CHAPTER 4
APPLICATION OF CRITERIA

4-1. General.

a. Performance Objectives. Seismic performance objectives for a building are defined by a desired performance level for the building (e.g., damage state or ability to perform an essential function) when subjected to a specified seismic hazard (i.e., deterministic or probabilistic ground motion). A performance objective for each of the four Seismic Use Groups (Table 4-1) is prescribed in the following paragraphs. The performance objectives (Table 4-4) are derived from appropriate combinations of three performance levels (Table 4-3), and two design ground motions.

b. Basis of Provisions.

(1) Performance Objective 1A. All buildings governed by this document are required to comply with Performance Objective 1A, which is intended to protect life safety for Ground Motion A, defined as two-thirds of the Maximum Considered Earthquake (MCE). The Acceptance criteria for the performance objectives require compliance with the 1997 edition of the *NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures* (FEMA 302). The following are excerpted from Chapter 1 of those provisions:

"These provisions present criteria for the design and construction of structures to resist earthquake ground motions. The purposes of these provisions are as follows:

(a) To provide minimum design criteria for structures appropriate to their primary function and use considering the need to protect the health, safety, and welfare of the general public by minimizing the earthquake-related risk to life, and

(b) To improve the capability of essential facilities and structures containing substantial quantities of hazardous materials to function during and after design earthquakes. The design earthquake ground motion levels specified here could result in both structural and nonstructural damage. For most structures designed and constructed according to these Provisions, structural damage from the design earthquake would be repairable, although perhaps not economically so. For essential facilities, it is expected that the damage from a design earthquake would not be so severe as to preclude continued occupancy and function of the facility. The actual ability to accomplish these goals depends upon a number of factors, including the structural framing type, configuration, materials, and as-built details of construction. For ground motions larger than the design levels, the intent of these Provisions is that there be a low likelihood of structural collapse."

(2) Enhanced performance objectives. Performance levels and performance objectives prescribed in this document are generally based on guidance provided in SEAOC Vision 2000. The acceptance criteria for the enhanced performance objectives and the nonlinear analytical procedures are adapted from FEMA 273.

c. Analytical Procedures. Minimum requirements for the analytical procedures associated

Seismic Use Group	Occupancy or Function of Structure
I. Standard Occupancy Structures	All structures having occupancies or functions not listed below.
II. Special Occupancy Structures	Covered structures whose primary occupancy is public assembly with a capacity greater than 300 persons.
	Day care centers with a capacity greater than 150 persons.
	Educational buildings through the 12th grade with a capacity greater than 250 persons.
	Buildings for colleges or adult education schools with a capacity greater than 500 students.
	Medical facilities with 50 or more resident incapacitated patients, but not otherwise designated as Seismic Use Group IIIE facility.
	Jails and detention facilities.
	All structures with occupancy capacity greater than 5,000 persons.
	Structures and equipment in power-generating stations and other public utility facilities not included in Seismic Use Group IIIE, and are required for continued operation.
	Water treatment facilities required for primary treatment and disinfecting of potable water.
	Waste water treatment facilities required for primary treatment.
	Facilities having high value equipment, when justification is provided by the using agency.

Table 4-1 Seismic Use Groups

III H. Hazardous Facilities	Structures housing, supporting or containing sufficient quantities of toxic or explosive substances to be dangerous to the safety of the general public if released.
III E. Essential Facilities[1]	Facilities involved in handling or processing sensitive munitions, nuclear weaponry or materials, gas and petroleum fuels, and chemical or biological contaminants.
	Facilities involved in operational missile control, launch, tracking or other critical defense capabilities.
	Mission-essential and primary communication or data handling facilities.
	Hospitals and other medical facilities having surgery and emergency treatment areas.
	Fire, rescue, and police stations.
	Designated emergency preparedness centers.
	Designated emergency operations centers.
	Designated emergency shelters.
	Power generating stations or other utilities required as emergency back-up facilities for Seismic Use Group IIIE facilities.
	Emergency vehicle garages and emergency aircraft hangars.
	Designated communications centers.
	Aviation control towers and air traffic control towers.
	Waste treatment facilities required to maintain water pressure for fire suppression.

[1] Essential facilities are those structures that are necessary for emergency operations subsequent to a natural disaster.

Table 4-1 Seismic Use Groups-Continued

with each performance objective are presented in Table 4-4, and each of the analytical procedures is described in Chapter 5. These procedures are considered to provide acceptable analytical results for most low-rise (i.e., six stories or less) regular buildings. Chapter 5 provides guidance regarding the limitations of these minimum analytical procedures, as well as when more rigorous analyses are required. It should be noted that most military buildings are classed as Seismic Use Group I (Standard Occupancy) that have Performance Objective 1A (Life Safety). For these buildings, the basic design approach used in this document prescribes a linear elastic (ELF or modal analysis) procedure that has not changed from previous criteria. The most basic change from previous design procedures is that the comparison of the demand of the design loads to the structural component capacity is performed at the strength level, rather than working or allowable stress.

d. Acceptance Criteria. The acceptance criteria for each of the performance objectives and the applicable analytical procedures are prescribed in Chapter 6. Numerical acceptance limits for specific structural systems are provided in Chapter 7.

4-2. Seismic Use Groups.

