Earthquake Towers

BBHHS

Goubeaux

Skyscrapers

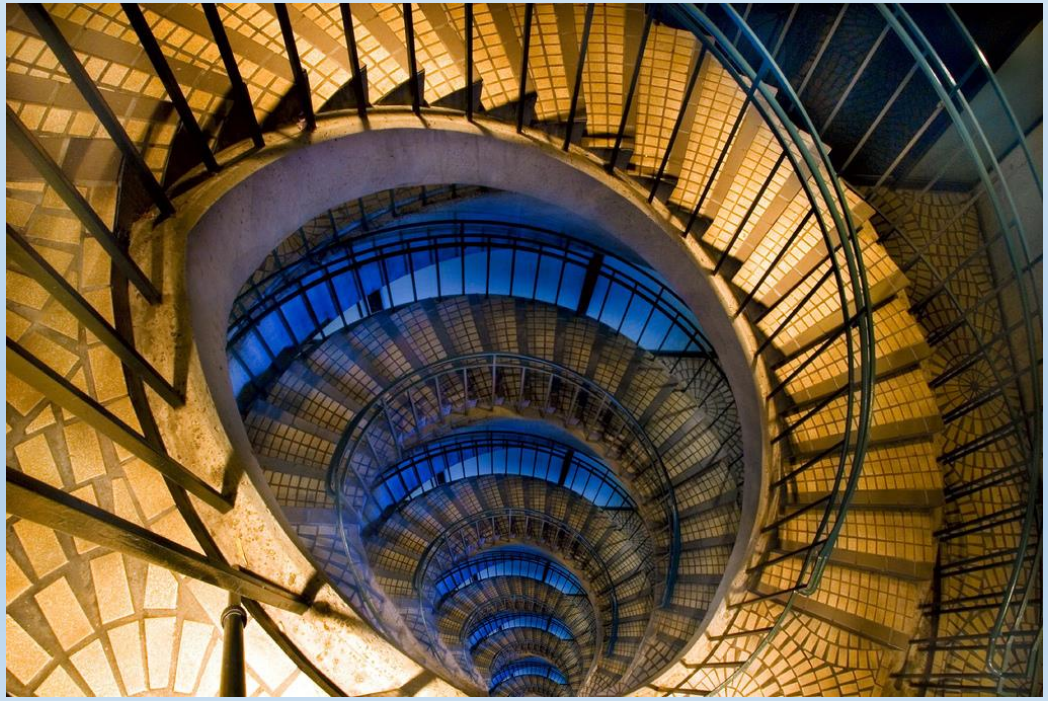
- Skyscraper – Tall building used for residential or commercial use
  - Come in all shapes and sizes.
  - Nearly every major city has one.
  - Would not be possible without many engineering innovations.
  - Need to stand up to anything nature or man can throw at it.

Hurdles Skyscrapers Overcome

- Mobility
- Materials
- Heat
- Construction Time (Speed)
- Wind
- Earthquakes
- Evacuation or Safety (Terrorism)

Mobility

- The invention of the elevator is one of the key parts that make skyscrapers possible.
- Highest floors are now the most desirable. (highest rent)

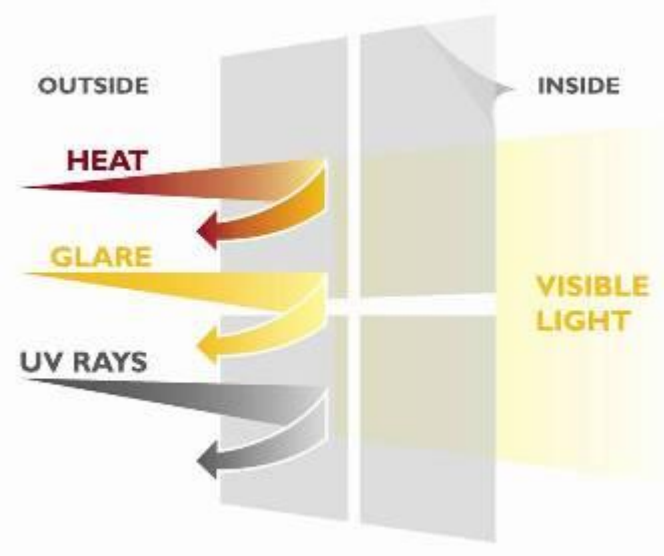


Materials

- Early buildings where made of stone which is very heavy.
- The use of steel frame and reinforced concrete allows engineers to build the skyscrapers we know today.

Heat

- Many windows on a building allows for a much larger and open floor plans.
- The windows create a greenhouse effect and a lot of heat.
- The invention of air conditioning and reflective glass is one key components that make skyscrapers possible.



Construction Speed

- Pre built sections and moving forms allow construction crews to build faster than ever before.

Wind

- As structures rise taller wind effects them more.
- The wind pushes on the build and creates vortices that threaten to knock the tower over.

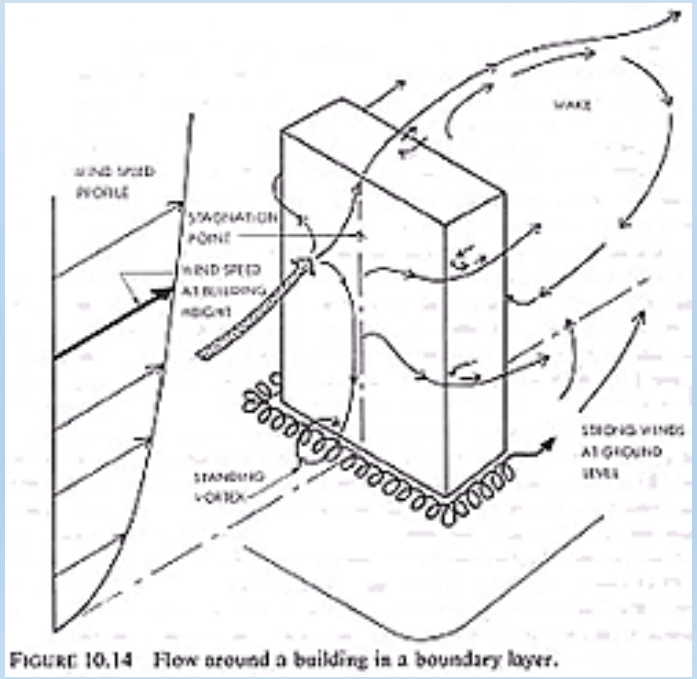


FIGURE 10.14 Flow around a building in a boundary layer.

Earthquakes

- Earthquakes are the largest treat to skyscrapers.
- The taller the tower the worse the effect the earthquake has on the structure because of the leverage it has.

Terrorism (Evacuation)

- Terrorism is an ever growing threat these days and skyscrapers are a relatively easy target.
- Stairways and elevators can be very restrictive during a mass evacuation.
- Some towers now have evacuation or panic rooms.

