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The Study on Earthquake and their impact on Structural Engineering

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Abstract- In earthquake, a tremendous quantity of energy is released in the form of seismic waves, which are then communicated to structures via their foundations, causing them to vibrate. The reaction acceleration will be nearly equivalent to the peak ground acceleration for constructions with a very short time period (high frequency). . The creation of creative design concepts to safeguard civil engineering structures from harm, including material contents and human occupants, from the hazards of strong winds and earthquakes is one of the key difficulties facing structural engineers in the current decade. Tall building analysis and design are often undertaken using more advanced approaches and methodologies because each tall building represents a major investment. Furthermore, most building codes are designed without special consideration for tall buildings, which account for a very small percentage of development activity in most areas. As a result, structural engineers and academics who want a better knowledge of the design and performance of these modern megacity landmarks must comprehend new approaches to seismic analysis and design of tall buildings.

Keywords- Earthquakes, Geologic Earthquake Effects, Seismic Design, Earthquake Resistant Buildings

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INTRODUCTION

Strong earthquakes, explosions, wind, moving loads, machinery, and enormous ocean waves have raised the need for more flexible civil engineering structures such as towering buildings & long span bridges, which are susceptible to unwanted vibration, deformation, and accelerations. Excessive vibration in structures is an undesired phenomena that causes human discomfort, energy loss, partial collapse of structural sections, transmits unneeded stresses, and poses a threat to structural safety, leading to collapse in some cases. It is vital to understand the behaviour & response of structural systems subjected to dynamic loads such as earthquakes and wind loads in order to eliminate the negative impacts of vibrations in structures. The creation of creative design concepts to safeguard civil engineering structures from harm, including material contents and human occupants, from the hazards of strong winds and earthquakes is one of the key difficulties facing structural engineers in the current decade. To survive under extreme dynamic loading and blast loads, structural structures have traditionally depended on their inherent strength and capacity to dissipate energy. Inelastic cycle deformations at the extremely detailed plastic hinge areas of structural elements may cause energy dissipation in such systems. This produces localised structural damage since the structure must absorb much of the input energy from dynamic forces, which has a significant repair cost. Hospitals, police stations, and fire stations, on the other hand, must stay operational even after an earthquake. The traditional design technique is ineffective for keeping a structure functional after an earthquake since it allows for significant damage.

Tall structures are a distinct type of structure with unique qualities and requirements. Tall buildings are frequently occupied by huge crowds. As a result, their destruction, loss of functionality, or collapse will have extremely serious and negative effects for human life and the economy of the impacted areas. Tall building analysis and design are often undertaken using more advanced approaches and methodologies because each tall building represents a major investment. Furthermore, most building codes are designed without special consideration for tall buildings, which account for a very small percentage of development activity in most areas. As a result, structural engineers and academics who want a better knowledge of the design and performance of these modern megacity landmarks must comprehend new approaches to seismic analysis and design of tall buildings. Innovative methods of improving structural functionality and safety against dynamic loadings have gained traction in recent years. To alleviate the consequences of these dynamic loadings, additional energy absorption & dissipation devices are used in structures. These systems function by absorbing & reflecting some of the energy that would otherwise be passed to the structure. Based on how they function to regulate vibrations, these systems could be classed as passive, active, semi-active, or hybrid vibration control systems.