The following Seismic Use Groups are established based on the occupancy or function of a building:

a. Group IIIE. Seismic Use Group IIIE buildings are those containing essential facilities that are required for post-earthquake recovery, and/or those structures housing mission-essential functions. Mission-essential functions are those absolutely critical to mission continuation of the activity (there is no redundant back-up facility on- or off-site) as determined by the Commanding Officer at the activity and/or the Major Claimant.

b. Group IIIH. Seismic Use Groups IIIH buildings are those containing substantial quantities of hazardous substances that could be dangerous to the safety of the public, if released.

c. Group II. Seismic Use Group II buildings are those that constitute a substantial public hazard because of the occupancy or use of the building.

d. Group I. Seismic Use Group I buildings are those that are not assigned to Seismic Use Groups II or III.

e. Hazardous Critical Facilities. These facilities (e.g., nuclear power plants, dams, and LNG facilities) are not included within the scope of this document, but are covered by other publications or regulatory agencies. For any facilities housing hazardous items not covered by criteria in this document, guidance should be requested from DAEN-ECE-D (Army), NAVFAC Code 04BA (Navy), or HQ USAF/LEEE (Air Force).

Examples of buildings or structures in each of the above groups are provided in Table 4-1. Buildings with multiple occupancies will be categorized according to the most important occupancy, unless the portion of the building that houses the most important occupancy can be shown to satisfy all of the requirements for that occupancy.

4-3. Seismic Design Categories.

All buildings shall be assigned a Seismic Design Category based on their assigned Seismic Use Group and their applicable spectral acceleration coefficients, S_{DS} and S_{DI} for Ground Motion A. Each building or structure shall be assigned to the more severe Seismic Design Category in accordance with Table 4-2a or Table 4-2b. The category designations are used in FEMA 302 to determine permissible structural systems, limitations on height and irregularity, and coefficients related to overstrength and drift.

4-4. Redundancy.

FEMA 302 prescribes a reliability factor, D, to be assigned to all buildings based on the extent of structural redundancy inherent in the lateral-force-resisting system. The value of D may be taken as 1.0 for buildings in Seismic Design Categories A, B, C. For buildings in Seismic Design Categories D, E, and F, D shall be taken as the largest of the values of $?_x$ calculated at each story of the building, x, in accordance with the following equation:

$$?_x = 2 - \frac{20}{r_{\max_x}\sqrt{A_x}} \qquad (4\text{-}1)$$

where:

$r_{\max_x}$ = the ratio of the design story shear resisted by the single element carrying the most shear force in the story to the total story shear, for a given direction of loading. For braced frames, the value of $r_{\max_x}$ is equal to the lateral-force component in the most heavily loaded brace element divided by the story shear. For moment frames, $r_{\max_x}$ shall be taken as the maximum of the sum of the shears in any two adjacent columns, in the plane of a moment frame, divided by the story shear. For columns common to two bays with moment-resisting connections on opposite sides at the level under consideration, 70 percent of the shear in that column may be used in the column shear summation. For shear walls, $r_{\max_x}$ shall be taken as equal to the shear in the most heavily loaded wall or wall pier multiplied by $10/l_w$ (the metric equivalent is 3.3 (l_w), where l_w is the wall or wall pier length in feet (m), divided by the story shear. For dual systems, $r_{\max_x}$ shall be taken as the maximum value as defined above considering all lateral-load-resisting elements in the story. The lateral loads shall be distributed to elements based on relative rigidities considering the interaction of the dual system. For dual systems, the value of D need not exceed 80 percent of the value calculated above.

A_x = the floor area in square feet of the diaphragm level immediately above the story.

The metric equivalent of Equation 4-1 is:

$$r_x = 2 - \frac{6.1}{r_{\max_x} A_x}$$

where A_x is in square meters.

The value of D need not exceed 1.5, which is permitted to be used for any structure. The value of D shall not be taken as less than 1.0.

Exception: For structures with lateral-force-resisting systems in any direction comprised solely of special moment frames, the lateral-force-resisting system shall be configured such that the value of D calculated in accordance with this section does not exceed 1.25.

Table 4-2a Seismic Design Category Based on Short Period Response Accelerations

Value of S_{DS}	Seismic Use Group		
	I	II	III
$S_{DS} < 0.167g$	A	A	A
$0.167g \leq S_{DS} < 0.33g$	B	B	C
$0.33g \leq S_{DS} < 0.50g$	C	C	D
$0.50g \leq S_{DS}$	D[a]	D[a]	D[a]

[a] See footnote on Table 4-2b.

Table 4-2b Seismic Design Category Based on 1 Second Period Response Accelerations

Value of S_{DI}	Seismic Use Group		
	I	II	III
$S_{DI} < 0.067g$	A	A	A
$0.067g \leq S_{DI} < 0.133g$	B	B	C
$0.133g \leq S_{DI} < 0.20g$	C	C	D
$0.20g \leq S_{DI}$	D[a]	D[a]	D[a]

[a] Seismic Use Group I and II structures located on sites with mapped maximum considered earthquake spectral response acceleration at 1 second period, S_1, equal to or greater than 0.75g shall be assigned to Seismic Design Category E and Seismic Use Group III structures located on such sites shall be assigned to Seismic Design Category F.

4.5. Overstrength.

A system overstrength factor, S_o, provided in Table 7-1 is intended to quantify the actual force that can be delivered to sensitive individual brittle elements, the failure of which could result in the loss of a complete lateral-force-resisting system or in instability or collapse. The factor is similar in application to the $3R_w/8$ factor prescribed in the UBC, and represents an estimate of the combined design, material, and system overstrengths that could effect a brittle or force-controlled element.

