Engineering Knowledge Against Natural Disasters

Harbi S. Arafat
(Governor - WOBO)

Prepared By: Tamer Z. Arafat

Acknowledgment

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Aim

The main aim of this presentation is to investigate and share relevant experience in using of engineering knowledge to reduce the effect of natural disasters.

Methodology

- Introduction to Natural Disasters (5 min)
- Literature Review and Discussion(20 min)
  - Earthquakes
  - Hurricanes
- Conclusions and Recommendations (10 min)
- Questions (10 min)

Introduction

Natural Disasters

(The Act of God)

History

- humans fought against forces of natural disasters Since the old beginning of history course.
- Natural Disasters are called by humans Act of God.
- Natural disasters are mentioned in holy books as the punishment of god to unfaithful humans.

Defining Natural Disasters

An event that involves more groups who normally do not need to interact in order to manage emergencies, requires involved parties to relinquish the usual autonomy & freedom to special response measures and organizations, changes the usual performance measures, and requires closer operations between public and private organizations.

Types of Natural Disasters

- Avalanche.
- Disease.
- Drought.
- Earthquake
- Flood.
- Heat.
- Hurricane.
- Landslide.
- Storm surge.
- Tsunami.

Types of Natural Disasters

Avalanche:

- An Avalanche is a slippage of built-up snow down an incline, possibly mixed with ice, rock, soil or plant life in what is called a debris avalanche.

Types of Natural Disasters

Disease:

- Disease becomes a disaster when it spreads in a pandemic or epidemic as a massive outbreak of an infectious agent.

- Disease is historically the most dangerous of all natural disasters

Types of Natural Disasters

Drought:

- A drought is a long-lasting weather pattern consisting of dry conditions with very little or no precipitation. during this period, food and water supplies can run low, and other conditions, such as famine, can result.

- The Dust Bowl is a famous example of a severe drought.

Types of Natural Disasters

Earthquake:

- An earthquake is a sudden shift or movement in the tectonic plate in the Earth's crust. On the surface, this is manifested by a moving and shaking of the ground, and can be massively damaging to poorly built structures. The most powerful earthquakes can destroy even the best built of structures.

- In addition, they can trigger secondary disasters, such as Tsunamis and volcanic eruptions.

Types of Natural Disasters

Flood:

- A flood is a natural disaster caused by too much rain or water in a location, and could be caused by many different sets of conditions.

- A river which floods particularly often is the Huang He in China, and a particularly damaging flood was the Great Flood of 1993.

Types of Natural Disasters

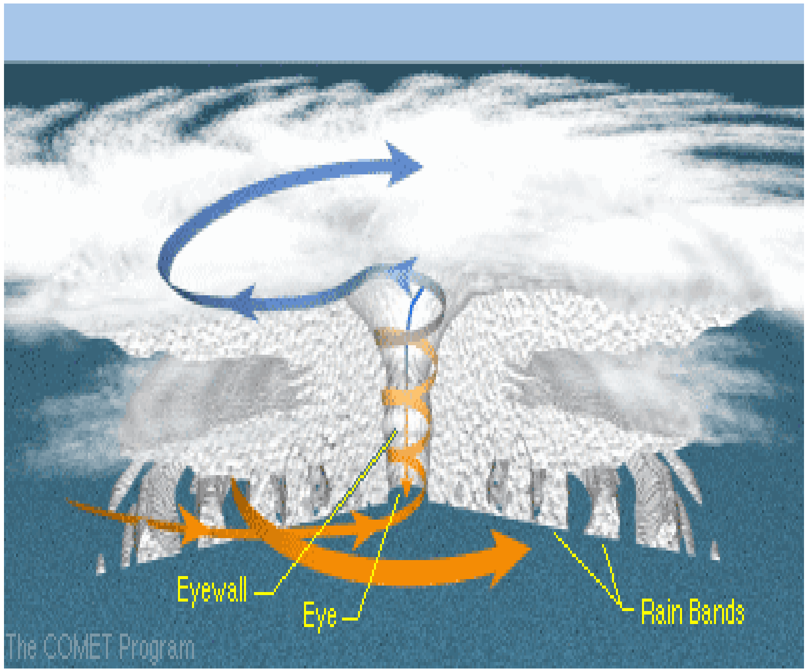
Heat:

- A heat wave is a disaster characterized by heat which is considered extreme and unusual in the area in which it occurs.
- Heat waves are rare and require specific combinations of weather events to take place.
- The worst heat wave in recent history was the European Heat Wave of 2003.

Types of Natural Disasters

Hurricane:

- A hurricane is a low-pressure cyclonic storm system which forms over the oceans.
- Hurricane is caused by evaporated water which comes off of the ocean and becomes a storm. The Carioles Effect causes the storms to spin, and a hurricane is declared when this spinning mass of storms attains a wind speed greater than 74mph.
- In different parts of the world hurricanes are known as cyclones (if occurred in Indian oceans) or typhoons (Pacific Ocean).



Types of Natural Disasters

Landslide:

- A landslide is a disaster closely related to an avalanche, but instead of occurring with snow,

- it occurs involving actual elements of the ground, including rocks, trees, parts of houses, and anything else which may happen to be swept up.

- Mudslides, or mud flows, are a special case of landslides, in which heavy rainfall causes loose soil on steep terrain to collapse and slide downwards.

