Soil Dynamics

Lecture 14

Seismic Codes

California Building Code - Part IV

In a Problem Format

List of Symbols.

- a_p is the in-structure component of the amplification factor.
- C_a is the seismic response coefficient for proximity.
- C_p is the horizontal force factor.
- C_t is a numerical coefficient for the period.
- Cv is the seismic response coefficient.
- F_p is total (design or service) lateral seismic force.
- F_t is the concentrated force at the top of the structure.
- h_n is defined as the height of the building above the base to the nth level.
- I is the seismic importance factor.
- N_a is the near source factor for C_a.
- N_v is the near source factor for C_v.
- R is the response modification factor; it reflects the inherent over-strength and global ductility capacity of different lateral-force resisting systems.
- R_p is the component response modification factor; the horizontal force factor.
- S is the soil profile classification, such as, S_A, S_B, S_C, S_D, S_E and S_F).
- T is the fundamental period.
- V is the shear force at the base of the building.
- W is the weight of the entire structure (dead + live loads).
- Z is the seismic zone influence factor.
- Ω_o is the seismic force amplification factor.
- Δ_s is the inter-story drift.

Question #01.

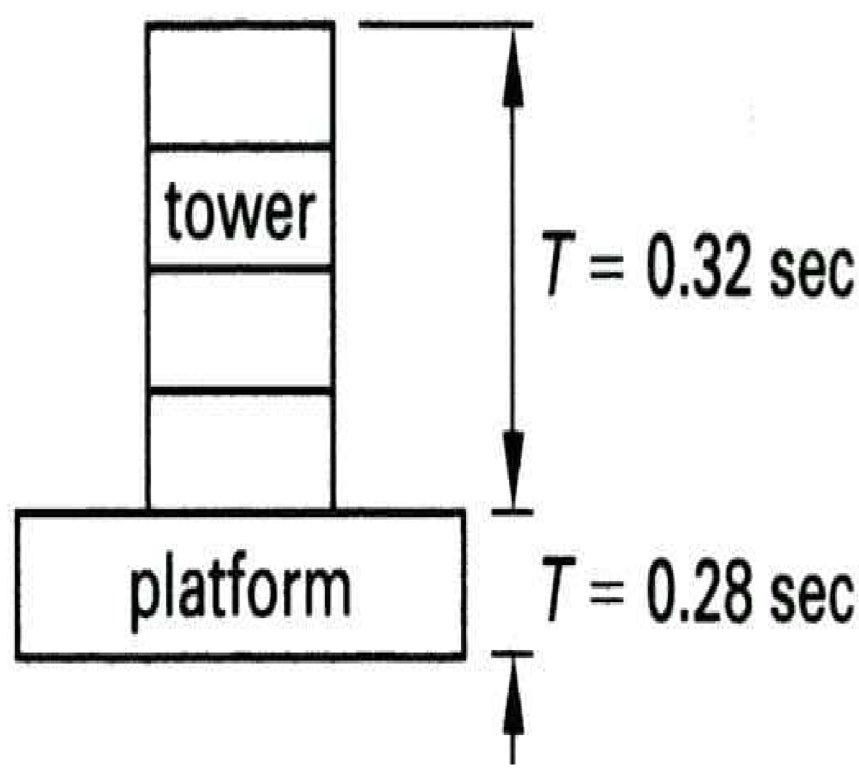
A residential high-rise building has a flexible upper portion (its tower) and a more rigid lower platform portion (the parking garage). Both portions are classified as "regular". Using the static lateral force procedure, what is the maximum period for the entire structure?

A. 0.28 sec.

B. 0.32 sec.

C. 0.35 sec.

D. 0.50 sec.



Answer to #01.

C.

CBC Section 1629.8.3, Item 4 states that the static lateral force procedure of CBC Section 1630 is the appropriate method of calculation if,

$$T_{entire\ structure} \leq 1.1\ T_{upper\ portion}$$

The maximum period of the entire structure is,

$$T_{maximum} \leq (1.1)(0.32\ \text{sec}) = 0.35\ \text{sec}$$

Question #02.

