FINAL EXPRESS TERMS
OF [TC1]
PROPOSED BUILDING STANDARDS
OF THE
DIVISION OF THE STATE ARCHITECT (DSA)

REGARDING THE CALIFORNIA BUILDING CODE
CALIFORNIA CODE OF REGULATIONS, TITLE 24, PART 2
(December 1, 2000 Version)

AMEND DIVISION III-R OF THE 1995 CALIFORNIA BUILDING CODE FOR STATE OWNED BUILDINGS AND BUILDINGS OWNED BY THE UNIVERSITY OF CALIFORNIA AND CALIFORNIA STATE UNIVERSITY AS FOLLOWS:

Division VI-R

EARTHQUAKE EVALUATION AND DESIGN FOR RETROFIT OF EXISTING STATE-OWNED BUILDINGS

Section 1640A-GENERAL

1640A.1 Purpose. All modifications, alterations, and/or repairs to existing structures or portions thereof shall, at a minimum, be designed and constructed to resist the effects of seismic ground motion as provided in this division. When applicable, the structural system shall be evaluated by the design professional of record and, if not meeting or exceeding the minimum seismic design purpose of this division, shall be retrofitted in compliance with these requirements.

1640A.1.1 Minimum Seismic Design. The purpose of this division is to provide a minimum level of seismic performance. At this essential life-safety level, in general, persons in and around the building will be able to safely exit or be evacuated from the building or its vicinity following an earthquake. It does not mean that persons will not be injured or not be in need of medical attention. This level of seismic performance is presumed to be achieved when a) the building has some margin against either total or partial collapse of the structural system even though significant damage may have occurred that may not be economical to repair; b) major structural elements have not fallen or been dislodged so as to pose a life-safety threat; and c) nonstructural systems or elements that are heavy enough to cause severe injuries either within or outside the building have not been dislodged so as to pose a life-safety threat.

1640A.2 Applicability. a) For all state-owned structures, including all buildings owned by the University of California and California State University: The requirements of this division apply wherever the structure is to be retrofitted, repaired, or modified and 1) total construction cost, not including cost of furnishings, fixtures and equipment, or normal maintenance, for the building exceeds 25 percent of the construction cost for the replacement of the existing building; or 2) changes in occupancy category; or 3) changes to structural elements reduce the lateral load capacity by more than 5 percent at any story; or 4) structural elements need repair where the damage has reduced the lateral load capacity by more than 10 percent at any story; or 5) changes in live or dead load increase the story shear by more than 5 percent. The changes in Item 1) are cumulative for past alterations to the building that occurred after adoption of this division and did not require the application of this division.

1640A.2.1 Evaluation required. If the criteria in Section 1640A.2 apply to the project under consideration, the design professional of record shall provide an evaluation in accordance with Section 1643 A to determine the seismic performance of the building in its current configuration and condition. If the structure's seismic performance is evaluated as satisfactory and the peer reviewer(s), when Method B of Section 1648 A is used, concur, then no structural retrofit is required.

EXCEPTION: In some cases a technical review and evaluation may be waived under the EXCEPTION of Section 1648 A.1, where the life-safety threat posed by the building is clearly minimal.

1640A.2.2 Retrofit required. Where the evaluation indicates the building does not meet the essential life-safety objective of this division, the owner shall take appropriate steps to ensure that the building's structural system is retrofitted in accordance with the provisions of this division. Appropriate steps are either 1) undertake the seismic retrofit as part of the modifications, alterations and/or repairs; or 2) provide a plan, acceptable to the enforcement agent, to complete the seismic retrofit in a timely manner.

1640A.3 The modification to any existing building may be prepared in accordance with the requirements for a new building, Chapter 16A, Division VI, Part 2, Title 24, California Code of Regulations ~~1999~~ *2001* Edition.

1640A.4 The requirements of the 1997 Uniform Building Code (UBC) Appendix Chapter 16, Sections 1654-1665, are to apply to the use of seismic isolation for the repair, modification or retrofit of an existing structure. When seismic isolation or passive energy dissipation is used, the project must have project peer review as prescribed in Section 1649A.

1640A.5 Any construction required this division shall include structural observation by the licensed structural engineer, civil engineer or architect of record who is responsible for the structural design in accordance with 1643A.12.

1640A.6 Where Method B peer review is required by Sections 1643A.7 and 1648A.2, the proposed method of building evaluation and design procedures must be accepted by the enforcement agent prior to the commencement of the work.

1641A-DEFINITIONS

1641A.1 For the purposes of this division certain terms are defined in addition to those in 1997 UBC Section 1627 as follows:

ACTIVE EARTHQUAKE FAULT is one that has exhibited surface displacement within Holocene time (about 11,000 years) as determined by the California Division of Mines and Geology under the Alquist-Priolo Special Studies Zones Act or other authoritative source, Federal, State or Local Governmental Agency.

CODE-COMPLYING ELEMENT is an element that complies with the Seismic Zone 3 and 4 detailing requirements for elements that are part of the selected lateral-force-resisting system as given in the 1976 or later editions of the UBC. Refer to Section 1645A for specific elements and materials.

CODE-COMPLYING SYSTEM is a system that complies with the Seismic Zone 3 and 4 requirements for lateral-force-resisting systems and materials as given in the 1976 or later editions of the Uniform Building Code.

DESIGN is the procedure that includes both the evaluation and retrofit design of an existing element and the design of a new element.

DESIGN BASIS EARTHQUAKE is the earthquake ground motion having a 5 percent damped acceleration response spectrum as represented by R/I times the Base Shear V given by Formulas (44A-1) and (44A-2).

DISTANCE FROM AN ACTIVE EARTHQUAKE FAULT is measured from the nearest point of the building to the closest edge of an Alquist-Priolo Special Study zone for an active fault, if such a map exists, or to the closest mapped splay of the fault.

DUCTILE ELEMENT is an element capable of sustaining large cyclic deformations beyond the attainment of its nominal strength without any significant loss in capacity. Refer to Section 1645A for specific elements and materials.

ELEMENT is a part of an architectural, electrical, mechanical, or structural system.

ENFORCEMENT AGENT is that individual within the agency or organization charged with responsibility for agency or organization compliance with the requirements of Division VI-R.

ESSENTIALLY COMPLYING STRUCTURAL SYSTEM or ELEMENT is a lateral force resisting system or element that may deviate from but can provide comparable elastic and inelastic cyclic load-deformation behavior as a system or element that complies to the 1976 or later editions of the Uniform Building Code provisions for systems or elements resisting seismic forces. Refer to Section 1645A for specific elements and materials.

ESSENTIAL LIFE SAFETY. The retrofit or repair of a structure to a goal of essential life safety as a level of expected structural performance is taken to mean that occupants will be able to exit the structure safely following an earthquake. It does not mean that they will be uninjured or not be in need of medical attention. A structure is presumed to achieve this level of performance where: although significant damage to the structure may have occurred, some margin against either total or partial structural collapse remains, even though damage may not be economical to repair; major

structural elements have not become dislodged or fallen so as to pose a life-safety threat; and, nonstructural systems or elements, which are heavy enough to cause severe injuries either within or outside the building, have not become dislodged so as to pose a life-safety threat.

INELASTIC DEMAND RATIO (IDR) is the ratio of the total load demand on an element to the nominal strength capacity of an element; where load demand is the combination of gravity loads and the unreduced (by R) elastic response force due to the specified earthquake ground motion.

LATERAL LOAD CAPACITY is the capacity as determined either by Method A or Method B of the subject element. A system, is the sum of all element capacities acting individually reduced by the β factor for the element and meeting the requirements of Section 1646A.2.4. All forms of loading are to consider both displacements in orthogonal directions and torsion.

LIMITED DUCTILE ELEMENT is an element that is capable of sustaining moderate cyclic deformations beyond the attainment of nominal strength without significant loss in strength. The deformation capability is less than that of a ductile element and these elements do not meet the ductile element criteria of the 1976 or later versions of the UBC. Refer to Section 1645A for specific elements and materials.

METHOD A refers to the procedures contained in Sections 1645A through 1647A.

METHOD B refers to the procedures contained in Sections 1648A.

NOMINAL STRENGTH is the peak capacity of an element using specified material and assembly properties of the applicable materials chapters of Title 24. Examples are the flexural strength of a reinforced concrete beam M_n when the maximum concrete strain is at 0.003, or the plastic flexural capacity of a steel beam $M_p = Zf_y$ when all fibers in the section are at yield stress F_y and Z is the plastic section modulus. It is also the accepted peak strength from test results.

NON-DUCTILE ELEMENT is an element having a mode of failure that results in an abrupt loss of resistance when the element is deformed beyond the deformation corresponding to the development of its nominal strength. Non-ductile elements cannot reliably sustain any significant deformation beyond that attained at their nominal strength.

PEER REVIEW refers to the procedures contained in Section 1649A.

PROBABLE STRENGTH is the level of strength of an element likely in as-built or existing materials. For example, in reinforced concrete, it is common that actual steel yield is larger than the specified design value, and therefore probable strength is taken as equal to 1.25 times the nominal strength in flexure.

REPAIR as used in this division means all the design and construction work undertaken to restore or enhance the structural and nonstructural load resisting system participating in the lateral response of a structure that has experienced damage from earthquakes or other destructive events.

USABLE STRENGTH or FACTORED STRENGTH is the product of under strength factor Φ times the nominal strength in the appropriate material.

Section 1642A-SYMBOLS AND NOTATIONS

1642A.1 The following symbols and notations apply to this division in addition to those of Section 1628:

ΦC_n = usable strength or capacity of an element as determined in the materials chapters where Φ is the strength reduction factor .

C_w = allowable or working stress resistance of an element.

E = seismic load action on an element due to the specified total design base shear

H = the seismic coefficient defined in Section 1643A.8.

IDR = Inelastic Demand Ratio

IDR$_L$ = Limit value of the IDR that an element can develop without failure.

β = Seismic Load Penalty Factor representing the limited inelastic deformation capability of non-ductile and limited-ductile elements with respect to that of ductile elements in a given mode of failure (attainment of nominal strength).

Ω_o = Seismic Force Amplification Factor set forth in Table 16A-N.