EARTHQUAKES & THEIR IMPACT ON SOCIETY

The mankind has been facing and struggling with the natural disasters since the evolution of life on the planet Earth. These natural disasters include earthquakes, tsunamis, landslides, avalanches, forest fire, volcanoes, hurricanes, and floods. These disasters seriously disturb the normal functioning of the society and pose considerable and widespread threats to life, property and environment. Among these disasters, earthquakes affect and disrupt the society suddenly and without warning. An earthquake is the result of a sudden release of energy in the earth's crust. At the earth surface earthquakes manifest themselves by shaking and sometimes displacing the ground. The maximum loss during the earthquake is caused because of the collapse of the physical systems (houses, buildings, industries, dams etc.) which in turn causes great loss of economy, life and property. Historically, there is no other natural phenomenon that has produced loss of life as great as the 8 lakhs people killed in the Chinese earthquake of 1556 (Yeats et al., 1997). A recent example of such damage was Japan earthquake (M 8.6) which hit the East coast of Honshu, Japan on March 11, 2011. A ferocious tsunami spawned by one of the largest earthquakes ever recorded slammed Japan's eastern coast, killing hundreds of people as it swept away boats, cars and homes while widespread fires burned out of control. At least 15,703 people killed, 4,647 missing, 5,314 injured, 130,927 displaced and at least 332,395 buildings, 2,126 roads, 56 bridges and 26 railways destroyed or damaged by the earthquake and tsunami along the entire east coast of Honshu from Chiba to Aomori. The total economic loss in Japan was estimated at 309 billion US dollar (www.earthquake.usgs.gov). Japan's worst previous quake was in 1923 in Kanto, an 8.3- magnitude temblor that killed 143,000 people, according to USGS. The Bhuj (Gujarat) earthquake occurred on January 26, 2001 killed about 20,000 people, injured another 167,000, and destroyed nearly 400,000 homes and 600,000 people left homeless (www.gujarat-info.co.in). Due to this earthquake not only the region near to source is affected but the region at far distances is also affected. There is not only the loss of life but the economy losses are also very heavy.

GEOLOGIC EARTHQUAKE EFFECTS

As seen in Figure 1, the earth's crust is made up of a series of huge plates. The forces caused by the earth's rotation & flow of magma within the molten core constantly push & twist these "tectonic plates." Friction locks the plates together at their edges, preventing them from moving relative to one another. Stress builds up along these borders over hundreds to thousands of years. Infrequently, the stress at a plate boundary surpasses the frictional force that holds the plates collected, or the tension within a plate exceeds the rock's strength. When this happens, the overstressed rock splits or slips, liberating stored energy & triggering an earthquake.

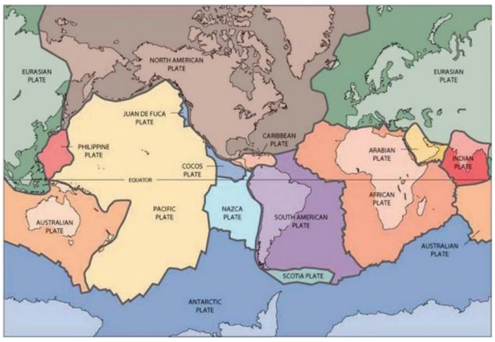


Figure 1: Tectonic plates of major importance (courtesy of USGS).

The majority of earthquakes strike along plate boundaries or in sections of the earth's surface that have formerly slid due to prior earthquakes. "Faults" is the collective term for these locales. Faults are more common along plate boundaries, but they can also form within a plate's interior. Existing faults are most likely to be the site of future earthquakes; but, stress patterns in the earth alter over time, as new faults are infrequently formed. During an earthquake, rock slide can occur close to the surface or thousands of kilometres beneath it. When it reaches the surface, it can cause "ground fault ruptures," which are abrupt lateral (Figure 2) and vertical (Figure 3) offsets. The forces generated by these ground fault ruptures can be enormous, making it challenging to design structures that will not be ripped apart in the event of a rupture. Avoiding construction over the known track of an active fault is the best prevention against damage from ground fault rupture. If there is evidence that a fault has shifted within the last 10,000 years, it is termed active.

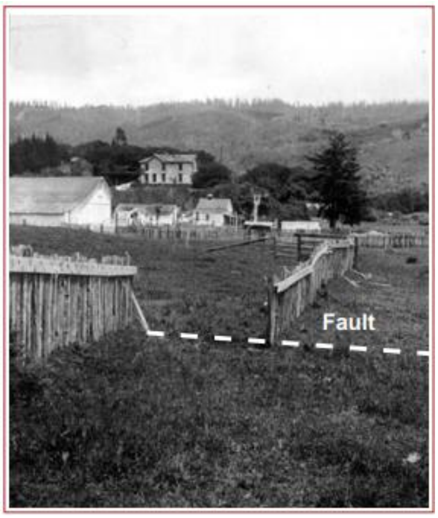


Figure 2: Fault movements can damage buildings and other structures by breaking the ground surface. When the San Andreas Fault

moved in the 1906 San Francisco earthquake (magnitude 7.8), this fence in Point Reyes was shifted 8 feet (2.5 m) (photo courtesy of USGS).