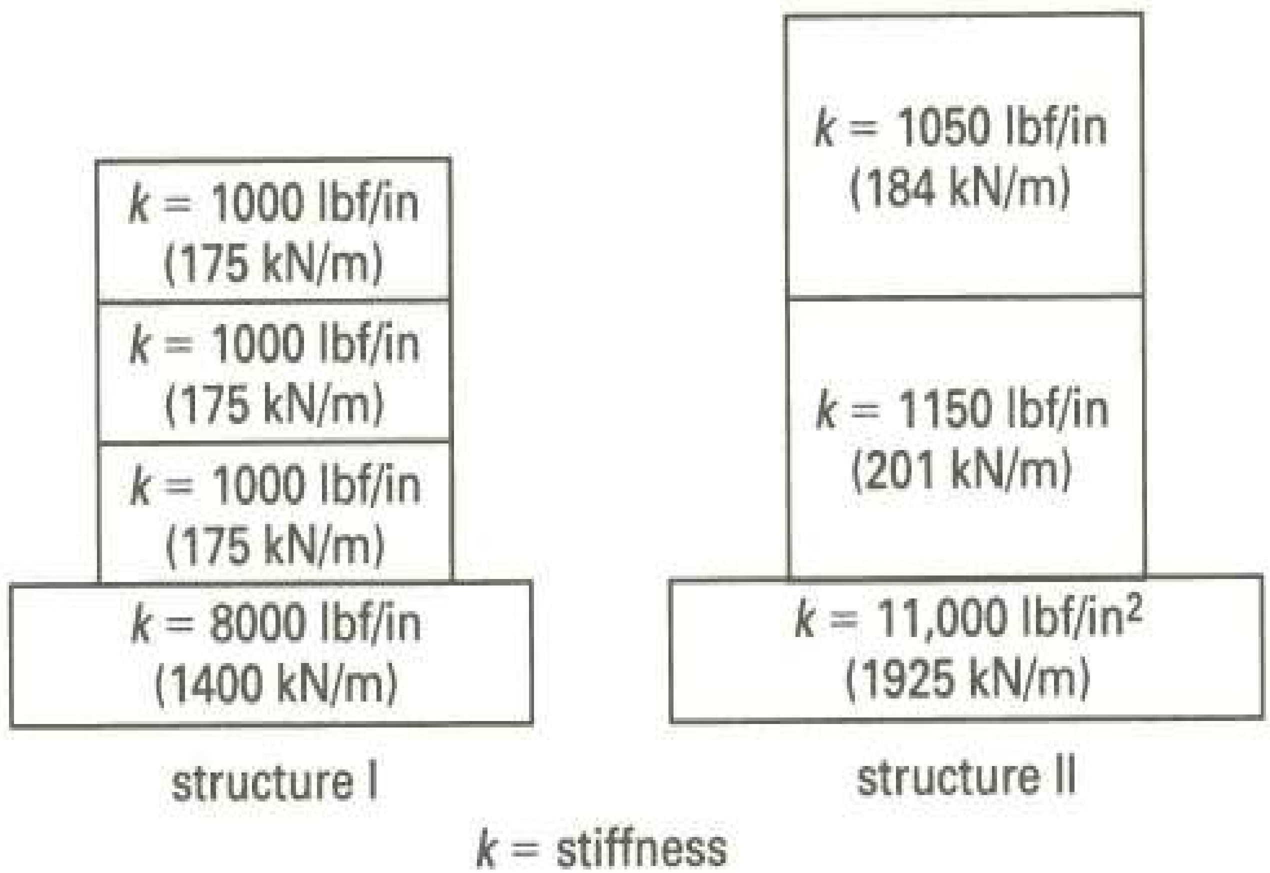
Both structures shown below are regular and have an upper flexible tower with a lower stiffer platform. Using CBC Section 1629, which of the structures can be designed using the static lateral force procedure, provided that the period of the entire structure is not greater than 1.1 times the period of the upper portion?

A. Structure I only.

B. Structure II only.

C. Both I and II.

D. Neither.



Answer to #02.

B.

CBC Section 1629.8.3, Item 4 permits the use of the static lateral load procedure of Section 1630 when the average story stiffness of the lower portion is at least 10 times the average story stiffness of the upper portion.

K average, rigid lower portion **$\geq$ 10** ***K average, flexible upper portion***

For structure I,

Question #03.

An 80 foot structure in California has a concrete bearing wall system along one principal axis and a special moment-resisting steel frame along the orthogonal principal axis.

What value of *R* should be used?

A. *R* = 4.5.

B. *R* = 5.5.

C. *R* = 6.4.

D. *R* = 8.5.

<u>Answer to #03.</u>

A.

This structure has a concrete bearing wall system (where $R = 4.5$) in only one direction and a special moment-resisting steel frame (where $R = 8.5$) in the orthogonal direction.