Δ_S = Design Level Response Displacement, which is the total drift or total story drift that occurs when the structure is subjected to the specified Seismic Forces.

Δ_M = Maximum Inelastic Response Displacement, which is the total drift or total story drift given by 0.7 R Δ_S.

Section 1643A-CRITERIA SELECTION

1643A.1 Basis for Evaluation and Design. This section determines what technical approach is to be used for the seismic evaluation and design for existing buildings. For those buildings or portions of buildings for which Section 1640A.2 requires action, the procedures and limitations for the evaluation of existing buildings and design of retrofit systems and/or repair thereof shall be implemented in accordance with this section. One of three alternative approaches must be used: the first, Method A (Sections 1644A-1647A) is prescriptive and comparable to the Division VI provisions for new structures; the second, Method B (Section 1648A) for complex or potentially hazardous situations is performance based and depends on the independent review of a peer reviewer (Section 1649A); the third is the use of one of the applicable ~~UCBC~~ special procedures given in Section 1643A.1.1.

1643A.1.1 Special Procedures: Where there are *either* special prescriptive procedures for the repair and/or retrofit of existing buildings as a part of these regulations, the ~~Uniform Code for Building Conservation (UCBC)~~ *Guidelines for the Seismic Retrofit of Existing Buildings (GSREB, pending publication by ICBO)*, or accepted practice by the Enforcement Agent, these procedures may be used in lieu of the requirements of Chapter 34. The following special prescriptive procedures may be used for their respective types of construction to meet the requirements of this division:

1643A.1.1.1 The ~~UCBC~~ *GSREB* for Seismic Strengthening Provisions for Unreinforced Masonry Bearing Wall Buildings (~~Appendix~~ Chapter 1).

1643A.1.1.2 The ~~UCBC for Cripple Walls and Anchor Bolts (Appendix Chapter 6)~~. *The GSREB for Prescriptive Provisions for Seismic Strengthening of Cripple Walls and Sill Plate Anchorage of Light, Wood-Framed, Residential Structures (Chapter 6).*

1643A.1.1.3 ~~The UCBC for Flexible Diaphragm-Rigid Wall Buildings (Appendix Chapter 5).~~ *The GSREB Earthquake Hazard Reduction in Existing Reinforced Concrete and Reinforced Masonry Wall Buildings with Flexible Diaphragms (Chapter 5).*

1643A.1.1.4 *The GSREB Earthquake Hazard Reduction in Existing Wood Frame Residential Buildings with Soft, Weak or Open Front Walls (Chapter 7).*

1643A.1.1.5 *The GSREB Earthquake Hazard Reduction in Existing Concrete Buildings and Concrete Masonry Infill Buildings (Chapter 8).*

1643A.1.1.6 The SAC Interim Guidelines for the Evaluation, Repair, Modification, and Design of Welded Steel Moment Frame Structures, FEMA 267, August, 1995 or subsequent editions. The ground motion specifications of this division shall be used when the SAC procedures are applied.

1643A.2 Existing Conditions. The existing condition and properties of the entire structure must be determined and documented by: thorough inspection; review of all available related construction documents; and, performance of necessary testing and

investigations. Where samples from the existing structure are taken or in situ tests are performed, they shall be selected and interpreted in a statistically appropriate manner to assure that the properties determined and used in the evaluation or design are representative of the conditions and structural circumstances likely to be encountered in the structure as a whole.

The entire load path of the lateral force resisting system shall be determined, documented, and evaluated. The load path includes all the horizontal and vertical elements participating in the structural response such as diaphragms, diaphragm chords, diaphragm drags, vertical lateral force resisting system (walls, frames, braces, etc.), foundations, and the connection between the elements of the load path.

1643A.3 Site Geology and Soil Characteristics. Soil profile shall be assigned in accordance with the requirements of Section 1629.3

1643A4 Occupancy Categories. For purposes of earthquake–resistant design, each structure shall be placed in one of the occupancy categories in accordance with the requirements of Section 1629.2.

1645A.5 Configuration Requirements. Each structure shall be designated as being structurally regular or irregular in accordance with the requirements of Section 1629.5.

1643A.6 Selection of the Design Method. The requirements of Method B (Section 1648A) may be used for any existing building.

1643A.7 The requirements of Method A (Sections 1644A –1647A) may be used except under the following conditions, where Method B must be used:

1643A.7.1 When the building contains prestressed or post-tensioned structural elements (beams, columns, walls, or slabs) or contains precast structural elements, (beams, columns, walls or flooring systems).

1643A.7.2 When the building is classified as irregular in vertical or horizontal plan by application of Table 16A-L or 16A-M unless the irregularity is demonstrated not to affect the seismic performance of the building;

EXCEPTION: If the retrofit design removes the configurational attributes that caused the building to be classed as irregular, then Section 1643A.7.2 does not apply and Method A may be used.

1643A.7.3 For any building which has an importance factor I greater than 1.00, Table 16A-K.

1643A.7.4 For any building using undefined or hybrid structural systems;

1643A.7.5 When passive or active energy absorption systems are used in the retrofit or repair, either as part of the existing structure or as part of the modifications;

1643A.7.6 When the height of the structure exceeds 240 feet.

1643A.8 Seismic Hazard Factor The Seismic Hazard Factor H shall be determined according to the following procedure.

1643A.8.1 When the Importance Factor, I, is equal to 1 then H is equal to:

1643A.8.1.1 Three-quarters (0.75) when the seismic coefficients C_a and C_v arre determined from Table 16A-Q and Table 16A-R.

1643A.8.1.2 Unity (1.0) when the seismic coefficients C_a and C_v are determined from a 5 percent damped acceleration response spectrum with a 20% probability of exceedance in 50 years determined from a probabilistic seismic hazard analysis for the specific site. The smoothed response spectrum value at the period of 0.3 seconds provides the value of 2.5 C_a g and the spectrum at 1.0 seconds provides the value of C_v g, where g is the gravity constant.

EXCEPTION 1: The results of a community-wide probabilistic seismic analysis (Section 1643A.8.1.2) may be used when the responsible Enforcement Agent has accepted a probabilistic seismic hazard study for the jurisdiction to determine the values required by 1643A.8.1.2 within the jurisdiction, provided that the study on which it is based was accepted by reviewers, who were selected and charged consistent with the professional requirements of Section 1649A.

1643A.8.2 Otherwise, the H value is equal to unity (1.0), and the seismic coefficients C_a and C_v may be determined either from Table 16A-Q and Table 16A-R or from a 5 percent damped acceleration response spectrum with a 10% probability of exceedance in 50 years determined from a probabilistic seismic hazard analysis for the specific site.

EXCEPTION 1: The EXCEPTION of Section 1643A.8.1.2 applies.

EXCEPTION 2: For Section 1643A.8.2, when the importance factor, I, is greater than 1 and less than or equal to 1.25, then I may be set equal to 1 for subsequent load determinations if the seismic coefficients C_a and C_v are determined from a 5 percent damped response spectrum with a 10% probability of exceedance in 100 years determined from a probabilistic analysis for the specific site.

1643A.9 Capacity Requirements All elements of the lateral force resisting system must have the capacity to resist the seismic demand. Any element not having this capacity shall have its capacity increased by modifying or supplementing its capacity so that it exceeds the demand, or the demand reduced to less than the existing capacity by making other modifications to the structural system.

EXCEPTION 1: An element's usable strength capacity may be less than that required by the specified seismic load combinations if it can be demonstrated that the associated reduction in seismic performance of the element or its removal due to the failure does not result in a structural system in which there is a life safety hazard due to: the loss of support of gravity loads; a laterally unstable structure; or, falling structural or non-structural elements or parts thereof. If this exception is taken for an element, then it cannot be considered part of the primary lateral load resisting system.

EXCEPTION 2: The load transferred from an adjoining element to a given element need not exceed the probable strength 1.25 C_n of the adjoining element, given that the assembly remains stable. For elements where the resistance is expressed in terms of the allowable or working stress method, the usable strength ΦC_n may be determined using an allowable stress increase of 1.70, or may be established by acceptable published factors for a given material or element, or by the use of appropriate available test data and the applicable principles of mechanics.

EXCEPTION 3: This requirement does not apply to a mechanical penthouse when its floor area is less than 1/3 of that of the immediately lower floor.

1643A.10 New Elements: All new elements shall either be "code-complying or ductile" or "limited-ductile", and shall be selected and designed to have compatible force-deformation performance with existing elements and non-structural components.

EXCEPTION: The use of "non-ductile" elements is allowed, if the particular material provides the only means of ensuring compatible performance without detrimental interaction effects on the existing element material. Code-complying or essentially code-complying details shall be used where possible.

1643A.11 Deformation Compatibility: The compatibility of the deformation characteristics of all elements activated in the response shall be considered, as well as the configuration of the structural and nonstructural systems, the continuity, or lack thereof, of load paths, the redundancy, if any, of these load paths, and the physical condition of the materials and elements.

1643A.12 Structural Observation: Structural observation as used in this chapter shall mean visits to the project site by the responsible design professional to observe existing conditions and to review the construction work for general compliance with approved plans, specifications, and applicable structural regulations. Such visits shall occur at significant construction stages and at the completion of the structural retrofit. Structural observation shall be provided in Seismic Zones 3 and 4 for all structures regulated by this division. High rise construction requires an interim progress report each month in addition to observation reports for the significant construction stages.

The owner shall directly employ the engineer or architect, or their designee, responsible for the structural design to perform structural observation.

After each visit, the structural observer shall report in writing on the general conformity of the work to the approved plans and note any observed deficiencies to the owner's representative, project inspector, contractor and the Enforcement Agent. The structural observer shall notify the Enforcement Agent in writing in a timely manner how the structural deficiencies are to be corrected. If satisfactory resolution of the deficiency is not obtained, the Enforcement Agent shall be notified for any necessary action.

At the conclusion of construction, the structural observer shall submit to the Enforcement Agent and the owner a final written statement that the required site visits have been made, and that the observed structural deficiencies have been resolved and/or listing those, to the best of the structural observer's knowledge and belief, that have not been satisfactorily corrected.

1643A.12.1 The requirement for structural observation shall be noted and prominently displayed on the front sheet of the approved plans and incorporated into the general notes on the approved plans.