Types of Natural Disasters

Storm surge:

- A storm surge is an onshore rush of water associated with a low pressure weather system, typically a tropical cyclone.
- Storm surge is caused primarily by high winds pushing on the ocean's surface. The wind causes the water to pile up higher than the ordinary sea level.
- Storm surges are particularly damaging when they occur at the time of a high tide, combining the effects of the surge and the tide.

Storm surge pushing water ashore during hurricane
Historic NWS Collection Credit: U.S. Navy

Types of Natural Disasters

Tsunami:

- A tsunami is a giant wave of water which rolls into the shore of an area with a height of over 15 m (50 ft).
- It comes from Japanese words meaning harbour and wave.
- Tsunami can be caused by undersea earthquakes as in the 2004 Indian Ocean Earthquake, or by landslides such as the one which occurred at Latoya Bay, Alaska.

Country where deaths occurred	Deaths	Injured	Missing	Displaced
Indonesia	126,915	100,000	37,063	700,000
Sri Lanka	30,957	15,686	5,637	573,000
India	10,749	0	5,640	380,000
Thailand	5,395	8,457	2,932	0
Somalia	298	0	0	5,000
Myanmar	61	45	200	3,200
Malaysia	74	299	0	0
Maldives	82	0	26	22,000
Secycelles	3	0	0	0
Tanzania	10	0	0	0
Bangladesh	2	0	0	0
South Africa	2	0	0	0
Kenya	1	2	0	0
Yemen	1	0	0	0
Madagascar	0	0	0	1,000
Total	**174,550**	**124,489**	**51,498**	**1,684,200**

Losses of Natural Disasters

- Death and losing of human beings : (almost 1.5 million people died between the years 1980 and 2000).

- Economically (Katrina losses by property damage reached $34.4 billion) [1-10-05].

Country	People killed annually
Ethiopia	14,330
Democratic People's Republic of Korea	12,888
Bangladesh	7,931
Sudan	7,160
Mozambique	4,828
India	2,932
Iran	2,393
China	2,173
Venezuela	1,449
Armenia	1,191

Power of Knowledge

- There were always people in history with special powers to fight against natural disasters.
- Nowadays, these powers are called “Knowledge”.
- The knowledge needed against each disaster depends on type of natural disaster attack.

Engineering Responsibilities

- Engineering knowledge should provide the safest solutions for humans to protect them selves against possible types of Natural disasters.
- The main two types to consider in this report are :
  - Earthquakes.
  - Hurricanes.

