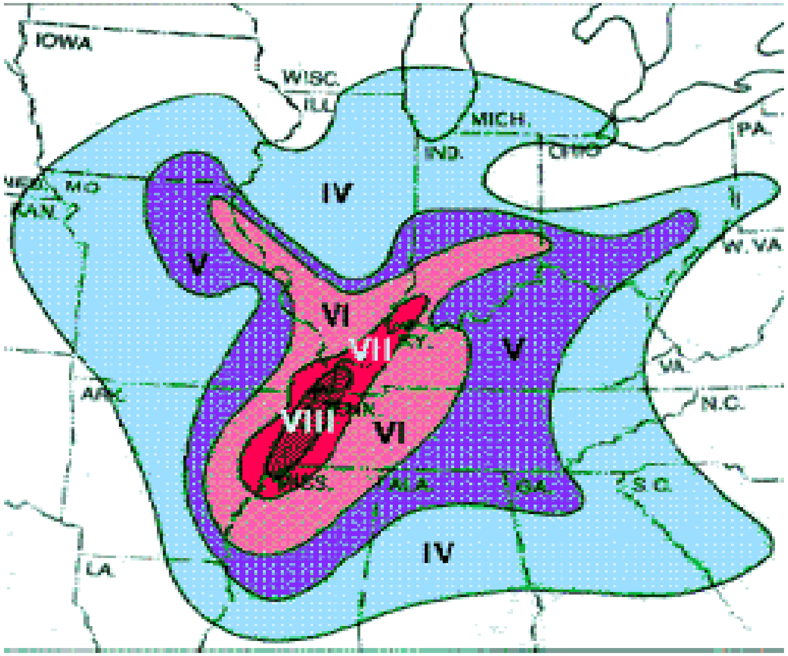


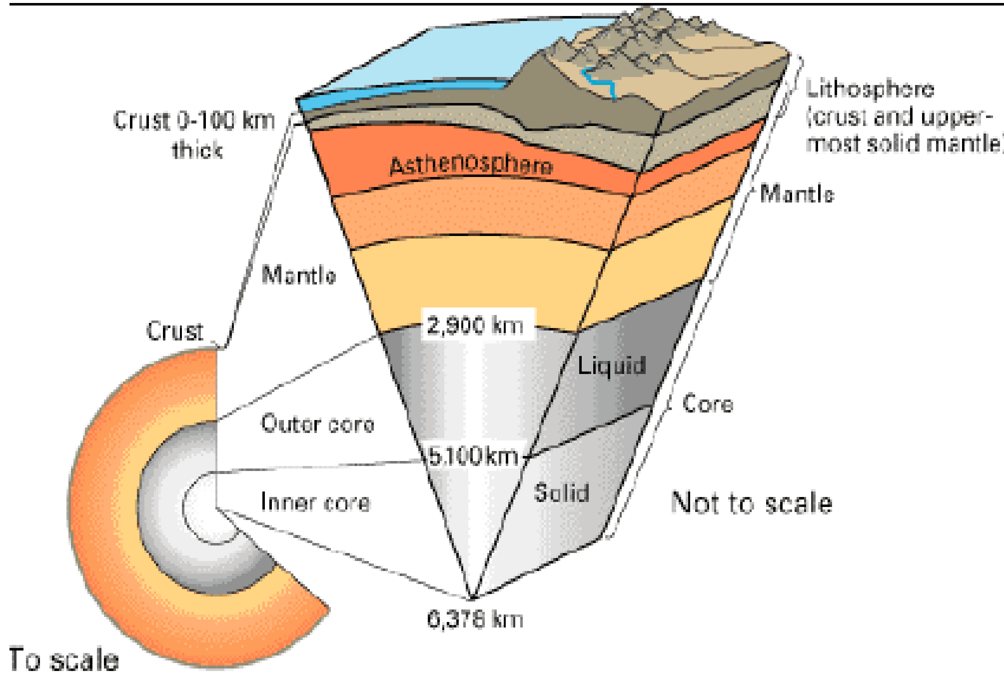
Fault plane diagram. (Image courtesy of Kian H. Chong, Univ. of California, Davis)


Epicenter
Hypocenter


Strike-slip
Normal
Thrust


Ridge
Lithosphere
Trench
"SLAB PULL"
Trench
Asthenosphere
Mantle
700 km
Outer core
Inner core





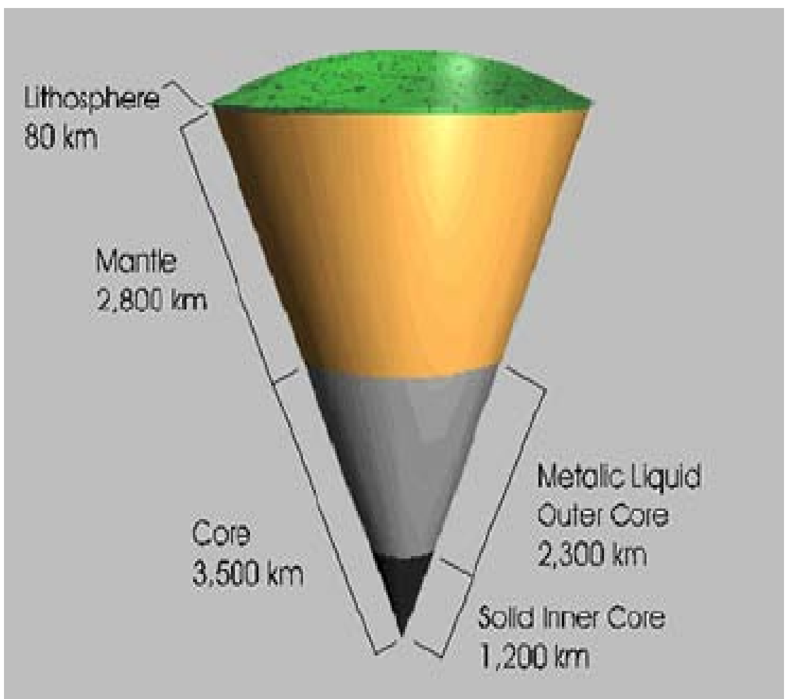


Figure 10-24. Failure of the weak concrete in the *topi* just below the beam (Bhuj).

How Many Earthquakes Happen Each Year?

Description	**Magnitude**	**Frequency per year**
Great	8.0+	1
Major	7.0-7.9	18
Large (destructive)	6.0-6.9	120
Moderate (damaging)	5.0-5.9	1,000
Minor (damage slight)	4.0-4.0	6,000
Generally felt	3.0-3.9	49,000
Potentially perceptible	2.0-2.9	300,000
Imperceptible less than	2.0	600,000+

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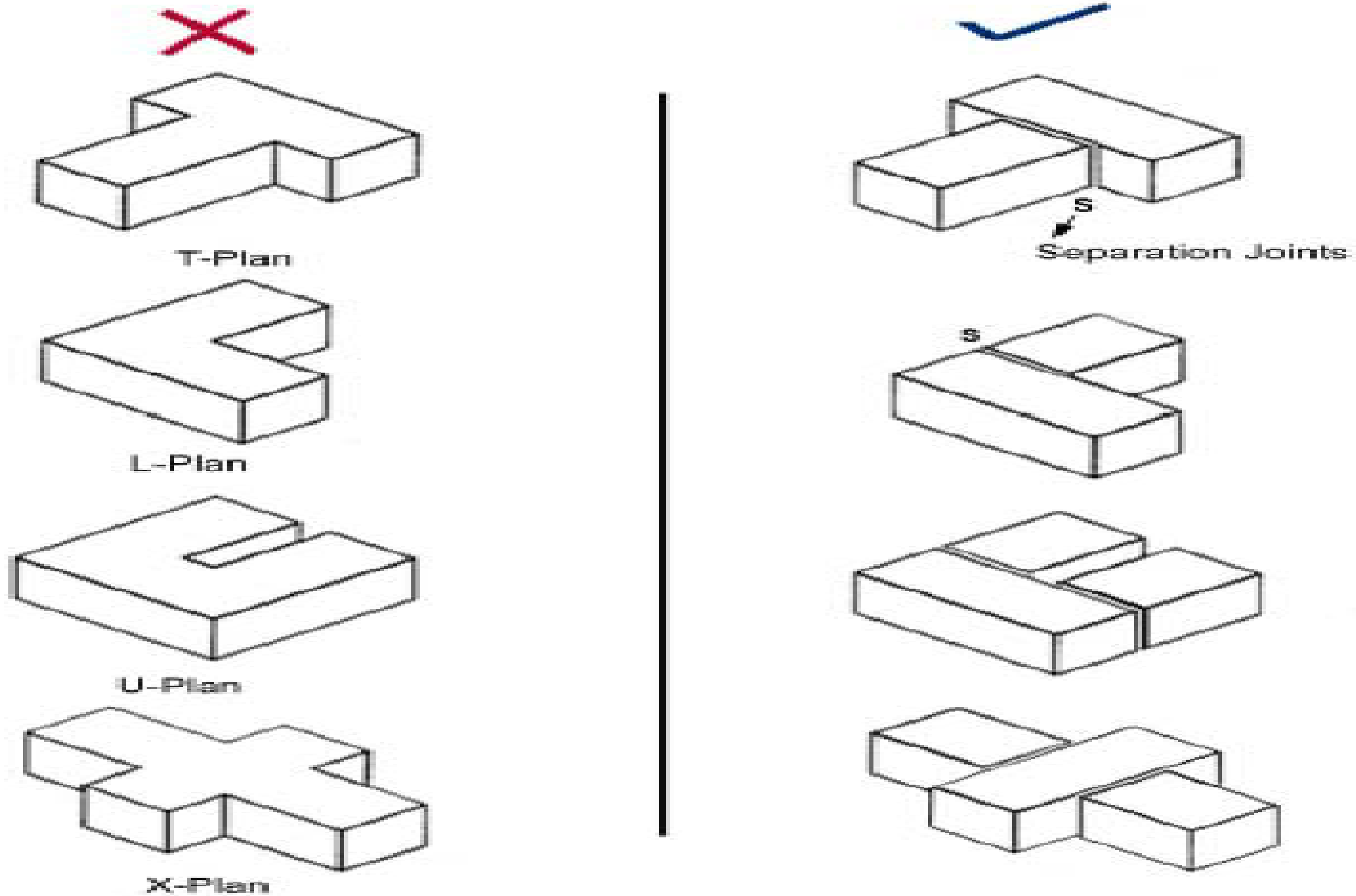
PLAN OF BUILDING