For design in the orthogonal direction in seismic zones 3 and 4, based on the CBC Section 1630.4.3, the value of R should not be greater than that used for the bearing wall system.

Question #04.

In designing structures that support flexible non-structural elements in seismic zones 3 and 4, when should interaction effects between the structure and the supporting elements be considered?

A. The combined weight exceeds 25% of the weight of the structure.

B. The combined weight does not exceed 25% of the weight of the structure.

C. The combined weight exceeds 75% of the weight of the structure.

D. The combined weight does not exceed 75% of the weight of the structure.

Answer to #04.

A.

Non-building structures carry gravity loads and resist the effects of earthquakes. They include all self-supporting structures other than buildings.

Based on CBC Section 1634.1.6, those structures that support flexible nonstructural elements whose combined weight exceeds 25% of the weight of the structure should be designed considering the interaction effects between the structure and the supporting elements.

Question #05.

Using allowable stress design loads, the CBC minimum resisting force for retaining walls against overturning is,

A. half of the overturning moment.

B. ¾ of the overturning moment.

C. equal to the overturning moment.

D. 1.5 of the overturning moment.

Answer to #05.

D.

In designing retaining walls against overturning, CBC Section 1611.6 requires that the minimum resisting force should be 1.5 times the lateral force using the allowable stress design loads.

Question #06.

Using the allowable stress design loads, the CBC requires retaining walls to be designed to resist sliding by al least,

A. 50% of the lateral force.

B. 85% of the lateral force.

C. 100% of the lateral force.

D. 150% of the lateral force.

Answer to #06.

D.

For retaining walls, CBC Section 1611.6 requires the minimum resisting force against sliding should be 1.5 times the lateral force using allowable stress design loads.

Question #07.

CBC requires that interior walls, permanent and temporary partitions that exceed 6 feet in height should be designed to which of the following criteria?

I. to resist all loads to which they are subjected?

II. to resist a minimum force of 5 lb_f/ft^2 applied perpendicular to the walls?

III. to deflect a maximum of *L*/360 of the walls' span.

A. I only.

B. I and II.

C. I and III.

D. II and III.

Answer to #07.

B.

In designing interior walls, permanent and temporary partitions where the height exceeds 6 feet, the CBC Section 1611.5 requires the following,

1) They must resist all loads to which they are subjected?

2) They must resist a minimum force of 5 lbf/ft^2 applied perpendicular to the walls. The 5 psf load need not be applied simultaneously with wind or seismic loads.

3) They must deflect a maximum of 1/240 or 1/120 of the span of the wall with brittle and flexible finishes, respectively.

Question #08.

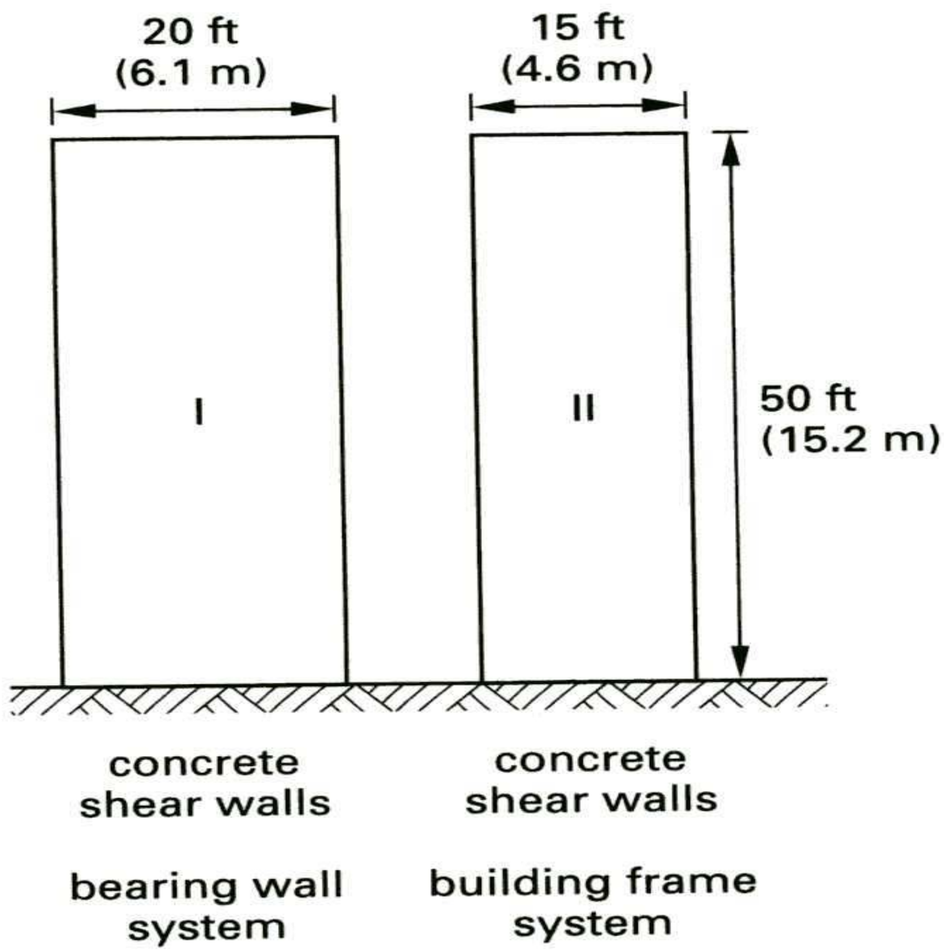
The structures shown below are located in a seismic zone 4. During an earthquake, they will drift equally (ie, the design level response displacements are the same, $\Delta_{SI} = \Delta_{SII} = \Delta_S$). There is no justification for rational analyses. Based on this information, what is the minimum required separation between these structures?

