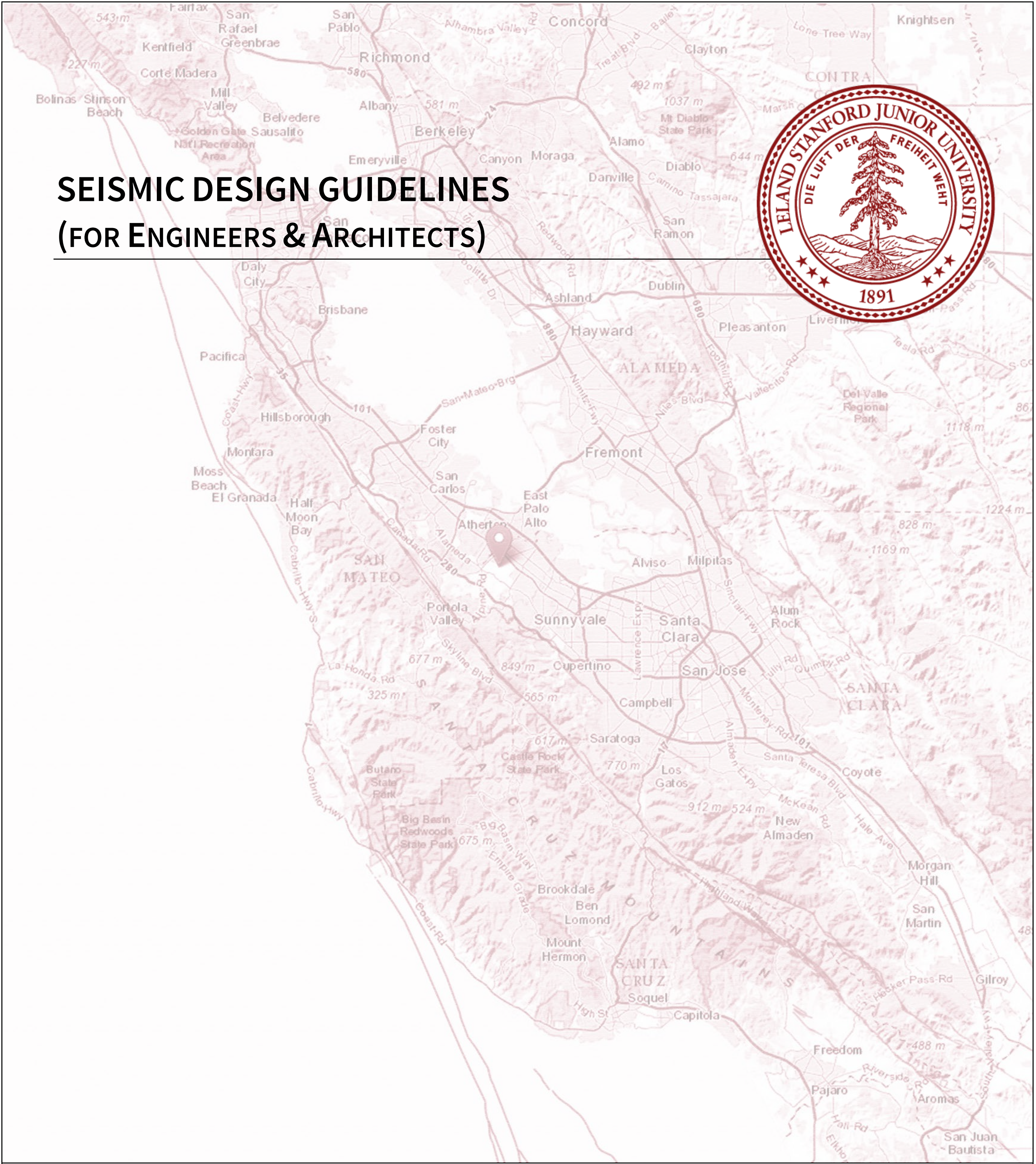
SEISMIC DESIGN GUIDELINES
(FOR ENGINEERS & ARCHITECTS)



Stanford | Land, Buildings & Real Estate

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These guidelines are to be applied in conjunction with The Project Delivery Process at Stanford Department of Project Management (DPM) August 2010, Version 2.0

PREFACE

The Stanford ***Seismic Design Guidelines (for Engineers & Architects)*** serve as a supplement to the Department of Project Management's ***Project Delivery Process***, and was developed in collaboration with the Seismic Advisory Committee (SAC), a committee within LBRE that supports the University's seismic program and helps assure consistency in the application of the guidelines on Stanford projects. The use of these guidelines is directed, but not limited, to consulting engineers and architects involved in the design of new campus buildings and renovations requiring approval by the Stanford Board of Trustees or as recommended by the Office of the Vice President for Land, Buildings and Real Estate.

In 1987, Stanford adopted a performance-based design approach to seismic engineering in recognition of the potential consequences of a major earthquake in Northern California. While the design of campus buildings must meet the minimum life safety provisions prescribed by code, performance-based design provides an added measure of structural design analysis to help achieve specific performance goals and to ensure that the design of campus buildings keeps pace with the most current knowledge base of seismic engineering and testing.

A key part of performance-based design at Stanford incorporates the use of Structural Design Peer Review early in the design process and through the finalization of construction documents. The peer reviewer reports to Stanford's project manager and assists the engineer of record in ensuring that the latest seismic engineering practices are addressed, that viable alternative options are explored, and that the design detailing is comprehensive and sound. SAC oversees and facilitates the implementation of the peer review process for LBRE.

Stanford's fundamental goal for these guidelines is to ensure that each building's evaluation and design reaches its prescribed level of seismic performance while at the same time controlling construction cost. The challenge of achieving Stanford's performance goals within approved budgets is facilitated by the design of buildings with little or no lateral system irregularities as defined by seismic codes. Design engineers and architects must address these considerations when proposing structural design options to Stanford.

Because codes and practices are continually evolving, the content of this document will be periodically annotated. Users of the guidelines should check the DPM website to ensure they are using the most up-to-date version, and to consult with SAC when codes are in transition.

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1. INTRODUCTION

The purpose of the ***Seismic Design Guidelines (for Engineers & Architects)***, also referred to as the guidelines, is to document Stanford's approach for the analysis and design of new and existing facilities on campus. The guidelines are based on the concept of performance-based design. Design professionals working on Stanford projects are required to follow these guidelines as a part of their contractual obligations to Stanford. Specifically, the guidelines set a facilities classification and related performance levels for Stanford buildings to address the following three earthquake-risk, reduction objectives:

1. Protect life safety of the Stanford community
2. Secure Stanford's critical infrastructure and facilities
3. Resume core teaching and research programs

1.1 SEISMIC RESILIENCY

Stanford's overall seismic performance goal is to improve the seismic resiliency of the campus. Seismic resiliency is defined as:

"The capability to sustain functionality and recover from losses generated by seismic events "

This encompasses all aspects of recovery, including the retrofit of existing buildings and construction of new buildings so that they can better withstand seismic forces with less damage, as well as the rapid evaluation and repair of buildings following a seismic event.

1.2 CODES AND STANDARDS

These guidelines supplement and augment the requirements of prevailing codes and standards required by law and by local jurisdictions. The guidelines shall not supersede or pre-empt any legal requirement, building code, or industry standard. Medical facilities governed by OSHPD (Office of Statewide Health Planning and Development) are not addressed by these guidelines. The approach presented in these guidelines is based on, but not limited to, the following codes and standards (or their latest update) from the American Society of Civil Engineers (ASCE) and other relevant code regulatory bodies:

- 2019 California Building Code (CBC)
- ASCE 7-16 *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*
- ASCE 41-17 *Seismic Evaluation and Retrofit of Existing Buildings*

Project teams will need to consider their respective schedules to determine applicability of the appropriate code.

The guidelines recognize that the knowledge, science, and practice of structural and earthquake engineering are evolving. The guidelines do not preclude an engineer from utilizing other analysis and design approaches that may better address the specific structural characteristics of a building. However, all evaluation, analysis, design considerations, and assumptions, should be clearly delineated in the design documents.
Stanford typically seeks building configurations with a continuous lateral load-resisting path with regular distributions of mass and stiffness in plan and elevation. Program and architectural design requirements

may, however, result in buildings with irregular load systems. The design team shall present the rationale for such irregular building configurations to SAC for Stanford's approval as part of the peer review process.

In addition to regular building configurations, Stanford seeks lateral system components known to provide a higher level of performance. While many structural systems are allowed by code, it is generally accepted that certain systems deliver performance that is more reliable. For example, buckling resistant braced frames (BRBFs), concrete shear walls and steel moment frames, deliver more reliable performance than special concentric braced frames and plywood shear walls. Stanford therefore recommends the use of lateral structural systems that have demonstrated improved seismic performance in buildings. Innovative structural systems can be proposed, but they need to be supported by sound analytical research and testing and be accepted by the Building Inspector.

While these guidelines emphasize structural engineering aspects of seismic design, there is information contained in the guidelines that is critical for architects and MEP engineers to know as well. In general, Stanford expects a high-level standard of care from all design professionals and members of the project team. The guidelines encourage and support constructive communication and collaboration between the project manager and all team members. In addition, the Seismic Advisory Committee (SAC) was established to assist the project manager and the entire project design team when these objectives are at issue and/or when guidance is needed.

1.3 GROUND MOTION

Stanford developed risk-based, site-specific spectra for the evaluation and design of its buildings and facilities. For this purpose, the main campus has four (4) zones for which previous spectra have been updated to ASCE 7-16 Earthquake Spectra (MCE_R), Design Earthquake Response Spectra (DE), and ASCE 41-17 BSE-1N and BSE-2N spectra and should be used by consulting engineers. For the assessment and retrofit of existing buildings, Stanford considers BSE-1N and BSE-2N, which are equivalent to ASCE 7-16 MCE_R and DE, appropriate.[1] That is, the same spectra are used for new as well as existing buildings. This is based upon a design approach where ground motion levels are not reduced, but instead acceptable building performance levels are lowered for existing buildings compared to new buildings.

