What is an Earthquake?

Earthquakes:

Causes

Processes

Effects

Countermeasures

Case of Ethiopia

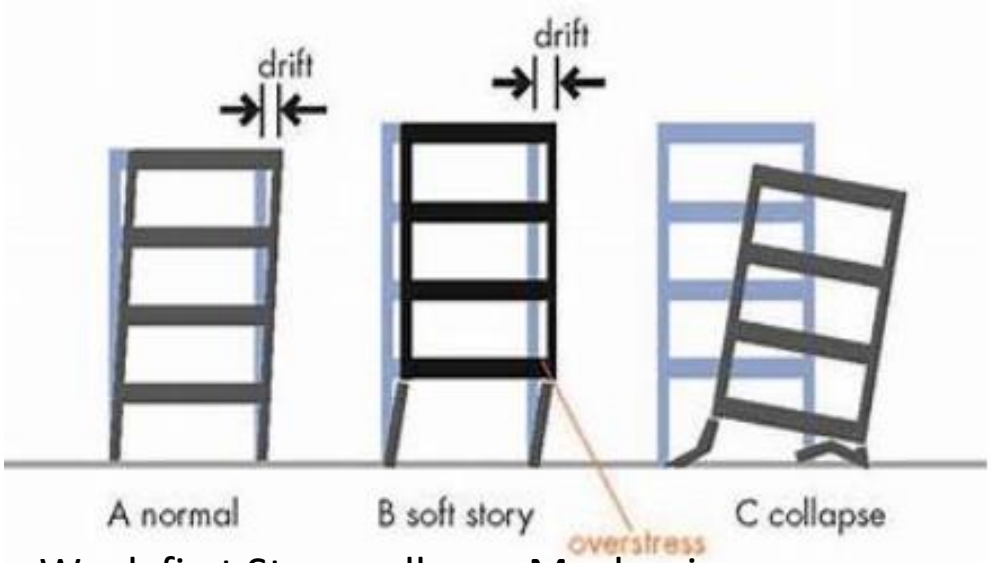
October 28. 2024

Messele Haile: Earthquake Engineering(PhD)

Sponsors 1. Ethiopian Association of Civil Engineers(EACE)

2. Ethiopian Construction Works Corporation(ECWC)

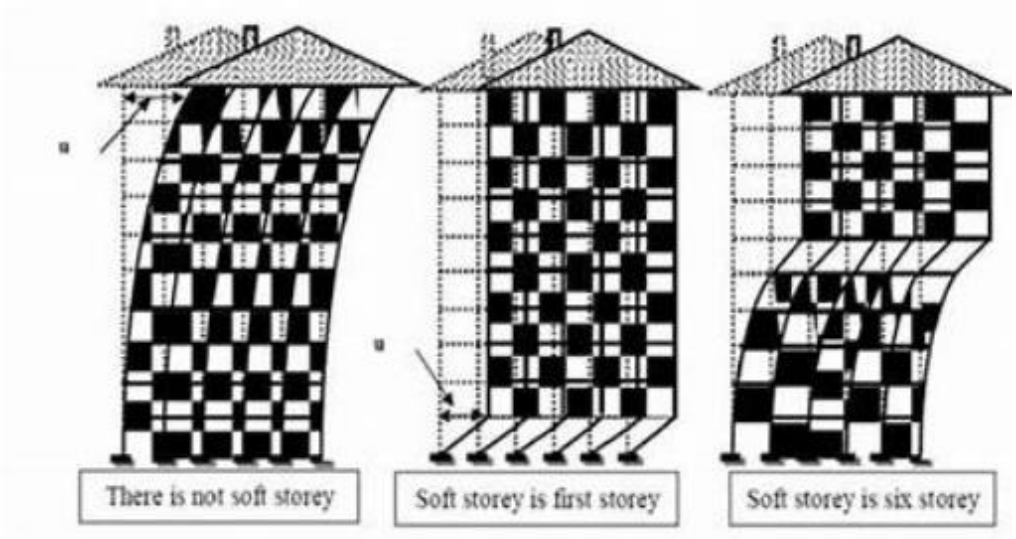
Part 2/8 Earthquake induced damages, mechanisms and Pictures



