Prefabrication.

Prefabrication is the practice of assembling components of a structure in a factory or other manufacturing site, and transporting complete assemblies or sub assemblies to the construction site where the structure is to be located.

- It is combination of good design with modern high performance components and quality controlled manufacturing procedures.
- This work is carried out in two stages, manufacturing of components in a place other than final location and their erection in position.
- Prefabrication, or prefab, is a construction method where building components are manufactured off-site and then assembled on-site.
- It's like bringing the construction site to a factory, where walls, floors, and even entire rooms are built as pre-made modules.
- This approach enhances efficiency, reduces construction time, improves quality control, and can lead to cost savings.
- Prefabrication is like the IKEA of construction, making building projects faster, more streamlined, and often more environmentally friendly.
- Prefabrication has brought a substantial change in the development of construction industry worldwide over the last few decades.
- Prefabricated units may include doors, stairs, window, walls, wall panels, floor panels, roof trusses, room-sized components, and even entire buildings.
- The term is used to distinguish this process from the more conventional construction practice of transporting the basic material to the construction site where all assembly is carried out.
- Prefabricated building is the completely assembled and erected building, of which is the structural parts consist of prefabricated individual units or assemblies using ordinary or controlled materials.

ADVANTAGES OF PREFABRICATION

- High quality product
- Mass production is easier and quick
- Protected and controlled production environment
- Potential for lower production costs and other cost savings
- Independence of climatic conditions
- The disruption of traffic is avoided
- Ensures high degree of Safety
- Saving in cost, material, time & manpower.
- Shuttering and scaffolding is not necessary.
- Installation of building services and finishes can be done immediately.
- Independent of weather condition.
- Components produced at close supervision in a controlled environment in factories .so quality is good .
- Clean and dry work at site.
- Possibility of alterations and reuse.
- Correct shape and dimensions and sharp edges are maintained.
- Very thin sections can be entirely precast with precision.

Dis-advantages :

- Careful handling of prefabricated components such as concrete panels or steel and glass panels is required.
- Attention has to be paid to the strength and corrosion-resistance of the joining of prefabricated sections to avoid failure of the joint.
- Similarly, leaks can form at joints in prefabricated components.
- Transportation costs may be higher for voluminous prefabricated sections than for the materials of which they are made, which can often be packed more compactly.
- Large prefabricated sections require heavy-duty cranes and precision measurement and handling to place in position.

- **The Main reasons to choose Precast Construction method over conventional in method**.

1. Economy in large scale project with high degree of repetition in work construction.
2. Special requirement in finishing.
3. Consistency in structural quality control.
4. Fast speed of construction.
5. Constraints in availability of site resources(e.g. materials & Laborites)
6. Other space & environmental constraints.
7. Overall assessment of some or all of the above factors which points to the superiority of adopting precast construction over convention method. The following details gives. The cost implications of precast construction & conventional in situ method.
8. Large groups of buildings from the same type of prefabricated elements tend to look drab and monotonous.

Principles of prefabrication

- The prefabrication will be done in two stages.
  1) Manufacturing at factory condition.
  2) Erection of components at required location.
- This requires certain stage of preparation. They are
  i) **Casting**. - Precast components are casted with controlled cement concrete in moulds of required shape and sizes. The vibrator is used to vibrate concrete and this removes any honeycombing inside the components.
  ii) **Curing:** - After 24 hours of casting, the casted components are released from the mould and transported to curing tanks. Certain special components like railway sleepers where high strength is required are steam cured.
  iii) **Transportation and erection**: - After complete curing is done the components are transported to the site with heavy trucks and erection will be done using cranes with skilled labor force.

Materials of prefabrication.

- Structural Insulated Panels (SIPs)
- Insulating Concrete Forms (ICFs)
- Prefab foundation system
- Steel framing
- Concrete framing
- Large modular system

Process of prefabrication

Before the installation of a prefabricated building

1) The construction site undergoes soil assessment for suitable foundation requirements, with third-party inspections ensuring compliance with local, state, and international building codes.
2) Following inspections, modular companies secure building, utility, and occupancy permits for approval.
3) The evolution and standardization of construction codes, combined with the rising demand for efficient spaces, drive continuous innovation in prefabricated buildings.
4) The integration of tools like Building Information Modeling (BIM) enhances collaboration among architects, engineers, and contractors by digitally representing structural characteristics.
5) BIM facilitates on-site assembly management, mitigating business risks associated with prefabricated construction.