The values and graphs of all the spectra are provided in **Appendix A**. Further provisions on the site-specific spectra are provided in Section 3. A technical report on the development of the Stanford Site-Specific Ground Motion and the Campus Zonation study is documented in:

2019 Update to the Site-Specific Seismic Hazard Analyses and Seismic Design Ground Motions for Stanford University, Stanford, California (Final Report). Lettis Consultants International (LCI), 30 October 2019.

1.4 SEISMIC ADVISORY COMMITTEE (SAC)

The Seismic Advisory Committee (SAC) supports and guides the university's structural/seismic objectives in mitigating damage and the potential effects of a major earthquake on the Stanford campus. The committee

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[1] ASCE 41-17 includes the definition of two sets of earthquake hazard parameters. The first, defined as BSE-1E and BSE-2E are intended to be used in performance analyses for existing buildings. These spectra are anchored on lower return period times (i.e., 225-year and 975-year, respectively) than the ones for new buildings. The second, defined as BSE-1N and BSE-2N, are equivalent to the MCE_R and DE of ASCE 7-16. The "N" suffix indicates new building standards' equivalent hazard level.

consists of Stanford project managers and planners, along with professional support from earthquake engineering consultants. SAC engages the assistance of other design professionals and earthquake experts as warranted. The committee plays a key role in coordinating the implementation of the guidelines on Stanford capital projects, and facilitating communication related to seismic issues. The SAC's primary responsibilities are in the following areas:

- Seismic risk analysis and capital planning guidance;
- Seismic resiliency guidance;
- Attend structural presentations by design teams regarding projects at the beginning of the design phase. Presentation to discuss the structural approach as well as issues related to the Class 2 and Class 3 performance. SAC to comment and provide direction to the design teams;
- Development and administration of the ***Seismic Design Guidelines*** including performance levels, facilities classifications, and guidelines interpretation;
- Recommendation for peer reviewer and peer review oversight;
- Resolution of project-specific issues and decision-making support on capital projects, which cannot be resolved satisfactorily by the project team and project manager;
- Staff education and training of structural engineering/seismic trends, changes, codes, seismic risk analysis, and seismic performance of buildings and structures;
- Earthquake preparedness and awareness;
- Post-earthquake response, recovery and safety inspections of buildings.

1.5 Seismic Database (EQDBASE)

Stanford has assembled basic structural and seismic information on most campus buildings in a database called EQDBASE. This database uses a color classification system as an indicator of each building's seismic status, which is based on the building's expected overall earthquake performance without respect to occupancy, use or content. The yellow, orange and red classifications correlate with performance that does not meet Stanford's minimum seismic performance objectives and the level of earthquake damage expected during major and moderate earthquakes. A detailed discussion of the performance objectives is presented in Section 2.

The following chart indicates the expected level of damage for the yellow, orange and red classifications:

Color Classification		**RED**		**ORANGE**		**YELLOW**	
Earthquake Severity		Moderate	Major	Moderate	Major	Moderate	Major
Level of EQ Damage	Minimal					🟨	
	Moderate			🟧			🟨
	Severe	🟥	🟥		🟧		

The color classifications are defined as follows:

Green - These buildings meet or exceed Stanford's minimum seismic performance goals (Class 4 for existing; Class 3 for new). A seismic evaluation or upgrade is not indicated unless a major change to the building (e.g., use or occupancy) is anticipated. Typically, newer buildings (i.e., constructed after 1992) are classified as green.

Yellow - These buildings have a few structural components that do not meet Stanford's minimum Class 4 seismic performance goals but are expected to perform satisfactorily during smaller to moderate earthquakes. Retrofitting of yellow buildings is generally undertaken as a result of major program changes.

Orange - These buildings have some structural components that do not meet Stanford's minimum Class 4 seismic performance goals but are expected to perform adequately during smaller earthquakes. Orange buildings warrant a moderate priority for seismic retrofit.

Red - These buildings have many significant structural components that do not meet Stanford's minimum Class 4 seismic performance goals and pose a significant seismic performance concern. These buildings warrant a high priority for seismic retrofit.

White - This classification is a temporary color designation. The minimum information needed to determine the respective seismic color classification includes structural system, year built, number of stories and seismic rating.

Brown - This classification consists of buildings that are considered insignificant in terms of seismic performance (e.g., wood frame construction less than 3,000 gross square feet), trailers and modular facilities that generally do not pose a seismic concern in an earthquake. If Stanford has definitive seismic information on a building that would otherwise be brown, the building is shifted to the yellow, orange, red, or green classification.

Gray - These buildings are currently not addressed by SAC. This category generally includes off-campus leased buildings (quads 20 and 90), Department of Energy facilities at SLAC (quad 40), or Stanford Hospital functions (primarily quad 7). A gray classification has no bearing on a building's actual performance level.

The color classifications should not be viewed as being the product of a detailed structural evaluation. Rather, they are intended to reflect the anticipated seismic performance of the building based on current information. A building's color classification is subject to change as new information is obtained through additional structural analysis, code changes, and evolving engineering practices and standards.

2. PERFORMANCE OBJECTIVES

Stanford University has established goals for building performance levels during earthquakes in order to assure life safety, limit property damage and to improve the seismic resilience of the campus. These performance levels reflect Stanford's expectation of both the level of damage to a facility and the ability to continue operations. The levels account for both structural and non-structural elements. The performance level is for the building as a whole (and not for particular components) and follows similar evaluation concepts and performance criteria as those indicated in ASCE 41, or other structural standards addressing earthquake performance.

The design team (and structural peer reviewer) shall make at least one presentation to SAC regarding how the seismic performance objectives indicated in this section are being addressed. This should occur early in the design and prior to completion of schematic design. It shall include the following:

1. The Stanford performance goal being used for the design of the facility.
2. Description of the overall lateral system for the building and a summary of why it was chosen.
3. Provide a summary of the type of structural analysis used to show the building meets the performance objectives.
4. Describe any measures that have been taken to improve seismic performance.
5. Identify any Irregularities or other characteristics that may affect seismic performance.
6. Identify any nonstructural elements such as cladding and tile roofs that could affect the seismic performance.
7. Describe any measures taken to address these nonstructural elements.
8. For Class 3 buildings, provide a summary of the enhancements that might be needed to bring the building up to Class 2 and their impact on the project. This should include costs as well impacts on architecture.

Following the meeting, SAC will determine if additional SAC presentations are required.

2.1 BUILDING PERFORMANCE LEVELS

Stanford has identified five building performance levels as described in this section:

- Level 1 – Immediate Occupancy
- Level 2 – Limited Damage
- Level 3 – Life Safety/Seismic Resiliency
- Level 4 – Life Safety
- Level 5 – Collapse Prevention

Stanford has also identified four building non-structural performance levels:

- Level A – Operational
- Level B – Position Retention

- Level C – Life Safety/Seismic Resiliency
- Level D – Hazards Reduced

In addition, Stanford has identified four facilities classifications that are tied to the performance levels and help guide the building's performance objectives.

Facility classifications are associated with structural and non-structural system performance objectives and are based on the type of occupancy housed in the facility, and how critical it is to emergency response and/or university operations. The facilities classifications include:

- Class 1 – Facilities Critical to Emergency Response
- Class 2 – High Seismic Resiliency
- Class 3 – Enhanced Seismic Resiliency
- Class 4 – Basic Seismic Resiliency

All performance levels and facilities classifications are subject to the following two earthquake hazard levels: MCE_R/BSE-2N and DE/BSE-1N, which are used for performance-based evaluations and designs of Stanford buildings. The definitions of the MCE_R/ BSE-2N and DE/BSE-1N are provided in Section 3.

Stanford's minimum seismic performance objectives are included in **Table 1**. Table 1 summarizes these objectives for each of Stanford's four facilities classifications, and describes the implied relationship between the facilities class, the expected levels of performance, and the anticipated damage for the two earthquake levels DE/BSE-1N and MCE_R/BSE-2N.

Table 1: Minimum Seismic Performance Objectives

Facilities Class	Earthquake Demand Level	Performance	Seismic Performance/Damage Description					Expected Performance
			Very Light	Light	Moderate	Extensive		
			Immediate Occupancy	Limited Damage	Life Safety / Seismic Resilience	Life Safety	Collapse Prevention	
Class 1 Facilities Critical to Emergency Response	**BSE-1N**	**1A**	■					• Reoccupy very shortly after EQ (within hours) • May be some disruption to normal operations
	BSE-2N	**2B**		■				• Reoccupy shortly (within one day) after EQ • May require minor repairs • May be some disruption to normal operations
Class 2 New Building High Seismic Resilience	**BSE-1N**	**2B**		■				• Reoccupy shortly after EQ (1 - 2 months) • May require some structural repairs
	BSE-2N	**3C**			■			• Medium term closure (6 - 9 months), or have limited access to allow for repairs
Class 3 New Building Enhanced Seismic Resilience	**BSE-1N**	**3C**			■			• Medium term closure (6 - 9 months) • Performance should be comparable to that of a typical CBC building without structural irregularities
	BSE-2N	**4D**				■		• Long term closure (9 - 15 months) • Performance should be comparable to that of a typical CBC building without structural irregularities
Class 4 Existing Building Basic Seismic Resilience	**BSE-1N**	**4D**				■		• Extended closure (1 - 2 years) • Life safety maintained but may not be repairable damage
	BSE-2N	**5D**					■	• Extended closure (1 - 2 years) • Life safety maintained but will likely not be repairable damage

Life safety is a priority for each of Stanford's five building performance levels. The objective of the university's earthquake risk reduction program is to retrofit, close, or demolish any building that does not meet a minimum level 4 performance under BSE-1N or level 5 under BSE-2N. New Stanford buildings shall be designed to achieve a performance level of 1, 2, or 3 for the indicated Earthquake Demand Level, subject to the building's facility classification, as described in section 2.5 below. Performance levels 4 and 5 are applicable to existing buildings only (excluding a new class 3 building under BSE-2N).

For comparison purposes, the estimated performance of a new building subject to the CBC Safety Earthquake-1 (DE/BSE-1N) level of shaking is also provided in the performance level descriptions, below. They also include a comparison to ASCE 41 standard performance levels for both structural and non-structural systems. ASCE 41 defines structural performance levels as 1 through 5 with 1 being the highest level, and non-structural levels as A thru E with A being the highest, and E meaning not considered.