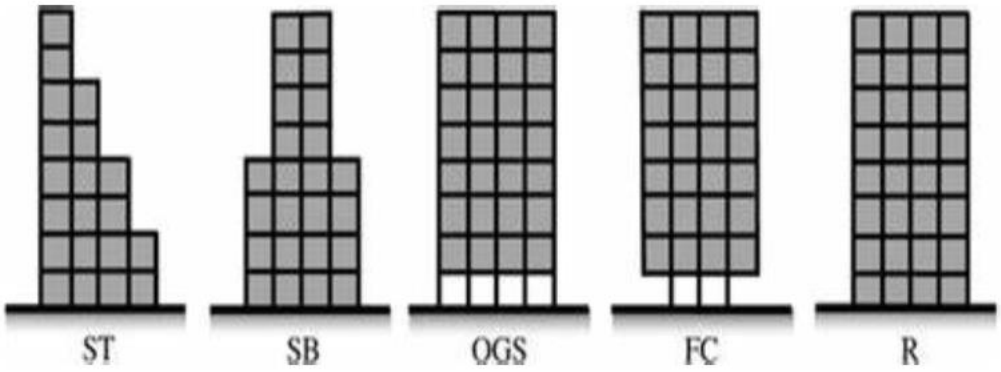
Weak first Story collapse Mechanism

What creates weak story

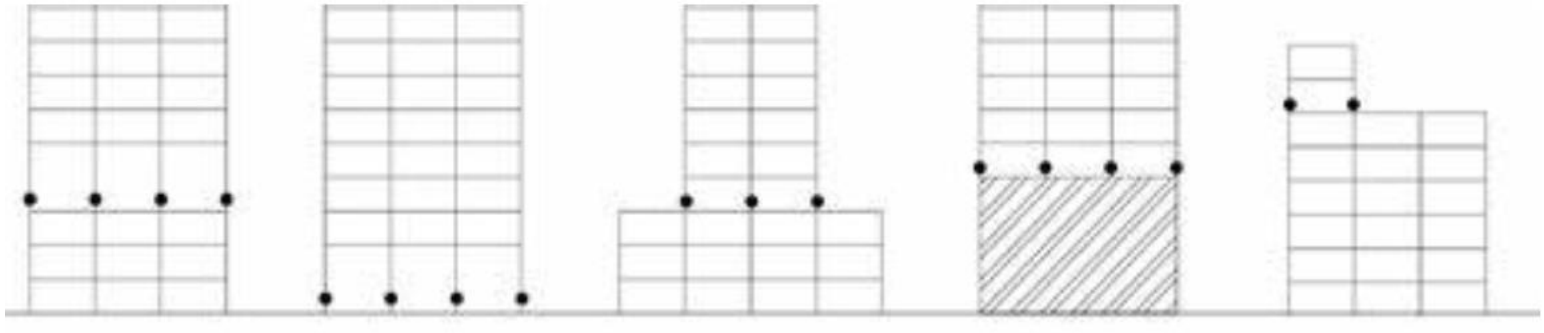
1. Bigger heights
2. Open walls and plans
3. Weaker materials



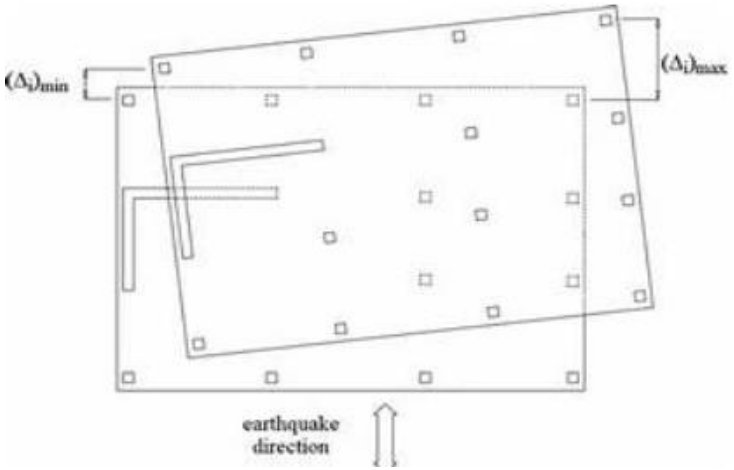
Weak Story collapse Mechanism at any level