Types of prefabrication

A prefabricated (prefab) building, by definition, is where an entire building or an assembly of its components is manufactured at an offsite facility and assembled onsite from self-sustained volumetric modules or separate panels

Offsite-manufactured prefabricated building systems are built in three main types of construction, as listed below:

1. Modular (volumetric) construction: manufacturing of fully self-contained units in an offsite facility to be transported to site to be assembled to form a complete structure.
2. Panelised construction: manufacturing of flat panel units in an offsite facility to be transported to site to be assembled to form a complete structure.
3. Hybrid prefab construction (semi-volumetric): combining both panelised and modular methods. Compact modular units (pods) are used for the highly serviced and more repeatable areas such as kitchens and bathrooms, with the remainder of the building constructed using panels or modules.

Modular construction

Definition: A construction method that involves prefabricating building components (modules) off-site in a controlled factory environment and assembling them on-site.
the construction process for modular construction can be broken down into six main stages:

1. Design and Planning:

Conceptual Design: Architects and engineers develop the initial design concept, including the overall layout, functionality, and desired aesthetic.
Detailed Design: Using a modular grid, the design team translates the concept into detailed drawings and specifications for each module, including floor plans, elevations, and component specifications.
Module Design: Engineers design individual modules with specific dimensions and configurations to fit together seamlessly.
Manufacturing Planning: Production schedules and logistics are established for efficient module manufacturing.

2. Module Manufacturing:

Material Procurement: Raw materials are procured and delivered to the factory.
Component Fabrication: Wall panels, floor cassettes, and other building components are fabricated according to the design specifications.
Module Assembly: Components are assembled into individual modules within a controlled factory environment.
Quality Control: Rigorous inspections and testing are conducted throughout the manufacturing process to ensure quality and compliance with standards.

3. Site Preparation:

Foundation Work: Foundation systems are constructed according to the design plans.
Utility Installation: Electrical, plumbing, and other utility systems are installed on the site.
Site Logistics: Access roads and staging areas are established for efficient module delivery and assembly.

4. Module Delivery and Installation:

Module Transportation: Completed modules are transported to the construction site using specialized trucks or trailers.
Module Lifting and Placement: Cranes or other lifting equipment carefully position and connect the modules onto the prepared foundation.
Module Connection: Skilled technicians secure the modules together using bolts, welds, or other specified methods.

5. Finishing and Integration:
Exterior Cladding: The exterior walls are clad with materials like bricks, panels, or siding.
Interior Finishes: Flooring, ceilings, walls, and other interior finishes are installed.
MEP Integration: Plumbing, electrical, and HVAC systems are connected and commissioned.
Site Improvements: Landscaping, paving, and other site improvements are completed.

6. Inspection and Handover:

Final Inspection: The completed building undergoes comprehensive inspections by engineers and regulatory authorities to ensure compliance with safety standards and building codes.
System Commissioning: All MEP systems are tested and commissioned to verify functionality.
Handover: Upon completion of inspections and commissioning, the building is handed over to the owner or client and is ready for occupancy.

Planning And Modules And Sizes Of Components In Prefabrication

Planning

a) Such drawings shall describe the elements and the structure and assembly including all required data of physical properties of component materials. Material specification, age of concrete for demoulding, casting/ erection tolerance and type of curing to be followed.
b) Details of connecting joints of prefabricates shall be given to an enlarged scale.
c) Site or shop location of services, such as installation of piping, wiring or other accessories integral with the total scheme shall be shown separately.

d) Data sheet indicating the location of the inserts and acceptable tolerances for supporting the prefabricate during erection, location and position of doors/windows/ventilators, etc, if any.
e) The drawings shall also clearly indicate location of handling arrangements for lifting and handling the prefabricated elements. Sequence of erection with critical check points and measures to avoid stability failure during construction stage of the building.