Level 1A - Immediate Occupancy: This level anticipates **very light-to-light** damage. The basic vertical and lateral force resisting systems of the building retain most of their pre-earthquake strength and stiffness. Structural and non- structural damage is minimal. Some disruption to normal operation may be expected. Equipment, while secured, may not be working immediately after the earthquake, but should be restored easily. Essential services such as utilities may need to be provided from standby sources. Although some minor structural and non-structural repairs may be required, the building should remain functional, and occupants should be able to remain in the building.

Level 1 anticipates much less damage than a CBC-designed building under the design earthquake motions. It will generally correspond to ASCE 41 performance level 1-A (where 1 indicates the structural performance level and A the nonstructural performance level).

Level 2B - Limited Damage: Damage is generally within the **light** category. Structural and non-structural repairs may result. Buildings can be occupied but may not be fully operational and may require limited repairs. Structural and non- structural damage is minimal, and occupants should be able to occupy the building safely, after inspections are completed and limited repairs assessed or undertaken. Equipment may not be fully working, but essential services such as utilities should be available shortly after the earthquake, provided possibly from outside standby sources.

Level 2 anticipates less damage than a CBC-designed building under the design earthquake motions. It will generally correspond to ASCE 41 performance level 2-B.

Level 3C - Life Safety/Seismic Resilience: In this level, damage is within the **light-to-moderate** category. Structural and non-structural repairs may be expected but should be minimal. The building shall be life safe but may have limited access to allow for repairs. Non-structural components, which may be damaged, should not result in a life safety hazard.

Level 3 performance is comparable to a CBC-designed building without major irregularities. The performance of a Stanford building with irregularities shall have a similar performance to that of a non-irregular building that meets a standard CBC design. It will generally correspond to ASCE 41 performance level 3-C.

Level 4D - Life Safety: Damage may range from **moderate-to-extensive**. Residual strength and stiffness of structure may be reduced but still provide a margin of safety against collapse. Non-structural elements are likely to be extensively damaged but are generally restrained to prevent collapse. The building would need to be evacuated for repairs. In some cases, repairs may not be economical, and the building may need to be demolished and replaced. It will generally correspond to ASCE 41 performance level 4-D.

Level 5D - Limited Safety: This level indicates **extensive damage** to the facility where the margin against collapse has been significantly reduced. Little residual stiffness and strength remain, but load-bearing columns and walls function and prevent any collapse mechanism from forming. Some exits may be blocked. The building would need to be evacuated following an earthquake because of the risk of collapse from aftershocks. The building is likely to be demolished because repairs would not be economical. It will generally correspond to ASCE 41 performance level 5-D.

2.2 NON-STRUCTURAL COMPONENTS

It is important for the entire design team to review the seismic performance of non-structural components and assist with the selection and design of these components so that they will perform well during a seismic event. The non-structural ASCE 41 D performance levels described in the previous section apply only to typical components. However, some components are generally considered more critical to life safety and seismic resilience and should not fall below the ASCE 41 C performance level. This includes the following:

1. Stairs and Fire Escapes
2. Plumbing
3. Glazing
4. Cladding
5. Piping

The design team should review these elements and determine how best to achieve at least a C performance level. This may include items such as additional seismic bracing, flexible connections and larger seismic drift joints. At locations where a C performance level is difficult or cost prohibitive to achieve, the design team shall notify SAC.

2.3 BUILDING FACILITIES CLASSIFICATION

Prior to the start of the design of a new building or the retrofit design of an existing building, DPM establishes the classification for a facility based on the primary function of the building and the post-earthquake need of the space and program housed in the building. The DPM project manager should consult with SAC in making that determination. It is expected that most new buildings will fall under the Class 3 category and most retrofit buildings will fall under the Class 4 category.

Class 1 - Facilities Critical to Emergency Response (New and Existing Buildings):
These facilities generally house functions or services that are critical during and immediately after a disaster such as an earthquake. Examples include fire and police stations, critical medical treatment facilities, communications and emergency response centers.

The performance objective for the buildings in Class 1 should be commensurate with Level 1A performance (i.e., Immediate Occupancy), which should allow these buildings to be utilized very shortly after a DE/BSE-1N. Level 1A performance is expected for structural elements, non-structural elements, and equipment. In order for the building to be operational, some utilities may need to be backed up by standby sources. Under a MCE_R/BSE-2N earthquake, a Level 2B performance is expected.

Class 2 – High Seismic Resiliency (New and Existing Buildings):
Continuation of the academic/research program at Stanford after a seismic event requires a minimum amount of space in virtually all of the different types of facilities on campus. To help ensure the university has enough stock of functioning buildings after a major earthquake, some of the new buildings on campus will be designed to meet Class 2. Of particular importance are those buildings that house functions such as research labs and student housing, which are very important to the seismic resiliency of the campus. SAC may also consider Class 2 for buildings where the additional construction cost to get from Class 3 to Class 2 performance is not significant. As new buildings are brought forward for design, the SAC will review and decide which ones are good candidates for Class 2.

The performance objective for Class 2 buildings should be commensurate with Level 2B performance (i.e., Limited Damage) under a DE/BSE-1N earthquake and Level 3C (i.e., Enhanced Safety) under a MCE_R/BSE-2N earthquake, which permits building occupancy; however, operations may be limited and repairs may be required.

To reach this performance level, the design team is expected to provide a lateral system, a building configuration, and an attention to design that control the amount and type of damage. In addition, protection of non-structural components and equipment should be addressed.

Class 3 – Enhanced Seismic Resiliency (New and Existing Buildings):
This category is utilized for all buildings that do not fall into either Class 1 or Class 2. This is considered the minimum class for new buildings.

The performance level for Class 3 buildings is expected to be commensurate with Level 3C (i.e., Enhanced Safety) under a DE/BSE-1N earthquake. Under a MCE_R /BSE-2N earthquake, the performance level should be at Level 4D. As a basis of comparison, the life safety performance target assigned to this class should be similar to the performance of a CBC-designed building without any major irregularities. The design team is expected to carefully consider seismic performance issues when selecting a lateral system and building configuration. Performance of non-structural components and equipment should be commensurate with the performance of structural components.

Class 4 – Basic Seismic Resiliency (Existing Buildings):
This category is utilized for all **existing** buildings, which do not fall into the previous classes. This is the minimum performance level needed to achieve life safety.

The performance level for Class 4 buildings under a DE/BSE-1N earthquake demand level should be commensurate with Level 4D (i.e., Basic Safety); under a MCE_R/BSE-2N earthquake demand, the performance level should be commensurate with Level 5D (i.e., Limited Safety).

2.4 BASIC SAFETY PERFORMANCE LEVELS

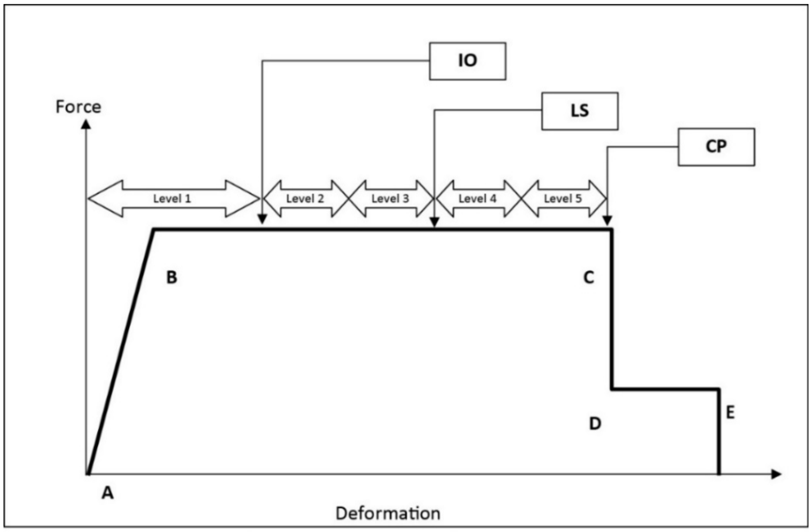
The building performance levels presented above include structural system components, non-structural components, and protection of equipment and content. Non-structural components include elements such as partitions, stone and heavy façade ornaments and screens, glass curtain walls, parapets, roof tiles and other covering, any attached prefabricated enclosures, suspended ceilings, light fixtures, etc. Equipment includes all mechanical and electrical equipment, fire protection equipment, piping (all kinds), standby power generators, fume hoods, tanks, cold rooms, and other attached or unattached elements necessary for the function of the building. Content consists of material and equipment that are needed by the building users in order to exercise their function in the building.

A Basic Safety performance level should address the performance of the vertical and lateral systems, non-structural components, and protection of equipment and content. Particular attention should be given to elements whose failure may constitute a life safety hazard to occupants or surrounding pedestrians, as well as obstruct ways of egress from the building. Given the wide variety of non-structural components, this may require that the project manager and design professionals establish an understanding of the proposed scope of work related to non-structural components at the outset of the project. Non-structural items may be a minor issue in some buildings (e.g., standard dorm construction), but a major issue in other buildings (e.g., bioengineering labs or sport/performance venues). They are also a source for secondary hazards such as fire following an earthquake or release of hazardous material. Section 8 of the guidelines provides more information on non-structural components, equipment and content.

The performance of non-structural components, equipment and content for achieving Level 1 and Level 2 is particularly important. Programmatic requirements may also warrant that a portion of a building be constructed to a higher performance level than the rest of the building. For example, the basement or first floor of a building may be designed to a higher performance level if it houses a critical function such as a data center or a communications hub.

ASCE 41 provides additional descriptions of damage levels that are similar to the ones described above for both structural and non-structural systems. In particular, the curve shown in Figure 1 identifies component deformation limits for typical ductile behavior. The structural engineer may use this curve along with the component tables located in ASCE 41 when evaluating <u>deformation-controlled</u> elements. When evaluating the performance of **existing** buildings, the engineer may need to evaluate the performance of <u>force-controlled</u> elements. In this case, the lower bound strength shall not be exceeded when the building is subjected to the gravity plus design level earthquake loading.

