IITK - BMTPC Earthquake Tip 10

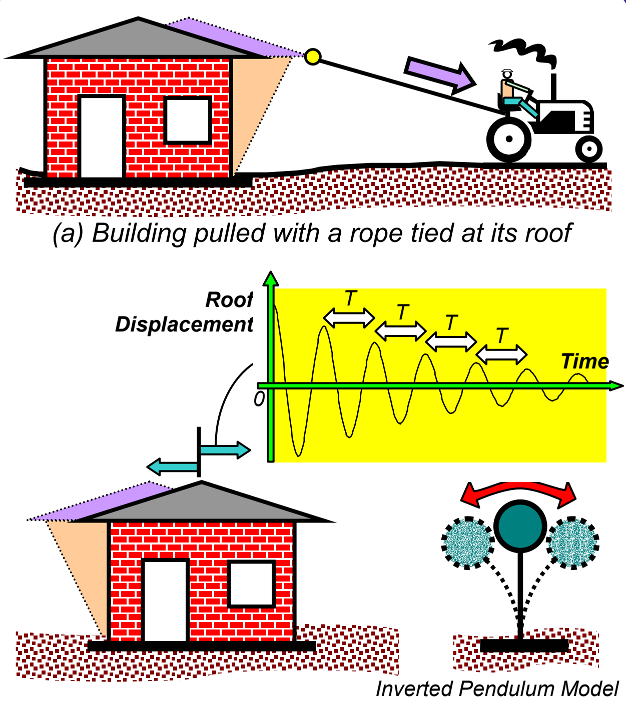
Learning Earthquake Design and Construction

How Flexibility of Buildings Affects their Earthquake Response?

Oscillations of Flexible Buildings

When the ground shakes, the base of a building moves with the ground, and the building swings back-and-forth. If the building were rigid, then every point in it would move by the same amount as the ground. But, most buildings are flexible, and different parts move back-and-forth by different amounts.

Take a fat coir rope and tie one end of it to the roof of a building and its other end to a motorized vehicle (say a tractor). Next, start the tractor and pull the building; it will move in the direction of pull (Figure 1a). For the same amount of pull force, the movement is larger for a more flexible building. Now, cut the rope! The building will oscillate back-and-forth horizontally and after some time come back to the original position (Figure 1b); these oscillations are periodic. The time taken (*in seconds*) for each complete cycle of oscillation (*i.e.,* one complete *back-and-forth* motion) is the same and is called *Fundamental Natural Period T* of the building. Value of *T* depends on the building flexibility and mass; more the flexibility, the longer is the *T*, and more the mass, the longer is the *T*. In general, taller buildings are more flexible and have larger mass, and therefore have a longer *T*. On the contrary, low- to medium-rise buildings generally have shorter T (less than 0.4 sec).

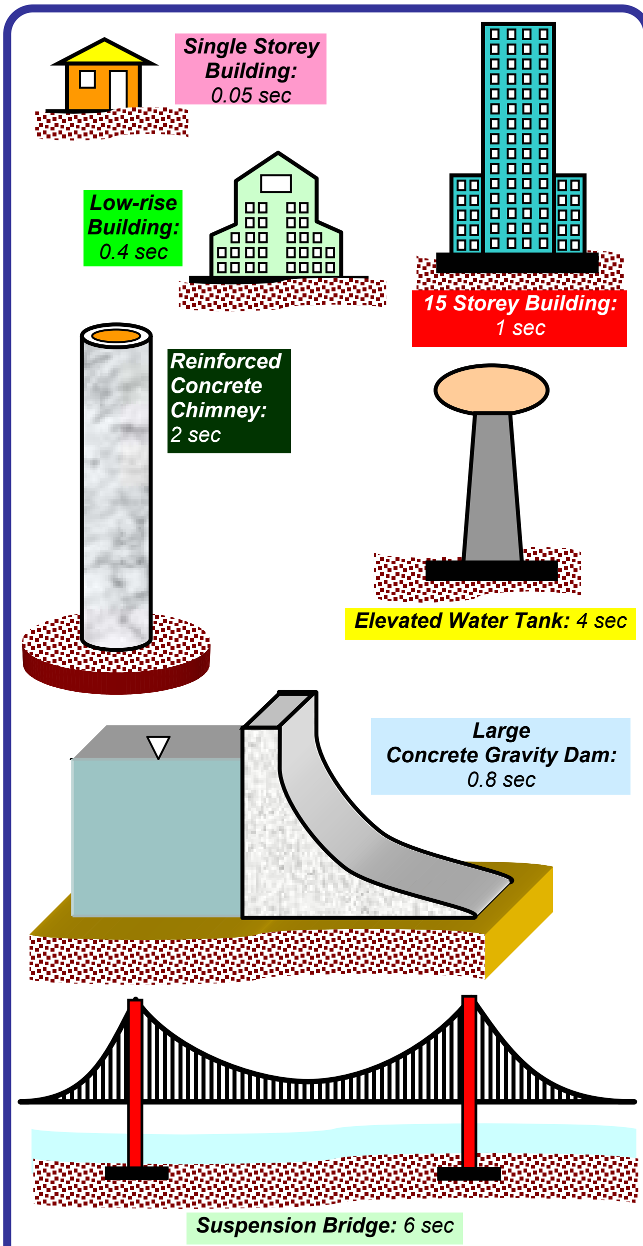


(a) Building pulled with a rope tied at its roof

(b) Oscillation of building on cutting the rope

Figure 1: Free vibration response of a building: *the back-and-forth motion is periodic.*

Fundamental natural period *T* is an inherent property of a building. Any alterations made to the building will change its *T*. Fundamental natural periods *T* of normal single storey to *20* storey buildings are usually in the range *0.05-2.00 sec*. Some examples of natural periods of different structures are shown in Figure 2.