Pervasive US economic recession with bank failures, known as Long Depression

1873 → 1878

British banking crisis, precipitated by the near insolvency of Barings Bank and a world recession

1890

US panic marked by the collapse of railroad overbuilding, a series of bank failures, and a run on gold

1893

US stock market crash and panic, the first stock market crash on the New York Stock Exchange

1901

US economic crisis, speculation in coffee, Union Pacific, monetary expansion from trust companies

1907 → 1910

US and European economic Crisis, end of extended Post-War booms speculation in land and stocks, monetary expansion from stocks bought on margin

1929 → 1933

US and worldwide economic crisis, collapse of Bretton Woods and OPEC price rises, speculation in stocks, property, ships and aircraft, monetary expansion from the Eurodollar market

1973 → 1975

Asian economic crisis, currency devaluation speculation in stock and property, monetary expansion from foreign lending

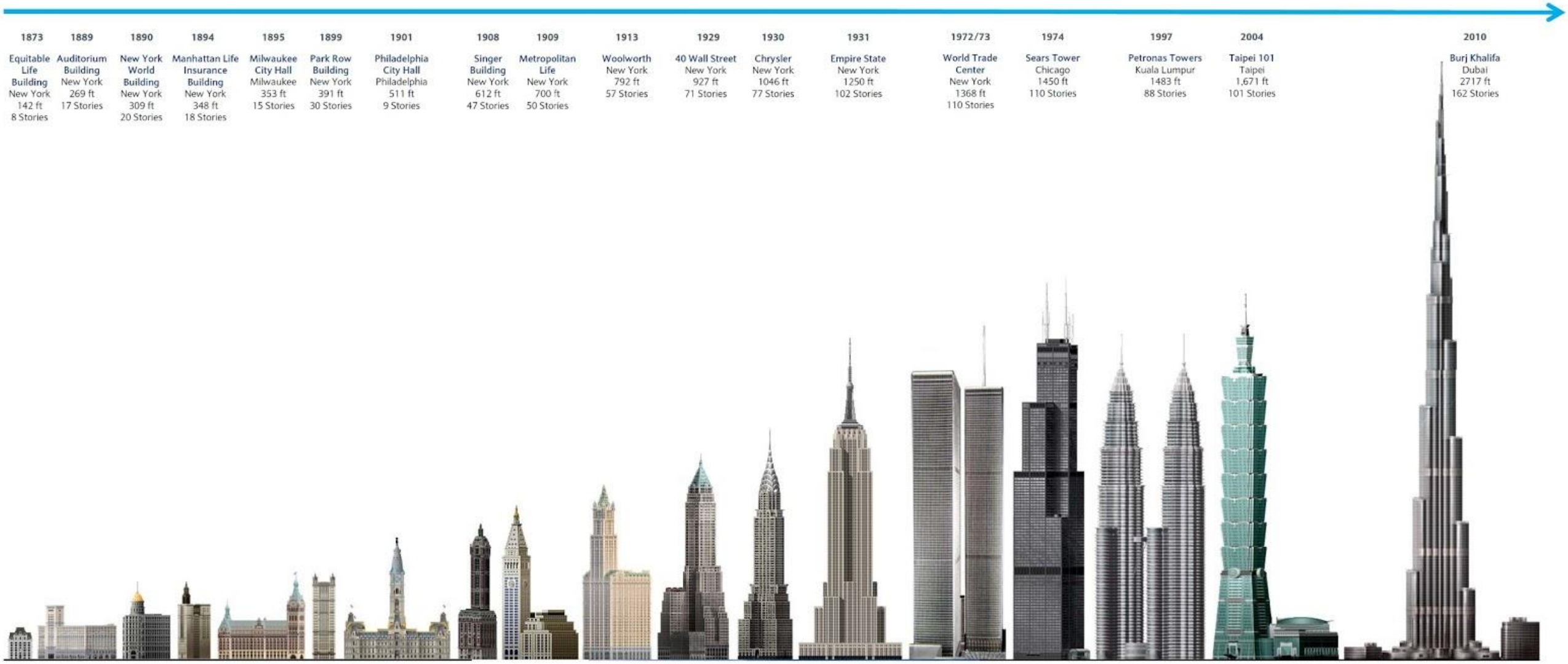
1997 → 1998

Dot-com bubble bursts causing a stock market crash and the loss of US$5trillion market value

2000 → 2003

Great Recession, rooted in US property market and the subprime lending crisis affected the entire world; financial crisis followed with large banks' collapse