1643A.12.2 Pre-construction meeting. A pre-construction meeting is mandatory for all projects which require structural observation. The meeting shall include, but is not limited to, the design engineer or architect, structural observer, general contractor, affected subcontractors, the project inspector and a representative of the enforcement agency (designated alternates may attend if approved by the structural observer). The structural observer will schedule and coordinate this meeting.

The purpose of the meeting is to identify and clarify all essential structural elements and connections that affect the lateral and vertical load systems and to review scheduling of the required observations for the project's structural system retrofit.

1643A.13 Temporary actions: When compatible with the building use, and the time phasing for both use and the retrofit program, temporary shoring or other structural support may be considered. Temporary bracing, shoring, and prevention of falling hazards can offer an affordable means of qualifying for the EXCEPTION in Section 1644A.4.1.1 that allows inadequate capability in some existing elements as long as life safety can be provided.

Section 1644A—METHOD A

1644A.1 General. Structures shall be designed for seismic forces coming from any horizontal direction. The design seismic forces may be assumed to act non-concurrently in the direction of each principal axis of the structure, except as required by Section 1646A.1.4. Seismic dead load, W, is the total dead load and applicable portions of other loads listed below:

1644A.1.1 In storage and warehouse occupancies, a minimum of 25 percent of the floor live load shall be applicable.

1644A.1.2 Where a partition load is required in the floor design, a load of not less than 10 pounds per square foot (psf) (0.48 kN/m^2) shall be included.

1644A.1.3 Design snow loads of 30 pounds per square foot (psf) (1.44 kN/m^2) or less need not be included. Where design snow loads exceed 30 psf (1.44 kN/m^2) the design snow load shall be included, but may be reduced up to 75 percent where consideration of siting, configuration and load duration warrant when approved by the Enforcement Agent.

1644A.1.4 Total weight of permanent equipment shall be included.

1644A.2 Determine the most applicable complying or essentially complying structural system as described in Section 1629.6. All elements that are capable of providing significant resistance to the actions of lateral forces shall be included in the system.

EXCEPTION : Elements made of non-complying materials and/or details, and non-structural components may be omitted from the system provided that their rigidity, capacity, and load-deformation behavior are established for use in the investigation of the effects of these elements on the structural system as required by Section 1646A.2.4 Deformation Compatibility and Sub-Section 1646A.2.4.1 Adjoining rigid elements.

1644A.2.1 Classify each element included in the assigned structural system and foundation as being either "ductile", "limited-ductile", or "non-ductile" according to its relative compliance with required provisions and/or its ability to deform beyond the nominal strength level without an abrupt or significant loss of resistance.

All elements shall be considered as non-ductile if they do not comply or do not essentially comply with the requirements for ductile elements. The limited-ductile classification must be established by related empirical data and analysis, or by meeting the requirements given in Section 1645A.

Section 1645A provides a listing of code dates and extra provisions that apply for given elements and materials in order to qualify for the "code-complying or ductile" classification. Section 1645A also provides the procedures and criteria that apply for the "limited-ductile" and "non-ductile" classification.

The stiffness and nominal strength or capacity C_n of each element shall be determined for each possible mode of failure of the element.

1644A.2.2 Evaluate the uplift and/or sliding resistance of joints and connections at all levels including the diaphragm-to-wall or frame connection and collectors, and including the foundation soil-structure interface along with the soil compressive resistance to seismic forces; the contribution of existing piles and caissons shall be considered where they occur.

1644A.2.3 Modeling requirements. The mathematical model of the physical structure shall comply with Section 1630.1.2.

1644A.3 General. Structural systems shall be classified with the requirements of Section 1627.6 as one of the types listed in Table 16A-N and defined in this subsection. The system selected for an existing building to be most appropriate for a given existing building may contain non-complying elements and/or elements which essentially comply to the required provisions and details for that system provided that all the non-complying and essentially complying elements have been properly classified as "non-ductile," "limited-ductile," or "ductile" and the corresponding ß values are applied to their seismic load.

1644A.3.1 The system R value shall be taken as 4.5 for all existing structural systems except for the following conditions:

1644A.3.1.1 R may be taken as 5.5 if the system constructed meets the requirements for a Building Frame System as defined in Section 1627.6.3.

1644A.3.1.2 For structural systems designed to meet all of the seismic provisions of the 1976 or later editions of the R may be taken as equal to the appropriate R value given in Table 16A-N for the corresponding basic structural system.

1644A.4 STATIC FORCE PROCEDURES.

1644A.4.1 Design base shear. The total design base shear in a given direction shall be determined from the following formula:

$$V = \frac{H\, C_v\, I\, W}{R\, T} \qquad (44A\text{-}1)$$

where: The total design base shear need not exceed the following:

$$V = \frac{2.5\, H\, C_a\, I\, W}{R} \qquad (44A\text{-}2)$$

The total design base shear shall not be less than the following:

$$V = 0.11\, H\, C_a\, I\, W \qquad (44A\text{-}3)$$

In addition, for Seismic Zone 4, the total base shear shall also not be less than the following:

$$V = \frac{0.8\, H\, Z\, N_v\, I\, W}{R} \qquad (44A\text{-}4)$$

1644A.4.1.1 Strength Basis for Evaluation and Design. Elements subject to seismic load E due to the specified total design base shear V shall have the usable strength capacity ΦC_n to resist the following load combinations:

(A) For the case where the actions D, L, and E are all in the same sense,

$$\Phi C_n = 1.05D + 0.25L + \beta E \qquad (44A\text{-}5)$$

where the live load L is the realistic live load, but shall not be less than the design load specified for the occupancy.

(B) For the case where the action E is opposite to the sense of D.

$$\Phi C_n = \beta E - 0.9D \qquad (44A\text{-}6)$$

In the load combinations (44A-5) and (44A.6) the seismic load penalty factor ß represents the limited inelastic deformation capability of non-ductile and limited-ductile elements for an associated mode of failure. Values of ß for specific types of elements and modes of failure are given in Section 1645A.

EXCEPTION: See EXCEPTIONS 1 and 2 in Section 1643A.9.

1644A.4.1.2 Allowable or Working Stress Basis for Evaluation and Design. Allowable or working stress method along with the one third allowable stress increase as permitted by Section 1612A.3.2 may be used to establish the allowable or working stress capacity C_w of an element. The capacity C_w shall meet the following load combination requirements:

(C) For the case where the actions D, L, and E are all in the same sense,

$$C_w = D + L + \frac{\beta E}{1.4} \qquad (44A\text{-}7)$$

(D) For the case where the action E is opposite to the sense of D,

$$C_w = \frac{\beta E}{1.4} - 0.9D \qquad (44A\text{-}8)$$

EXCEPTION: Section 1644A.4.1.2 may not be used for reinforced concrete.

1644A.4.2 Structure period. The value of T shall be determined in the same manner as for a new building contained in Section 1630.2.2.

1644A.5 Combinations of Structural Systems. General. Where combinations of structural systems are incorporated into the same structure, the same requirements as for a new building of Section 1630.4 shall be satisfied.

1644A.6 Vertical Distribution of Force. The total force shall be distributed over the height of the structure in conformance with the requirements of Section 1630.5 for new buildings.

1644A.7 Horizontal Distribution of Shear. The design story shear shall be distributed over the height of the structure in conformance with the requirements of Section 1630.6 for new buildings.

1644A.8 Horizontal Torsional Moments. Provisions shall be made for the increased shears resulting from horizontal torsion where diaphragms are not flexible. The most severe load combination for each element shall be considered for design in conformance with the requirements of Section 1630.7 for new buildings.

1644A.9 Overturning.

1644A.9.1 General. Every structure shall be designed to resist the overturning effects caused by earthquake forces specified in Section 1630,5. At any level, the overturning moments to be resisted shall be determined using those seismic forces (F_t and F_x) which act on levels above the level under consideration. At any level, the incremental changes of the design overturning moment shall be distributed to the various resisting elements in the manner prescribed in Section 1630.6. Overturning effects on every element, wherever possible, shall be carried down directly in a linear path to the foundation. See load combinations in Sections 1644A.4.1.1 and 1644A.4.1.2 for combining gravity and seismic loads.

1644A.9.2 Seismic Zones 3 and 4. In Seismic Zones 3 and 4, where a lateral load–resisting element is discontinuous, such as for vertical irregularity Type 4 in Table 16A-L or plan irregularity Type 4 in Table 16A-M, columns supporting such elements shall have the strength to resist the axial force resulting from the following load combinations, in addition to all

other applicable load combinations:

$$\Phi C_n = D + 0.8L + \Omega_o \beta E \quad (44A\text{-}9)$$

$$\Phi C_n = \Omega_o \beta E - 0.9D \quad (44A\text{-}10)$$

$\Omega_o \beta E$ in Formulas (44A-9) and (44A-10) need not exceed $\mathbb{R}\mathbb{E}$.

1644A.9.2.1 The axial forces in such columns need not exceed the resultant of the probable strengths of the other elements of the structure that transfer such loads to the column.

1644A.9.2.2 Such columns shall be capable of carrying the above–described axial forces without exceeding the usable axial load capacity (ΦC_n) of the column. For designs using working stress methods this capacity may be determined using an allowable stress increase of 1.7 or acceptable published factors for a given material or element.

EXCEPTION: See Exceptions 1 and 2 in Section 1643A.9.

1644A.9.2.3. ~~Such columns shall either resist the above described axial forces without exceeding the usable axial capacity (ΦC_n), or shall meet the following detailing and member limitations~~*: In order to qualify for a β value equal to 1.0, such columns shall meet the following detailing and member limitations:*

1. Chapter 19, Section 1921.4, for concrete, and Chapter 22, Sections 2210, 2211.4 and 2211.5 for steel in structures in seismic Zones 3 and 4, except for welded steel moment connections where the current SAC Guidelines for columns apply

2. Chapter 19, Section 1921.8, for concrete and Chapter 22, Divisions I and IX, special provisions for developing plastic hinges at ultimate loading, for steel in structures in Seismic Zone 2.

1644A.9.2.4 Transfer girders that support such columns or that provide support for the discontinuous lateral load-resisting element shall resist the above-described axial forces or support reactions without exceeding the capacity ΦC_n for each mode of failure. For this case, the β factor shall correspond to the properties of the girder.