Adapted from: **Newmark, (1970),** *Current trends in the Seismic Analysis and Design of High Rise Structures*, **Chapter 16, in Wiegel, (1970),** *Earthquake Engineering*, **Prentice Hall, USA.**

Figure 2: Fundamental natural periods of structures differ over a large range. *The natural period values are only indicative; depending on actual properties of the structure, natural period may vary considerably.*

Importance of Flexibility

The ground shaking during an earthquake contains a mixture of many sinusoidal waves of different frequencies, ranging from short to long periods (Figure 3). The time taken by the wave to complete one cycle of motion is called *period of the earthquake wave*. In general, earthquake shaking of the ground has waves whose periods vary in the range *0.03-33sec*. Even within this range, some earthquake waves are stronger than the others. Intensity of earthquake waves at a particular building location depends on a number of factors, including the *magnitude* of the earthquake, the *epicentral distance*, and the type of ground that the earthquake waves travelled through before reaching the location of interest.

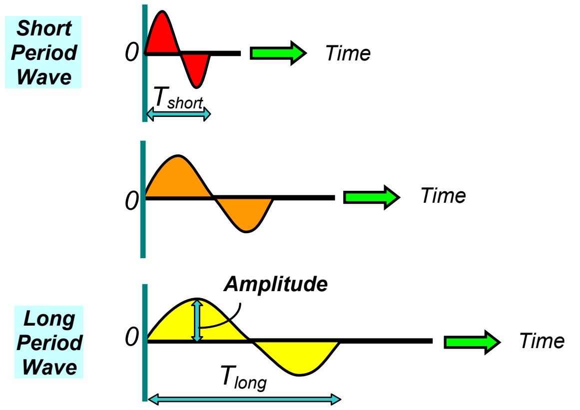
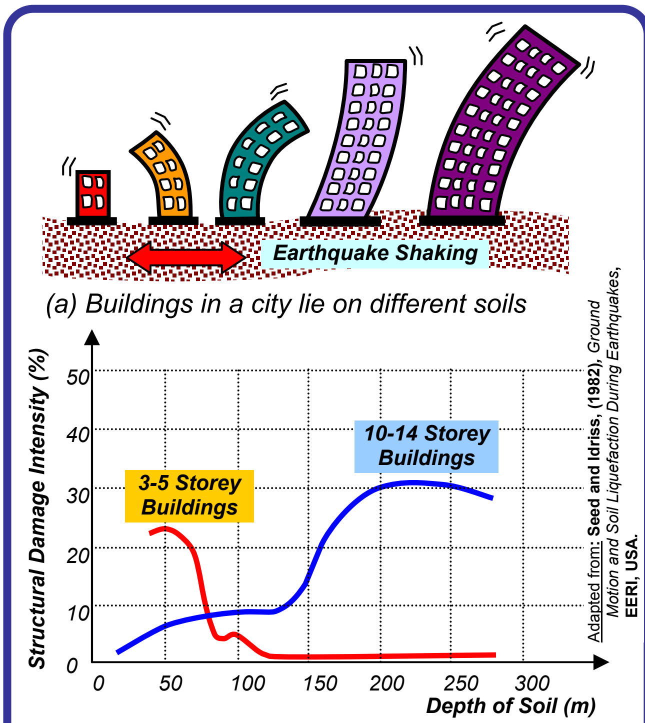


Figure 3: Strong Earthquake Ground Motion is transmitted by waves of different periods.

In a typical city, there are buildings of many different sizes and shapes. One way of categorizing them is by their *fundamental natural period T*. The ground motion under these buildings varies across the city (Figure 4a). If the ground is shaken back-and-forth by earthquake waves that have short periods, then *short period buildings* will have large response. Similarly, if the earthquake ground motion has long period waves, then *long period buildings* will have larger response. Thus, depending on the value of *T* of the buildings and on the characteristics of earthquake ground motion (*i.e.*, the periods and amplitude of the earthquake waves), some buildings will be shaken more than the others.

During the 1967 Caracas earthquake in South America, the response of buildings was found to depend on the thickness of soil under the buildings. Figure 4b shows that for buildings 3-5 storeys tall, the damage intensity was higher in areas with underlying soil cover of around 40-60m thick, but was minimal in areas with larger thickness of soil cover. On the other hand, the damage intensity was just the reverse in the case of 10-14 storey buildings; the damage intensity was more when the soil cover was in the range 150-300m, and small for lower thickness of soil cover. Here, the soil layer under the building plays the role of a filter, allowing some ground waves to pass through and filtering the rest.



(b) Intensity of damage depends on thickness of underlying soil layer: 1967 Caracas Earthquake

Figure 4: Different Buildings Respond Differently to Same Ground Vibration.

Flexible buildings undergo larger relative horizontal displacements, which may result in damage to various nonstructural building components and the contents. For example, some items in buildings, like glass windows, cannot take large lateral movements, and are therefore damaged severely or crushed. Unsecured shelves might topple, especially at upper stories of multi-storey buildings. These damages may not affect safety of buildings, but may cause economic losses, injuries and panic among its residents.

Related IITK – bmtpc Tip

IITK-BMTPC Earthquake Tip 2: How the Ground Shakes?
IITK-BMTPC Earthquake Tip 5: What are the Seismic Effects on Structures?

Resource Material

Wiegel,R., (1970), *Earthquake Engineering*, Prentice Hall Inc., USA.
Chopra,A.K., (1980), *Dynamics of Structures – A Primer*, Earthquake Engineering Research Institute, USA.

Next Upcoming Tip

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