Figure 1: Deformation Limits vs. Earthquake Performance - Levels 1 through 5



IO: Immediate Occupancy; **LS:** Life Safety; **CP:** Collapse Prevention

2.5 PERFORMANCE EVALUATION

When evaluating a building, the engineer of record (EOR) should determine the expected performance level of the **building** (structural components, non-structural components, and equipment) under the postulated earthquake levels DE/BSE-1N and MCE_R /BSE-2N. This determination should be based on a structural analysis of the building's lateral load resisting system and non-structural elements such as appendages, parapets, etc. (as described in the previous section).

New Building: For a new building, the performance should be based on an evaluation of the performance of individual building components such as shear walls, floor diaphragms, coupling beams, and collectors following standard design procedures. Performance of non-structural components and equipment should also be evaluated. When **all** of these elements meet a specific performance level, then the building is identified as meeting the performance level. Particular attention should be provided to irregular buildings to ensure proper and complete load path and to detailing that adequately deals with the irregularities.

As a point of reference, a Class 3 new building with a regular configuration (as defined by the CBC) and designed according to the 2019 CBC is **generally** expected to be at structural performance objective Level 3 under the DE/BSE-1N earthquake, and no worse than Level 4 under the MCE_R/BSE-2N earthquake level. However, in some instances the engineer may need to verify through analysis, the latter performance. In particular, a non-regular building (as defined by the CBC) or a building where the demand from the BSE-2N spectrum is significantly greater than the BSE-1N spectrum, a rigorous analysis, such as prescribed in ASCE 41, is required to make sure that the performance of the building would not be worse than Level 4 (under BSE-2N). In all cases, concurrence must be reached between the EOR and the peer reviewer (or SAC) regarding the appropriate analysis required for the building and the satisfaction of the performance levels. This is one of the main objectives of the peer review.

Existing Building: For an existing building, the performance evaluation should follow the same approach as for a new building (i.e., based upon the performance of individual structural components, non-structural components, and equipment). However, when evaluating a building for structural performance **Level 4 or Level 5**, the engineer should consider how far below a performance level a particular element fall. The engineer should also evaluate how critical the performance of a particular component is to the performance level of the building as a whole. Non-structural components should be evaluated for their risk to life safety (Level 4D). This evaluation typically involves parapets, screens, ornaments, ceilings, roof tiles, and means of egress. When a particular element (structural and/or non-structural) is not critical or if it falls only slightly below the minimum performance level, then the engineer may conclude that the performance level of the **building** as a whole still meets the performance level. In some cases, engineering judgment will be needed to determine how the specific performance of structural/non-structural components will factor in the overall building's performance level. In these instances, the engineer should work with the peer reviewer to develop a best estimate of the performance. Where uncertainty remains with regard to the performance level of the building as a whole, the structural engineer and peer reviewer may consent to perform a more detailed non-linear analysis of the building. In cases where the performance level is not assessed with certainty, the design team should inform the project manager of these issues. The project manager should seek advice from SAC to help resolve the matter of building performance.

3. EARTHQUAKE LEVELS AND LOAD CRITERIA

There are two levels of earthquake hazards to be used for performance-based evaluations and designs of Stanford buildings, which are represented by Risk Based Site-Specific Spectra:

- **DE/BSE-1N** (design earthquake/basic safety earthquake 1)
- **MCE$_R$ /BSE-2N** (Maximum Considered Earthquake/basic safety earthquake 2)

Further details on the ground motion to be considered for design are indicated below.

3.1 SITE-SPECIFIC GROUND MOTION ZONES

For defining the level of design ground motion, Stanford has developed risk-based site-specific response spectra. For this purpose, the campus has been divided into four zones, each with its own ground motion levels as indicated in Figure 2 below. The risk-based design response spectra for DE/BSE-1N and MCE$_R$/BSE-2N have been calculated on the basis of a site-specific ground motion response analysis to incorporate the effects of the near surface geology beneath the campus in the ground motion.[2] The seismic design ground motions were developed following the standards of ASCE 7-16 *Minimum Design Loads and Associated Criteria for Buildings and Other Structures* and ASCE 41-17 *Seismic Rehabilitation of Existing Buildings*.

ASCE 41-17 prescribes two sets of design ground motions: BSE-2N/BSE-1N, which are equivalent to ASCE 7-16 MCE$_R$/DE spectra, and BSE-2E/BSE-1E, which are lower ground motions with 975 and 475-year return periods. However, to be consistent with the evaluation criteria established in the performance-based design embedded in these guidelines, MCE$_R$/BSE- 2N and DE/BSE-1N are selected for use with all buildings. The rationale is that Stanford's ***Seismic Design Guidelines*** already establish lower performance criteria for existing buildings (i.e., Level 4 or Level 5). As a result, there is no need to reduce the ground motion further, compared to the one for which new buildings are designed. The site-specific seismic hazard study shows that the seismic design ground motions on campus are driven by the maximum earthquake on the San Andreas fault (**M** 8.0) (i.e., 84th percentile MCE), which is a repeat of the Great San Francisco Earthquake of 1906 because its ground motions are lower than the 2,475 year return period ground motions.

Response spectra for each of the DE/BSE-1N and MCE$_R$ /BSE-2N earthquake levels for Zones 0, 1, 2 and 3 are provided in Tables 4 to 7 and Figures 5 and 6 in **Appendix A**.

Design acceleration parameters as per ASCE 7-16, Section 21.4 are provided in Table 8 of **Appendix A** for all zones. The site-specific S_{DS} is taken as 90% of the maximum site-specific SA for periods between 0.2 and 5.0 sec. The S_{D1} parameter is the maximum T*SA for periods between 1 and 2 sec. S_{MS} and S_{M1} are 1.5 times S_{DS} and S_{D1}, respectively.

ASCE 7-16 also requires the calculation of the MCE$_G$ PGA, which is used in liquefaction analyses. The site-specific MCE$_G$ PGA is the lesser of the 2,475-year return period PGA (geometric mean) and the 84th percentile PGA (geometric mean). For all zones, the MCE$_G$ PGA is the site-specific 84th percentile PGA (geometric mean). (Refer to the LCI Report October 2019 for more details).

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[2] ***2019 Update to the Site-Specific Seismic Hazard Analyses and Seismic Design Ground Motions for Stanford University, Stanford, California (Final Report)***. Lettis Consultants International (LCI), 30 October 2019.

3.2 CONDITIONAL MEAN SPECTRA (CMS)

The CMS approach was developed for the purpose of using the results of a Probabilistic Seismic Hazard Analysis (PSHA) to develop input to the seismic evaluation of a structure utilizing dynamic response calculations. The approach provides a method for defining the ground motion response spectrum input to a structural response analysis, where the estimated response is linked to the PSHA result (the hazard curve for a spectral acceleration at a given period), and where the estimate of structural response is mean-centered (i.e., non-conservative). When design spectra are controlled by 84th percentile deterministic spectra, CMS may be advantageous if the period of the structure is known. The CMS conditioned to 84th percentile deterministic spectra represents a more realistic shape of an event likely to cause the 84th percentile ground motion at the target period. Note that the DRS_R spectra for all Stanford zones are controlled by the 84th percentile deterministic event for all period ranges.

Depending on the period of a specific facility on campus, the use of CMS may be more rigorous to use than the conventional spectra. When a structure is sensitive to a single or a few period ranges, a broad UHS may be overly conservative for design ground motions. ASCE 7-16 allows for the use of 2 or 3 CMS in place of a single design spectrum. These CMS, conditioned to the design spectra, instead of the broad DE spectrum, can be used to select input time histories, as they represent a more realistic response spectrum shape. However, the use of 2 or 3 CMS in place of a single design spectrum increases the number of non-linear dynamic analyses that must be done. The methodology for using the CMS can be found in Baker (2011).[3]

Additional Notes on the use of the site-specific design response spectra:

1. For longer period structures (say T>0.7 sec), the site response spectra are driven by the soil amplification.
2. In general, the site-specific design ground motions computed in this study are similar to ASCE 7-16 code-based ground motions for T>1 sec. At shorter periods, the site-specific spectra are controlled by the 80% minimums of ASCE 7-16. This is due to the use of ASCE 7-16, particularly its adoption of increased site factors.
3. For construction sites outside of the main campus, the design team should explain the methodology derived to determine the response spectra and compare to the sub-surface soil conditions to the one on the main campus. SAC can provide further guidance on the validity of the spectra outside the main campus.
4. The October 2019 LCI Report, providing the details of the site-specific hazard analysis and development of the Stanford ground motions, can be provided to consultants if needed.