2007 → 2010



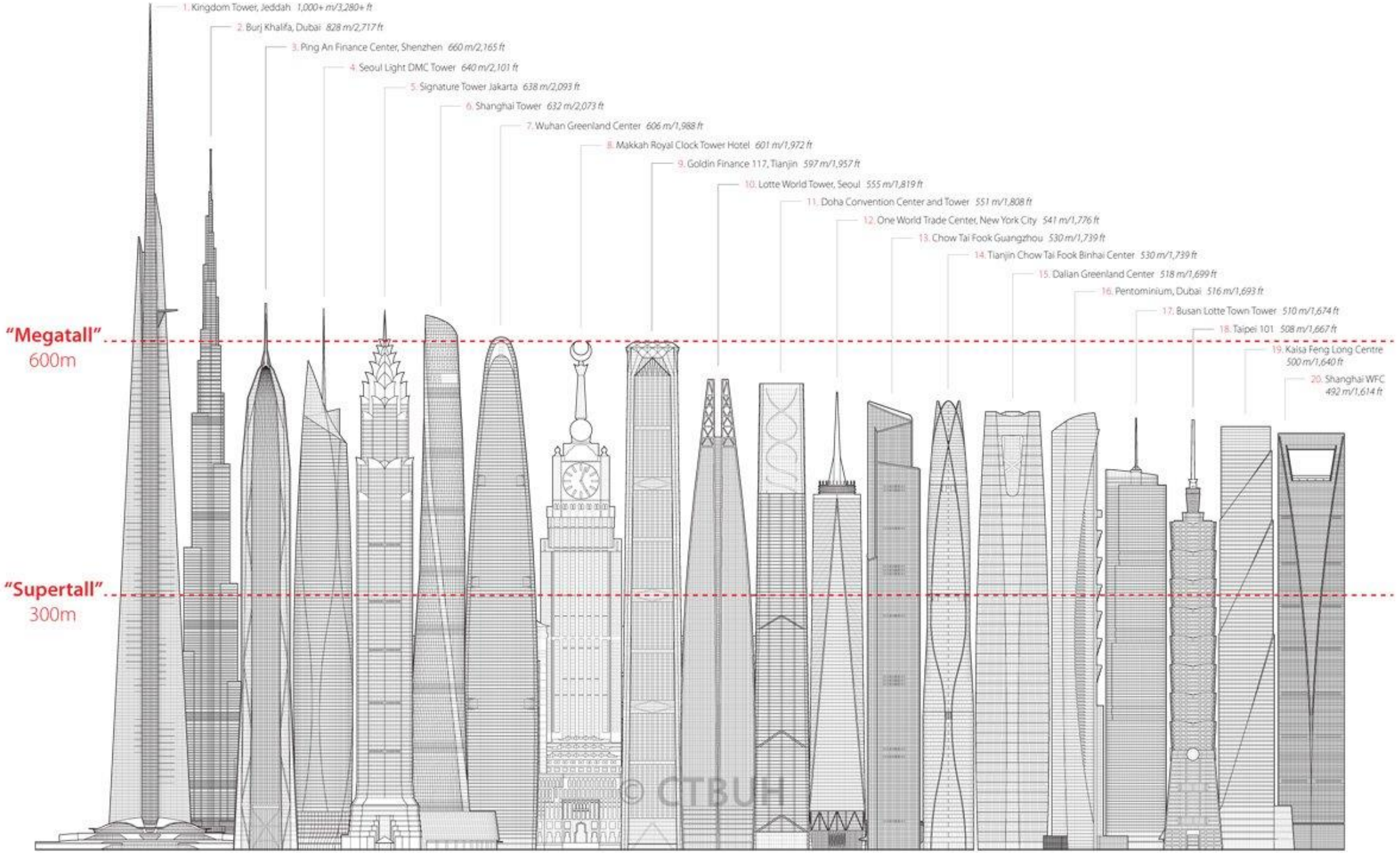
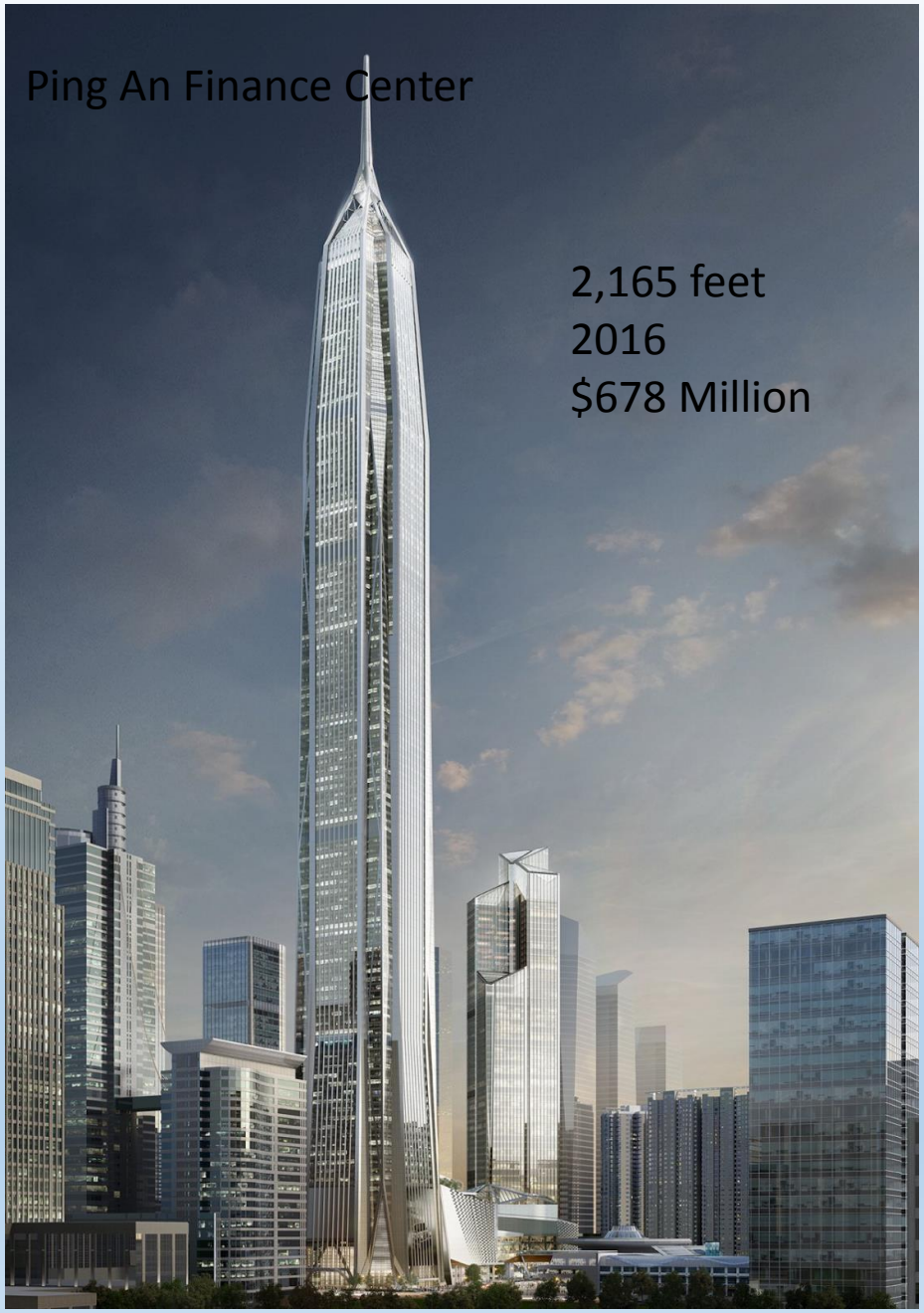


Diagram of the World's 20 Tallest in 2020 (estimated as of Dec 2011) © CTBUH


Kingdom Tower or Jeddah Tower
3,281 feet
2018
$1.2 Billion

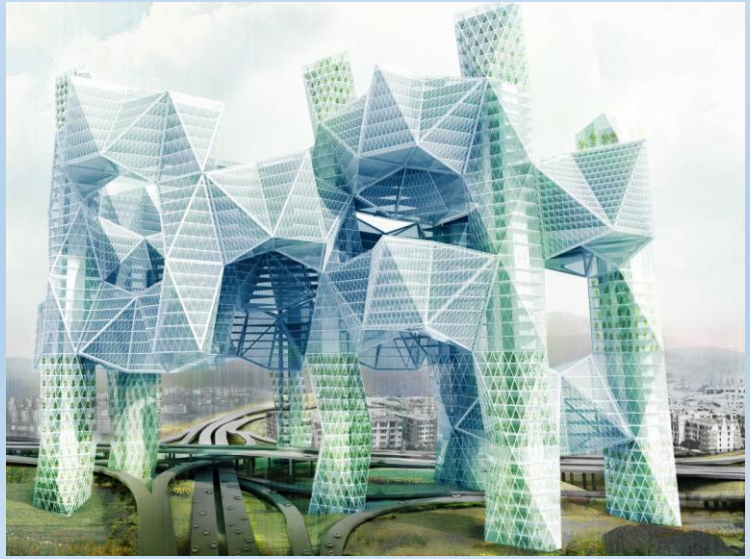

Ping An Finance Center
2,165 feet
2016
$678 Million

Trends Over Time

- Building Materials
- Height
- Shape
- Function

Future of Skyscrapers

- Taller?
- Design?
- Materials?
- How many?
- Function?