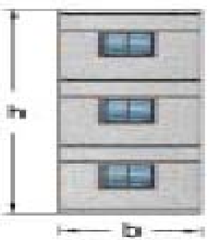
(Asymmetry should be avoided)

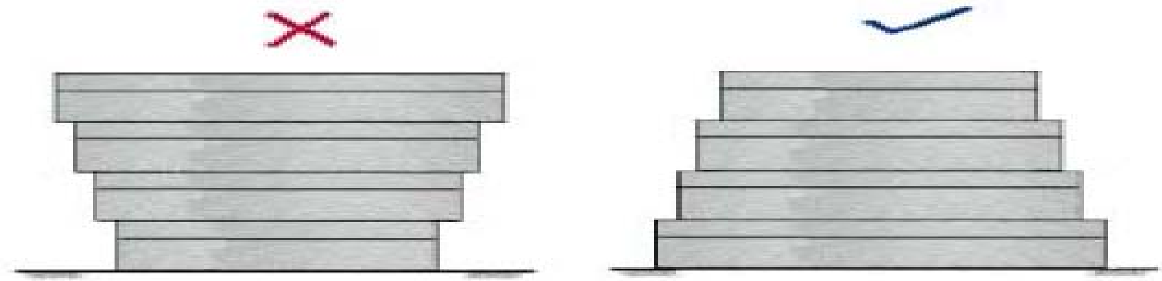


Asymmetric buildings undergo torsion and the extreme corners of asymmetric buildings are subjected to very large earthquake forces.

GENERAL SHAPE OF BUILDING

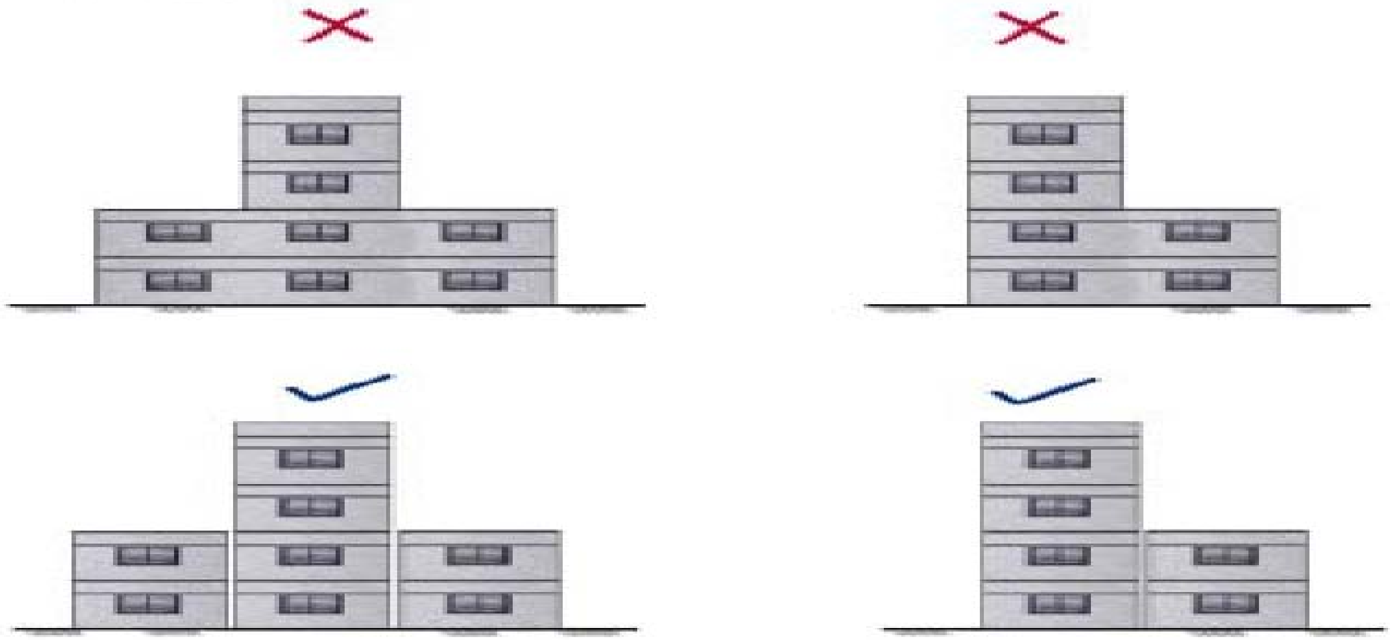
h/b ratio < 4





Very slender buildings should be avoided

Inverted pendulum type buildings are unstable

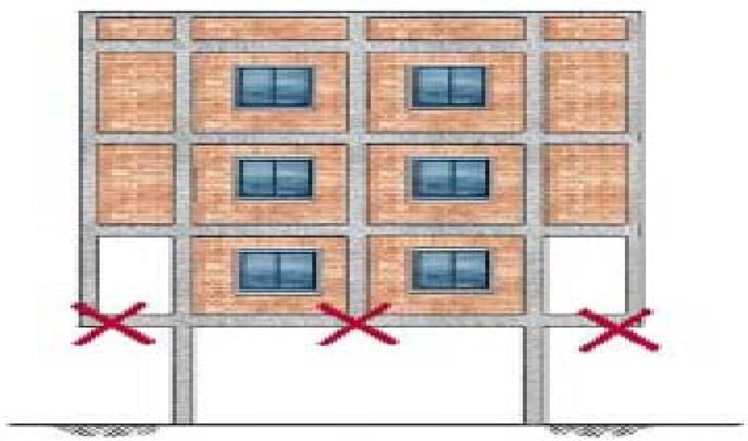


Sudden change in lateral stiffness should be avoided

PROJECTIONS AND LARGE OVERHANGS

Avoid long projected balcony

Large projections should be avoided



Floating columns should be avoided

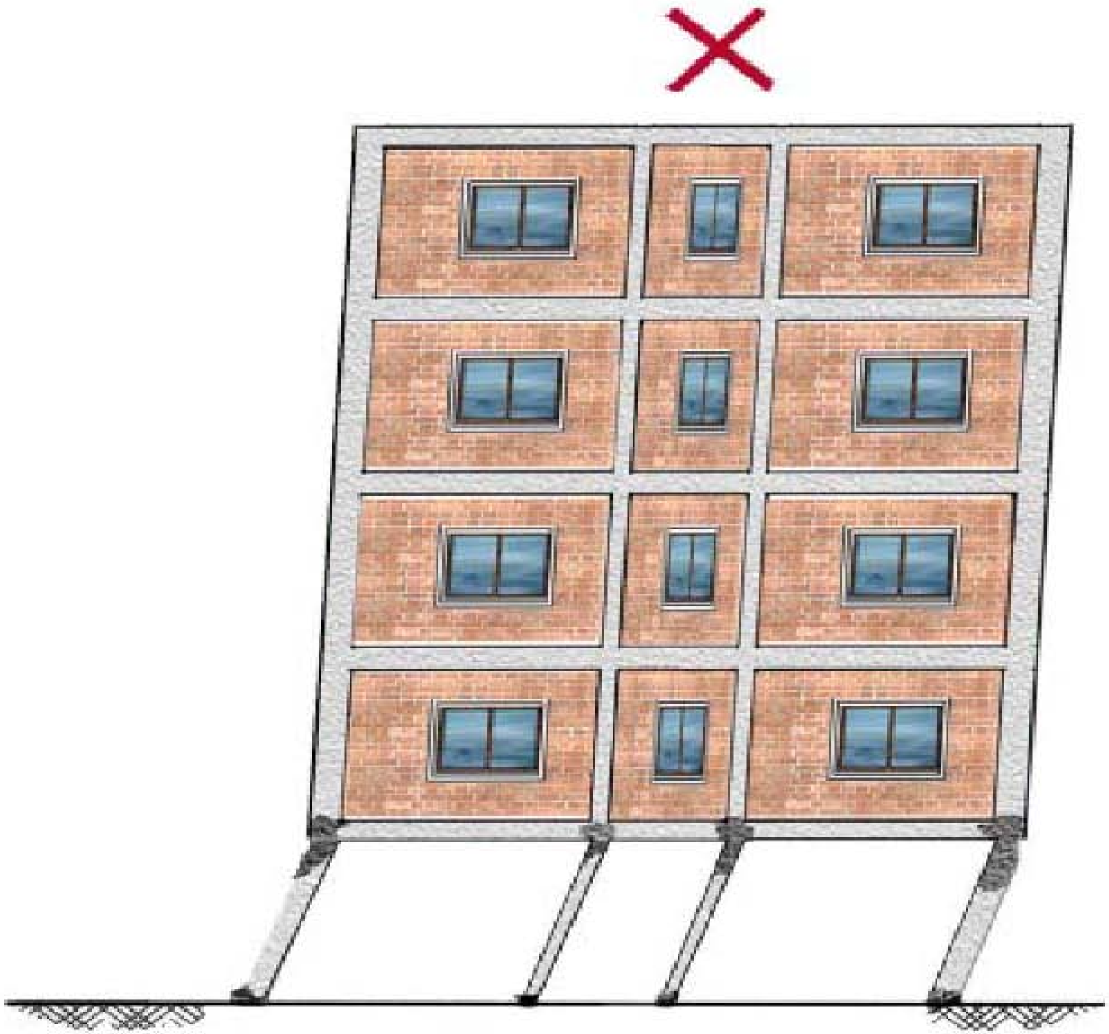
Large overhangs, projections and floating columns