1) Modular coordination

- Modular coordination is a concept of coordination of dimension and space, in which buildings and components are dimensioned and positioned in a term of a basic unit or module, known as '1M' which is equivalent to 100 mm.
- The fundamental module used in modular coordination, the size of which is selected for general application to building and its components.
- It is denoted by 'M'
- The different modules are
    i) Basic Module: M
    ii) Multi modules: 3M, 6M etc.,
- The value of basic module 'M' has been chosen as 100mm for maximum flexibility and convenience.
- The purpose of modular co-ordination are,
    a) to reduce the variety of component sizes produced; and
    b) to allow the building designer greater flexibility in the arrangement of components.
- Modular coordination means the interdependent arrangement of a dimension based on a primary value accepted as a module. The strict observance of rules of modular coordination facilitated,
    1. Assembly of single components into large components.
    2. Fewest possible different types of component.
    3. Minimum wastage of cutting needed.

The basic module shall be adopted. After adopting this, further work is necessary to outline suitable range of multi modules with greater increments, often referred to as preferred increments. A set of rules as detailed below would be adequate for meeting the requirements of conventional and prefabricated construction. These rules relate to the following basic elements:

a) The planning grid in both directions of the horizontal plan shall be:
    1) 15 M for industrial buildings, and
    2) 3 M for other buildings.

    The centre lines of load bearing walls should preferably coincide with the gridlines.
b) The planning module in the vertical direction shall be 2 M for industrial buildings and 1 M for other buildings.
c) Preferred increments for sill heights, doors, windows and other fenestration shall be 1 M.

d) In the case of internal columns, the grid lines shall coincide with the centre lines of columns. In case of external columns and columns near the lift and stair wells, the grid lines shall coincide with centre lines of the column in the topmost storey.

Planning and designing of residential buildings against earthquake forces

Earthquakes are one of the most devastating natural disasters that can occur. They can cause wide spread damage to buildings and infrastructure, and lead to loss of life. In earthquake-prone areas, it is essential to design and build residential buildings that can withstand the forces of an earthquake.

There are a number of factors that need to be considered when planning and designing earthquake-resistant residential buildings. These include:

1) **The location of the building**:

Selecting the Location of a Building to Withstand Earthquakes, The location of a building is one of the most important factors to consider when designing for earthquake resistance. Certain locations are inherently more susceptible to earthquake damage than others. Here are some key factors to consider when selecting the location of a building to withstand earthquake forces:

- **Fault Lines:**
  Avoid building on or near fault lines, which are cracks in the Earth's crust where tectonic plates move against each other. Earthquakes are more likely to occur and be stronger near fault lines.
- **Soil Type:**
  Different types of soil have different properties that affect how they respond to earthquake shaking. Soft, loose soils, such as sand and silt, are more likely to liquefy during an earthquake, which can cause buildings to settle or tilt. Hard, rocky soils are generally more stable and can better support buildings during an earthquake.
  (note :- Liquefaction can occur when the ground shakes so violently that it loses its strength and begins to behave like a liquid.)
- **Slope and Topography:**
  Avoid building on steep slopes or hillsides, as these areas are more susceptible to landslides, which can be triggered by earthquakes.
- **Flood Zones:**
  Avoid building in flood zones, as earthquakes can cause tsunamis or flooding, which can damage buildings.
- **Existing Infrastructure:**
  Consider the location of existing infrastructure, such as power lines, water mains, and gas lines. Damage to this infrastructure can disrupt essential services following an earthquake.
- Conduct a geotechnical investigation to assess the soil conditions and identify any potential hazards.
- Consult with local authorities and experts to obtain information about earthquake risks in the area.
- Choose a location that provides easy access for emergency responders.
- Consider the impact of the building on the surrounding environment, such as the potential for landslides or flooding.

2) **Flexible Foundations for Earthquake-resistant Buildings**

Creating a flexible foundation for a building can significantly increase its resistance to earthquake forces. Here are two promising approaches:

- Seismic Isolation Pads:

  These pads are constructed from steel, rubber, and lead and act as a buffer between the building and the ground. During an earthquake, the pads isolate the building from the shaking ground, protecting the structure from the damaging effects of seismic waves.

- Sand-Cushioned Foundation Slab:

  This method involves placing a solid foundation slab made of reinforced concrete on top of a layer of sand. The sand acts as an additional cushion, absorbing and dissipating earthquake energy before it reaches the building. Additionally, a trench surrounding the foundation provides further protection by directing seismic waves away from the structure.