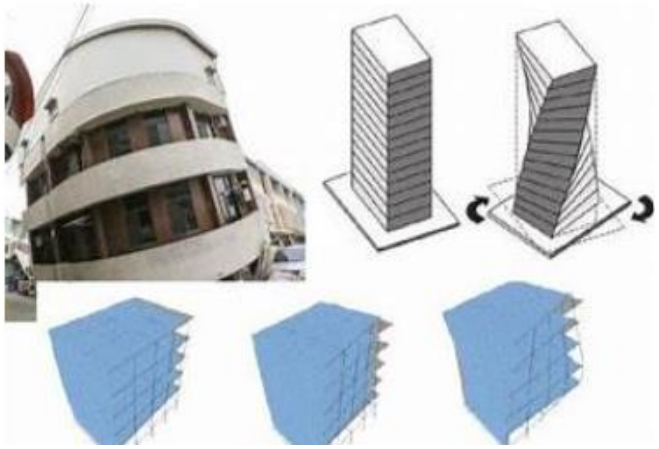


Different irregularities that causes failures

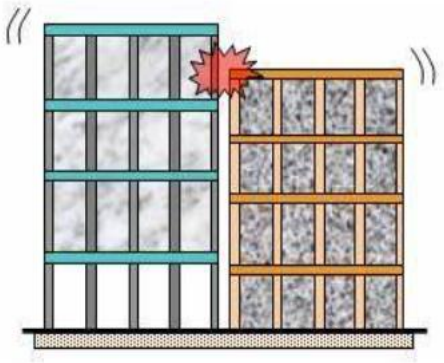


Different failure mechanisms Energy release that causes failures

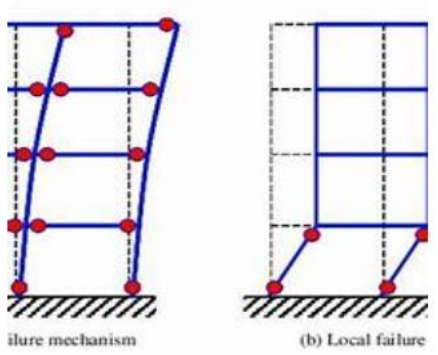




Effects of Torsional Eccentricity



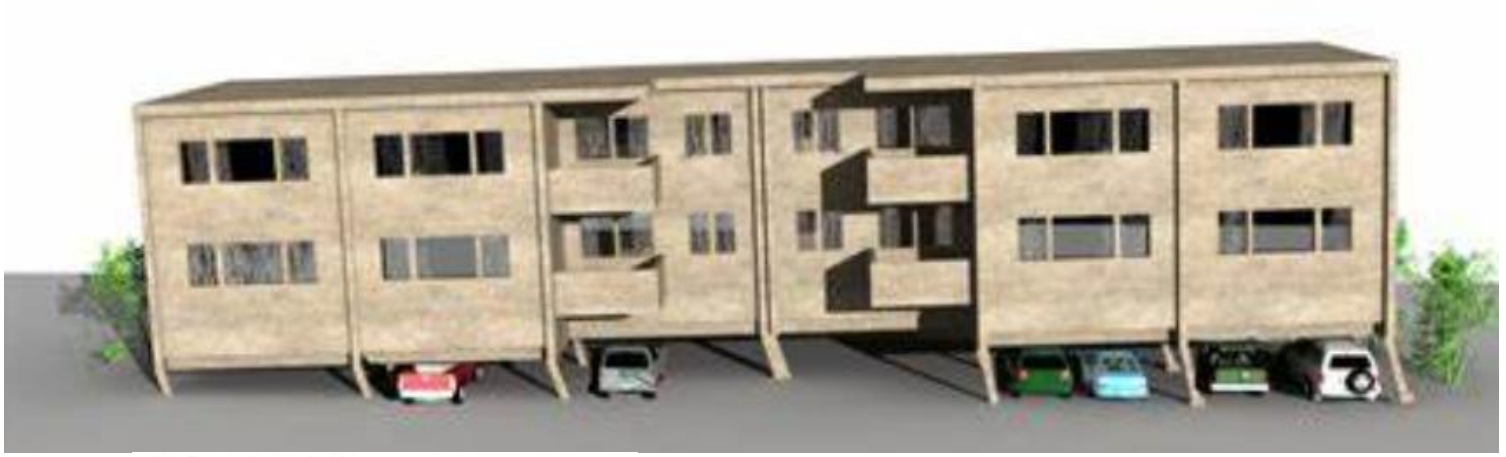
Effects of Knife edge



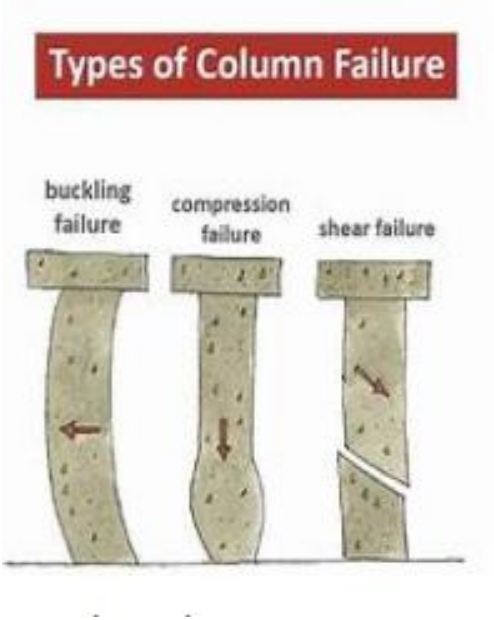
Failure mechanism shift

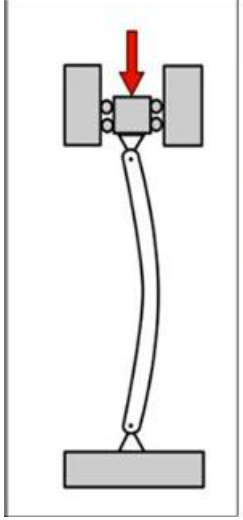






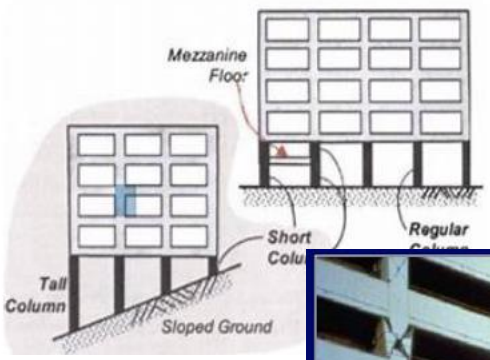








Column Buckling



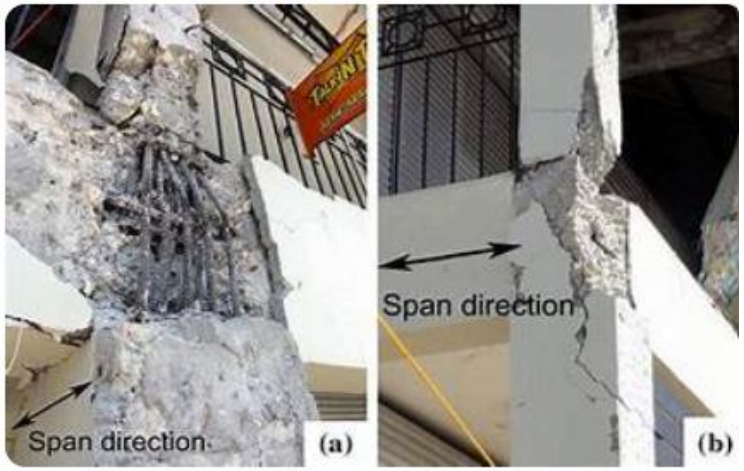


$$V=\frac{(M_1-M_2)}{L}$$

Shear Failure



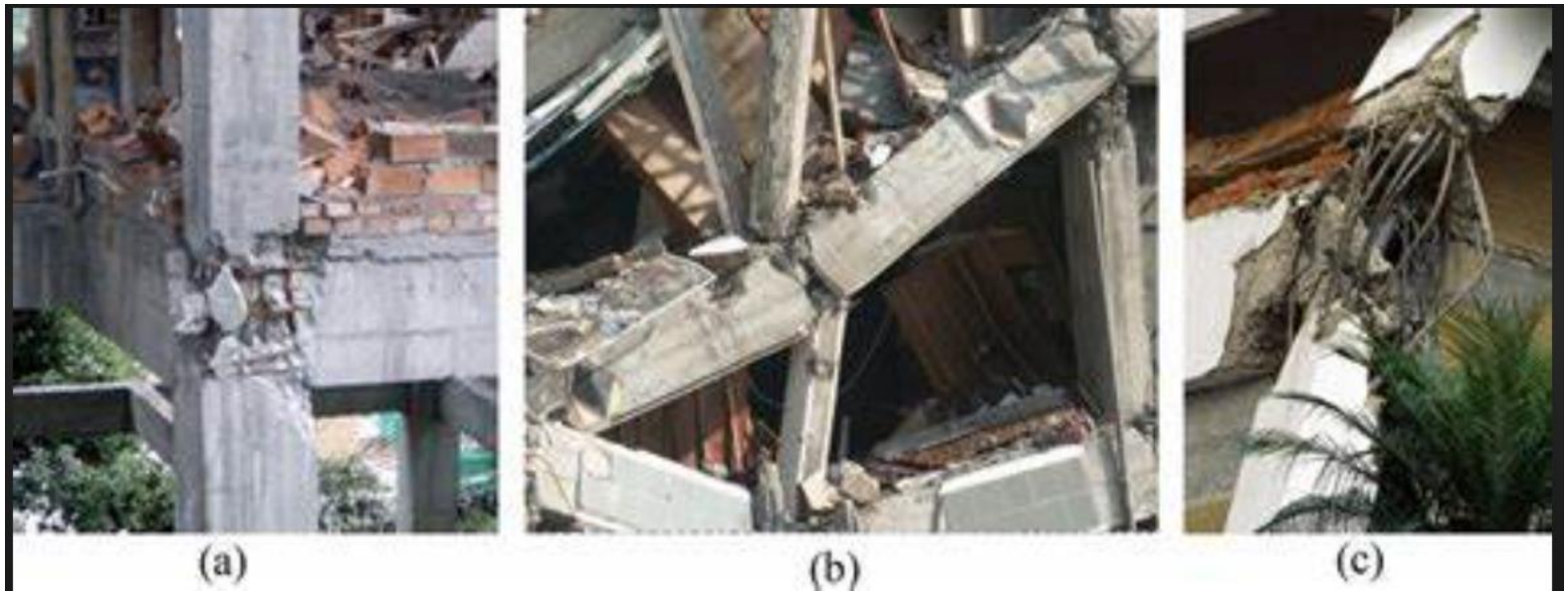
Brittle failure: Unconfined Stirrup. Space and bending



No Stirrup at Joints



Inadequate Concrete cover



Brittle joints : lack of ductility



Pancake type of failure Philippines, 1990
Ms = 7.8 Weak Column



Old buildings North Ridge 1994

R





The 1994 Northridge California Earthquake M=6.7 , 3000 Dead, 28,000 buildings damaged ED=30 km inadequate support width









Failure in Hanshin expressway(column failure, slip)

Hyogo-ken Nambu Earthquake 1995, M=7.2 E=0-10km : 6700

Died, 25,000 injured , 300,000 lost home ,50,000 buildings Damaged los

USD 100B





Fire : Responsible for most deaths



Buildings Soft 1st Story(GF)