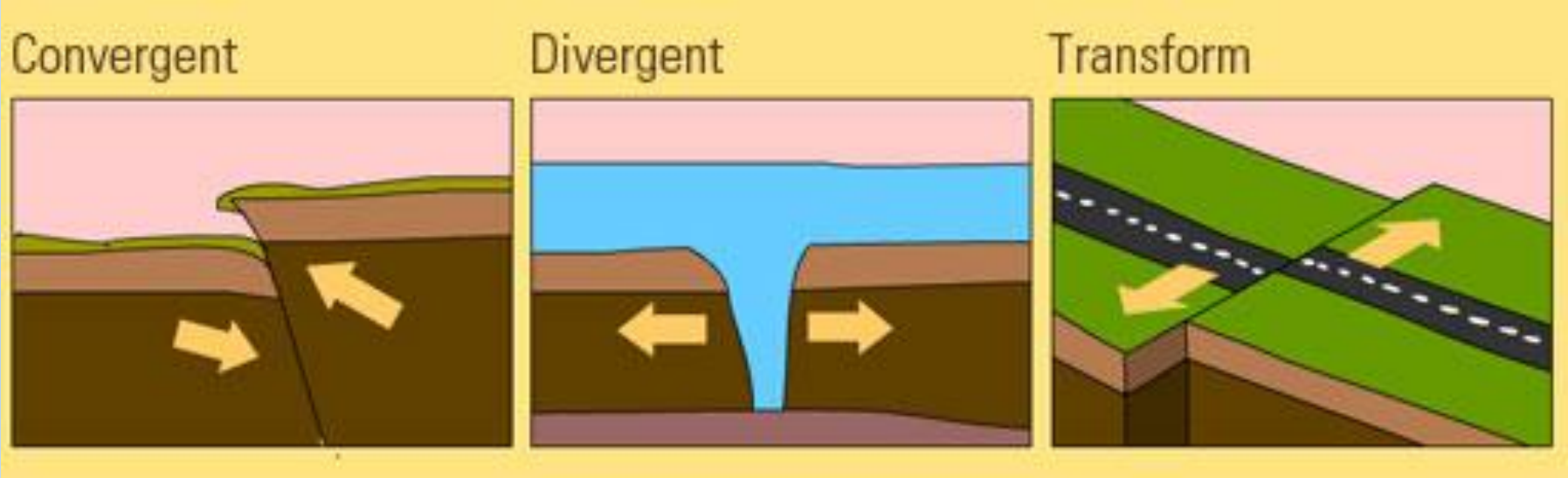
Earthquakes

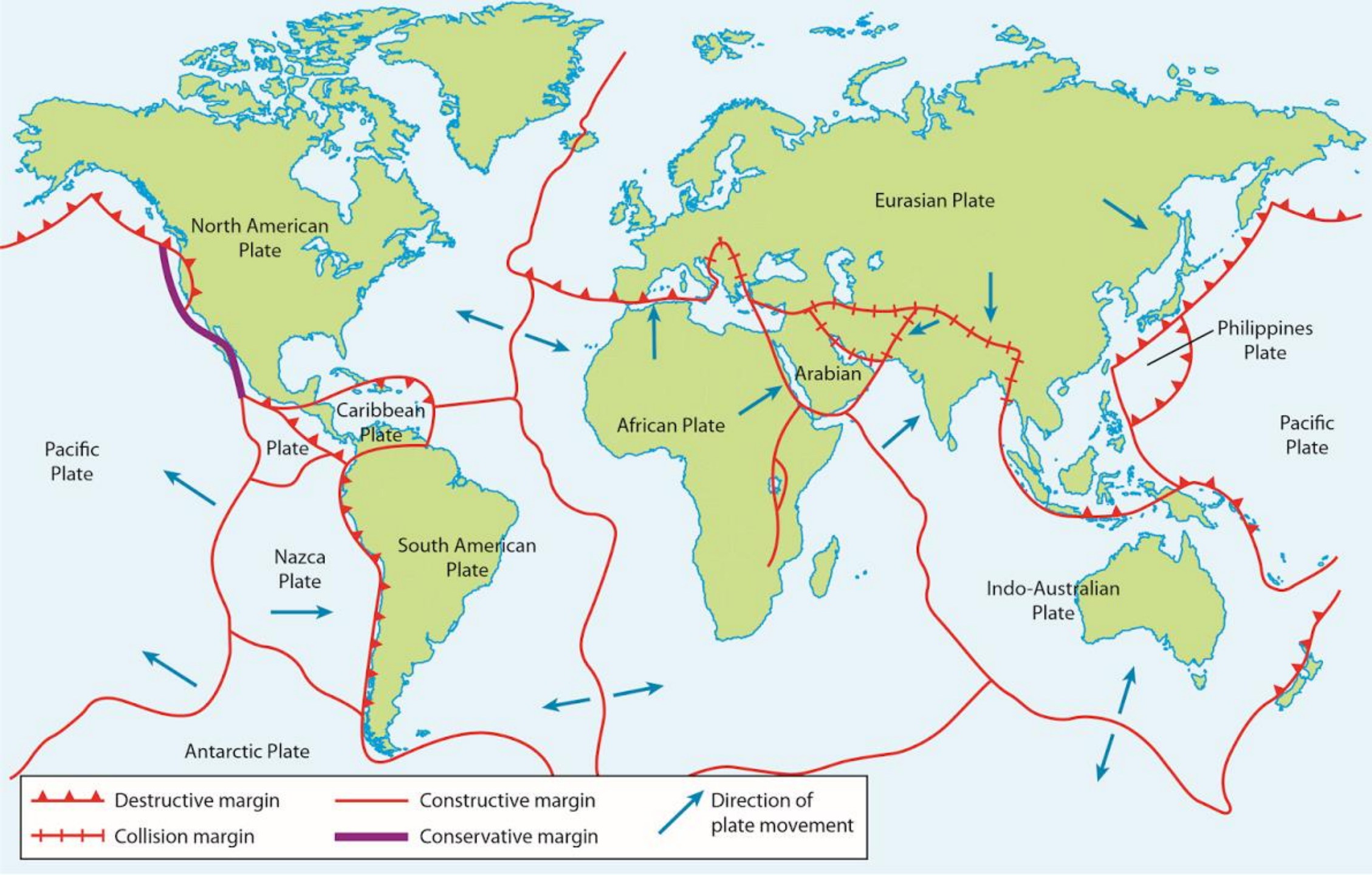
What is an Earthquake?

- A sudden and violent shaking of the ground, sometimes causing great destruction.

What Causes an Earthquake?

