Special Civil Engineer Examination Seismic Principles Test Plan

Definition of Seismic Principles

Seismic Principles is defined as the fundamental principles, tasks and knowledge's underlying those activities involved in the California practice of seismic design, seismic analysis or seismic evaluation of new and existing civil engineering projects such as:

- Buildings
- Non-building structures
- Non-structural components, equipment and lifelines

This area of practice is structured into six primary content areas. *The percentage given in parentheses represents the proportion of total test points that will address that test plan area.*

I. Seismic Data and Seismic Design Criteria (10%)
II. Seismic Characteristics of Engineered System (15%)
III. Seismic Forces: Building Structures (28%)
IV. Seismic Forces: Non-Building Structures, Components, and Equipment (12%)
V. Seismic Analysis Procedures (25%)
VI. Seismic Detailing and Construction Quality Control (10%)

NOTE: As used throughout this Test Plan, the term **applicable code** refers to the **current adopted** ***California Building Code*** **(i.e., *2016 CBC*)** including the adopted edition of *ASCE 7* (i.e., *ASCE 7-10*).

I. Seismic Data and Seismic Design Criteria (10% / 6 pts)

Professional Activities:

1. **Practice in accordance to laws, codes and standards governing seismic design**
2. **Identify design performance requirements for a project**
3. **Determine site-related coefficients**
4. **Determine effects of site characteristics on a structure**
5. **Determine Seismic Design Category**

Test questions on these professional activities may include one or more of the following:

A. Geologic seismic hazards and geotechnical data that affect design, including liquefaction and site classification *(Site Class = A, B, C, D*, E or F)*

B. Site-related seismic coefficients *(e.g., mapped MCE_R acceleration parameters S_S & S_1, site coefficients F_a & F_v, site adjusted MCE_R acceleration parameters S_{MS} & S_{M1}, and design acceleration parameters S_{DS} & S_{D1})*

C. Natural period of the structure *(T)* and the expected period of the seismic ground motion

D. The seismic design philosophy of the applicable code

E. Applicable laws, regulations and codes for civil engineering seismic design and construction

F. Seismic Design Categories *(SDC = A, B, C, D, E or F)*

G. Building Risk Categories *(I, II, III & IV)*

H. Seismic importance factors *(I_e & I_p)*

II. Seismic Characteristics of Engineered System (15% / 8 pts)

Professional Activities:

1. **Select appropriate seismic force-resisting structural system for new or existing structures**
2. **Identify effects of structural characteristics on seismic design/performance**
3. **Evaluate vulnerability of structures with previous poor seismic performance**
4. **Evaluate post-earthquake structural safety**
5. **Determine methods for improving seismic performance of existing structures**

Test questions on these professional activities may include one or more of the following:

A. The different structural systems and their design parameters

B. Limitations of different structural systems

C. Requirements for structures having horizontal irregularities (e.g., torsional response, re-entrant corners, out-of-plane offset)

D. Requirements for structures with vertical irregularities (e.g., vertical discontinuities, offsets, soft stories)

E. Drift and *P*-Delta effects

F. Effects of ductility and damping on seismic performance

G. Effects of redundancy on seismic performance

H.	Anchorage and stability in existing unreinforced masonry (URM) bearing wall buildings
I.	Weak connections in pre-cast concrete structures
J.	Punching shear failures in cast-in-place *(flat slab)* concrete structures
K.	Diaphragm to wall connection failures in *(concrete)* tilt-up and masonry buildings
L.	Buckling or brittle connections in steel braced frame structures
M.	Welded connection failures in steel moment frames
N.	Assessment and identification of post-earthquake damage and risk
O.	Methods to improve seismic performance and the effects on the existing structures
P.	Methods and effects of adding stiffness to protect brittle elements
Q.	Methods and effects of improving ductility of brittle elements
R.	Methods and effects of strengthening connections in structural elements

III. Seismic Forces: Building Structures (28% / 15 pts)

Professional Activities:

1. **Determine structural characteristics required to calculate seismic design forces**
2. **Determine seismic design forces for structures**
3. **Perform vertical distribution of seismic forces for structures**
4. **Determine seismic diaphragm forces**
5. **Determine seismic forces for structural elements**

Test questions on these professional activities may include one or more of the following:

A.	Mass and stiffness *(W, K, etc.)*
B.	Methods to determine the structure's fundamental period *(T, T_a, etc.)*
C.	Selection of seismic factors and coefficients required for design *(ρ, R, Ω_0, C_d, etc.)*
D.	Static force procedures and formulas *(ELF or Simplified Procedure, C_s, etc.)*
E.	Structural system seismic coefficient application *(R, Ω_0, C_d, etc.)*
F.	Design base shear *(V)*
G.	Vertical force distribution *(F_x, C_{vx}, etc.)*
H.	Design seismic forces on diaphragms *(F_{px})*
I.	Design seismic forces on structural elements
J.	Out-of-plane seismic forces on structural elements *(F_p)*
K.	Design lateral force formulas

IV. Seismic Forces: Non-Building Structures, Components, and Equipment (12% / 7 pts)

Professional Activities:

1. **Determine seismic forces for non-structural building components and equipment**
2. **Determine seismic forces for non-building structures**

Test questions on these professional activities may include one or more of the following:
A. Mass and stiffness *(W or W_p , K or K_p , etc.)*
B. Methods to determine the structure's fundamental period *(T or T_p)*
C. Selection of seismic factors and coefficients required for design *(ρ , R , Ω_0 , C_d , or a_p , R_p , etc.)*
D. Static force procedures and formulas
E. Design base shear *(V)*
F. Application of seismic factors and coefficients for design of non-building structures *(R , Ω_0 & C_d)*
G. Application of seismic factors and coefficients for design of non-structural components and equipment *(a_p & R_p)*
H. Design lateral force formulas *(V or F_p)*

V. Seismic Analysis Procedures (25% / 14 pts)

Professional Activities:

1. **Perform analysis of seismic force-resisting systems**
2. **Perform the distribution of seismic forces to structural elements**
3. **Perform the seismic analysis of diaphragms** (e.g., rigid and flexible)

Test questions on these professional activities may include one or more of the following:
A. Applicable load combinations *(SD , $LRFD$, ASD , E , E_h , E_v , E_m , Q_E , D , L , L_r , S , etc.)*
B. Distribution of internal and external forces
C. Application of deflection and drift requirements
D. Diaphragm force distribution to structural elements (e.g., chord forces, drag forces, and diaphragm shear)
E. Methods used to calculate rigidities of structural elements
F. Distribution of seismic forces based on rigidity
G. Assumptions controlling the analysis for rigid diaphragms
H. Methods to determine centers of rigidity and mass *(C.R. & C.M.)*
I. Torsional moment requirements in rigid diaphragms *(e.g., inherent torsion - M_t , accidental torsion - M_{ta} , accidental eccentricity, etc.)*
J. Assumptions controlling the analysis of flexible diaphragms
K. Sub-diaphragm analysis

VI. Seismic Detailing and Construction Quality Control (10% / 5 pts)

Professional Activities:

1. **Identify the detailing requirements that are critical for seismic performance** (e.g., load path, wall anchorage, chord and collector)
2. **Recognize need for construction quality control of the seismic design aspects of the project** (e.g., testing, special inspection and observation requirements)

Test questions on these professional activities may include one or more of the following:
A. Seismic detailing and inherent seismic performance characteristics for steel
B. Seismic detailing and inherent seismic performance characteristics for concrete
C. Seismic detailing and inherent seismic performance characteristics for masonry
D. Seismic detailing and inherent seismic performance characteristics for wood
E. Deformation compatibility requirements for structural and non-structural elements
F. Required building separation and setback
G. Requirements for ties and continuity, collectors and drags
H. Requirements for anchorage of concrete and masonry *(structural)* walls
I. Seismic materials testing requirements
J. Seismic special inspection requirements
K. Seismic structural observation requirements