3) **Seismic Dampers: Guardians against Earthquakes**

Seismic dampers are vital components in earthquake-resistant buildings, acting as shock absorbers to protect the structure from the destructive energy of seismic waves. Here's a deeper dive into their role and latest developments:

- Various types of seismic dampers exist, each offering unique benefits:
  1. Viscous dampers: These utilize viscous fluids to dissipate energy through friction.
  2. Friction dampers: These rely on friction between metallic surfaces to absorb energy.
  3. Tuned mass dampers: These utilize a counterweight that moves in opposition to the building's motion, reducing vibrations.
  4. Yielding dampers: These yield and deform to absorb energy before returning to their original shape.

The selection of a specific damper type depends on the building's size, design, and specific seismic threats.

4) **A Drainage Mechanism**

Pooled water can create structural complications. That’s why parking garages often have double-tee load-bearing structures with a twist that lowers one corner — a feature called warping. Engineers achieve positive drainage with 1.5 percent minimum slopes across the diagonal toward floor drains. Drainage is also crucial to help structures tolerate earthquakes.

When the disasters occur in places with loose, sandy soils, the shaking can result in a phenomenon called liquefaction. It makes buildings sink or move to one side, and sewage pipes may rise to the surface. When the soil solidifies again after an earthquake, the buildings stay in their sunken, tilted positions.

However, earthquake drains help collected water escape, preventing liquefaction. They are prefabricated pieces wrapped in a filtering fabric. Each drain measures between 3 and 8 inches in diameter. A successful installation requires a grid-style placement. Depending on the size of the area prone to liquefaction, a building may need hundreds or thousands of drains.

5) **Structural Reinforcement**

Engineers and designers have various methods for strengthening a building's structure against potential earthquakes. Many of those redirect seismic forces. For example, shear walls and braced frames transfer lateral forces from the floors and roof to the foundation. Then, diaphragms are rigid horizontal planes that move lateral forces to vertical-resistant parts of the building, such as a building's walls or framework. There are also movement resistant frames. Those possibilities make a building frame's joints rigid while letting the other parts move.

Shorter buildings have less flexibility than taller ones. Thus, engineers typically realize they must provide more structural reinforcement for structures that are only a few stories tall versus skyscrapers.

6) **Material With Adequate Ductility**

- Ductility describes how well a material can tolerate plastic deformation before it fails.
- Thus, materials with high ductility can absorb large amounts of energy without breaking.
- Structural steel is one of the most ductile materials, while brick and concrete are low-ductility materials.
- Researchers have also developed creative solutions that show how structural steel is not the only earthquake-resistant material worth considering.

  (For example, scientists engineered a fiber-reinforced concrete with properties similar to steel. They called the material ecofriendly ductile cementitious composite. Experiments showed applying a 10-millimeter-thick layer to interior walls protected them from damage during a 9.0-magnitude simulated quake.

  Projects are also underway to build earthquake-resistant residences in nations that lack the resources for safely built houses made from materials that people may need to import or lack the skills to use correctly — such as concrete and bricks. A civil engineering company showed how people in Indonesia could construct earthquake-resistant homes almost entirely from bamboo. The roofs feature corrugated sheets made from recycled Tetra Pak, a lightweight material that reflects heat.)

The design of the building:

The design of earthquake-resistant buildings involves several key principles aimed at ensuring the safety and functionality of the structure during seismic events. These principles focus on mitigating the impact of earthquake forces and ensuring the building can withstand the shaking and deformation without collapsing.

Here are some of the main design principles for earthquake-resistant buildings:

1. Strong and Flexible Foundation:
   - The foundation is the cornerstone of the building and needs to be strong enough to withstand the shaking ground without significant movement or cracking.
   - Deep foundations are preferred, anchored firmly into the ground for increased stability.
   - Materials like reinforced concrete offer the necessary strength and flexibility for earthquake-resistant foundations.
2. Shear Walls and Moment-Resisting Frames:
   - Shear walls: These vertical walls resist lateral forces, acting like a spine to maintain the building's upright position during an earthquake. They are typically constructed

from concrete or reinforced masonry and strategically placed throughout the structure.

- Moment-resisting frames: These are interconnected steel or concrete beams and columns designed to bend without breaking, absorbing and dissipating the earthquake's energy.