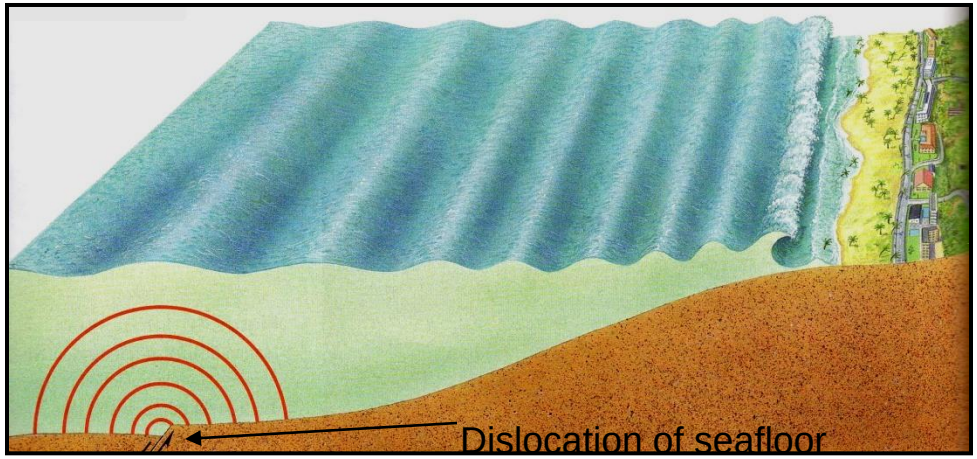
Residential houses

Hyogo-ken Nambu Earthquake 1995

Earthquakes: Tsunamis

➢Big Earthquakes at subduction zones, create Tsunamis are sometimes called seismic sea waves. They can destroy everything in the coastal zone, but they occur as small unnoticeable waves out at sea.

➢ This is because the earthquake generates a rolling wave out in the open water; however, as the waves approach shore, specially bays the path gets narrow. The waves slow down near the bottom, causing a huge wave to build up on top as the top is still moving at its original speed. The can be over 30 m high moving up to/above 700 Km/h



Sketch showing the generation of a Tsunami from an underwater earthquake.









Damages Due to Tsunami (Costal community issue , Predictable , bay induced. Not easy to prevent)



Northridge 1994 , 11000Ls



Kobe EQ 1995, 30 died due to EQ



Japan , Kumamoto EQ, M= 7.1 2024,



Alaska EQ Mo= 9.2, 1964, 130 died total

EQ induced Land Slides



Kobe, Japan, 1995 M=7.2(CM)



Japan Nigata EQ 1974 M= 7.6 (CM)



USA Loma Prieta EQ 1989 M=6.9 (CM)



USA , Alaske EQ 1964 M= 9.2 (FL)

EQ Induced Gross Instability: Liquefaction(Cyclic Mobility: Excess PP)



Flow Liquefaction (Once triggered Static SS>Strength)

Anchorage Alaska 1964.