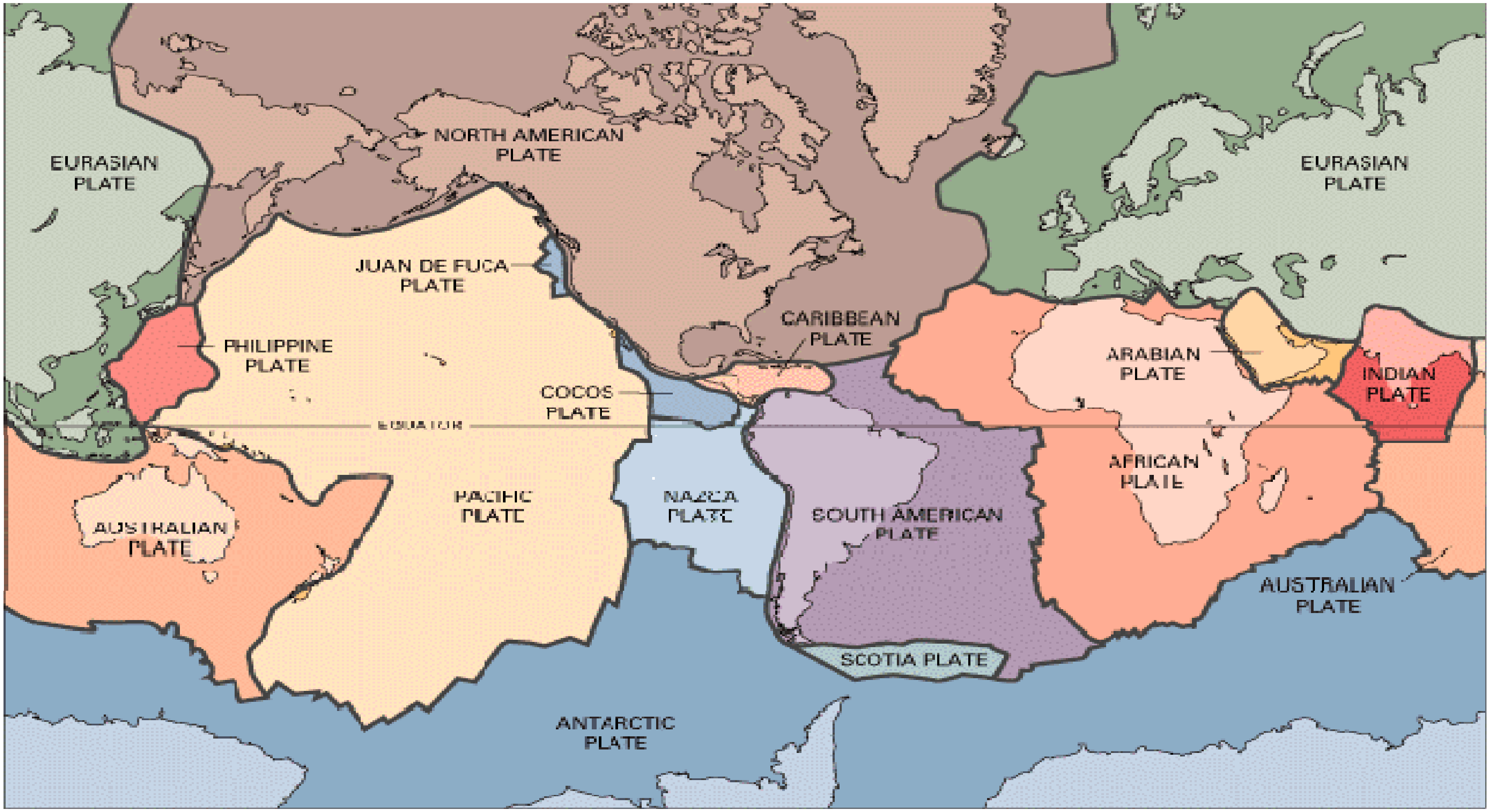
Earthquakes

Most frequent known natural disaster

Earthquakes

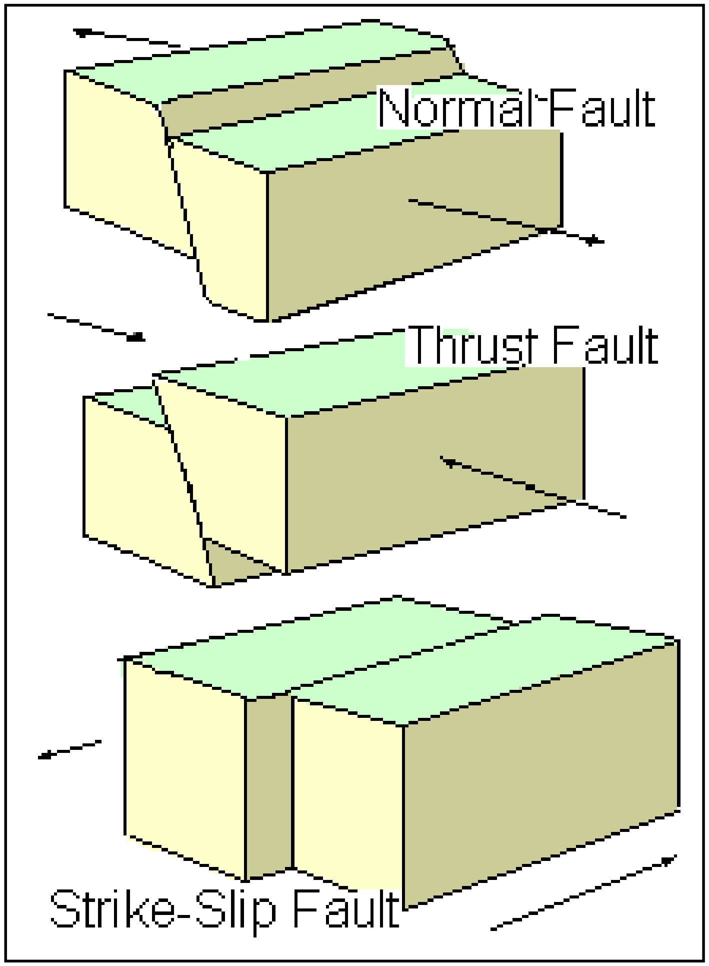
- Earthquakes can be defined as the sudden, sometimes violent movement of the earth's surface from the release of energy in the earth's crust.

Tectonic Plates



Types of Faults

- **Normal Fault.**
- **Thrust Fault.**
- **Strike-slip Fault.**
  - Left-Lateral strike-slip Fault.
  - Right-Lateral Strike-Slip Fault.



Measurements and classes of earthquakes

- **Richter Scale:**

The Richter magnitude scale was developed in 1935 by Charles F. Richter of the California Institute of Technology as a mathematical device to compare the size of earthquakes.

Class	**Magnitude**	**Effect**	**Estimated Number /yr**
Great	8 or more	can totally destroy communities near the epicenter.	one every 5 to 10 years
Major	7-7.9	serious damage for structures.	20
Strong	6-6.9	may cause a lot of damage in very populated areas.	100
Moderate	5-5.9	slight damage to buildings and other structures.	500
Light	4-4.9	often felt, but only causes minor damage.	30,000
Minor	3-3.9	usually not felt, but can be recorded by seismograph.	900,000

Measurements and classes of earthquakes

- **Modified Mercalli Intensity (MMI) Scale:**

The modified Mercalli Intensity (MMI) scale was first developed in 1931, by the American seismologists Harry Wood and Frank Neumann.

Level	Effect
I to II	Not felt except by a very few under especially favorable conditions.
II to III	Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing.
III to IV	Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibration similar to the passing of a truck. Duration estimated.
IV to V	Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.
V to VI	Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
VI to VII	Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.
VII to VIII	Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.
VIII to IX	Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.
IX to X	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
X to XI	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.
XI to XII	Few, if any (masonry) structures remain standing. Bridges destroyed. Rails bent greatly.
XII and more	Damage total. Lines of sight and level are distorted. Objects thrown into the air.

