(BASIC EARTHQUAKE ENGINEERING DEFINITIONS)

Basic Terminologies in Earthquake Engineering

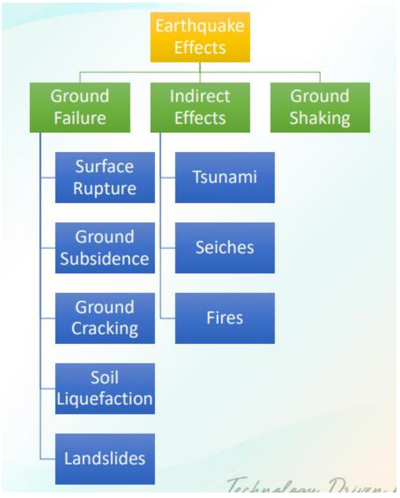
- ***Base*** - It is the level at which the earthquake motions are considered to be imparted to the structure or the level at which the structure, as a dynamic vibrator, is supported.
- ***Base Shear*** - It is the total design lateral force or shear at the base of a structure.
- ***Bearing Wall System*** - It is a structural system that does not have a compete vertical load-carrying space frame. ***Boundary Element*** - It is an element at edges of openings or at perimeters of shear walls or diaphragms.
- **Braced Frame** - It is essentially a vertical truss system of the concentric or eccentric type that is provided to resist lateral forces.
- ***Building Frame System*** - It is essentially a complete space frame that provides support for gravity loads.
- ***Building (Enclosed)*** - It is a building that does not comply with the requirements for open or partially enclosed buildings.
- ***Building Envelope*** - It refers to cladding, roofing, exterior wall, glazing, door assemblies, window assemblies, skylight assemblies and other components enclosing the building.
- ***Building (Flexible)*** - It refers to slender buildings that have a fundamental natural frequency less than 1.0 Hz. ***Building (Low Rise)*** - It is an enclosed or partially enclosed building that complies with the following conditions: (a) mean roof height "h" less than or equal to 18m and (b) mean roof height "h" does not exceed least horizontal dimension.
- ***Building (Open)*** - It refers to a building having each wall at least 80 percent open. This condition is expressed for each wall by the equation $Ao \geq 0.8Ag$
- ***Building (Regular Shaped)*** - It refers to a building or other structure having no unusual geometrical irregularity in spatial form.
- ***Building (Partially Enclosed) -*** It is a building that complies with both of the following conditions:
- The total area of openings in a wall that receives positive external pressure exceeds the sum of the areas of openings in the balance of the building envelope (walls and roof) by more than 10%; and
- The total area of openings in a wall that receives positive external pressure exceeds 0.5m2 or 1 percent of the area of that wall, whichever is smaller, and the percentage of openings in the balance of the building envelope does not exceed 20 percent.
- ***Building (Partially Enclosed)*** - It is a building that complies with both of the following conditions:
- These conditions are expressed by the following equations:

$$Ao > 1.10Aoi$$
$$Ao > Smaller\ of\ (0.5m2\ or\ 0.01Ag)$$
$$Aoi\text{T}Agi \leq 0.20$$

- ***Building (Rigid) -*** It refers to a building or other structure whose fundamental frequency is greater than or equal to 1.0 Hz.
- ***Cantilevered Column Element -*** It is a column element in a lateral-force-resisting system that cantilevers from a fixed base and has minimal moment capacity at the top, with lateral forces applied essentially at the top.
- ***Collector -*** It is a member or element provided to transfer lateral forces from a portion of a structure to vertical elements of the lateral-forceresisting system. ***Component -*** It is a part or element of an architectural, electrical, mechanical or structural system.
- ***Component (Equipment) -*** It is a mechanical or electrical component or element that is part of a mechanical and/or electrical system.
- ***Component (Flexible) -*** It is component, including its attachments, having fundamental period greater than 0.06s.
- ***Concentrically-Braced Frame*** - It is a braced frame in which the members are subjected primarily to axial forces.
- ***Cripple Wall -*** It is a framed stud wall extending from the top of the foundation to the underside of floor framing for the lowest occupied level.
- ***Dead Loads -*** It consists of the weight of all materials and fixed equipment incorporated into the building or other structure.
- ***Deck -*** It is an exterior floor system supported on at least two opposing sides by an adjacent structure and/or posts, piers, or other independent supports.
- ***Design Basis Ground Motion -*** It is that ground motion that has a 10 percent chance of being exceeded in 50 years as determined by a site-specific hazard analysis or may be determined from a hazard map.
- ***Design Response Spectrum*** - It is an elastic response spectrum for 5 percent equivalent viscous damping used to represent the dynamic effects of the Design Basis Ground Motion for the design of structures.
- ***Design Seismic Force -*** It is the minimum total strength design base shear, factored and distributed.
- ***Diaphragm -*** It is a horizontal or nearly horizontal system acting to transmit lateral forces to the vertical resisting elements. It includes horizontal bracing systems.
- ***Diaphragm (Blocked) -*** It is a diaphragm in which all sheathing edges not occurring on framing members are supported on and connected to blocking. Diaphragm ***Chord/Shear Wall Chord -*** It is the boundary element of a diaphragm or shear wall that is assumed to take axial stresses analogous to the flanges of a beam.
- ***Diaphragm Strut*** - It is the element of a diaphragm parallel to the applied load that collects and transfers diaphragm shear to the vertical resisting elements or distributed loads within the diaphragm. Such members may take axial tension or compression.

- ***Diaphragm (Unblocked) -*** It is the diaphragm that has edge nailing at supporting members only.
- ***Drift (Storey Drift) -*** It is the lateral displacement of one level relative to the level above or below.
- ***Dual System -*** It is a combination of moment-resisting frames and shear walls or braced frames
- ***Elastic Response Parameters -*** These are forces and deformations determined from an elastic dynamic analysis using an unreduced ground motion representation.
- ***Essential Facilities -*** These are buildings, towers and other vertical structures that are intended to remain operational in the event of extreme environmental loading from earthquakes.
- ***Flexible Element*** - It is one whose deformation under lateral load is significantly larger than adjoining parts of the system.
- ***Horizontal Bracing System -*** It is a horizontal truss system that serves the same function as a diaphragm.
- ***Importance Factor*** - It is a factor that accounts for the degree of hazard to human life and damage to property.
- ***Lateral-Force-Resisting System -*** It is that part of the structural system designed to resist the Design Seismic Forces.
- ***Limit State -*** It is a condition beyond which a structure or member becomes unfit for service and is judged to be no longer useful for its intended functions (serviceability limit state) or to be unsafe (strength limit state)
- ***Live Loads -*** These are those loads produced by the use and occupancy of the building or other structure and do not include dead load, construction load, or environmental loads.
- ***Loads -*** These are forces or other actions that results from the weight of all building materials, occupants and their possessions, environmental effects, differential movements, and restrained dimensional changes. ***Moment-Resisting Frame -*** It is a frame in which members and joints are capable of resisting forces primarily by flexure.
- ***Moment-Resisting Wall Frame (MRWF)*** - It is a masonry wall frame especially detailed to provide ductile behavior.
- ***Ordinary Moment-Resisting Frame (OMRF) -*** It is a moment-resisting frame not meeting special detailing requirements for ductile behavior.
- ***Orthogonal Effects -*** These are the earthquake load effect on structural elements simultaneously occurring to the lateral-force-resisting systems along two orthogonal axes.
- ***PΔ Effect -*** It is the secondary effect on shears, axial forces and moments of frame members induced by the horizontal displacement of vertical loads from various loading, when a structure is subjected to lateral forces.
- ***Rotation*** - It is the torsional movement of a diaphragm about a vertical axis.
- ***Shear Wall -*** It is a wall designed to resist lateral forces parallel to the plane of the wall (sometimes referred to as vertical diaphragm or structural wall).
- ***Shear Wall-Frame Interactive System -*** It uses combinations of shear walls and frames designed to resist lateral forces in proportion to their relative rigidities, considering interaction between shear walls and frames on all levels.
- ***Subdiaphragm*** - It is a portion of a diaphragm used to transfer wall anchorage forces to diaphragm cross ties.
- ***Soft Storey -*** It is one in which the lateral stiffness is less than 70 percent of the stiffness of the storey above.
- ***Storey -*** It is the space between levels.
- ***Storey Drift Ratio*** - It is the storey drift divided by the storey height.
- ***Storey Shear*** - It is the summation of design lateral forces above the storey under consideration.
- ***Strength -*** It is an assemblage of framing members designed to support gravity loads and resist lateral forces.
- ***Weak Storey*** - It is one in which the storey strength is less than 80 percent of the storey above.

MODULE 1: EARTHQUAKE EFFECTS



STRUCTURAL EFFECTS OF EARTHQUAKES

Ground Failures - These are generally considered part of geotechnical earthquake engineering, and they involve the movement of the ground surface at a location where geological fissures or zones of weakness in the crust of the earth (faults) slip slowly or suddenly.

Surface Faulting

- Occurs when the relative movement of rocks on the two sides of a fault takes place deep within the earth and breaks through to the surface. - Occur as slow movement in the form of fault creep or suddenly resulting in an earthquake. - This type of ground failure typically follows a pre-existing fault line.

Ground Subsidence

- Occurs as loose soils rearrange and settle into a denser state during vibrations cause by earthquakes

Ground Cracking

- It is usually observed along the edges of ground subsidence.

- It is also be the result of slope failure or liquefaction, all of which cause the ground to lose its support and sink, with the ground surface breaking up into fissures, scarps, horsts and grabens.

- The most damaging effect of ground subsidence is differential settlement, which can severely disrupt the function of any infrastructure system near the vicinity of cracking locations, particularly those with long foundations that straddle the cracks.

Soil Liquefaction - It occurs when loose, saturated granular soils temporarily change from a solid to a liquid state, losing their shear strength, which corresponds to a loss in effective stress between soil particles.

- Loose saturated (or moderately saturated) sands and non-plastic silts are most susceptible to this ground failure; however, in rare cases, gravel and clay can also experience liquefaction. - In all cases, poor drainage within the loose soil causes an increase in the pore water pressure as the soil is compressed by the vibratory effect of seismic waves.

Landslides

- Landslides caused by earthquakes are uncommon. Consequently, in order for a structure to experience damage during the event, it must be located at the top or bottom of the soil mass that slides down; for this reason, damage resulting from earthquake-induced landslides is rare.

- Sloped land that is marginally stable under static conditions is most susceptible to sliding during the intense shaking of strong earthquakes. - For the most severe cases, debris (soil, boulders, and other materials) flow can move at avalanche speeds and can travel long distances depending on the slope from which the landslide was formed.

Landslides

- Furthermore, earthquake-induced landslides can be sudden and unpredictable, producing the total destruction of communities in the path of the debris flow.

INDIRECT EFFECTS OF EARTHQUAKES

Tsunamis

- These are long-period sea waves that are generated when an earthquake causes the vertical movement of the seafloor.

- Tsunamis travel far, at high speeds (over 500 mph) in the open ocean and are difficult to detect because of their small crest-to-trough height, and long wavelengths, which typically, are hundreds of miles long.

- Unobstructed, these waves can travel around the world and dissipate all their energy without causing damage.

- However, as they approach a shore, the water depth decreases causing an increase in wave speed and wave amplitude (height of wave run-ups).

- Wave run-ups of 75 feet have been observed at several locations. - Wave run-ups can push water that rushes far inland, and have created devastating damage to infrastructure and great loss of life.

Seiches

- These are earthquake-induced waves in an enclosed body of water, such as a lake or a reservoir, or one that is partially enclosed, such as a bay.

- These are caused when long-period seismic waves resonate with oscillations of the enclosed water and cause standing waves. - Earthquakes may happen within or far outside the perimeter of the body of water. - Although this type of wave has been observed during most earthquakes (even in swimming pools), related damage to infrastructure has been minimal.

Fire

- It is probably the most terrifying indirect effect of earthquakes, particularly considering that people who survived in collapsed buildings, but were trapped in the debris, were burnt alive.

- Traditional firefighting methods are often ineffective against earthquake-induced fires because most water mains that supply water hydrants break.

- Earthquake-induced fires are started by ruptured combustible substance conduits (such as gas mains) or destroyed combustible substance storage containers (such as oil tanks), and then ignited by sparks from sources such as downed powerlines.

Ground Shaking

- It causes the majority of earthquake damage; additionally, most of the aforementioned effects are caused by shaking. In fact, where the shaking intensity is low, the hazard of other effects can be minimal.

- Consequently, shaking is the only effect experienced by everyone within an afflicted area, and intense shaking can produce widespread damage from various seismic hazards.

- For this reason, ground shaking is the main focus of earthquake engineering.

- Although earthquakes are caused by numerous natural and human induced phenomena, the events posing the highest seismic risks are caused by the relative deformation of crustal tectonic plates.

- Seismic waves that radiate from the location where a fault ruptures (the focus) quickly travel throughout the earth's crust, producing ground shaking when they reach the ground surface. The intensity and duration of shaking experienced at a particular site during an earthquake are primarily because of three factors:

- **Earthquake size (magnitude):** It can be measured objectively or subjectively—larger earthquakes cause stronger shaking. A strong earthquake can cause ground shaking over widespread areas, suddenly affecting large numbers of structures. Even relatively small earthquakes can have a significant impact on large numbers of buildings.

- **Location (distance from the focus or epicenter**): Generally, the closer to the epicenter, the stronger the shaking. Structures near the epicenter of a strong earthquake can experience extensive damage, in some cases partial or total collapse;

Seismic waves that radiate from the location where a fault ruptures (the focus) quickly travel throughout the earth's crust, producing ground shaking when they reach the ground surface. The intensity and duration of shaking experienced at a particular site during an earthquake are primarily because of three factors:

- The subsurface materials beneath the structure: Soft soils amplify the shaking, while rocks do not. This is the most insidious of the three factors because the site can be located at a long distance from the epicenter and still experience extensive ground shaking due to local soil conditions. Seismic waves travel through rock for most of their trip from the focus to the surface; however, at many sites, the final part of the trip is through soil, the geological characteristics of which have a major influence on the nature of ground shaking. Some soils act as seismic wave filters, attenuating shaking at some frequencies while amplifying it at others.

TYPES OF EARTHQUAKES

Man – Made Earthquakes

- These generally have a much smaller magnitude than the other two types of earthquakes, and thus have a lesser impact on infrastructure. However, man-made earthquakes can lead to earlier fault ruptures (tectonic earthquakes) because the shaking can increase critical stresses at the plate boundaries.

- One of the most intense cases is due to explosions, both from conventional and nuclear weapons.

- For example, it is estimated that the Boxcar nuclear bomb explosion in 1968, with a yield of 1200,000 tons TNT equivalent, excited an earthquake of magnitude 5.0 that lasted for 10– 12 s. This shook buildings in nearby communities, including Las Vegas, NV (30 miles away), but no serious damage or casualties occurred.

Volcanic Earthquakes

- These are caused by the same energy source as tectonic earthquakes, which is the heat from the earth's core. Volcanic seismicity affects limited areas near volcanic regions.

- The movement of magma through tubes below the volcanic vents creates pressure changes in the surrounding rock that can rupture, releasing elastic strain energy as seismic waves.

- These seismic waves have been successfully used to predict eruptions of volcanos such as Mount St. Helen in 1980 and Pinatubo in 1991.

- Other seismic waves can be induced by sudden, irregular movement of magma whose path has been obstructed, or by steady magma movement deep in the mantle.

- Damage from all these earthquakes is relatively minor compared with that produced by tectonic earthquakes.

Tectonic Earthquakes

- These are caused by a sudden dislocation of segments of the earth's crust, the structure of which is composed of plates (large and small) known as tectonic plates that float on a liquid layer, the mantle.

- This arrangement resulted from the formation of planet Earth five billion years ago, when hot gasses cooled into a semi-solid mass.

- It is estimated that after one to two billion years of cooling, the crust solidified and cracked forming tectonic plates (different ones than those that exist today).

- Damage from all these earthquakes is relatively minor compared with that produced by tectonic earthquakes.

TYPES OF EARTHQUAKES

Continental Drift Theory

- From the beginning, the plates have been in constant motion forming and breaking up continents over time, including the formation of supercontinents that contained most of the landmass. The latest supercontinent, Pangea, started separating approximately 200 million years ago, and its parts have drifted apart to the current configuration of the earth's surface. This process was originally proposed by Alfred Wegener in the early 1900s. He noted several different pieces of evidence to support his theory of the continental drift, including

Continental Drift Theory

1. How the current shape of some continents appears to fit together, particularly the east coast of South America and the west coast of Africa? Map Taken from the USGS Website

2. The significant similarities between fossil records (both flora and fauna) found in several continents that could only have occurred if the continents were attached.

3. The similarity in geology across several continents, including grooves carved by glaciers and the sediments deposited by these glaciers.

Basic Terminologies

Faults - At the boundaries of the plates, rocks fracture, usually at many locations, creating a web of smaller plates with edges that rub and push relative to each other; these edges are called faults. - When this energy is released with a sudden movement (slip), it causes brief strong ground vibrations.

Slip - The specific location (generally a volume of rock) where the movement or energy release occurs is known as the focus, or hypocenter.

Hypocenter/Focus

- The specific location (generally a volume of rock) where the movement or energy release occurs is known as the focus, or hypocenter.

Epicenter - The point on the earth's surface directly above the hypocenter is called the epicenter.

Aftershocks - Usually, the vibrations cause the rocks near the focus to become unstable; and as these rocks settle into a new equilibrium state they cause aftershocks.

Seismology - The discipline that studies seismic activity is known as seismology

Epicenter - The point on the earth's surface directly above the hypocenter is called the epicenter.

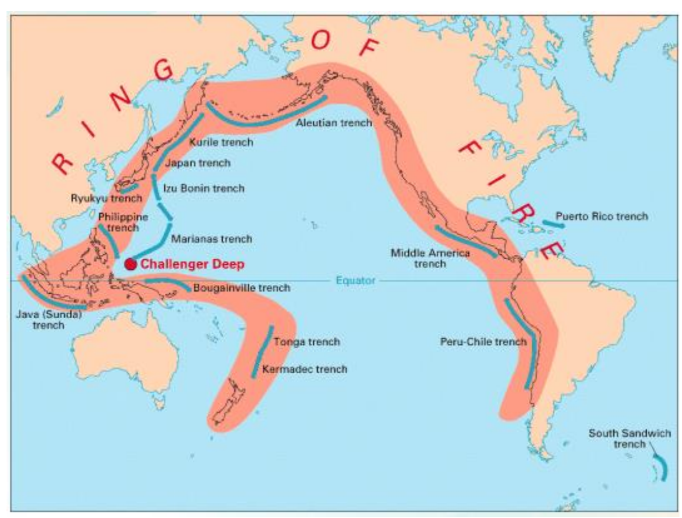
Aftershocks - Usually, the vibrations cause the rocks near the focus to become unstable; and as these rocks settle into a new equilibrium state they cause aftershocks.

Seismology - The discipline that studies seismic activity is known as seismology

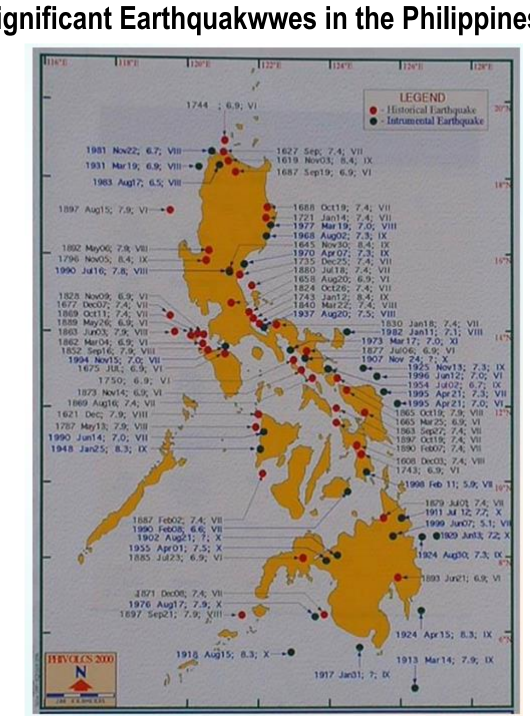
Magnitude 8 and Greater Earthquakes Since 1900

The May 22, 1960 Chile Earthquake is the highest magnitude earthquake recorded (9.5) since 1900. The December 26, 2004 Sumatra, Indonesia Earthquake has the highest fatalities recorded since 1900. The April 14, 1924 Mindanao, Philippines Earthquake has the highest magnitude recorded (8.3) since 1900.

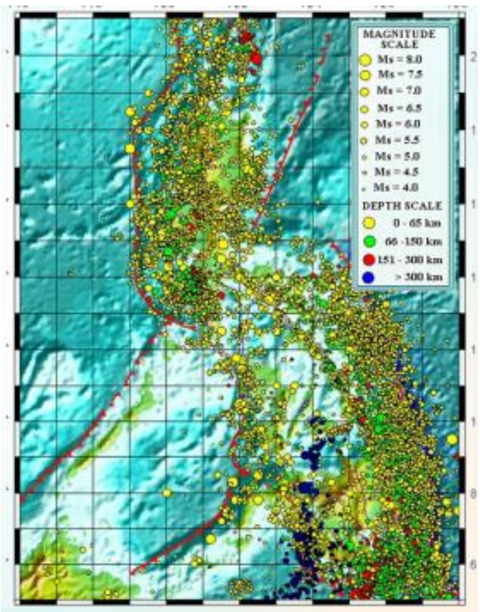
"Ring of Fire" – Regions of High Seismicity



Significant Earthquakwwes in the Philippines



Earthquakes for the Past 400 Years



History of the Development of Mitigation Strategies for the Effects of Seismic Hazards

1. Development of construction practices to mitigate the effects of shaking.

2. The first half of the twentieth century focused on characterizing the effect of shaking using lateral forces.

3. In the 1940s, the development of the response spectrum theory marked a major step forward.

4. In the 1960s, concepts of structural dynamics were incorporated into design practice.

5. The last stage has implicitly been included in building codes since the 1970s and deals with performance-based design.

The dynamic forces are only equivalent to code-specified lateral forces in that a structure designed to resist these forces has the capability of deforming without overstressing from load reversals, and provide adequate member ductility, as well as provide connections with sufficient strength and resiliency to accomplish the following performance goals:

1. Resist minor earthquakes without damage.

2. Resist moderate earthquakes without structural damage, but with some nonstructural damage.

3. Resist major earthquakes without collapse, but with both structural and nonstructural damage.

Engineering Seismology

Epicenter

- It is the geographical point on the ground surface where an earthquake is estimated to be centered.

Focal Depth

- Together with the epicenter, it gives the location where the rock ruptures at a fault (fault rupture) that generates the main earthquake, the focus or hypocenter.

Focal Depth - This is an area (not a point) that can extend for many miles along a fault.

Fault Plane - The plane along which the rock ruptures and slips.

Dip Angle - An angle with respect to the ground surface.

Strike Angle - The angle the fault plane makes with respect to the north direction along the surface

Fault Slip- - The relative displacement between the two sides of the fault plane.

Epicentral Distance - The radiating seismic waves are recorded using a seismometer at an observation station located at a distance

CLASSIFICATION OF FOCAL DEPTH

Shallow Focal Depth - It is characterized by focal depths less than 70 km (43 miles)

Intermediate Focal Depth - - It is characterized by focal depths between 70km (43 miles) and 300km (186 miles).

Deep Distance - It is characterized by focal depths greater than 300 km (186 miles).

Engineering Seismology Terminology

FIGURE 2.3 Horizontal movement, *strike-slip* fault.

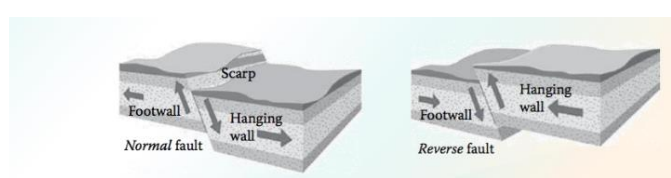


FIGURE 2.2 Vertical movement, *dip-slip* faults.

ELASTIC REBOUND THEORY

Elastic Rebound Theory: Tectonic Plate Movement

- The elastic-rebound theory is an explanation for how energy is released during an earthquake.

- As the Earth's crust deforms, the rocks which span the opposing sides of a fault are subjected to shear stress. Slowly they deform, until their internal rigidity is exceeded.
- Then they separate with a rupture along the fault; the sudden movement releases accumulated energy, and the rocks snap back almost to their original shape.

SEISMIC WAVES

- Seismic waves radiate from the focus and travel in every direction, as shown

- The portion of the energy released from a fault rupture as shaking first travels through the interior of the earth as body waves, following the shortest path to the ground surface where they are transformed into surface waves.