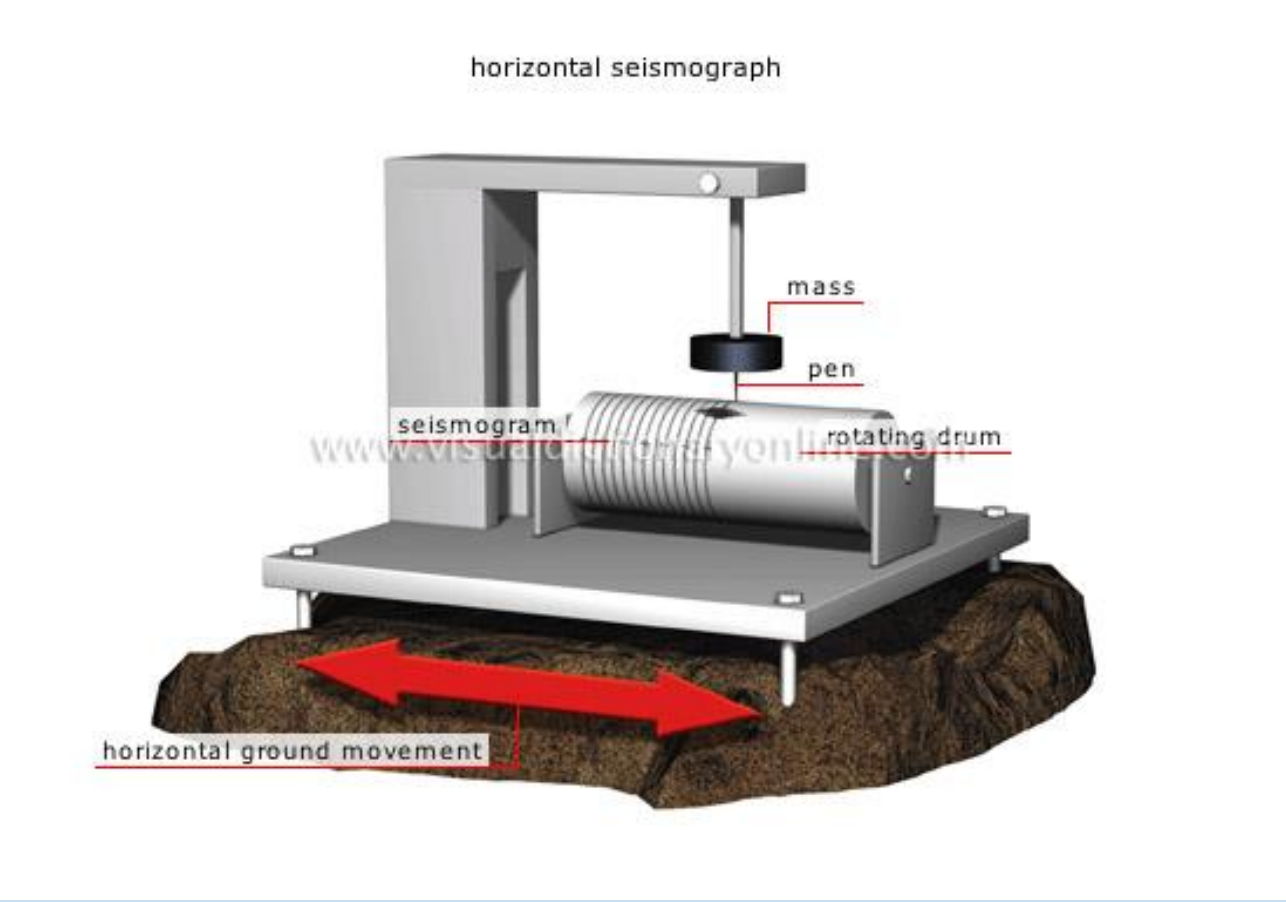
- **Earthquakes** are usually **caused** when rock underground suddenly breaks along a fault. This sudden release of energy **causes** the seismic waves that make the ground shake.




North American Plate
Eurasian Plate
Philippines Plate
Arabian
African Plate
Caribbean Plate
Plate
Pacific Plate
Pacific Plate
South American Plate
Nazca Plate
Indo-Australian Plate
Antarctic Plate
Destructive margin
Collision margin
Constructive margin
Conservative margin
Direction of plate movement

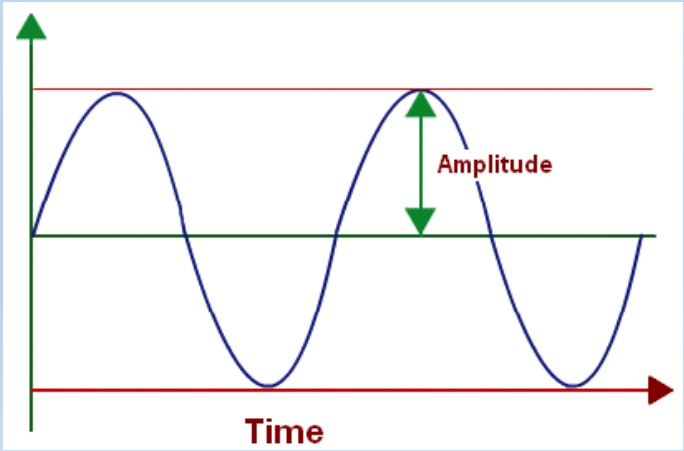
How are Earthquakes Recorded?

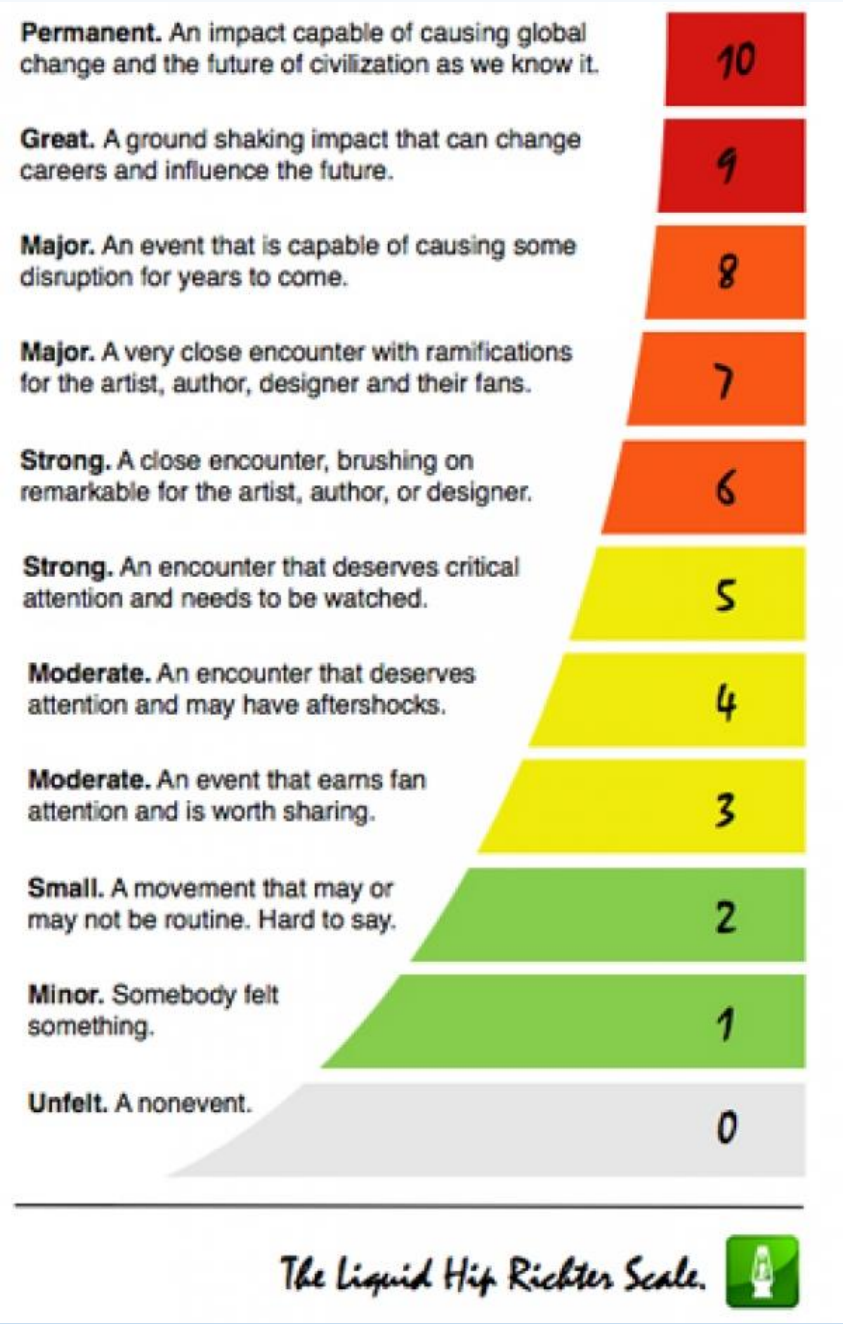
- **Earthquakes** are **recorded** by instruments called seismographs