Energy of Earthquakes

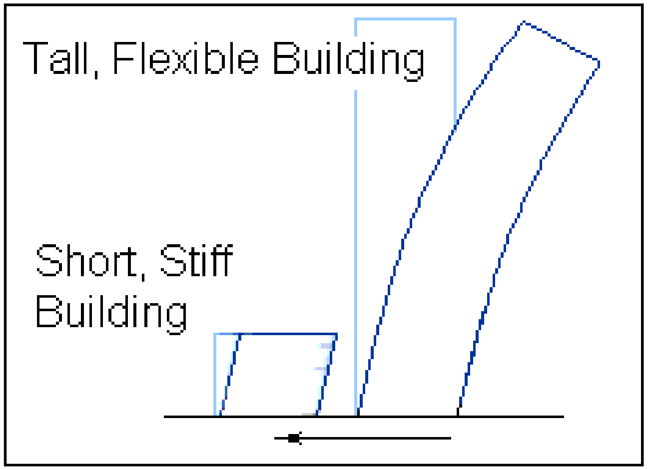
Magnitude	Approximate TNT Energy (Tons)
4.0	6
5.0	199
6.0	6,270
7.0	199,000
8.0	6,270
9.0	99,000,000

Important building characteristics related to earthquakes

- Height of buildings:

the higher the building the higher natural period to complete frequency of the earthquake wave needed

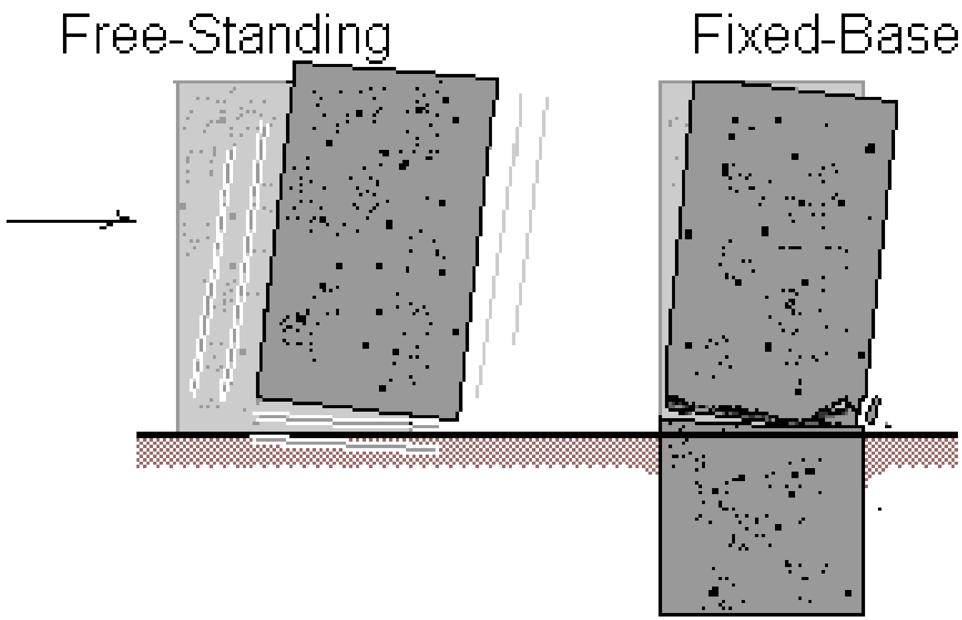
Building Height (story)	Typical Natural Period (seconds)
2	0.2
5	0.5
10	1.0
20	2.0
30	3.0



Important building characteristics related to earthquakes

- Acceleration & Flexibility:

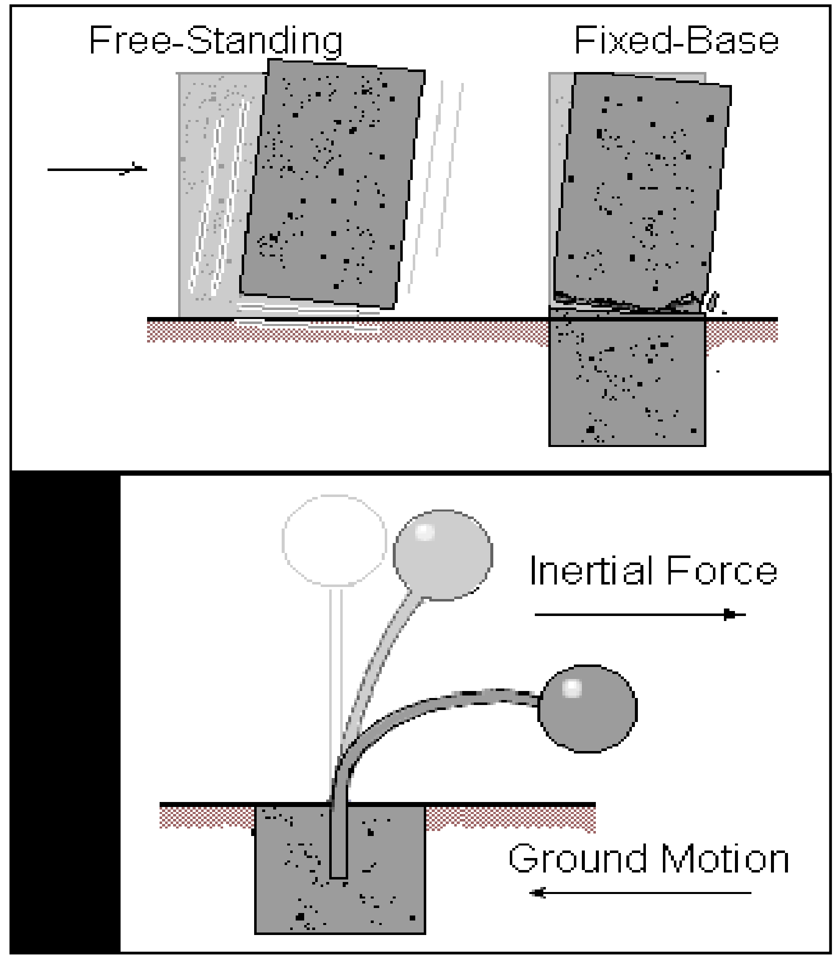
The affect of this factored was derived from the belief that damages in building during earthquakes do not usually occur due displacements, but because the buildings is suddenly forced to move very quickly



Important building characteristics related to earthquakes

- Ductility:

Ductility can be defined as the ability to undergo distortion or deformation (bending) without resulting in complete breakage or failure.