- Thus, body waves arrive at an observation station (or site) before any surface waves. An understanding of these different waves is necessary to establish the epicenter and to characterize the size of the earthquake (earthquake magnitude and ground acceleration).

Types of Seismic Waves

P-Waves (Primary or Pressure)

- P-waves travel faster than other seismic waves and hence are the first signal from an earthquake to arrive at any affected location or at a seismograph.

S-Waves (Secondary or Shear)

- S-waves are transverse waves, meaning that the oscillations of an S-wave's particles are perpendicular to the direction of wave propagation, and the main restoring force comes from shear stress.

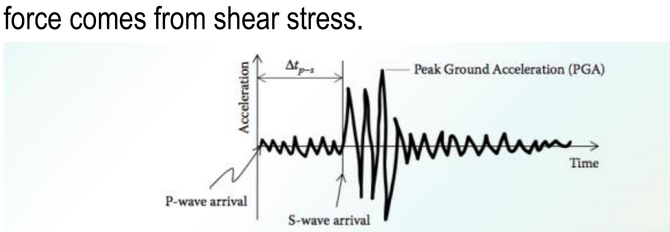


FIGURE 2.6 Seismograph—a strong-motion recording using a seismometer.

Estrada and Lee, 2017

MEASURING EARTHQUAKES

Earthquake Intensity

- The intensity of an earthquake is a subjective, non-empirical approach for estimating the size of an earthquake based on the subjective assessment of human observations of the effects of earthquake shaking on buildings (amount of damage sustained by structures and land surface) and on people.

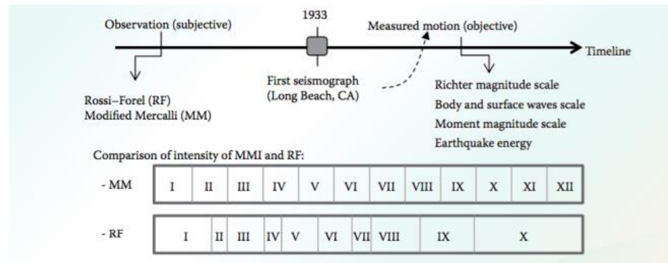


FIGURE 2.7 Scales used to estimate the relative size of earthquakes.

EARTHQUAKE INTENSITY

TABLE 2.1
Modified Mercalli Intensity Scale, and Comparison to Magnitude and PGA

Degree	Intensity Description	Magnitude	PGA (g)
I	Not felt, except by some in rare circumstances.	<3.0	<0.03
II	Felt only by a few persons at rest on upper floors of buildings.	3.0–3.9	
III	Felt indoors, but many people do not recognize it as an earthquake.		
IV	During the day felt indoors by many, outdoors by few, while at night some awakened. Dishes, windows, doors are disturbed and walls make creaking sounds.	4.0–4.9	
V	Felt by nearly everyone during the day and many awakened at night. Some dishes, windows, etc. are broken; cracked plaster in a few places; unstable objects overturned.		0.03–0.08
VI	Felt by all, many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster and damaged chimneys. Damage slight.	5.0–5.9	0.08–0.15
VII	Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures; some chimneys damaged.		0.15–0.25
VIII	Damage slight in specially designed structures; considerable in ordinary buildings (some with partial collapse); great in poorly built structures. Chimneys, factory stack, columns, monuments, walls toppled. Heavy furniture overturned.	6.0–6.9	0.25–0.45
IX	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb; great damage for others, including partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken.	7.0–7.9	0.45–0.6
X	Some well-built wooden structures destroyed; most masonry and frame structures destroyed. Ground badly cracked.		0.6–0.8
XI	Few masonry structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipelines completely out of service.	>8.0	0.8–0.9
XII	Damage total. Waves seen on ground surface. Objects thrown into the air.		>0.90

Earthquake Magnitude

- Whereas the intensity of a given earthquake varies from one observation point to another, earth- quakes can be associated with a single value of magnitude.

- The consensus measure of magnitude is based on the Richter scale, which quantifies the size of an earthquake with an index of the amount of energy released, and while this approach is an improvement as compared to the intensity scales, the Richter scale does not accurately account for all factors that contribute to the actual size of an earthquake.

- This scale, however, does appropriately measure the relative strength of an earthquake and remains an important parameter in earthquake hazard analysis.

Earthquake Magnitude

- In addition to being used for earthquake hazard analysis by seismologists and engineers, it is the preferred scale used to inform the public of the size of an earthquake.

- Because it was originally developed to quantify the strength of Southern California earthquakes, the Richter scale is also known as the local magnitude scale, ML . Richter defined ML using the base-10 logarithm of the peak trace amplitude (in micrometers, μm) of a standard Wood–Anderson seismograph (which has a magnification factor of 2800, a natural period of 0.8 s, and damping of 80%), located on firm ground at a distance of 100 km from the epicenter.

Earthquake Hazard Assessment

The deterministic approach can be used in areas where seismic activity is frequent and its sources are well defined. The process is relatively simple and entails the following:

1. Identifying nearby seismic sources.

2. Identifying the distance to the structure site from nearby seismic sources.

3. Determining the magnitude and characteristics of nearby seismic sources.

4. Establishing the structural response to the effects from all nearby seismic sources.

5. Selecting the case that produces the largest structural response

MODULE 2 – BASE SHEAR COMPUTATIONS

208.5.1. Simplified Static Force Procedure

Structures conforming to the requirements of Section 208.4.8.1 may be designed using this procedure.

Section 208.4.8.1. Simplified Static

The simplified static lateral force procedure set forth in Section

208.5.1.1. may be used for the following structures of Occupancy Category IV or V.

1. Building of any occupancy (including single – family dwellings) not more than three stories in height excluding basements that use light frame construction.

2. Other buildings not more than two stories in height excluding basements.

The total design base shear in a given direction shall be determined from the following equation:

$$\boldsymbol{V = \frac{3C_a}{R}W}$$

Where the value of Ca shall be based on Table 208-7 for the soil profile type.

When the soil properties are not known in sufficient detail to determine the soil profile type, Type SD shall be used in Seismic Zone 4 and Type SE shall be used in Seismic Zone 2.

In Seismic Zone 4, the Near Source Factor, Na, need not be greater than 1.2 if none of the following structural irregularities are present:

1. Type 1, 4 or 5 of Table 208-9 or
2. Type 1 or 4 of Table 208-10

VERTICAL DISTRIBUTION

The forces at each level shall be calculated using the following equation:

$$\boldsymbol{F_x = \frac{3(C_a)}{R}W_i}$$

Where the value of C_a shall be determined as in Section 208.5.1.1.

TABLE 103-1: OCCUPANCY CATEGORY

A. ESSENTIAL FACILITIES

- Occupancies having surgery and emergency treatment areas
- Fire and police stations
- Garages and shelters for emergency vehicles and emergency aircraft
- Structures and shelters in emergency preparedness centers
- Aviation control towers
- Structures and equipment in communication centers and other facilities required for emergency response
- Facilities for standby power-generating equipment for Category 1 structures
- Tanks or other structures containing housing or supporting water or other fire-suppression material or equipment required for the protection of Category I, II, or III, IV and V structures
- Public school buildings
- Hospitals
- Designated evacuation centers and
- Power and communication transmission lines

2. HAZARDOUS FACILITIES

- Occupancies and structures housing or supporting toxic or explosive chemicals or substances
- Non-building structures storing, supporting or containing quantities of toxic or explosive substances
- Buildings with an assembly room with an occupant capacity of 1,000 or more
- Educational buildings such as museums, libraries, auditorium with a capacity of 300 or more occupants
- Institutional buildings with 50 or more incapacitated patients, but not included in Category 1

3. SPECIAL OCCUPANCY STRUCTURES

- Mental hospitals, sanitariums, jails, prisons and other buildings where personal liberties of inmates are similarly restrained
- Churches, Mosques and other Religion Facilities
- All structures with an occupancy of 5,000 or more persons
- Structures and equipment in power-generating stations and other public utility facilities not included in Category 1 or Category 2 and required for continued operation

4. STANDARD OCCUPANCY STRUCTURES

- All structures housing occupancies or having functions not listed in Category I, II or III, and Category V.

5. MISCELLANOUS STRUCTURES

- Private garages, carports, sheds and fences over 1.5m high

208.5.2 STATIC FORCE PROCEDURE

208.5.2.1. Design Base Shear

The total design base shear in a given direction shall be determined from the following equation:

$$V = \frac{C_v I}{RT} W \; (MAXIMUM)$$

The total design base shear need not exceed the following:

$$V = \frac{2.5 C_a I}{R} W \; (MAXIMUM)$$

The total design base shear shall not be less than the following:

$$V = 0.11 C_a I \; (MINIMUM)$$

In addition, for Seismic Zone 4, the total base shear shall also not be less than the following:

$$V = \frac{0.8 Z N_v I}{R} W \; (MINIMUM)$$

TABLE 208-1: SEISMIC IMPORTANCE FACTORS

OCCUPANCY CATEGORY	SESISMIC IMPORTANCE FACTOR, I	SEISMIC IMPORTANCE FACTOR, I_p^2
ESSENTIAL FACILITIES	1.50	1.50
HAZARDOUS FACILITIES	1.25	1.50
SPECIAL OCCUPANCY STRUCTURES	1.00	1.00
STANDARD OCCUPANCY STRUCTURES	1.00	1.00
MISCELLANEOUS STRUCTURES	1.00	1.00

2. The limitation of Ip for panel connections in Section 208.7.2.3 shall be 1.0 for the entire connector

3. Structural observation requirements are given in Section 107.9

4. For anchorage of machinery and equipment required for life-safety systems, the value of Ip shall be taken as 1.5

208.4.3. Site Geology and Soil Characteristics

Each site shall be assigned a soil profile type based on properly substantiated geotechnical data using the site categorization procedure set forth in Section 208.4.3.1.1 and table 208-2

Exception:

When the soil properties are not known in sufficient detail to determine the soil profile type, **Type S_d** shall be used.

Soil Profile Type S_e or S_f need not be assumed unless the building official determines that Type S_e or S_f may be present at the site or in the event that Type S_e or S_f is established by geotechnical data.

TABLE 208-2: SOIL PROFILE TYPES

Soil Profile Type	Soil Profile Name/Generic Description	Average Soil Properties for Top 30m of Soil Profile		
		Shear Wave Velocity, V_s (m/s)	SPT, N (blows/300mm)	Undrained Shear Strength, S_U (kPa)
S_A	Hard Rock	> 1500		
S_B	Rock	760 to 1500		
S_C	Very Dense Soil and Soft Rock	360 to 760	> 50	> 100
S_D	Stiff Soil Profile	180 to 360	15 to 50	50 to 100
S_E [1]	Soft Soil Profile	< 180	< 15	< 50
S_F	Soil Requiring Site-specific Evaluation. (See Section 208.4.3.1)			

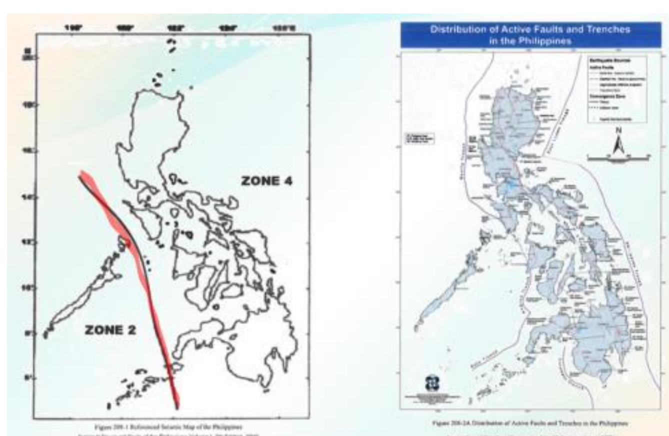
1 Soil Profile Type S_E also includes any soil profile with more than 3.0m of soft clay defined as a soil with plasticity index, PI>20, $w_{mc} \geq 40\%$ and s_u < 24 kPa. The Plasticity Index, PI and the moisture content, w_{mc} shall be determined in accordance with approved national standards.

208.4.4. SITE SEISMIC HAZARD CHARACTERISTICS

Seismic hazard characteristics for the site shall be established based on the seismic zone and proximity of the site to active seismic sources, site soil profile characteristics and the structure's importance factor.

208.4.4.1 SEISMIC ZONE

The Philippine Archipelago is divided into two seismic zones only. Zone 2 covers the provinces of Palawan (except Busuanga), Sulu and Tawi-Tawi while the rest of the country is under Zone 4 as shown in figure 208-1. Each structure shall be assigned a seismic zone factor Z, in accordance with Table 208-3.



PHIVOLCS FAULT FINDER

You can determine the distance from a known source using the link below:
http://faultfinder.phivolcs.dost.gov.ph/

Table 208-3: Seismic Zone Factor Z

Zone	2	4
Z	0.20	0.40

208.4.4.2 SEISMIC SOURCE TYPES

Table 208-4 defines the types of seismic sources. The location and type of seismic sources to be used for design shall be established based on approved geological data.

Type A sources shall be determined from figure 208-2B, 2C, 2D, 2E or the most recent mapping of active faults by the Philippine Institute of Volcanology and Seismology (PHIVOLCS)

Table 208-4: Seismic Sources Types

Seismic Source Type	Seismic Sources Description	Seismic Source Definition (Maximum Moment Magnitude, M)
A	Faults that are capable of producing large magnitude events and that have a high rate of seismic activity.	$7.0 \leq M \leq 8.4$
B	All faults other than Types A and C.	$6.5 \leq M < 7.0$
C	Faults that are not capable of producing large magnitude earthquakes and that have a relatively low rate of seismic activity.	$M < 6.5$

208.4.4.3. SEISMIC ZONE 4 NEAR SOURCE FACTOR

In Seismic Zone 4, each site shall be assigned near-source factors in accordance with Tables 208-5 and 208-6 based on the Seismic Source Type as set forth in Section 208.4.4.2.

For high rise structures and essential facilities within 2.0km of a major fault, a site specific seismic elastic design response spectrum is recommended to be obtained for the specific area.

TABLE 208-5: NEAR-SOURCE FACTOR N_a^1

SEISMIC SOURCE TYPE	CLOSEST DISTANCE TO KNOWN SEISMIC SOURCE		
	< 2 km	≤ 5 km	≥ 10 km
A	1.5	1.2	1.0
B	1.3	1.0	1.0
C	1.0	1.0	1.0

TABLE 208-6: NEAR-SOURCE FACTOR N_v^1

SEISMIC SOURCE TYPE	CLOSEST DISTANCE TO KNOWN SEISMIC SOURCE			
	< 2 km	≤ 5 km	10 km	>10km
A	1.5	1.6	1.2	1.0
B	1.3	1.2	1.0	1.0
C	1.0	1.0	1.0	1.0

1. The Near-Source Factor may be based on the linear interpolation of values for distances other than those shown in the table.

2. The closest distance to seismic source shall be taken as the minimum distance between the size and the area described by the vertical projection of the source on the surface. The surface projection need not include portions of the source at depths of 10km or greater. The largest value of the Near-Source Factor considering all sources shall be used for design.

The value of N_a used to determine C_a need not exceed 1.1 for structures complying with all the following conditions:

1. The soil profile type is SA , SB , SC , or SD

2. ρ = 1.0

3. Except in single storey structures, residential building accomodating 10 or fewer persons, private garages, carports, shed and agricultural buildings, moment frame systems designated as part of the lateral-forceresisting system shall be special moment-resisting frames.

4. The exceptions to Section 515.6.5 shall not apply, except for columns in one storey buildings or columns at the top storey of multi-storey buildings.

5. None of the following structural irregularities is present: Type 1, 4 or 5 of Table 208-9 and Type 1 or 4 of Table 208-10..

STEPS FOR IDENTIFYING SEISMIC LOADS

1. Determine the occupancy category of the structure to be analyzed.

Table 103-1. Occupancy Category

Occupancy Category	Occupancy or Function of Structure
I. Essential Facilities	• Occupancies having surgery and emergency treatment areas
	• Fire and police stations
	• Garages and shelters for emergency vehicles and emergency aircraft
	• Structures and shelters in emergency preparedness centers
	• Aviation control towers
	• Structures and equipment in communication centers and other facilities required for emergency response
	• Facilities for standby power-generating equipment for Category I structures
	• Public School buildings, Hospitals, Evacuation centers
	• Power and communication transmission lines
Occupancy Category	**Occupancy or Function of Structure**
II. Hazardous Facilities	• Occupancies and structures housing or supporting toxic or explosive chemicals or substances
	• Non-building structures storing, supporting or containing quantities of toxic or explosive substances
III Special Occupancy Structures	• Buildings with an assembly room with an occupant capacity of 1000 or more
	• Educational buildings such as museums, libraries, auditorium with a capacity of 300 or more occupants
	• Buildings used for college or adult education with a capacity of 500 or more occupants
	• Institutional buildings with 50 or more incapacitated patients, but not included in Category I
Occupancy Category	**Occupancy or Function of Structure**
II. Hazardous Facilities	• Occupancies and structures housing or supporting toxic or explosive chemicals or substances
	• Non-building structures storing, supporting or containing quantities of toxic or explosive substances
III Special Occupancy Structures	• Buildings with an assembly room with an occupant capacity of 1000 or more
	• Educational buildings such as museums, libraries, auditorium with a capacity of 300 or more occupants
	• Buildings used for college or adult education with a capacity of 500 or more occupants
	• Institutional buildings with 50 or more incapacitated patients, but not included in Category I
Occupancy Category	**Occupancy or Function of Structure**
III Special Occupancy Structures	• Mental hospitals, sanitariums, jails, prisons and other buildings where personal liberties of inmates are similarly restrained
	• Churches, Mosques, and other Religion Facilities
	• All structures with an occupancy of 5,000 or more persons
	• Structures and equipment in power-generating stations, and other public utility facilities not included in Category I or Category II, and required for continued operation.
IV Standard Occupancy Structures	• All structures housing occupancies or having functions not listed in Category I, II or III and Category V
V Miscellaneous Structures	• Private garages, carports, shed and fences over 1.5 m high

2. Determine the Seismic Importance Factors.

Table 208 – 1. Seismic Importance Factors

Occupancy Category	Seismic Importance Factors, I	Seismic Importance[2] Factors, I_p
I. Essential Facilities[3]	1.50	1.50
II. Hazardous Facilities	1.25	1.50
III. Special Occupancy Structures	1.00	1.00
IV. Standard Occupancy Structures	1.00	1.00
V. Miscellaneous Structures	1.00	1.00

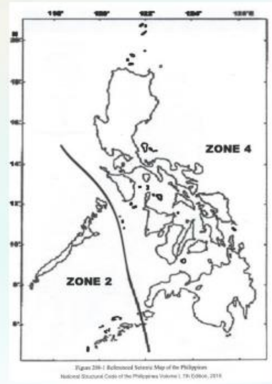
3. Determine the Soil Profile Type

Table 208 – 2. Soil Profile Types

Soil Profile Type	Soil Profile Name/Generic Description	Average Soil Properties for Top 30 m of Soil Profile		
		Shear Wave Velocity, $v_s\ (m/s)$	SPT, N (blows/300 mm)	Undrained Shear Strength, S_U (kPa)
S_A	Hard Rock	> 1500		
S_B	Rock	760 to 1500		
S_C	Very Dense Soil and Soft Rock	360 to 760	> 50	> 100
S_D	Stiff Soil Profile	180 to 360	15 to 50	50 to 100
S_E[1]	Soft Soil Profile	<180	< 15	< 50
S_F	Soil Requiring Site-specific Evaluation.			

4. Determine the Seismic Zone Factor

Table 208 – 3. Seismic Zone Factor



Zone	2	4
Z	0.2	0.4

5. Determine the Seismic Source Types

SST	Seismic Source Description	Seismic Source Definition
		Maximum Moment Magnitude, M
A	Faults that are capable of producing large magnitude events and that have a high rate of seismic activity.	$7.0 \le M \le 8.4$
B	All faults other than Types A and C.	$6.5 \le M < 7.0$
C	Faults that are uncapable of producing large magnitude earthquakes and that have a relatively low rate of seismic activity.	$M < 6.5$

6. Determine the Seismic Zone 4 Near-Source Factors

Table 208 – 5. Near-Source Factor N_a[1]

Seismic Source Type	Closest Distance To Known Seismic Source[2]		
	$\le 2\ km$	$\le 5\ km$	$\ge 10\ km$
A	1.5	1.2	1.0
B	1.3	1.0	1.0
C	1.0	1.0	1.0

Table 208 – 6. Near-Source Factor N_v[1]

Seismic Source Type	Closest Distance To Known Seismic Source[2]			
	$\le 2\ km$	$5\ km$	$10\ km$	$\ge 15\ km$
A	2.0	1.6	1.2	1.0
B	1.6	1.2	1.0	1.0
C	1.0	1.0	1.0	1.0

7. Determine the Seismic Coefficient, Ca

Table 208 – 7. Seismic Coefficient, C_a

Soil Profile Type	Seismic Zone Z	
	$Z = 0.2$	$Z = 0.4$
S_A	0.16	$0.32N_a$
S_B	0.20	$0.40N_a$
S_C	0.32	$0.40N_a$
S_D	0.40	$0.44N_a$
S_E	0.64	$0.44N_a$
S_F	Site-specific geotechnical investigation and dynamic site response analysis shall be performed to determine seismic coefficients	

8. Determine the Seismic Coefficient, Cv

Table 208 – 8. Seismic Coefficient, C_v

Soil Profile Type	Seismic Zone Z	
	$Z = 0.2$	$Z = 0.4$
S_A	0.16	$0.32N_v$
S_B	0.20	$0.40N_v$
S_C	0.32	$0.56N_v$
S_D	0.40	$0.64N_v$
S_E	0.64	$0.96N_v$
S_F	Site-specific geotechnical investigation and dynamic site response analysis shall be performed to determine seismic coefficients	

9. Calculate the Structure Period

$$T = C_T(h_n)^{0.75}$$

C_t =**0.0853** for steel moment-resisting frames

C_t=**0.0731** for reinforced concrete moment-resisting frames and eccentrically braced frames

C_t=**0.0488** for all other buildings

10. Calculate the Response Modification Factor based on Table 208- 11A of NSCP 2015.

CONCRETE

Table 208-11A Earthquake-Force-Resisting Structural Systems of Concrete

Basic Seismic-Force Resisting System	R	Ω_o	System Limitation and Building Height Limitation by Seismic Zone, m	
			Zone 2	Zone 4
A. Bearing Wall Systems				
• Special reinforced concrete shear walls	4.5	2.8	NL	50
• Ordinary reinforced concrete shear walls	4.5	2.8	NL	NP
B. Building Frame Systems				
• Special reinforced concrete shear walls or braced frames (shear walls)	5.0	2.8	NL	75
• Ordinary reinforced concrete shear walls or braced frames	5.6	2.2	NL	NP
• Intermediate precast shear walls or braced frames	5.0	2.5	NL	10
C. Moment-Resisting Frame Systems				
• Special reinforced concrete moment frames	8.5	2.8	NL	NL
• Intermediate reinforced concrete moment frames	5.5	2.8	NL	NP
• Ordinary reinforced concrete moment frames	3.5	2.8	NL	NP
D. Dual Systems				
• Special reinforced concrete shear walls	8.5	2.8	NL	NL
• Ordinary reinforced concrete shear walls	6.5	2.8	NL	NP
E. Dual System with Intermediate Moment Frames				
• Special reinforced concrete shear walls	6.5	2.8	NL	50
• Ordinary reinforced concrete shear walls	5.5	2.8	NL	NP
• Shear wall frame interactive system with ordinary reinforced concrete moment frames and ordinary reinforced concrete shear walls	4.2	2.8	NP	NP
F. Cantilevered Column Building Systems				
• Cantilevered column elements	2.2	2.0	NL	10
G. Shear Wall- Frame Interaction Systems	5.5	2.8	NL	50

STEEL

Table 208-11B Earthquake-Force-Resisting Structural Systems of Steel

Basic Seismic-Force Resisting System	R	Ω_o	System Limitation and Building Height Limitation by Seismic Zone, m	
			Zone 2	Zone 4
A. Bearing Wall Systems				
• Light steel-framed bearing walls with tension-only bracing	2.8	2.2	NL	20
• Braced frames where bracing carries gravity load	4.4	2.2	NL	50
• Light framed walls sheathed with steel sheets structural panels rated for shear resistance or steel sheets	5.5	2.8	NL	20
• Light-framed walls with shear panels of all other light materials	4.5	2.8	NL	20
• Light-framed wall systems using flat strap bracing	2.8	2.2	NL	NP
B. Building Frame Systems				
• Steel eccentrically braced frames (EBF), moment-resisting connections at columns away from links	8.0	2.8	NL	30
• Steel eccentrically braced frames (EBF), non-moment-resisting connections at columns away from links	6.0	2.2	NL	30
• Special concentrically braced frames (SCBF)	6.0	2.2	NL	30
• Ordinary concentrically braced frames (OCBF)	3.2	2.2	NL	NP
• Light-framed walls sheathed with steel sheet structural panels / sheet steel panels	6.5	2.8	NL	20
• Light frame walls with shear panels of all other materials	2.5	2.8	NL	NP
• Buckling-restrained braced frames (BRBF), non-moment-resisting beam-column connection	7.0	2.8	NL	30
• Buckling-restrained braced frames, moment-resisting beam-column connections	8.0	2.8	NL	30
• Special steel plate shear walls (SPSW)	7.0	2.8	NL	30

11. Calculate the Design Base Shear

The total design base shear in a given direction shall be determined from the following equation:

$$V = \frac{C_v I}{RT} W \ (MAXIMUM)$$

The total design base shear need not exceed the following:

$$V = \frac{2.5 C_a I}{R} W \ (MAXIMUM)$$

The total design base shear shall not be less than the following:

$$V = 0.11 C_a I \ (MINIMUM)$$

In addition, for Seismic Zone 4, the total base shear shall also not be less than the following:

$$V = \frac{0.8 Z N_v I}{R} W \ (MINIMUM)$$

12. Distribute the force vertically

$$V = F_t + \sum_{i=1}^{n} F_i$$

$$F_t = 0.07TV$$

$$F_t = 0.25V \ (should\ not\ exceed)$$

• F_t need not exceed **0.25V** and may be considered as zero **where T is 0.7** s or less. The remaining portion of the base shear shall be distributed over the height of the structure

$$F_x = \frac{(V - F_t) w_x h_x}{\sum_{i=1}^{n} w_i h_i}$$

KEY ANSWER REVIEWER (KAHOOT):

NSCP stands for?

