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## **Chapter 1 Introduction:**

There are no problems provided in this chapter, but the instructor can assign case study essay style questions regarding past earthquakes, or performance of specific buildings during one of the earthquakes discussed. Students could then write short essays and make brief presentations of their findings.

## Chapter 2 Engineering Seismology Overview:

2.1 A Richter magnitude earthquake of 6.8 would radiate how much more energy than an  $M_L$  5.8 earthquake?

**Answer:**

Equation 2-2 results in a 32 fold increase in energy radiated for each unit increase in  $M_L$ . Therefore, in this case we have one unit increase in  $M_L$ , resulting in an increase of 32 times more energy.

2.2 A Richter magnitude earthquake of 5.0 is how much stronger than an  $M_L$  3.0 earthquake?

**Answer:**

The base ten logarithmic scales in Equation 2-1 indicate that each unit increase in  $M_L$  corresponds to a tenfold increase of the earthquake wave amplitude. Therefore, in this case we have a two unit increase in  $M_L$  resulting in the 5.0  $M_L$  earthquake being 100 ( $10 \times 10 = 100$ ) times stronger than the 3.0  $M_L$  event.

2.3 Estimate the local magnitude of a southern California earthquake recorded using a standard Wood-Anderson seismograph that shows trace amplitude of 23mm, and the P- and S-wave arrival times at the recording station of 07:19:45 and 07:20:09, respectively.

**Answer:**

- i) The amplitude in millimeters,  $A$  is given as 23mm.
- ii) Determine the time between the arrival of P- and S-waves in seconds,  $\Delta t_{p-s}$ .

$$\Delta t_{p-s} = 07:20:09 - 07:19:45 = 69\text{sec} - 45\text{sec} = 24\text{sec}$$

- iii) Determine the Richter magnitude,  $M_L$  using Equation 2-1.

$$\begin{aligned} M_L &= \log_{10} A + 3 \log_{10} (8\Delta t_{p-s}) - 2.92 \\ &= \log_{10} (23\text{mm}) + 3 \log_{10} (24\text{sec}) - 2.92 \\ &= 2.58 \end{aligned}$$

2.4 An earthquake at a transformed fault caused an average strike-slip displacement of 2.5m over an area equal to 80km long by 23km deep. Assuming the rock along the fault has average shear stiffness of 175kPa; estimate the seismic moment and moment magnitude of the earthquake.

**Answer:**

- i) Determine the fault's rupture area,  $A_f$  and fault slip,  $D$  in centimeters.

$$A_f = (80\text{km})(23\text{km}) = (80 \times 10^5\text{cm})(23 \times 10^5\text{cm}) = 18.4 \times 10^{12}\text{cm}^2$$

$$D_s = 2.5\text{m} = 250\text{cm}$$

- ii) Determine the seismic moment,  $M_0$  using Equation 2-5.

$$\begin{aligned} M_0 &= GA_f D_s \\ &= (3.2 \times 10^{11}\text{dyne/cm}^2)(18.4 \times 10^{12}\text{cm}^2)(250\text{cm}) \\ &= 14.72 \times 10^{26}\text{dyne-cm} \end{aligned}$$

- iii) Determine the moment magnitude,  $M_w$  using Equation 2-7.

$$M_w = 2/3 \log_{10} M_0 - 10.7$$

$$\begin{aligned}
 &= 2/3 \log_{10} (14.72 \times 10^{26} \text{ dyne-cm}) - 10.7 \\
 &= 7.41
 \end{aligned}$$

2.5 Estimate the seismic moment and moment magnitude of the February 27, 2010 Chile earthquake.

It is estimated that the thrust fault (the slip plane ends before reaching the Earth's surface) caused an average strike-slip displacement of 5m over an area equal to 600km long by 150km deep. Assume the rock along the fault has average shear rigidity of  $3 \times 10^{11} \text{ dyne/cm}^2$ .