1644A.9.3 At Foundation. See Section 1809.4 for overturning moments to be resisted at the foundation soil interface. The foundation soil interface shall be capable of resisting the following load combinations on the allowable stress basis of Section 1809.2 and Table 18A-1-A, and other load combinations need not apply:

$$D + L + \frac{E}{1.4} \quad (44A\text{-}11)$$

$$\frac{E}{1.4} - 0.9D \quad (44A\text{-}12)$$

In order to determine the strength design basis loads for the elements of the foundation structure, the soil pressures and pile or caisson reactions due to these load combinations shall be load factored by 1.4. The resulting bending moments, shears, axial loads on the sections of the foundation structure are to be factored by the appropriate β value and shall be resisted by the corresponding usable strength ΦC_n of the section. If piles or caissons are required for overturning moment tension resistance due to the load combination (44A-12), then the minimum tensile load-carrying resistance ΦC_n shall be E/14.

1644A.10 Drift and Story Drift Limitations.

Drift or horizontal displacements of the structure shall be computed where required by this code. For both Allowable Stress Design and Strength Design, the Maximum Inelastic Response Displacement, Δ_M, of the structure caused by the Design Basis Ground Motion shall be determined in accordance with this section. The drifts corresponding to the design seismic forces of Section 1644A.4.1, Δ_S, shall be determined in accordance with Section 1644A.10.1. To determine Δ_M, these drifts shall be amplified in accordance with Section 1644A.10.2.

1644A.10.1 Determination of Δ_S. . A static, elastic analysis of the lateral force-resisting system shall be prepared using the design seismic forces from Section 1644A.4.1 and 1644A.6. The mathematical model shall comply with Section 1644A.2.3. The resulting deformations, denoted as Δ_S shall be determined at all critical locations in the structure. Calculated drift shall include translational and torsional deflections.

1644A.10.2 Determination of Δ_M.

The Maximum Inelastic Response Displacement, Δ_M, shall be computed as follows:

$$\Delta_M = 0.7 \, R \, \Delta_S \qquad (44A\text{-}13)$$

1644A.10.3. Story drift defined. Story drift is the displacement of one level relative to the level above or below using the Maximum Inelastic Displacement, Δ_M, at each level.

1644A.10.4 Story drift limits. Calculated story drift using Δ_M shall not exceed 0.025 times the story height for structures having a fundamental period of less than 0.7 second. For structures having a fundamental period of 0.7 second or greater, the calculated story drift shall not exceed 0.020 times the story height.

EXCEPTION: These story drift limits may be exceeded when it is demonstrated that greater drift can be tolerated by both structural elements and nonstructural elements that could affect life safety.

1644 A.11 PΔ Effects. The resulting member forces and moments and the story drifts induced by PΔ effects shall be considered in the evaluation of overall structural frame stability and shall be evaluated using the specified design forces and their corresponding displacements Δ_S. PΔ need not be considered when the ratio of secondary moment to primary moment does not exceed 0.10; the ratio may be evaluated for any story as the product of the unfactored total dead, floor live load, and snow load above the story times the seismic drift Δ_S in that story divided by the product of the corresponding seismic shear in that story times the height of that story. In Seismic Zones 3 and 4, PΔ need not be considered where the story drift ratio does not exceed 0.02/R.

1644 A.12 Vertical Component. The following requirements apply in Seismic Zones 3 and 4 only.

Horizontal cantilever components shall have the usable strength capacity ΦC_n to resist (0.7) H C_a W_p, or have an allowable or working stress capacity C_w to resist (0.5) H C_a W_p. The value of the seismic hazard factor H shall be as prescribed by Section 1643A.9 according to the occupancy and conditions of the building.

1644A.13 Lateral Force on Elements of Structures, Nonstructural Components and Equipment Supported by Structures.

Elements of structures and their attachments, permanent nonstructural components and their attachments, and the attachments for permanent equipment supported by a structure shall be designed to resist the total design seismic forces prescribed in Section 1644A.13.1.

Attachments for floor– or roof–mounted, but not suspended, equipment weighing less than 400 pounds (181 kg), and furniture need not be designed.

Attachments shall include anchorage and required bracing. Friction resulting from gravity loads shall not be considered to provide resistance to seismic forces.

When the failure of the lateral force–resisting anchorage, bracing, or connection of non rigid equipment would cause a life hazard, such elements shall be designed to resist the seismic forces prescribed in Section 1644A.13.1.

When allowable design stresses and other acceptance criteria are not contained in or referenced by this code, such criteria shall be obtained from approved national standards.

1644A.13.1 Design for Total Lateral Force. The total design lateral seismic force, F_p, shall be determined from the following formula:

$$F_p = 4.0\ H\ C_a\ I_p\ W_p \qquad (44A\text{-}14)$$

Alternatively, F_p may be calculated using the following formula:

$$F_p = a_p\ H\ C_a / R_p\ (\ 1 + 3h_x / h_r\ )\ W_p \qquad (44A\text{-}15)$$

Except that:

F_p shall not be less than $0.7\ H\ C_a\ I_p\ W_p$ and
Need not be more than $4\ H\ C_a\ I_p\ W_p$. (44A-16)

Where:

h_x is the element or component attachment elevation with respect to grade. h_x shall not be taken less than 0.0.
h_r is the structure roof elevation with respect to grade.

a_p is the in-structure Component Amplification Factor that varies from 1.0 to2.5.
A value for a_p shall be selected from Table 16A-O.

R_p is the Component Response Modification Factor that shall be taken from Table 16A-0, except that R_p for anchorages shall equal 1.5 for shallow expansion bolts, shallow chemical anchors, or shallow cast-in-place anchors. Shallow anchors are those with an embedment length-to-diameter ratio of less than 8. Where anchorage is constructed of nonductile materials, or has nonductile behavior, or the component is attached with an adhesive surface joint, R_p shall equal 1.0. The β factor may be taken as 1.0 for anchorages requiring R_p equal to 1.0, 1.5, or 3.0.

The design lateral forces determined using Formula (44A-14) or (44A-15) shall be distributed in proportion to the mass distribution of the element or component.

Forces determined using Formula (44A-14) or (44A-15) shall be used to design members and connections that transfer these forces to the seismic-resisting systems. Members and connections shall use the load combinations and factors specified in Section 1644A.4.1.1 or 1644A.4.1.2. The member or connection actions due to F_p are the earthquake load E to be used in the load combinations. The appropriate β factor shall be assigned for the elements and connections.

To determine the out-of-plane loading for elements such as walls or wall panels that have points of attachment at two or more different elevations, the following procedure may be used. For the vertical span of the element having a unit weight w_p between two successive attachment elevations h_x and h_{x+i} evaluate the force coefficients F_p / W_p at each of the two points, observing the minimum and maximum limits, and compute the average of the two values. The resulting average coefficient times the unit weight w_p provides the distributed seismic load for the span between the attachment points, and this load may be extended to the top of any wall parapet above the roof attachment point at h_r ..

Section 1645A—PROCEDURES FOR THE CLASSIFICATION OF ELEMENTS INTO THE DUCTILE, LIMTED-DUCTILE AND NONDUCTILE CATEGORIES

1645A.1 General: All elements will be classified as either being "Ductile, Limited-Ductile, or Non-Ductile". The purpose of this section is to provide the procedures and guidelines necessary for this classification and assignment of β values. The general requirements for all materials are listed below, and these will be followed by the specific requirements for each material.

1645A.1.1 Ductile Category: A ductile element is one that complies with the definition of ductile. Code complying elements shall be classified as Ductile, except as noted in Section 1644A.9.2.3. Otherwise a rational analysis as described in the Non-Ductile Category below, may be used to justify the use of the Ductile Classification.

1645A.1.2 Non-Ductile Category: Any element that does not comply with the code compliant definition shall be classified as Non-Ductile; except for the case where it either complies with the specific provisions of Section 1645A required for the Limited-Ductile Category, or a rational analysis based on the principals of mechanics, related research and test results can demonstrate that it has the cyclic inelastic deformation behavior required for the Limited-Ductile or Ductile Categories.

1645A.1.3 Limited-Ductile Category: An element that does not qualify as ductile, but does comply or essentially complies with the specific material Limited-Ductile provisions of Section 1645A, may be classified as Limited-Ductile. Otherwise,

a rational analysis as described in the Non-Ductile Category above, may be used to justify the use of the Limited-Ductile Classification.

1645A.2 For each element and loading condition, a β value is assigned that represents the expected load-deflection behavior of the element during the full earthquake loading of the element, including repeated, reversing loads. β values that are significantly different from those given in Section 1645A must receive the acceptance of the Enforcement Agency when they are used in the analysis and design.

1645A.2.1 Sections 1645A.3 through 1645A.7 provide reference values for selected elements and loading conditions; these β values are to be used as guidance for the assignment of values for conditions and elements not listed by comparison of expected performance to that expected for listed elements.

1645A.2.2 Alternative β values to those listed may be used where experimental results, coupled with rational analysis, lead to the conclusion that a different β value better represents the behavior of a given element and its conditions. Such interpretation and analysis shall be subject to the review and approval of the enforcement agent and shall consider the following items:

1. The effects of cyclic load reversals representative of seismic loading beyond the strength level of the element, considering the specific nature of the loading used in the test, especially whether essentially static or dynamic.

2. The size or scale effect of the test data, along with the compatibility of the test specimen details with those of the existing element.

3. The sample size of the test program and range of related test variables necessary to reasonably define behavior.

1645A.3 Reinforced Concrete: Reinforced concrete is considered to be any combination of concrete with steel reinforcing that can develop the compressive and tensile properties of the respective materials. The procedures and provisions for the classification of ductile, limited-ductile, and non-ductile elements are given in the following Sections 1645A.3.1 through 1645A.3.3. The corresponding β values are given in Table 16A-R-1.

1645A.3.1 Reinforced concrete frame elements

1645A.3.1.1 Any frame element in conformance with the requirements of 1976 UBC Section 2626 or later editions (Section 1921.1 through 1921.5 for Seismic Zones 3 and 4) may be classified as ductile and the β value taken as 1.0.