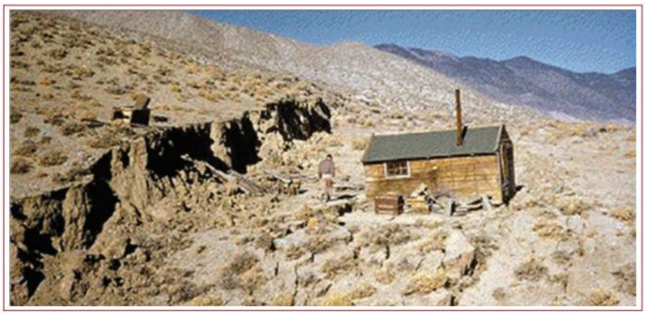


Figure 3: The 1954 Dixie Valley earthquake caused a vertical fault offset in Nevada. (photo by K. V. Steinbrugge).

When an earthquake happens, the energy released emits external in the form of random vibrations in directions from the region of rock displacement. These vibrations are seen as "earth shaking" on the surface. Ground shaking can last anywhere from a few seconds to several minutes in larger earthquakes, & it is implicated for more than 90% of earthquake losses & damages. Ground tremors can cause a variety of ground failures, which can cause structural damage in addition to direct injury. Landslides are one of the most prevalent ground failures produced by earthquakes. A steeply sloping site with loose soils is ideal for an earthquake-induced landslide. Landslides produced by earthquakes have previously destroyed structures and even entire towns (Figure 4). The 1964 Prince William Sound earthquake in Anchorage, Alaska, as example, created landslides that destroyed an entire community.

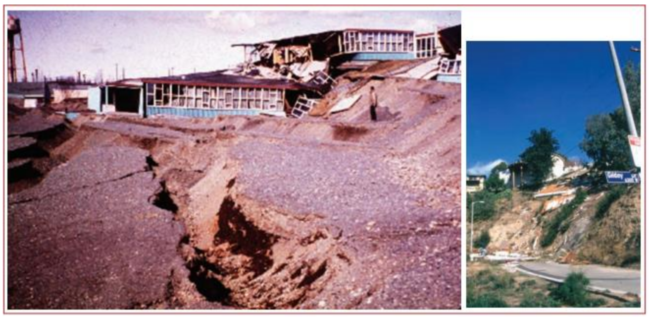


Figure 4: Landslides can occur as a result of earthquakes, causing damage to roads, buildings, pipelines, and other infrastructure.

Earthquake-induced landslides are most likely to occur in steeply sloping locations underlain by loose or soft rock. The photo on the left depicts Government Hill School in Anchorage, Alaska, which was devastated by a landslide triggered by the 1964 earthquake; the building's south wing crumbled into a graben at the landslide's head (photo courtesy of USGS). Following the magnitude 6.7 Northridge earthquake in 1994, the hillside beneath the property on the right fell way, destroying the house (FEMA photo).

Soil liquefaction is another prominent earthquake-induced ground breakdown. When loose saturated sands & silts are violently agitated, they can liquefy. Strong shaking compacts or densifies these materials, forcing a portion of the water that saturates them out in the process. As the water is forced out, it runs higher, causing the soils to lose their bearing pressure. Structures sustained on liquefied soils can sink & settle significantly, and subsurface structures can float free, when soil liquefaction occurs (Figure 5).

Figure 5: illustrates liquefaction-induced settling of flat buildings in Nigata, Japan, following the Earthquake of 1964 (courtesy of the University of Washington). The bottom photo shows one of the numerous manholes that floated to the surface in Nigata, Japan, as a consequence of the 2004 Chuetsu earthquake (photo courtesy of Wikimedia Commons).

Liquefaction-related lateral spreading is a form of ground instability. When liquefaction happens on a site with even a slight slope, surface soils can move downward like a fluid. Carrying with them any buildings they support. Figure 6 depicts pavement damage at a site where liquefaction & lateral spreading occurred.

Figure 6: The 1959 Hegben Lake earthquake caused lateral spreading damage to roadway street in Yellowstone Park (photo courtesy of the USGS).