Magnitude + Richter Scale

- The magnitude of an **earthquake**, usually expressed by the Richter Scale, is a **measure** of the amplitude of the seismic waves. The moment magnitude of an **earthquake** is a **measure** of the amount of energy released.
- Increases by 10x





Intensity + Mercalli Scale

- The **Mercalli** intensity **scale** is a seismic **scale** used for measuring the intensity of an earthquake. It measures the effects of an earthquake, and is distinct from the moment magnitude usually reported for an earthquake (sometimes misreported as the Richter magnitude), which is a measure of the energy released.

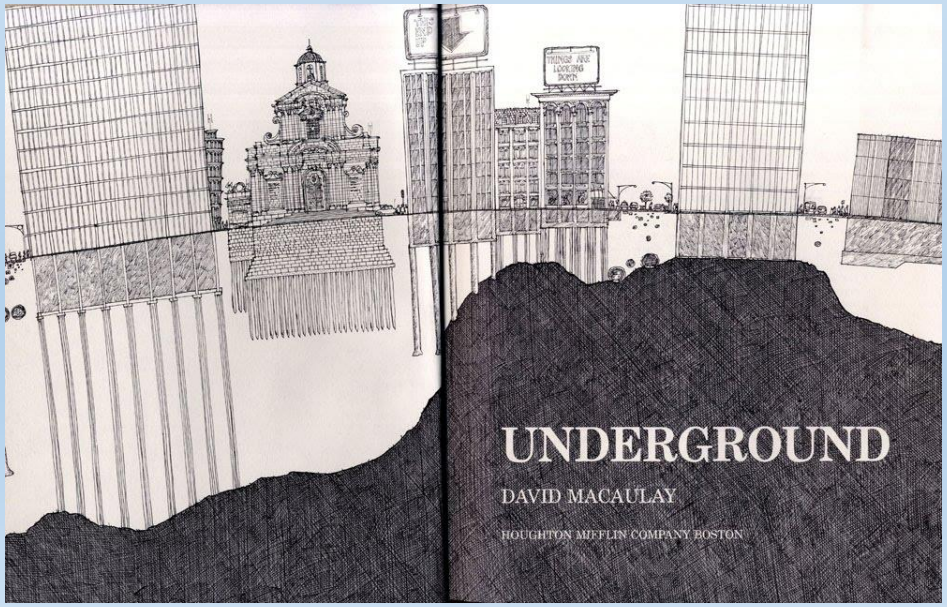
Modified Mercalli Scale		Richter Magnitude Scale
I	Detected only by sensitive instruments	1.5
II	Felt by few persons at rest, especially on upper floors; delicately suspended objects may swing	2
III	Felt noticeably indoors, but not always recognized as earthquake; standing autos rock slightly, vibration like passing truck	2.5
IV	Felt indoors by many, outdoors by few, at night some may awaken; dishes, windows, doors disturbed; autos rock noticeably	3
V	Felt by most people; some breakage of dishes, windows, and plaster; disturbance of tall objects	3.5
VI	Felt by all, many frightened and run outdoors; falling plaster and chimneys, damage small	4
VII	Everybody runs outdoors; damage to buildings varies depending on quality of construction; noticed by drivers of autos	4.5
VIII	Panel walls thrown out of frames; fall of walls, monuments, chimneys; sand and mud ejected; drivers of autos disturbed	5
IX	Buildings shifted off foundations, cracked, thrown out of plumb; ground cracked; underground pipes broken	5.5
X	Most masonry and frame structures destroyed; ground cracked, rails bent, landslides	6
XI	Few structures remain standing; bridges destroyed, fissures in ground, pipes broken, landslides, rails bent	6.5
XII	Damage total; waves seen on ground surface, lines of sight and level distorted, objects thrown up in air	7
		7.5
		8

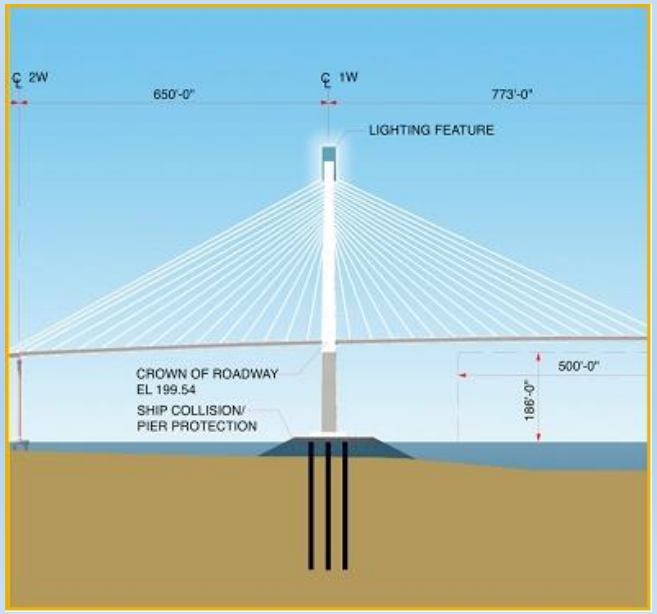
Engineering For Earthquake

- Traditionally few “tall” structures built in high earthquake areas.
- Proper building permits and approvals must be given before people build in these areas.
- California codes very strict