Exception 1: Hooked bar development length shall comply with Section 1921.5.4 to qualify the bar anchorage as ductile.

Exception 2: For a column to be classified as ductile, no more than one-third of the columns in a story level of its frame-line may have the weak column-strong beam condition; otherwise, each column in the story level frame-line shall be classified as no more than limited ductile.

1645A.3.1.2 Any frame element in essential conformance with the requirements of Section 1921.8 or equivalent requirements of earlier editions, shall be classified as limited ductile and assigned a β value equal to or greater than that given in Table 16A-R-1.

1645A.3.1.3 Any column members in essential compliance with the requirements of Section 1921.7.2 and 19217.3 shall be classified as limited-ductile and assigned a β value equal to or greater than that given in Table 16A-R-1.

1645A.3.1.4 Any element not meeting the requirements of Sections 1645A.3.1.1, 1645A.3.1.2 or 1645A.3.1.3 shall be classified as non-ductile, with corresponding β value equal to or greater than that given in Table 16A-R-1, except where Section 1645A.2 allows use of another value. The Section 1645A.2.2 analysis shall consider at a minimum:

1. Reinforcing bar lap splice length, cover, and ties.
2. Pile-to-footing connection resistance to tension due to overturning moment. (Section 1644A.9.3)

3. Footing flexural and shear capacity.
4. Column ties for both shear resistance and concrete confinement.
5. Positive Moment tension bar pullout or slab flexural failure. (Section 1646A.1.3.2)
6. Negative moment hook pullout.
7. Stirrups for both shear resistance and concrete confinement.
8. Non-continuous longitudinal steel leaving sections with weakness in flexural and shear resistance (Section 1921.8.4.1)
9. Joint shear reinforcing and confinement.
10. Weak column-strong beam condition. (Section 1645A.3.1.1, EXCEPTION 2 and Section 1921.4.2.2).
11. Slab punching shear.
12. Short or captive column.
13. The shear capacity of columns.

1645A.3.2 Shear Walls and Diaphragms

1645A.3.2.1 Any shear wall or diaphragm in conformance with the requirements of the 1976 UBC Section 2626 or later editions (Section 1921.6) may be classified as ductile and the β value taken as 1.0.

Exception: A shear wall that essentially meets the boundary zone requirements of Section 1921.6.6 may be classified as ductile.

1645A.3.2.2 Any shear wall or diaphragm in conformance with 1976 UBC Section 2614 may be classified as a limited-ductile element and assigned a β value equal to or greater than that given in Table 16A-R-1.

1645A.3.2.3 Any wall element not meeting the requirements of Sections 1645A.3.2.1 or 1645A.3.2.2 shall be classified as non-ductile, with corresponding β value equal to or greater than that given in Table 16A-R-1, except where Section 1645A.2 allows use of another value. The Section 1645A.2.2 analysis shall consider at a minimum:

1. Dowel and reinforcing bar lap spice length, cover, and ties.
2. Boundary element or boundary zone confinement ties.
3. Horizontal shear steel and its anchorage in boundary element or boundary zone.
4. Location and characteristics of construction joints.
5. Relative stiffness and friction resistance of soil-footing interface to determine if the effects of foundation rotation and/or horizontal slip need to be included in the analytical model. (Section 1646A.1.3.4)
6. Diaphragm drag or collector elements and connection of diaphragm to wall or braced frame. (Section 1646A.1.3.3 and 1646A.1.3.4)
7. Spandrel capacity to resist flexure and vertical shear.
8. Pile-to-footing connection resistance to tension due to overturning moment. (Section 1644A.9.3)

1645A.3.2.4 Any diaphragm element not meeting the requirements of Section 1645A.3.2.1 or 1645A.3.2.2 shall be classified as non-ductile, with corresponding β value equal to or greater than that given in Table 16-R-1, except where Section 1645A.2 allows use of another value. The Section 1645A.2.2 analysis shall consider at a minimum:

1. Thickness of slab and positioning of reinforcing
2. Shear connection to walls
3. Shear reinforcing
4. Reinforcing around openings

5. Chord element
6. Drag or collector elements

{PRIVATE }**Table 16A-R-1 Table of β Values for Reinforced Concrete Elements.** These values are given for selected systems; systems not listed, they are meant to guide the selection of β values by comparison of expected performance at the design level of loading that for listed systems. Elements that are not included in the lateral load resisting system shall be checked for capacity as required in Secti 1646A. Refer to Section 1645A.3 for classification provisions.

Element/Action	Ductile	Limited Ductile	Non-Ductile	Notes: D is for ductile, LD is for limited ductile, ND is for non-ductile
Beams/Slabs				
Shear	1.0	2.0	4.5	D: Flexure Controlled
Flexure	1.0	1.5	2.4	LD: Continuous Top and Bottom Bars, and Axial Load less than 10 percent of nominal axial strength capacity.
Columns				
Shear	1.0	2.0	4.5	LD: Ties spaced at not more than the lesser value of one half c column minimum dimension or 12 inches; or shear resistance governed by flexure, D: Flexure controlled.
Axial-Flexural Yield	1.0	1.5	3.0	Axial-Flexural Yield is when tensile steel yield occurs before concrete reaches compressive strain limit: below balanced poi on interaction curve, or where P_u with ß=1.0 is less than $0.35P_o$.
Axial-Flexural Crushing	1.0	1.5	4.5	Axial-Flexural crushing is when concrete reaches compressive strain limit before tensile steel yield occurs: above balanced point on interaction curve.
Beam-column Joints				
Constrained on Four sides	1.0	2.0	N/A	Joints without transverse tie reinforcement may use nominal shear strength equal to two-thirds of the values in Section 1921.5.3, provided that the β value is applied to the loading. The loading need not exceed the probable yield capacity of the beam longitudinal reinforcement.
Not constrained on four sides	1.0	3.0	N/A	Same as above.

Table 16A-R-1 Table of β Values for Reinforced Concrete Elements (continued)

Element/ Action	Ductile	Limited Ductile	Non-Ductile	Notes: D is for ductile, LD is for limited ductile, ND is for non-ductile
Walls Governed by Flexure				
Shear	1.0	2.0/1.5	3.0	LD: For wall or pier $l_w/h_w<11/2$ use 2.00; otherwise use 1.50. Wall steel to be anchored. Wall or pier shall be considered as nonductile if width l_w is less than 4 times wall thickness t.
Flexure	1.0	1.5	2.5	LD: Continuous longitudinal reinforcing steel at top of wall, and Axial Load less than 10 percent of nominal axial strength capacity.
Boundary Elements	1.0	1.5	3.0	LD: Continuous edge bars at boundary of walls, and Axial Load less than 10 percent of nominal axial strength capacity.
Wall Governed by Shear				
Shear	1.0	2.5/2.0	3.5	LD: For wall and pier $l_w/h_w<1/2$ use 2.5; otherwise use 2.0. Wall steel to be anchored. Wall or pier shall be considered as non-ductile if width l_w is less than 4 times wall thickness t.
Flexure	1.0	2.5	2.5	
Boundary	1.0	3.0	3.0	
Foundations				
Shear	1.0	1.5	2.5	LD: Longitudinal reinforcing bars are provided, with steel ratio$\geq \rho_{min}$ but not sufficient to comply with Code. ND: Reinforcement is with unknown or not provided.
Flexure	1.0	1.5	2.5	LD: Reinforcing bars are provided, but not sufficient to comply with Code. ND: Reinforcement is with unknown or not provided.
Shear Friction	1.0	2.0	---	LD: Dowels have embedment length at least 50% of their development length.
Anchorage	1.0	3.0	4.5	
Collectors	1.0	3.0	4.5	

1645A.4 Masonry

1645A.4.1 Ductile or Code Complying: Any element in essential conformance with the seismic requirements of Chapter 21, Sections 2106.1.12.4 and 2108.2.3.8 may be classified as ductile and the β value taken as 1.0.

Exception: Any shear wall pier and spandrel element having height or clear span to depth ratios greater than two shall comply with Section 2108.2.6 (Wall Frames) to be classified as ductile; otherwise, it shall be classified as a limited-ductile element with $\beta = 2.5$ or greater.

1645A.4.2 Limited-Ductile: Any masonry element in essential conformance with 1994 UBC Sections 2106.1.12.3 (Special Provisions for Seismic Zone 2), and 2108.2.3.8 (Seismic Design Provisions), shall be classified as limited ductile and assigned a β value equal to or greater than 2.5 for all modes of failure.

1645A.4.3 Non-Ductile: Systems and elements that do not comply with Sections 1645A.4.1 or 1645A.4.2 shall be classified as non-ductile, with corresponding β value equal to or greater than 4.5 for all modes of failure, except where Section 1645A.2 allows use of another value. The Section 1645A.2.2 analysis shall consider at a minimum:

Wall elevation:

1. Horizontal and vertical reinforcing;
2. Reinforcing at edges of wall and openings;
3. Slenderness proportions of wall piers and spandrels;
4. Height to thickness ratio of wall;
5. Special reinforcing for slender piers;
6. Spandrels and openings;
7. Diaphragm connections.
8. Quality of dry-pack mortar joints and grouting of shear friction dowels at the horizontal joint between the top of masonry walls and adjoining reinforced concrete beams or slabs.

Grouting:

1. Grouting of cells, particularly those containing reinforcing steel;
2. Potential for incomplete grouting because of large or pairs of reinforcing bars in one cell or in bond beams;
3. Bond beams at required spacing and location;
4. Splice lengths for vertical and horizontal reinforcing;
5. Quality of construction joint at base of wall and vertical control joints.

Wall and diaphragm connections:

1. Wall joints and separations for pounding or hard-spot effects;
2. Wall reinforcing ties at wall intersections and corners;
3. Wall-to-diaphragm connections.

1645A.4.4 Where an element is unreinforced masonry, then the seismic capacities shall be determined in the manner consistent with the testing requirements specified in the Guidelines for the Retrofit of Existing Buildings (GSREB), Chapter 1.

1645A.4.5 For masonry buildings with wood diaphragms, the requirements for Earthquake Hazard Reduction in Existing Reinforced Concrete and Reinforced Masonry Wall Buildings with Flexible Diaphragms (GSREB), Chapter 5 shall apply.