ANSWER: NATIONAL STRUCTURAL CODE OF THE PHILIPPINES

What is intensity V in Rossi-Forrel Scale?

ANSWER: Shock of Moderate Intensity

It occurs when loosely packed sediments near the ground surface lose their strength in response to strong ground shaking.

ANSWER: Liquefaction

What is the meaning of PHIVOLCS?
ANSWER: Philippine Institute of Volcanology and Seismology

Who is the Director of PHIVOLCS?
ANSWER: Dr. Renato Solidum Jr.

Philippines have 4 seismic zones.
ANSWER: False

What is the 2nd "S" in USGS?
"ANSWER: Survey" - United States Geological Survey

The highest magnitude earthquake in the Philippines occur in the year? **ANSWER: 1924**

The highest recorded magnitude earthquake since the 1900s is? **ANSWER: 1960 Chile Earthquake**

It is a ground shaking caused by sudden slip on a fault, volcanic activity or other sudden stress changes in the earth.

ANSWER: Earthquake

It is a point on the earth's surface vertically above the point in the crust where a seismic rupture nucleates.
ANSWER: Epicenter

It is a path along the Pacific Ocean characterized by active volcanoes and frequent earthquakes.
ANSWER: Pacific Ring of fire

In Geography, where is Mt. St. Helens Located?

ANSWER: Washington

San Andreas fault is located in?
ANSWER: California

On average, how many earthquakes does the Philippines experiencing in a year?
ANSWER: 2000

On average, how many earthquakes are recorded worldwide every year?
ANSWER: 500,000

How many soil profile types are listed in the NSCP?
ANSWER: 6

How many seismic zones in the Philippines?
ANSWER: 2

What Chapter in the NSCP can you find the Earthquake Loads?
ANSWER: Chapter 2

The Following are under the seismic zone 2, except:
ANSWER: Basilan

The highest magnitude earthquake recorded in 2021 is a magnitude 8.2 earthquake. Name this seismic event.
ANSWER: 2021 Chignik, Alaska Earthquake

The highest recorded earthquake in the Philippines in 2021 is a 7.1 magnitude earthquake last August 11 occurred in?
ANSWER: Davao Oriental

The fault line that is traversing Metro Manila is known as ____ except:
ANSWER: Philippine Fault System

This even struck the island of Luzon with an estimated magnitude of 7.8 occurred on?

ANSWER: July 1990

In Rossi-Forrel Scale, it is described to be felt generally by everyone with disturbance of furniture.

ANSWER: Shock of Moderate Intensity

It is the structural level at which earthquake movements are anticipated to be transmitted to the structure.

ANSWER: Base

It is the total design lateral force or shear at the base of a structure.
ANSWER: Base Shear

It is a factor that accounts for the degree of hazard to human life and damage to property.
ANSWER: Importance Factor

These are loads produced by the use and occupancy of the building and do not include construction loads.
ANSWER: Live Load

These are forcing those results from the weight of all building materials, occupants and their environmental effects.
ANSWER: Loads

It is a frame in which members and joints are capable of resisting forces primarily by flexure.

ANSWER: MRF

It is designed to resist lateral forces parallel to the plane of the wall. **ANSWER: Shear Wall**

Storey is the space between levels. **ANSWER: True**

Storey moment is the summation of design lateral forces above the storey under consideration. **ANSWER: False**

Amplitude N-S comp. = 8000, epicentral distance = 120 km, find the local magnitude. **ANSWER: 4.1 Magnitude**

It is the first step in earthquake hazard assessment.
ANSWER: Identifying nearby seismic sources

The simplified static lateral force procedure may be used for Occupancy Category IV only.

ANSWER: False

Simplified static force procedure may be used for buildings not more than 2 storeys in height including the basements. **ANSWER: False**

When the soil is not known for the simplified static procedure, which soil type should be used in seismic zone 4?

ANSWER: D

When the soil is not known for the simplified static procedure, which soil type should be used in seismic zone 2?
ANSWER: E

In zone 4, the Na should not be greater than 1.2 if none of the ff. irregularities are present: Vert. Irreg Type 1, 4, & 5.
ANSWER: True

Which of the following is NOT under Occupancy Category 1?
ANSWER: Mental Hospitals

Occupancy Category 1 is described as:
ANSWER: Essential Facilities

The FEU Tech and FEU Alabang Building is Occupancy Category 1.
ANSWER: False

Structures with a total occupancy of 2000 persons is under Special Occupancy Structures.

ANSWER: False

Miscellaneous structures include private garages, sheds, and carports. **ANSWER: True**

What is the seismic importance factor for Occupancy Category 3? **ANSWER: 1.00**

For static force procedure, if the soil is not known in sufficient detail, what soil type should be used? **ANSWER: D**

It is a soil profile described as very dense soil and soft rock. **ANSWER: C**

Soil Type B has a shear wave velocity ranging from 760 to 1500 m/s. **ANSWER: True**

Philippines has 4 seismic zones. **ANSWER: False**

Jolo, Sulu is under Seismic Zone 2. **ANSWER: True**

Busuanga, Palawan is under Seismic Zone 2.
ANSWER: False

There are 2 seismic source types. **ANSWER: False**

It is the seismic source type capable of producing Magnitude 7 earthquake. **ANSWER: A**

Type D faults are not capable of producing large magnitude earthquakes and have low rate of seismic activity. **ANSWER: False**

If the distances other than those shown in the table is given, the near source factor can be calculated using _______.

ANSWER: Linear Interpolation

Near Source factor Na and Nv is based on the seismic source type and distance to the known seismic source.
ANSWER: True

The value of seismic coefficient Ca is based on the soil profile type and seismic zone factor.
ANSWER: True

What is the value of Ct for a composite structure made up of reinforced concrete and steel MRFs? **ANSWER: 0.0488**

There are three methods for solving the structural period. **ANSWER: False**

The value of T using method B shall not exceed 35% greater than T obtained using Method A. **ANSWER: False**

What is the value of the force at the top if V = 1000 kN and T = 3.8 sec? **ANSER: 250 kN**

The value for the force at the top if T is equal to 0.7 sec is not equal to zero. **ANSWER: False**

The Fx in each level of the structure is applied over the area of the building in using the mass distribution at that lvl.
ANSWER: True

For the calculation of T of a structure, basement heights were included. **ANSWER: False**

Roof penthouses are generally not considered in determining hn for T calculations, but heights of setbacks are included.
ANSWER: True

The simplified static procedure is a more conservative approach than the static procedure.
ANSWER: True

The R value used for the orthogonal direction cannot be greater than that for the bearing wall system.
ANSWER: True

When a combi. of struct. systems is used in the same direction, the value of R < least value of utilized in the system.
ANSWER: True

MODULE #1

SAMPLE PROBLEM #1

Estimate the local magnitude of a southern California earthquake recorded in two perpendicular directions at several stations using standard Wood–Anderson seismographs. The trace amplitudes and epicentral distances are as follows (Richter, 1958):

Station	Amplitude on the Seismograph, A (μm) N–S Component	E–W Component	Epicentral Distance, Δ (km)
1	8400	6000	114
2	7900	8500	179
3	24,500	30,000	90
4	8100	7000	246

SOLUTION:

FOR STATION #1:

$$\boldsymbol{M_{L_{N-S}}} = \log_{10} A_{N-S} + 2.56 \log_{10} \Delta_{N-S} - 5.12$$

$$\boldsymbol{M_{L_{N-S}}} = \log_{10}(8400) + 2.56 \log_{10}(114) - 5.12$$

$$\boldsymbol{M_{L_{N-S}} = 4.0699}$$

$$\boldsymbol{M_{L_{E-W}}} = \log_{10} A_{E-W} + 2.56 \log_{10} \Delta_{E-W} - 5.12$$

$$\boldsymbol{M_{L_{E-W}}} = \log_{10}(6000) + 2.56 \log_{10}(114) - 5.12$$

$$\boldsymbol{M_{L_{E-W}} = 3.92}$$

$$\boldsymbol{M_{L1}} = \frac{4.07 + 3.92}{2} = \boldsymbol{4.0}$$

FOR STATION #2:

$$\boldsymbol{M_{L_{N-S}}} = \log_{10} A_{N-S} + 2.56 \log_{10} \Delta_{N-S} - 5.12$$

$$\boldsymbol{M_{L_{N-S}}} = \log_{10}(7900) + 2.56 \log_{10}(179) - 5.12$$

$$\boldsymbol{M_{L_{N-S}} = 4.54}$$

$$\boldsymbol{M_{L_{E-W}}} = \log_{10} A_{E-W} + 2.56 \log_{10} \Delta_{E-W} - 5.12$$

$$\boldsymbol{M_{L_{E-W}}} = \log_{10}(8500) + 2.56 \log_{10}(179) - 5.12$$

$$\boldsymbol{M_{L_{E-W}} = 4.58}$$

$$\boldsymbol{M_{L2}} = \frac{4.54 + 4.56}{2} = \boldsymbol{4.6}$$

FOR STATION #3:

$$\boldsymbol{M_{L_{N-S}}} = \log_{10} A_{N-S} + 2.56 \log_{10} \Delta_{N-S} - 5.12$$

$$\boldsymbol{M_{L_{N-S}}} = \log_{10}(24500) + 2.56 \log_{10}(90) - 5.12$$

$$\boldsymbol{M_{L_{N-S}} = 4.27}$$

$$\boldsymbol{M_{L_{E-W}}} = \log_{10} A_{E-W} + 2.56 \log_{10} \Delta_{E-W} - 5.12$$

$$\boldsymbol{M_{L_{E-W}}} = \log_{10}(3000) + 2.56 \log_{10}(90) - 5.12$$

$$\boldsymbol{M_{L_{E-W}} = 4.36}$$

$$\boldsymbol{M_{L3}} = \frac{4.27 + 4.36}{2} = \boldsymbol{4.3}$$

FOR STATION #4:

$$\boldsymbol{M_{L_{N-S}}} = \log_{10} A_{N-S} + 2.56 \log_{10} \Delta_{N-S} - 5.12$$

$$\boldsymbol{M_{L_{N-S}}} = \log_{10}(8100) + 2.56 \log_{10}(246) - 5.12$$

$$\boldsymbol{M_{L_{N-S}} = 4.91}$$

$$\boldsymbol{M_{L_{E-W}}} = \log_{10} A_{E-W} + 2.56 \log_{10} \Delta_{E-W} - 5.12$$

$$\boldsymbol{M_{L_{E-W}}} = \log_{10}(7000) + 2.56 \log_{10}(246) - 5.12$$

$$\boldsymbol{M_{L_{E-W}} = 4.85}$$

$$\boldsymbol{M_{L3}} = \frac{4.91 + 4.85}{2} = \boldsymbol{4.9}$$

$$\boldsymbol{M_{L}} = \frac{4.0 + 4.6 + 4.3 + 4.9}{4}$$

$$\boldsymbol{M_{L} = 4.5}$$

PROBLEM #2

Estimate the seismic moment and moment magnitude of the January 12, 2010 Haiti earthquake. It is estimated that the blind thrust fault (the slip plane ends before reaching the earth's surface) caused an average strike-slip displacement of 2 m over an area equal to 30 km long by 15 km deep (Eberhard et al. 2010). Assume that the rock along the fault has an average shear rigidity of 3.2 × 1011 dyne/cm2.

SOLUTION:

Determine the fault's rupture area Af and fault slip, Ds in consistent units.

FAULT RUPTURE AREA

$$A_f = (30x10^5 cm)(15x10^5 cm)$$

$$\boldsymbol{A_f = 4.5x10^{12} cm^2}$$

FAULT SLIP

$$\boldsymbol{D_s = 2\ m = 200\ cm}$$

2. Determine the seismic moment M_O

$$M_o = GA_fD_s$$

$$M_o = \left(3.2x10^{11}\frac{Dyne}{cm}\right)(4.5x10^{12}cm^2)(200\ cm)$$

$$\boldsymbol{M_o = 2.88x10^{26} dyne - cm}$$

3. Determine the moment magnitude $\boldsymbol{M_w}$

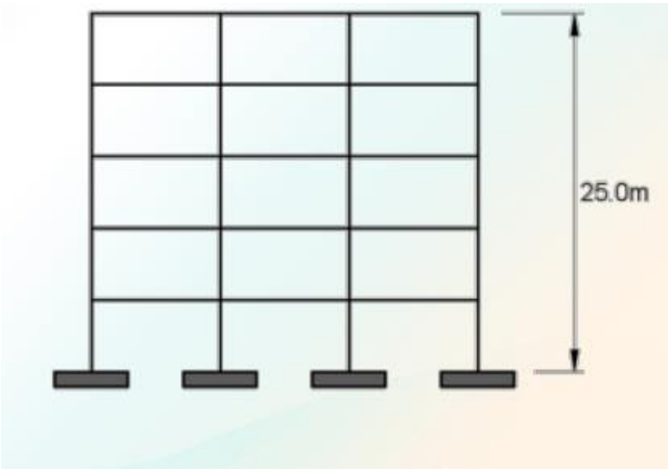
$$\boldsymbol{M_w} = \frac{2}{3}log_{10}M_o - 10.7$$

$$\boldsymbol{M_w} = \frac{2}{3}log_{10}(2.88x10^{26}) - 10.7$$

$$\boldsymbol{M_w = 6.94}$$

PROBLEM 1: BASE SHEAR COMPUTATION

Determine the design base shear for a five-storey concrete special moment resisting frame building. The following information is given:



Zone 4, Z = 0.4

Seismic Source Type: Type A

Distance to Seismic Source = 10km

Soil Profile Type = Sc

I = 1.0

R = 8.5

W = 7300 Kn

METHOD A:

A. SOLVE FOR THE STRUCTURE PERIOD

$$T = C_T(h_n)^{0.75}$$

C_t**=0.0731** for reinforced concrete moment-resisting frames and eccentrically braced frames

$$T = (0.0731)(25.0)^{0.75}$$

$$\boldsymbol{T = 0.817\ seconds}$$

$$\boldsymbol{if\ T > 0.7\ sec, therefore; F_t \neq 0}$$

B. FIND THE NEAR SOURCE FACTOR N_a and N_v

Table 208 – 5. Near-Source Factor N_a [1]

Seismic Source Type	Closest Distance To Known Seismic Source[2]		
	$\leq 2\ km$	$\leq 5\ km$	$\geq 10\ km$
A	1.5	1.2	1.0
B	1.3	1.0	1.0
C	1.0	1.0	1.0

Table 208 – 6. Near-Source Factor N_v [1]

Seismic Source Type	Closest Distance To Known Seismic Source[2]			
	$\leq 2\ km$	$5\ km$	$10\ km$	$\geq 15\ km$
A	2.0	1.6	1.2	1.0
B	1.6	1.2	1.0	1.0
C	1.0	1.0	1.0	1.0

$$\boldsymbol{N_a = 1.0 \quad N_v = 1.2}$$

C. DETERMINE THE SEISMIC COEFFICIENT C_a and C_v

Table 208 – 7. Seismic Coefficient, C_a

Soil Profile Type	Seismic Zone Z	
	$Z = 0.2$	$Z = 0.4$
S_A	0.16	$0.32N_a$
S_B	0.20	$0.40N_a$
S_C	0.32	$0.40N_a$
S_D	0.40	$0.44N_a$
S_E	0.64	$0.44N_a$
S_F	Site-specific geotechnical investigation and dynamic site response analysis shall be performed to determine seismic coefficients	

$$C_a = 0.40(N_a)$$

$$\boldsymbol{C_a} = 0.40(1.0) = \boldsymbol{0.40}$$

$$\boldsymbol{C_a = 0.40}$$

Table 208 – 8. Seismic Coefficient, C_v

Soil Profile Type	Seismic Zone Z	
	$Z = 0.2$	$Z = 0.4$
S_A	0.16	$0.32N_v$
S_B	0.20	$0.40N_v$
S_C	0.32	$0.56N_v$
S_D	0.40	$0.64N_v$
S_E	0.64	$0.96N_v$
S_F	Site-specific geotechnical investigation and dynamic site response analysis shall be performed to determine seismic coefficients	

$$C_v = 0.56(N_v)$$

$$\boldsymbol{C_a} = 0.56(1.2) = \boldsymbol{0.672}$$

$$\boldsymbol{C_a = 0.672}$$

D. DETERMINE THE BASE SHEAR

$$\boldsymbol{V_1 = \frac{C_v I}{RT} W\ (MAXIMUM)}$$

$$\boldsymbol{V_1} = \frac{(0.672)(1.0)}{(8.5)(0.817)}(7300)$$

$$\boldsymbol{V_1 = 706.401\ kN}$$

$$\boldsymbol{V_2 = \frac{2.5 C_a I}{R} W\ (MAXIMUM)}$$

$$\boldsymbol{V_2} = \frac{2.5(0.40)(1.0)}{8.5}(7300)$$

$$\boldsymbol{V_2 = 858.824\ kN}$$

$$\boldsymbol{V_3 = 0.11 C_a I W\ (MINIMUM)}$$

$$\boldsymbol{V_3} = 0.11(0.40)(1.0)(7300)$$

$$\boldsymbol{V_3 = 321.2\ kN}$$

$$\boldsymbol{V_4 = \frac{0.8 Z N_v I}{R} W\ (MINIMUM)}$$

$$\boldsymbol{V_4} = \frac{0.8(0.4)(1.2)(1.0)}{8.5}(7300)$$

$$\boldsymbol{V_4 = 329.788\ kN}$$

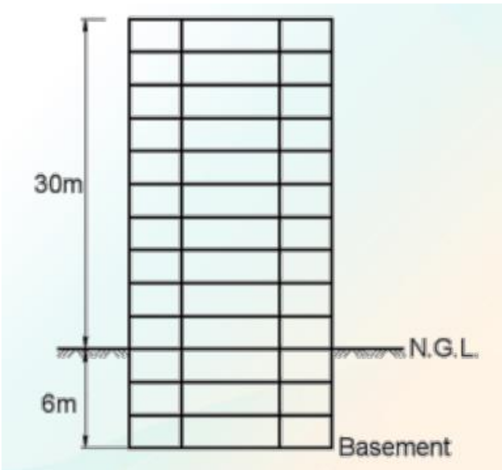
$$\boldsymbol{THEREFORE:}$$

$$\boldsymbol{V = 706.401\ kN}$$

PROBLEM # 2

Determine the period for each of the structure shown below using Method A

Method A period calculations involves the following expression:



1.) Steel special moment-resisting frame structure

The height of the structure above its base is 30m with a basement 6m from the ground levels.

The height below the ground will not be included in determining $\boldsymbol{h_n}$ for calculating the period T.

SOLUTION:

$$T = C_T(h_n)^{0.75}$$

$\boldsymbol{C_t}$ =**0.0853** for steel moment-resisting frames

$$T = (0.0853)(30)^{0.75}$$

$$\boldsymbol{T = 1.09\ sec}$$

2.) Concrete special moment-resisting frame structure

The height of the tallest part of the building is 12meters. Roof Penthouses are generally not considered in determining $\boldsymbol{h_n}$ for period calculations, but heights of setbacks are included.

$$T = C_T(h_n)^{0.75}$$

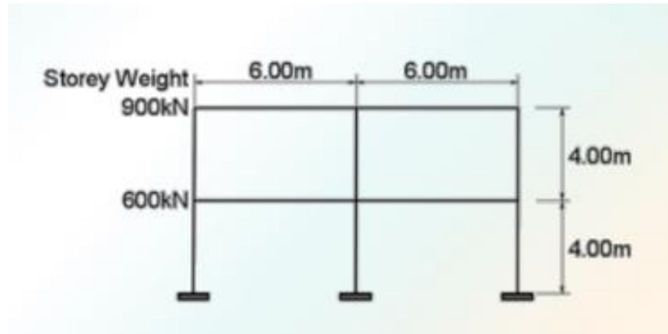
$\boldsymbol{C_t}$=**0.0731** for reinforced concrete moment-resisting frames and eccentrically braced frames

$$T = (0.0731)(12)^{0.75}$$

$$\boldsymbol{T = 0.471\ sec}$$

PROBLEM # 3

Determine the base shear and the design lateral forces for a two-storey reinforced SMRF office building using the ***simplified design base shear*** given the following information:



Zone 4, Z = 0.4
Seismic Source Type C
Soil Profile Type = unknown
R = 8.5
W = 1500 kN

SOLUTION: (SIMPLIFIED DESIGN BASE SHEAR)

1. **Check the applicability of the simplified method**

   The simplified static lateral-force procedure may be used for the following structures of Occupancy Category IV or V.

   a. Buildings of any occupancy (including single-family dwellings) not more than three storeys in height excluding basements, that use light frame construction.

   b. Other buildings not more ***than two stories in height excluding basements.***

   $\boldsymbol{Therefore: can\ use\ simplified\ design\ method}$

2. **Determine Base Shear**

   -Since soil properties are not known, the suggested ***soil profile type*** $\boldsymbol{S_D}$ shall be used per NSCP Section 208.4.3

Table 208 – 5. Near-Source Factor N_a[1]

Seismic Source Type	Closest Distance To Known Seismic Source[2]		
	$\le 2\ km$	$\le 5\ km$	$\ge 10\ km$
A	1.5	1.2	1.0
B	1.3	1.0	1.0
C	1.0	1.0	1.0

$$N_a = 1.0\ (Type\ C)$$

Table 208 – 7. Seismic Coefficient, C_a

Soil Profile Type	Seismic Zone Z	
	$Z = 0.2$	$Z = 0.4$
S_A	0.16	$0.32N_a$
S_B	0.20	$0.40N_a$
S_C	0.32	$0.40N_a$
S_D	0.40	$0.44N_a$
S_E	[illegible]	[illegible]
S_F	Site-specific geotechnical investigation and dynamic site response analysis shall be performed to determine seismic coefficients	

$$C_a = 0.44N_a = 0.44(0.1)$$

$$C_a = 0.44$$

COMPUTE FOR DESIGN BASE SHEAR (SIMPLIFIED)

$$V = \frac{3.0C_a}{R}W$$

$$V = \frac{3.0(0.44)}{8.5}(1500)$$

$$V = 232.941\ kN$$

DETERMINE THE LATERAL FORCE AT EACH LEVEL

$$F_x = \frac{3.0C_a}{R}W_x$$

$$F_1 = \frac{3.0(0.44)}{8.5}(600)$$

$$F_1 = 93.176\ kN$$

$$F_2 = \frac{3.0(0.44)}{8.5}(900)$$

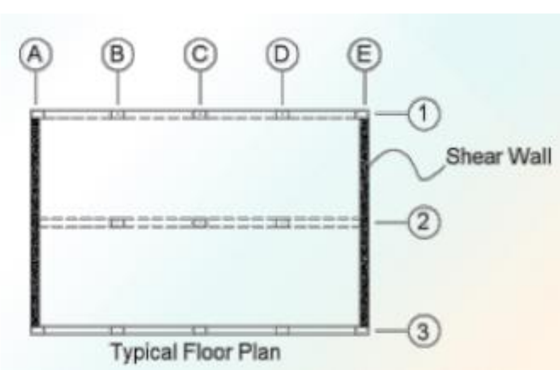
$$F_1 = 139.765\ kN$$

PROBLEM #4

This example illustrates determination of R values for a building that has different structural systems along different axes (i.e., directions) of the building.