3. Diaphragms and Horizontal Distribution of Forces:
   - Diaphragms: These horizontal floors or roofs act as rigid plates, distributing earthquake forces evenly throughout the building. They help prevent one part of the building from moving independently of others, reducing stress and potential damage.
   - Horizontal force distribution: The design ensures that the earthquake forces are distributed horizontally across the building's structure, minimizing localized stress and potential for failure.

4. Damping and Vibration Control:
   - Damping systems: These mechanisms absorb the energy of vibrations caused by the earthquake, reducing the overall shaking and stress on the structure. Examples include viscous dampers, tuned mass dampers, and friction dampers.
   - Vibration control: Design considerations minimize the building's natural period of vibration, making it less susceptible to resonance with the earthquake's frequency and reducing the amplification of forces.

5. Base Isolation:
   This technique involves isolating the building from the ground using special bearings. During an earthquake, the bearings allow the building to move slightly relative to the ground, reducing the amount of force transmitted to the structure and further minimizing damage.

Additional Design Considerations:

- Ductile Materials:
  Using ductile materials that can bend without breaking is crucial. Steel and concrete are two common examples.
- Regularity in Shape:
  Buildings with regular shapes are more resistant to earthquake forces than irregular ones.
- Redundancy:
  Redundancy involves providing multiple load paths within the building so that if one fails, others can still support the structure.
- Connections:
  All connections between structural elements must be strong enough to withstand earthquake forces.
- Construction Quality:
  High-quality materials and skilled construction practices are essential for earthquake-resistant buildings.

By implementing these principles, engineers can design and construct buildings that can withstand the forces of an earthquake, protecting lives and property.

Principles

The following are design principles of Earthquake

Design basis earthquake:

In the earthquake-resistant design, it can't be possible to make the structure absolutely earthquake proof that will not suffer any damage during the rarest of the earthquakes. A fully earthquake-proof structure will be very huge and highly expensive. Instead an attempt shall be made that the structure should be able to withstand the minor earthquakes that take place frequently in that region. Moreover, the structure should be able to resist the moderate earthquakes called design basis earthquakes (DBE), without significant structural damages. Such earthquakes occur once during the life time of structure. Even a major earthquake called maximum considered earthquake (MCE) with intensity greater than that of the design basis earthquake would not be able to cause collapse of the properly designed and constructed structure and losses would be limited.

Pseudo-static earthquake:

Earthquakes cause dynamic loading on the structures. However, for the design of earthquakeresistant structures, the dynamic analysis is usually not carried out. Instead a pseudo-static analysis shall be employed in which the earthquake forces are replaced by equivalent static forces. These forces are considered in addition to the normal loads on the structure for its design. It is assumed that the forces due to earthquake are not likely to occur simultaneously with other occasional forces such as wind loads, maximum flood forces or maximum sea wave forces.

Components of acceleration:

Earthquakes can cause acceleration in any direction. It is the usual practice to consider the components of acceleration in the vertical direction and in two perpendicular horizontal directions. Moreover, the acceleration components can be either positive or negative in these three directions. Since the three components of earthquake acceleration may not act at the same time with their maximum magnitude, the code recommends that when maximum response from one component occurs, the response from the other two components can be 30 percent of their maximum values. All possible combinations, including plus or minus signs should be considered in the design. Principally the horizontal acceleration is the most predominant.

Increase in permissible stresses:

The vertical component of acceleration can increase the normal vertical loads on the structure. Because of the provision of adequate factors of safety used in the normal design of structures, most of the structures are able to resist the additional momentary vertical loads due to earthquakes.

According to the code when earthquake are considered along with the normal design forces, the permissible stresses in materials in the elastic method of design can be increased by onethird. However, for steels having a definite yield stress the increased stress may be limited to the yield stress and for steels without a definite yield point, the stress may be limited to 80 percent of the ultimate strength or 0.2 percent proof strain, whichever is smaller.

Increase in allowable bearing pressure:

The allowable bearing pressure in the soils can be increased by 25 to 50 percent depending upon the type of foundation as per details given in the code.

Horizontal and vertical inertia forces:

The predominant direction of ground motion is usually horizontal. Therefore, the horizontal seismic forces are most important for the earthquake-resistant design. However, as per the code the vertical inertia forces are to be considered in the design unless checked and proven that they are significant. When effects due to vertical earthquake loads are to be considered, the design vertical acceleration spectrum is taken as two-thirds of the design horizontal acceleration spectrum.