4-6. Combination of Load Effects.

a. Basic Load Combinations. The basic load combinations from ASCE 7 are:

$$1.2D + 1.0E + 0.5L + 0.2S \qquad (4\text{-}2)$$

or $$0.9D + 1.0E \qquad (4\text{-}3)$$

where: D,E,L, and S, are respectively, dead, earthquake, live, and snow loads.

The effect of the earthquake load, E, is defined by:

$$E = DQ_E + 0.2S_{DS}D \qquad (4\text{-}4)$$

or $$E = DQ_E - 0.2S_{DS}D \qquad (4\text{-}5)$$

Where:

E = the effect of horizontal and vertical earthquake-induced forces.

D = the reliability factor defined in Paragraph 4-4

Q_E = the effect of horizontal seismic forces

S_{DS} = the design spectral acceleration at 0.2 sec

D = the effect of dead load.

b. Special Combination of Loads. When specifically required by FEMA 302, or when in the judgement of the designer the effects of structural overstrength need to be considered, the design seismic force on brittle or force-controlled components shall be defined by the following equations:

$$E = S_o Q_E + 0.2S_{DS}\, D \qquad (4\text{-}6)$$

$$E = S_o Q_E - 0.2S_{DS}\, D \qquad (4\text{-}7)$$

Where E, Q_E, S_{DS} and D are as defined in Paragraph *a* above, and S_o is the system overstrength factor defined in Paragraph 4-5 and listed in Table 7-1. Example applications for Equations 4-6 and 4-7 include the design of columns under discontinuous shear walls or braced frames, and the design of frame members in braced frames effected by overstrength in the bracing.

4-7. Performance Levels.

Three structural performance levels, as described in Table 4-3, are considered to be acceptable by this document. Performance Level 1 (Life Safety) is the minimum performance level required of all Seismic

Structural Performance Levels

Performance Level	Building Response Range
CP	Collapse Prevention-The building barely remains standing with significant structural and nonstructural damage. This range of performance, where collapse is imminent, is an unacceptable performance range for all new military buildings.
LS (1)	Life Safety-The building remains stable with significant reserve capacity. Structural damage is moderate requiring significant post-earthquake repairs, however, collapse is precluded. This is the basic range of performance for all new military buildings, except as defined below.
SE (2)	Safe Egress-The building structural system remains fully safe for occupancy following the earthquake. Essential functions are sufficiently disrupted to prevent immediate post-earthquake occupancy of the building. Structural damage is light, allowing fairly rapid post-earthquake repairs.
IO (3)	Immediate Occupancy-The building structure remains safe to occupy and all essential functions remain operational. It may be used for post-earthquake recovery and to perform essential operational military missions within a few hours following an earthquake. The building has limited structural damage, which may be repairable while occupied.

Table 4-3. Structural Performance Levels

Use Groups. Performance Levels 2 (Safe Egress) and 3 (Immediate Occupancy) are enhanced performance levels for Seismic Use Groups II and III. The Collapse Prevention performance level indicated in Table 4-3 is an assumed ultimate response level for structural components and is not an applicable design performance level. The physical significance of these performance levels is indicated in Figures 1-1 and 1-2.

4-8. Design Ground Motions.

As indicated in Table 4-4, two ground motions, derived from the MCE, are considered in this document, and their derivation is discussed in Chapter 3. Ground Motion A is the basic ground motion in the FEMA 302 provisions; it is approximately equivalent to 10 percent probability of exceedence in 50 years, and is the ground motion associated with Performance Level 1 (Life Safety) for all seismic use groups. Ground Motion A is also used with Performance Level 2 to provide Performance Objective 2A (Safe Egress) for Seismic Use Group II, while Ground Motion B is used to provide Performance Objective 2B (Safe Egress) for Seismic Use Group IIIH and Performance Objective 3B (Immediate Occupancy) for Seismic Use Group IIIE. Note that while "Safe Egress" is used to describe the performance level in both Performance Objectives 2A and 2B, different ground motions and acceptance criteria are used to comply with the two performance objectives.

4-9. Performance Objectives.

The seismic performance objectives for the various seismic use groups in Table 4-1 consist of the combination of performance levels from Table 4-3 with an appropriate ground motion. As indicated above, Performance Objective 1A (Life Safety) is required of all seismic use groups, and the other objectives in Table 4-4 pertain to buildings in Seismic Use Group II or III.

4-10. Minimum Requirements for Analytical Procedures.

Minimum analytical procedures for the various performance objectives associated with each of the seismic use groups are indicated in Table 4-4. The analysis procedures are described in Chapter 5, the acceptance criteria for each of the procedures are prescribed in Chapter 6, and the numerical acceptance limits for the various structural systems are provided in Chapter 7. Note that for Performance Objective 1A, FEMA 302 provisions are prescribed with appropriate *R* factor and an Importance Factor, *I*, equal to 1.0. For enhanced performance objectives, more severe ground motion and/or more restrictive acceptance criteria are prescribed in lieu of the *R* or *I* factors.