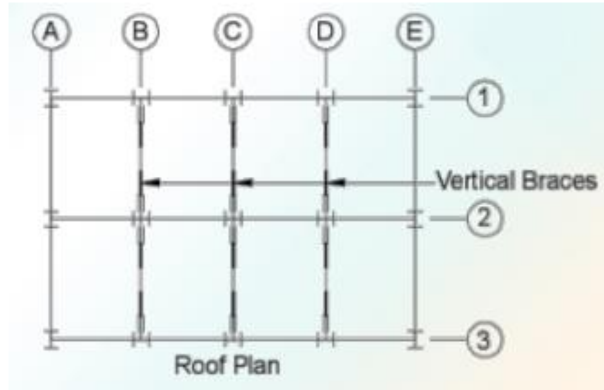
In this example, a 3-storey building has concrete shear walls in one direction and concrete moment frames in the other. Floors are concrete slab, and the building is located in Zone 4.

Determine the R value for each direction.



- Lines A and E are reinforced concrete bearing walls: **R = 4.5**
- Lines 1,2 and 3 are concrete special moment-resisting frames: **R=8.5**

PROBLEM #5



Occasionally, it is necessary to have different structural systems in the same direction. This example shows how the R value is determined in such a situation.

One-storey steel frame structure has the roof plan shown below. The structure is located in Zone 4. **Determine the R value for the N/S direction.**

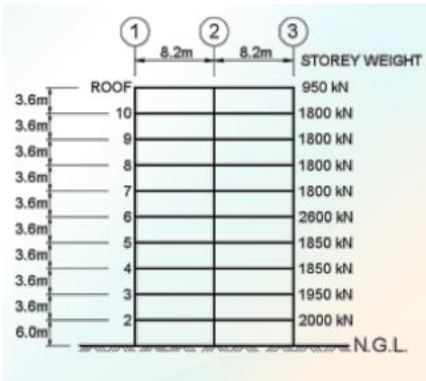
1. Determine the R value for N/S Direction

When a combination of structural systems is used in the same direction, NSCP Section 208.5.4.3 requires that the value of R used be not greater than the least value of the system utilized.

$Use\ R\ =\ 4.5$ for the entire structure.

PROBLEM #6

A 10 Storey building has a moment resisting steel frame for a lateral force-resisting system. Find the vertical distribution of lateral forces Fx. The following information is given:



- Zone 4
- W = 18,400 kN
- Cv = 0.56
- R = 8.5
- I = 1.0
- T = 1.32 sec
- V = 918.4 Kn

SOLUTION

1. Determine Ft

This is the concentrated forc applied at the top of the structure. It is determined as follows. First, check that Ft is not zero.

$$\boldsymbol{T} = 1.32\,\text{sec} > 0.7\,sec$$

$$\therefore \boldsymbol{F_1 \neq 0}$$

$$\boldsymbol{F_1 = 0.07TV}$$

$$\boldsymbol{F_1} = 0.07(1.32)(918.4)$$

$$\boldsymbol{F_1 = 84.86\ kN}$$

$$\therefore \boldsymbol{Check\ if\ F_1\ is\ less\ than\ 0.25\ V}$$

$$0.25V = 0.25(918.4)$$

$$0.25V = \boldsymbol{229.6}$$

$$\therefore \boldsymbol{F_t < 0.25V - OK}!$$

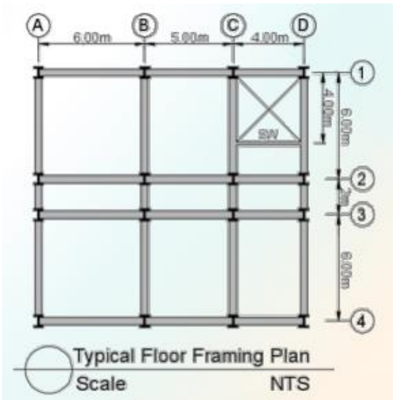
2. Find Fx at each level.

			V	918.4	
			FT	84.86	
LEVEL	Wx	Hx	Wx*Hx	/x*Hx/SUM (Wx*H	Fx
ROOF	950	38.4	36480	0.094161375	163.3472727
10	1800	34.8	62640	0.161684993	134.7709091
9	1800	31.2	56160	0.144958959	120.8290909
8	1800	27.6	49680	0.128232926	106.8872727
7	1800	24	43200	0.111506892	92.94545455
6	2600	20.4	53040	0.136905684	114.1163636
5	1850	16.8	31080	0.080223014	66.86909091
4	1850	13.2	24420	0.063032368	52.54
3	1950	9.6	18720	0.048319653	40.27636364
2	2000	6	12000	0.030974137	25.81818182
			387420		918.4
			SUM		sum

MODULE 3: CENTER OF MASS, RIGIDITY AND ECCENTRICITIES

EXAMPLE #1 – DEAD LOAD (STEEL STRUCTURE)

A sample set of plans were presented in the figure. Using the following minimum design loads from the NSCP:



A. Dead Load (DL)

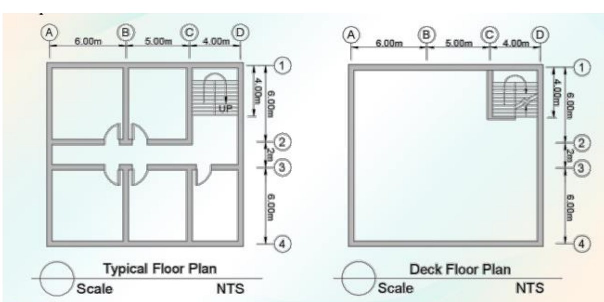
a. **0.125m THK slab** = 3.00 kPa
b. **0.050m THK Lean Concrete** = 1.20 kPa
c. **Marble** = 1.58 kPa
d. **Gypsum Board =** 0.04 kPa
e. **Suspended Steel Chanel** = 0.10 kPa
f. **Beam/Column** = 1.00 kPa

$W_{walls/parapet}$ = 2.70 kPa
Height of Walls & Parapet = 3.6m/1.5m

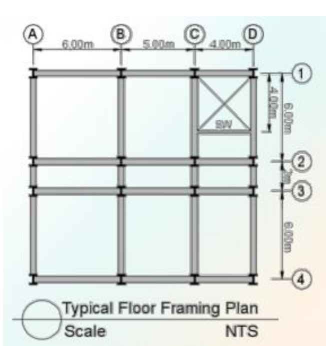
1. **COMPUTE FOR TOTAL LOADS**

$$DL_{Total} = 3.0 + 1.2 + 1.58 + 0.04 + 0.1 + 1.0$$
$$\boldsymbol{DL_{Total} = 6.92\ kPa}$$
$$\boldsymbol{*\ w/o\ movable\ partition}$$

$$\boldsymbol{+1.00\ kpa\ (m.p)}$$
$$\boldsymbol{DL_{Total} = 7.92\ kPA\ (with\ m.p)}$$



2. **SOLVE FOR THE TRIBUTARY AREA**



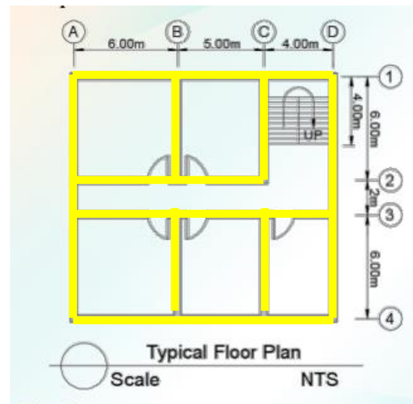
$$\boldsymbol{T.A = EW(NS)}$$
$$T.A = 15(14) = \boldsymbol{210\ m^2}$$

3. **SOLVE FOR THE W_{DL}**

$$\boldsymbol{W_{DL} = DL * T.A}$$
$$W_{DL} = 6.92 \frac{kN}{m2} * 210\ m^2$$
$$\boldsymbol{W_{DL} = 1453.2\ kN}$$

4. **SOLVE FOR THE PERIMETER OF THE WALLS**

- **TYPICAL LEVELS**



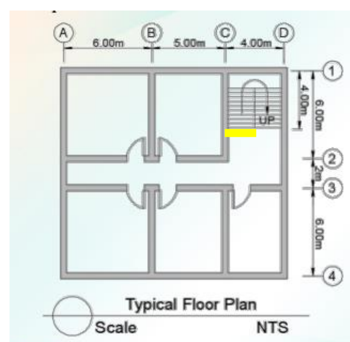
$$\boldsymbol{P} = 15 + 14 + 15 + 14 + 11 + 15 + 6(4)$$
$$\boldsymbol{P = 108\ m}$$

5. **SOLVE FOR THE WEIGHTS OF THE WALL**

- **TYPICAL LEVELS**

$$\boldsymbol{W_{wall} = 2.70(H_{wall})(P)}$$
$$\boldsymbol{W_{wall}} = 2.70(3.6)(108)$$
$$\boldsymbol{W_{wall} = 1049.76\ kN}$$

6. **SOLVE FOR THE WEIGHT OF THE PARAPET**

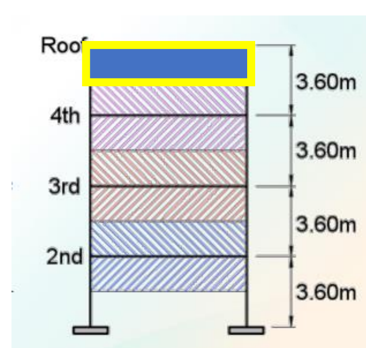


- **TYPICAL LEVEL**

$$\boldsymbol{W_{PAR} = 2.70(H_{PAR})(P_{PAR})}$$
$$W_{PAR} = 2.70(1.50)(2.0)$$
$$\boldsymbol{W_{PAR} = 8.1\ kN}$$

7. **SOLVE FOR THE WEIGHT OF THE WALLS**

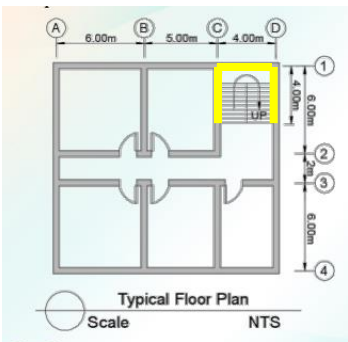
- **BELOW DECK LEVEL**



$$\boldsymbol{W_{WALL\ BELOW\ DECK} = 2.7(H_{BELOW\ DECK})(P_{typ})}$$
$$\boldsymbol{W_{WALL\ BELOW\ DECK} = 2.7(1.8)(108)}$$
$$\boldsymbol{W_{WALL\ BELOW\ DECK} = 524.88\ kN}$$

8. **SOLVE FOR THE PERIMETER OF THE WALLS**

- **DECK LEVEL**



$$P_{WALL} = 4 + 4 + 4$$

$$\boldsymbol{P_{wall} = 12\ m}$$

9. **WEIGHT OF WALLS @ DECK LEVEL**

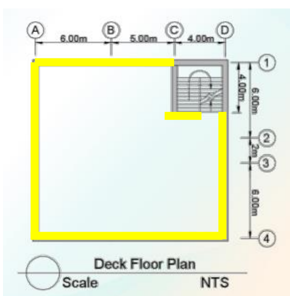
$$\boldsymbol{W_{WALL} = 2.7(H_{deck})(P_{wall})}$$

$$\boldsymbol{W_{wall} = 2.7(3.6)(12)}$$

$$\boldsymbol{W_{wall} = 116.64\ kN}$$

10. **PERIMETER OF PARAPET**

- **DECK LEVEL**



$$\boldsymbol{P_{PAR}} = 11 + 14 + 15 + 10 + 2$$

$$\boldsymbol{P_{PAR} = 52\ m}$$

11. WEIGHT OF PARAPET

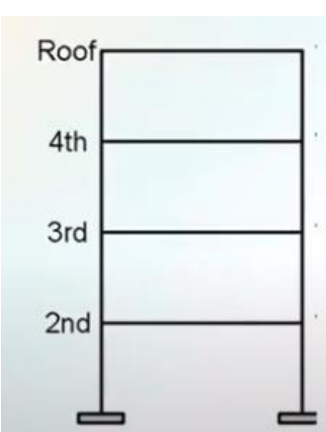
- **DECK LEVEL**

$$\boldsymbol{W_{PAR} = 2.7(H_{par})(P_{par})}$$

$$\boldsymbol{W_{PAR} = 2.7(1.5)(52)}$$

$$\boldsymbol{W_{parapet} = 210.6\ kN}$$

12. **SOLVE FOR THE FINAL WEIGHT OF THE STRUCTURE**



$\boldsymbol{W_{DL}}$ $\boldsymbol{W_{WALL}}$ $\boldsymbol{W_{PAR}}$ $\boldsymbol{W_{LEVEL}}$

1453.2+116.64+210.6 + 524.88 = **<u>2305.32 kN</u>**

1453.2+1049.76+8.1 **= 2511.06 kN**

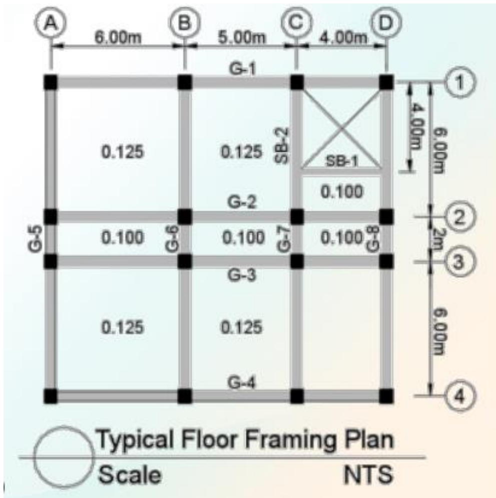
1453.2+1049.76+8.1 =**2511.06 kN**

1453.2+1049.76+8.1 =**2511.06 kN**

$$\boldsymbol{Weight_{TOTAL} = 9838.42\ kN}$$

EXAMPLE #2 – DEAD LOAD (RCD STRUCTURE)

A sample set of plans were presented in the figure. Using the following values:



A. Beam/Column Sizes

a. EB/SB = 0.25m x 0.40m

b. Joist = 0.25m x 0.50m

c. Girder = 0.35m x 0.60m

d. Column = 0.40m x 0.40m

B. Design Loads

a. Parapet/Wall = 2.70 kPa

b. Superimposed DL = 1.60 kPa

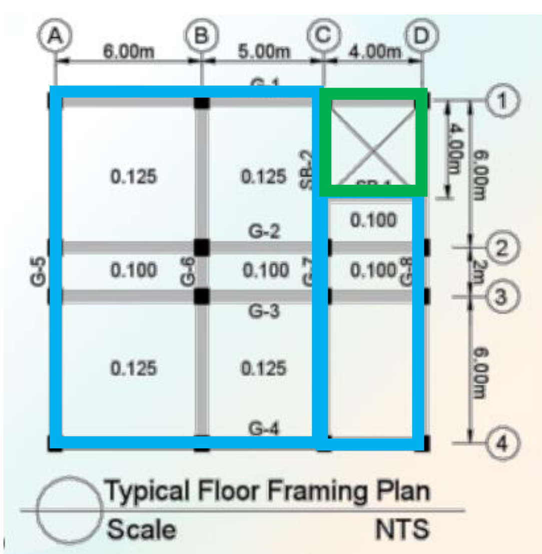
c. Unit Weight of Concrete = 24 kN/m3

d. Height of Wall = 3.2m

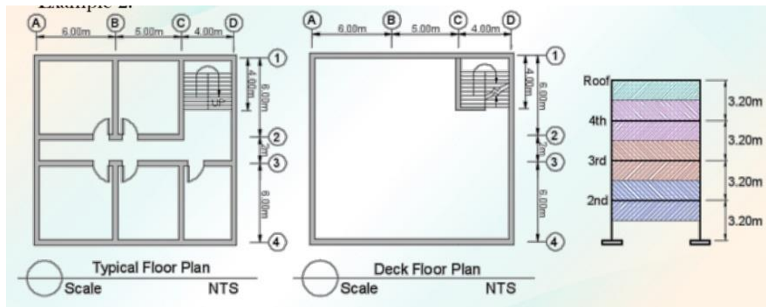
e. Height of Parapet = 1.5m

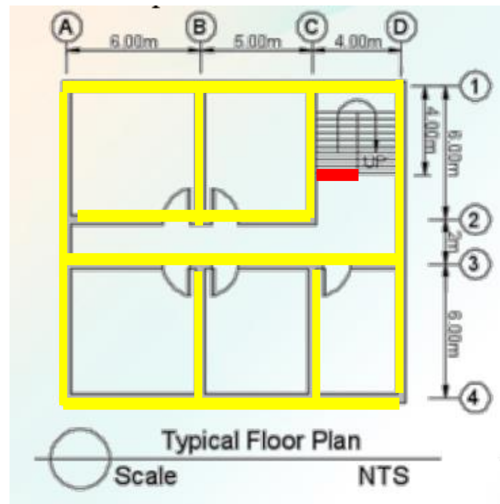
f. Stairs = 5 kPa

1. SOLVE FOR TRIBUTARY AREAS



$$T_{AREA} = 11(14) + 4(10)$$
$$T_{AREA} = 194\ m^2$$





A. PERIMETER OF THE WALLS

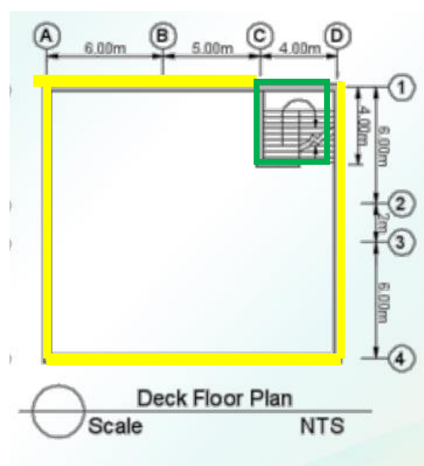
- TYPICAL LEVELS

$$P = 15 + 14 + 15 + 14 + 11 + 15 + 6(24)$$
$$P_{WALL-TL} = 108\ m$$

B. PERIMETER OF PARAPET

- TYPICAL LEVELS

$$P_{PARAPET-TL} = 2\ m$$



C. PERIMETER OF WALLS (DECK LEVEL)

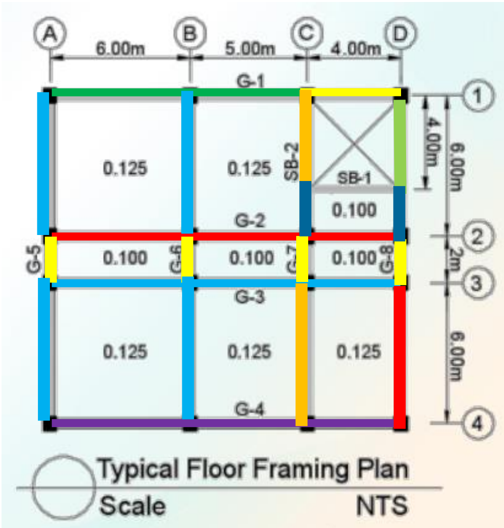
$$P = 4 + 4 + 4$$
$$P_{WALL-DL} = 12\ m$$

D. PERIMETER OF PARAPET

$$P = 11 + 14 + 15 + 10 + 2$$
$$P_{PARAPET-DL} = 52\ m$$

WEIGHT COMPUTATIONS

$$AREA_{CROSS} * L = V * P_{CONC} = Weight$$



A. **DECK LEVELS**

HORIZONTAL DIRECTION

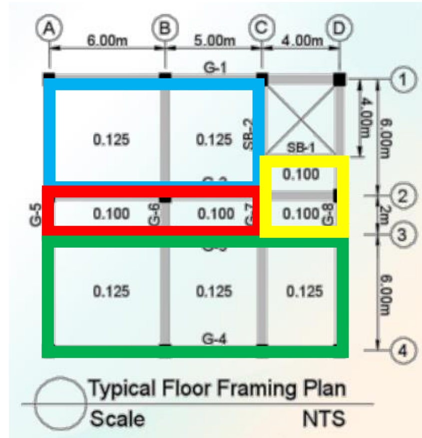
- **SB=** 0.25 (0.4-0.1) (4)(24) **= 7.2 KN**
- **G-1** =0.35(0.6-0.125) (11)(24) **=43.89 KN**
- **G-1=0.35(0.6)(4)(24) = 20.16**
- **G-2**=0.35(0.6-0.1)(15)(24)=**63 KN**
- **G-3**=0.35(0.6-0.1)(15)(24)=**63 KN**
- **G-4**=0.35(06-0.125)(15)(24)=**59.85**

VERTICAL DIRECTION

- **G-5**=0.35(0.6-0.1)(2)(24)=**8.40 KN**
- **G-6**=0.35(0.6-0.1)(2)(24)=**8.40 KN**
- **G-7**=0.35(0.6-0.1)(2)(24)=**8.40 KN**
- **G-8**=0.35(0.6-0.1)(2)(24)=**8.40 KN**

- **G-5=0.35(0.6-0.125)(12)(24)=47.88 KN**
- **G-6=0.35(0.6-0.125)(12)(24)=47.88 KN**

- **G-7=0.35(0.6-0.125)(10)(24)=39.9 KN**
- **G-7=0.35(0.6-0.1)(2)(24)=8.40 KN**
- **G-8=0.35(0.6)(4)(24)=20.16 KN**
- **G-8=0.35(0.6-0.1)(2)(24)=8.40 KN**
- **G-8=0.35(0.6)(6)(24)=23.94 KN**



$$FORMULA: (A * T * P_{CONC})$$

- **SLAB1 = (11)(6)(0.125)(24) = 198 KN**
- **SLAB2 = (11)(2)(0.1)(24) = 52.8 KN**
- **SLAB3 = (15)(6)(0.125)(24) = 270 KN**
- **SLAB4= (4)(4)(0.1)(24) = 38.4 KN**

- **PARAPET =** 2.7(52)(1.5) **= 210.6 KN**
- S_{DL}**=** (1.6)(194) = **310.4 KN**
- **COLUMNS= (**0.4)(0.4)(1.6) (24) (16) **= 98.3 KN**
- **WALLS -A =** 2.7 (12)(3.2) **= 103.68 KN**
- **WALLS – B =** 2.7 (108)(1.6) **= 466.56 KN**

TOTAL WEIGHT = SUMMATION OF LOADS

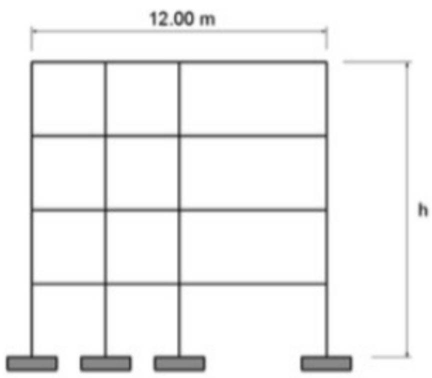
$$TOTAL\ WEIGHT = W_{SLABS} + W_{GIRDERS} + W_{SB} + W_{PARAPET} + W_{SDL} + W_{COLUMNS} + W_{WALLS-A} + W_{WALLS-B}$$

$$TOTAL\ WEIGHT = 7.2 + 480.06 + 559.2 + 210.6 + 310.4 + 98.3 + 570.24$$

$$TOTAL\ WEIGHT = 2236\ KN$$

FORMATIVE ASSESSMENT 2: DESIGN BASE SHEAR

1. A concrete special moment resisting frame structure is shown below. Which of the following most nearly gives the maximum height of the structure so that force at top need not be considered?



