

# Earthquake

## Introduction: -

An earthquake is a sudden movements of the ground that release built-up energy in rocks and generates seismic waves, these elastic waves radiate outward from the source and vibrate the ground.

Measurement a magnitude of earthquake

There are two devices to measure a magnitude of earthquake:-

### 1) The Richter scale

The Richter scale was developed in 1935 by Charles Richter of the California Institute of Technology as a mathematical device to compare the size of earthquakes, each whole number increase in magnitude represents a ten fold increase in measured a amplitude.

An earthquake of 6 is ten times more sever than one of 5

### Disadvantage Richter scale

- 1) It does not tell any thing about the physics of the earthquake .
- 2) It has no upper limit, with highest recorded magnitude of 8.8 to 8.9
- 3) It is only defined for local earthquake.
- 4) At large magnitude it is inaccurate.

### Table (1) characteristics of magnitude measured by Richter Scale

Magnitude	Name	Possible Efects
1	Micro earthquake	Generally not felt, but recorded locally
2	Micro earthquake	Generally not felt, but recorded locally
3	Mild earthquake	Often felt, but rarely cause damage
4	Mild earthquake	Often felt, but rarely cause damage
5	Moderate earthquake	Structure damage
6	Large earthquake	Some buildings collapse

7	Major earthquake	Some buildings collapse
8	Great earthquake	Large building destroyed

## 2) **Moment magnitude scale**

A new scale has been developed to overcome the shortcoming of the Richter Magnitude scale. Moment magnitude tells you something about the physical size of the earthquake. Moreover, Moment magnitude is much more accurate than the Richter magnitude, especially in case of large magnitudes.

## **Tall building behavior during earthquake**

### **Introduction:**

The seismic motion of the ground does not damage a building by impact, or by externally applied pressure such as wind, but rather by internally generated inertial forces caused by vibration of the building mass, and the horizontal vibration has the most destructive effect, this effect is emphasized in the case of soft first story.

When the mass pushing down exerts its force on member bent or moved out of plumb by the lateral forces, this phenomenon is known as P-DELTA effect.

### **Response of tall building**

In general, tall buildings respond to seismic motion somewhat differently than low rise buildings.

The magnitude of inertia force induced in an earthquake depends on the building mass, ground acceleration, nature of foundation, and the dynamic characteristics of the structure.

The inertia force (  $F$  ) for given ground acceleration is given by Newton second law (  $F = m * a$  ).

Where  $m$ : is the building mass.

An increase in the mass of building has two undesirable effects on seismic design.

First, it results in an increase in force.

Second, it can cause buckling and crushing of vertical element, such columns and walls.

If the building and its foundation were infinity rigid, it would have the same acceleration as the ground and for a structure that deforms only slightly, thereby absorbing some energy.

If ( $F < m * a$ ), tall building are invariably more flexible than low rise building, but flexible buildings subjected to ground motions for a prolonged period may experience much larger forces if its natural period is near that the ground waves.

### **Seismic separation**

Drift is lateral displacement of one floor relative to the floor below. Building subjected to earthquakes need drift control to limit damage to the interior partitions, elevator and stair enclosures, glass and cladding systems.

Stress limitations do not always provide adequate drift control especially for tall buildings with relative flexible moment resisting frames and narrow shear walls.

Adjoining building or adjoining section of the same building do not have identical modes of response and therefore have a tendency to pound against one another.

Building separation or joints must be provided to permit adjoining building to respond independently to earthquake ground motion.

## Methods which calculate earthquake loads

### A) The Static Lateral Force Procedure(UBC:94){Equivalent Static Force Analysis}

The earthquake loads are dynamic loads, and to determine it depend on a lot of factors which stay in unknown judgment, and for difficult to determine it, we put static loads to compress and give internal stresses which similar the stresses due to dynamic loads.

\*The static lateral force procedure may be used for the following structures(UBC:94)

- 1) All structures, regular or irregular, in seismic zone no.1 and in standard occupancy structures in seismic zone no.2
- 2) Regular structures under 73m in height with lateral force resistance provided by systems given in the table (2.8 a and b) except for structures located in soil profile type S4 which have a period greater than .7 sec
- 3) Irregular structures not more than five stories or 20m in height.
- 4) Structures having a flexible upper portion supported on a rigid lower portion where both portions of the structure considered separately can be classified as being regular, the average story stiffness of the lower portion is at least ten times the average stiffness of the upper portion and the period of the entire structure is not greater than 1.1 times the period of the upper portion considered as a separate structure fixed at the base.

## **B)The Dynamic Lateral Force Procedure(UBC:94) {Modal Analysis =Pseudo-Dynamic}**

We suppose the house moves in a rhomb acceleration and the movement creates the moment and shear, but really this far from the situated because this assume the acceleration is constant, and this not found in the earthquake.