4-11. General Design Procedures.

a. Performance Objectives 1A (All Buildings). Table 4-5 provides a step-by-step tabulation of procedures for the analysis and design of buildings, in accordance with FEMA 302, to comply with Performance Objective 1A (Protect Life Safety). Reference is made to applicable sections in FEMA 302 and to corresponding paragraphs in this document. Additional guidance pertaining to the total design process is provided in Chapter 2. The analyses and design procedures for this performance

Structural System Performance Objectives

Performance Parameters				Minimum Analysis Procedures	
Seismic Use Group	Performance Level	Ground Motion	Performance Objective	Linear Elastic with R Factors	Linear Elastic with m Factors
I	LS(1)	2/3 MCE (A)[1]	1A	√	
II	SE(2)	2/3 MCE (A)[1]	2A	√[2]	√[3]
IIIH	SE(2)	¾ MCE (B)[1]	2B	√[2]	√[3]
IIIE	IO(3)	¾ MCE (B)[1]	3B	√[2]	√[3]

[1] MCE refers to the spectral ordinate values from the Maximum Considered Earthquake spectral acceleration maps that accompany FEMA 302.

[2] All buildings will be initially designed to comply with Performance Objective 1A using a linear elastic analysis with R factors. This will establish the member sizes required to check compliance with the m factor criteria for the enhanced performance objectives.

[3] For certain buildings in Seismic Design Categories C, D, E, & F, the minimum analysis method to be used may be a nonlinear static (or pushover) procedure. See paragraph 5-4b to determine when nonlinear analysis procedures are required.

[4] For buildings in Seismic Design Categories A and B, the analysis for enhanced performance objectives may be performed with the applicable ground motion and a linear elastic analysis with the R and I factors from Table 7-1 and the I factors from FEMA 302.

Table 4-4. Structural System Performance Objectives

Step	Procedure	References FEMA 302	TI-809-04
	A. Preliminary Determinations (See Flow Chart in Figure 4-1)		
1.	Determine appropriate Seismic Use Group, Performance Objectives & Analysis Procedures	Sec. 1.3	Table 4-1, Table 4-4 para. 4-2
2.	Determine site seismicity, (S_S&S_I)	MCE Maps	para. 3-1c
3.	Determine site characteristics	Sec. 4.1.2.1	Table 3-1 para. 3-4i
4.	Determine site coefficient: F_a F_v	Table 4.1.2.4.a Table 4.1.2.4.b	Table 3-2a Table 3-2b para. 3-1d
5.	Calculate $S_{MS} = F_aS_s$ $S_{MI} = F_VS_I$	Eq. 4.1.2.4-1 Eq. 4.1.2.4.-2	Eq. 3-1 Eq. 3-2
6.	Calculate $S_{DS} = 2/3\ S_{MS}$ $S_{DI} = 2/3\ S_{MI}$	Eq. 4.1.2.5-1 Eq. 4.1.2.4-2	Eq. 3-3 – Eq. 3-6 para. 3-2b
7.	Select Seismic Design Category	Table 4.2.1a Table 4.2.1b	Table 4-2a Table 4-2b para. 4-3
8.	Select structural system		para. 2-5b – para. 2-5e
9.	Select R, Ω_o, & C_d factors	Table 5.2.2	Table 7-1 para. 4-5 para. 6-2c
10.	Determine preliminary member sizes for gravity load effects	ASCE 7	ASCE 7 para. 2-5a
	B. Equivalent Lateral Force Procedure (See Flow Chart in Figure 4-1)		
1.	Calculate fundamental period, T	Eq. 5.3.3.1-1 or Eq. 5.3.3.1-2	
2.	Determine dead load, W	Sec. 5.3.2	
3.	Calculate base shear, V	Eq. 5.3.2	para. 3-2c
4.	Calculate vertical distribution of seismic forces	Sec. 5.3.4.	
5.	Perform static analyses		para. 5-2
6.	Determine cr and cm		Figure 7-47
7.	Perform torsional analyses	Secs. 5.3.5.1 to 5..3.5.3	para. 7-7b(4)
8.	Determine need for redundancy factor, ρ.	Sec. 5.2.4.2	para. 2-5c, para. 4-4
9.	Determine need for everstrength factor Ω_o	Sec. 5.2.7.1	para. 4-5
10.	Calculate combined load effects	ASCE 7 and Sec. 5.27	para. 4-6

Table 4-5 Step-by-Step Procedures for Performance Objective 1A (Life Safety)

Sheet 1 of 2

Step	Procedure	FEMA 302	TI-809-04
11.	Determine structural member sizes	Chapters 8 through 12	Chapter 7 para. 2-5f
12.	Check allowable drift and PΔ effect	Sec. 5.2.8 & 5.3.7 and Table 5.2.8	para. 6-2d and Table 6-1
1.	C. Modal Analyses Procedure (See Flow Chart in Figure 4-1) Sec. 5.4 in FEMA 302 provides general guidance for modeling and performance of modal analyses. Available computer programs calculate the equivalent of steps B1 through B7 above with proper input of structural member properties, distributed dead loads, and appropriate response spectra. (The general response spectrum defined by Figure 3-1 is applicable to the fundamental mode while the spectrum shown in Figure 3-2 applies to higher modes). Most computer programs will combine the modal responses for individual structural members by SRSS, CQC, or absolute sum, at the designer's option. Steps B8 through B12 above also apply to this procedure.		

Table 4-5 Step-by-Step Procedures for Performance Objective 1A (Life Safety)

Sheet 2 of 2

objective are illustrated by the flow chart in Figure 4-1.

b. Enhanced Performance Objectives.