Important building characteristics related to earthquakes

- Damping:

Damping can be defined as the force (absorption of energy) by structural elements to stop the horizontal vibration of building

Designing systems against earthquakes

Lateral loads resisting systems:

- Shear walls.
- Braced frames.
- Moment resisting frames.
- Horizontal trusses.
- Diaphragms.

Designing systems against earthquakes

- Shear walls:

Shear walls are the vertical systems that are designed to receive lateral forces from diaphragms and transmit them to the ground

Designing systems against earthquakes

- Braces frames:

Braced frames are usually used in steel structures to resist lateral loads through designs connections.

Designing systems against earthquakes

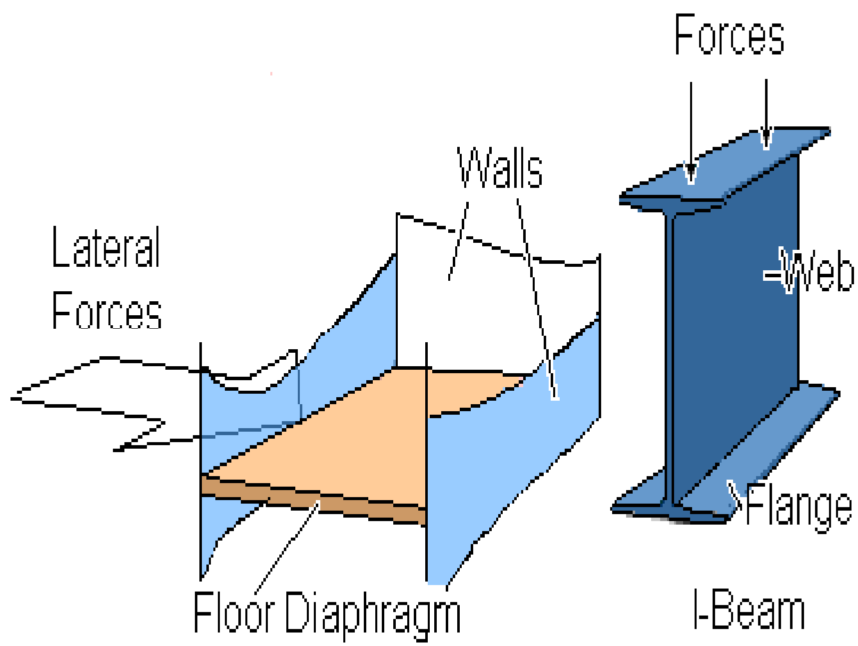
- Moment Resisting Frames:

The moment resistant frames usually resist lateral forces by either bolted or welded joints between columns and beams.

Designing systems against earthquakes

- Diaphragms:

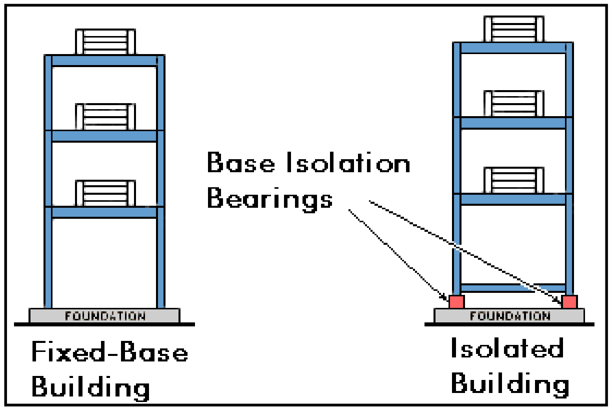
Diaphragms are horizontal resistance elements, generally floors and roofs, that transfer the lateral forces between the vertical resistance elements (shear walls or frames)

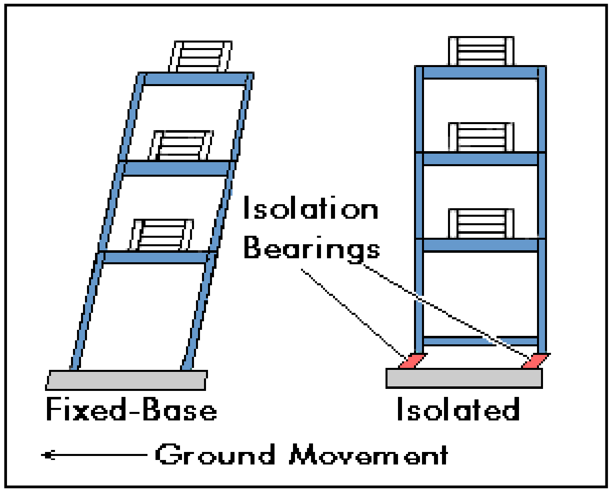


Advanced techniques to reduce Earthquake forces.