\*The dynamic lateral force procedure is applied to all other structures not covered by the static lateral force procedure.

## **C) Time history Analysis**

We applied changeable acceleration with the time according to the earthquake .

But this is not true because no one can expect the earthquake condition.

## **Types of Damage which the earthquake can cause it:-**

Earthquake cause different kinds of damage depending on the strength of the quake, distance, type of underlying rock or soil, and the building construction.

### **1) Building Collapse**

People can be trapped in collapse building or under rubble that collapse into the street .

This type of damage leads to the worst casualties. Falling debris cause a lot of injuries or death to people waking out into the streets during the earthquake.



*A typical, collapsed 7-story reinforced concrete commercial building in Gölcük, near the shoreline.*



**Badly damaged communication building** Near the Oriental Hotel at 8:00 A.M. January 13, 1995. Gus Tanaka is standing near the badly damaged communication building. The fourth floor collapsed onto the third floor. Note the street upheaval behind Mr. Tanaka.



**Collapsed walkway between two buildings** Another view of the high rise building. Note the collapsed walkway between two buildings. The lower walkway remains intact and the glass in the windows remains unbroken.

## 2) Building Knocked off their foundation

Building that can otherwise withstand the quake can be knocked off their foundations and severely damaged.



**Leaning office building** An office building in Kobe. Many buildings were out of plumb, or leaning. This was usually caused by partial collapse of a floor on one side of the building, or by permanent offset of the structural system.



**Office building with partially destroyed first floor** Another office building with a partially destroyed first floor. The majority of partial or complete collapses were in the older, reinforced concrete buildings built before 1975. However, significant non-structural damage was also observed for buildings of relatively recent steel or composite construction

### 3) Fire

Fires often break out following earthquakes. They can be caused by flammable materials being thrown into a cooking or heating fire or broken gas lines.



*The burning Tüpras oil refinery at Korfez three days after the earthquake.*



*This collapsed concrete building in Kobe completely blocked the street.*

#### 4) Landslides and Liquefaction

Buildings can be damaged when the ground gives way beneath them. This can be in the form of landslide down a hill,

Liquefaction of soils can cause severe settling of the ground . The combination of uncompacted soil with a lot of water in it led to a phenomenon called liquefaction.

Liquefaction occurs when the ground loses its cohesion and behaves like a liquid. When this happens during an earthquake it can result in an increased intensity of the shaking, or landslides. It can cause rapid settling and collapse of buildings.



*Ground settlement in central Kobe.*



*Damage due to faulting and lateral spreading at the main pier and seawall of the Gölcük, Naval Base.*



### **Ground movement due to Liquefaction**

This bridge is two years old and has been built on one of the reclaimed islands that link the mainland sections of Japan and is the equivalent of our motor bridges. It has failed because the right hand column has shifted to the right causing the span to simply fall to the ground. The right hand column has shifted because the ground it was built on "liquefied" in the earthquake. This occurs because the soil vibrates to such an extent that the water in it is forced to the top causing the soil to act as a liquid. This liquid is then not stiff enough to withstand the forces on it from the columns foundations and so moves causing the failure

## **Major Causes of Failure:**

### **1) Soft-Story:**

Major damage occurs in buildings with a soft story. Soft stories consist of an open space with stand-alone columns supporting the above stories of the building. The first floor does not have enough strength to resist the horizontal shaking force of the upper parts of the building.



## 2) Geotechnical and Foundation problems:

Liquefaction occurs when a saturated granular soil is shaken over a period, the pore water pressure will tend to increase . When this pressure reaches the confining pressure of the soil, a sharp drop in soil strength takes place, behaving similar to a liquid.

This results in ground deformation and settlement, tipping of buildings, failures of each dams, and other hazards.