The location of a building in relation to probable relevant faults, the local geology & types of soil existing at the construction site, & geography of the site all influence whether or not it will practice any of these earthquake-induced ground failures.

BASIC FEATURES OF SEISMIC DESIGN

Because earthquakes create inertia forces proportionate to the building mass, The 1964 Earthquake (courtesy of the University of Washington). The bottom photo depicts some of the several manholes that floated to the surface as outcome of the 2004 Chuetsu earthquake in Nigata, Japan (courtesy of Wikimedia Commons). Ground instability is caused by liquefaction-related lateral spreading. Surface soils can slide downward like a fluid when liquefaction happens on a site with even a minor slope.

As a result, structures are only constructed to withstand a fraction of the force that they would stipulation they were considered to endure elastic during the projected intense ground shaking (Figure 8), allowing damage to occur (Figure 9). However, in order to avoid structural damage during minor shaking, sufficient initial stiffness must be provided. As a result, seismic design strikes a balance between lower costs and tolerable damage in order to make the project profitable. This delicate balancing act is the result of intensive research and rigorous post-earthquake damage assessments. A great deal of this data is converted into exact seismic design specifications. Under design wind forces, however, structural damage is not acceptable. As a result, the term "earthquake-resistant design" rather than "earthquake-proof design" is used to describe earthquake-resistant design.

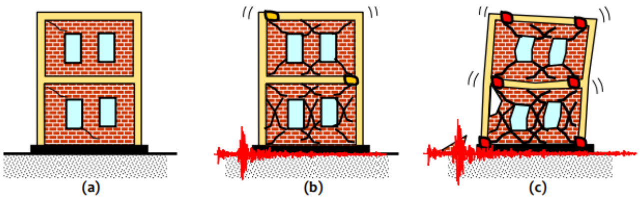


Figure 7: Design for Earthquake Resistance Building philosophy is as follows: (a.)Minor (Frequent) Shaking – No/Hardly any damage, (b.) Moderate Shaking – Minor structural damage & some non-structural damage, & (c.) Severe (Infrequent) Shaking – Structural damage but NO fall

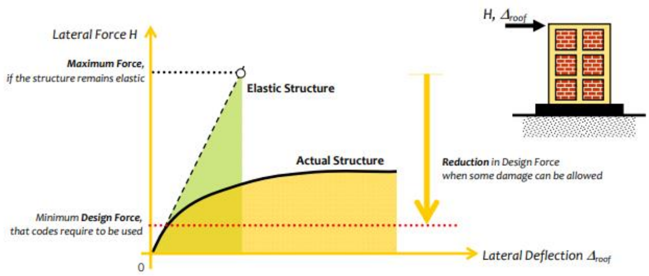


Figure 8: Calculate maximum elastic forces and multiply by a factor to get design forces in earthquake design.

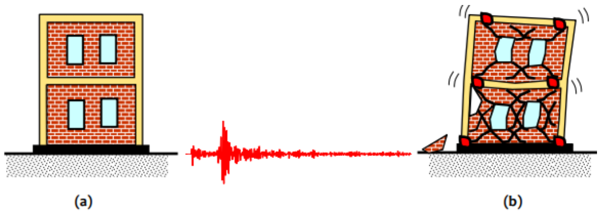


Figure 9: NOT Earthquake-Resistant Damage is predictable in normal builds (a) undamaged buildings, (b) damaged buildings during an earthquake.

Only if the building can stably resist substantial displacement demands through structural damage without collapse & undue loss of strength is it conceivable to plan for only a portion of the flexible level of seismic forces. The term for this characteristic is ductility (Figure 10). By properly proportioning the size and material of the components, it is relatively straightforward to build structures with specific lateral strength and initial stiffness. However, getting appropriate ductility is more difficult & necessitates considerable laboratory testing on full-scale specimens to determine the best detailed procedures. In conclusion, the load enacted by earthquake shaking underneath the structure is displacement-type, while wind & other hazards apply force-type loading. Buildings must be able to withstand precise relative displacement within them as a result of forced displacement at their base in earthquake shaking, whereas wind and other hazards require buildings to withstand a specific amount of force (Figure 11a). While the greatest force that may be exerted on a building can be exactly estimated, the maximum displacement that can be inflicted beneath the building is not. Wind design requires just elastic behavior across the whole range of displacement for the same maximum displacement to be borne by a building (Figure 11b), whereas earthquake design has 2 options: design the building to endure elastic or to suffer inelastic behavior. The second option is used in ordinary structures, whereas the previous is used in specific buildings such as nuclear power plant essential buildings.