Base Isolation:

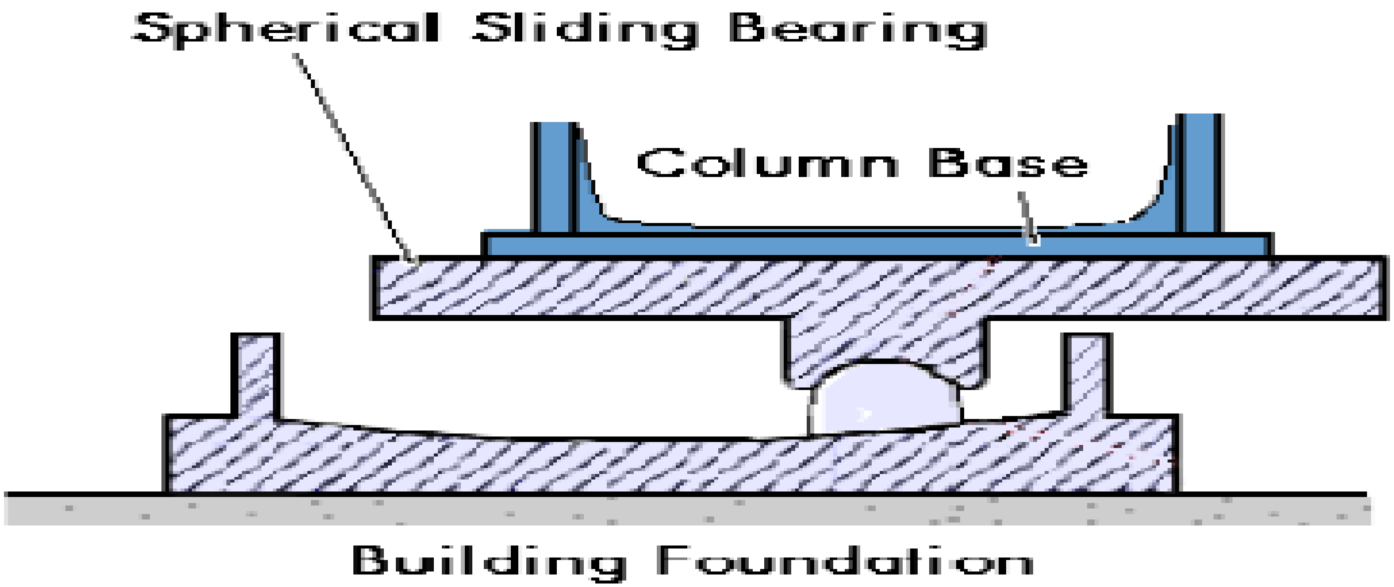
- This technique consist of bearing pads (either rubber or springs) which are placed between the building and the building's foundations.





Advanced techniques to reduce Earthquake forces.

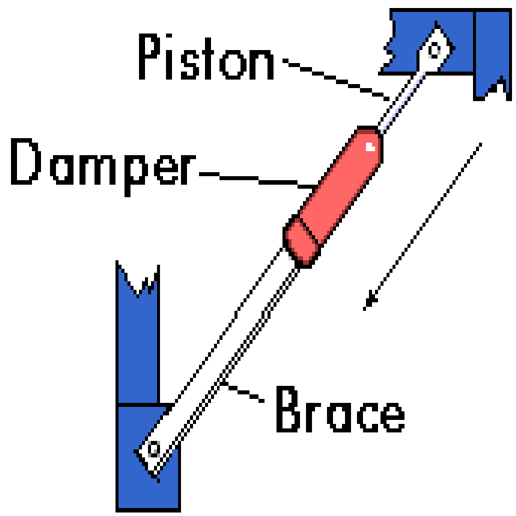
Spherical sliding isolation systems :

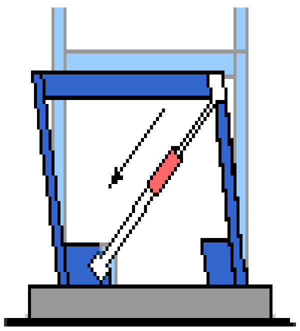


Advanced techniques to reduce Earthquake forces.

Energy Dissipation Devices:

- Friction dampers.
- Metallic dampers.
- Visco-elastic Dampers.
- Viscous dampers.





Hurricanes

Greatest Storms on Earth

Hurricanes

The term hurricane is derived from the Spanish word, *huracan*.

When they occur in the Pacific Ocean they are called "typhoons", in the Indian Ocean, "cyclones", and in the Atlantic, "hurricanes".