California Special Civil P.E. Seismic Principles Examination Statistics

Exam	% Passed	Cut off score	Total Score	Passing %
April 1997	46.5%	126	270	47%
October 1997	45.9%	130	274	47%
April 1998	33.3%	163	294	55%
October 1998	44.0%	139	294	47%
April 1999	35.8%	155	282	55%
October 1999	39.3%	168	289	58%
April 2000	37.5%	127	261	49%
October 2000	39.4%	148	288	51%
April 2001	37.3%	121	268	45%
October 2001	40.3%	150	294	51%
April 2002	39.6%	138	276	50%
October 2002	44.2%	136	287	47%
April 2003	37.1%	155	300	52%
October 2003	40.4%	136	281	48%
April 2004	35.6%	125	263	48%
October 2004	38.5%	154	300	51%
April 2005	39.8%	159	292	54%
October 2005	44.8%	164	295	56%
April 2006	37.4%	152	300	51%
October 2006	37.2%	142	263	54%
April 2007	36.7%	156	292	53%
October 2007	39.9%	177	292	61%
April 2008	36.3%	153	295	52%
October 2008	36.6%	151	285	53%
April 2009	39.5%	25	50	50%
October 2009	39.2%	*Pass / Fail Only*		
April 2010	38.6%	*Pass / Fail Only*		
October 2010	38.7%	*Pass / Fail Only*		
April 2011	43.0%	*Pass / Fail Only*		
October 2011	35.3%	*Pass / Fail Only*		
April 2012	40.8%	*Pass / Fail Only*		
October 2012	41.0%	*Pass / Fail Only*		
April 2013	46.6%	*Pass / Fail Only*		
October 2013	44.6%	*Pass / Fail Only*		
Spring 2014	48.0%	*Pass / Fail Only*		
Fall 2014	41.1%	*Pass / Fail Only*		
Spring 2015	51.7%	*Pass / Fail Only*		
Fall 2015	41.1%	*Pass / Fail Only*		
Spring 2016	53.7%	*Pass / Fail Only*		
Fall 2016	43.5%	*Pass / Fail Only*		
Spring 2017	54.9%	*Pass / Fail Only*		
Fall 2017	43.9%	*Pass / Fail Only*		

9.27 What is the maximum length-width ratio for the blocked wood structural panel (WSP) horizontal diaphragms (second floor and roof)?

a. 2:1
b. 2½:1
c. 3:1
d. 4:1

9.28 Given a structure assigned to *Seismic Design Category* C with a typical *subdiaphragm* span of 20 feet, what would be the minimum required depth of each structural *subdiaphragm*?

a. 10′-0″
b. 8′-0″
c. 6′-8″
d. 5′-0″

9.29 What is the minimum seismic design force for structural *subdiaphragms* that are part of a flexible diaphragm in *SDC* = C, D, E or F?

a. $\frac{F_{px}}{L}$ plf
b. $\frac{F_x}{L}$ plf
c. $0.2K_a I_e W_p$
d. 280 plf

> Given a single-story wood frame Police Station assigned to *Seismic Design Category* F with wood structural panels used for the flexible roof diaphragm and for the shear walls. The roof diaphragm is to use 19/32″ rated sheathing with 10d common nails (3″ x 0.148″) fastened to 2x nominal framing members, with blocking omitted at intermediate joints. The shear walls are to use 15/32″ Structural I sheathing with 10d common nails (3″ x 0.148″) fastened to 2x nominal framing members. Answer questions 9.30 through 9.33.

9.30 What is the allowable unit shear for the roof diaphragm with seismic loads perpendicular to the continuous panel joints (CASE 1)?

a. 285 plf
b. 255 plf
c. 215 plf
d. 190 plf

9.31 What is the allowable unit shear for a shear wall with 4″ o.c. edge nailing, a height (h) of 12′-0″ and a width (b_s) of 8′-6″ resisting seismic loads?