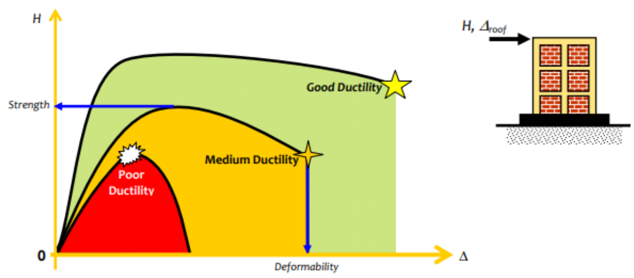


Figure 10: Buildings are built and developed in order to generate favourable failure processes with required lateral strength, suitable stiffness, and, most importantly, good post-yield ductility.

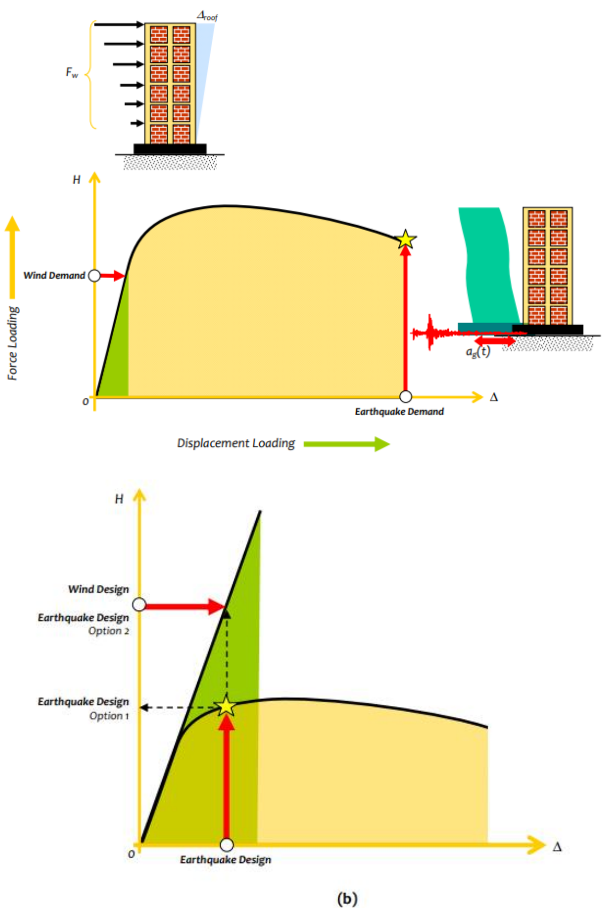


Figure 11: All other risks impose force loading, whereas earthquake shaking puts displacement loading only on buildings.

EARTHQUAKE RESISTANT BUILDINGS' FOUR VIRTUES

In order for a building to achieve adequately during an earthquake, it necessity adhere to the earthquake-resistant design philosophy outlined earlier.

Features of Buildings

Architects & design engineers work with four components of structures to produce an earthquake-resistant design, including seismic structural configuration, lateral stiffness, lateral strength, and ductility, as well as other aspects such as form, aesthetics, utility, and comfort of the building. Buildings' lateral stiffness, lateral strength, & ductility can all be guaranteed by closely adhering to most seismic design rules. However, by adhering to consistent architectural elements that outcome in decent structural behaviour, decent seismic structural formation can be ensured.

(a) Seismic Structural Configuration: There are three basic aspects to seismic structural configuration: (a) the building's geometry, shape, & size, (b) the location & size of structural elements, (c) the location & size of substantial non-structural elements (Figure 12). The easiest approach to comprehend the influence of a building's geometry on its seismic performance is to remember the simple geometries of convex & concave lenses from elementary school physics class (Figure 13). The line that links any 2 places inside the region of the convex lens is completely enclosed within the lens. The concave lens is not the same; a piece of the line may be outside of the concave lens's area. Convex geometries are preferred over concave geometries because convex geometries perform better in earthquakes. Concave structures require bending of load paths for ground shaking in specific directions, convex-shaped structures have direct load channels for delivering seismically inertia forces to their bases in any direction of ground shaking, but concave-shaped buildings have stress concentrations at all points where the load paths curve.