Stages of Development

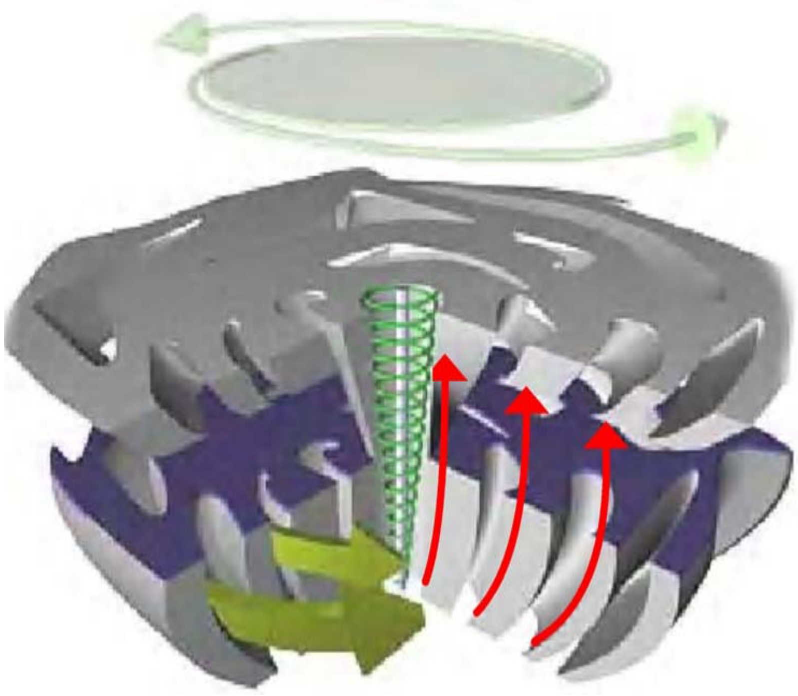
- Tropical disturbance.
- Tropical wave.
- Tropical depressions.
- Tropical storm.
- Hurricane.

Structure of the Hurricane

The structure of a hurricane is made up of spiral bands of thunderstorms and areas of heavy rain. These spiral bands flow inward toward the centre of the storm. Surrounding the centre is an area of very strong thunderstorms and a concentration of very high winds. This area is known as the eye-wall and is where the most destruction occurs.

Creation of a Hurricane

Hurricanes are born over warm oceans; the top 50 meters of the ocean surface needs to be at least 26.5oC, the air above the ocean must be cooler than the water temperature, that would allow thunderstorms to form; hurricanes are fueled by water vapor that is pushed up from the warm ocean surface, so they can last longer and sometimes move much further over water than over land. The combination of heat and moisture, along with the right wind conditions, can create a hurricane.



Hurricane Forces (Dangers)

- Wind.
- Rain.
- Storm surge.
- Storm tide.
- Tornados.

External Forces.

Hurricane missiles

The term missiles refers to debris and other objects picked up by the wind and moved with enough force to damage and even penetrate windows, doors, walls, and other parts of a building.

Measurements and classification of Hurricanes

- **Saffir-Simpson Scale:**

The Saffir-Simpson scale was created on 1977 by Robert Simpson (former Director of the National Hurricane Centre), and Herbert Saffir (consulting engineer known as father of Miami building code)

Saffir-Simpson Hurricane Scale Classification	Maximum Wind Speed --- km/h	Minimum Pressure --- kPa	Storm Surge --- meters	Damage Level
Tropical Depression	< 61	Not Applicable	Not Applicable	**None or Minimal**
Tropical Storm	61-117	Not Applicable	Not Applicable	**Minimal**
Category 1: Hurricane	118-153	> 98.0	1.0 - 1.7	**Minimal**
Category 2: Major Hurricane	154-177	96.5 - 97.9	1.8 - 2.6	**Moderate**
Category 3: Major Hurricane	178-209	94.5-96.4	2.7 - 3.8	**Extensive**
Category 4: Major Hurricane	210-248	92.0 - 94.4	3.9 - 5.6	**Extreme**
Category 5: Major Hurricane	> 248	< 92.0	> 5.6	**Catastrophic**

Type of failures due to hurricanes

- Total failures.
- Component Failure.

Main causes of Total Failures.

- Height of un-engineered structure.
  - By Logic: a one story house is less likely to experience wind damage than a two storey house.

Main causes of Total Failures.

- Weak Foundations:
  - Foundations of any construction is the most important element.
  - The uplift forces from hurricanes with high categories can sometimes pull buildings completely out of the ground.
  - The lighter loading of the building on foundations the larger the foundation needs to be designed for resisting hurricanes.
  - Any damage or transferring of foundations can lead to a total damage in the building members.

Main causes of Total Failures.

- Ignoring the use of sheer walls or framing methods.
- Very low and very steep sloped roofs.
- Low quality control (QC) during construction – specially in connections.

Main causes of Component Failures.

- Inadequate fastening devices.
- Inadequate sheet thickness.
- Insufficient frequencies of fasteners.
- Weak connection and bonding details for Windows, Doors, roof tiles, rafters, and cantilevered parapets.

Engineering Conclusions

(study the past to protect the future)

Engineering Conclusions

- Natural disaster's dangers can be reduced.
- Earthquakes attack with internal forces.
- Hurricanes attack with external forces.
- Human & Economic losses due to natural disasters are much greater than any costs might be needed to protect against future hazards.

Recommendations

(Human being is the most precious resource we have)

Words of his majesty King Hussein, The King of Jordan

Recommendations

- General.
- Roofs.
- Walls.
- Foundations.

Recommendations

General:

- Full understanding of the hazards likely for the zone where the building is to be sited should be maintained.

- Most countries had not overcome the hurricane dangers yet, the author advice whom is concerned to start preparing an international code to protect construction against hurricanes.

Recommendations

General:

- The less the height the building the more resistance available against earthquakes and hurricanes.

- Providing rules with extra control on following manuals, standards, specifications and procedures of erecting any of the materials used in the construction even finishing materials.

Recommendations

General:

- Quality control is a must in ensuring the adequacy of each connection in building either the design or construction process to fulfill the required resistance needed against earthquake or hurricane forces.

- Any site of construction without engineering design, and construction supervision should be prohibited.