CONSTRUCTION PRACTICE IN URBAN AREAS

Open Ground Floor and Discontinuous Columns

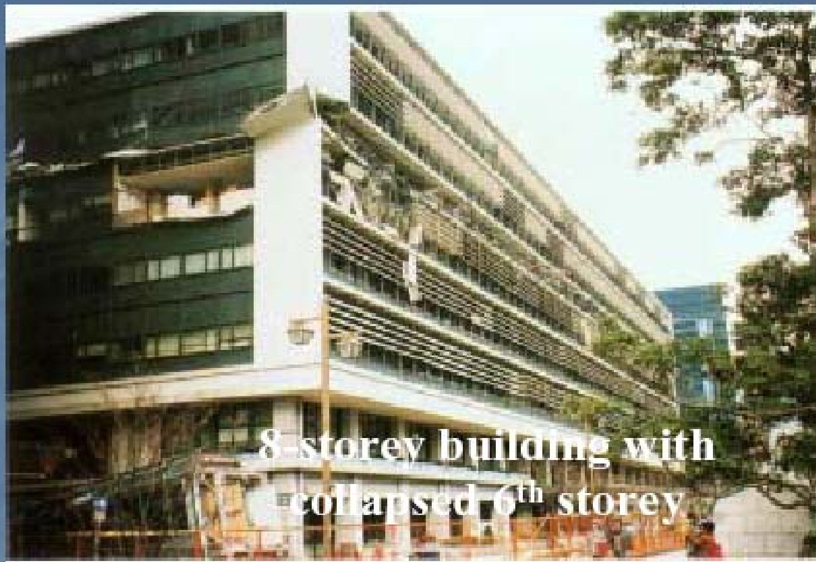
STIFFNESS IRREGULARITY – SOFT STORY

BUILDING WITH SOFT FIRST STOREY



Damage to soft ground storey building

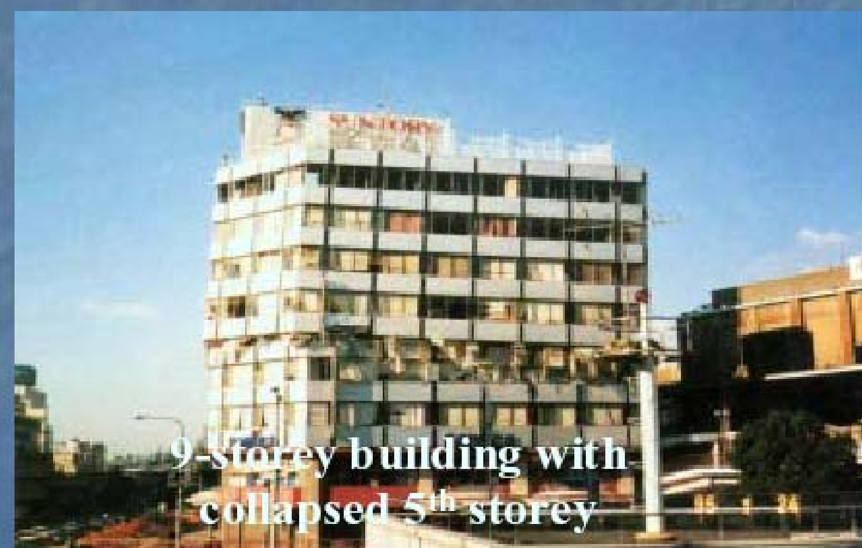
Weak Storeys



8-storey building with collapsed 6th storey

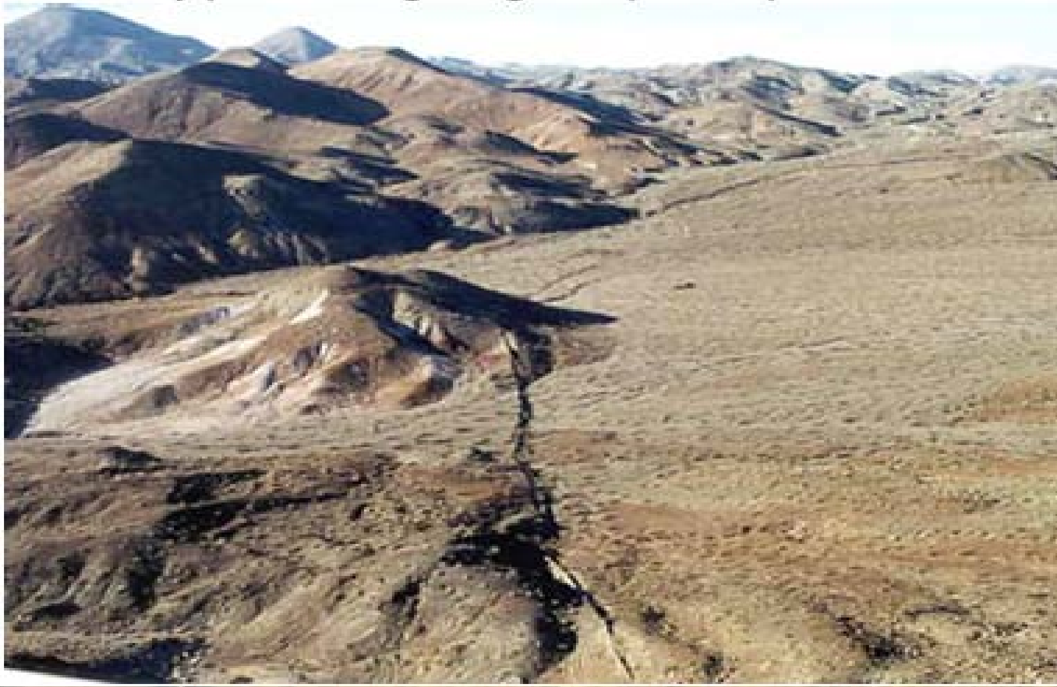
8-storey building with collapsed 4th storey

10-storey building with collapsed 3rd storey



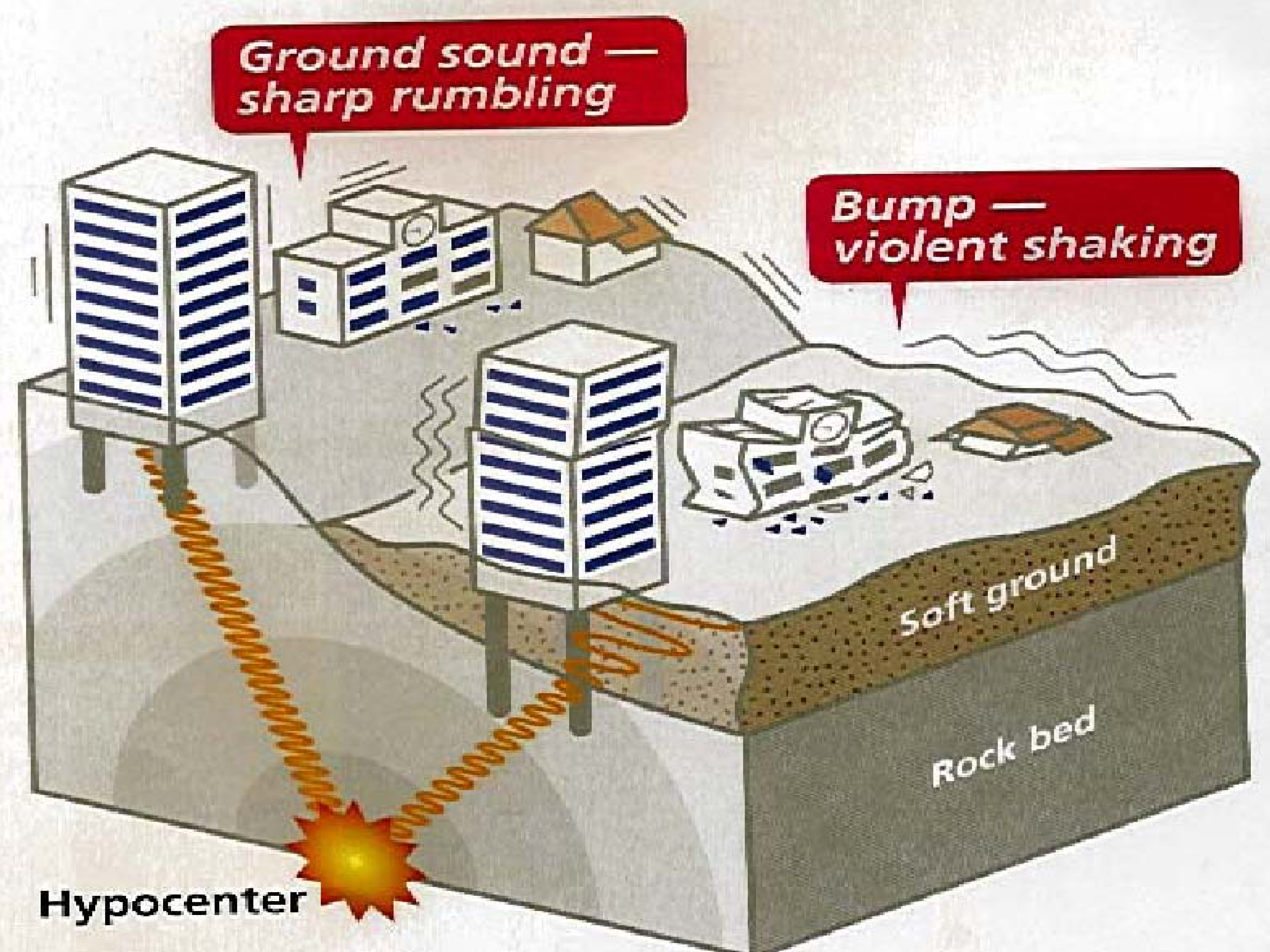
9-storey building with collapsed 5th storey

