Soil Dynamics

Lecture 12

Seismic Codes

California Building Code – Part II

In a Problem Format

List of Symbols.

- ***ap*** **is the in-structure component of the amplification factor.**
- ***Ca*** **is the seismic response coefficient for proximity.**
- ***Cp*** **is the horizontal force factor.**
- ***Ct*** **is a numerical coefficient for the period.**
- ***Cv*** **is the seismic response coefficient.**
- ***Fp*** **is total (design or service) lateral seismic force.**
- ***Ft*** **is the concentrated force at the top of the structure.**
- ***hn*** **is defined as the height of the building above the base to the nth level.**
- ***I*** **is the seismic importance factor.**
- ***Na*** **is the near source factor for *Ca*.**
- ***Nv*** **is the near source factor for *Cv*.**
- ***R*** **is the response modification factor; it reflects the inherent over-strength and global ductility capacity of different lateral-force resisting systems.**
- ***Rp*** **is the component response modification factor; the horizontal force factor.**
- ***S*** **is the soil profile classification, such as, *SA*, *SB*, *SC*, *SD*, *SE* and *SF*).**
- ***T*** **is the fundamental period.**
- ***V*** **is the base shear force.**
- ***W*** **is the weight of the entire structure (dead + live loads).**
- ***Z*** **is the seismic zone influence factor.**
- ***Ωo*** **is the seismic force amplification factor.**
- **Δs is the inter-story drift.**

Question #01.

CBC provides the following formula to determine the fundamental period *T* of a building with reinforced concrete shear walls (Method A, Section 1630.2.2),

$$A_C = \sum A_e \left[0.2 + \left(\frac{D_e}{h_n} \right)^2 \right] \quad \textbf{where} \quad C_t = \frac{0.1}{\sqrt{A_c}}$$

What is the maximum value of D_e / h_n ?

A. 0.30.

B. 0.90.

C. 2.75.

D. ⅜ R_w

Answer to #01.

B.

Method A of the CBC Section 1630.2.2, Item 1 details that the value of D_e / h_n should not exceed 0.9 when used in CBC Formula 30-9.

Question #02.

In order to determine the fundamental period *T* of a building, the CBC gives the following formula,

$$T = 2\pi \sqrt{\frac{\sum_{i=1}^{n} w_i \delta_i^2}{g \sum_{i=1}^{n} f_i \delta_i}}$$

This formula represents,

A. The period defined by Method A.

B. The period defined by Method B.

C. The static period.

D. The dynamic period.

Answer to #02.

B.

Model B defined in CBC Section 1630.2.2, Item 2, Formula 30-10 used to calculate the fundamental period *T*. The terms *static period* and *dynamic period* have no meaning.

Question #03.

The natural period *T* of a building is 4 seconds. At the roof level of the structure, the concentrated force F_t (which is additional to the base shear *V*), should be determined by which of the following formulas?

A. $F_t = 0$

B. $F_t = 0.07\ TV$

C. $F_t = C_t\ (h_n)^{0.75}$

D. $F_t = 0.25\ V$

Answer to #03.

D.

CBC Section 1630.5 states that, *if* the value of T is 0.7 seconds or less, the additional concentrated force at the top, F_t is equal to zero.

Otherwise, use the CBC Formula 30-14, $F_t = 0.07\ TV$

For this problem's structure, the natural period of 4 seconds, is greater than 0.7 seconds, so use Formula 30-14.

However, F_t need not exceed 0.25 V, therefore perform the following calculation,

$$F_t = 0.07\ TV = (0.07)(4\text{ sec})\ V = 0.28\ V$$

Since 0.28 V is greater than the maximum value of 0.25 V, use $F_t = 0.25\ V$.

Question #04.

If a building's natural period T is 0.60 seconds, what is the concentrated force F_t at the top of the structure?

A. $F_t = 0$

B. $F_t = 0.06\ TV$

C. $F_t = 0.07\ TV$

D. $F_t = 0.25\ V$

Answer to #04.

A.

CBC Section 1630.5 states that the concentrated force at the top F_t is determined from Formula 30-14, that is,

$$F_t = 0.07\,TV$$

This formula should be used when T is greater than 0.7 seconds. If T is less or equal to 0.7 seconds, then F_t can be considered to be zero.

Question #05.

The maximum base shear *V* can be calculated from which of the following formulas?