**Answer:**

i) Determine the fault's rupture area,  $A_f$  and fault slip,  $D$  in centimeters.

$$A_f = (600 \text{ km})(150 \text{ km}) = (600 \times 10^5 \text{ cm})(150 \times 10^5 \text{ cm}) = 9 \times 10^{14} \text{ cm}^2$$

$$D_s = 5 \text{ m} = 500 \text{ cm}$$

ii) Determine the seismic moment,  $M_0$  using Equation 2-5.

$$\begin{aligned}
 M_0 &= GA_f D_s \\
 &= (3 \times 10^{11} \text{ dyne/cm}^2)(9 \times 10^{14} \text{ cm}^2)(500 \text{ cm}) \\
 &= 1.35 \times 10^{29} \text{ dyne-cm}
 \end{aligned}$$

iii) Determine the moment magnitude,  $M_w$  using Equation 2-7.

$$\begin{aligned}
 M_w &= 2/3 \log_{10} M_0 - 10.7 \\
 &= 2/3 \log_{10} (1.35 \times 10^{29} \text{ dyne-cm}) - 10.7 \\
 &= 8.72
 \end{aligned}$$

It is worth noting that a magnitude 8.8  $M_w$  was widely reported in the media.

2.6 What is the energy difference between the Haiti and Chile earthquakes from Example 2 and Problem 2.5, respectively?

**Answer:**

Since Equation 2-2 was calibrated using various types of seismic waves, it is also applicable to magnitude scales other than Richter's. Therefore, Equation 2-2 results in a 32 fold increase in energy radiated for each unit increase in  $M_w$ . In this case then we have  $8.72 - 6.94 = 1.78$  units increase in  $M_w$ , resulting in an increase of  $32^{1.78} = 478$  times more energy.

Also, using Equation 2-1 we can estimate the relative strength of the two events. The base ten logarithmic scales in Equation 2-1 indicate that each unit increase in  $M_w$  corresponds to a tenfold increase of the earthquake wave amplitude. Therefore, in this case we have  $8.72 - 6.94 = 1.78$  units increase in  $M_w$ , resulting in the Chilean earthquake being  $10^{1.78} = 60$  times stronger than the Haiti event.

### Chapter 3 Single Degree-of-Freedom Structural Dynamic Analysis:

3.1 Determine the effective weight at the roof and floor levels for a 60ft by 150ft, three-story office building with equal story heights of 10ft and the following loading:

$$\text{Roof DL} = 20\text{psf},$$

$$\text{Roof LL} = 20\text{psf},$$

$$\text{Floor DL} = 20\text{psf},$$

$$\text{Floor LL} = 60\text{psf},$$

$$\text{Wall DL} = 10\text{psf},$$

Also, the partition load is 10psf since the occupancy is designated as office building and the floor live load is less than 80psf.

**Answer:**

i) Calculate individual weights of components tributary to floors and roof.

The weight of the walls is calculated by multiplying the area of the walls with the wall dead load.

Roof (effective height of wall is 5ft):

$$W_{\text{walls}} = \text{Area}_{\text{walls}} \cdot \text{Wall DL} = 2(60\text{ft} + 150\text{ft})(5\text{ft}) \cdot 10\text{psf} = 21,000\text{lbs}$$

Floors (effective height of wall is 10ft):

$$W_{\text{walls}} = \text{Area}_{\text{walls}} \cdot \text{Wall DL} = 2(60\text{ft} + 150\text{ft})(10\text{ft}) \cdot 10\text{psf} = 42,000\text{lbs}$$

The weight of the roof and floor diaphragms is calculated by multiplying the area of the roof or floors with the roof or floors dead load.

Roof:

$$W_{\text{rooflevel}} = \text{Area}_{\text{roof}} \cdot \text{Roof DL} = (60\text{ft})(150\text{ft}) \cdot 20\text{psf} = 180,000\text{lbs}$$

Floors:

$$\begin{aligned} W_{\text{floorlevel}} &= \text{Area}_{\text{floor}} \cdot (\text{Floor DL} + \text{partition}) = (60\text{ft})(150\text{ft}) \cdot (20\text{psf} + 10\text{psf}) \\ &= 270,000\text{lbs} \end{aligned}$$

This problem specifies a live load pressure, which is not included in the seismic weight calculations because it is not a storage load.

ii) The effective seismic weight for the roof and floors can be determined by summing the weight contribution from each of the components.