(1) Performance Objective 2A (Safe Egress for Special Occupancy). This performance objective, for Seismic Use Group II, uses the same ground motion as in Performance Objective 1A in Paragraph 4-11a above. Step-by-step procedures for analysis and design are provided in Table 4-6. Note that if proper consideration is given in the selection of the analytical procedure for Performance Objective 1A, the seismic effects may be scaled for compliance with the prescribed acceptance criteria in Chapter 6. The design and analysis procedures for this performance objective are illustrated by the flow chart in Figure 4-2.

(2) Performance Objective 2B (Safe Egress for Hazardous Occupancy and safe post-earthquake protection of hazardous materials stored in these buildings). This performance objective, for Seismic Use Group IIIH, uses the same performance level as Performance Objective 2A, but requires this level of performance for Ground Motion B (3/4 MCE). The seismic response effects for this ground motion can also be scaled from the initial analysis for Performance Objective 1A. The step-by-step procedures are similar to those in Table 4-6, and a flow chart illustrates these procedures in Figure 4-3.

(3) Performance Objective 3B (Immediate Occupancy for Essential Facilities). This performance objective for Seismic Use Group IIIE is the most demanding objective applicable to buildings governed by this document. The step-by-step design and analysis procedures described in Table 4-7 and the flow chart in Figure 4-4 illustrate the implementation of nonlinear elastic static analysis for this objective.

4-12. Performance Objectives for Nonstructural Systems and Components.

The minimum performance objective for nonstructural systems and components will be similar to structural Performance Objective 1A, as described in the preceding paragraph of this chapter. Compliance with the provisions of Chapter 6 of FEMA 302 will be considered as fulfilling this minimum performance objective. Provisions for enhanced performance objective and additional requirements for nonstructural systems and components are provided in Chapter 10 of this document.

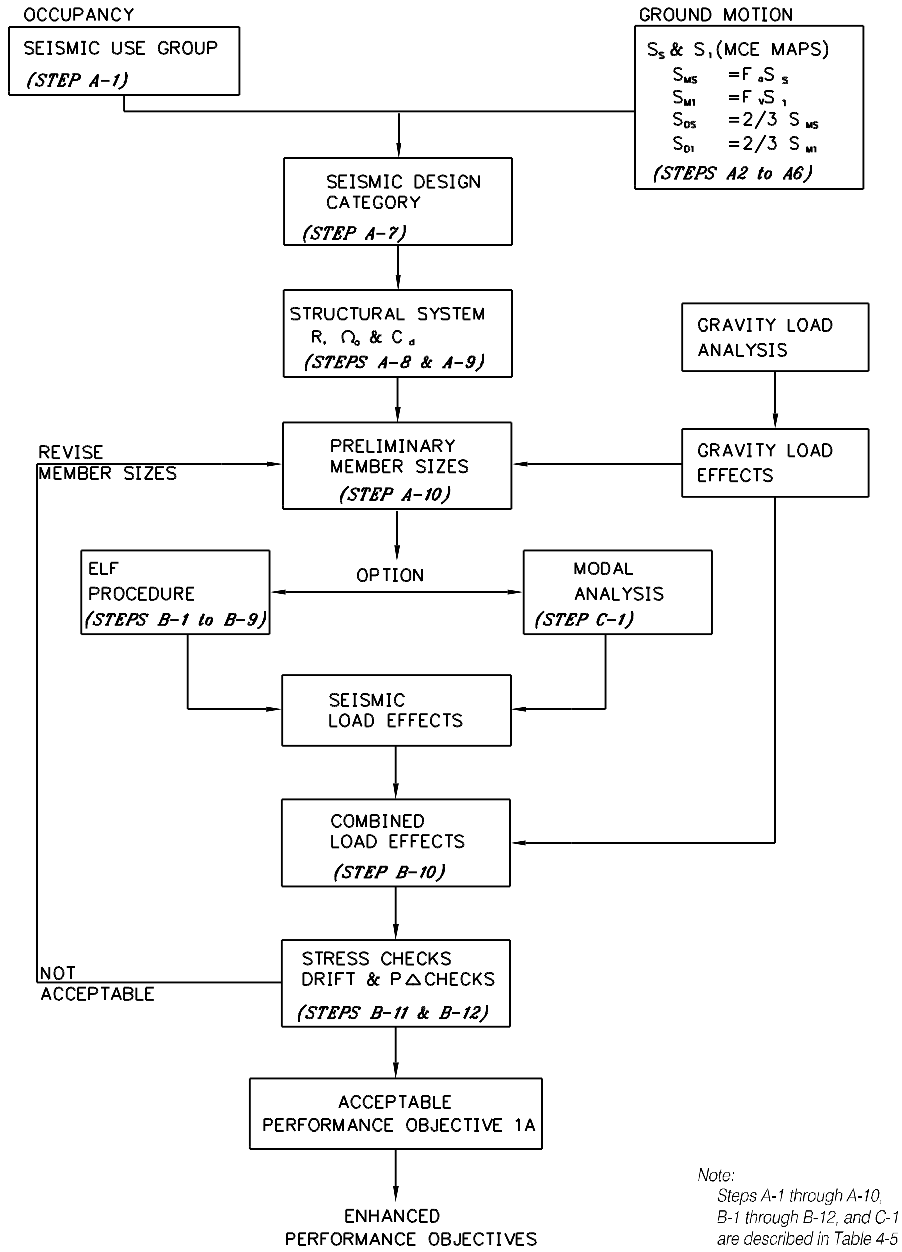

Figure 4-1. Flow Chart for Performance Objective 1A (All Buildings)