WEAK COLUMNS

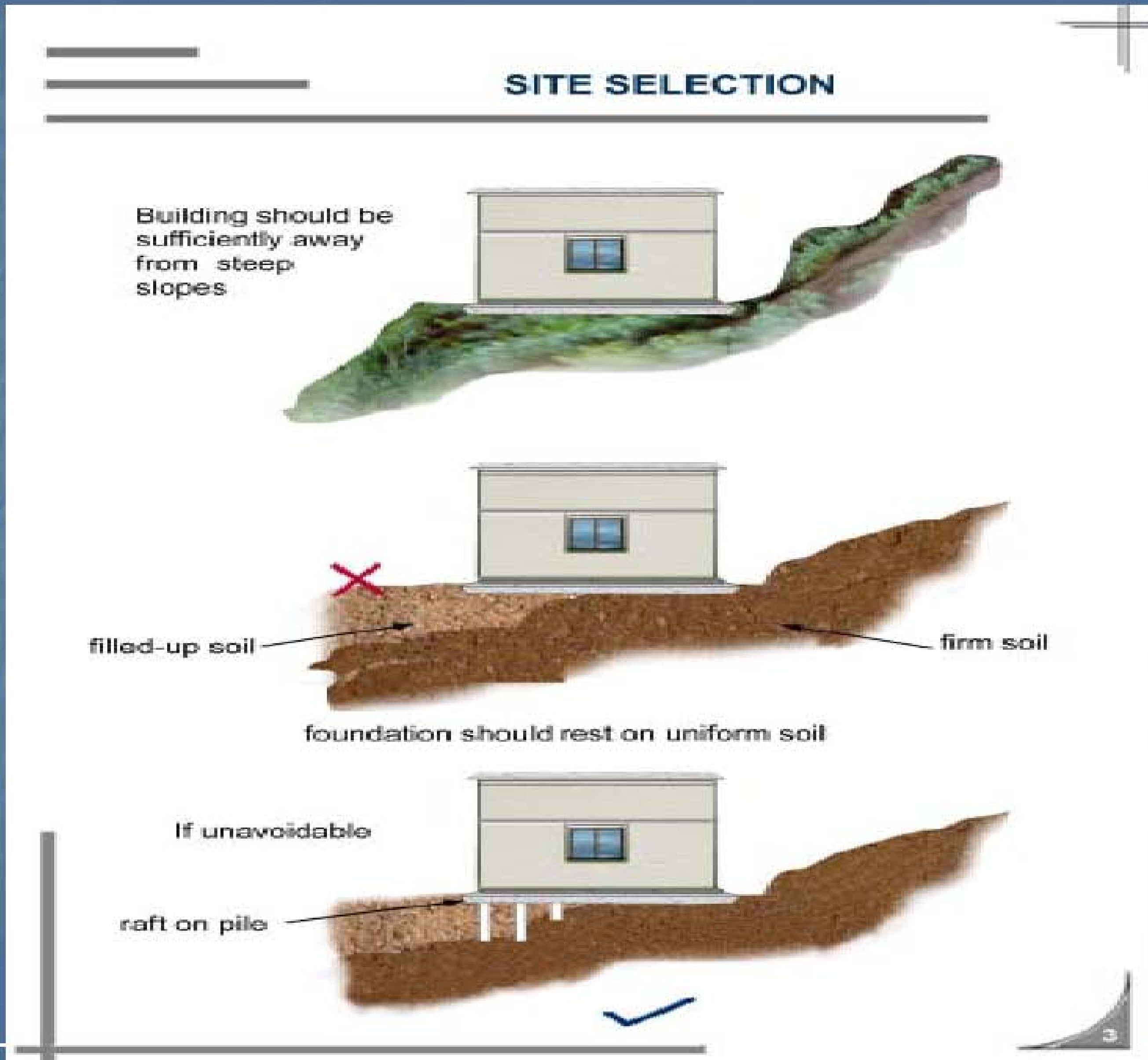


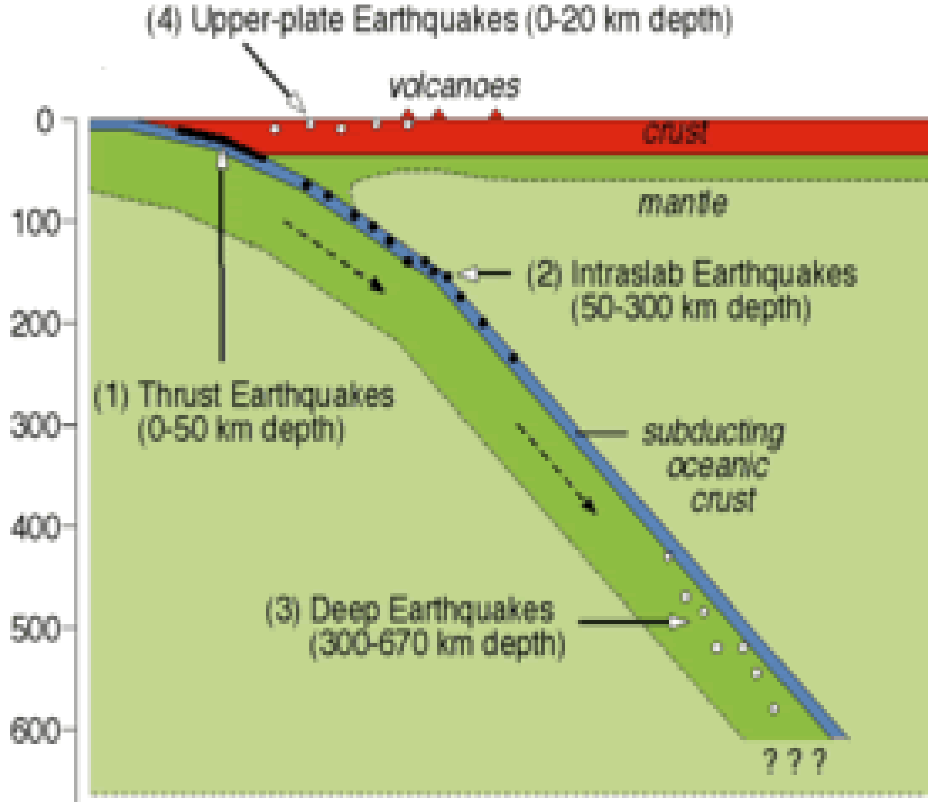
POOR WALL-FRAME CONNECTION

No load transfer mechanism


Ground sound — sharp rumbling
Bump — violent shaking
Soft ground
Rock bed
Hypocenter

LOCAL GEO-TECHNICAL CONDITIONS





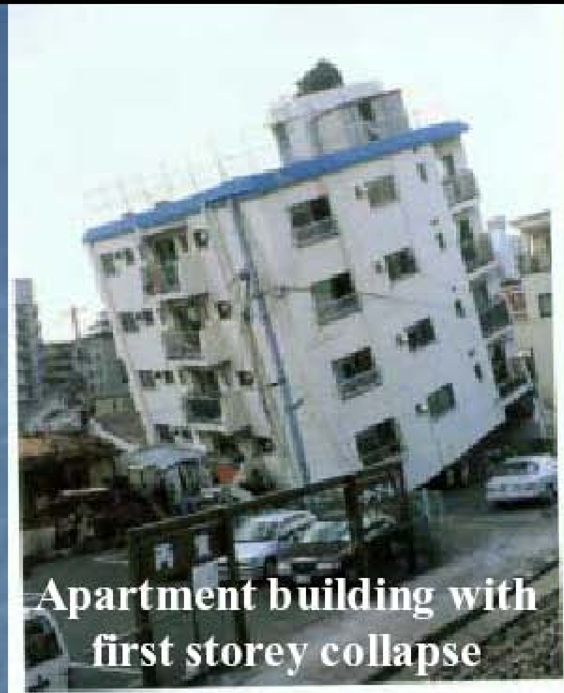
(4) Upper-plate Earthquakes (0-20 km depth)
volcanoes
crust
mantle
(2) Intraslab Earthquakes
(50-300 km depth)
(1) Thrust Earthquakes
(0-50 km depth)
subducting
oceanic
crust
(3) Deep Earthquakes
(300-670 km depth)
???
0
100
200
300
400
500
600