Resonance:

Based on code the resonance of the type as visualized under steady-state conditions will not occur because the earthquake have irregular motion of short duration in which there is not adequate time to build up the required amplitudes. However, if the structure's fundamental period is close to that of site, resonance may not occur. Such conditions have been observed for some tall buildings on deep soft soils.

Base shear:

Inertia forces generated in the structure due to an earthquake are assumed to be transferred to the base structure as the base shear. The base transfers these forces tot eh foundation, which in turn transfers to the ground.

Seismic forces:

Seismic forces are inertia forces. When any object, such as a building, experiences acceleration, inertia force is generated when its mass resists the acceleration. We experience inertia forces while travelling. Especially when standing in a bus or train, any changes in speed (accelerations) cause us to lose our balance and either force us to change our stance or to hold on more firmly.

Effect of buildings from the Earthquakes

1. Inertia Forces in Structures

The generation of inertia forces in a structure is one of the seismic influences that detrimentally affect the structure. When an earthquake causes ground shaking, the base of the building would move but the roof would be at rest. However, since the walls and columns are attached to it, the roof is dragged with the base of the building.

The tendency of the roof structure to remain at its original position is called inertia. The inertia forces can cause shearing of the structure which can concentrate stresses on the weak walls or joints in the structure resulting in failure or perhaps total collapse. Finally, more mass means higher inertia force that is why lighter buildings sustain the earthquake shaking better.

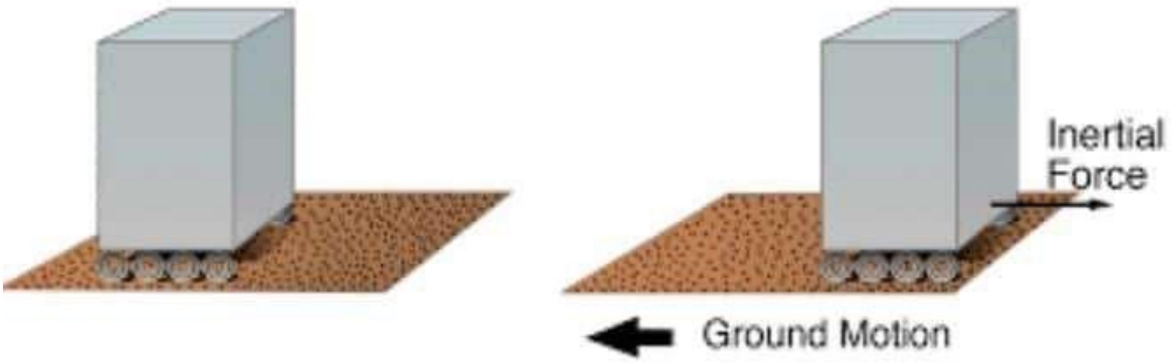

Fig. 1: Direction of Inertia Forces

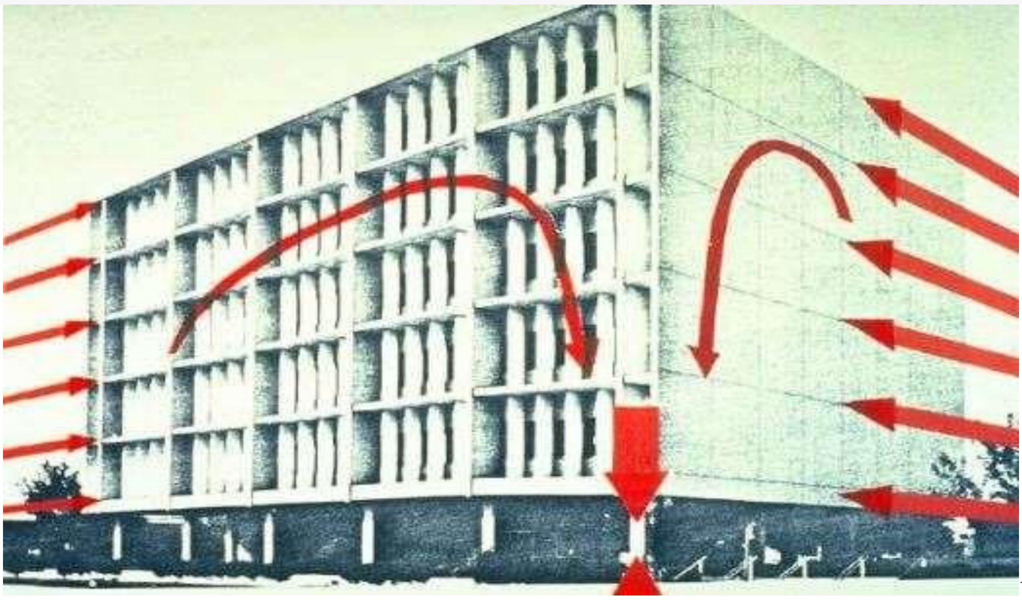
Fig. 2: Development of Great Inertia Forces in the Six Storey of Imperial County Services Building