Step	Procedure	TI-809-04
1.	D. Performance Objective 2A (Safe Egress for Special Occupancy) (See Flow Chart in Figure 4-2) This performance objective utilizes the same basic ground motion as the Life Safety Performance Objective (1A). For one- or two-story buildings that have been analyzed by the ELF procedure or for buildings that have been subjected to a 3-D modal analysis procedure, the seismic effects, Q_E, in step B10 of Table 4-5 may be scaled to the appropriate values as indicated in Step 3 below.	
2.	Determine pseudo lateral load $V=C_1 C_2 C_3 S_a W$.	para. 6-3a(2) Eq. 6-1
3.	Determine seismic effects (Seismic effects in Steps B-4 through B-9 in Table 4-5 may be scaled by the factor R x C_1 x C_2 x C_3.)	Steps B-4 through B-9 in Table 4-5
4.	Determine the combined load effects.	para. 4-6 and Eq. 6-2
5.	Identify force-controlled and deformation-controlled structural components.	para. 6-3a(3)(a)
6.	Determine Q_{UD} and Q_{CE} for deformation-controlled components.	Chapter 7 and para. 6-3a(3)(b)
7.	Determine DCR's for deformation-controlled components and compare with allowable m values for Safe Egress.	Chapter 7 and Eq. 6-3
8.	Determine Q_{UF} and Q_{CL} for force-controlled components and compare Q_{UF} with Q_{CL}.	para. 6-3a(3)(b) Eq. 6-4a and 6-4b and Chapter 7
9.	Revise member sizes, as necessary, and repeat analysis.	
1.	E. Performance Objective 2B (Safe Egress for Hazardous Occupancy) (See Flow Chart in Figure 4-3) Same as Performance Objective 2A above, except that Ground Motion B (3/4 MCE) is to be used . As indicated above, if a suitable analyses has been performed for Performance Objective 1A, the seismic effects may be scaled by R x C_1 x C_2 x C_3 x 0.75/0.67. The m values for Safe Egress are applicable.	
Step	Procedure	TI-809-04
	F. Performance Objective 3B (Immediate Occupancy for an Essential Facility) Same as Performance Objective 2B, except that the m values for Immediate Occupancy are applicable.	

Table 4-6 Step-by-Step Procedures for Enhanced Performance Objectives with Linear Elastic Analyses Using m Factors

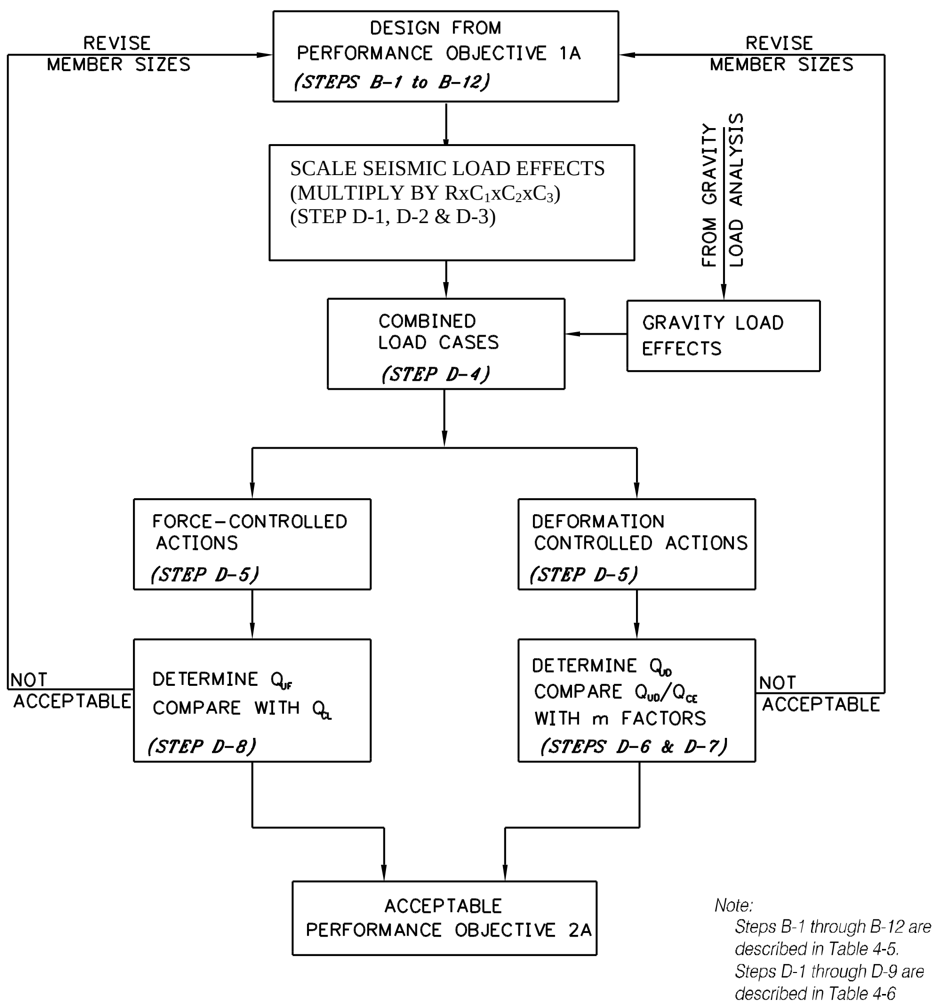

Figure 4-2. Flow Chart for Performance Objective 2A (Seismic Use Group II Buildings)