POOR FOUNDATION

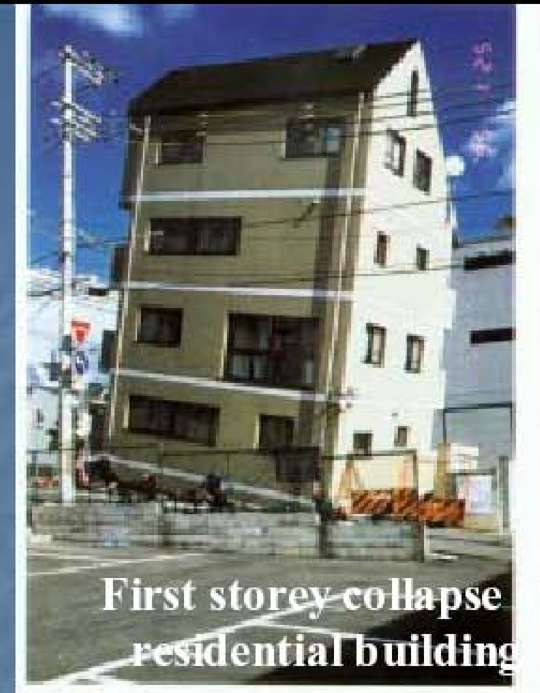
TYPICAL EARTHQUAKE DAMAGE PATTERN

NON-ENGINEERED CONSTRUCTION

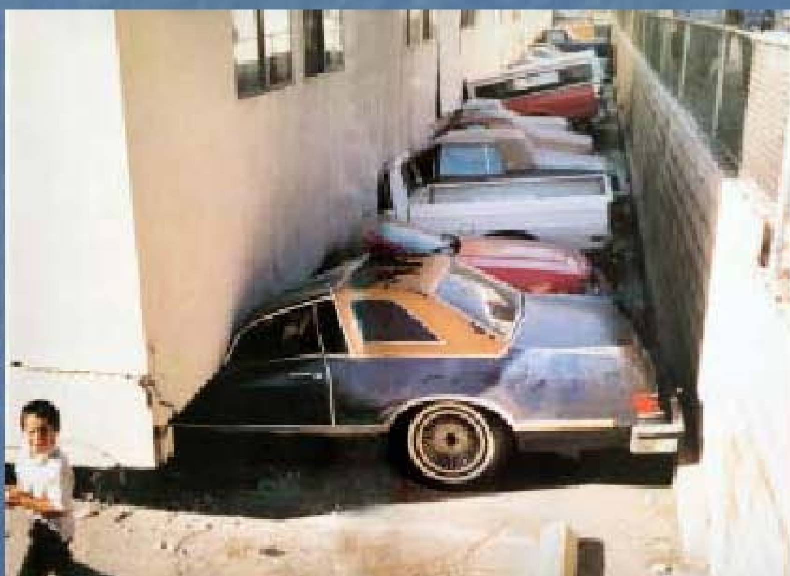
COMPLETE DAMAGE TO STONE MASONRY HOUSES



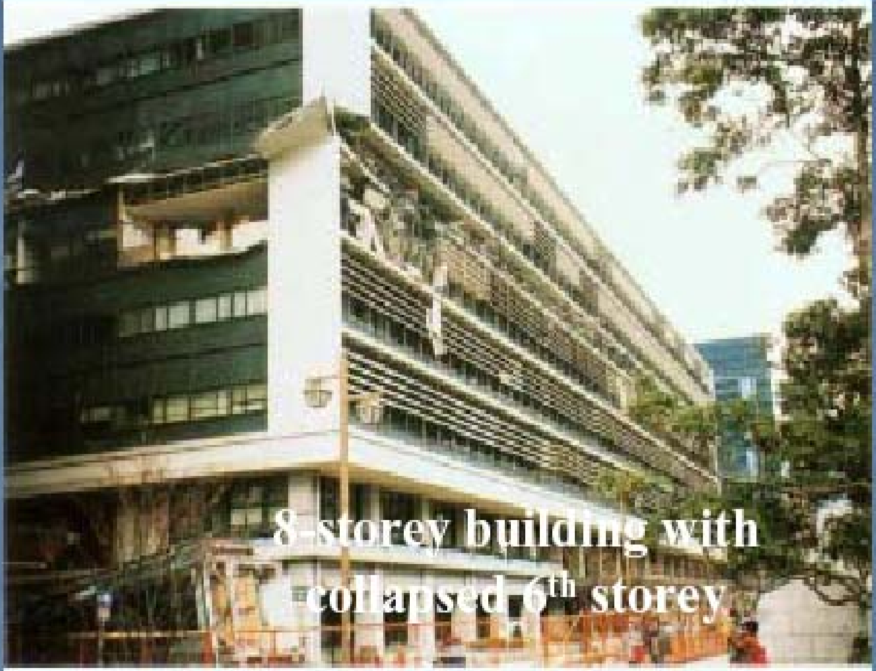
Apartment building with first storey collapse



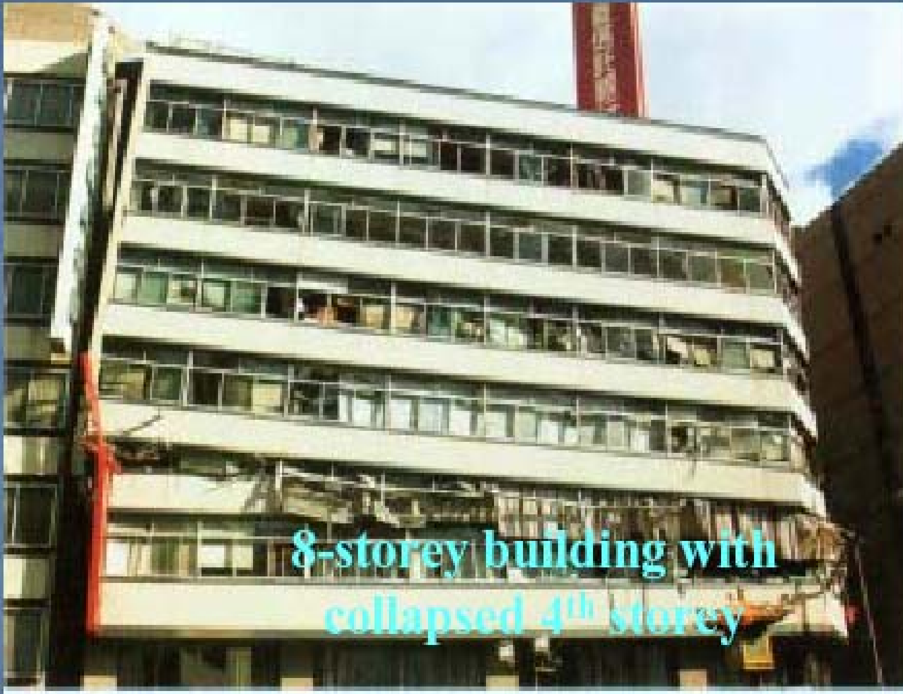
First storey collapse of residential building



Soft storey collapse

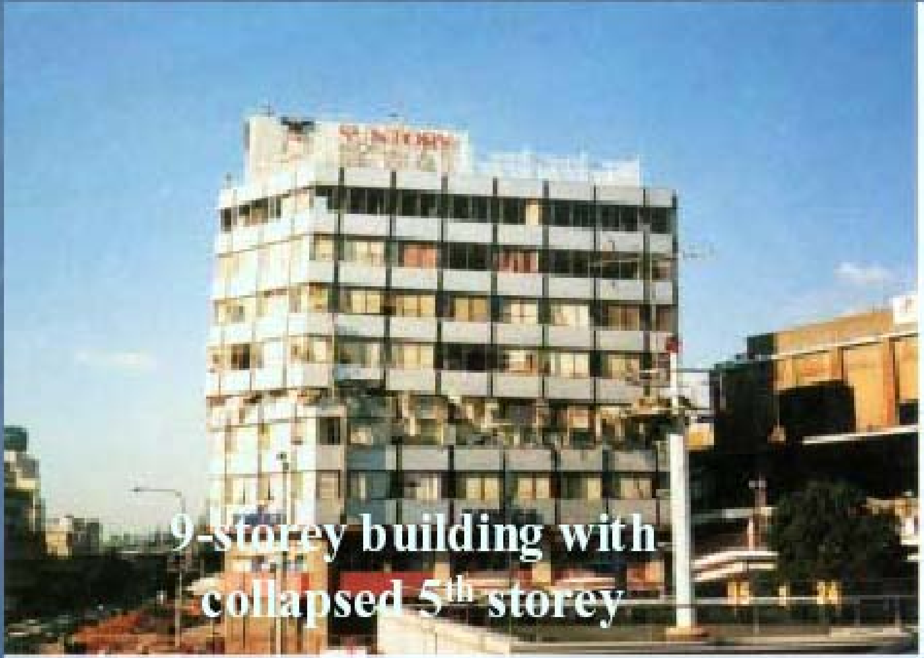


8-storey building with collapsed 6th storey



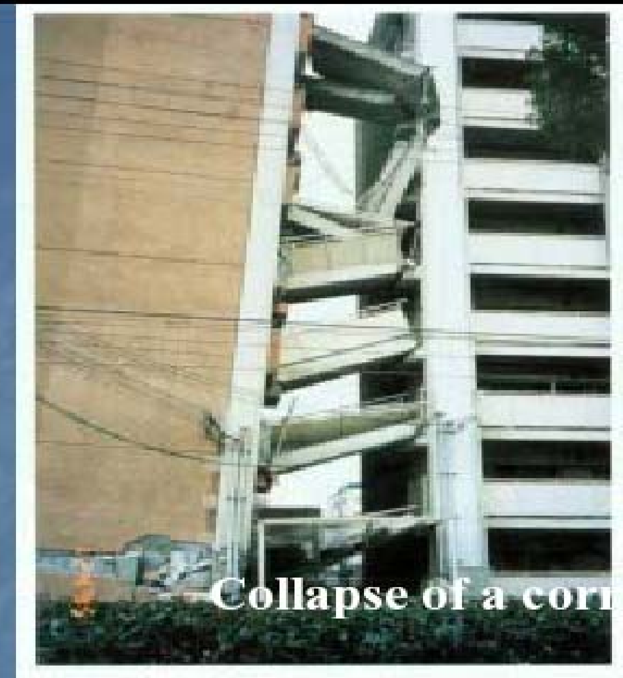
8-storey building with collapsed 4th storey