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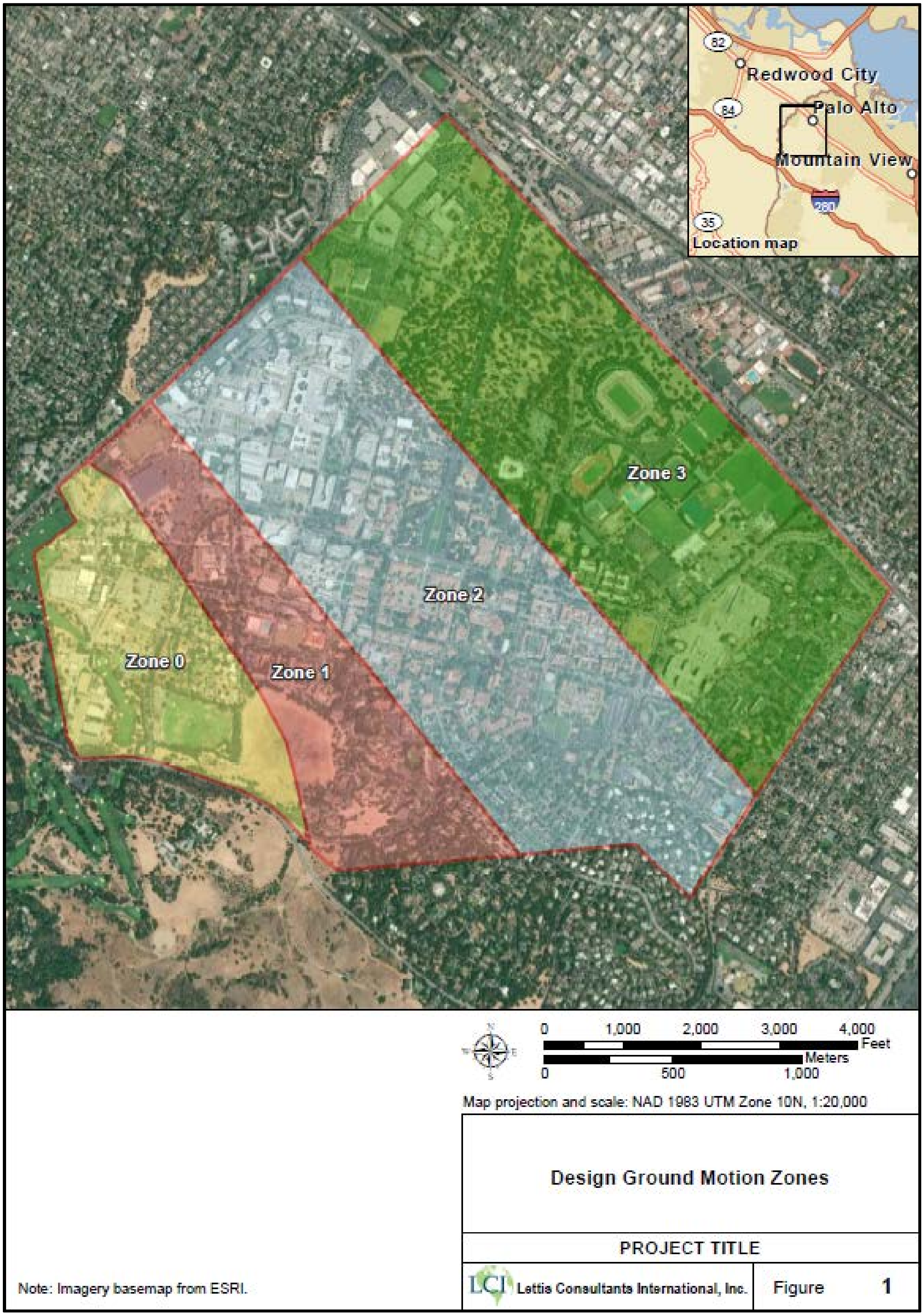
[3] Baker, J.W., 2011, *The Conditional Mean Spectrum: A Tool for Ground Motion Selection*, American Society of Civil Engineers, Journal of Structural Engineering, v. 137, p. 322-331.

Figure 2: Design Ground Motion Zones



3.3 DESIGN LOADS AND LOADING CRITERIA

SEI/ASCE 7-16 Minimum Design Loads and Associated Criteria for Buildings and Other Structures (ASCE 2016) (referred hereafter as ASCE 7-16) is an integral part of the 2019 CBC and other building codes. In particular, the earthquake load provisions in ASCE 7-16 are substantially adopted by reference in the CBC. The ASCE 7-16 should be considered as the reference for the basic loading criteria for building structures, non-structural components and non-building structures. The ASCE 7-16 should also be considered in its entirety, including its Quality Assurance provisions.

3.4 OTHER CODES AND STANDARDS

In addition to the referenced codes and standards listed above (i.e., ASCE 41-17, ASCE 7-16, 2019 CBC), the latest edition of these and other referenced codes shall be used appropriately (except as noted above), including:

- ACI 318-08 Building Code Requirements for Structural Concrete and Commentary (ACI, 2008)
- ANSI/AISC 341-10 Seismic Provisions for Structural Steel buildings
- ANSI/AISC 358-10 Prequalified Connections for Special and Intermediate Steel Moment Frames for Seismic Applications
- ANSI/AISC 360-10 Specification for Structural Steel Buildings
- ANSI/AISC 303-10 Code of Standard Practice for Steel Buildings and Bridges
- TMS 402-11 Building Code Requirements and Specifications for Masonry Structures
- ACI 318-11 Building Code Requirements for Structural Concrete
- ANSI/AF&PA NDS 2012 National Design Specification for Wood Construction
- ANSI/AF&PA SDPWS 08 Special Design Provisions for Wind and Seismic (Wood)

The above examples are published by the American Concrete Institute (ACI), Masonry Society (TMS), American Forest and Paper Association (AF&PA), American National Standards Institute (ANSI), and American Institute of Steel Construction (AISC).

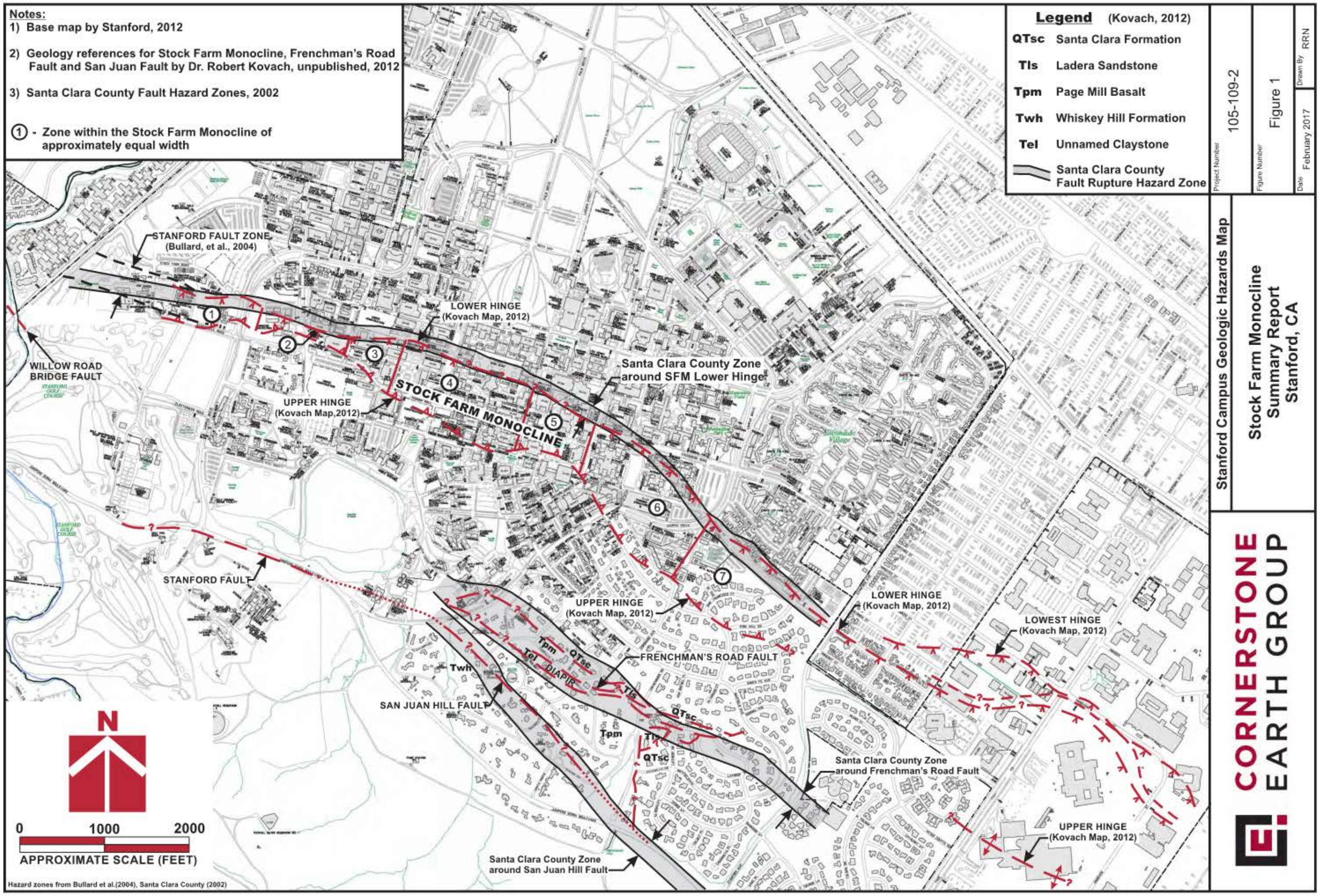
3.5 STOCK FARM MONOCLINE

Santa Clara County has identified additional measures that must be taken to address dynamic ground movement from an earthquake for buildings located in the area of the Stock Farm Monocline. The following summarizes the expected movement in each zone shown in Figure 3:

Table 2: SFM Deformation Design Criteria by Zone Over a Distance of 100 Feet

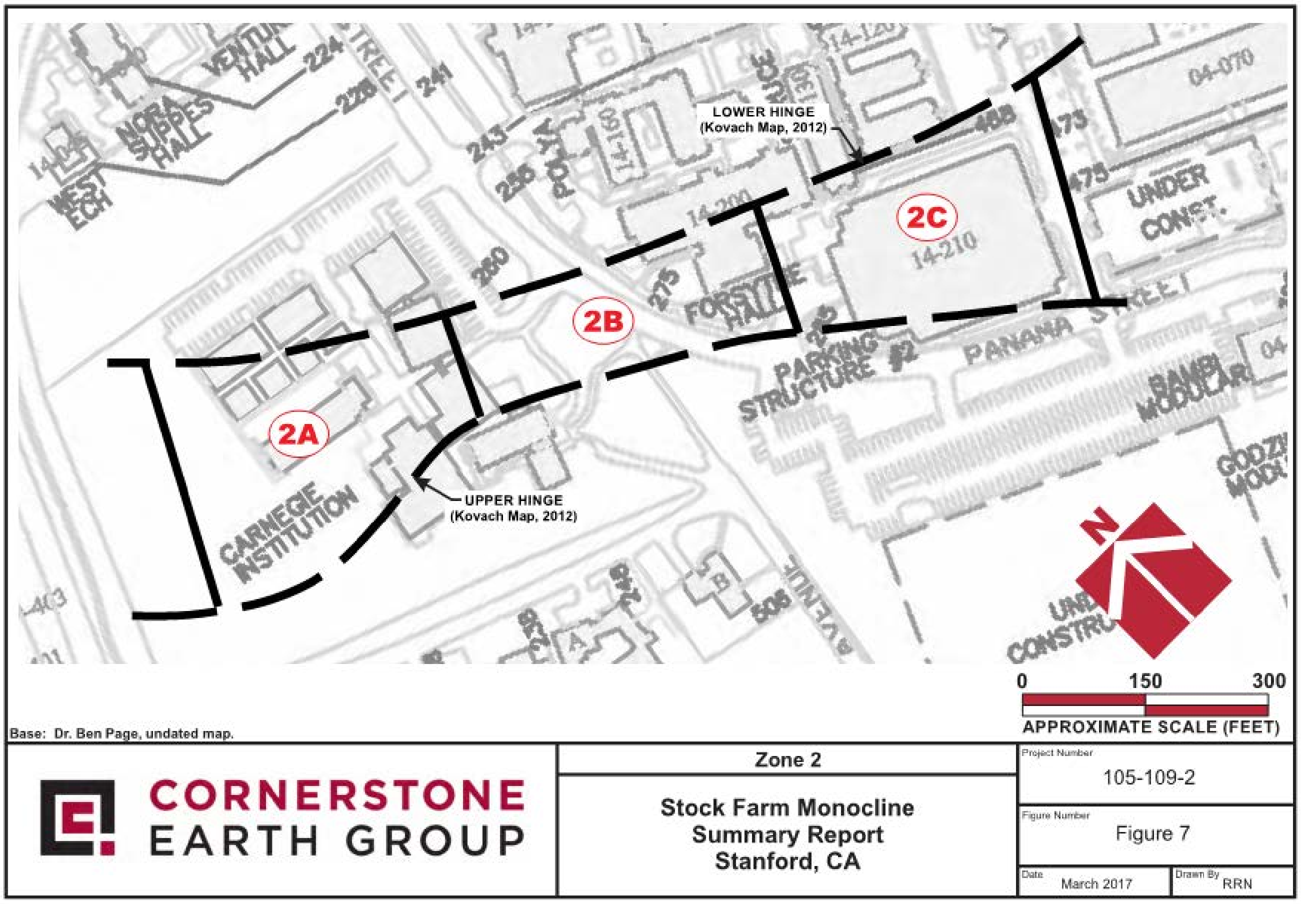
	Average Width (feet)	Vertical Deformation (inches)	Horizontal Shortening (inches)
Zone 1	361	0.70	0.09
Zone 2A	202	1.30	0.20
Zone 2B	120	2.10	0.30
Zone 2C	164	1.50	0.20
Zone 3	559	0.50	0.06
Zone 4	883	0.30	0.04
Zone 5	755	0.30	0.04
Zone 6	955	0.30	0.03
Zone 7	854	0.30	0.04

Figure 3: Stock Farm Monocline Zones



The County will require the EOR to issue a letter that indicates the building can accommodate this movement. Typically, this foundation movement is expected to be easily addressed by standard foundations (for all zones except Zone 2B) and should not add significant costs to a project. If the design team determines that significant additional measures are required, they should notify SAC. SAC may decide to conduct additional discussions with the county to determine whether these measures are appropriate. Figure 4 below shows an enlarged view of zone 2A, 2B and 2C:

Figure 4: Stock Farm Monocline Zone 2A, 2B, 2C



4. SEISMIC EVALUATION OF EXISTING FACILITIES

Seismic evaluations typically occur when existing buildings are being reviewed from a seismic resiliency standpoint based on issues such as major programming changes, re-roofing, previously identified seismic concerns, the return of a leased building to the academic, etc.

4.1 EVALUATION PROCESS

LBRE utilizes a standardized seismic evaluation process for the completion of seismic studies on existing Stanford buildings. This process assures uniformity in the way buildings are analyzed and consistency in the way their results are presented (See Flow Chart C in **Appendix B**).

As described in Section 1.3, Stanford has assembled basic structural information on most campus buildings that utilize a color classification system as an indicator of each building's seismic status. The color classification system, in combination with previously undertaken structural studies and reports, assists Stanford in determining the need for subsequent structural evaluation. Where basic seismic information is not available, SAC and/or individual departments may request the completion of a Tier 1, Tier 2 or Tier 3 evaluation by a structural engineer. The Tier 1 evaluation compiles basic structural information. The Tier 2 or Tier 3 evaluation is a more calculation-intensive analysis of major non-compliant Tier 1 items. The Tier 2 or Tier 3 calculations will identify if a building or components of a building require seismic retrofit. Where further analysis and/or seismic retrofit is recommended, the evaluation approach shall consider the complexity of the building's lateral load system and the performance objective for the particular building.

Table 3 defines three levels of complexity and the associated level of analysis required for each. The process of classifying a building helps to ensure that an appropriate level of analysis is completed and that buildings of similar complexity are evaluated in a consistent manner.

Table 3: Lateral System Classification

Complexity	Definition	Analysis Required	Examples
High	Buildings with lateral systems that are not composed of force- controlled elements (such as URM shear walls) and have: • Highly irregular and/or discontinuous lateral systems • Combination of vertical lateral load resisting elements such as shear walls and steel or concrete frames • Non-orthogonal lateral system	ASCE 41 Tier 2 or Tier 3 (Section 5.3 Method B or C)	Blackwelder/Quillen Florence Moore Mudd Chemistry Durand
Moderate	Buildings which have the above characteristics but: • Where irregularities and/or discontinuities are only associated with particular frame lines • Where diaphragms are not expected to redistribute loads to adjacent vertical elements as yielding occur	ASCE 41 Tier 2 (Section 5.3 Method A or B)	Agassiz Branner Mitchell Outer Quad - Corner Buildings Edwards
Low	• All buildings not included in the above categories	ASCE 41 Tier 1, Tier 2 (Section 5.3 Method A)	Mirrielees Owens House Kingscote Gardens 333 Bonair Siding URM Buildings (1/2 stories)

Based on the results of the Tier 1 and/or Tier 2 evaluation the University will consider the building's priority and develop a remedial action plan. If the analysis results in a capital project that continues into design, the project will follow the process outlined in **Appendix B** for Building Retrofit (Flow Chart B).

4.2 REMEDIAL ACTIONS

Stanford develops a remedial action plan for a building when a seismic evaluation determines that the building's performance does not meet its performance objective or is mandated by law. Remedial action is undertaken in particular when a building is confirmed to have a Performance Level below 5 under BSE-2N or a Performance Level below 4 under BSE-1N. Remedial action does not necessarily result in a retrofit project; it may also include demolition and/or permanent closure.

Some changes in occupancy may trigger a mandated seismic retrofit. Where any codes mandate a seismic upgrade, the evaluation presented in this section is most likely not needed. In these cases, the structural engineer may proceed directly to the retrofit design phase since regardless of the results of the study, a seismic upgrade will be required. Mandated seismic retrofits have to address specific codes and ordinances required by Santa Clara County and/or the State of California. These may include the California Building Code; the California Existing Building Code (CEBC) and California Historic Building Code.

There may be cases where detailed seismic evaluations will be completed early in a project or even prior to a project becoming established. Unless the findings determine that a seismic retrofit is not required, early evaluations should define exactly which tasks or analyses have been completed and which are pending. The results of these seismic evaluations should be recorded in the EQDBASE for future reference.

4.3 PEER REVIEW

The peer review process may coincide with the start of any seismic evaluation but is particularly important in buildings with complex structural systems. The peer reviewer can assist the engineer of record with confirming the type of evaluation approach to be utilized.

4.4 SPECIFIC TESTS AND INSPECTIONS

At the recommendation of the structural engineer and SAC, Stanford may commission additional tests and inspections of buildings, including:

- In situ strength and deformation tests of structural elements
- Laboratory tests on samples taken from buildings
- Tests on mock-ups or prototypical models' representative of field conditions
- Removal of buildings finishes or components to allow inspection of critical elements

5. SEISMIC RETROFIT OF EXISTING FACILITIES

Buildings that require a seismic upgrade, based on either Stanford or other jurisdictional requirements, are subject to the following design process.

5.1 CODES AND STANDARDS

All design and construction must conform to the requirements of all applicable codes and ordinances of the County of Santa Clara and the State of California. These include:

- 2019 California Building Code
- ASCE 41 Seismic Rehabilitation of Existing Buildings
- State Historic Building Code (when applicable)

OSHPD projects are not subject to these guidelines.

5.2 SEISMIC PERFORMANCE OBJECTIVES

The seismic performance objective for an existing building is based on its facilities classification which is determined by LBRE. The typical classification for building retrofit work is Class 4, which relates to a Level 4 or Level 5 performance objective under the BSE-1N and BSE-2N earthquake demands, respectively. There are, however, a few facilities on campus (e.g., dormitories, data centers), which LBRE may decide to upgrade to a higher performance level based on functions housed in these facilities.

5.3 ANALYSIS APPROACH

Based on a review of existing drawings and an initial inspection, the structural engineer should select an analysis approach for the building. The approach should be commensurate with the level of complexity of the structural system as well as any specific structural aspects of the building. It should lend itself to establishing the building's performance levels. Generally, one of the following two analysis levels is utilized. However, ASCE 41 shall be reviewed to verify that the analysis approach used is allowed based on items such as irregularities and demand capacity ratios. The EOR should also review the approach with the peer reviewer prior to starting the analysis:

Method A: This approach is based on an elastic analysis of the structure and attempts to relate the performance of the building to the elastic strength. The elastic strength may be compared to the strength requirements prescribed by standards or codes such as ASCE 41 or the CBC. This approach is appropriate for smaller one- and two-story buildings that do not have any major structural irregularities. It is also appropriate for performance objectives that include only "life safety." It should be noted that in some cases where a Method A evaluation determines that a building needs to be retrofitted, it might be appropriate to complete a Method B evaluation to confirm this assessment.

Method B: This approach is based on static non-linear analysis of the building. This method includes a "static pushover analysis" of the building and may provide a more accurate representation of the building's performance. ASCE 41 and ATC 40 provide detailed descriptions for this type of analysis. This approach is applicable to complicated structures such as multi-story structures or buildings that present irregularities. Method B is also needed to verify that a Level 2 or a Level 1 performance level is achieved.

Method C: This approach is based on a dynamic non-linear analysis of the building. This method of analysis provides a more accurate representation of the building's performance. ASCE 41 and ATC 40 provide detailed descriptions for this type of analysis. This approach is applicable to complicated structures such as multi-story structures or buildings that present irregularities. Prior to the EOR determining that Method C is to be used, they shall present their findings to SAC for review.