A. Twice the displacement Δ_S.

B. Thrice the displacement Δ_S.

C. Four times the displacement Δ_S.

D. Five times the displacement Δ_S.



Answer to #08.

D.

Based on CBC Section 1633.2.11, all structures should be separated from adjoining structures. Separations should be allowed for displacements Δ_M (the maximum inelastic response displacements) due to seismic forces.

The minimum separation between buildings on the same property should be Δ_{MT} where,

$$\Delta_{MT} = \sqrt{(\Delta_{MI})^2 + (\Delta_{MII})^2}$$

where Δ_{MI} equals the maximum inelastic response displacement of building I, and Δ_{MII} equals the maximum inelastic response displacement of building II.

CBC Section 1630.9.2 requires that Δ_M be computed from the CBC Formula 30-17,

$$\Delta_M = 0.7\, R\, \Delta_S$$

Δ_S is the total drift that occurs when the structure is subjected to the design forces. To determine Δ_M these drifts should be amplified.

For building I, using CBC Table 16-N, where R = 4.5,

$\Delta_{MI} = 0.7\, R_I\, \Delta_{SI} = (0.7)(4.5)\, \Delta_{SI} = 3.15\, \Delta_{SI}$

For building II, using CBC Table 16-N, where R = 5.5,

$\Delta_{MII} = 0.7\, R_{II}\, \Delta_{SII} = (0.7)(5.5)\, \Delta_{SII} = 3.85\, \Delta_{SII}$

Since $\Delta_{SI} = \Delta_{SII} = \Delta_S$

Using CBC Formula 33-2 to obtain the minimum required separation between the structures,

$$\Delta_{MT} = \sqrt{(\Delta_{MI})^2 + (\Delta_{MII})^2} = \sqrt{(3.15\Delta_S)^2 + (3.85\Delta_S)^2} = \sqrt{(24.75\Delta_S)^2} \approx 5\Delta_S$$

Question #09.

In San Francisco (seismic zone 4), a special moment-resisting steel frame structure with a height of 60 feet (five stories) is located next to a vacant space on the same property.

An investor wants to build an 80 foot concrete shear bearing wall structure (also, five stories) on the lot, close to the older building. The fundamental periods of the existing and the proposed buildings are 0.8 and 0.5 seconds, respectively.

Based on this information, what is the minimum separation between the two buildings, as required by the CBC?

A. 3 inches.

B. 23 inches.

C. 28 inches.

D. 35 inches.

Answer to #09.

B.

From CBC Table 16-N, the *R* value for the existing structure is 8.5, and the *R* value for the proposed structure is 4.5. Based on the CBC Section 1633.2.11 requirements, adjacent buildings on the same property should be separated by at least Δ_{MT}.

The existing structure has a *T* = 0.8 s. CBC Section 1630.10.2 requires that the calculated story drift using Δ_M should not exceed 0.020 times the story height for structures having a fundamental period of 0.7 s or greater (which is the case for building I). The inelastic displacement is, Δ_{MI} = (0.020)(60 ft)(12 in/ft) = 2.88 in.

For the proposed new structure, *T* = 0.5 s; the calculated story drift using Δ_M should not exceed 0.025 times the story height for structures having a fundamental period of less than 0.7 s. The inelastic displacement is, Δ_{MI} = (0.025)(80 ft)(12 in/ft) = 4.80 in.