$$TRIAL\ AND\ ERROR:$$

$$Satisfy: T < 0.7; to\ make\ F_t = 0$$

$$T = C_t(h_n)^{\frac{3}{4}}$$

$$T = (0.0731)(20.3)^{\frac{3}{4}}$$

$$T = 0.699 < 0.7\ ; OK!$$

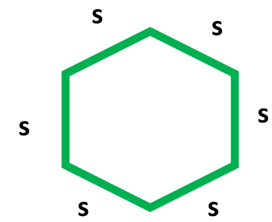
$$ANSWER: 20.3\ m$$

2. A 4-storey with Roof deck AFP armory is to be constructed in **Sulu**. The facility is essential for the housing of the Philippine Army's newly purchased weapons, ammunitions and explosives. The location of the facility ***is 7.5 km from the known source*** which is capable of producing a magnitude 6.7 earthquake. The ***structure is a Steel MRF*** with an overall ***height of 14m*** from the NGL. The weight per level of the ***slabs and stairs is equal to 1740 kN***. For the walls at the typical levels, ***the weight is computed as 2362.5 kN and*** for the parapet at the roof deck level, ***the weight is computed as 388.8 kN***. An ***equipment 2.0 meters*** high with a hexagonal cross - sectional area whose sides equal to 1 meter is installed at the second level and has ***a weight of 100 kPa.*** Using ***R = 8.5,*** which of the following most nearly gives the total design base shear in kN? Use ***Soil Type A.***

GIVEN:

- SULU – ZONE 4; Z=0.4
- Distance from the Source = 7.5 m
- M = 6.7
- $h_f = 14\ m\ from\ NGL$
- R = 8.5
- Soil Profile Type - S_a

- Weight per level (SLABS AND STAIRS) – **1740 kN**
- Weight @Typical (Walls) – **2362.5 kN**
- Weight @ Roof (Parapet) – **388.8 kN**



$$s = 1.0\ m$$

$$h_{hex} = 2.0\ m$$

$$Weight_{hex} = 100\ kPA$$

$$A_{HEX} = \frac{3\sqrt{3}}{2}(s)^2$$

$$W_{total} = 4102.5\ kN$$

$$W_{total-hex} = 4102.5 + 259.808$$

$$= 4362.308\ kN$$

SOLUTION:

- **TYPICAL LEVEL (2ND FLOOR)**

$$W_{total} = 1740 + 2362.5$$

$$W_{total} = 4102.5\ kN$$

- **COMPUTE FOR T**

C_t =**0.0853** for steel moment-resisting frames

$$T = C_t(h_n)^{3/4}$$

$$T = 0.0853(2.0)(14)^{3/4}$$

$$T = 0.617369 < 0.7$$

$$\therefore F_t = 0$$

- **DETERMINE THE OCCUPANCY CATEGORY**

Occupancy Category	Occupancy or Function of Structure
II. Hazardous Facilities	• Occupancies and structures housing or supporting toxic or explosive chemicals or substances
	• Non-building structures storing, supporting or containing quantities of toxic or explosive substances

Table 208 – 1. Seismic Importance Factors

Occupancy Category	Seismic Importance Factors, I	Seismic Importance[2] Factors, I_p
I. Essential Facilities[3]	1.50	1.50
III. Special Occupancy Structures	1.00	1.00
V. Miscellaneous Structures	1.00	1.00

$$I = 1.25$$

- $SOIL\ PROFILE\ TYPE: S_a$
- $SEISMIC\ SOURCY\ TYPE$:

SST	Seismic Source Description	Seismic Source Definition
		Maximum Moment Magnitude, M
A	Faults that are capable of producing large magnitude events and that have a high rate of seismic activity.	$7.0 \leq M \leq 8.4$
B	All faults other than Types A and C.	$6.5 \leq M < 7.0$
C	Faults that are uncapable of producing large magnitude earthquakes and that have a relatively low rate of seismic activity.	$M < 6.5$

$$Since\ M = 6.7; TYPE\ B$$

- **SOLVE FOR NEAR SOURCE FACTOR**
- **GIVEN DISTANCE: 7.5 KM**

Table 208 – 5. Near-Source Factor N_a[1]

Seismic Source Type	Closest Distance To Known Seismic Source[2]		
	$\leq 2\ km$	$\leq 5\ km$	$\geq 10\ km$
A	1.5	1.2	1.0
B	1.3	1.0	1.0
C	1.0	1.0	1.0

$$N_a = 1.0$$

Table 208 – 6. Near-Source Factor N_v[1]

Seismic Source Type	Closest Distance To Known Seismic Source[2]			
	$\leq 2\ km$	$5\ km$	$10\ km$	$\geq 15\ km$
A	2.0	1.6	1.2	1.0
B	1.6	1.2	1.0	1.0
C	1.0	1.0	1.0	1.0

$$\frac{1.2 - N_v}{1.2 - 1.0} = \frac{5 - 7.5}{5 - 10}$$

$$N_v = 1.10$$

- **SOLVE FOR SEISMIC COEFFICIENT, C_a**

Table 208 – 7. Seismic Coefficient, C_a

Soil Profile Type	Seismic Zone Z	
	$Z = 0.2$	$Z = 0.4$
S_A	0.16	$0.32N_a$
S_B	0.20	$0.40N_a$
S_C	0.32	$0.40N_a$
S_D	0.40	$0.44N_a$
S_E	0.64	$0.44N_a$
S_F	Site-specific geotechnical investigation and dynamic site response analysis shall be performed to determine seismic coefficients	

$$C_a = 0.32N_a = 0.32(1.0)$$

$$C_a = 0.3$$

- **SOLVE FOR SEISMIC COEFFICIENT, C_v**

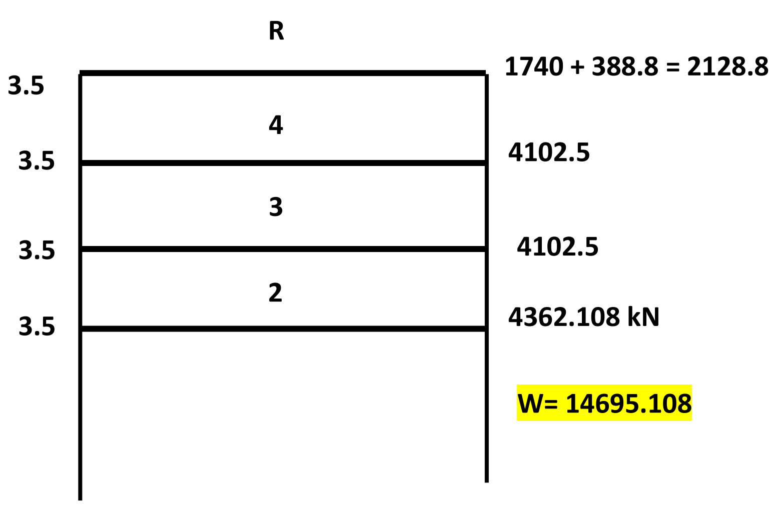
Table 208 – 8. Seismic Coefficient, C_v

Soil Profile Type	Seismic Zone Z	
	$Z = 0.2$	$Z = 0.4$
S_A	0.16	$0.32N_v$
S_B	0.20	$0.40N_v$
S_C	0.32	$0.56N_v$
S_D	0.40	$0.64N_v$
S_E	0.64	$0.96N_v$
S_F	Site-specific geotechnical investigation and dynamic site response analysis shall be performed to determine seismic coefficients	

$$C_v = 0.32N_v = 0.32(1.1)$$

$$C_a = 0.352$$

- **DETERMINE THE BASE SHEAR**



$$V_1 = \frac{C_v I}{RT} W \text{ (MAXIMUM)}$$

$$V_1 = \frac{(0.352)(1.25)}{(8.5)(0.617369)}(14695.108)$$

$$V_1 = 1232.144024\ kN$$

$$V_2 = \frac{2.5C_a I}{R} W \text{ (MAXIMUM)}$$

$$V_2 = \frac{2.5(0.32)(1.25)}{8.5}(14695.108)$$

$$V_2 = 1728.836\ kN$$

$$V_3 = 0.11C_a IW \text{ (MINIMUM)}$$

$$V_3 = 0.11(0.32)(1.25)(14695.108$$

$$V_3 = 646.5847\ kN$$

$$V_4 = \frac{0.8ZN_v I}{R} W \text{ (MINIMUM)}$$

$$V_4 = \frac{0.8(0.4)(1.1)(1.25)}{8.5}(14695.108)$$

$$V_4 = 760.687\ kN$$

$THEREFORE; GOVERNING\ SHEAR$:

$$V = 1232.144024\ kN$$

$ANSWER: 1233$

- **Which of the following most nearly gives the total lateral force at the deck level in kN?**

LEVEL	Wx	Hx	Wx*Hx	Wx*Hx/SUM (Wx*Hx)	Fx	V
ROOF	2128.8	14	29803.2	0.255023928	314.4445035	-
4TH	4102.5	10.5	43076.3	0.368600502	454.4844193	314.445
3rd	4102.5	7	28717.5	0.245733668	302.9896129	768.929
2nd	4362.11	3.5	15267.4	0.130641901	161.0814643	1071.92
Total	14695.9		116864	1	1233	1233

$ANSWER: 314\ KN$

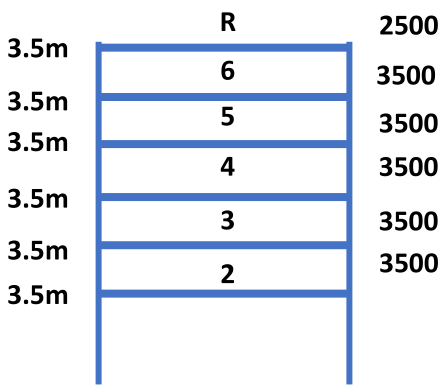
- ***Which of the following most nearly gives the maximum design base shear in kN?***

$ANSWER: 1729$

- **Which of the following most nearly gives the lateral force at the 4th level in kN?** Use Soil Type A.

$ANSWER: 455\ kN$

3. A 6 - storey with roof deck building has a total height of 21m. The computed base shear is 900 kN. Each floor has an average height of 3.5m. Each floor has a weight of 3500 kN except for the top most level with a weight of 2500 kN. Its natural period of oscillation is 0.75 sec.



$$T = 0.75\text{sec}$$
$$V = 900\ kN$$

$$\boldsymbol{F_t = 0.07TV}$$
$$F_t = 0.07(0.75)(900)$$
$$\boldsymbol{F_t = 47.25\ kN}$$

LEVEL	Hx	Wx	WxHx	Ratio	Fx'	FINAL Fx
Roof Deck	21	2500	52500	0.2222	189.5	236.75
6	17.5	3500	61250	0.2593	221.08	221.083
5	14	3500	49000	0.2074	176.87	176.867
4	10.5	3500	36750	0.1556	132.65	132.65
3	7	3500	24500	0.1037	88.433	88.4333
2	3.5	3500	12250	0.0519	44.217	44.2167
x			0	0	0	0
x			0	0	0	0
x			0	0	0	0
x			0	0	0	0
x			0	0	0	0
x			0	0	0	0
SUM			236250		852.75	900

- **What is the shear at the 3rd level?**

$$\boldsymbol{ANSWER: 88\ KN}$$

- **What is the shear at the 4th level?**

$$\boldsymbol{ANSWER: 133\ kN}$$

- **What is the shear at the deck level?**

$$\boldsymbol{ANSWER: 236.75\ KN}$$

- **What is the shear at the 6th level?**

$$\boldsymbol{ANSWER: 221\ kN}$$

- **What is the ratio of the force at the top the maximum allowable value (of the force at the top level)?**

SOLUTION

$$\boldsymbol{F_t} = 0.07TV$$
$$F_t = 0.25V\ (should\ not\ exceed)$$

$$\boldsymbol{V = 900\ KN}$$

$$\frac{0.07TV}{0.25V} = \frac{0.07(0.75)(900)}{0.25(900)}(100) = \mathbf{21\%}$$

$$\boldsymbol{ANSWER: 21\%}$$

The design base shear of a two - storey reinforced concrete SMRF office building is to be determined. If the base shear computed using the static force procedure is 258.8 kN, which of the following most nearly gives the value of the base shear if the simplified procedure will be utilized?

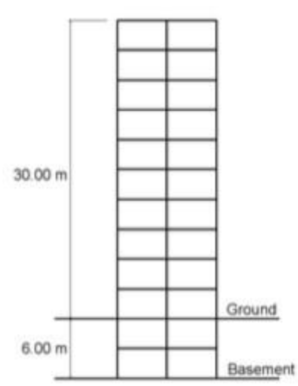
- TYPE S_D
- $0.44N_a$
- $C_a = 0.44(1)$

  $\boldsymbol{C_a = 0.44}$

$$\boldsymbol{V = \frac{2.5C_aI}{R}(W)}$$
$$\boldsymbol{258.8 = \frac{2.5(0.44)(1)}{8.5}W}$$
$$\boldsymbol{W = 1999.8181}$$

$$\boldsymbol{V = \frac{3.0C_a}{R}(W)}$$
$$\boldsymbol{V = \frac{3(0.44)(1999.8181)}{8.5}}$$
$$\boldsymbol{V = 310.56\ KN}$$

A steel special moment resisting frame structure is shown below. Which of the following most nearly gives the maximum height of the structure (including the basement) so that force at top need not be considered?



$$\boldsymbol{0.7 = 0.0853(h_n)^{3/4}}$$
$$\boldsymbol{h_n = 16.5525 + 6.0}$$
$$\boldsymbol{h_n = 22.5525\ (3.28)}$$
$$\boldsymbol{h_n = 73.97\ ft}$$
$$\boldsymbol{ANSWER: 73.97\ ft}$$

The new City Sanitarium is to be constructed in ***Valenzuela City.*** After conducting soil tests, the underlying soil of the location of the new sanitarium was found out that has a stiff soil profile. The structure is ***located 7 km*** from the nearest source that is capable of producing a ***Magnitude 6.5 earthquake***. Determine the ratio of the additional force at the top level of the structure to the maximum allowable (force at the top) if it will be ***made of concrete SMRF***, a total ***height of 21 meters*** and a ***total weight of 23,456.50 kN.***

- DISTANCE FROM SOURCE = 7 KM
- SOIL PROFILE TYPE = S_D
- SMRF (CONCRETE) = 0.0731
- R=8.5
- **SANITARIUM -**

3. Special Occupancy Structures	✓ Mental hospitals, sanitariums, jails, prisons and other buildings where personal liberties of inmates are similarly restrained

- **ZONE 4 = Z =0.4**
- **W = 23,456.50 KN**
- **Hn = 21 m**

$$T = C_T(h_n)^{\frac{3}{4}}$$

$$T = 0.0731(21)^{\frac{3}{4}}$$

$$T = 0.71710$$

$$SINCE\ T > 0.7$$

$$\therefore F_T \neq 0$$

- **SOLVE FOR NEAR SOURCE FACTOR**
- **GIVEN DISTANCE: 7.0 KM**

Table 208 – 5. Near-Source Factor N_a[1]

Seismic Source Type	Closest Distance To Known Seismic Source[2]		
	$\leq 2\ km$	$\leq 5\ km$	$\geq 10\ km$
A	1.5	1.2	1.0
B	1.3	1.0	1.0
C	1.0	1.0	1.0

$$N_a = 1.0$$

Table 208 – 6. Near-Source Factor N_v[1]

Seismic Source Type	Closest Distance To Known Seismic Source[2]			
	$\leq 2\ km$	$5\ km$	$10\ km$	$\geq 15\ km$
A	2.0	1.6	1.2	1.0
B	1.6	1.2	1.0	1.0
C	1.0	1.0	1.0	1.0

$$\frac{1.2 - N_v}{1.2 - 1.0} = \frac{5-7}{5-10}$$

$$N_v = 1.12$$

- **SOLVE FOR SEISMIC COEFFICIENCT, C_a**

Table 208 – 7. Seismic Coefficient, C_a

Soil Profile Type	Seismic Zone Z	
	$Z = 0.2$	$Z = 0.4$
S_A	0.16	$0.32N_a$
S_B	0.20	$0.40N_a$
S_C	0.32	$0.40N_a$
S_D	0.40	$0.44N_a$
S_E	0.64	$0.44N_a$
S_F	Site-specific geotechnical investigation and dynamic site response analysis shall be performed to determine seismic coefficients	

$$C_a = 0.44N_a = 0.44(1.0)$$

$$C_a = 0.44$$

- **SOLVE FOR SEISMIC COEFFICIENCT, C_v**

Table 208 – 8. Seismic Coefficient, C_v

Soil Profile Type	Seismic Zone Z	
	$Z = 0.2$	$Z = 0.4$
S_A	0.16	$0.32N_v$
S_B	0.20	$0.40N_v$
S_C	0.32	$0.56N_v$
S_D	0.40	$0.64N_v$
S_E	0.64	$0.96N_v$
S_F	Site-specific geotechnical investigation and dynamic site response analysis shall be performed to determine seismic coefficients	

$$C_v = 0.64N_v = 0.64(1.12)$$

$$C_a = 0.7168$$

- **CALCULATING BASE SHEARS**

$$V_1 = \frac{C_v I}{RT}W\ (MAXIMUM)$$

$$V_1 = \frac{(0.7168)(1.0)}{(8.5)(0.71710)}(23456.50)$$

$$V_1 = 2758.420258\ kN$$

$$V_2 = \frac{2.5C_a I}{R}W\ (MAXIMUM)$$

$$V_2 = \frac{2.5(0.44)(1)}{8.5}(23456.50)$$

$$V_2 = 3035.547056\ kN$$

$$V_3 = 0.11C_a IW\ (MINIMUM)$$

$$V_3 = 0.11(0.44)(1.0)(23456.50$$

$$V_3 = 1135.2946kN$$

$$V_4 = \frac{0.8ZN_v I}{R}W\ (MINIMUM)$$

$$V_4 = \frac{0.8(0.4)(1.0)(1.12)(1)}{8.5}(23456.50)$$

$$V_4 = 989.0364\ kN$$

$$THEREFORE; GOVERNING\ SHEAR:$$
$$V = 2758.420257\ kN$$

$$F_T = 0.07TV$$

$$F_T = 0.07(0.717035096)(2758.420257)$$

$$F_T = 138.465993$$

$$\frac{0.07FTV}{0.25V} = \frac{138.465993}{689.605}(100)$$

$$\%RATIO = 20.079\%$$

Faults that are capable of producing large magnitude events and that have a high rate of seismic activity.

$$\boldsymbol{ANSWER: SEISMIC\ SOURCE\ TYPE\ A}$$

Soil profile type of Hard Rock.

$$\boldsymbol{ANSWER: S_A}$$

Occupancy Category: Structures and shelters in emergency preparedness centers.

$$\boldsymbol{ANSWER: ESSENTIAL\ FACILITIES}$$

Occupancy Category: Fire and police stations.

$$\boldsymbol{ANSWER: ESSENTIAL\ FACILITIES}$$

Occupancy Category: Mental hospitals, sanitariums, jails, prisons and other buildings where personal liberties of inmates are similarly restrained.

$$\boldsymbol{ANSWER: SPECIAL\ OCCUPANCY\ STRUCTURES}$$

Occupancy Category: Power and Communication Transmission lines.

$$\boldsymbol{ANSWER: Essential\ Facilities}$$

Occupancy Category: HOSPITALS

$$\boldsymbol{ANSWER: Essential\ Facilities}$$

The forces at each level shall be calculated using the following equation:

$$\boldsymbol{V = \frac{3C_a}{R}W}$$

$$\boldsymbol{ANSWER: Simplified\ Design\ Base\ Shear}$$

Building of any occupancy (including single – family dwellings) not more than three stories in height excluding basements that use light frame construction.

$$\boldsymbol{ANSWER: Simplified\ Static}$$

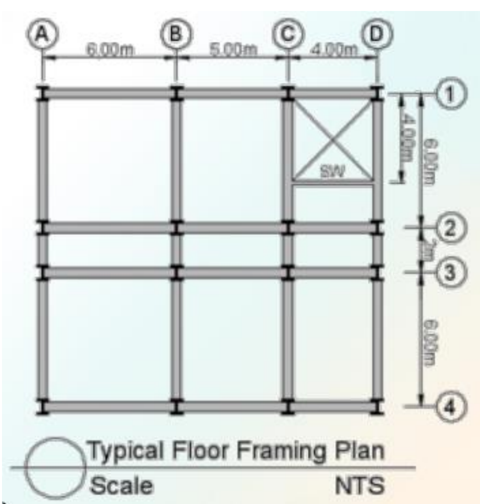
MODULE 3: CENTER OF MASS, CENTER OF RIGIDITY AND ECCENTIRICITIES

DISTRIBUTION OF LATERAL FORCES PER FRAME

SAMPLE PROBLEM #1

Given:

- **Zone 4, I = 1.0,**
- **Soil Profile Type A, Seismic**
- **Source Type A,**
- **Distance from the Source = 5km,**
- **R =8.5,**
- **h = 3.6m,**
- **Eacc = 5% (Longitudinal Dimension)**



SOLUTION:

$$\textit{For Steel } (SMRF)$$

$$C_T = 0.0853$$

$$T = C_t(h_n)^{\frac{3}{4}}$$

$$T = 0.0853(14.4)^{\frac{3}{4}}$$

$$T = 0.631 \text{ sec} < 0.7\ sec$$

$$Therefore;\ \boldsymbol{F_t = 0}$$

A. $\boldsymbol{Find\ N_a}$

Table 208-5: Near-Source Factor, N_a

Seismic Source Type	Closest Distance to Known Seismic Source[2]		
	< 2km	≤ 5km	≥ 10km
A	1.5	1.2	1.0
B	1.3	1.0	1.0
C	1.0	1.0	1.0

B. $\boldsymbol{Find\ N_v}$

Table 208-6: Near-Source Factor, N_v

Seismic Source Type	Closest Distance to Known Seismic Source[2]			
	< 2km	5km	10km	> 10km
A	2.0	1.6	1.2	1.0
B	1.6	1.2	1.0	1.0
C	1.0	1.0	1.0	1.0

C. $\boldsymbol{Determine\ the\ Seismic\ Coefficient\ C_a\ and\ C_v}$

Table 208-7: Seismic Coefficient, C_a

Soil Profile Type	Seismic Zone (Z)	
	Z = 0.2	Z = 0.4
S_A	0.16	$0.32N_a$
S_B	0.20	$0.40N_a$
S_C	0.24	$0.40N_a$
S_D	0.28	$0.44N_a$
S_E	0.34	$0.44N_a$
S_F	See Footnote 1 of Table 208-8	

$$C_a = 0.32\ N_a$$

$$C_a = 0.32\ (1.2)$$

$$\boldsymbol{C_a = 0.384}$$

Table 208-8: Seismic Coefficient, C_v

Soil Profile Type	Seismic Zone (Z)	
	Z = 0.2	Z = 0.4
S_A	0.16	$0.32N_v$
S_B	0.20	$0.40N_v$
S_C	0.32	$0.56N_v$
S_D	0.40	$0.64N_v$
S_E	0.64	$0.96N_v$
S_F	See Footnote 1 of Table 208-8	

$$C_v = 0.32\ N_v$$

$$C_v = 0.32\ (1.6)$$

$$\boldsymbol{C_a = 0.512}$$

D. ***Determine the Base Shear***

$$\boldsymbol{V_1 = \frac{C_v I}{RT} W\ (MAXIMUM)}$$

$$V_1 = \frac{(0.512)(1.0)}{(8.5)(0.631)}(9806.1)$$

$$\boldsymbol{V_1 = 936.091\ kN}$$

$$\boldsymbol{V_2 = \frac{2.5C_a I}{R} W\ (MAXIMUM)}$$

$$V_2 = \frac{2.5(0.384)(1)}{8.5}(9806.1)$$

$$\boldsymbol{V_2 = 1107.512\ kN}$$

$$\boldsymbol{V_3 = 0.11C_a IW\ (MINIMUM)}$$

$$V_3 = 0.11(0.384)(1.0)(9806.1)$$

$$\boldsymbol{V_3 = 414.210\ kN}$$

$$\boldsymbol{V_4 = \frac{0.8ZN_v I}{R} W\ (MINIMUM)}$$

$$V_4 = \frac{0.8(0.4)(1.6)(1)}{8.5}(9806.1)$$

$$\boldsymbol{V_4 = 590.673\ kN}$$

$$\boldsymbol{THEREFORE; GOVERNING\ SHEAR:}$$
$$\boldsymbol{V = 936.091\ kN}$$

E. ***Find F_x***

Level x	H_x	w_x	$w_x h_x$	F_x
Roof	14.4	2297.22	33079.968	355.342
4	10.8	2502.96	27031.968	290.375
3	7.2	2502.96	18021.312	193.583
2	3.6	2502.96	9010.656	96.792
			$\sum$= 87,143.904	$\sum$= 936.091 kN

F. ***Distribution of Lateral Force in each Frame***

WORKING EQUATIONS:

FOR D_x and D_y

$$d_X = \left| x - \sum xR_L \right|$$

$$d_Y = \left| y - \sum yR_T \right|$$

FOR M_T

$$M_T = 1.0(e_{govern})$$
$$e_x = |CM_x - CR_x|$$
$$e_y = |CM_y - CR_y|$$

$$e_{acc} = 5\%\ (building\ dimension)$$

FOR F_1 and F_2

$$\boldsymbol{F_1} = R_T\ or\ R_L$$

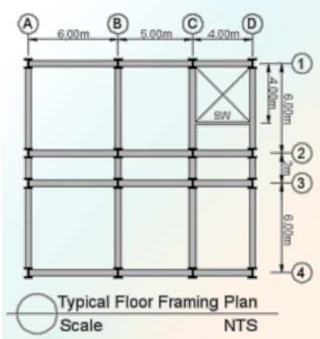
$$\boldsymbol{F_2} = \frac{M_T[R_d]}{\sum Rd^2}$$

FOR CR_x

$$\boldsymbol{CR_X = \frac{\sum xR_L}{\sum R_L}}$$

$$\boldsymbol{CR_Y = \frac{\sum xR_T}{\sum R_T}}$$

a. **West – East Direction**



Frame Mark	R_L	x	xR_L	d_x	R_Ld_x	$R_Ld_x^2$	F_1	F_2	F
A	1/4	0	0	8.00	2.00	16.00	1/4	0.048	0.298
B	1/4	6	1.5	2.00	0.50	1.00	1/4	0.012	0.262
C	1/4	11	2.75	3.00	0.75	2.25	1/4	0.018	0.268
D	1/4	15	3.75	7.00	1.75	12.25	1/4	0.042	0.292
			$\sum = 8.00$			$\sum = 31.5$			

$$\boldsymbol{CM_x = \frac{15}{2} = 7.5\ m}$$

$$\boldsymbol{CM_y = \frac{14}{2} = 7.0\ m}$$

$$\boldsymbol{M_T} = 1.0(0.75) = 0.75\ kN$$

$$\boldsymbol{F_2} = \frac{M_T(R_d)}{\sum Rd^2}$$

a. **North – South Direction**

Frame Mark	R_T	y	yR_T	d_y	R_Td_y	$R_Td_y^2$	F_1	F_2	F
A	1/4	0	0	7.00	1.75	12.25	1/4	0.053	0.303
B	1/4	6	1.50	1.00	0.25	0.25	1/4	0.008	0.258
C	1/4	8	2.00	1.00	0.25	0.25	1/4	0.008	0.258
D	1/4	14	3.50	7.00	1.75	12.25	1/4	0.053	0.303
			$\sum = 7.00$			$\sum = 25$			

$$\boldsymbol{CR_x} = \frac{8.0}{1} = 8.0\ m$$

$$\boldsymbol{CR_x} = \frac{7.0}{1} = 7.0\ m$$

$$e_x = |7.5 - 8.0| = 0.5\ m$$

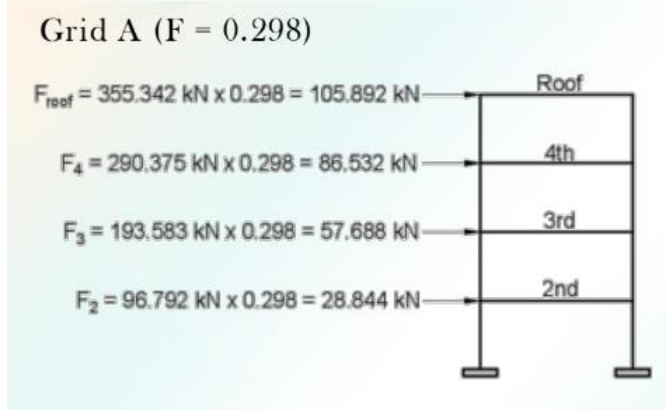
$$e_x = |7.0 - 7.0| = 0\ m$$

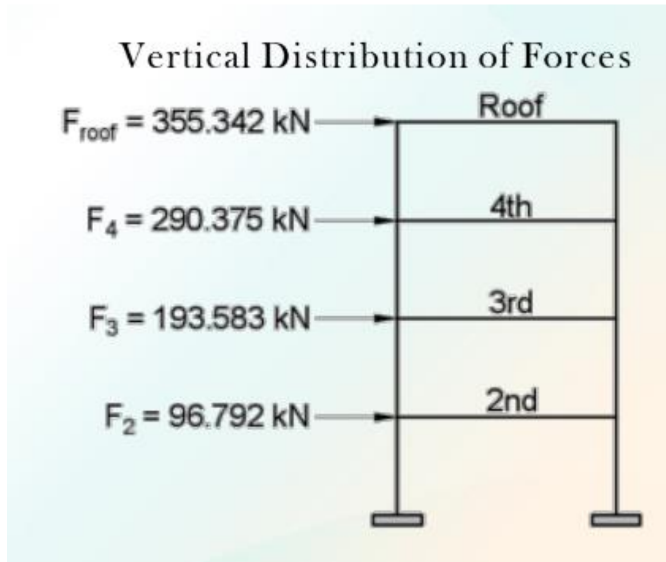
$$e_{acc} = (5\%)(15) = 0.75\ m$$

$$\boldsymbol{e_{govern} = 0.75\ m}$$

$$\boldsymbol{M_T} = 1.0(0.75) = 0.75\ kN$$

$$\boldsymbol{F_2} = \frac{M_T(R_d)}{\sum Rd^2}$$





FORMATIVE ASSESMENT 3 - SOLUTION

PROBLEM #1: A 4-storey with roof deck structural steel has the following minimum design loads from the NSCP:

A. Dead Load (DL)

1. 0.125m THK slab = 3.00 kPa
2. 0.050m THK Lean Concrete = 1.20 kPa
3. Marble = 1.58 kPa
4. Gypsum Board = 0.04 kPa
5. Suspended Steel Chanel = 0.10 kPa
6. Beam/Column = 1.00 kPa

Total = 7.92 kPa (with Movable Partition)

B. $W_{walls/parapet}$ = 2.70 kPa

C. Height of Walls and Parapet = 3.6m/1.5m

D. Tributary Area = 210 sq.m

E. P_{walls} = 108m (Typical Levels)

F. P_{walls} = 12m (Deck Levels)

G. $P_{parapet}$ = 50m (Deck Levels)

SOLUTION:

ROOF DECK LEVEL

$$\boldsymbol{DL} = Total_{LOAD}\ x\ T_A$$

$$\boldsymbol{DL} = 7.92\ x\ 210.00$$

$$\boldsymbol{DL = 1663.2\ kN}$$

$$\boldsymbol{WALLS_1} = W_{walls} * \frac{H_{Walls}}{2} * P_{walls(T.L)}$$

$$\boldsymbol{WALLS_1} = 2.7 * 1.8 * 108$$

$$\boldsymbol{WALLS_1 = 524.88\ kN}$$

$$\boldsymbol{WALLS_2} = W_{walls} * H_{Walls} * P_{walls(deck)}$$

$$\boldsymbol{WALLS_2} = 2.7 * 3.6 * 12$$

$$\boldsymbol{WALLS_1 = 116.64\ kN}$$

$$\boldsymbol{Parapet} = W_{Par} * Height_{Par} * P_{walls}$$

$$\boldsymbol{WALLS_2} = 2.7 * 1.5 * 50$$

$$\boldsymbol{WALLS_1 = 202.50\ kN}$$

$$\boldsymbol{TOTAL\ LOADS\ (DECK) = 2507.22\ kN}$$

TYPICAL LEVEL

$$\boldsymbol{DL} = Total_{LOAD}\ x\ T_A$$

$$\boldsymbol{DL} = 7.92\ x\ 210.00$$

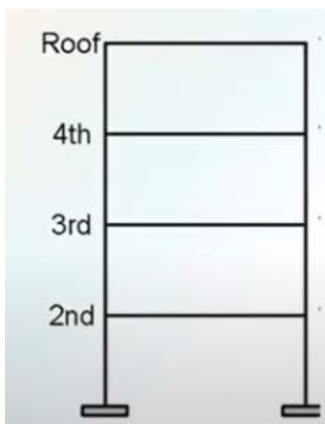
$$\boldsymbol{DL = 1663.2\ kN}$$

$$\boldsymbol{WALLS_1} = W_{walls} * Height_{Walls} * P_{walls}$$

$$\boldsymbol{WALLS_1} = 2.7 * 3.6 * 108$$

$$\boldsymbol{WALLS_1 = 1049.76\ kN}$$

$$\boldsymbol{T\_LOADS\ (T.L) = 2712.96kN}$$



2507.22 kN

2712.96 kN

2712.96 kN

2712.96 kN

$$= \boldsymbol{2507.22 + (3)(2712.96)}$$

$$\boldsymbol{W_T = 10,646.10\ kN}$$

What is the total weight of the structure?

ANSWER:
10646.10 kN

Solve for the W_{DL}.

ANSWER:
1663.20 kN

What is the total weight in the roof level?

ANSWER:
2507.22 kN

What is the weight of the walls in the typical levels?

ANSWER:
1049.76 kN

What is the weight of the walls below deck level?

ANSWER:
524.88 kN

What is the total weight in the 2nd level?

ANSWER:
2712.96 kN

What is the total weight in the 3rd level?

ANSWER:
2712.96 kN

What is the total weight in the 4th level?

ANSWER:
2712.96 kN

PROBLEM #2: A 4-storey with roof deck were presented in the figure. Using the following values:

A. Beam/Column Sizes

- EB/SB = 0.25m x 0.40m
- Joist = 0.25m x 0.50m
- Girder = 0.35m x 0.60m
- Column = 0.40m x 0.40m

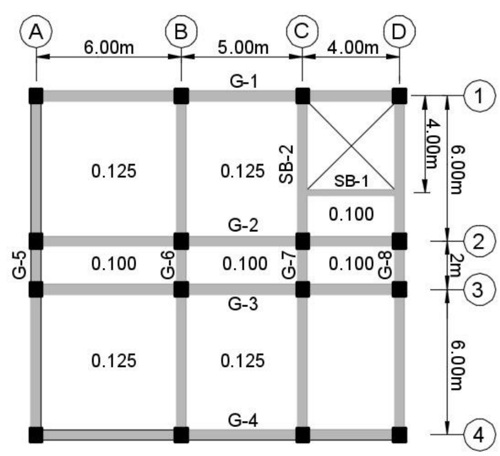
B. Design Loads

- Parapet/Wall = 2.70 kPa
- Superimposed DL = 1.60 kPa
- Unit Weight of Concrete = 24 kN/m^3
- Height of Wall = 3.2m
- Height of Parapet = 1.5m
- Stairs = 5 kPa

C. Perimeter of the walls in the typical level = 108m

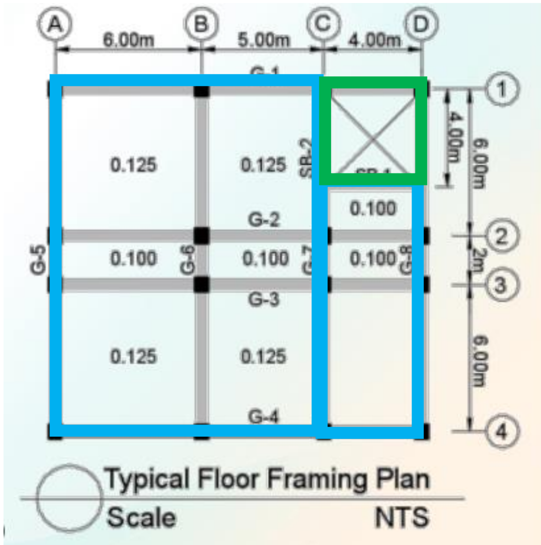
D. Perimeter of the walls at the deck level = 12m

E. Perimeter of the parapet in the deck level = 50m



Typical Floor Framing Plan
Scale NTS

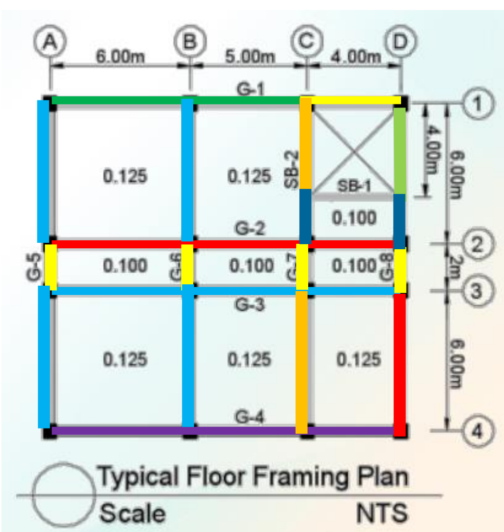
1. **SOLVE FOR TRIBUTARY AREAS**



$$T_{AREA} = 11(14) + 4(10)$$
$$T_{AREA} = 194\ m^2$$

WEIGHT COMPUTATIONS

$$AREA_{CROSS} * L = V * P_{CONC} = Weight$$



A. **DECK LEVELS**
HORIZONTAL DIRECTION

- **SB=** 0.25 (0.4-0.1) (4)(24) = **7.2 KN**

$$T.WEIGHT\ OF\ SB\ (DECK) = 7.2\ kN$$

- **G-1** =0.35(0.6-0.125) (11)(24) =**43.89 KN**
- **G-1=0.35(0.6)(4)(24) = 20.16**
- **G-2**=0.35(0.6-0.1)(15)(24)=**63 KN**
- **G-3**=0.35(0.6-0.1)(15)(24)=**63 KN**
- **G-4**=0.35(06-0.125)(15)(24)=**59.85**

VERTICAL DIRECTION

- **G-5**=0.35(0.6-0.1)(2)(24)=**8.40 KN**
- **G-6**=0.35(0.6-0.1)(2)(24)=**8.40 KN**
- **G-7**=0.35(0.6-0.1)(2)(24)=**8.40 KN**
- **G-8**=0.35(0.6-0.1)(2)(24)=**8.40 KN**

- **G-5=0.35(0.6-0.125)(12)(24)=47.88 KN**
- **G-6=0.35(0.6-0.125)(12)(24)=47.88 KN**

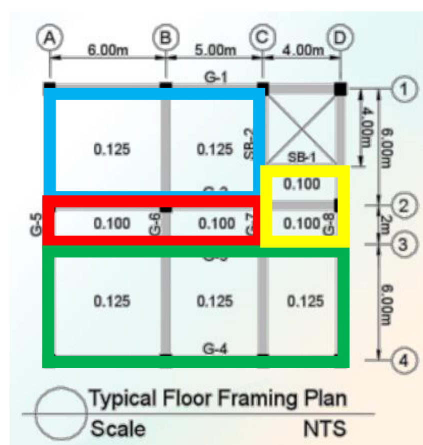
- **G-7=0.35(0.6-0.125)(6)(24)=23.94 KN**
- **G-7=0.35(0.6-0.1)(4)(24)=15.96 KN**

- **G-8=0.35(0.6)(4)(24)=20.16 KN**

- **G-8=0.35(0.6-0.1)(2)(24)=8.40 KN**

- **G-8=0.35(0.6)(6)(24)=23.94 KN**

$$T.WEIGHT\ OF\ GIRDER\ (DECK) = 471.66\ kN$$



$$FORMULA: (A * T * P_{CONC})$$

- **SLAB1 = (11)(6)(0.125)(24) = 198 KN**
- **SLAB2 = (11)(2)(0.1)(24) = 52.8 KN**
- **SLAB3 = (15)(6)(0.125)(24) = 270 KN**
- **SLAB4= (4)(4)(0.1)(24) = 38.4 KN**

$$T.WEIGHT\ OF\ SLAB = 559.2\ kN$$

- $\boldsymbol{PARAPET} = 2.7(50)(1.5) = \mathbf{202.5\ KN}$
- $\boldsymbol{S_{DL}} = (1.6)(194) = \mathbf{310.4\ KN}$
- $\boldsymbol{COLUMNS} =$
  $(0.4)(0.4)(1.6)\ (24)\ (16) = \mathbf{98.3\ KN}$
- $\boldsymbol{WALLS - A} = 2.7\ (12)(3.2) =$
  $\mathbf{103.68\ KN}$
- $\boldsymbol{WALLS - B} = 2.7\ (108)(1.6) =$
  $\mathbf{466.56\ KN}$

TOTAL WEIGHT = SUMMATION OF LOADS

$$\boldsymbol{TOTAL\ WEIGHT} = W_{SLABS} + W_{GIRDERS} + W_{SB} + W_{PARAPET} + W_{SDL} + W_{COLUMNS} + W_{WALLS-A} + W_{WALLS-B}$$

$$\boldsymbol{TOTAL\ WEIGHT} = 7.2 + 480.06 + 559.2 + 210.6 + 310.4 + 98.3 + 570.24$$

$$\boldsymbol{TOTAL\ WEIGHT = 2219.50\ KN}$$

What is the total weight of the girders in the deck level?

ANSWER:
471.66 Kn

What is the value of the super imposed deadload in the deck level?

ANSWER:
310.4 Kn

What is the total weight in the deck level?

ANSWER:
310.4 Kn

What is the total weight of the columns in the typical levels?

ANSWER:
196.608 kN

What is the total weight of the parapet in the deck level?

ANSWER:
202.5 kN

What is the total weight of the walls in the typical levels?

ANSWER:
933.12 kN

What is the weight of the stair beam in the deck level?

ANSWER:
7.2 Kn

What is the total weight in the 4^{th} level?

ANSWER:
2478.19 kN

What is the total weight of the walls in the deck level?

ANSWER:
570.24 kN

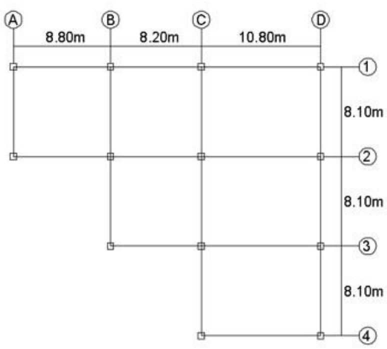
What is the total weight of the columns in the deck?

ANSWER:
98.30 kN

What is the total weight of the slabs in the deck level?

ANSWER:
559.2 Kn

PROBLEM #3 The framing plan of a two-storey post tensioned structure is shown below. Due to some issues, the ***owner suggests to change the corner columns to equivalent circular columns of the same section modulus as the initial square columns*** designated as shown in the figure. The ***size of the square columns is 0.50 by 0.50m***. ***Height per level is 3.60 meters***. ***E = 24.84 x 10⁶ kPa and G = 9.92 x 10⁶ kPa***. Use column A-1 as building reference point. Assume the lateral force is acting from north to south direction. Considering the framing plan below as a typical floor framing plan: Set your calculator to 5 decimal places.



GIVE

$$\boldsymbol{b} = 0.50\ m$$

$$\boldsymbol{d} = 0.50\ m$$

SOLUTION:

FOR SQUARE COLUMNS

$$\boldsymbol{Z}_{x(SC)} = \frac{bd^2}{6} = \frac{\mathbf{0.5^3}}{\mathbf{6}} = \frac{\mathbf{1}}{\mathbf{48}}\boldsymbol{m^3}$$

FOR CIRCULAR COLUMNS

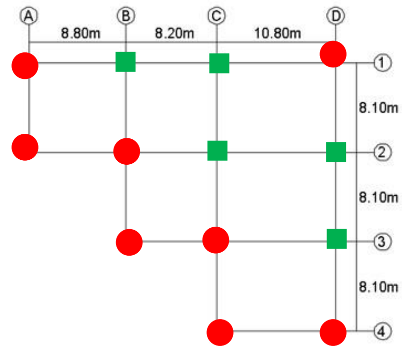
$$\boldsymbol{Z}_{x(CC)} = \frac{\pi D^3}{32}$$

FIND D NEEDED FOR EQUIVALENT CIRCULAR COLUMN

$$\frac{1}{48} = \frac{\pi D^3}{32}$$

$$\boldsymbol{D} = \sqrt[3]{\frac{\mathbf{32}}{\mathbf{48\pi}}}$$

$$\boldsymbol{D = 0.5965\ m}$$



- **CIRCULAR COLUMNS**
- **RECTANGULAR COLUMNS**

FOR THE VALUES OF B

$CIRCULAR\ COLUMNS - 0$

$RECTANGULAR\ COLUMNS\ -\ 0.5$

FOR THE VALUES OF D

$CIRCULAR\ COLUMNS - 0.5965$

$RECTANGULAR\ COLUMNS\ -\ 0.5$

FOR THE VALUES OF H

$CIRCULAR\ COLUMNS - 3.6$

$RECTANGULAR\ COLUMNS\ -\ 3.6$

FOR THE VALUES OF A

$$CIRCULAR\ COLUMNS - \frac{\pi * D^2}{4}$$

$$RECTANGULAR\ COLUMNS\ -\ B * D$$

FOR VALUES OF I (MOMENT OF INERTIA)

$$CIRCULAR\ COLUMNS = \frac{\pi * D^4}{64}$$

$$RECTANGULAR\ COLUMNS = \frac{B * H^3}{12}$$

FOR THE VALUES OF $\boldsymbol{\delta_f(m)}$

(DISPLACEMENT DUE TO FLEXURE)

$$\boldsymbol{\delta_f} = \frac{Ph^3}{12EI}$$

$\boldsymbol{\delta_f} = DISPLACEMENT\ DUE\ TO\ FLEXURE$

$\boldsymbol{P} = 1000\ kN$

$\boldsymbol{h} = Height\ of\ Column$

$\boldsymbol{E} = Modulus\ of\ Elasticity$

$\boldsymbol{I} = Moment\ of\ Inertia$

FOR THE VALUES OF $\boldsymbol{\delta_v(m)}$

(DISPLACEMENT DUE TO SHEAR)

$$\boldsymbol{\delta_V} = \frac{1.2Ph}{GA}$$

$\boldsymbol{\delta_V} = DISPLACEMENT\ DUE\ TO\ SHEAR$

$\boldsymbol{\delta_T} = TOTAL\ DISPLACEMENT$

$\boldsymbol{P} = 1000\ kN$

$\boldsymbol{h} = Height\ of\ Column$

$\boldsymbol{G} = Shear\ Modulus$

$\boldsymbol{A} = Column\ Area$

FOR THE VALUES OF $\boldsymbol{\delta_T(m)}$

(TOTAL DISPLACEMENT)

$$\boldsymbol{\delta_T} = \boldsymbol{\delta_f} + \boldsymbol{\delta_v}$$

$\boldsymbol{\delta_f} = DISPLACEMENT\ DUE\ TO\ FLEXURE$

$\boldsymbol{\delta_V} = DISPLACEMENT\ DUE\ TO\ SHEAR$

$\boldsymbol{\delta_T} = TOTAL\ DISPLACEMENT$

FOR THE VALUES OF (STIFFNESS FACTOR)

$$\boldsymbol{K} = \frac{\boldsymbol{1}}{\boldsymbol{\delta_T}}$$

$\boldsymbol{K} = STIFFNESS\ FACTOR$

$\boldsymbol{\delta_T} = TOTAL\ DISPLACEMENT$

$$\boldsymbol{E_c} = 4700\sqrt{f'c}$$

$$\boldsymbol{24.84 * 10^3 MPa} = 4700\sqrt{f'c}$$

$$f'c = 27.9323\ MPa\ x\ 145\frac{psi}{MPa}$$

$$\boldsymbol{f'c = 4050\ psi}$$

STIFFNESS OF COLUMNS

Center of Mass, Center of Rigidity, and Eccentricities

WEST TO EAST DIRECTION

Frame	Column	B	D	H	A	I	δ_f (m)	δ_v (m)	δ_T (m)	K	TOTAL
1	A	0	0.5965	3.6	0.2795	0.00621	0.02519	0.0016	0.02674	37.4	137.69
	B	0.5	0.5	3.6	0.25	0.00521	0.03005	0.0017	0.03179	31.5	
	C	0.5	0.5	3.6	0.25	0.00521	0.03005	0.0017	0.03179	31.5	
	D	0	0.5965	3.6	0.2795	0.00621	0.02519	0.0016	0.02674	37.4	
2	A	0	0.5965	3.6	0.2795	0.00621	0.02519	0.0016	0.02674	37.4	137.69
	B	0	0.5965	3.6	0.2795	0.00621	0.02519	0.0016	0.02674	37.4	
	C	0.5	0.5	3.6	0.25	0.00521	0.03005	0.0017	0.03179	31.5	
	D	0.5	0.5	3.6	0.25	0.00521	0.03005	0.0017	0.03179	31.5	
3	A	0	0	0	0.0000	0.00000	#DIV/0!	#DIV/0!	#DIV/0!	0.0	106.23
	B	0	0.5965	3.6	0.2795	0.00621	0.02519	0.0016	0.02674	37.4	
	C	0	0.5965	3.6	0.2795	0.00621	0.02519	0.0016	0.02674	37.4	
	D	0.5	0.5	3.6	0.25	0.00521	0.03005	0.0017	0.03179	31.5	
4	A	0	0	0	0.0000	0.00000	#DIV/0!	#DIV/0!	#DIV/0!	0.0	74.782
	B	0	0	0	0.0000	0.00000	#DIV/0!	#DIV/0!	#DIV/0!	0.0	
	C	0	0.5965	3.6	0.2795	0.00621	0.02519	0.0016	0.02674	37.4	
	D	0	0.5965	3.6	0.2795	0.00621	0.02519	0.0016	0.02674	37.4	
										TOTAL	456.39

What is the compressive strength used in psi considering that it is a normal weight concrete?