10-storey building with collapsed 3rd storey

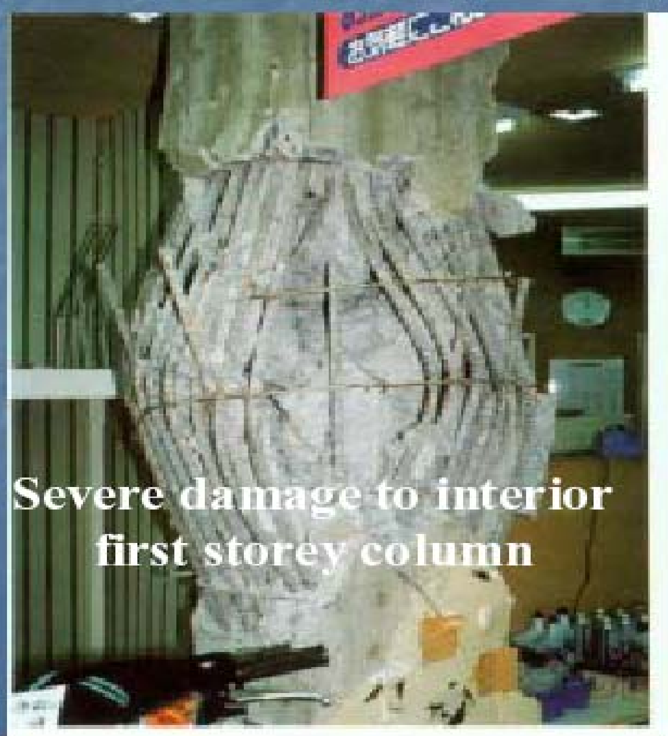


9-storey building with collapsed 5th storey

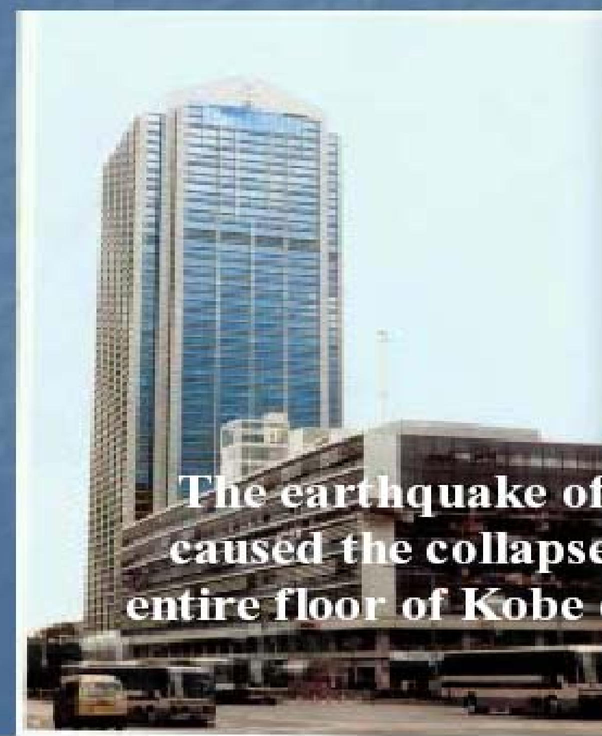
Damage to shear wall



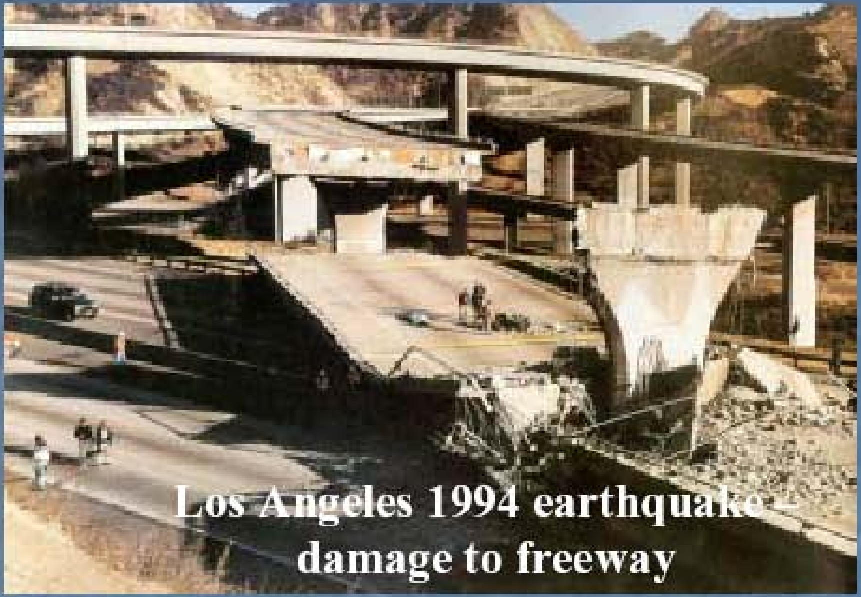
Collapse of a corridor



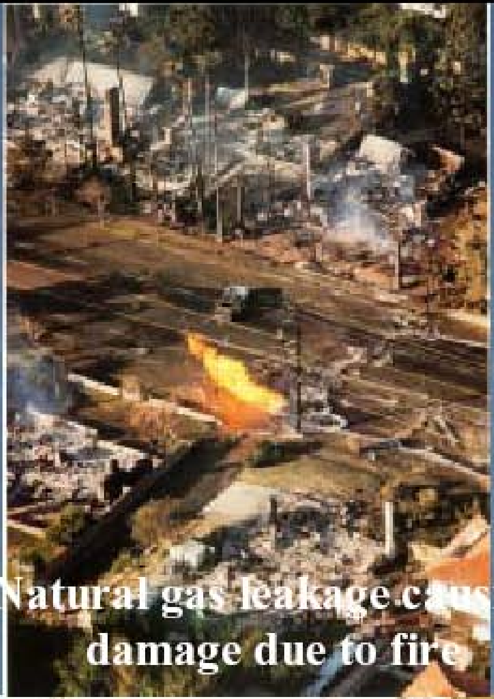
Severe damage to interior first storey column