For the minimum separation needed between these two buildings at a height of 60 feet (the point of impact between the two buildings), use CBC Formula 33-2,

$$\Delta_{MT} = \sqrt{(\Delta_{MI})^2 + (\Delta_{MII})^2} = \sqrt{\left[(2.88)(60/12)\right]^2 + \left[(4.8)(60/16)\right]^2} \approx 23.0\ s$$

Question #10.

Mechanical equipment is constructed on the top level (roof) of a building. The equipment is well attached to the structure. Its weight is 30 kips. With respect to grade, the structure's roof elevation is 80 feet, while the equipment attachment is at elevation 86 feet.

Using seismic zone 3 design criteria, determine the total design seismic force that this permanent nonstructural component and its attachment should resist.

A. 0 lb_f.

B. 7,560 lb_f.

C. 15,210 lb_f.

D. 48,000 lb_f.

Answer to #10.

C.

CBC Table 16-I shows a $Z = 0.3$; from Table 16-K $I_p = 1.0$. Also, from CBC Section 1629.3, when the soil properties are not known, type S_D should be used, which yields a $C_a = 0.36$ from Table 16-Q for a zone 3. table 16-O gives the in-structure component amplification factor $a_p = 1.0$ and the component response modification factor $R_p = 3.0$. Using CBC Formula 32-2,

$$F_p = \left(\frac{a_p C_a I_p}{R_p}\right)\left[1+3\left(\frac{h_x}{h_r}\right)\right]W_p = \left(\frac{(1.0)(0.36)(1.0)}{3.0}\right)\left[1+3\left(\frac{86}{80}\right)\right](30\ kips) = 15{,}210\ lb_f$$

But CBC Section 1632.2 states that F_p should not be less than 0.7 $C_a\ I_p\ W_p$,
F_p = (0.7)(0.36)(1.0)(30 kips)(1,000 lb/kip) = 7,560 lb_f

CBC Section 1632.2 also states that F_p should not be more than 4 $C_a\ I_p\ W_p$,
F_p = (4.0)(0.36)(1.0)(30 kips)(1,000 lb/kip) = 43,200 lb_f

Since 15,210 lb_f < 43,200 lb_f, this criterion is also met.

Question #11.

Backup electrical equipment for a surgery room of a San Francisco hospital is installed on the roof with adequate support and anchorage. The closest distance between this site and the seismic source type A is 3.11 miles. The equipment weighs 4,000 lb_f.

What is the lateral force on the equipment?

A. 3,600 lb_f.

B. 6,230 lb_f.

C. 7,200 lb_f.

D. 12,720 lb_f.

Answer to #11.

D.

CBC Table 16-I provides $Z = 0.4$. Table 16-K for the anchorage of the machinery and the equipment required for life-safety systems, gives $I_p = 1.5$. Also, CBC Section 1636.2, requires use of soil type S_D when the soil properties are not known. Table 16-Q gives the seismic coefficient $C_a = 0.44\ N_a$ for a soil profile S_D and $Z = 0.4$. Table 16-S gives the near-source factor $N_a = 1.2$ for a distance of 3.11 miles and a seismic source A.

Hence, the seismic coefficient Ca = 0.44 Na = 0.44 (1.2) = 0.53

CBC Formula 32-1, the total (design, or service) lateral seismic force F_p is,

$$F_p = 4.0\ C_a\ I_p\ W_p = (4.0)(0.53)(1.5)(4{,}000\ \text{lb}_\text{f}) = 12{,}720\ \text{lb}_\text{f}$$

Question #12.

For non-building structures with special and standard occupancy categories in seismic zones 3 and 4, the intermediate moment-resisting frame (IMRF) may be used when,

I. the structure is less than 50 feet in height.

II. the structure is less than 160 feet in height.

III. the value of R used in reducing calculate member forces and moments does not exceed 2.8.

A. I only.

B. II only.

C. I and III.

D. IMRF systems are prohibited in seismic zones 3 and 4.

Answer to #12.

C.

Intermediate moment-resisting frame (IMRF) is a concrete frame designed in accordance to the CBC Section 1921.8.

Based on CBC table 16-N, footnote 5, these systems are prohibited in seismic zones 3 and 4, except as permitted in CBC Section 1634.2. This section has an exception that indicates that IMRF systems may be used in seismic zones 3 and 4 for non-building structures in occupancy categories 3 and 4 (that is, special and standard occupancy structures) when the following criteria are met,

1) **The structure is less than 50 feet in height; and**

2) **The value of *R* taken from CBC Table 16-N does not exceed 2.8.**

Question #13.