1645A.4.6 Inspections Required. Unless inspection reports from the original construction are available and acceptable,

then appropriate destructive testing and inspections shall be performed, including core testing and removing masonry. For each wall that is part of the lateral resisting system at least one of each of the following tests shall be done:

1. Core test to determine the strength of the masonry, the bond between the grout and the masonry units, and the placement and size of reinforcing steel in the walls.

2. At sections of the construction joints where masonry adjoins concrete at slab, concrete framing or foundations, determine the value of shear transfer.

1645A.5 Structural Steel

1645A.5.1 Welded steel moment frame elements. The SAC references in this section are to the SAC Interim Guidelines for the Evaluation, Repair, Modification, and Design of Welded Steel Moment Frame Structures, FEMA 267, August, 1995, or subsequent editions.

1645A.5.1.1 Any frame element in conformance with the requirements of Chapter 7 of the SAC Guideline requirements for new construction or which has had its connections repaired and modified in accordance with the recommendations of Chapter 6 may be classified as ductile and the β value taken as 1.0.

1645A.5.1.2 For any frame element in essential conformance with the requirements of 1976 UBC Section 2722 for Seismic Zones 3 and 4 or later editions of the UBC, where the structure:

1. Has not experienced potentially damaging ground motions in an earthquake that by the recommendations of Chapter 4 of the SAC Guidelines require inspection may be classified as limited-ductile and the β value taken as 1.5; or,
2. Has been repaired and evaluated in conformance with the recommendations of Chapters 4 and 6 of the SAC Guidelines may be classified as limited-ductile and the β value taken as 1.5 or greater; or,
3. Has been repaired in conformance with the requirements of Chapter 6 of the SAC Guidelines requirements for the repair may be classified as limited-ductile and the β value taken as 2.0 or greater; or,
4. Has been inspected in accordance with the requirements of Chapters 3 and 4 of the SAC Guidelines,

    a. connections that have been inspected but not repaired or modified may be classified as limited-ductile and the β value taken as $1.5 + .5d_i$, where d_i is the damage index for the inspected connections;

    b. connections that have not been inspected may be classified as limited-ductile and the β value taken as 1.5 + .5DA, where DA is the average damage index for the inspected connections;

    c. connections that have been modified in accordance with the recommendations for Chapters 4 and 6 of the SAC Guidelines may be classified as ductile and the β value taken as 1.0;

    d. connections that have been repaired in accordance with the recommendations of Chapters 4 and 6 of the SAC Guidelines may be classified as limited-ductile and the value taken as 1.5; or,

5. Has not been inspected in accordance with the requirements of Chapters 3 and 4 of the SAC Guidelines, the connections of the structure may be classified as limited ductile and the β value taken as 3.0 or higher.

1645A.5.1.3 Any bolted frame element in conformance with the requirements of the 1997 UBC for bolted connections may be classified as ductile and the β value taken as 1.0. Where the frame element at least meets the requirements of 1976 UBC but not the 1997requirements, then the element may be classified as limited-ductile and the β value

taken as 1.5 or higher.

1645A.5.1.4 Any structural element having moment capacity but not qualifying as ductile under any UBC code provisions since 1976 may be classified as limited-ductile and the β value taken as 3.0 or higher.

1645A.5.1.5 Any truss girder or knee brace frame element may be classified as limited-ductile and the β value taken as 2.0 or higher.

1645A.5.1.6 Elements of frames with lateral girder buckling and/or noncompact column sections may be classified as limited-ductile and the β value taken as 2.0 or higher.

1645A.5.2 Braced steel frame elements

1645A.5.2.1 Any braced frame element in conformance with the requirements of 1997 UBC for braced frames may be classified as ductile and the β value taken as 1.0.

1645A.5.2.2 Any braced frame element in conformance with the requirements of 1997 UBC, except that the b/t ratio exceeds the 1997 requirements for special braced frames may be classified as limited-ductile and the β value taken as 1.5 for a special and 2.5 for ordinary braced frames.

1645A.5.2.3 Any braced frame element where the connection gusset plate is subject to buckling may be classified as limited-ductile and the β value taken as 2.0 or greater.

1645A.5.2.4 Any braced frame element with tension-only bracing, with rods or angles, may be classified as limited-ductile and the β value taken as 3.0 or greater.

1645A.6 Wood and Other Sheathing Materials

1645A.6.1 Wood elements and other sheathing materials that essentially comply with the 1976 UBC Chapter 25, Wood, and Chapter 47, Installation of Wall and Ceiling Coverings, or the equivalent Sections of later editions may be classified as ductile and assigned a β value of 1.0 as given in Table 16A-R-2.

Exception: Let-in bracing, plaster (stucco), gypsum wallboard, and particle board sheathing shall be classified as limited-ductile or non-ductile and assigned a β value given in Table 16A-R-2.

{PRIVATE }**TABLE 16A - R-2 Table of β Values for Wood and Other Sheathing Materials.**
These values are given for selected systems; for systems not listed, they are meant to guide the selection of ß values by comparison of expected performance at the design level of loading to that for listed systems. Elements that are not included in the lateral load resisting system shall be checked for capacity as required in Section 1646A. Drift should be considered for its effect on non-structural elements. These values apply to both shear and flexure.

Element/Action	Ductile	Limited Ductile	Non-Ductile	Notes: D is for ductile, LD is for limited ductile, ND is for non-ductile
Plywood walls	1.0	1.5	3.0	D: If boundary, collector and splice elements present, then use ß = 1.00; LD: for $l_w/h_w > 1/2$; ND: for $lw/h_w < 1/2$ and lacking hold downs.
Plywood diaphragms	1.0	1.5	2.5	D: If boundary, collector and splice elements present.
Walls with diagonal sheathing	---	2.0	3.0	ND: if in poor condition and limited nailing.
Diaphragms with diagonal sheathing	1.0	2.0	3.0	
Let-in bracing or steel strap bracing	---	---	4.5	
Straight sheathing	---	2.5	4.5	LD: If sheathing is greater than 1x6 and well nailed.
Stucco	---	2.0	4.5	LD: only if verified screen attachment, otherwise ND.
Lath and plaster	---	2.0	4.0	LD: if nailed lath and plaster in good condition.
Plaster on stiff substrate	---	---	4.5	
Particle board	---	2.0	4.0	LD: If boundary, collectors and splice elements present and nailing is certified to comply.
Gypsum wall board	---	2.5	4.5	LD: with full edge and field nailing without splitting of paper or plaster, and nailing is verified to comply.
Wood bracing (axial)	1.0	1.5	3.0	LD: Nailing relationship to the grain is a particularly important consideration.
Wood in flexure	1.0	2.0	4.0	LD: Nailing relationship to the grain is a particularly important consideration.
Collectors	1.0	1.5	4.0	LD: with added metal continuity elements properly installed.

1645A.6.2 Any element not meeting the requirements of Section 1645A.6.1 shall be classified as non-ductile, with corresponding β value equal to or greater than that given in Table 16A-R2, except where Section 1645A.2 allows use of another value. The Section 1645A.2.2 analysis shall consider at a minimum:

1. Anchoring attachment of tile or other heavy roofing elements, and chimneys.
2. In-plane and out-of-plane bracing of roof framing and trusses.
3. Wall-to-diaphragm connection for framing perpendicular to wall. (3A - Indirect shear path).
4. Wall-to-diaphragm connection for framing parallel to wall,
5. Shear transfer connection from shear panels or walls to framing and/or collector elements at top and bottom of shear walls.
6. Wall hold-down details between floors and a positive load path to foundation at base of wall.
7. Attachment of sheathing and stucco to transfer shear from wall to foundation.
8. Still bolts to transfer from wall framing to foundation.
9. Scabs and blocking and connections needed to transfer shear through floor framing.

Section 1646A-DETAILED SYSTEMS DESIGN REQUIREMENTS

1646A.1 General. All structural framing systems shall comply with the requirements of Section 1643A.9. The individual elements shall have the usable strength capacity ΦC_n or the allowable capacity C_w to resist the prescribed seismic load combinations. In addition, such framing systems and elements shall comply with the detailed system design requirements contained in Section 1646A.

1646A.1.1 All building components in Seismic Zones 3 and 4 shall be designed to resist the effects of the seismic forces prescribed herein and the effects of gravity loadings from dead, floor live and snow loads.

1646A.1.2 Consideration shall be given at each story level to the effects of uplift, reversed moment, and/or sliding, caused by seismic loads, as prescribed in Section 1646A.1.3 and 1646A.2.4.2.

1646A.1.3 The following provisions apply for all levels of the superstructure and its connection to the foundation structure:

1646A.1.3.1 Overturning moment tension resistance for elements and connections: if the tension action due to $\Omega_o E - 0.9D > 0$, then the usable tensile strength ΦC_n shall equal or exceed the greater of the tension due to $\Omega_o E - 0.9D$ or E/14 for semi-ductile and brittle elements; and E – 0.9D or E/14 for ductile elements.

1646A.1.3.2 Reversed Moment opposite to that caused by gravity loads in beams, slabs, and spandrels: if the flexural action due to $\Omega_o E - 0.9D > 0$ then the usable flexural strength ΦC_n shall equal or exceed the greater of the moment due to $\Omega_o E - 0.9D$ or E/14 for semi-ductile and brittle elements; and E – 0.9D or E/14 for ductile elements.

1646A.1.3.3 Resistance to sliding or slip of horizontal joints and/or the in-plane joints between diaphragms and walls or frames shall be such that the usable horizontal shear strength ΦC_n equals or exceeds the shear on the joint due to E.

1646A.1.3.4 For the following conditions:

1. Foundations at the soil-structure interface;
2. Horizontal construction joints in shear walls; or,
3. Diaphragm collectors, joints or connections of diaphragms to shear walls or frames.

if the strength capacity to resist overturning and/or sliding is exceeded by the application of a load combination of

$$\Omega_o E \pm 0.9D \qquad (46A\text{-}1)$$

then the deformations to be used in the investigation required by Section 1646A.2.4 shall be two times the displacement prescribed by Section 1646A.2.4.