The Mexico Michoacán EQ, 1985 M= 8



The Turkey EQ, 2023 M= 7.8



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Gross Instability: Faulting Geological hazard



USA IVE ELCentro EQ, 1940 M= 6.9
Fault passes by no damage : Directivity





Japan Kobe EQ 1995 , M=7.2

USA Loma Prieta EQ 1995 , M=6.9

EQ Induced Gross Instability: Subsidence

Turkye Earthquake, 2023

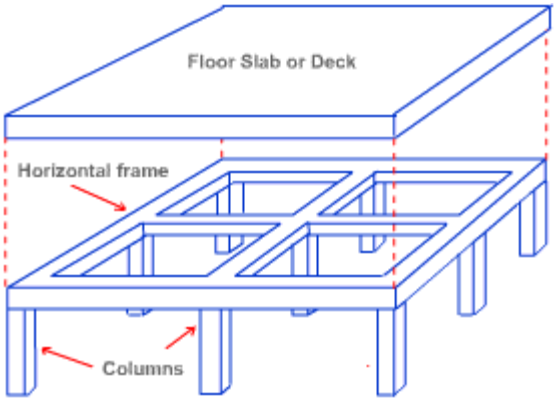


M_w 7.8 EQ and 9 hrs later Mw= 7.7 EQ struck SC Turkiye & NW Syria.

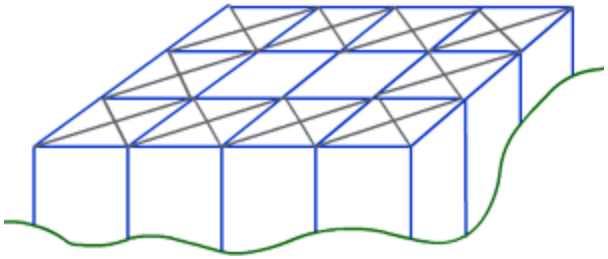
- It was the deadliest seismic event in the history of Turkey[9] since the 526 Antioch earthquake, (Byzantine empire 250,000 People died)

- Death toll over 50,900;
- Damage US$84.1 billion worth of damage
- 162,000 Buildings collapsed. 1.5 M left homeless.
- Most of the damage in Turkiye was from poor design and construction and non compliance to the Code requirement
- Investigation 612 people , 184 in prison: building owners, Contractors, legally responsible bodies Mayor etc.

Horizontal Diaphragms



Horizontal Trussing



Vertical structural systems

Made up from columns, beams, walls and bracing.
They transfer the sideways forces on the building to the ground.
They include:

- Braced frames
- Moment resisting frames
- Shear walls

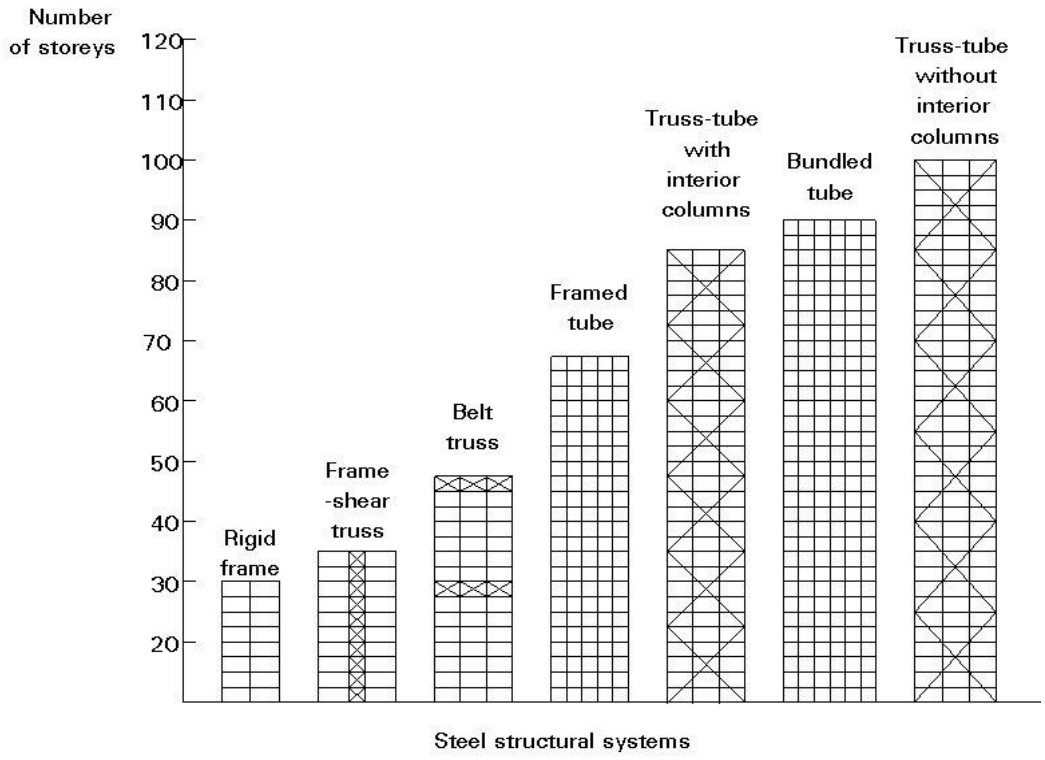
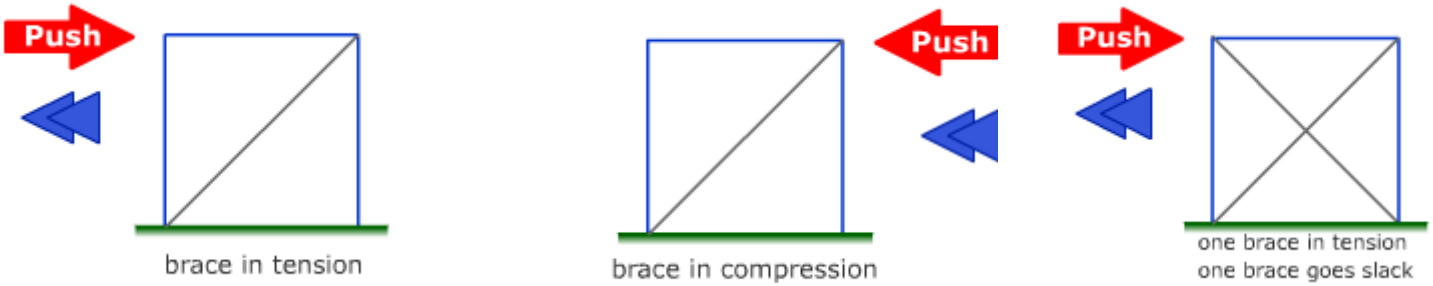