a. 310 plf
b. 380 plf
c. 460 plf
d. 510 plf

Problem	Answer	Reference / Solution
27	d	p. 1-110 - Vertical Flexible Diaphragm Analysis NOTE: this is a flexible diaphragm and you do not distribute the story shear (or base shear for a 1-story building) based on the shear wall rigidities provided. The rigidities are ignored to determine V_1 & V_2 (i.e., use tributary area). ∴ $V_1 = V_2 = V / 2$ = 116 kips / 2 = 58 kips ←
28	a	*ASCE 7-10* p. 63 - *§12.2.5.2* – Cantilever Column Systems *ASCE 7-10 – Table 12.2-1, Type G* refers to *ASCE 7-10 – §12.2.5.2* - " … shall not exceed 15% of the available axial strength, …" ∴ 15% ←
29	d	p. 1-117 to 122 From the figure: $\overline{X}_{CM} = 150' / 2 = 75'$ & $\overline{Y}_{CM} = 100' / 2 = 50'$ $\overline{X}_{CR} = 60'$ & $\overline{Y}_{CR} = 50'$ calculated/inherent eccentricity $e_x = \overline{X}_{CM} - \overline{X}_{CR} = 75' - 60' = 15'$ accidental eccentricity $e_x = \pm 5\%\ L_x = 5\%\ (150') = \pm 7.5'$ The governing (i.e., maximum) force to the shear wall on line 2 will occur when the *CM* is moved nearest to line 2 where the maximum additive torsional shear will occur: $e_{x1} = 15' + 7.5' = 22.5'$ $M_{T1} = V \cdot e_{x1}$ = 155 kips (22.5′) = 3488 kip-ft $\sum Rd^2 = R_1 d_1^2 + R_2 d_2^2 + R_A d_A^2 + R_B d_B^2$ $= 3\ (60')^2 + 2\ (90')^2 + 1.5\ (50')^2 + 1.5\ (50')^2 = 34{,}500\ \text{ft}^2$ max. $F_2 = V \dfrac{R_2}{R_1 + R_2} + \dfrac{M_{T1} R_2 d_2}{\sum Rd^2}$ = 155 kips (2) / (2 + 3) + 3488 kip-ft (2)(90 ft) / 34,500 ft^2 = 62 kips + 18 kips = 80 kips ←
30	b	p. 1-72 - Redundancy Factor, ρ Redundancy is a characteristic of structures in which multiple paths of resistance to loads are provided. ∴ Redundancy ←
31	b	p. 1-33 to 35 & *2015 IBC* p. 398 - *Tables 1613.3.5(1)* & *1613.3.5(2)* Office building w/ fire station in 1st story → *IBC Table 1604.5* → *RC* = IV Site Class E & S_S = 2.13 → *Table 3.2* → S_{DS} = 1.28 Site Class E & S_1 = 0.74 → *Table 3.3* → S_{D1} = 1.18 S_1 = 0.74 < 0.75 → must use *Tables 1613.3.5(1)* & *(2)* to determine *SDC* S_{DS} = 1.28 & *RC* = IV → *Table 1613.3.5(1)* → *SDC* = D S_{D1} = 1.18 & *RC* = IV → *Table 1613.3.5(2)* → *SDC* = D ∴ *SDC* = D ←

Problem	Answer	Reference / Solution
41	c	p. 1-88 & *ASCE 7-10* p. 76 - *§12.11.2.1* – Wall Anchorage Forces S_{DS} = 0.63 L_f = 150 feet or 110 feet … span of flexible diaphragms, BUT K_a will max out at 2.0 for any flexible diaphragm span > 100 feet K_a = 2.0 max. I_e = 1.5 – *ASCE 7-10* p. 4 - *Table 1.5-2* for Police station (*RC* = IV) h_w = height of wall to roof = 14′ h_p = height of parapet (above roof) = 2.67′ $W_p = W_{wall}\left(h_w/2 + h_p\right)$ … for (one-story) walls with a parapet = (75 psf)(14′/2 + 2.67′) = 725 plf $F_p = 0.4 S_{DS} K_a I_e W_p$ *ASCE 7 (12.11-1)* = 0.4 (0.63)(2.0)(1.5)(725 plf) = 548 plf ← governs $F_p \geq 0.2 K_a I_e W_p$ minimum = 0.2 (2.0)(1.5)(725 plf) = 435 plf minimum ∴ 550 plf ←
42	a	p. 1-63 - Structural Separation & *ASCE 7-10* p. 77 - *§12.12.3* Adjacent buildings on the same property, structural separation - $\delta_{MT} = \sqrt{(\delta_{M1})^2 + (\delta_{M2})^2}$ *ASCE 7 (12.12-2)* Structure 1: Medical Office building → *IBC Table 1604.5* → *RC* = II I_e = 1.0 – *ASCE 7-10* p. 4 - *Table 1.5-2* for *RC* = II Special reinforced concrete shear walls → *ASCE 7-10 – Table 12.2-1, Type A.1* or *B.4* → C_d = 5 $\delta_{M1} = \frac{C_d \delta_{max}}{I_e} = \frac{5(1.2")}{1.0} = 6.0"$ *ASCE 7 (12.12-1)* Structure 2: Hospital → *IBC Table 1604.5* → *RC* = IV I_e = 1.5 – *ASCE 7-10* p. 4 - *Table 1.5-2* for *RC* = IV Steel SMF's → *ASCE 7-10 – Table 12.2-1, Type C.1* → C_d = 5½ $\delta_{M2} = \frac{C_d \delta_{max}}{I_e} = \frac{5.5(4.0")}{1.5} = 14.7"$ *ASCE 7 (12.12-1)* $\delta_{MT} = \sqrt{(\delta_{M1})^2 + (\delta_{M2})^2} = \sqrt{(6.0")^2 + (14.7")^2}$ = 15.9 inches ∴ 16 inches ←
43	c	p. 1-75 - Basic (SD or LRFD) Load Combinations & *2015 IBC* p. 358 - *§1605.2* *IBC* equation *(16-5)* will govern for the maximum axial compression in the column while *IBC* equation *(16-7)* will govern for the minimum axial compression in the column. $E_h = \pm \rho Q_E$ *ASCE 7 (12.4-3)* = ± 1.3 (±37 kips) = ± 48 kips *(continued)*