Note: Because Stanford has a specific ground motion, DE/BSE-1N and MCE_R /BSE-2N should be used as defined in **Appendix A**. In accordance with ASCE 41-17, development of time histories should follow the criteria in Section 16 of ASCE 7-16, with the modifications listed in Section 2.4.3 of ASCE 41-17. The design ground motions represent a large earthquake on the nearby San Andreas fault, and so selected seed time histories should contain near-field effects (e.g., velocity pulses).

5.4 PEER REVIEW

The peer review process should commence prior to the schematic design phase. The peer reviewer works closely with the design engineer in confirming the type of design approach to be utilized as well as the scope of any retrofit work. The typical DPM renovation project undergoes several design phases, each of which is subject to some level of peer review. For additional information about the peer review process, see Section 7.

Appendix B includes a flow chart that summarizes the process used for seismic retrofit as presented in this section (Chart B).

6. DESIGN OF NEW FACILITIES

6.1 CODES AND STANDARDS

All design and construction must conform to the requirements of all applicable codes and ordinances of the County of Santa Clara (or City of Palo Alto) and the State of California, including the California Building Code (CBC). During code transition phases, the design team may propose to use particular provisions of the proposed changes in the code that the team feels would be an engineering advance compare to the ones that are in the applicable codes. However, these considerations may have to be confirmed with the Building Inspector.

6.2 SEISMIC PERFORMANCE OBJECTIVES

The seismic performance objective for any new building is determined by Stanford's facilities classification as indicated in Table 1. New buildings are typically Class 3 but may warrant a Class 1 or Class 2 designation depending on the role of the facility in post- earthquake operations or academic function.

For all new Class 3 buildings, design teams shall also evaluate and present to SAC the cost impact of meeting Class 2 performance. Where cost impacts are not substantial, or where based on use a higher performance is warranted, SAC may decide to adjust the performance goal from Class 3 to Class 2 or propose changes that would allow a build performance to get closer to Class 2.

6.3 ANALYSIS APPROACH

The structural design shall reflect current seismic engineering knowledge regarding the seismic performance of the subject type of building. Based on a review of the proposed structural system (and its layout), the structural engineer selects an analysis approach for the building. The approach should address the level of complexity of the structural system as well as any specific structural aspects of the building. It should lend itself to establishing the specific performance levels targeted for the building. Generally, one of the following two analysis levels are utilized:

> **Method A:** This approach is based on an elastic CBC design and analysis utilizing force levels from the response spectra included in **Appendix A**. This is applicable to a Class 3 facility where a performance objective Level 3 is prescribed under DE. When this level of analysis is used, it is important to minimize any building irregularities (as defined by the CBC) since these can result in a more complicated response than an elastic analysis can adequately predict. Irregularity issues are defined in the CBC and include items such as discontinuous shear walls and a lack of symmetry in the lateral load resisting elements. Where irregularities are minimized, the engineer may assume that the CBC design indicated above will also satisfy the Level 4 performance requirements under MCE_R /BSE-2N.
>
> **Method B:** This is typically used for either Class 1 or 2 facilities where a Level 1 or Level 2 performance objective is prescribed. It may also be required for Class 3 facilities with major irregularities. This approach is based on a linear dynamic and static non-linear analysis of the building which provides a more accurate representation of the building's performance. ASCE 41 and ATC 40 provide detailed descriptions for this type of analysis. This approach should also be used in the case of buildings with complex structural systems such as multi-story structures over underground basement or buildings that

present irregularities (as defined by CBC). Method B is also highly recommended for a Level 2 or a Level 1 performance levels.

Method C: This approach is based on a dynamic non-linear analysis of the building. This method of analysis provides a more accurate representation of the building's performance. ASCE 41 and ATC 40 provide detailed descriptions for this type of analysis. This approach is applicable to complicated structures such as multi-story structures or buildings that present irregularities. Prior to the EOR determining that Method C is to be used, they shall present their findings to SAC for review.

6.4 PEER REVIEW

As with existing buildings, the peer review process should commence prior to the schematic design phase. The peer reviewer works closely with the design engineer in confirming the proposed lateral load resisting system for the building, the type of design approach to be utilized, as well as the design criteria to reach the building's performance objectives. The peer review will continue through Schematic Design, Design Development and Construction Documents. See Section 7 for more information about this process.

Appendix B includes a flow diagram that summarizes the process used for new design as presented in this section (Chart A).

7. STRUCTURAL DESIGN PEER REVIEW FOR NEW BUILDINGS AND EXISTING BUILDINGS

Stanford requires a peer review process for all new buildings and the renovation of existing buildings involving significant structural alterations. In peer review, Stanford retains the services of an independent third-party structural engineer to review the concepts and detailing of the structural design performed by the structural engineer of record.

Peer reviews are intended to improve structural design and provide a measure of additional assurance with respect to the seismic performance, safety, and efficiency of the structure. Stanford recognizes the value of peer review because building code provisions represent minimum requirements, and compliance with building code criteria alone does not necessarily meet Stanford's desired structural performance and acceptable level of safety. Being in an active seismic region, Stanford recognizes the threat of earthquakes and adopts a proactive policy to protect itself against this threat. The peer review serves as a different "set of eyes" that comprehensively examines the structural design for enhanced constructability and increased assurance in the case where new and/or innovative solutions are proposed.

While peer review may have some of the attributes of a plan check, the peer review process is not the same as a Building Official's plan review. Jurisdictional plan reviews are mandated by law as part of the permit process and are designed to check for code compliance. A peer review does not replace normal design procedures and standards performed by the engineer of record, such as using appropriate codes, internal checking, and quality reviews.

7.1 RESPONSIBILITIES

The responsibility for the structural design remains fully with the engineer of record, who is contractually obligated to prepare structural drawings and related documents.

Responsibility for adherence to the peer review process lies with Stanford's project manager as outlined In **Appendix B**. After the project manager has retained the services of the peer reviewer, the engineer of record contacts the peer reviewer, schedules meetings to discuss the project and peer review process and provides structural documentation sufficiently in advance to facilitate the peer review. The engineer of record works with the peer reviewer to establish a mutually agreeable peer review scope of work, schedule, and deliverables.

The peer reviewer transmits appropriate recommendations, allowing adequate time to address and incorporate comments into the project design. The engineer of record ensures that final and complete documentation of the peer review process is obtained and copied to the project manager. The primary responsibility for communication and transmission of documents lies with the engineer of record.

The SAC is responsible for recommending prospective peer reviewers on capital projects, and assists in project orientation, oversight and resolution of differences.

7.2 QUALIFICATIONS

In order to render a thorough and impartial peer review, the peer reviewer should possess the following qualifications:

- "Peer(s)" of the project design professional(s) with a high level of technical expertise in seismic design and earthquake engineering
- Familiar with the governing regulations for the project being reviewed and Stanford's ***Seismic Design Guidelines***
- Independent from the design team, with no conflict of interest with the engineer of record
- Able to conduct peer review in an unbiased, objective, and constructive manner
- Cooperates with others involved in the project for the overall benefit of the project and other parties involved
- A registered Structural Engineer in California

7.3 SCOPE

The scope of the peer review shall be defined on a project-specific basis. The scope can vary but shall include the following:

- A definition of what is to be reviewed with an understanding of the building's function and performance objectives, including seismic design and vibration criteria. Impacts on budget and cost issues should also be addressed.
- Meetings with the project manager, the peer reviewer, and the engineer of record, and if necessary, a representative of SAC. It is important that a meeting take place at the conceptual stage of the design to review and agree on the process.
- Acknowledgement of the review process to be followed (schedule, submittals, document formats).

The peer review should consider value engineering. The peer reviewer should assist the engineering of record in examining alternative systems, materials and methods for a project to maximize structural efficiency and reduce project cost. The peer review should confirm that the structural design meets, but does not unreasonably exceed, the project's established performance objectives. The scope of the peer review may include the following:

Loading and structural framing with respect to:
- Architectural/functional requirements
- Site topography, soils and adjacent properties
- Wind and earthquake forces; seismic performance objectives

Performance Evaluation:
- Structural serviceability including deflection and lateral drift
- Vibrations
- Crack control
- Settlement, total and differential
- Effects of deflection, lateral drift, and other movement on non-structural elements
- Response to wind and earthquakes

Structural System:

- Ability of selected structural framing materials and systems to meet performance criteria
- Degree of redundancy, ductility, and compatibility
- Appropriateness of member sizes and locations
- Appropriateness of foundation type and design
- Compatibility of structural system and non-structural elements
- Detailing of structural system
- Basic constructability of structural elements and connections

Detailed Design:

- Methodology and spot-checking of structural calculations and/or independent calculations
- Structural design drawings and specifications for adequacy, clarity, basic constructability, and testing and inspection requirements

7.4 PROCESS

The peer review is initiated by the DPM project manager who retains the services of a qualified peer reviewer, as recommended by SAC, as early in the design process as possible. The peer review process shall start prior to the schematic design phase. An initial meeting should be arranged to review the peer review process and have agreement prior to the peer review actually taking place. A SAC representative may attend the initial meeting to facilitate the process, if necessary. The flow charts in **Appendix B** identify the specific points in the design process in which peer review is undertaken for both new buildings and renovations.

The peer reviewer is usually a single consultant from a structural engineering firm. For complex building projects, especially those that require innovative structural systems, the peer reviewer may enlist the assistance of other engineers with particular expertise in the project-related design issues to assist them in the peer review.

The peer review is complete when the engineer of record has satisfactorily addressed in writing all of the peer reviewer's comments. Stanford has prepared a Peer Review Report Form to facilitate the reporting process. A single form should be used to provide a comprehensive record of the completed peer review from start to finish. It identifies all of the issues that were raised at each step of the process and how they were resolved. At the end of the project, all issues should be resolved with agreements reached between the peer reviewer and the engineer of record. If there are any disagreements, they should be indicated in the form and brought to the attention of SAC. The final Peer Review Report Form remains in the project file and a copy is provided to SAC. An example of a Peer Review Report Form is shown in **Appendix C**.

7.5 REVIEW SUBMITTALS

The peer review process "Formal Reviews", generally occur at 100% Schematic Design and 50% Construction Drawing submittals. This review shall be based on the process noted in section 7.6.