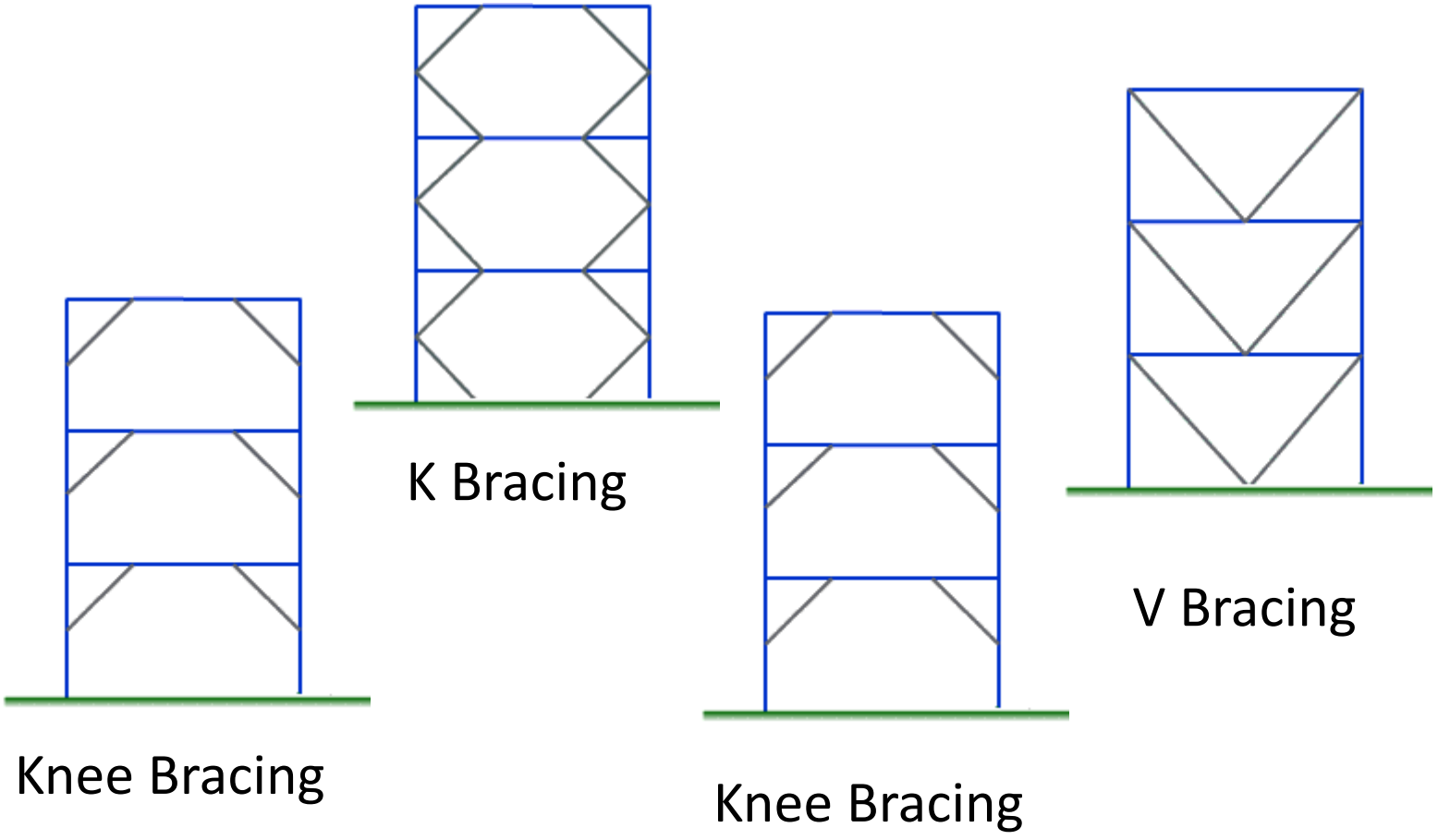
Figure 7 Steel structural systems and the number of storeys