The earthquake of kobe caused the collapse of an entire floor of Kobe city hall

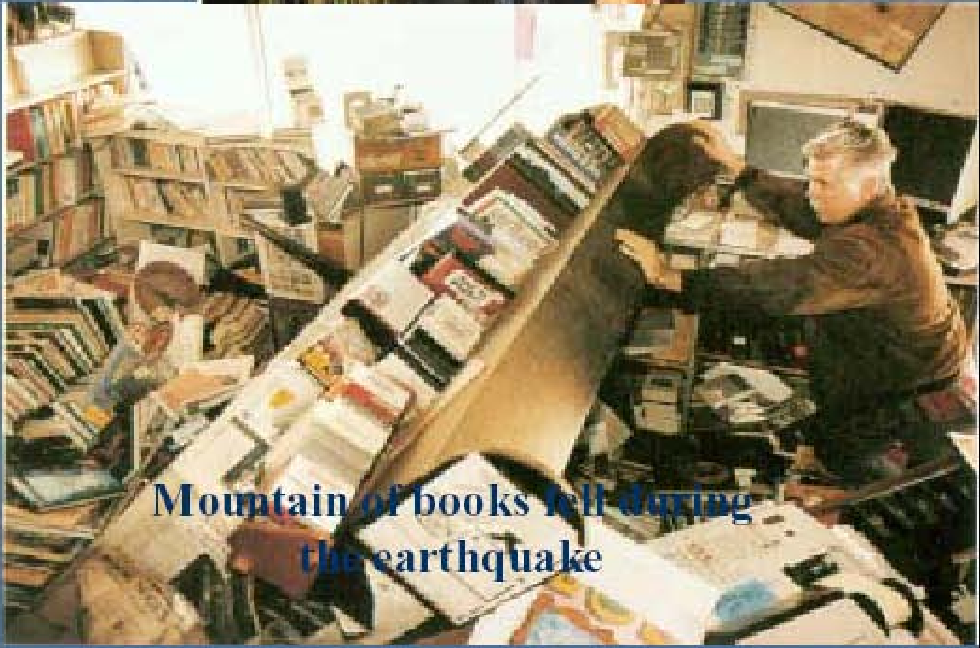


Los Angeles 1994 earthquake – damage to freeway



Natural gas leakage causing damage due to fire

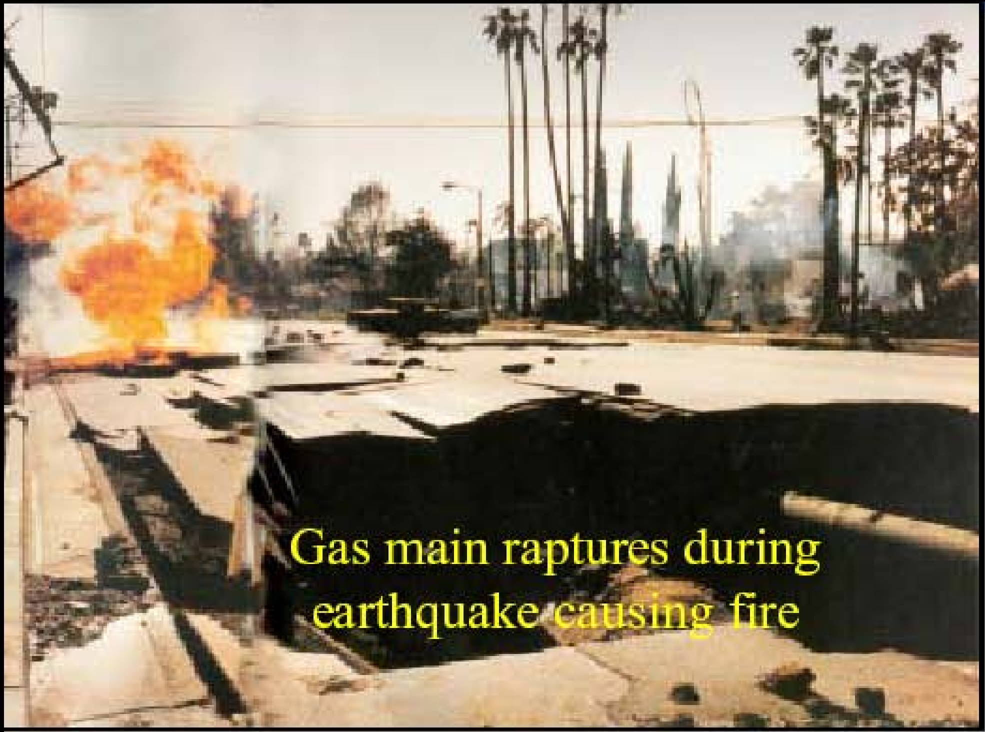
Los Angeles 1994 earthquake – damage to Anaheim stadium



Mountain of books fell during the earthquake

The great Hanshin-Awaji earthquake – collapsed highway

The great Hanshin-Awaji earthquake – Fire after earthquake in Kobe city



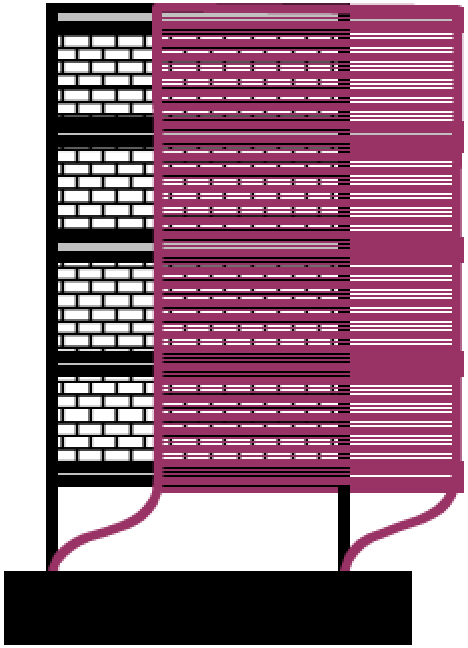
Gas main raptures during earthquake causing fire

Residents waiting for officials to decide if it is safe for them to return home

1994 Los Angeles earthquake





Open ground story

Figure 10-27. Shear cracking of nonductile columns of an open ground story building in Bhuj

Figure 10-28. Collapse of apartment building in Ahmedabad owing to open ground story failure. No structural damage is observed in the upper stories.

Figure 10-29. Complete collapse of apartment

Figure 10-31. RC columns sustained severe damage. Shutters were down at the time of the earthquake.

Figure 10-32. Many open ground story buildings did not collapse, but sustained severe damage to the columns in the ground story.

Figure 10-33. Shear failures in columns due to inadequate confinement reinforcement.

Figure 10-35. Disintegrated concrete within reinforcement cage.

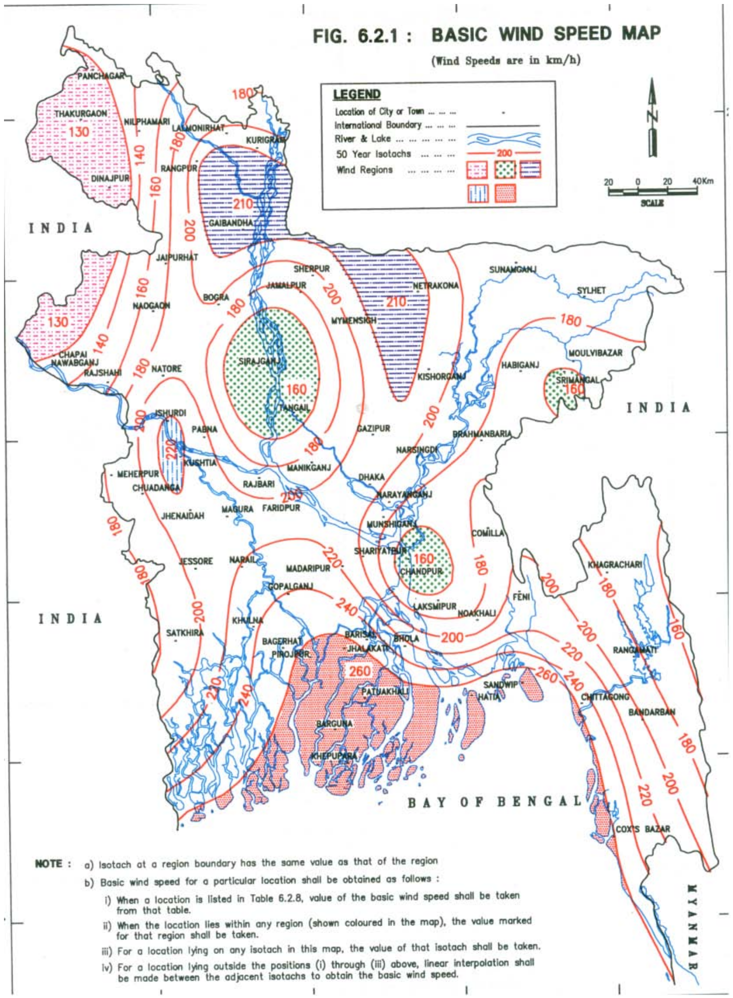
Figure 10-34. Shear failure.

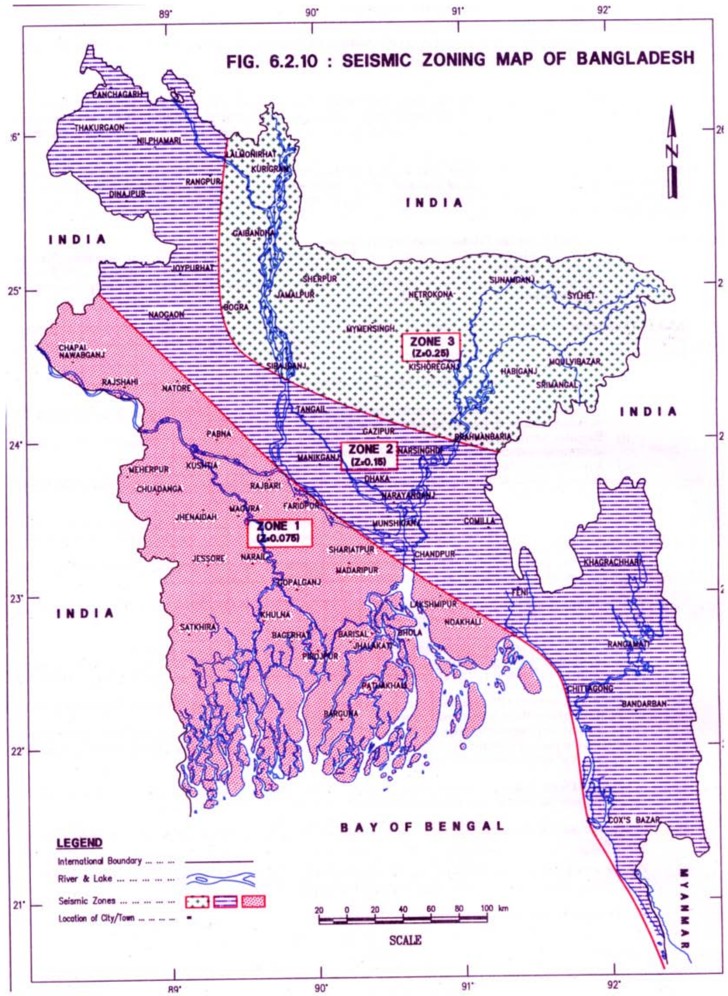
Figure 10-37. Open ground story collapse of short wing of same building.

Figure 10-40. Collapse of a partially open ground story building in Bhuj, coupled with vertical split of the building at the midline.