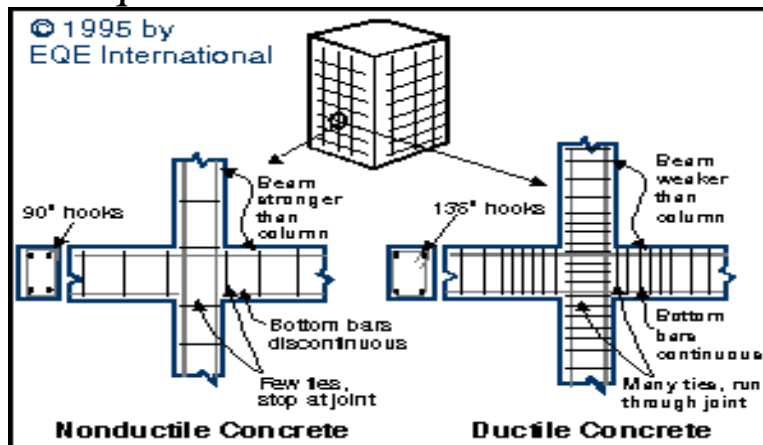
**Photo: Adam Crewe, KOBE 1995**

### **Settlement Around Grounnd Beams**

The above photogaraph once again shows the effects of liquefication and settlement. The building was built on bad ground, i.e. that which did not have good foundations and so ground beams were built to spread out the weight of the building. However in the earthquake the ground has settled and left the beams exposed. The design though has stopped the column collasping and so prevented loss of life. The only problem is that the ground has settled in different proportions and so the beams have settled also and so the buiding will need to be demolished. ---see [pcd2-052](#)

### 3) Joints and Connections:

Joints are often the weakest links in a structural system. It is necessary to provide strong horizontal confining reinforcement within the joint zone. Joints in reinforced concrete frame are often responsible for collapses in earthquakes.



*Diagram of typical detailing of ductile versus nonductile reinforced concrete columns*

### 4) Inadequate Shear Strength:

To enhance shear capacity one should first use suitable amount of stirrups and ties to prevent the brittle type of failure associated with shear.



## 5) Short Column

Frequently a column is shortened by elements which have not been taken into account in design, such as partial-height infill walls. This creates very large shear forces due to the short length of the column when subjected to very large bending moment. Even if very strong stirrups are used it is difficult to save such columns, therefore such collapses have been frequent.

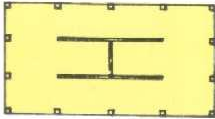
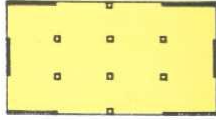
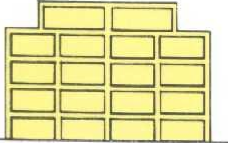
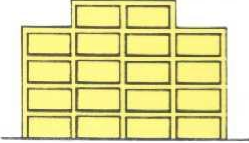
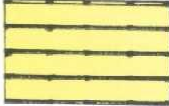
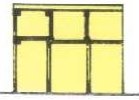
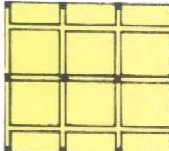
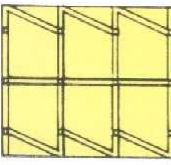
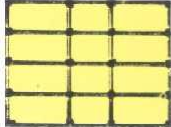


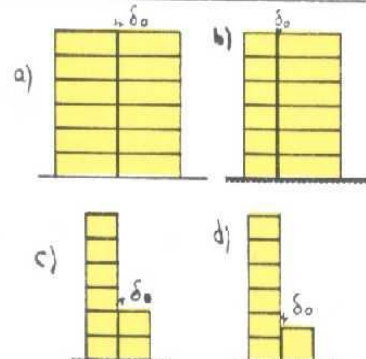
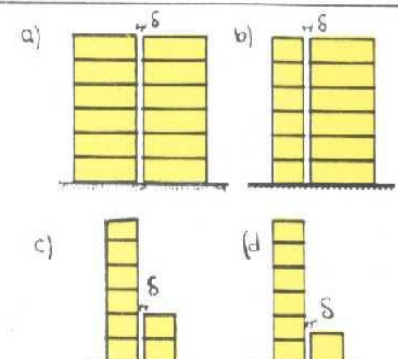
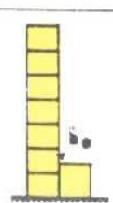
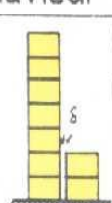
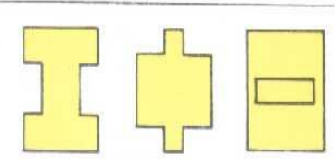
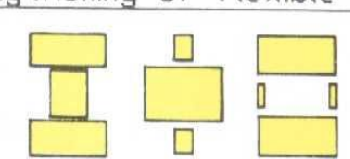
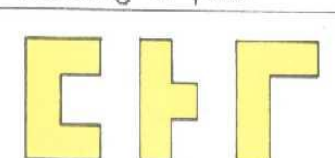
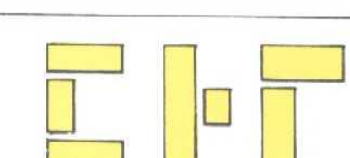
## 6) Plane Asymmetry

In structures with eccentric structural elements, seismic forces act in the center of gravity of each floor creating a torsional moment about the center of rigidity. This causes considerable damage in many buildings. To safeguard against these problems, buildings are to be simple, regular, and symmetrical. Another remedy is the careful positioning of shear wall.