•Braced frames

- Single Bracing
- Cross-bracing
- Other ways of bracing frames

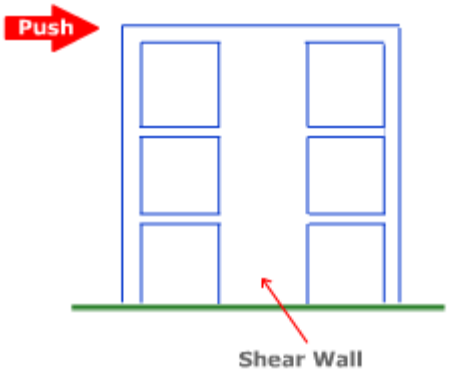


Other ways of bracing frames



Shear Walls

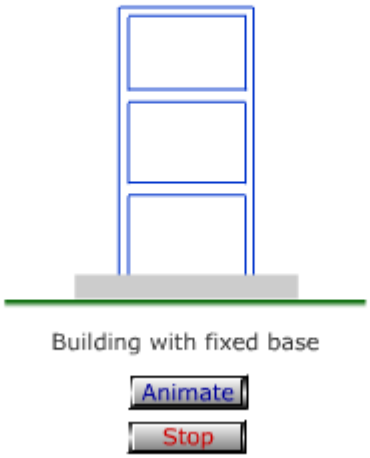
- Shear walls are vertical walls that are used to stiffen the structural frames of buildings. They help frames resist sideways earthquake forces
- **The earthquake forces are transferred to the ground mainly by shear forces in the walls**
- It is better to use walls with no openings in them.
- Usually the walls around lift shafts and stairwells are used
- Walls on the sides of buildings that have no windows can be used

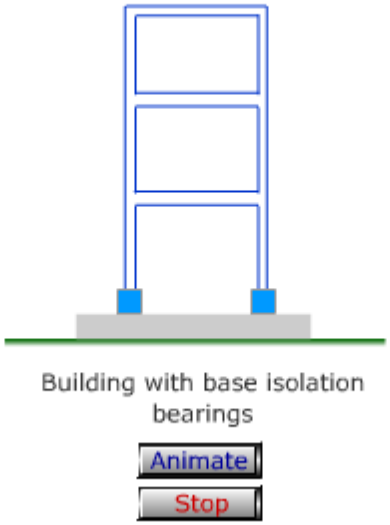


Isolation of Buildings

- During an earthquake, a fixed-base building can sway from side to side. When a base isolation system is used, the sideways movement occurs mainly in the bearings

- There are many types of bearings used for base isolation. Here are two of them.

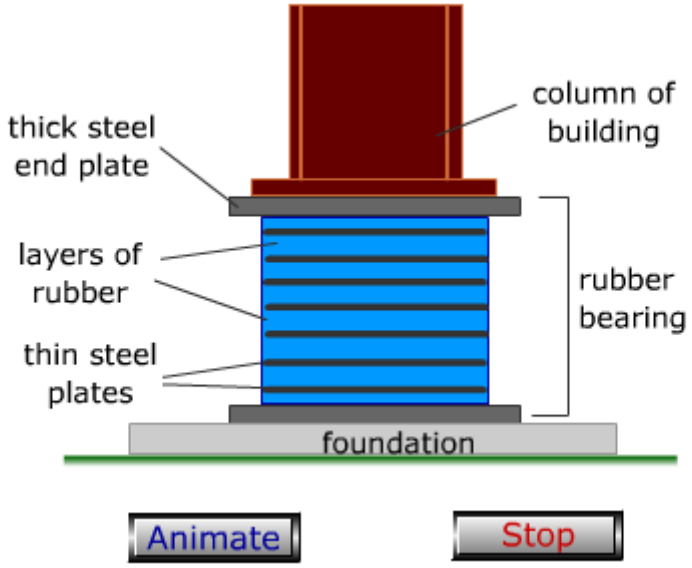




Rubber bearings

- Rubber bearings are made from layers of rubber with thin steel plates between them, and a thick steel plate on the top and bottom.
- The bearings are placed between the bottom of a building and its foundation .

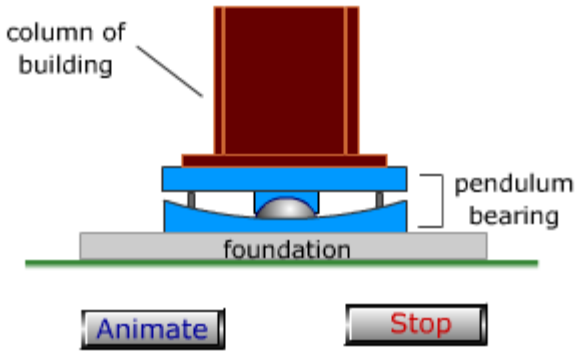
- The bearings are designed to be very stiff and strong for vertical load, so that they can carry the weight of the building. However, they are designed to be much weaker for horizontal loads, so that they can move sideways during an earthquake.



Friction Pendulum Bearings

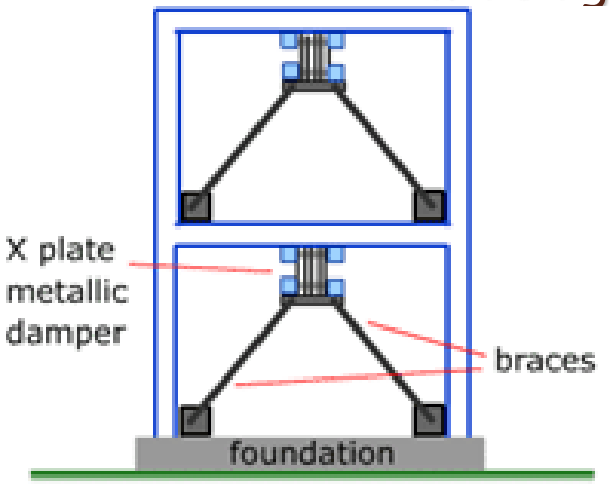
- Friction pendulum bearings are made from two horizontal steel plates that can slide over each other because of their shape and an additional articulated slider.

- They are designed to be very stiff and strong for vertical load, so that they can carry the weight of the building.