1646A.1.4 In Seismic Zones 3 and 4, provision shall be made for the effects of earthquake forces acting in a direction other than the principal axes in each of the following circumstances:

1. The structure has plan irregularity Type E as given in Table 16A-M;
2. The structure has plan irregularity Type A as given in Table 16A-M for both major axes;
3. A column of a structure forms part of two or more intersecting lateral-force-resisting systems.

EXCEPTION: If the axial load in the column due to seismic forces acting in either direction is less than 20 percent of the column allowable axial load.

The requirement that orthogonal effects be considered may be satisfied by designing such elements for 100 percent of the prescribed seismic forces in one direction plus 30 percent of the prescribed forces in the perpendicular direction. The combination requiring the greater component strength shall be used for design. Alternatively, the effects of the two orthogonal directions may be combined on a square root of the sum of the squares (SRSS) basis. When the SRSS method of combining directional effects is used, each term computed shall be assigned the sign that will result in the most conservative result.

1646A.2 Structural Framing Systems.

1646A.2.1 General. Four types of general building framing systems defined in Section 1629.6 are recognized in these provisions and shown in Table 16A-N. Each type is subdivided by the types of vertical elements used to resist lateral seismic forces. Special framing requirements are given in this section and in Chapters 19 through 23.

1646A.2.2 Detailing for combinations of systems. For components common to different structural systems, the more restrictive detailing requirements shall be used.

1646A.2.3 Connections. Connections which resist seismic forces shall be designed and detailed on the drawings.

1646A.2.4 Deformation compatibility. All vertical load bearing elements not included as a part of the lateral force resisting system shall be investigated and shown to be adequate for vertical load carrying capacity when displaced (0.7)R times the displacements Δ_s resulting from the required design lateral forces given in Section 1644A.4. A representation of cracked section stiffness properties for reinforced concrete and masonry elements shall be used in the calculation of the displacements. The displacements shall include diaphragm deformation.

For designs using working stress methods, this capacity may be determined using an allowable stress increase of 1.7 or acceptable published factors for a given material or element. The effects of adjoining rigid and exterior elements shall be considered as follows:

1646A.2.4.1 Adjoining rigid elements. Any framing elements, including those of the lateral force resisting system, may be enclosed by or adjoined by more rigid elements, which would tend to limit the frame from resisting lateral forces, where it can be shown that the action or failure of the more rigid elements will not impair the vertical and lateral load–resisting ability of the frame. Where failure of the more rigid elements is indicated, then the life safety consequences due to debris and other falling hazards shall be investigated and mitigated where appropriate.

1646A.2.4.2 Exterior elements. Exterior nonbearing, non- shear wall panels or elements that are attached to or enclose the exterior of the structure shall be designed to resist the forces per Formula (44A–14) or (44A-15) and shall accommodate movements of the structure resulting from lateral forces or temperature changes. In order to qualify

for the "code-complying or ductile" classification such elements shall be supported by means of cast–in–place concrete or by mechanical connections and fasteners in accordance with the following provisions:

1. Connections and panel joints shall allow for a relative movement between stories of not less than two times story drift caused by wind or the story drift corresponding to the (0.7) R factored displacements given in Section 1646A.2.4, (0.015 h), or 0.5 inch (13 mm), whichever is greater.
2. Connections to permit movement in the plane of the panel for story drift shall be sliding connections using slotted or oversize holes, connections which permit movement by bending of steel, or other connections providing equivalent sliding and ductility capacity.
3. Bodies of connections shall have sufficient ductility and rotation capacity so as to preclude fracture of the concrete or brittle failures at or near welds.
4. The body of the connection shall be designed for one and one–third times the force determined by Formula (44A–15) where $R_p = 3.0$ and $a_p = 1.0$.
5. All fasteners in the connecting system such as bolts, inserts, welds and dowels shall be designed using $\beta = 4.00$ in Formula (44A-15), where $R_p = 1.0$ and $a_p = 1.0$.
6. Fasteners embedded in concrete shall be attached to, or hooked around, reinforcing steel or otherwise terminated so as to effectively transfer forces to the reinforcing steel.

1646A.2.5 Ties and continuity. All parts of a structure shall be interconnected and the connections shall be capable of transmitting the seismic force induced by the parts being connected. As a minimum, any smaller portion of the building shall be tied to the remainder of the building with elements having at least a strength to resist 0.5 H C_a I times the weight of the smaller portion.

A positive connection for resisting a horizontal force acting parallel to the member shall be provided for each beam, girder or truss. This force shall not be less than 0.5 H C_a I times the dead plus live load.

1646A.2.6 Collector elements. Collector elements shall be provided which are capable of transferring the seismic forces originating in other portions of the building to the element providing the resistance to those forces. These elements shall be classified as "ductile", "limited-ductile", or "non-ductile" and assigned the corresponding β factor for the seismic load. Unless an element can qualify for a β value given in Section 1645A, β shall be 1.00 for code-complying or ductile elements, and 4.00 for non-ductile elements.

1646A.2.7 Concrete frames. In order to qualify for the "code-complying or ductile" classification and use of an R greater than 5.5, concrete frames that are part of the lateral–force–resisting system shall conform to the requirements of Division IV for special moment-resisting frames in seismic Zones 3 and 4.

1646A.2.8 Anchorage of concrete or masonry walls. Concrete or masonry walls shall be anchored to all floors and roofs that provide lateral support for the wall. The anchorage shall provide a positive direct connection between the wall and floor or roof construction capable of resisting the horizontal forces specified in Section 1644A.13.1 or Section 1611. Requirements for developing anchorage forces in diaphragms are given in Section 1646A.2.9 below. Diaphragm deformation shall be considered in the design of the supported walls.

1646A.2.9 Diaphragms:

1646A.2.9.1 The deflection in the plane of the diaphragm shall not exceed the permissible deflection of the attached elements. Permissible deflection shall be that deflection which will permit the attached element to maintain its structural integrity under the individual loading and continue to support the prescribed loads. For the purpose of this evaluation the deflection of the diaphragm shall be (0.7)R times the deflection Δ_s due to F_{px} with $\beta = 1.00$ in Formula (46A-2).

1646A.2.9.2 Floor and roof diaphragms shall be designed to resist the forces determined in accordance with the following formula:

$$F_{px} = \beta \frac{F_t + \sum_{i=x}^{n} F_i}{\sum_{i=1}^{n} w_i} w_{px} \qquad \text{(46A-2)}$$

The force F_{px} determined from Formula (46A–2) need not exceed $1.0 \beta H C_a I w_{px}$, but shall not be less than $0.5 \beta H C_a I w_{px}$.

The β value to be used in the capacity analysis is the factor appropriate to the element and condition of loading.

The actions on an element due to the force F_{px} are the seismic load E. The value of β shall be 1.00 for code complying or essentially complying elements and 4.00 for non-ductile elements, unless the element qualifies for a lower value as given in Table 16A-R-1 or 16A-R-2.

1646A.2.9.3 When the diaphragm is required to transfer lateral forces from the vertical resisting elements above the diaphragm to other vertical resisting elements below the diaphragm due to offset in the placement of the elements or to changes in stiffness in the vertical elements, these forces shall be added to those determined from Formula (46A–2).

1646A.2.9.4 Design forces for flexible diaphragms and their connections providing lateral supports for walls or frames of masonry or concrete shall be calculated using an R not to exceed 4.

1646A.2.9.5 Diaphragms supporting concrete or masonry walls shall have continuous ties or struts between diaphragm chords to distribute the anchorage forces specified in Section 1644A.13.1. Added chords may be used to form subdiaphragms to transmit the anchorage forces to the main cross ties.

1646A.2.9.6 Where wood diaphragms are used to laterally support concrete or masonry walls, the anchorage shall conform to Section 1644A.13.1 above. Anchorage shall not be accomplished by use of toenails or nails subject to withdrawal, nor shall wood ledgers or framing be used in cross–grain bending or cross–grain tension, and the continuous ties required by Section 1646A.2.9.5 above shall be in addition to the diaphragm sheathing.

Exception: The prohibited details may be used if an appropriate β factor is assigned to allow for non-ductile behavior.

1646A.2.10 Framing below the base. Elements of the lateral-force-resisting system and all framing elements between the base and the foundation are subject to the same provisions as required for the superstructure.

1646A.2.11 Building separations. When the gap separating the building from adjacent structures is less than 0.7R times the displacement due to seismic forces of the building Δ_s, then the effects of pounding shall be investigated and the structure modified so that pounding or interaction does not pose a life-safety threat to the building.

EXCEPTION: Smaller separations may be permitted when justified by rational analyses based on maximum expected ground motions. Under this EXCEPTION, as a minimum, building separations shall not be less than R/5.5 times the displacements due to specified seismic forces.

1647A NONBUILDING STRUCTURES

1647A.1 General Nonbuilding existing structures include all self–supporting structures other than buildings which carry gravity loads and resist the effects of earthquake. Nonbuilding existing structures shall be designed to resist the minimum lateral forces specified in this division. Design shall conform to the applicable provisions of Section 1632 for new structures except as modified by the provisions contained in this division.

Section 1648A-METHOD B

1648A.1 The existing or retrofitted structure shall be demonstrated to have the capability to sustain the deformation response due to the specified earthquake ground motions. The engineer shall provide an evaluation of the response of the existing structure in its current configuration and condition to the ground motions specified. If the building's seismic performance is evaluated as satisfactory and the peer reviewer(s) concurs, then no further engineering work is required. When the evaluation indicates the building does not meet the objective of the safety goals of this division, then a retrofit and/or repair design shall be prepared that yields a structure that meets the life-safety performance objectives of Section 1640A of this division and reflects the appropriate consideration of existing conditions. Any approach to analysis and design may be used that yields a building of reliable stability in the prescribed design earthquake loads and conditions. The approach shall be rational, shall be consistent with the established principals of mechanics, and shall use the known performance characteristics of materials and assemblages under reversing loads typical of severe earthquake ground motions.

Exception: Further consideration of the structure's seismic performance can be waived by the Enforcement Agent if both the engineer-of-record and peer reviewer(s) conclude that the structural system can be expected to perform at least as well as required by this division's provisions without completing an analysis of the structure's conformance to these requirements. A detailed report shall be submitted to the responsible Enforcement Agent that presents the reasons and basis for this conclusion. This report shall be prepared by the engineer of record. The peer reviewer(s) shall concur in this conclusion and affirm to it in writing.