A. $V = \left(\frac{C_V I}{RT}\right) W$

B. $V = \left(\frac{2.5 C_a I}{R}\right) W$

C. $V = 0.11 C_a I\, W$

D. $V = \left(\frac{0.8 Z N_V I}{R}\right) W$

Answer to #05.

B.

For the base shear V the CBC Formula 30-4 should be used,

$$V = \left(\frac{C_V I}{RT}\right) W$$

However, CBC Section 1630.2.1 states that the maximum base shear can be calculated from,

$$V = \left(\frac{2.5 C_a I}{R}\right) W$$

The seismic coefficients *Ca* and *Cv* can be obtained from CBC Tables 16-Q and 16-R respectively. The maximum value of

$$\frac{C_V}{T} \text{ is } 2.5 C_a$$

Question #06.

Which of the following systems is without a complete vertical load-carrying space frame?

A. A bearing wall system.

B. A moment-resisting frame.

C. A building frame system.

D. Dual systems.

Answer to #06.

A.

CBC Section 1629.6.2 defines a *bearing wall system* as a structural system that is *without* a complete vertical load-carrying frame.

Bearing walls give support for all of the gravity loads, and the lateral loads are resisted by either shear walls or by braced frames.

Question #07.

For a moment-resisting structural system, resistance to lateral loads is provided by which of the following?

A. **Complete space frames.**

B. **Shear walls.**

C. **Braced frames.**

D. **The flexural action of its members.**

Answer to #07.

D.

Moment-resisting structural systems are designed as complete frames that support both vertical and lateral loads.

CBC Section 1629.6.4 states that the lateral resistance to loads from moment-resisting systems must be provided by the flexural actions of its members.

Question #08.

Which of the following structural systems have the lowest ductility for structures that are three stories or less in height?

A. **Reinforced concrete shear walls.**

B. **Steel braced bearing walls.**

C. **Heavy timber braced bearing walls.**

D. **Wood structural panels bearing walls.**

Answer to #08.

C.

The *response modification factor R* has been assigned to reflect the inherent over-strength and global ductility capacity of different lateral-force resisting systems. As the value of *R* decreases, the ductility of the structure decreases.

For the *R* values, CBC uses table 16-N, which are for this problem,

A. $R = 4.5$

B. $R = 4.4$

C. $R = 2.8$

D. $R = 5.5$

Question #09.

Reinforced concrete is preferred over steel for designing a seven-story apartment complex in Los Angeles. What type of moment-resisting frame should be used?

A. Special.

B. Intermediate.

C. Ordinary.

D. Any of the above.

Answer to #09.

A.

There are three types of reinforced concrete moment-resisting frames:

- **special,**
- **intermediate, and**
- **ordinary.**

These reinforced concrete frames are required by design to be part of the lateral-force resisting system.

The CBC permits these three systems to be constructed only in certain seismic zones. Los Angeles is in seismic zone 4. CBC Table 16-N, footnotes 5 and 8, and Section 1633.2.7, Item 1 narrow the choice to a *special* moment-resisting reinforced concrete frame.

Question #10.

For a building in San Francisco, different types of structural systems are being analyzed. Since the height of the buildings is 200 feet (61 m) which of the following combinations are allowed by the CBC?

I dual systems
II special moment-resisting frames
III building frame systems

A. I only.

B. I and II.

C. I and III.

D. I, II and III.

<u>Answer to #10.</u>

B.

The CBC Section 1630.4.3 allows only combinations of dual systems and special moment-resisting frames to be used to resist seismic forces in seismic zones 3 and 4, plus any structure exceeding a height of 160 feet (48.8 m).

Question #11.

A structure consists of a special moment-resisting steel frame and shear walls.

According to CBC requirements, what is the lowest percentage of base shear *V* that the special moment-resisting steel frame must resist independently?

A. 0%

B. 25%

C. 50%

D. 75%

Answer to #11.

B.

Since the structure consists of a combination of a special moment-resisting steel frame and shear walls, the CBC Section 1629.6.5 defines it as a *dual system*.

For *dual systems*, CBC Section 1629.6.5, item 2 specifies that the moment-resisting frames shall be designed to independently resist at least 25% of the design base shear *V*.

Question #12.

Consider an 80 foot (24.4 m) tall building with a special moment-resisting steel frame.

Applying Method A of CBC Section 1630.2.2, what is the period *T* of the building?