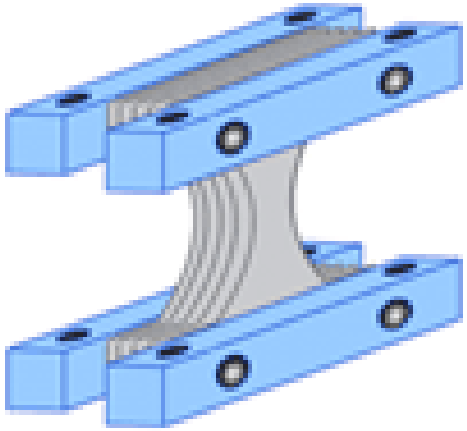


Dampers: Metallic Dampers

- Metallic dampers are usually made from steel.
- They are designed to deform so much when the building vibrates during an earthquake that they cannot return to their original shape.
- This permanent deformation is called inelastic deformation, and it uses some of the earthquake energy which goes into building.



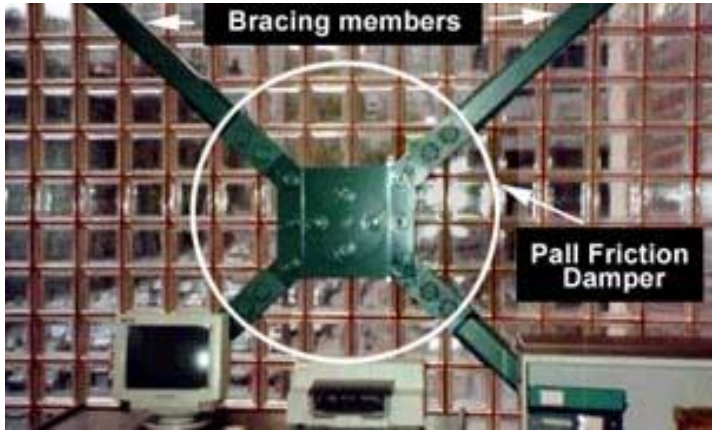
2 storey steel frame with metallic dampers in position



X - Plate Metallic Damper

Friction Dampers

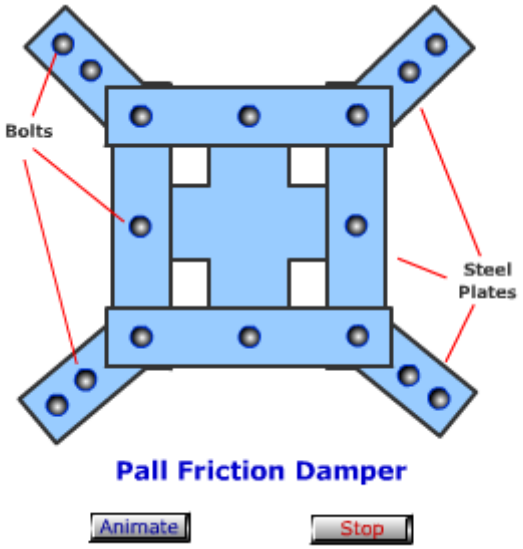
- Friction dampers are designed to have moving parts that will slide over each other during a strong earthquake.
- When the parts slide over each other, they create friction which uses some of the energy from the earthquake that goes into the building.

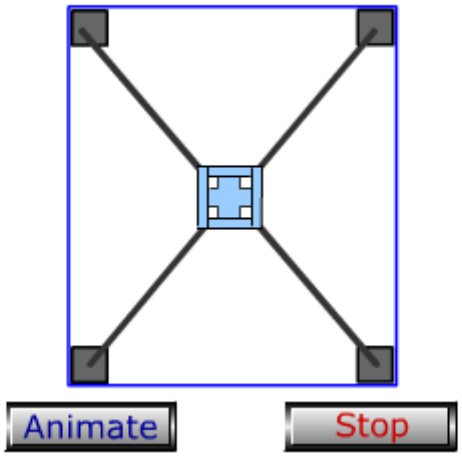




- The damper is made up from a set of steel plates, with slotted holes in them, and they are bolted together. At high enough forces, the plates can slide over each other creating friction.

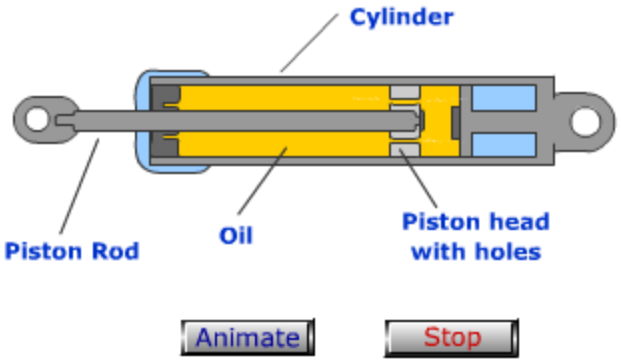
- The plates are specially treated to increase the friction between them.





Viscous fluid dampers

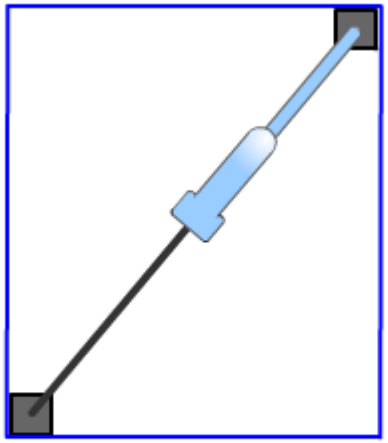
- Viscous fluid dampers are similar to shock absorbers in a car. They consist of a closed cylinder containing a viscous fluid like oil.
- A piston rod is connected to a piston head with small holes in it. The piston can move in and out of the cylinder. As it does this, the oil is forced to flow through holes in the piston head causing friction.





Viscous fluid dampers

- The friction converts some of the earthquake energy going into the moving building into heat energy.
- The damper is usually installed as part of a building's bracing system using single diagonals. As the building sways to and fro, the piston is forced in and out of the cylinder.



Animate Stop