4050 psi

Determine the stiffness for column A-1.

ANSWER:
37.4 kN

Determine the stiffness for column B-1.

ANSWER:
31.5 kN

Determine the stiffness for column C-1.

ANSWER:
31.5 Kn

Determine the stiffness for column D-1.

ANSWER:
37.4 kN

Determine the stiffness for column A-2.

ANSWER:
37.4 kN

Determine the stiffness for column B-2.

ANSWER:
37.4 kN

Determine the stiffness for column C-2.

ANSWER:
31.5 kN

Determine the stiffness for column D-2.

ANSWER:
31.5 kN

Determine the stiffness for column A-3.

ANSWER:
0 kN

Determine the stiffness for column B-3

ANSWER:
37.4 kN

Determine the stiffness for column C-3.

ANSWER:
37.4 kN

Determine the stiffness for column D-3.

ANSWER:
31.5 kN

Determine the stiffness for column A-4.

ANSWER:
0 kN

Determine the stiffness for column B-4.

ANSWER:
0 kN

Determine the stiffness for column C-4.

ANSWER:
37.4 Kn

Determine the stiffness for column D-4.

ANSWER:
37.4 kN

What is the compressive strength used in psi considering that it is a normal weight concrete?
ANSWER:
4050 psi

FORMATIVE ASSESMENT 3 - SOLUTION

PROBLEM #1: A 4-storey with roof deck structural steel has the following minimum design loads from the NSCP:

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4. Gypsum Board = 0.04 kPa
5. Suspended Steel Chanel = 0.10 kPa
6. Beam/Column = 1.00 kPa

Total = 7.92 kPa (with Movable Partition)

B. $W_{walls/parapet}$ = 2.70 kPa

C. Height of Walls and Parapet = 3.6m/1.5m

D. Tributary Area = 210 sq.m

E. P_{walls} = 108m (Typical Levels)

F. P_{walls} = 12m (Deck Levels)

G. $P_{parapet}$ = 50m (Deck Levels)

SOLUTION:

ROOF DECK LEVEL

$$\boldsymbol{DL} = Total_{LOAD}\ x\ T_A$$

$$\boldsymbol{DL} = 7.92\ x\ 210.00$$

$$\boldsymbol{DL = 1663.2\ kN}$$

$$\boldsymbol{WALLS_1} = W_{walls} * \frac{H_{Walls}}{2} * P_{walls(T.L)}$$

$$\boldsymbol{WALLS_1} = 2.7 * 1.8 * 108$$

$$\boldsymbol{WALLS_1 = 524.88\ kN}$$

$$\boldsymbol{WALLS_2} = W_{walls} * H_{Walls} * P_{walls(deck)}$$

$$\boldsymbol{WALLS_2} = 2.7 * 3.6 * 12$$

$$\boldsymbol{WALLS_1 = 116.64\ kN}$$

$$\boldsymbol{Parapet} = W_{Par} * Height_{Par} * P_{walls}$$

$$\boldsymbol{WALLS_2} = 2.7 * 1.5 * 50$$

$$\boldsymbol{WALLS_1 = 202.50\ kN}$$

$$\boldsymbol{TOTAL\ LOADS\ (DECK) = 2507.22\ kN}$$

TYPICAL LEVEL

$$\boldsymbol{DL} = Total_{LOAD}\ x\ T_A$$

$$\boldsymbol{DL} = 7.92\ x\ 210.00$$

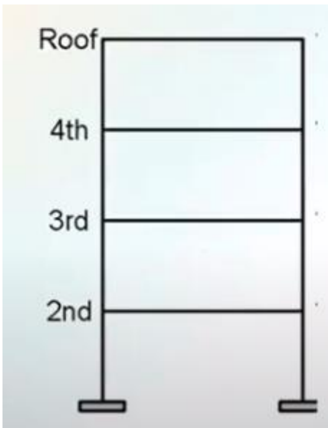
$$\boldsymbol{DL = 1663.2\ kN}$$

$$\boldsymbol{WALLS_1} = W_{walls} * Height_{Walls} * P_{walls}$$

$$\boldsymbol{WALLS_1} = 2.7 * 3.6 * 108$$

$$\boldsymbol{WALLS_1 = 1049.76\ kN}$$

$$\boldsymbol{T\_LOADS\ (T.L) = 2712.96kN}$$



2507.22 kN

2712.96 kN

2712.96 kN

2712.96 kN

$$\boldsymbol{W_T = 2507.22 + (3)(2712.96)}$$

$$\boldsymbol{W_T = 10,646.10\ kN}$$

What is the total weight of the structure?

ANSWER:
10646.10 kN

Solve for the W_{DL}.

ANSWER:
1663.20 kN

What is the total weight in the roof level?

ANSWER:
2507.22 kN

What is the weight of the walls in the typical levels?

ANSWER:
1049.76 kN

What is the weight of the walls below deck level?

ANSWER:
524.88 kN

What is the total weight in the 2^{nd} level?

ANSWER:
2712.96 kN

What is the total weight in the 3^{rd} level?

ANSWER:
2712.96 kN

What is the total weight in the 4^{th} level?

ANSWER:
2712.96 kN

PROBLEM #2: A 4-storey with roof deck were presented in the figure. Using the following values:

A. Beam/Column Sizes

- EB/SB = 0.25m x 0.40m
- Joist = 0.25m x 0.50m
- Girder = 0.35m x 0.60m
- Column = 0.40m x 0.40m

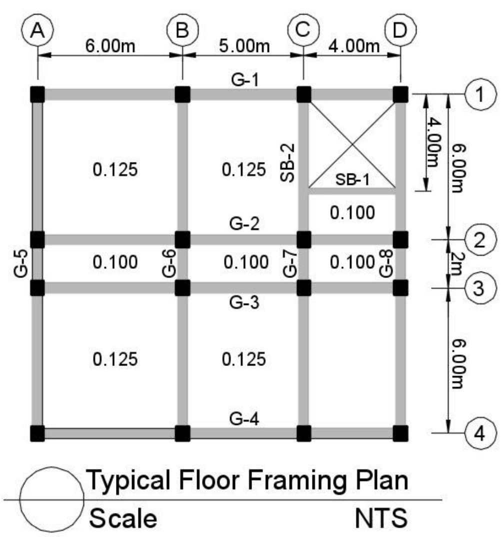
B. Design Loads

- Parapet/Wall = 2.70 kPa
- Superimposed DL = 1.60 kPa
- Unit Weight of Concrete = 24 kN/m^3
- Height of Wall = 3.2m
- Height of Parapet = 1.5m
- Stairs = 5 kPa

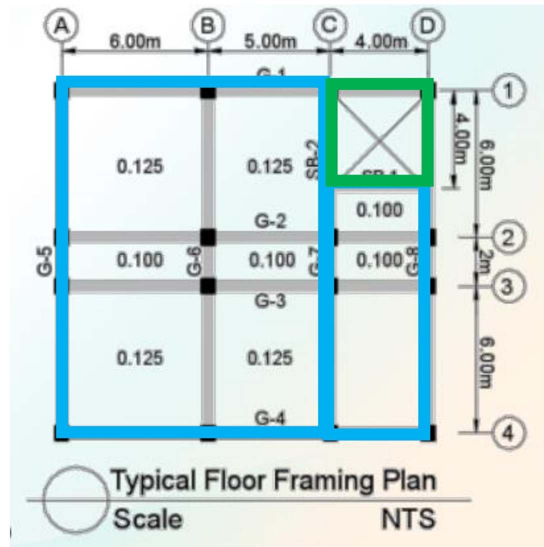
C. Perimeter of the walls in the typical level = 108m

D. Perimeter of the walls at the deck level = 12m

E. Perimeter of the parapet in the deck level = 50m



1. SOLVE FOR TRIBUTARY AREAS

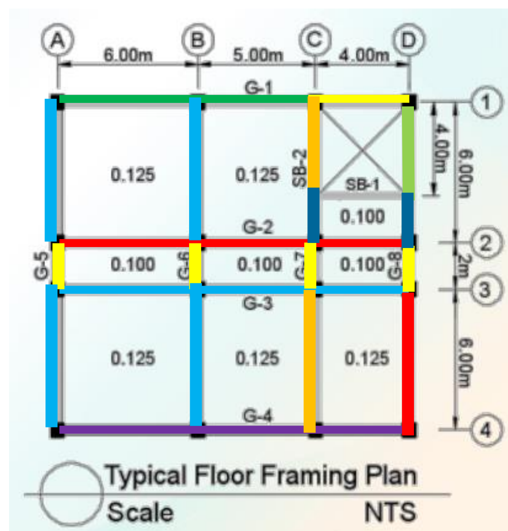


$$T_{AREA} = 11(14) + 4(10)$$

$$T_{AREA} = 194\ m^2$$

WEIGHT COMPUTATIONS

$$AREA_{CROSS} * L = V * P_{CONC} = Weight$$



A. DECK LEVELS

HORIZONTAL DIRECTION

- **SB=** 0.25 (0.4-0.1) (4)(24) = **7.2 KN**

$$T.WEIGHT\ OF\ SB\ (DECK) = 7.2\ kN$$

- G-1 =0.35(0.6-0.125) (11)(24) **=43.89 KN**
- **G-1=0.35(0.6)(4)(24) = 20.16**
- **G-2**=0.35(0.6-0.1)(15)(24)=**63 KN**
- **G-3**=0.35(0.6-0.1)(15)(24)=**63 KN**
- **G-4**=0.35(06-0.125)(15)(24)=**59.85**

VERTICAL DIRECTION

- **G-5**=0.35(0.6-0.1)(2)(24)=**8.40 KN**
- **G-6**=0.35(0.6-0.1)(2)(24)=**8.40 KN**
- **G-7**=0.35(0.6-0.1)(2)(24)=**8.40 KN**
- **G-8**=0.35(0.6-0.1)(2)(24)=**8.40 KN**

- **G-5=0.35(0.6-0.125)(12)(24)=47.88 KN**
- **G-6=0.35(0.6-0.125)(12)(24)=47.88 KN**

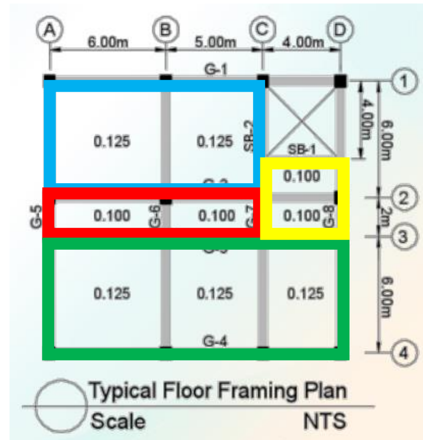
- **G-7=0.35(0.6-0.125)(6)(24)=23.94 KN**
- **G-7=0.35(0.6-0.1)(4)(24)=15.96 KN**

- **G-8=0.35(0.6)(4)(24)=20.16 KN**

- **G-8=0.35(0.6-0.1)(2)(24)=8.40 KN**

- **G-8=0.35(0.6)(6)(24)=23.94 KN**

$$\boldsymbol{T.WEIGHT\ OF\ GIRDER\ (DECK)} = \boldsymbol{471.66\ kN}$$



$$\boldsymbol{FORMULA}: (\boldsymbol{A * T * P_{CONC}})$$

- **SLAB1 = (11)(6)(0.125)(24) = 198 KN**
- **SLAB2 = (11)(2)(0.1)(24) = 52.8 KN**
- **SLAB3 = (15)(6)(0.125)(24) = 270 KN**
- **SLAB4= (4)(4)(0.1)(24) = 38.4 KN**

$$\boldsymbol{T.WEIGHT\ OF\ SLAB = 559.2\ kN}$$

- $\boldsymbol{PARAPET} = 2.7(50)(1.5) = \boldsymbol{202.5\ KN}$

- $\boldsymbol{S_{DL}} = (1.6)(194) = \boldsymbol{310.4\ KN}$
- $\boldsymbol{COLUMNS} = (0.4)(0.4)(1.6)\ (24)\ (16) = \boldsymbol{98.3\ KN}$

- $\boldsymbol{WALLS - A} = 2.7\ (12)(3.2) = \boldsymbol{103.68\ KN}$

- $\boldsymbol{WALLS - B} = 2.7\ (108)(1.6) = \boldsymbol{466.56\ KN}$

TOTAL WEIGHT = SUMMATION OF LOADS

$$\boldsymbol{TOTAL\ WEIGHT} = W_{SLABS} + W_{GIRDERS} + W_{SB} + W_{PARAPET} + W_{SDL} + W_{COLUMNS} + W_{WALLS-A} + W_{WALLS-B}$$

$$\boldsymbol{TOTAL\ WEIGHT} = 7.2 + 480.06 + 559.2 + 210.6 + 310.4 + 98.3 + 570.24$$

$$\boldsymbol{TOTAL\ WEIGHT = 2219.50\ KN}$$

What is the total weight of the girders in the deck level?

ANSWER:
471.66 Kn

What is the value of the super imposed deadload in the deck level?

ANSWER:
310.4 Kn

What is the total weight in the deck level?

ANSWER:
310.4 Kn

What is the total weight of the columns in the typical levels?

ANSWER:
196.608 kN

What is the total weight of the parapet in the deck level?

ANSWER:
202.5 kN

What is the total weight of the walls in the typical levels?

ANSWER:
933.12 kN

What is the weight of the stair beam in the deck level?

ANSWER:
7.2 Kn

What is the total weight in the 4th level?

ANSWER:
2478.19 kN

What is the total weight of the walls in the deck level?

ANSWER:
570.24 kN

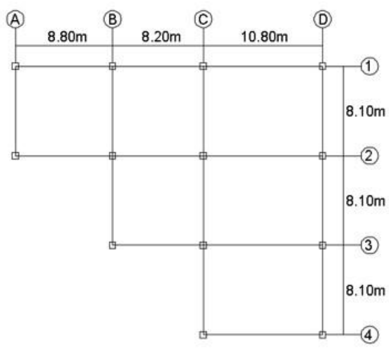
What is the total weight of the columns in the deck?

ANSWER:
98.30 kN

What is the total weight of the slabs in the deck level?

ANSWER:
559.2 Kn

PROBLEM #3 The framing plan of a two-storey post tensioned structure is shown below. Due to some issues, the ***owner suggests to change the corner columns to equivalent circular columns of the same section modulus as the initial square columns*** designated as shown in the figure. The ***size of the square columns is 0.50 by 0.50m***. ***Height per level is 3.60 meters***. ***E = 24.84 x 10^6 kPa and G = 9.92 x 10^6 kPa***. Use column A-1 as building reference point. Assume the lateral force is acting from north to south direction. Considering the framing plan below as a typical floor framing plan: Set your calculator to 5 decimal places.



GIVEN:

$$\boldsymbol{b} = 0.50\ m$$

$$\boldsymbol{d} = 0.50\ m$$

SOLUTION:

FOR SQUARE COLUMNS

$$Z_{x(SC)} = \frac{bd^2}{6} = \frac{\mathbf{0.5^3}}{\mathbf{6}} = \frac{\mathbf{1}}{\mathbf{48}}\boldsymbol{m^3}$$

FOR CIRCULAR COLUMNS

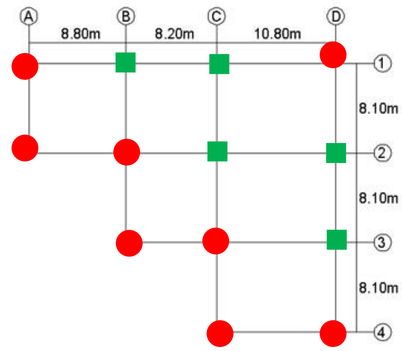
$$Z_{x(CC)} = \frac{\pi D^3}{32}$$

FIND D NEEDED FOR EQUIVALENT CIRCULAR COLUMN

$$\frac{1}{48} = \frac{\pi D^3}{32}$$

$$\boldsymbol{D} = \sqrt[3]{\frac{\mathbf{32}}{\mathbf{48\pi}}}$$

$$\boldsymbol{D = 0.5965\ m}$$



- CIRCULAR COLUMNS

- RECTANGULAR COLUMNS

FOR THE VALUES OF B

$CIRCULAR\ COLUMNS - 0$

$RECTANGULAR\ COLUMNS\ -\ 0.5$

FOR THE VALUES OF D

$CIRCULAR\ COLUMNS - 0.5965$

$RECTANGULAR\ COLUMNS\ -\ 0.5$

FOR THE VALUES OF H

$CIRCULAR\ COLUMNS - 3.6$

$RECTANGULAR\ COLUMNS\ -\ 3.6$

FOR THE VALUES OF A

$CIRCULAR\ COLUMNS - \frac{\pi * D^2}{4}$

$RECTANGULAR\ COLUMNS\ -\ B * D$

FOR VALUES OF I (MOMENT OF INERTIA)

- $CIRCULAR\ COLUMNS = \frac{\pi * D^4}{64}$
- $RECTANGULAR\ COLUMNS = \frac{B * H^3}{12}$

FOR THE VALUES OF $\boldsymbol{\delta_f (m)}$

(DISPLACEMENT DUE TO FLEXURE)

$$\boldsymbol{\delta_f} = \frac{Ph^3}{12EI}$$

$\boldsymbol{\delta_f} = DISPLACEMENT\ DUE\ TO\ FLEXURE$

$\boldsymbol{P} = 1000\ kN$

$\boldsymbol{h} = Height\ of\ Column$

$\boldsymbol{E} = Modulus\ of\ Elasticity$

$\boldsymbol{I} = Moment\ of\ Inertia$

FOR THE VALUES OF $\boldsymbol{\delta_v (m)}$

(DISPLACEMENT DUE TO SHEAR)

$$\boldsymbol{\delta_V} = \frac{1.2Ph}{GA}$$

$\boldsymbol{\delta_V} = DISPLACEMENT\ DUE\ TO\ SHEAR$

$\boldsymbol{\delta_T} = TOTAL\ DISPLACEMENT$

$\boldsymbol{P} = 1000\ kN$

$\boldsymbol{h} = Height\ of\ Column$

$\boldsymbol{G} = Shear\ Modulus$

$\boldsymbol{A} = Column\ Area$

FOR THE VALUES OF $\boldsymbol{\delta_T (m)}$

(TOTAL DISPLACEMENT)

$$\boldsymbol{\delta_T = \delta_f + \delta_v}$$

$\boldsymbol{\delta_f} = DISPLACEMENT\ DUE\ TO\ FLEXURE$

$\boldsymbol{\delta_V} = DISPLACEMENT\ DUE\ TO\ SHEAR$

$\boldsymbol{\delta_T} = TOTAL\ DISPLACEMENT$

FOR THE VALUES OF (STIFFNESS FACTOR)

$$\boldsymbol{K} = \frac{\boldsymbol{1}}{\boldsymbol{\delta_T}}$$

$\boldsymbol{K} = STIFFNESS\ FACTOR$

$\boldsymbol{\delta_T} = TOTAL\ DISPLACEMENT$

$$\boldsymbol{E_c} = 4700\sqrt{f'c}$$

$$\boldsymbol{24.84 * 10^3 MPa} = 4700\sqrt{f'c}$$

$$f'c = 27.9323\ MPa\ x\ 145\frac{psi}{MPa}$$

$$\boldsymbol{f'c = 4050\ psi}$$

STIFFNESS OF COLUMNS

Center of Mass, Center of Rigidity, and Eccentricities

WEST TO EAST DIRECTION

Frame	Column	B	D	H	A	I	δ_f (m)	δ_v (m)	δ_T (m)	K	TOTAL
1	A	0	0.5965	3.6	0.2795	0.00621	0.02519	0.0016	0.02674	37.4	137.69
	B	0.5	0.5	3.6	0.25	0.00521	0.03005	0.0017	0.03179	31.5	
	C	0.5	0.5	3.6	0.25	0.00521	0.03005	0.0017	0.03179	31.5	
	D	0	0.5965	3.6	0.2795	0.00621	0.02519	0.0016	0.02674	37.4	
2	A	0	0.5965	3.6	0.2795	0.00621	0.02519	0.0016	0.02674	37.4	137.69
	B	0	0.5965	3.6	0.2795	0.00621	0.02519	0.0016	0.02674	37.4	
	C	0.5	0.5	3.6	0.25	0.00521	0.03005	0.0017	0.03179	31.5	
	D	0.5	0.5	3.6	0.25	0.00521	0.03005	0.0017	0.03179	31.5	
3	A	0	0	0	0.0000	0.00000	#DIV/0!	#DIV/0!	#DIV/0!	0.0	106.23
	B	0	0.5965	3.6	0.2795	0.00621	0.02519	0.0016	0.02674	37.4	
	C	0	0.5965	3.6	0.2795	0.00621	0.02519	0.0016	0.02674	37.4	
	D	0.5	0.5	3.6	0.25	0.00521	0.03005	0.0017	0.03179	31.5	
4	A	0	0	0	0.0000	0.00000	#DIV/0!	#DIV/0!	#DIV/0!	0.0	74.782
	B	0	0	0	0.0000	0.00000	#DIV/0!	#DIV/0!	#DIV/0!	0.0	
	C	0	0.5965	3.6	0.2795	0.00621	0.02519	0.0016	0.02674	37.4	
	D	0	0.5965	3.6	0.2795	0.00621	0.02519	0.0016	0.02674	37.4	
										TOTAL	456.39

What is the compressive strength used in psi considering that it is a normal weight concrete?

4050 psi

Determine the stiffness for column A-1.

ANSWER:
37.4 kN

Determine the stiffness for column B-1.

ANSWER:
31.5 kN

Determine the stiffness for column C-1.

ANSWER:
31.5 Kn

Determine the stiffness for column D-1.

ANSWER:
37.4 kN

Determine the stiffness for column A-2.

ANSWER:
37.4 kN

Determine the stiffness for column B-2.

ANSWER:
37.4 kN

Determine the stiffness for column C-2.

ANSWER:
31.5 kN

Determine the stiffness for column D-2.

ANSWER:
31.5 kN

Determine the stiffness for column A-3.

ANSWER:
0 kN

Determine the stiffness for column B-3

ANSWER:
37.4 kN

Determine the stiffness for column C-3.

ANSWER:
37.4 kN

Determine the stiffness for column D-3.

ANSWER:
31.5 kN

Determine the stiffness for column A-4.

ANSWER:
0 kN

Determine the stiffness for column B-4.

ANSWER:
0 kN

Determine the stiffness for column C-4.

ANSWER:
37.4 Kn

Determine the stiffness for column D-4.

ANSWER:
37.4 kN

What is the compressive strength used in psi considering that it is a normal weight concrete?
ANSWER:
4050 psi

Horizontal Torsional Moments: In the equation below, δ_{avg} = the maximum displacement at Level x, mm
Ax=[δmax/1.2δavg]2

False

Horizontal Torsional Moments: The accidental torsional moment shall be determined by assuming the mass displaced as required by Section 208.5.1.3.

Group of answer choices
True

Horizontal Distribution of Shear: The design storey shear, V_x in any storey is the sum of the forces F_t and F_x above that storey.

True

A single storey building has a roof diaphragm. Shear walls resists lateral forces at both directions. The mass of the roof can be considered to be uniformly distributed, and in this example, the weight of the wall is neglected. In actual practice, particularly with concrete shear walls, the weight of the walls should be included in the determination of the center of mass (CM). The following information is given:

Design base shear:

V = 450 kN

Wall Rigidities:

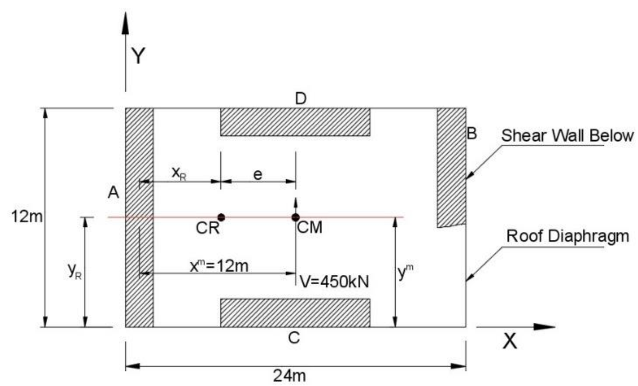
R_A = 54 kN/mm

R_B = 18 kN/mm

R_C = R_D = 36 kN/mm

Center of Mass:

x_m = 12m, y_m = 6m



What is the value of the direct shear in Wall B?