Foundation

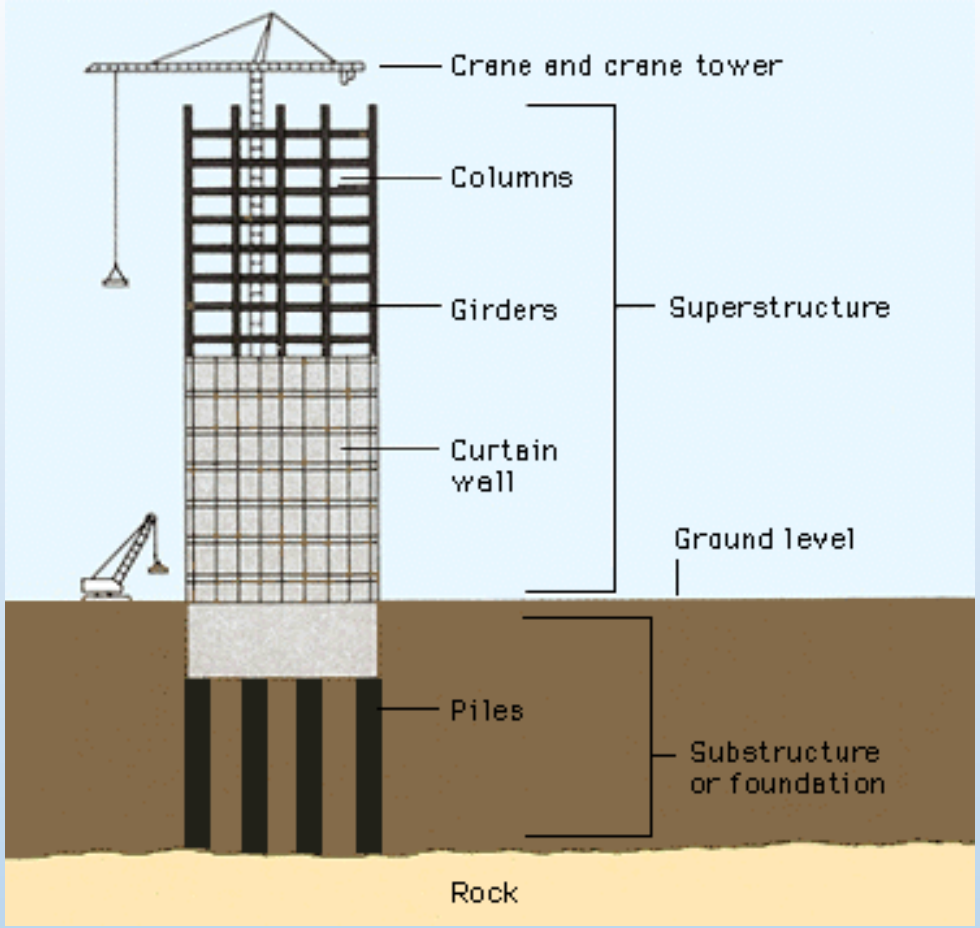
- Anchors structure to bedrock
- Like roots for a tree
- Deep, Shallow, Wide, Narrow
- Avg. house = 70 tons Avg. skyscraper 350,000 tons