*Severe racking of a steel building in Sannomiya.*

		N O	Y E S
شكل مسطح البناء وتوزيع العناصر الإنشائية الرا	VIII	 <p>Small contribution of S.W. in torsional resistance</p>	 <p>Increase of torsional resistance</p>
	IX	 <p>Indirectly supported columns (Overstress of joints)</p>	 <p>Uniform columns</p>
	X	 <p>No frame beams in Y</p>  <p>Eccentric loading of columns</p>  <p>Inadequate frame behavior in X</p> 	 <p>Good frame behavior in X &amp; Y</p>

		N O	Y E S
الفواصل الزلزالية	IV	 <p>SSI min for case a max for case d</p> <p><math>\delta_0 &gt; 3 \text{ cm}</math></p>	 <p>Seismic joint  <math>\delta = (\delta_{el,1} \cdot K_1 + \delta_{el,2} \cdot K_2)</math>  <math>\delta_{el,i}</math> - elastic displacement of building on top of concrete  <math>K_i</math> behaviour fact. of building</p>
	V	 <p>SSI (<math>\delta_0 = 0-3 \text{ cm}</math>)</p>	 <p>If there is no provision of seismic joint</p> <p>Equal story heights + strengthening of flexible bldg.</p>
	VI	 <p>Abrupt stiffness change of building in plan</p>	 <p>Seismic joints</p>
	VII	 <p>Asymmetric of building in plan</p>	 <p>Seismic joints or strengthening of connection areas</p>

## **7) Pounding of adjacent Buildings**

When adjacent separated structural units are at different heights the lower building receives an unexpected loading while the higher building suffers damage at the roof level of the lower building.



## **8) Detailing Structural Elements:**

Closed – spaced stirrups and ties are used in column and walls, to hold reinforcement in place and to prevent buckling of longitudinal bars. Closely –spaced stirrups and ties are used in potential regions of beams.



**Photo: Adam Crewe, KOBE 1995**

### **Column failure**

This is classic example of failure due to too few links in a load bearing column. The photograph shows a column from an office building which has failed in shear due to the shaking of an earthquake. It is possible to see a link at the bottom and top of the photo which have kept the reinforcement in shape at these points and so stopped failure. However where the links have failed, most likely due to lack of suitable anchorage, the vertical reinforcement bars have been able to twist and fail. In technical terms this is because the effective lengths of the bars has been increased past their design strengths. This failure is the cause of inadequate detailing in the design stage.



**Photo: Adam Crewe, KOBE 1995**

**Column Detailing Damage.**

The detailing in the above column is the main reason for failure. There is lack of links to keep the vertical bars in position and additionally the vertical bars that are there are different, there are both ribbed and plain steel bars which will affect the stiffness and produce a non uniform strength across the column. Part of the problem here is that the links are missing. They have probably not been anchored sufficiently in the centre of the column and so when the cover of the concrete was lost in the first shakes the links have sprung off allowing the vertical bars to twist and become ineffectual.



**Photo: Adam Crewe, KOBE 1995**

### **Column Detailing Failure**

The failure here is due to bad detailing of the links in the column. Where the concrete has cracked and the reinforcement bulged the links have become separated. As the links have not been anchored sufficiently they have been simply pulled apart allowing the vertical bars to deform. This highlights the need for special attention to detailing in earthquake design as this anchoring would have been adequate for static conditions but not as the picture shows for dynamic.

### **Conclusion**

1) The ratio of plan dimensions should be large to prevent different types of forces from acting on different longitudinal sections of the structure.

- 2) Weak and soft stories are to be avoided, because they are the dominant causes of failures in earthquake struck areas.
- 3) Compact plan shapes are preferred since flexible extensions such as cantilevers are susceptible to vibrate in a different frequency than the rest of the building.
- 4) Heavy masses at high level are to be avoided because they tend to cause unfavorable effects, as they amplify the forces at these levels.
- 5) A mix of shear walls and moment-resisting frames are preferable as they provide system redundancy.
- 6) Lack of continuity in the horizontal diaphragms due to openings is to avoided as it causes stree concentrations.

### To Ensure Ductility

The ductility of the structure can be considered as a measure of its ability to sustain large deformations without endangering its load carrying capacity. Therefore in addition to seismic strength, the ductility of the structure should be given serious consideration.

- The required ductility can be achieved by proper choice of framing and connections details.
- Ductility is improved by limiting the ratio of reinforcement on the tension side of beams.
- Using compression reinforcement in beams enhance ductility.
- Using adequate shear reinforcement enhances ductility
- Providing spiral reinforcement or closely spaced ties improves ductility.