Problem	Answer	Reference / Solution
		$T = T_a = 1.15$ sec > $T_s = 0.60$ sec → *ASCE 7 (12.8-2)* will not govern for C_s $C_S = \dfrac{S_{D1}}{T(R/I_e)}$ *ASCE 7 (12.8-3)* $= \dfrac{0.68}{1.15(8/1.0)} = \underline{0.074}$ ← governs C_S shall not be less than: $C_S = 0.044 S_{DS} I_e$ *ASCE 7 (12.8-5)* = 0.044 (1.13)(1.0) = 0.050 < 0.074 In addition, when $S_1 \geq 0.6$, C_S shall not be less than: $C_S = \dfrac{0.5S_1}{(R/I_e)}$ *ASCE 7 (12.8-6)* $= \dfrac{0.5(0.78)}{(8/1.0)} = 0.049 < 0.074$ $V = C_S W$ *ASCE 7 (12.8-1)* = 0.074 (7,250 kips) = 537 kips ∴ 535 kips ←
50	b	p. 1-113 - Chord Force, Figure 8.10 M_{max} & CF_{max} occur at midspan of $L = 100'$ (i.e., at $x = L / 2 = 50'$) … BUT this problem is asking for the Chord Force at "A" where $x = 25'$ which is not the maximum. $V_1 = V_2 = V / 2$ = 25 kips / 2 = 12.5 kips $w_s = F_{p1} / L = V / L$ = (25 kips) / (100′) = 0.25 klf = 250 plf $M_x = \left(\dfrac{w_s L}{2}\right)x - \dfrac{w_s x^2}{2}$ = (250 plf)(100′)(25′) / 2 – (250 plf)(25′)^2 / 2 = 234,400 lb-ft $CF_x = \dfrac{M_x}{d}$ = (234,400 lb-ft) / (40′) = 5860 lbs ∴ 5900 lbf ←
51	a	p. 1-61 & *ASCE 7-10* p. 77 - *§12.12.1* Emergency Operations Center (1st story) → *IBC Table 1604.5* → *RC* = IV 6-story building > 4 stories Steel CBF (All other structures) & *RC* = IV → *ASCE 7-10 – Table 12.12-1* → $\Delta_{ax} \leq 0.010\, h_{sx}$ allowable *story drift ratio* = (Δ_{ax} / h_{sx}) = 0.010 ← ∴ 0.010 ←
52	b	p. 1-33 to 35 & *2015 IBC* p. 398 - *Tables 1613.3.5(1) & 1613.3.5(2)* Retail warehouse → *IBC Table 1604.5* → *RC* = II "Rock" = Site Class B Site Class B & $S_S = 0.699$ → *Table 3.2* → $S_{DS} = 0.47$ Site Class B & $S_1 = 0.316$ → *Table 3.3* → $S_{D1} = 0.21$ (by interpolation) *(continued)*