2. Effect of Deformations in Structures

When a building experiences earthquake and ground shaking occurs, the base of the building moves with the ground shaking. However, the roof movement would be different from that of the base of the structure. This difference in the movement creates internal forces in columns which tend to return the column to its original position.

These internal forces are termed stiffness forces. The stiffness forces would be higher as the size of columns gets higher. The stiffness force in a column is the column stiffness times the relative displacement between its ends.

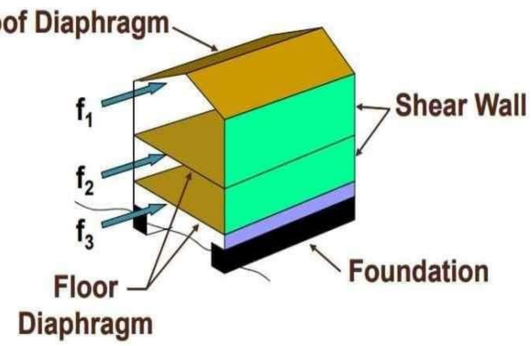

Fig. 3: Lateral Force Resisting System in a House

3. Horizontal and Vertical Shaking

Earthquake causes shaking of the ground in all the three directions X, Y and Z, and the ground shakes randomly back and forth along each of these axis directions. Commonly, structures are designed to withstand vertical loads, so the vertical shaking due to earthquakes (either adds or subtracts vertical loads) is tackled through safety factors used in the design to support vertical loads.

However, horizontal shaking along X and Y directions is critical for the performance of the structure since it generates inertia forces and lateral displacement and hence adequate load transfer path shall be provided to prevent its detrimental influences on the structure.

Proper inertia force transfer path can be created through adequate design of floor slab, walls or columns, and connections between these structural elements. It is worth mentioning that the walls and columns are critical structural members in transferring the inertial forces. It is demonstrated that, masonry walls and thin reinforce concrete columns would create weak points in the inertia force transfer path.

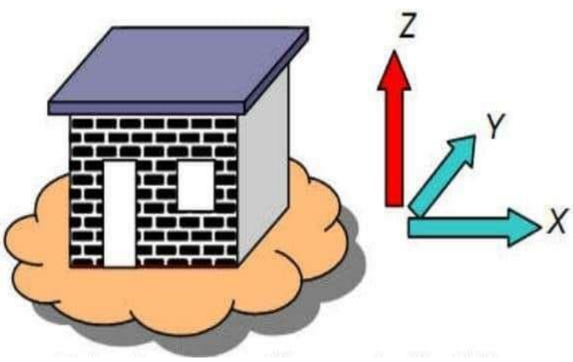

Fig. 4: Principal Directions of a Building

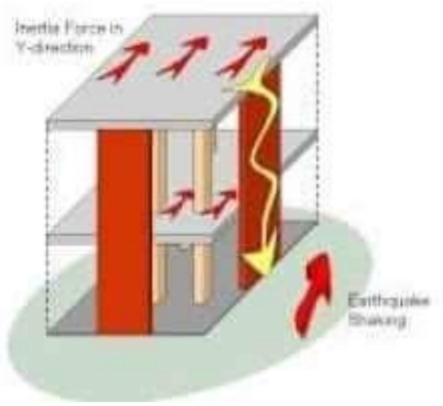

Fig. 5: Load Path for Lateral Inertia Forces

4. Other Effects

Apart from the direct influences of earthquakes on a structure which are discussed above, there are other effects such as liquefaction, tsunami, and landslides. These are the indirect effects of strong earthquakes that can cause sizable destruction.