Recommendations

General:

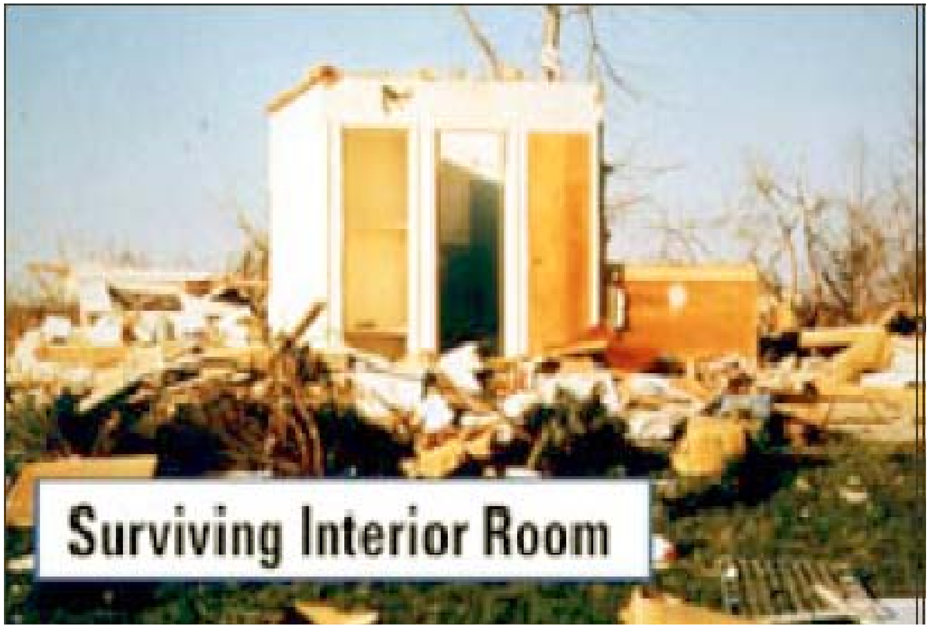
- Protection of opening in building either by impact resistant glazing, or permanent shutters, or at least temporary plywood panels with special screws design to resist wind suction forces.

- It's recommended to encourage architectural designers to promote and use more of aerodynamic building shapes. Aerodynamic building designs reduce direct wind forces experienced perpendicular to windward plans of buildings.

Recommendations

General:

- It is recommended for designers and safety engineers to apply a “safe room” in Timber structures.



Recommendations

Roofs:

- Avoid roof tiling, it was founded that the most common failure occurs in a reason of lack of bonding between the mortar connections.
- Very low and very steep sloped roofs generally create increased uplift and lateral wind loads, and should be ignored.

Recommendations

Roofs:

- It is preferable to avoid sheeting, even it easily exposes the building to water penetration, but also it can provides a major source of wind borne debris.

- From expert's experience, trusses were founded to be the safest solution, when well connected; the safest while hurricane attack as it is almost transmit most of the wind load to the rest of the structure members.

Recommendations

Roofs:

- Roofs should be well isolated to prevent leakage of water inside the building, using proper finishing materials is advisable even if higher cost.

- It is recommended to avoid half porches, as wind trapped underneath an open and in a result increases uplift forces on the roof. Full porches roofs should be separated from the rest of the building so that during hurricane failure will not affect anything else but the porch.

Recommendations

Walls:

- Larger factors and professional Quality control to be taken in consideration during design and construction process.

- Wood framed walls are disfavored as they suffer failures during hurricanes due to the difficulties of making quality control during construction process; the failure can be a result of improperly construction of corner studs, not enough overlapping of plates at intersections, in adequate nail connections, improper splicing or notching of member, missing hurricane straps in stud plate connections, and missing sill plate anchors.

Recommendations

Walls:

- It is recommended to reduce the distance between reinforced has inserted in hollow block walls, so that it can with the attached tie beams on top and bottom to resist the combination of uplift and pressure forces.
- Avoid using un-reinforced masonry walls.

Recommendations

Walls:

- It is suggested to increase the bonding between the wall reinforcement and tie beams, either by using hooking methods or by increasing the length of dowels inside tie beams.

- It is advised to insist on linking all walls together by providing a continuous ring/tie beams at each floor and roof levels.

Recommendations

Walls:

- As it is hard to prepare a high percentage of quality control on connections between old existing structure and upper new construction, it is recommended to use the same type of lower structure. Composite construction is not preferable in this case.

Recommendations

Foundations:

- The main weakness in foundation appears during flooding attack of water is connection strength between substructure (foundation) and superstructure.
- Weakness was experienced in shallow embedment foundation and though should be avoided as well as avoiding wooden cross bracing, steel rods, and even slabs on grade in a reason that they show high ability to fail during hurricane attacks.

Recommendations

Foundations:

- Pile foundations are highly recommended to resist hurricanes and floods, and it is preferable to increase depth and width as much as possible.
- While constructing piles, the method of driven piles is more acceptable than water jetted piles, as it compresses the soil and increases friction between the soil and the pile, while jetting piles loosens the surrounding soil and creates a void around the pile (friction = 0).

Recommendations

Foundations:

- Piles must be braced against horizontal forces either by knee braces, trusses, or grade beams. The knee braces are most recommended.
- As for foundations in zones were earthquakes expected, piles might not be the best sufficient solution as more the movements allowed the more building is safe against internal horizontal forces.
- Consider adding damping devices like shock absorbers to increase artificially the essential damping of a building and so improve the earthquake performance.

Questions or Comments???