112.5 kN

What is the value of the direct shear in Wall B?

112.5 kN

Accidental torsion amplification factor.

1.37

A single storey building has a roof

What is the value of the direct shear in Wall A?

Group of answer choices

337.5 kN

What is the initial total shear at A?

266.625 kN

What is the center of rigidity at the x-direction?

6m

The framing plan of a concrete SMRF building is shown below. If the total height of the structure is 21 meters (3 meters per level), compute the displacements for both N-S and W-E direction (in each levels). Use column A-1 as the building reference point. Assume the lateral forces to be acting at the building's least dimension. Columns are located at the intersections of the grid lines.

Column Properties:

$E = 24.84 \times 10^6$ kPa $G = 9.92 \times 10^6$ kPa

Seismic Data:

$C_v = 0.51$

$I = 1.25$

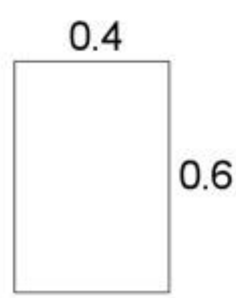
$R = 8.5$

$C_a = 0.38$

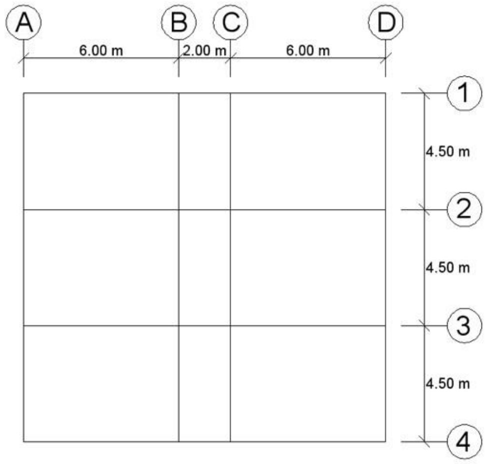
$Z = 0.40$

$N_v = 1.60$

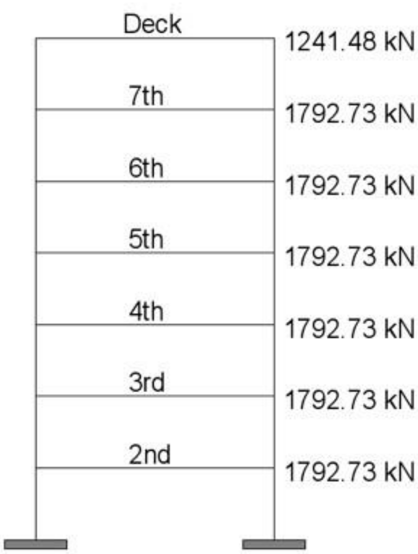
Column Size:



Framing Plan:



Weight per Level:



What is the lateral force at the 6th level (vertical distribution)?

Group of answer choices

230.6 kN

What is the stiffness of frame D (North to South Direction)?

Group of answer choices

284 kN

What is the total stiffness of the columns in the north to south direction?

Group of answer choices

1136 kN

What is the stiffness of frame 3 (West to East Direction)?

Group of answer choices

134 kN

What is the lateral force at the deck level (vertical distribution)?

286.5 kN

What is the lateral force at the 7th level (vertical distribution)?

276.7 kN

What is the governing design base shear?

1255 kN

What is the lateral force at the 5th level (vertical distribution)?

Group of answer choices

184.4 kN

What is the lateral force at the 3rd level (vertical distribution)?

92.2 kN

What is the total stiffness of the columns in the west to east direction?

537 kN

The plan configuration of a ten – storey special moment frame building is a shown below.

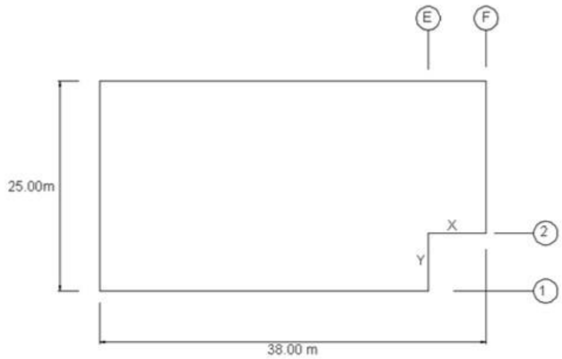


Figure A

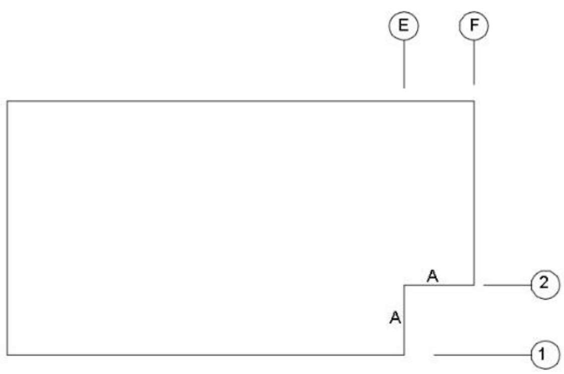


Figure B

Which of the following most nearly gives the maximum area of the re – entrant corner in figure A so that plan irregularity type 3 will not exist?

21375 sq.m.

The plan configuration of a ten – storey special moment frame building is a shown below.

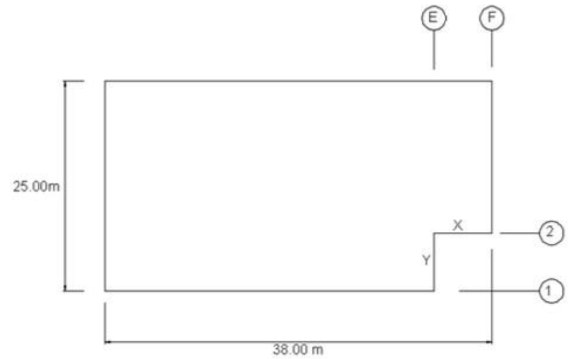


Figure A

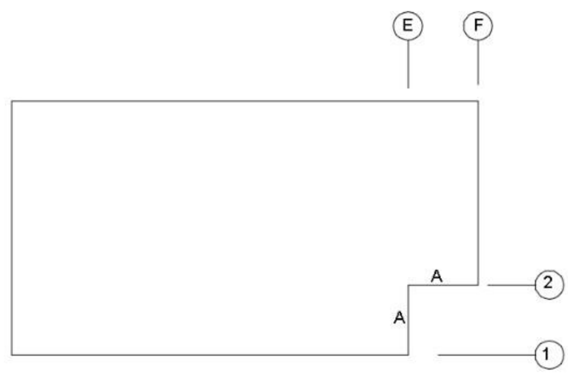
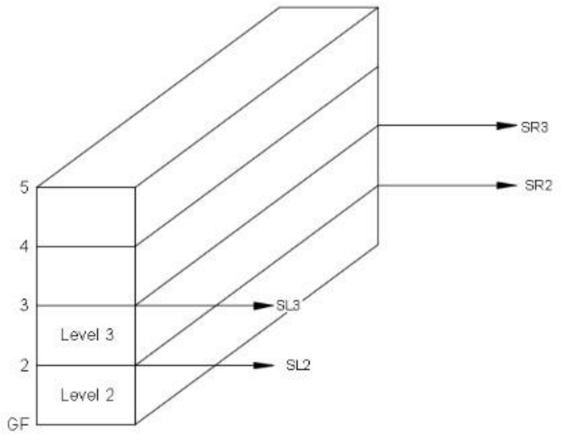


Figure B

Which of the following most nearly gives the maximum area of the re – entrant corner in figure B if the total area is 500 sq.m so that plan irregularity type 3 will not exist?

11.25 sq.m.

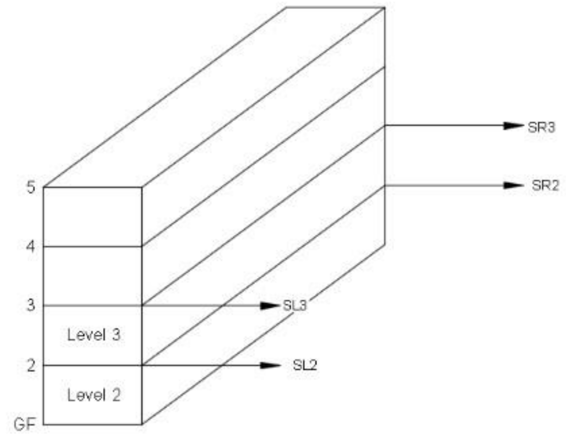
A four – storey special moment resisting frame building has rigid floor diaphragms. Under specified seismic forces, including the effects of accidental torsion, it has the following displacement at levels 2 and 3. S_{L2} = 28 mm, S_{R2} = 31.5 mm and S_{L3}=32 mm. The maximum storey drift is at the right side of the structure.



Which of the following most nearly gives the governing eccentricity if the structural dimension is 15m by 14m and the value of SR3 = 60.4mm, ex = 0.50m and ey = 0.60m? Assume the lateral force acting on the least dimension of the structure.

0.84m

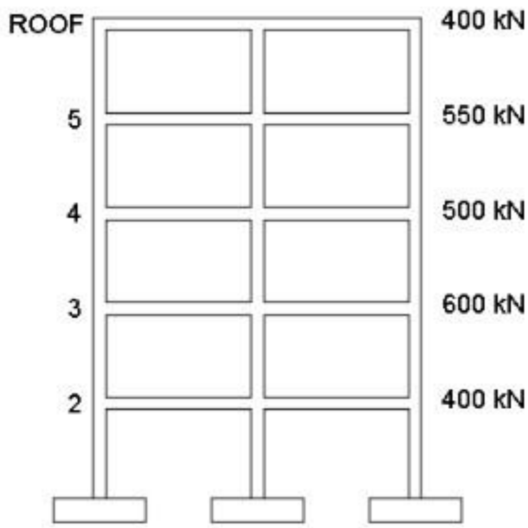
A four – storey special moment resisting frame building has rigid floor diaphragms. Under specified seismic forces, including the effects of accidental torsion, it has the following displacement at levels 2 and 3. S_{L2} = 28 mm, S_{R2} = 31.5 mm and S_{L3}=32 mm. The maximum storey drift is at the right side of the structure.



Which of the following most nearly gives the value of the governing amplification factor at the third level if the value of SR3 = 37.5 mm?

1.00

The five storey special moment frame office building has a heavy utility equipment installation at level 3. This results in the floor weight distribution shown below. Set of equipment weighing 1/3 of the 3rd floor weight was installed in the 3rd level.

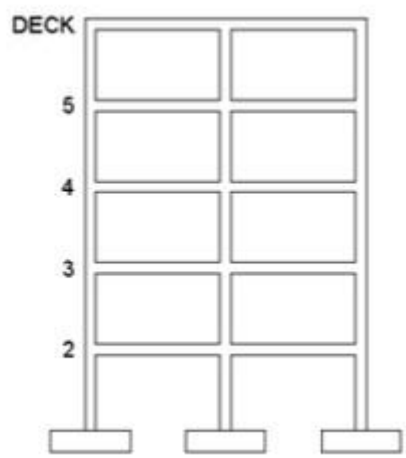


Which of the following most nearly gives the level/s (adjacent levels only) that will have type 2 vertical irregularity considering the weight at the 5th level?
Type 2 vertical irregularity does not exist

In horizontal irregularity type 1, when the ratio of maximum drift to average drift exceeds the given limit, there is the potential for an unbalance in the inelastic deformation demands at the two extreme sides of a storey.
True

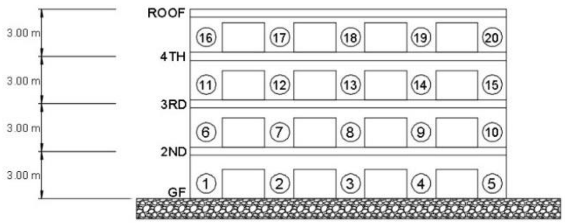
In horizontal irregularity type 2, the opening and closing deformation response or flapping action of the projecting legs of the building plan adjacent to re-entrant corners can result in concentrated forces at the corner point.
True

A six storey concrete special moment – resisting frame is shown below. The specified lateral forces Fx have been applied and the corresponding storey displacement per floor level have been determined in the ground level equal to zero and the storey displacement at the typical levels is described by equation $y = 2x^{0.75} + 15$ where "y" is the storey displacement per floor level in mm and the "x" is the height per level from the natural grade line (in meters). The height of each level is 3.2 meters. Use 5 decimal places.



Which of the following most nearly gives the storey displacement at the 5th level?
1.112 in

A concrete bearing wall building has the typical transverse shear wall configuration shown below. All walls in this direction are identical and the individual piers have the shear contribution given below.

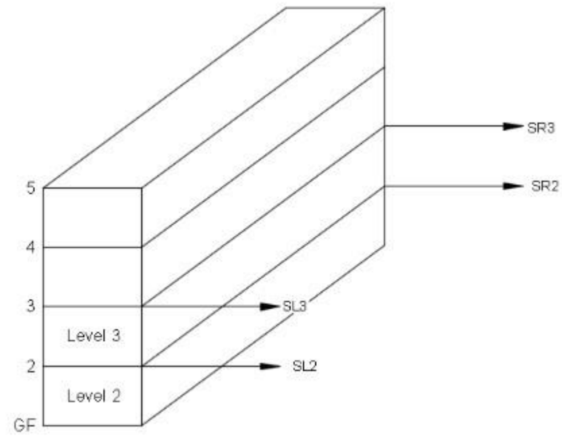


PIER	Vn (kN)	Vm (kN)	PIER	Vn (kN)	Vm (kN)
1	15	25	5	31	32
2	20	18	6	35	30
3	20	22	7	29	35
4	24	30	8	21	18
9	15	16	15	16	25
10	36	27	16	27	30
11	30	40	17	34	27
12	25	20	18	38	29
13	36	31	19	16	25
14	-	-	20	32	19

Which of the following most nearly gives the strength of the third storey?

119

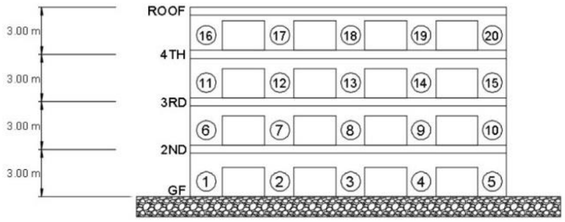
A four – storey special moment resisting frame building has rigid floor diaphragms. Under specified seismic forces, including the effects of accidental torsion, it has the following displacement at levels 2 and 3. S_{L2} = 28 mm, S_{R2} = 31.5 mm and S_{L3}=32 mm. The maximum storey drift is at the right side of the structure.



Which of the following most nearly gives the maximum displacement at the right side in the third level of the structure so that plan irregularity type 1 will not exist?

37.5 mm

A concrete bearing wall building has the typical transverse shear wall configuration shown below. All walls in this direction are identical and the individual piers have the shear contribution given below.

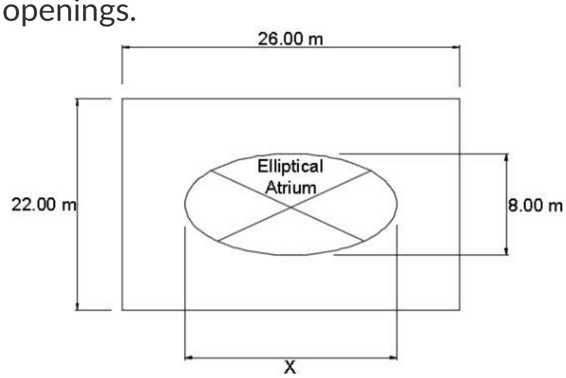


PIER	Vn (kN)	Vm (kN)	PIER	Vn (kN)	Vm (kN)
1	15	25	5	31	32
2	20	18	6	35	30
3	20	22	7	29	35
4	24	30	8	21	18
9	15	16	15	16	25
10	36	27	16	27	30
11	30	40	17	34	27
12	25	20	18	38	29
13	36	31	19	16	25
14	-	-	20	32	19

Which of the following most nearly gives the strength of the second storey?

108 kN

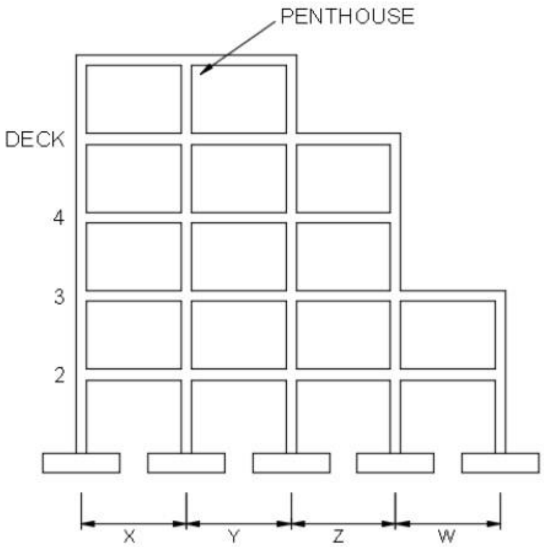
A five – storey concrete building has a bearing wall system located around the perimeter of the building. Lateral forces are resisted by the bearing walls acting as shear walls. The floor plan of the second floor of the building Is shown below. The open area in the diaphragm is for an atrium. All diaphragms above the second floor are without significant openings.



Which of the following most nearly gives the maximum ratio of the deflection of the 2nd level to that of the 3rd level so that horizontal irregularity type 3 will not exist?

1.500

The lateral force – resisting system of the four storey special moment frame building is shown below. X = 3m, y = 4m and z = 3.6m.



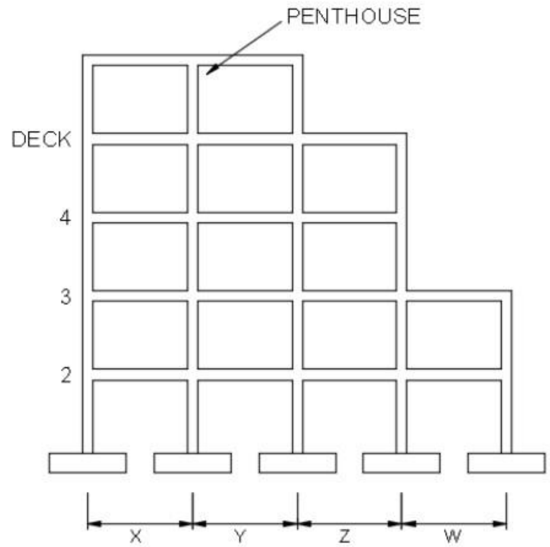
Which of the following most nearly gives the maximum value of "w" so that vertical irregularity type 3 will not exist?

10.433 ft
9.433 ft
8.433 ft
7.433 ft

In horizontal irregularity type 5, The response deformations and load patterns on a system with non-parallel lateral force-resisting elements can have significant differences from that of a regular system.

True
False

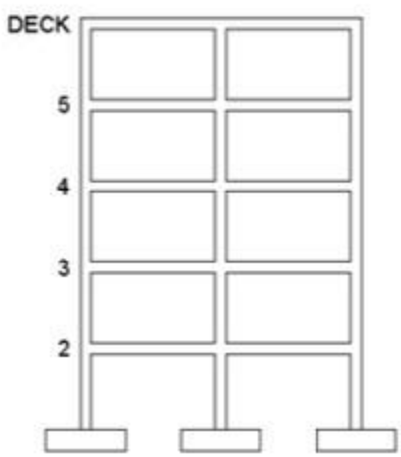
The lateral force – resisting system of the four storey special moment frame building is shown below. X = 3m, y = 4m and z = 3.6m.



Which of the following most nearly gives the levels with vertical irregularity type 3 if w = 3m?

No vertical type 3 irregularity
Penthouse – deck and Level 3 – 4
Level 3 – 4 only
Penthouse – deck only

A six storey concrete special moment – resisting frame is shown below. The specified lateral forces Fx have been applied and the corresponding storey displacement per floor level have been determined in the ground level equal to zero and the storey displacement at the typical levels is described by equation $y = 2x^{0.75} + 15$ where "y" is the storey displacement per floor level in mm and the "x" is the height per level from the natural grade line (in meters). The height of each level is 3.2 meters. Use 5 decimal places.



Which of the following most nearly gives the level/s with soft storey status?

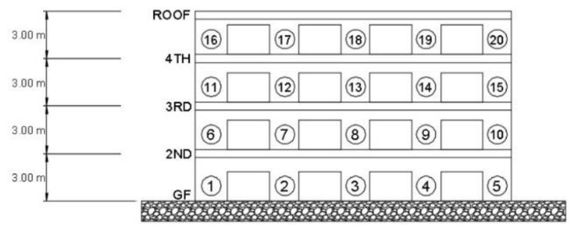
Level 2 only

Level 3 only

Level 2 and 3

Level 4, 5, 6 and deck

A concrete bearing wall building has the typical transverse shear wall configuration shown below. All walls in this direction are identical and the individual piers have the shear contribution given below.



PIER	Vn (kN)	Vm (kN)	PIER	Vn (kN)	Vm (kN)
1	15	25	5	31	32
2	20	18	6	35	30
3	20	22	7	29	35
4	24	30	8	21	18
9	15	16	15	16	25
10	36	27	16	27	30
11	30	40	17	34	27
12	25	20	18	38	29
13	36	31	19	16	25
14	-	-	20	32	19

Which of the following most nearly gives the maximum strength of pier 14 so that vertical irregularity type 5 will not exist between level 3 and 4?

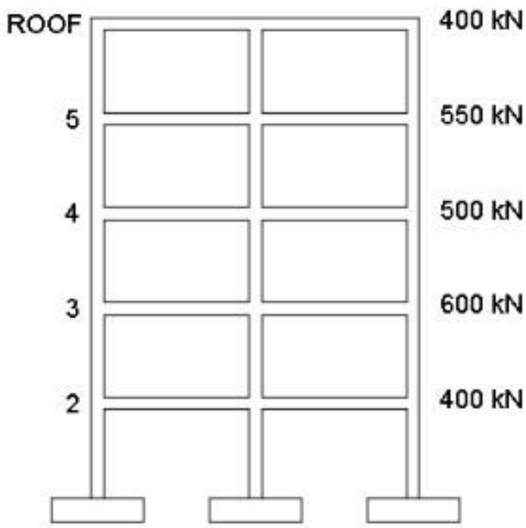
51.75kN

81.75 kN

73.00 kN

60.50 kN

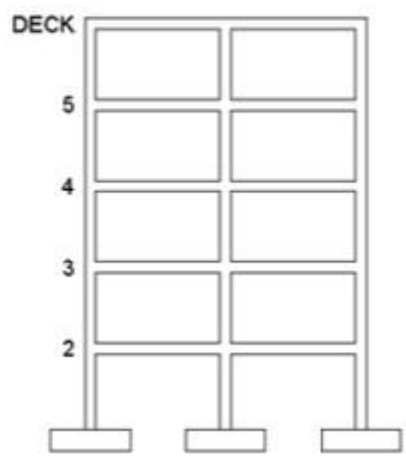
The five storey special moment frame office building has a heavy utility equipment installation at level 3. This results in the floor weight distribution shown below. Set of equipment weighing 1/3 of the 3rd floor weight was installed in the 3rd level.



Which of the following most nearly gives the minimum weight of additional equipment to be installed at the 2nd level so that type 2 vertical irregularity will not exist considering the applied equipment at the third level?

133.3 kN
132.3 kN
135.3 kN
134.3 kN

A six storey concrete special moment – resisting frame is shown below. The specified lateral forces Fx have been applied and the corresponding storey displacement per floor level have been determined in the ground level equal to zero and the storey displacement at the typical levels is described by equation $y = 2x^{0.75} + 15$ where "y" is the storey displacement per floor level in mm and the "x" is the height per level from the natural grade line (in meters). The height of each level is 3.2 meters. Use 5 decimal places.



Which of the following most nearly gives the storey drift at the 4th level?

0.113 in
0.127 in
0.103 in
0.095 in

In horizontal irregularity type 4, shears and overturning moments must be transferred from the level above the offset, and there is a horizontal "offset" in the load path for the shears.

True
False