1648A.2 The approach, models, analysis procedures, assumptions on material and system behavior, and conclusions shall be peer reviewed in accordance with the requirements of Section 1649A and accepted by the peer reviewer(s)

EXCEPTIONS:

1. The enforcement agency may perform the work of peer review when qualified staff is available within the jurisdiction.
2. The enforcement agency may modify or waive the requirements for peer review when appropriate.

1648A.2.1 The approach used in the development of the design shall be acceptable to the peer reviewer(s). Approaches that are specifically tailored to the type of building, construction materials and specific building characteristics may be used, if they are acceptable to the independent peer reviewer(s). Section 1648A.3 provides several approaches that may be considered. The following conditions apply to whatever approach is selected:

1648A.2.1.1 If load (e.g., R ,β) factors, capacity reduction factors (e.g., Φ), or measures of inelastic deformation capability (e.g., IDR_L, μ_L ,rotation θ_L) are used, the basis for their use and the specific values assigned shall be assessed and supported in a consistent manner;

1648A.2.1.2 Where dynamic time history analysis is used, at least three distinct representative records with simultaneous loadings in different directions, as appropriate, shall be used in the analysis. The maximum response parameter of interest shall be used for design.

1648A.2.1.3 When an elastic analysis approach is adopted, the stiffness characteristics for the elements of the elastic model should be representative of the inelastic behavior at: the maximum response for the strength degrading materials; and, the nominal strength deformation for non-degrading materials. The following items are given for consideration:

1. For reinforced concrete frame elements, and reinforced concrete and masonry shear wall elements this stiffness may be taken as one-half of that of the gross section or that of the cracked section. A more appropriate value may be used if justified by analysis.
2. Steel framing and bracing elements are to have their elastic section stiffness.
3. Steel framing elements encased in reinforced concrete are to have the composite section stiffness which may be taken as 1.3 times the concrete gross-section stiffness, and beam-column joints may be assumed to be rigid.
4. Framing elements shall have model lengths equal to the clear span length, or have a suitable rigid element

representation of the joint configuration.

5. If framing element connections and/or supports are not fully rigid, then these shall be modeled as springs.

6. The representation of foundation flexibility shall be included when it results in more than a 25% reduction in the assumed full fixity of supported elements. This includes the effects of both rotational and horizontal deformations and sliding.

1648A.2.1.4 Reliable capacities shall be used for all elements, consistent with the fundamental behavior of the element and/or system under reversing loads at the design level of earthquake loads.

1648A.2.1.5 The value of the earthquake loading of an element need not exceed the force action induced in the element when the inelastic structure is displaced due to the prescribed ground motions, and the elements are assigned their probable strength values.

1648A.2.1.6 All nonstructural elements that can effect life-safety shall be shown to have acceptable behavior in the design loadings. For structural elements not considered as part of the lateral load resisting system the requirements of Section 1644A.13 are sufficient to meet this requirement.

1648A.2.2 The ground motion characterization used for Method B shall be consistent with those required by 1643A.8. Where response spectra are used, they may be determined from a probabilistic site hazard analysis, or as the standard spectrum of Figure 16A-3, scaled by the factor H as determined in 1643A.8 Where the importance factor is greater than 1, the Section 1643A.8.2 Exception 1 ground motion used shall include consideration of the importance factor; for response spectrum analysis use HI in place of H as the scaling factor.

1648.2.3 Whatever evaluation or analysis method is used in meeting the requirements of Section 1648A, the designer shall, unless the exception of Section 1648A.1 applies, at a minimum:

1648A.2.3.1. Identify all elements and systems (both vertical and horizontal) that are subject to the response loads and deformations due to the specified maximum expected earthquake ground shaking. Elements include: beams, columns, joints, connections, walls, diaphragms, construction joints, pre-cast element joints, exterior panel connections, bracing, diaphragms, collectors, diaphragm-to-wall or frame connection and foundations.

1648A.2.3.2. Identify the vertical elements (e.g., walls, frames, braced frames, in-filled frames, moment frames, etc.) that will participate in the lateral load resisting system.

1648A.2.3.3. Identify the horizontal or nearly-horizontal elements that form the diaphragm systems that inter-connect the vertical elements, along with the chords, drags or collector elements, and connections to the vertical systems, and the internal connections within the diaphragm (pre-cast planks, metal decking, bracing systems, pour-strips for prestressed slabs, etc.).

1648A.2.3.4. Identify the foundation system supporting the lateral load resisting system including all connections and the means of resisting the actions of overturning moment and sliding.

1648A.2.3.5. Assign the expected strength level to all elements for all of their possible modes of yielding or failure. For reinforced concrete use nominal capacity. For structural steel use either 1.7 times allowable stress capacity, or the nominal capacity from LRFD. For all other materials use either 1.7 times allowable stress capacity, or estimated strength from tests and/or existing research results.

1648A.2.3.6. Assign the effective elastic stiffness for all elements for each type and directional sense of action (flexural, shear, torsion, axial) that the element shall resist. The effective stiffness should be the best estimate of the secant stiffness at the development of the element strength representing the onset of the constant yield threshold.

1648A.2.3.7. Assign the element deformation behavior beyond the development of the strength or constant yield threshold for each mode of failure or yielding. Identify elements having a sudden brittle or buckling mode of failure. The effects of reversed cycles of loading should be considered to evaluate the degree of strength degradation and/or the pinching of the shape of the hysterisis loop. The deformation behavior may be in the form of load-deformation curves, allowable inelastic demand ratio (IDR_L) values, or allowable ductility demand (μ_L) values, or maximum allowable strain values ε_L or allowable rotation values θ_L. The classification of the elements

as “ductile”, “limited-ductile”, or “non-ductile” may be a part of the element deformation behavior description.

1648A.2.4 Prior to implementation, the procedures, methods, material assumptions and acceptance/rejection criteria proposed by the engineer will be peer reviewed as provided in Section 1649A.

1648A.2.5 The conclusions and design decisions shall be reviewed and accepted by the peer reviewer(s).

1648A.3 Any method of analysis meeting the requirements of Sections 1648A.2 and 1648A.3 may be used, subject to acceptance by the peer reviewer(s). Among those that can be used are the following types of analysis and assessment provisions, if the specific characteristics of the structure warrant their use:

1. Equivalent stiffness (or substitute structure) methods
2. Inelastic demand ratio methods
3. Push-over or capacity spectrum methods
4. Inelastic time history methods

Section 1649A-PEER REVIEW REQUIREMENTS

1649A.1. General: Independent peer review is an objective technical review by a knowledgeable reviewer(s) experienced in the structural design, analysis, and performance issues involved. The reviewer(s) shall examine the available information on the condition of the building, the basic engineering concepts employed, and the recommendations for action.

1649A.2. Timing of Independent Review: The independent reviewer(s) shall be selected prior to initiation of substantial portions of the design and/or analysis work that is to be reviewed, and review shall start as soon as practical after Method B is adopted and sufficient information defining the project is available.

1649A.3. Qualifications and Terms of Employment: The reviewer shall be independent from the design and construction team.

1649A.3.1 The reviewer(s) shall have no other involvement in the project before, during, or after the review, except in a review capacity.

1649A.3.2 The reviewer(s) shall be selected and paid by the owner and shall have technical expertise in repair of buildings similar to the one(s) being reviewed, as determined by the responsible Enforcement Agent.

1649A.3.3 The reviewer (or in the case of review teams, the chair) shall be a California licensed Structural Engineer who is familiar with the technical issues and regulations governing the work to be reviewed.

1649A.3.4 The reviewer shall serve through completion of the project and shall not be terminated except for failure to perform the duties specified herein. Such termination shall be in writing with copies to the Enforcement Agent, Owner, and the engineer of record. When a reviewer is terminated or resigns, a qualified replacement shall be appointed within ten (10) working days

1649A.4. Scope of Review: Review activities shall include, where appropriate, available construction documents, observations of the condition of the structure, all inspection and testing reports, including methods of sampling, analyses prepared by the engineer of record and consultants, and the retrofit or repair design. Review shall include consideration of the proposed design approach, methods, materials and details.

1649A.5. Reports: The reviewer(s) shall prepare a written report to the owner and responsible Enforcement Agent that covers all aspects of the review performed, including conclusions reached by the reviewer. Reports shall be issued after the schematic phase, during design development, and at the completion of construction documents, but prior to their issuance for permit. Such reports should include, at the minimum, statements of the following:

1649A.5.1 Scope of engineering design peer review with limitations defined.

1649A.5.2 The status of the project documents at each review stage.

1649A.5.3 Ability of selected materials and framing systems to meet performance criteria with given loads and configuration.

1649A.5.4 Degree of structural system redundancy and the deformation compatibility among structural and nonstructural elements.

1649A.5.5 Basic constructibility of the retrofit or repair system.

1649A.5.6 Other recommendations that would be appropriate to the specific project.

1649A.5.7 Presentation of the conclusions of the reviewer(s) identifying any areas which need further review, investigation and/or clarification.

1649A.5.8 Recommendations.

1649A.6. Responses and Corrective Actions: The engineer of record shall review the report from the reviewer(s) and shall develop corrective actions and other responses as appropriate. Changes observed during construction that affect the seismic resisting system shall be reported to the reviewer in writing for review and recommendations.

1649A.7. Distribution of Reports: *All reports, responses and corrective actions prepared pursuant to this section shall be submitted to the responsible Enforcement Agent and the owner along with other plans, specifications and calculations required. If the reviewer resigns or is terminated by the Owner prior to completion of the project, then the reviewer shall submit copies of all reports, notes, and correspondence to the responsible Enforcement Agent, the owner, and the engineer of record within ten (10) working days of such termination.*

1649A.8. Design Professional of record: *The design professional of record shall retain full responsibility for the retrofit decisions and design as outlined in the California Business and Professional Code, Chapter 3, Division 3 and Chapter 7, Division 3.*

1649A.9. Resolution of Differences: *If the engineer of record does not agree with the recommendation of the reviewer, then such differences shall be resolved by the responsible Enforcement Agent.*