A. **0.40 seconds.**

B. **0.53 seconds.**

C. **0.80 seconds.**

D. **0.94 seconds.**

Answer to #12.

D.

CBC Section 1630.2.2, Item 1 gives the value of C_t = 0.035 for steel moment-resisting frame structures.

Using Formula 30-8 of Method A, the building period T is given by,

$$T = C_t \left(h_n\right)^{3/4} = (0.035)(80)^{0.75} = 0.94 \text{ seconds}$$

where h_n is defined as the height of the building in feet.

Question #13.

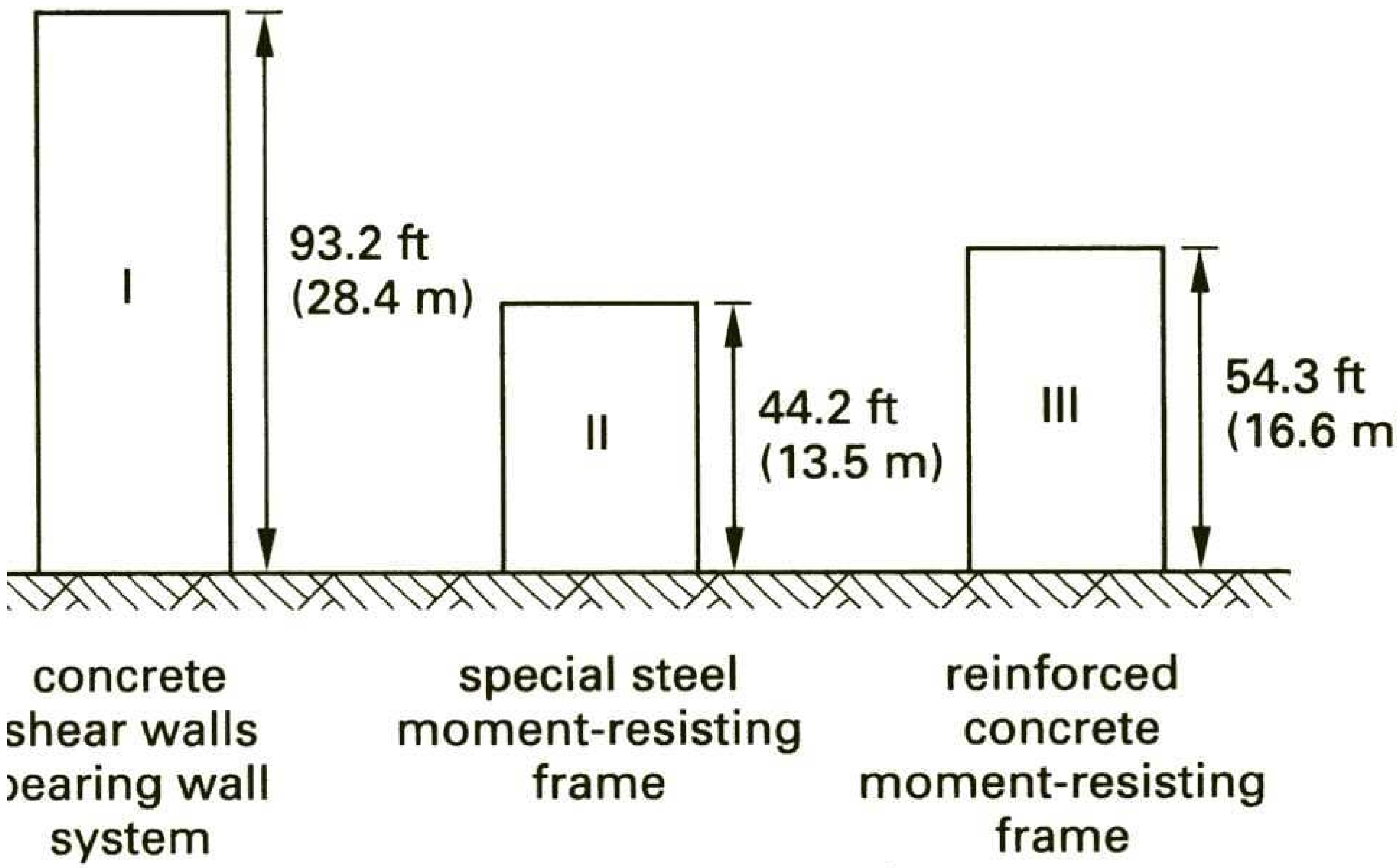
The three types of structures shown below are all located in seismic zone 4 with the same soil profile. If an earthquake occurs with a predominant period *T* of 0.6 seconds, which of the following buildings has the greatest possibility of being in resonance with the earthquake?