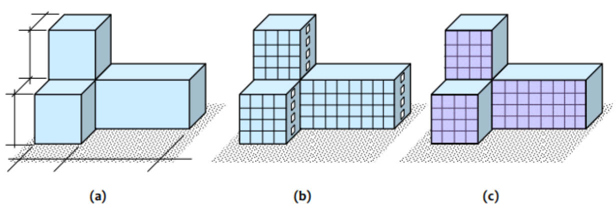


Figure 12: Total geometry, structural elements (moment resistant frames & structural walls), major non-structural features (façade glass) are all components of seismic structural configuration.

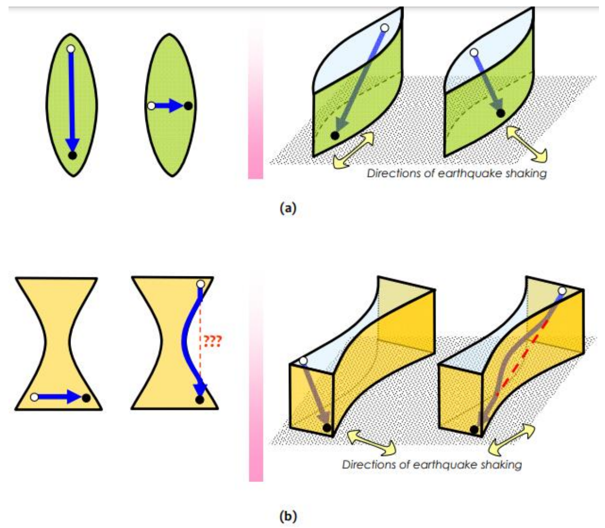
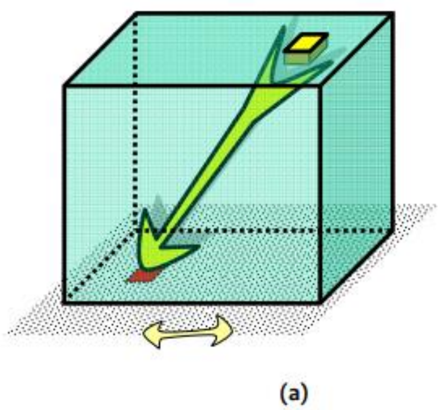


Figure 13: Two geometries of architectural shapes are the simple forms of seismic structural configuration. (a) convex, (b) concave

According to the preceding discussion, usually constructed buildings could be divided into two categories: simple & complex (Figure 14). Buildings with rectangular layouts & straight heights have the best chance of surviving an earthquake because inertia forces are conveyed without the need to bend due to the geometry of the building (Figure 14a). On either side, buildings with setbacks & central openings impose geometric limits on the flow of inertia forces, that must bend prior falling to the ground. (Figure 14b, 10c)



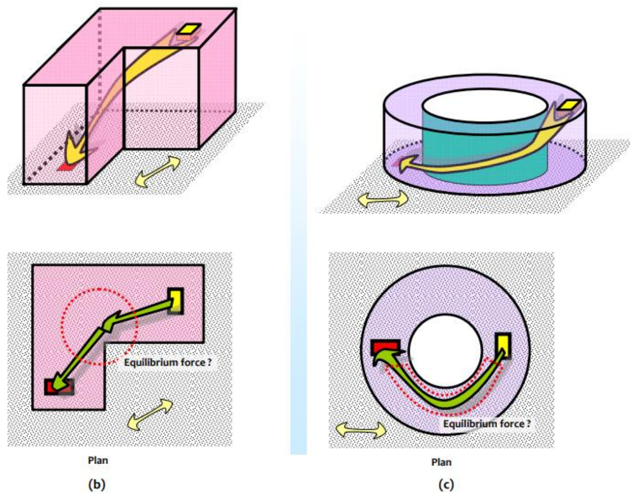


Figure 14: Classification of buildings: (a) Simple, and (b) Structural Stiffness, Strength and Ductility, (c) Complex