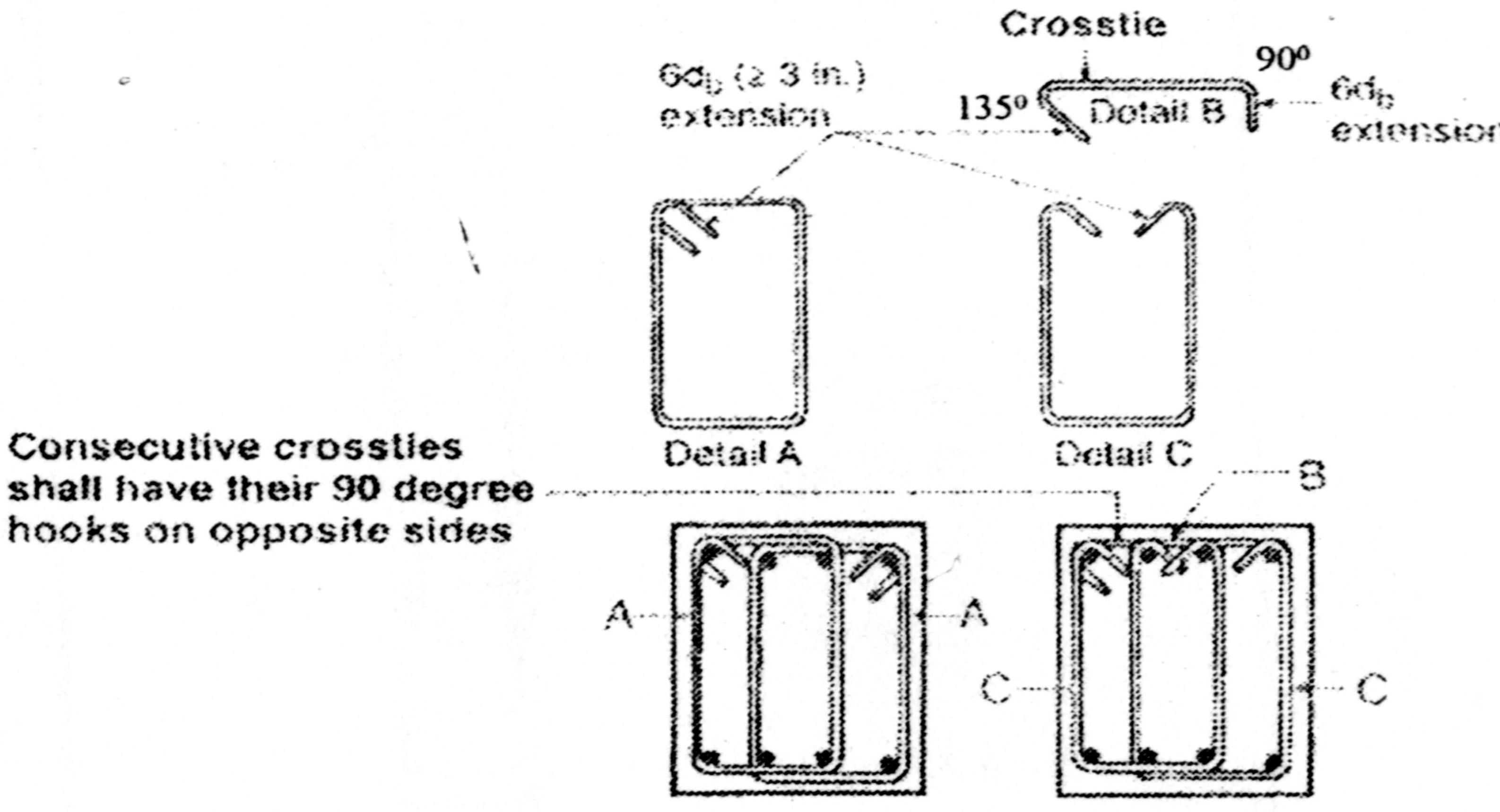
Figure 10-65. Improper anchorage into stiff RC elevator core walls in Gandhidham.

Wind and Seismic Map



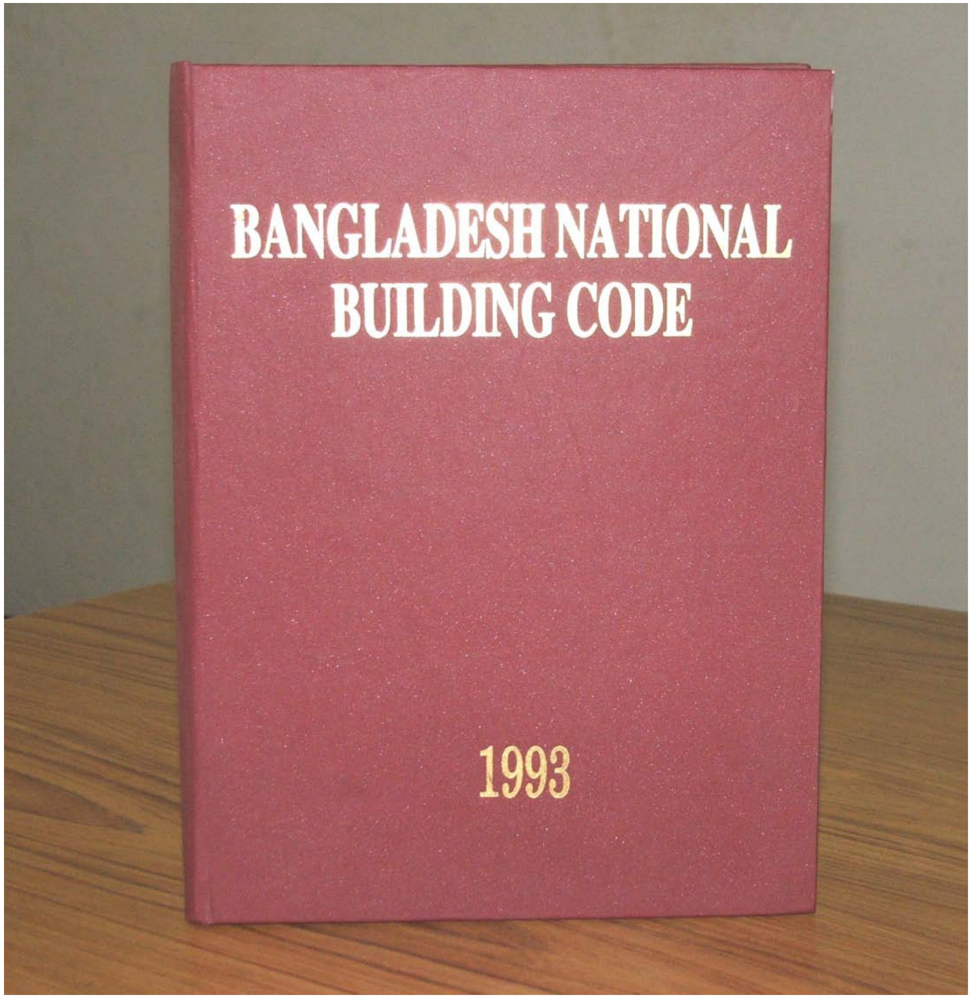


Stirrups



Single- and Two-Piece Hoops

Bangladesh National Building Code



ভূমিকম্প চলাকালে

আপনার বা আপনাদের যা করা উচিত


DANGER
যত দ্রুত সম্ভব বাড়ির বৈদ্যুতিক মেইন সুইচ ও গ্যাসের চাবি বন্ধ করুন


যত দ্রুত সম্ভব রান্নাঘর থেকে বের হয়ে আসুন


সম্ভব হলে
খোলা জায়গায়
আশ্রয় নিন


যদি খোলা জায়গায় যাওয়া সম্ভব না হয় তবে দরজার চৌকাঠ, খাট বা টেবিলের নিচে অথবা আর.সি.সি কলামের গোড়ায় আশ্রয় নিন


বড় গাছ, বৈদ্যুতিক
বা টেলিফোনের খুঁটি অথবা
উঁচু দেয়াল থেকে নিরাপদ
দূরত্বে অবস্থান নিন


শিশু, প্রতিবন্ধী,
গর্ভবতী,সদ্য প্রসূতি
ও বৃদ্ধদের
নিরাপত্তা বিধানে
সহায়তা করুন

You can't plan ahead for an earthquake.

FICTION: There are plenty of things you can do right now to prepare if you live in an earthquake-prone area.

1. Make sure each member of your family knows what to do no matter where they are when earthquakes occur:

o Establish a meeting place where you can all reunite afterward.

o Find out about earthquake plans developed by children's school or day care.

o Remember transportation may be disrupted, so keep some emergency supplies--food, liquids, and comfortable shoes, for example--at work.

2. KNOW where your gas, electric and water main shutoffs are and how to turn them off if there is a leak or electrical short. Make sure older members of the family can shut off utilities.

3. LOCATE your nearest fire and police stations and emergency medical facility.

4. TALK to your neighbors--how could they help you, or you them after an earthquake?

5. TAKE Red Cross First Aid and CPR Training Course.

6. MAKE your disaster supply kit. Beyond the usual flashlights, batteries and radios,

include a first-aid kit; work gloves; sturdy shoes or boots; a week's supply of any presciption medications you or your family might need; credit card and cash; personal identifcation; extra set of keys; matches in a waterproof container; map of your area; phone numbers of family and other important people (doctors, veterinarians, etc.); copies of insurance policies and other important documents; special needs equipment (diapers, baby formula, hearing aid batteries; spare eyeglasses, etc.); three gallons of water per person; three-day supply of food per person; hand tools; a portable ABC fire extinguisher; sanitation supplies for you and your family; entertainment (toys, books, coloring books and crayons, playing cards)

7: BOLT bookcases, china cabinets, tall furniture, file cabinets, etc. to wall studs. Brace or anchor heavy electronics and other heavy items. Secure items that might fall. Move heavy or fragile items to lower shelves. Fasten drawers and cabinet doors with latches or locks. Brace overhead light fixtures. Strap your water heater to wall studs and bolt down any gas appliances. Look for other non-structural steps you can take in your home and workplace to reduce your chances for injury and loss.

8. ASK AN ENGINEER about the seismic safety of your home and/or business. It's well known that unreinforced masonry structures can fail quickly during earthquakes. An inspection by a structural engineer now can help you decide if retrofitting will help your property withstand shaking.