A. I only.

B. I and II.

C. II and III.

D. I, II and III.



Answer to #13.

D.

Resonance occurs when the building period coincides with the earthquake period. Each building's period *T* is found from CBC Formula 30-8, whilst choosing C_t from CBC Section 1630.2.2, Item 1, namely,

$C_t = 0.020$ for structure I,

$C_t = 0.035$ for structure II, and

$C_t = 0.030$ for structure III.

Therefore,

$$T_I = C_t (h_n)^{3/4} = (0.020)(93.2)^{0.75} = 0.6 \text{ seconds}$$

$$T_{II} = C_t (h_n)^{3/4} = (0.035)(44.2)^{0.75} = 0.6 \text{ seconds}$$

$$T_{III} = C_t (h_n)^{3/4} = (0.030)(54.3)^{0.75} = 0.6 \text{ seconds}$$

All of the buildings have an equal fundamental period of vibration, and they are all located on the same soil profile. Therefore, all three buildings have the same possibility of being in resonance with the earthquake.

Question #14.

A ten-story office building is being designed for the city of Los Angeles. The building will be placed on a site with a soil profile type S_B, with R = 5.6, W = 2 Mips, N_a = 1.0 and N_v = 1.0. What is the minimum allowable design base shear V for this structure?

A. 88.0 kips.

B. 115.0 kips.

C. 230.0 kips.

D. 393.0 kips.

Answer to #14.

B.

CBC Section 1630.2.1 states that the minimum design base shear in a given direction can be found from Formula 30-6,

$$V = (0.11)\ C_a\ I\ W$$

Los Angeles is in zone 4, therefore the computed base shear should not be less than the base shear obtained from CBC Formula 30-7,

$$V = (0.8\ Z\ N_r\ I\ /\ R)\ W$$

CBC Table 16-Q gives the seismic coefficient $C_a = 0.40\ N_a$ for the soil profile S_B in a seismic zone 4. Therefore,

Formula 30-6 $$V = 0.11 C_a I W = (0.11)(0.40)(1.0)(1.0)(2{,}000\ \textit{kips}) = 88\ \textit{kips}$$

Formula 30-7 $$V = \left(\frac{0.8 Z N_r I}{R}\right) W = \left(\frac{0.8(0.4)(1.0)(1.0)}{5.6}\right)(2{,}000\ \textit{kips}) = 114.3\ \textit{kips}$$

Since V = 88 kips < 114.3 kips, the latter should be used.

Question #15.

For a structure with a seismic base shear coefficient $C_v\, I\, /\, R\, T = 0.14$, what is the effective spectral acceleration, expressed as a percentage of gravity?

A. **5%**

B. **10%**

C. **14%**

D. **25%**

Answer to #15.

C.

$$F = ma = \left(\frac{W}{g}\right)a \quad and \quad V = \left(\frac{C_V I}{RT}\right)W = 0.14W$$

but,

$$F = V \quad \therefore \quad \left(\frac{W}{g}\right)a = 0.14W \quad \therefore \quad \underline{a = 0.14g}$$

Question #16.

A special moment-resisting steel structure is being designed to a height of 240 feet (73.2 m) in a seismic zone 4. The site for this building is underlain with very dense soil and soft rock. The soil-rock strata transmit a shear wave with a velocity of 2,500 ft/sec. Based on the CBC requirements, the value of the ratio C_v / T in designing the base shear need not exceed which of the following values?

A. 0.56 N_v

B. 0.96 N_v / T

C. 1.92 / T

D. 2.5 C_a

<u>Answer to #16.</u>

D.

CBC Table 16-J shows that the soil profile is an S_C for dense soil and soft rock with an S-wave of 2,500 ft/sec. From CBC Table 16-R the value of the seismic response coefficient C_v is 0.56 N_v for this same soil. From CBC Table 16-T the maximum value of the near-source factor N_a is 2.0. Therefore, the maximum value of the seismic response coefficient C_v is,

$$C_v = 0.56\, N_v = (0.56)(2.0) = 1.12$$

However, CBC Section 1630.2.1 specifies that the total design shear in a given direction should be determined from the CBC Formula 30-4 and not to exceed CBC Formula 30-5,

$$V = \left(\frac{C_V I}{RT}\right) W \quad and \quad V = \left(\frac{2.5 C_a I}{R}\right) W$$

therefore,

$$\left(\frac{C_V I}{RT}\right) W = \left(\frac{2.5 C_a I}{R}\right) W \quad \therefore \quad \frac{C_V}{T} = 2.5 C_a$$

Question #17.