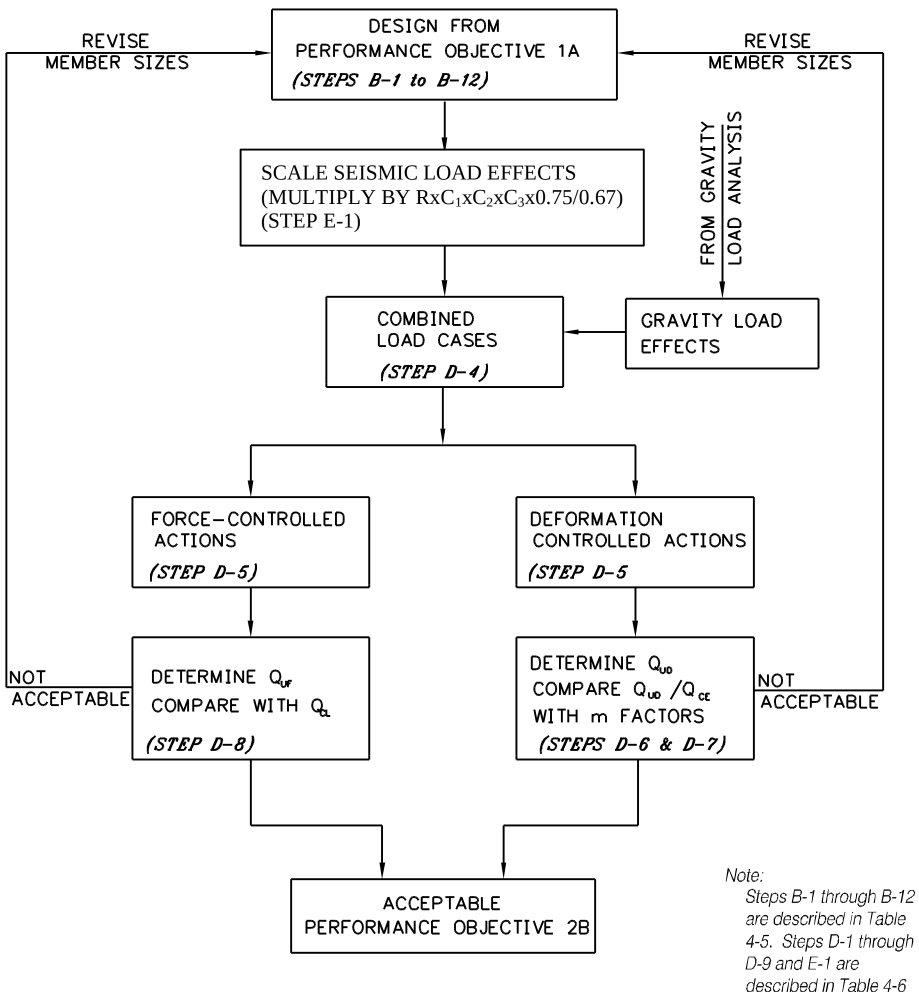

Figure 4-3. Flow Chart for Performance Objective 2B (Seismic Use Group III H Buildings)

Step	Procedure	TI-809-04
	G. Performance Objective 3B (Immediate Occupancy for Essential Facility) (See Flow Chart in Figure 4-4)	
1.	Using the mathematical model of the building developed for Performance Objective 1A, perform a 3D spectral response analysis using Ground Motion B (3/4 x MCE).	para. 5-4e(3) para. 5-4e (5) and (6)
2.	Using only fundamental mode responses, calculate combined load effects, displacement of center of mass at roof level, and base shear.	para. 5-4f(1)
3.	Calculate DCR's for the structural elements and identify element with highest DCR and any other elements within 10% of that value.	para. 5-4f(1)
4.	Determine necessary reduction in seismic effects to reduce highest DCR to 1.0. Reduce the seismic effects ,base shear, and roof displacement by the seismic effects reduction. Plot base shear vs. roof displacement.	para. 5-4f(1) Fig. 5-3
5.	Modify elements identified in Step 4 by inserting plastic hinges at the yielding ends in the mathematical model.	para. 5-4f(1)(c)
6.	Repeat the analyses, add the new seismic effects to the reduced seismic effects from the prior analyses, and repeat Steps 2 and 3.	para. 5-4f(1)(d)
7.	Determine necessary reduction in the new seismic effects to reduce highest DCR to 1.0. Reduce the new seismic effects, base shear, and roof displacement by the reduction in the new seismic effects. Plot the new increment of base shear and roof displacement by superposition on prior plot.	Fig. 4-5
8.	Repeat Steps 5,6,and 7 until plot results in undesirable response or failure of critical elements.	para. 5-4f(1)(f)
9.	Idealize the plot to determine V_y, $0.6V_y$, and K_e.	Fig. 5-3
10.	Obtain the elastic fundamental period T_i, from step 2 and calculate the effective fundamental period, T_e, by $T_e = T_i\sqrt{K_i/K_e}$	para. 5-4e(4)
11.	Determine appropriate values for coefficients C_0, C_1, C_2, and C_3 and for spectral acceleration S_a.	para. 5-4f(2)
12.	Calculate target displacement, δ_t, by $\delta_t = C_0\, C_1\, C_2\, C_3\, S_a \dfrac{T_e^{\,2}}{4\Pi^2}$	Eq. 5-5