(b) Structural Stiffness, Strength & Ductility: Figure 14 depicts the subsequent 3 overall attributes of a structure, explicitly lateral stiffness, lateral strength, & ductility, using the building's lateral load – lateral deformation curve. Although the building's stiffness reduces as damage increases, lateral stiffness refers to the building's initial stiffness. The strongest level of resistance to relative deformation that the building has ever offered is considered to as lateral strength. The ratio of maximal deformation to idealised yield deformation is used to define ductility towards lateral deformation. The deformation refers to the maximum deformation maintained by the load-deformation curve if it does not drop after reaching peak strength, or 85 percent of the ultimate load on the falling side of the load-deformation response curve after reaching peak strength if it does drop after reaching peak strength.

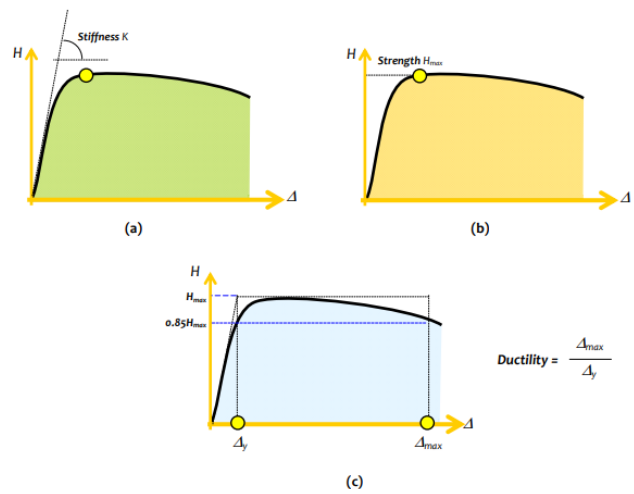


Figure 15: Structural Characteristics: Overall load deformation curves of a building, indicating (a) lateral stiffness, (b) lateral strength, (c) ductility to lateral deformation

EARTHQUAKE RESISTANT STRUCTURES GOALS

Ordinary buildings cannot be designed to be completely earthquake resistant due to cost constraints. The Earthquake Resistant Design (EQRD) aims, on the other hand, are listed below.

Level of serviceability Earthquake

- Seismic activity, both major and minor
- The structure should not be destroyed and should continue to function.
- Expected ten times during the course of the building's lifespan

Level of vulnerability Earthquake

- Occasional moderate earthquakes are expected with no structural damage.
- There should be no deaths as a result of non-structural damage.
- Once or twice during the life of the structure.

Level of security Earthquake

- Major earthquakes should be rare
- Buildings should not collapse
- Non-structural and structural damage should not result in any deaths

LATERAL LOADS ON BUILDINGS

The loads acting on a structure are mainly the vertical and lateral loads. The vertical loads mainly consist of dead load and the imposed loads and the behaviour of the structure when subjected to various vertical loads are the same. Seismic forces, blast loads, wind loads, mooring loads, tsunamis, and other lateral loads are the most common, with seismic and wind forces being the most common. The way these forces are applied and how the structure behaves varies (Aravind Ashok 2011). The forces acting on a structure must be defined in order to build it to withstand wind and earthquake loads. The exact forces that will occur during the structure's lifetime are impossible to anticipate. Most national building codes indicate specific criteria that must be given for life safety based on the boundary circumstances of each building examined in the analysis (Khaled & Magdy 2012).

CONCLUSION

During earthquake, a tremendous quantity of energy is released in the form of seismic waves, which are then communicated to structures via their foundations, causing them to vibrate. The reaction acceleration will be nearly equal to the peak ground acceleration for structures with a very short time period (high frequency). The system is particularly flexible for constructions with a long time period, and the mass will remain fixed while the ground below moves and the relative deformation is the same as ground displacement. Generally, the structures are neither fully rigid nor fully flexible. Most of these structures falls into the intermediate frequency range, corresponding to the velocity sensitive region in a response spectrum, which is smoothened as a constant velocity region.

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