A walkway tunnel connects two high-rise office buildings in San Francisco. What connections should be used between the walkway and the buildings?

A. Fixed connections on both ends.

B. Hinges on both ends.

C. Sliding connections on both ends.

D. Sliding connections on one end and hinges on the other end.

Answer to #13.

D.

The relative lateral displacement due to seismic loads of two structures produces additional lateral force effects on the walkway. The connecting walkway should have a sliding connection on one end and a hinge on the other end to provide sufficient movement between structures.

Question #14.

An engineer under supervision of a registered civil engineer can prepare which of the following?

A. Plans.

B. Reports.

C. Quantity calculations.

D. All of the above.

Answer to #14.

D.

Plans, reports and quantity calculations can be prepared by a registered civil engineers and their bona fide employees.

However, only the registered civil engineer can seal and sign all final professional documents.

Question #15.

Which of the following final documents must bear the seal of a registered civil engineer?

I. Plans.

II. Specifications.

III. Reports.

A. I only.

B. I and II.

C. I and III.

D. I, II and III.

Answer to #15.

D.

All final plans, specifications, reports and documents shall bear the seal of a registered civil engineer, as well as his (or her) signature.

Question #16.

A report characterizing the potential for liquefation is needed for the site of an office building. Who provides this information?

A. An architect.

B. A contractor

C. A civil engineer.

D. A geotechnical engineer.

Answer to #16.

D.

Geotechnical engineers should provide the analysis of geotechnical data for a site.

Question #17.

For a single family home, who is responsible for signing the final soils report?

A. A geotechnical engineer.

B. An architect.

C. A registered civil engineer.

D. A contractor.

Answer to #17.

C.

The soils report (also called the geotechnical report) is prepared by engineers in the geotechnical branch of civil engineering. The person who signs the report and is reponsible for the document must be a registered civil engineer.

Question #18.

Who should sign the plans, specifications, and reports of an engineering firm?

A. The owner of the firm.

B. The property owner.

C. A registered civil engineer.

D. A building inspector.

Answer to #18.

C.

Regardless of ownership of the engineering firm, the registered civil engineer is responsible for all final plans, specifications and reports.

Question #19.

For one-story residential buildings, which of the following registered professionals can design and sign plans?

A. Architects.

B. Civil engineers.

C. Structural engineers.

D. All of the above.

Answer to #19.

D.

Architects, civil engineers and structural engineers can design and sign/seal plans for one-story residential buildings.

Question #20.

Who should sign and seal the structural plans for a school in California?

A. A registered civil engineer.

B. A registered structural engineer.

C. An experienced engineer.

D. A geotechnical engineer.

Answer to #20.

B.

The requirements of the Division of the State Architect, State Department of General Services, registered structural engineers must sign and seal engineering design plans for schools in California.

Question #21.

For structural systems, the details of connections that resist seismic forces should be,

A. provided by the contractor.

B. designed by the engineer.

C. dictated by the building inspector.

D. all of the above.

Answer to #21.

B.

Engineers should design the details of connections according to requirements and limitations prescribed in the CBC.

Question #22.

What does the California Hospital Act require?

A. no construction of hospitals near faults.

B. fully functional hospitals after an earthquake.

C. using special moment-resisting frames for hospitals.

D. construction of hospitals with base isolation.

Answer to #22.

B.

The California Hospital Act requires that hospitals be fully functional and operational after an earthquake.

Question #23.

The California legislature act, that pertains to enforcing minimum standards for lateral resistance in all structures is,

A. the Field Act.

B. the Riley Act.

C. the CBC Act.

D. none of the above.

<u>Answer to #23.</u>

B.

The 1933 Long Beach earthquake caused much structural damage. Following the earthquake,

- the Riley Act was established, which set minimum standards for lateral force resistance in all structures, and

- the Field act imparted school design approved in the Division of the State Architect, State Department of General Services.

Question #24.

What California Administrative Code requires that hospitals can be operational after an earthquake?

A. Title 6.

B. Title 12.

C. Title 18.

D. Title 24.

<u>Answer to #24.</u>

D.

Title 24 of the California Building Standards Administrative Code mandates that hospitals be operational after an earthquake.

It also requires that school buildings resist the earthquake forces generated by major earthquakes without catastrophic collapse.