A building must be designed such that it will not require an additional force F_t at the roof level (that is, $F_t = 0$). Assume the maximum possible natural period for this building. Use $R = 5.5$, the soil profile is type S_A, $Z = 0.4$ and the near source factor $N_v = 1.2$.

What is the design base shear V using CBC Formula 30-4?

A. 0

B. 0.10 *I W*

C. 1.0 *I W*

D. 10 *I W*

Answer to #17.

B.

Given a soil profile of S_A, and $Z = 0.4$, yields a $C_v = 0.32\ N_v$

CBC Section 1630.5, for $F_t = 0$ the maximum value of $T = 0.7$ seconds. From Table 16-R, the seismic coefficient C_v is,

$$C_v = 0.32\ N_v = (0.32)(1.2) = 0.384$$

CBC Formula 30-4,

$$V = \left(\frac{C_V I}{RT}\right)W = \left(\frac{0.384I}{(5.5)(0.7)}\right)W = \underline{0.10IW}$$

Question #18.

When using CBC Table 16-P, which of the following structures *can not* use the CBC Formula $F_p = 4.0\ C_a\ I_p\ W_p$?

A. Penthouses.

B. Water tanks.

C. Braced parapet walls.

D. Roof-mounted equipment.

Answer to #18.

B.

The CBC Table 16-P identifies non-building structures, including water tanks.

CBC Section 1634.1.1 discusses non-building structures, which include all self-supporting structures other than buildings that carry gravity loads and resist the effects of lateral forces.

Penthouses, braced parapet walls, and roof-mounted equipment are considered elements of structures, non-structural components and equipment, and their attachments. For the latter, CBC Formula 32-1,

$$F_p = 4.0\ C_a\ I_p\ W_p$$

determines the total design lateral seismic force. The value of C_a should be based on CBC Table 16-Q for the soil profile type. The value of I_p is obtained from Table 16-K.

Question #19.

What are the minimum and maximum values of R_p for the attachments of permanent equipment supported by a structure?

Note: attachments include anchorages and required bracing.

A. 1.0 and 3.0

B. 1.0 and 1.5

C. 1.5 and 3.0

D. 1.5 and 4.0

Answer to #19.

C.

The attachments for permanent equipment supported by a structure should be designed to resist the total design seismic forces outlined in CBC Section 1632.2.

In CBC Section 1632.2, R_p is the Component Response Modification Factor. A value for R_p should be taken from CBC Table 16-O. This table refers to R_p as the horizontal force factor and lists values varying from 1.5 to 4.0.

For attachments including anchorages and requiring bracing, the maximum value is 3.0.

Question #20.

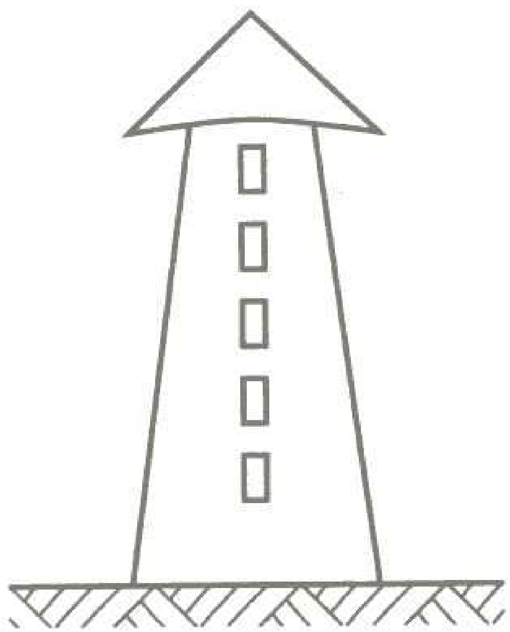
An airport control tower, or any tall and slender building such as the monument shown below, will require what value for *R* ?

A. 2.0

B. 2.2

C. 2.9

D. 3.6



Answer to #20.

B.

A monument is considered a non-building structure.

For amusement structures and monuments, the *R* value is 2.2 (use CBC Table 16-P).