Table 4-7 Step-by-Step Procedure for Enhanced Performance Objective with Nonlinear Elastic Static Analysis

Sheet 1 of 2

Step	Procedure	TI-809-04
13.	Locate δ_t on Base Shear vs. Roof Displacement plot. a. If δ_t is beyond effective portion of the plot, significant strengthening of the yielding elements may be required. b. If δ_t is within the effective portion of the plot, check interstory drift and PΔ effects. If allowable limits have been exceeded, stiffening of yielding elements may be required. c. If interstory drift and PΔ effects are acceptable, check inelastic responses of yielding elements against acceptance criteria.	para. 5-4f(1)(i)
14.	If evaluations in Step 13 are negative, mathematical model must be strengthened and/or stiffened and the analyses repeated. Available computer programs can perform Steps 1 to 8 above, including PΔ effects. For a given building displacement, maximum inelastic responses (Δ/Δ_y or chord rotations) are developed which can be checked against the acceptance criteria. Chapter 7 provides acceptance criteria for the nonlinear response (Δ/Δ_y or chord rotations) for the structural components of various structural systems. Acceptance values are provided for Life Safety, Safe Egress, and Immediate Occupancy.	para. 6-3b Chapters 5 and 7

Table 4-7 Step-by-Step Procedure for Enhanced Performance Objective with Nonlinear Elastic Static Analysis

Sheet 2 of 2

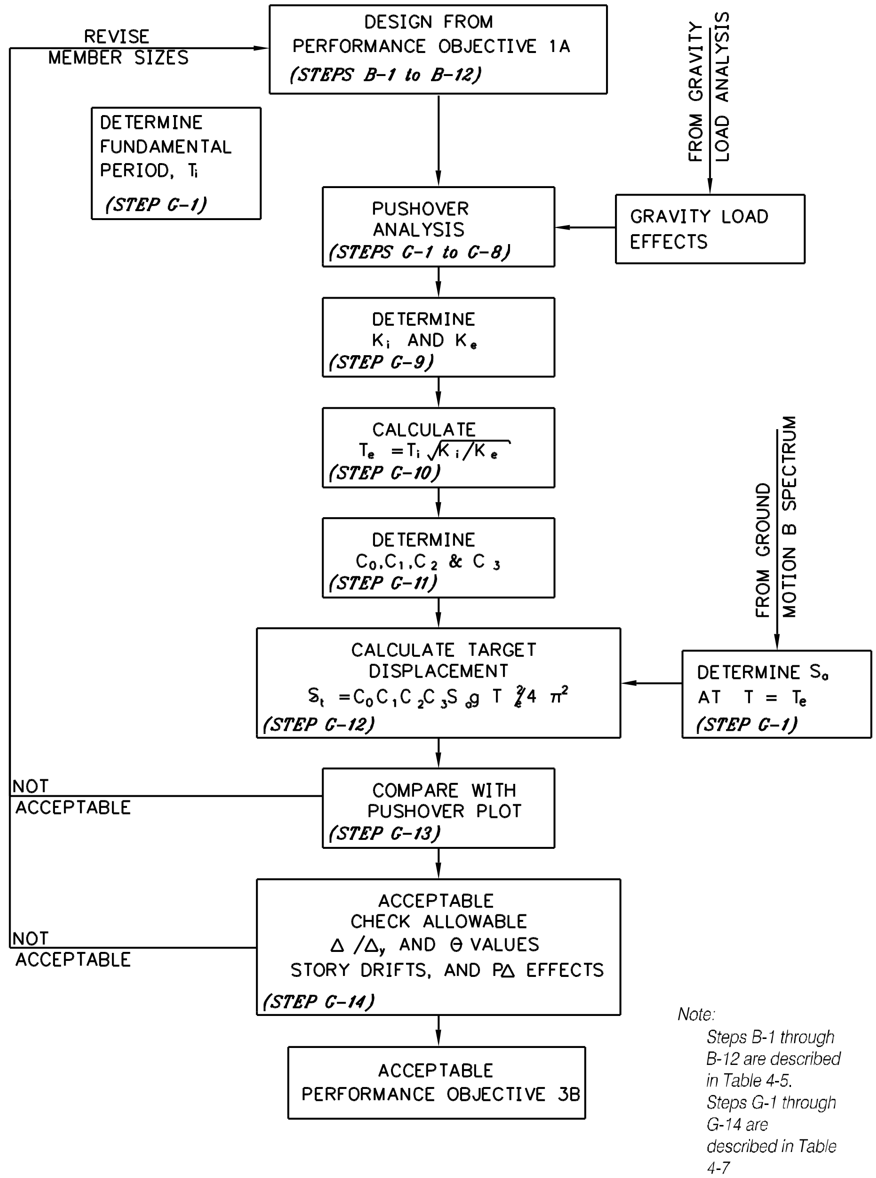

Figure 4-4. Flow Chart for Performance Objective 3B (Seismic Use Group III E Buidlings)