The effective seismic weight of the roof is denoted as  $W_3$  (3<sup>rd</sup> level):

$$W_3 = 21,000\text{lbs} + 180,000\text{lbs} = 201,000\text{lbs} = 201\text{kips}$$

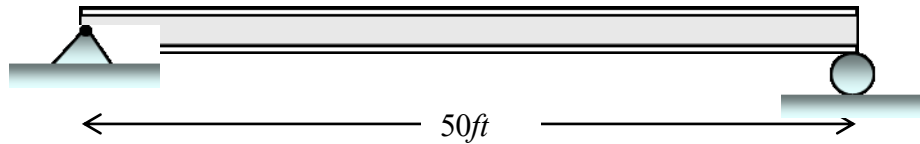
The effective seismic weight of the 2<sup>nd</sup> level is denoted as  $W_2$ :

$$W_2 = 42,000\text{lbs} + 270,000\text{lbs} = 312,000\text{lbs} = 312\text{kips}$$

The effective seismic weight of the 1<sup>st</sup> level is denoted as  $W_1$ :

$$W_1 = 42,000\text{lbs} + 270,000\text{lbs} = 312,000\text{lbs} = 312\text{kips}$$

3.2 The bridge beam depicted below supports a rigid deck that weighs 200kips. Assuming the weight is lumped at midspan, determine the natural frequency and period of the system. ( $E = 29,000\text{kip/in}^2$  and  $I_x = 13,000\text{in}^4$ ).

**Answer:**

- i) Idealize the structural system.  
The weight of the beam is considered negligible with respect to the weight of the bridge deck. Also, consider only the vertical displacement of the beam.
- ii) Determine the stiffness parameters.  
From Example 3, the stiffness of the SDOF system is,

$$k = \frac{48EI}{L^3} = \frac{48(2.9 \times 10^7 \text{ psi})(13,000 \text{ in}^4)}{(50 \text{ ft} \times 12 \frac{\text{in}}{\text{ft}})^3} = 83,778 \frac{\text{lb}}{\text{in}}$$

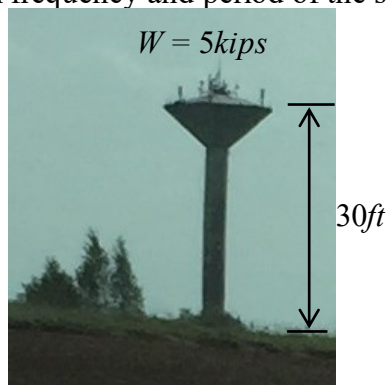
- iii) Determine the natural frequency and period of the system.  
Since the bridge is modeled as a SDOF system, the equation of motion is described by Equation 3.1. The natural frequency of bridge is determined using Equation 3.2.

$$\omega_n = \sqrt{\frac{k}{m}} = \sqrt{\frac{83,778 \frac{\text{lb}}{\text{in}}}{\left( \frac{200,000 \text{ lb}}{32.2 \frac{\text{ft}}{\text{s}^2} \times 12 \frac{\text{in}}{\text{ft}} \right)}}} = 12.72 \frac{\text{rad}}{\text{s}}$$

The natural period of vibration is determined using Equation 3.5.

$$T_n = \frac{2\pi}{\omega_n} = \frac{2\pi}{12.72 \frac{\text{rad}}{\text{s}}} = 0.49 \text{ sec}$$

- 3.3 Given a water tank supported on a slender ( $I = 10,000 \text{ in}^4$ ), concrete ( $E = 3 \times 10^7 \text{ psi}$ ) column as shown, determine the natural frequency and period of the system.

**Answer:**

- i) Idealize the structural system.  
The weight of the column is considered negligible with respect to the weight of the water tank. Also, consider only the horizontal displacement of the water tank.
- ii) Determine the stiffness parameters.