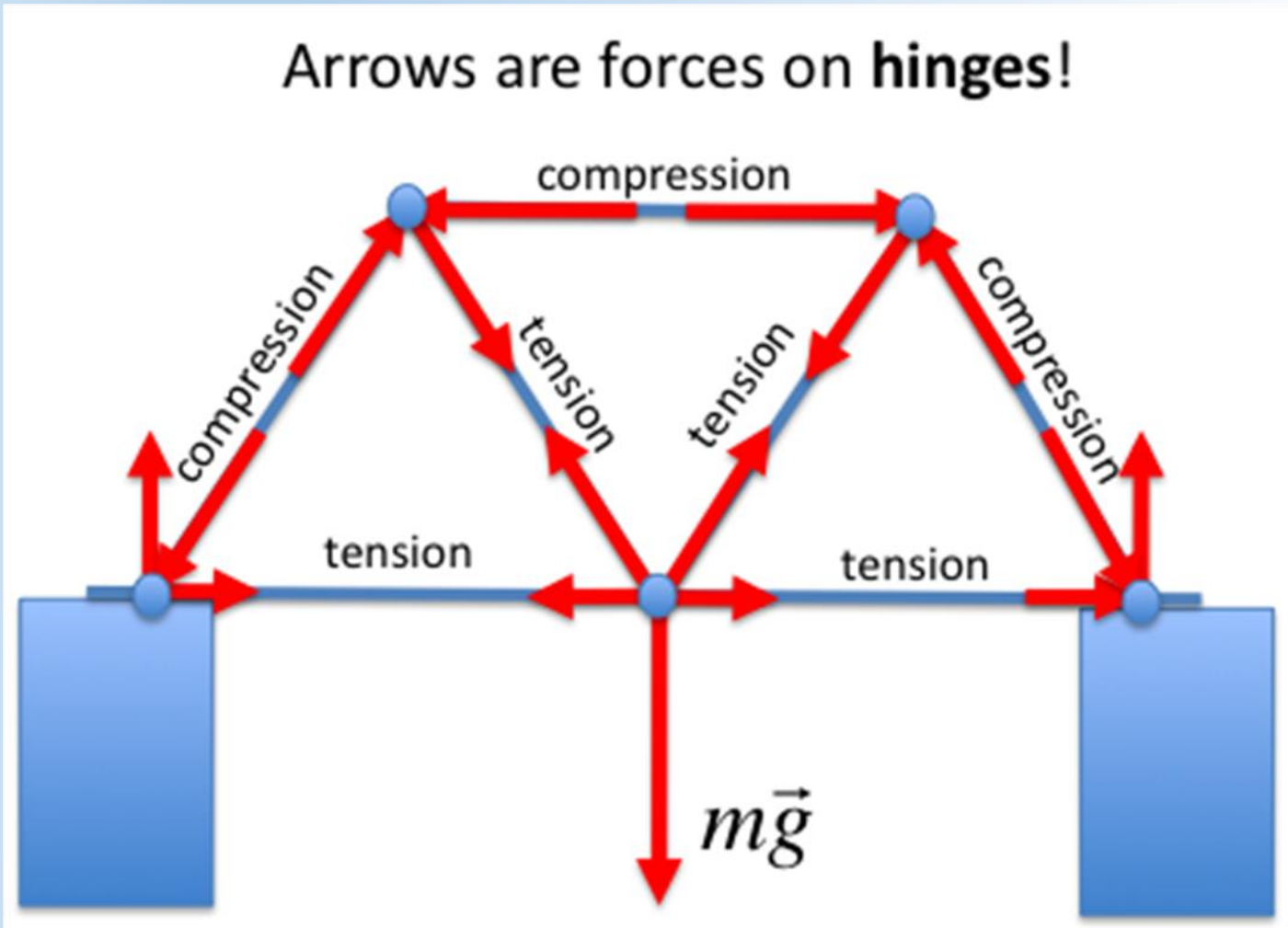


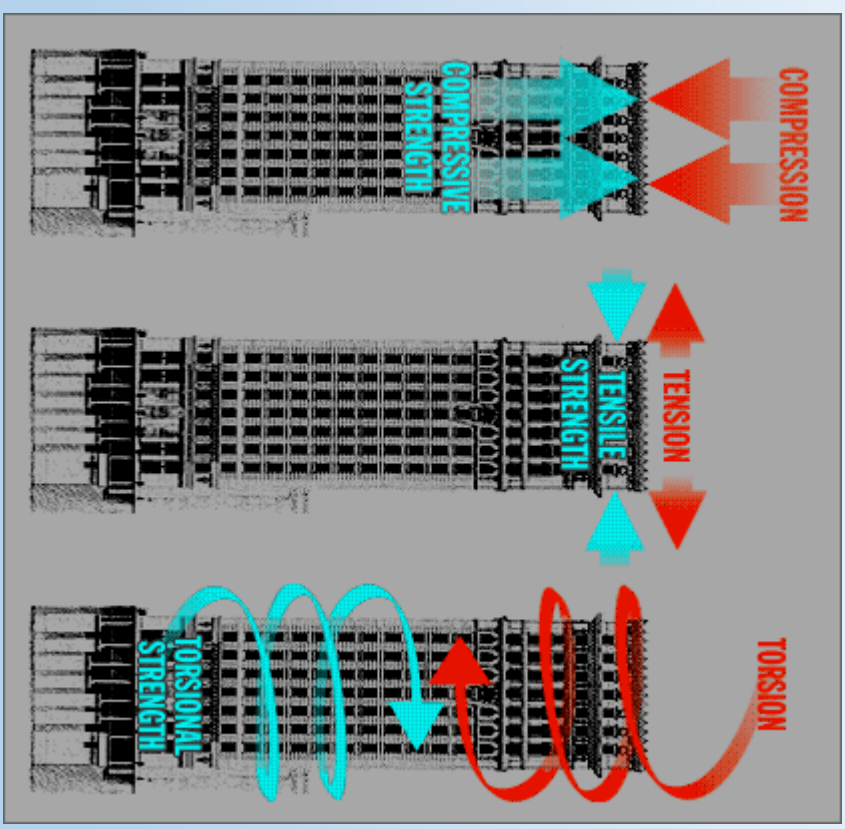
Structure

- Bedrock – layer of solid rock in earth's surface
- Pile or Caisson – Tubes of concreate and or steel
- Columns – Vertical components
- Girders/Beams – Horizontal components
- Curtain Wall – Exterior Wall



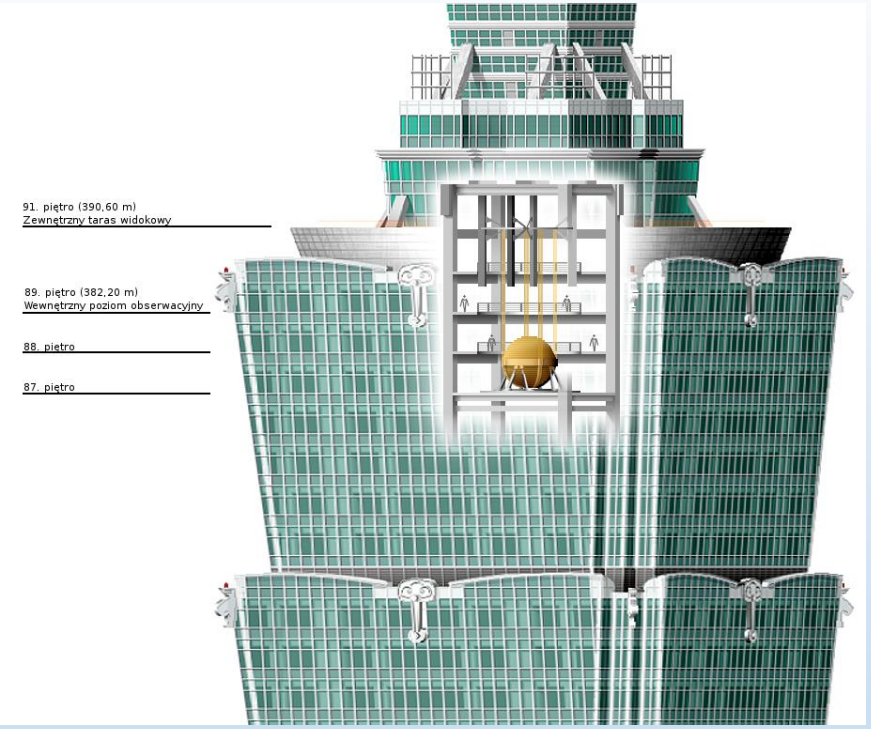
Construction

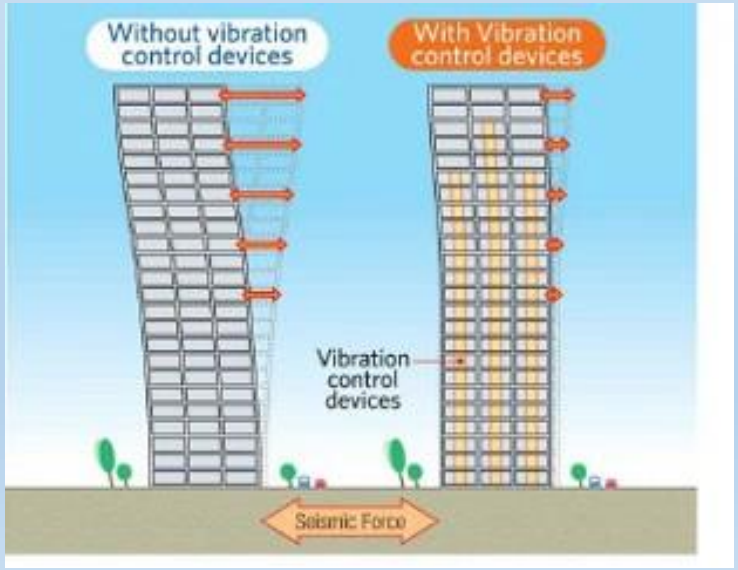

Arrows are forces on **hinges**!
compression
compression
tension
tension
compression
tension
tension
$m\vec{g}$

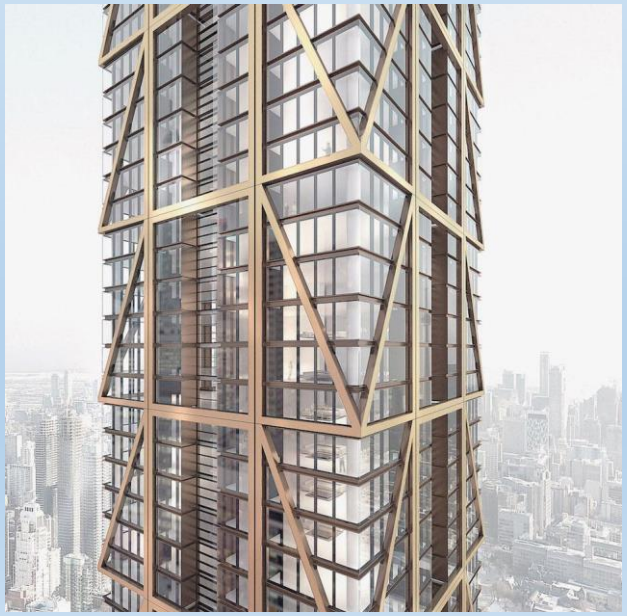

COMPRESSIVE STRENGTH
COMPRESSION
TENSILE STRENGTH
TENSION
TORSIONAL STRENGTH
TORSION

Build for an Earthquake

- Ridged
  - Resist movement
  - Overpower other forces
  - Exo skeleton or extra support
- Flexible
  - Absorbs energy
  - Moves with the earth
  - Mass dampeners
- Forces?







Problem Statement

- You are to take the role as a civil engineer at a large engineering firm. You and your partner have been given a pre-designed structure the client wants built. It is your job to stay under budget and create the strongest structure possible. The structure being built is located in an area that has a high frequency of earthquakes.

Restraints (To Scale)

- Structure must be at least 18” in height.
- Structure must be start exactly 4” in width.
- Structure must have 5 floors.
- Floors must be evenly spaced (3.5” per floor).
- Use only build materials given and wood or hot glue.
- 5 floor plates, 1 foundation, and 14 1/8” strips.
- Excessive glue results in loss of credit.