The peer reviewer is also expected to complete a general review of the design and provide input at the concept and design development phases for new construction; and at the seismic evaluation, concept and design development phases for renovations of existing buildings. This "Peer Review Input" will likely include an assessment of the lateral analysis to be used and comments on any critical aspects of the design that are noted. This input may be completed through discussions at SAC meeting(s) and/or emails to the design team and SAC.

Stanford projects may have unique design and schedule requirements. This may require the Stanford Project Manager to adjust the peer review process. For example, if the SD submittal is not complete, then the peer review may provide input on the SD documents and then complete the formal review at the end of the Design Development phase. In addition, if the seismic performance level is determined to be Class 1 or 2 and/or the lateral system has some unique characteristics, i.e. base isolation, then the number of peer review submittals may be increased.

The following information is considered to be the minimum general information submitted by the engineer of record to ensure a proper peer review. More information may be deemed appropriate on large or complicated projects and should be discussed and mutually agreed upon by the project manager, the engineer of record, and the peer reviewer prior to the commencement of work:

- Project Schedule including key milestone delivery dates
- Structural System Design Narrative including:
    - Performance Objectives
    - Seismic Design Criteria
    - Geotechnical Design Criteria
    - Structural Systems Descriptions (Foundation, Gravity and Lateral Force Resisting Systems)
    - Relevant/current drawings and calculations appropriate to the project phases identified above

In addition to the general information above, the following is the minimum drawing information required at the Schematic Design and 50% Construction Drawing milestones:

Schematic Design: As noted in the Stanford Project Delivery Process (PDP), the Schematic Design package should be developed beyond industry standard. The structural drawings should include sufficient information such that the peer reviewer can complete a thorough review and a contractor can accurately price the design within a reasonable contingency. As a minimum, the drawings shall include the following:

- Complete foundation plans showing major foundation elements such as footings, grade beams and basement walls.
- The super structure system fully developed, including sizing of all primary elements in the gravity and lateral load resisting systems.
- Typical details for the above items with sufficient information that overall construction of the building is fully understood.
- Seismic bracing and anchorage for non-structural components and equipment is defined with sufficient detail that it can be included in the cost estimate.
- Building specific details, as well as the design of secondary structural elements, are not expected to be fully developed for this submittal.

50% Construction Documents: The structural drawings should incorporate any of the SD phase peer review comments that are applicable. As a minimum, the drawings shall include the following:

- Completion of the foundation plans.

- Completion of the super structure system plans, including support of cladding elements and major equipment.
- Completion of most of the typical and building specific details.

The following are expected to be the primary remaining structural tasks after 50% CD:

- Address any applicable 50% peer review comments
- Completion of the few remaining details
- Final coordination with the other design team disciplines

7.6 REVIEW COMMENTS

The peer reviewer is required to provide a professional opinion as to the compliance of the design with the performance criteria established for the building. They should also provide a general assessment of the level of completion of the drawings as noted in section 7.5. The peer review process must be fully documented. Peer review comments are to be provided in writing to the engineer of record and copied to the project manager (See **Appendix C**). Review comments shall be numbered and shall indicate the specification section or drawing number the comment references. As a minimum, each comment shall be identified by one of the following four categories:

- Type 1 - Potential structural design concern or code violation
- Type 2 - Missing information, coordination problem or constructability concern
- Type 3 - Suggestion, drawing error or discrepancy (no response required)
- Type 4 - Value Engineering and/or Seismic Performance Issue

The engineer of record shall provide written responses to all Type 1, 2 and 4 comments.

7.7 RESOLUTION OF DIFFERENCES

While the responsibility of the structural design rests fully with the engineer of record, the peer review should be one of teamwork and cooperation between the engineer of record and the peer reviewer to produce a structural design that achieves the prescribed level of performance for the building. Direct and open communication between the engineer of record and the peer reviewer is necessary to avoid misunderstanding. Despite this, honest differences may arise. The differences are generally worked out by extended consultation between all parties, which may be presented to SAC. If irreconcilable differences arise between the peer reviewer and the engineer of record, the project manager shall resolve the matter internally with the assistance of SAC.

8. NON-STRUCTURAL COMPONENTS, EQUIPMENT AND CONTENT

8.1 GENERAL PROVISIONS

Non-structural components, equipment and content are to be considered in both the seismic retrofit of existing buildings as well as in new building designs. The design team shall address seismic bracing and anchorage of all non-structural components that are part of or are connected to the structural system. This should include MEP systems (such as sprinklers, ducts, pipes, conduits, HVAC and other mechanical and electrical equipment), racks, shelves, optical tables, benches, tables, cold rooms, fume hoods, etc., as well as architectural components (such as partition walls and ceilings, ornaments, screens, curtain walls, light fixtures, roof tiles, and others).

The design team should also provide systems, such as uni-strut rails, in areas of the facility that will support lab functions and which are intended for storage of heavy equipment (e.g., freezers, incubators, etc.) to enable the bracing of furnishings and lab equipment.[4] Such bracing shall be placed at heights and locations that are most appropriate for the type of content intended for that particular location. Further instructions and illustrative details are provided in the **ProtectSU** Seismic Restraint Program, a database developed by Environmental Health and Safety (EH&S) at Stanford.

As a minimum, the design shall be based on lateral force levels as determined by the provisions of the ASCE 7-16 or ASCE 41-17, whichever is applicable. Importance factors shall be assigned in accordance with the CBC, with Class 1 facilities meeting the Immediate Occupancy standards and Class 2 and 3 facilities meeting the Life Safety standards. The structural engineer and other design team members should either include bracing and anchorage requirements on the structural contract documents or review and approve Architectural and MEP documents, which address these issues.[5] The structural engineer should also review typical anchorage and bracing installation details during construction site visits and work with the general contractor and special inspection and testing agency to develop a quality assurance plan that ensures that all bracing is installed correctly. The structural engineer should also review all attachment details of non-structural components, equipment, and content to ensure they do not impact the performance of the building's structural system. Design and anchoring of non- structural systems is also subject to peer review.

8.2 CODES AND STANDARDS

The following codes, standards, guides and references can be used in the choice and design of the anchoring system. These include Stanford's own internal guidelines.

- ASCE/SEI 7-16, Minimum Design Loads and Associated Criteria for Buildings and Other Structures (ASCE, 2016), Section 13 and Section 15.
- ASCE 41-17, Section 13 Architectural, Mechanical and Electrical Components
- NFPA 13 Standards for Fire Sprinkler piping
- ANSI/ASCE/SEI 25-06 for Earthquake-Actuated Gas Shutoff Devices

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[4] Refer to EH&S Laboratory Standard and Design Guidelines: General Requirements for Stanford Laboratories for more details. Portions of the EH&S laboratory guidelines are reproduced below to ensure consistency of all designs.

[5] Refer also to Stanford Facilities Design Guidelines (FDG) http://maps.stanford.edu/fdg_main

- California Code of Regulations (CCR), Title 24, Part 2, Table 16A-O, California Building Standards Commission (2007)
- California Code of Regulations (CCR), Title 8, 3241, California Building Standards Commission (2007)
- Federal Emergency Management Agency (FEMA) Guides (http://www.fema.gov/library):
  - Reducing the Risks of Nonstructural Earthquake Damage: A Practical Guide - FEMA E-74
  - Installing Seismic Restraints for Duct and Pipe - FEMA 414
  - Installing Seismic Restraints for Electrical Equipment - FEMA 413
  - Installing Seismic Restraints for Mechanical Equipment - FEMA 412
  - Seismic Considerations for Steel Storage Racks Located in Areas Accessible to the Public - FEMA 460
- Stanford Seismic Restraint Manual (**ProtectSU** program), Environmental Health & Safety Department, Stanford University (https://ehs.stanford.edu/manual/seismic-restraint-manual)
- Stanford Laboratory Standard and Design Guide, Section 2, General Requirements for Stanford University Laboratories (https://ehs.stanford.edu/manual/laboratory-standard-design-guidelines)

Other relevant references:

- W. T. Holmes and M.C. Comerio, --, PEER Report 2003-13, University of California Berkeley (2003)

8.3 RELEVANT PROVISIONS OF ENVIRONMENTAL HEALTH AND SAFETY LABORATORY GUIDELINES

This section updates and reproduces parts of the EH&S Laboratory Standard and Design Guidelines for reference and compatibility between the ***Seismic Design Guidelines***. The following items are excerpted from Section 2, General Requirements for Stanford University Laboratories (*with italicized text added by LBRE*).

2.4 Building Design Issues:
(2) An automatically triggered main gas shutoff valve for the building shall be provided for use in a seismic event. In addition, interior manual shutoff valves shall be provided for both research and teaching areas.

2.5 Laboratory Design Considerations - Earthquake Restraints:
(22) All equipment requiring anchoring shall be anchored, supported and braced to the building structure in accordance with all relevant standards and codes. For example, any equipment, including but not limited to, appliances and shelving that are 48 inches or higher and have the potential for falling over during an earthquake, shall be permanently braced or anchored to the wall and/or floor.

In conditions where codes and standards do not apply or are not available, good practices for earthquake bracing of equipment and content should be used. Several of these are reproduced in ProtectSU, Stanford Seismic Restraint Manual. Appropriate bracing practice keeps equipment and content in a building from falling or overturning in the event of an earthquake and assures that safety while exiting is not compromised. This practice should also be applied to laboratory equipment, especially those components which are expensive to replace, unique or irreplaceable, or are deemed critical for the continuation of research.

(23) A channeled anchoring station for seismic bracing of equipment, named the Universal Restraining Bar *(or, alternatively, a strut system such as uni-strut or other appropriate restraint-anchoring device*) shall be installed along all benchtop/counters in laboratories and other horizontal surfaces that house equipment. These bars shall be installed at the back edge of the bench to minimize bench space used.

Examples and guidance are provided on the ProtectSU website protectsu.stanford.edu. This system will allow a bracing point for all benchtop equipment and will provide standard bracing locations for all benchtop equipment.

(24) All shelves must have a passive restraining system to adequately prevent shelf contents from toppling over. Seismic shelf lips (3/4 inch or greater), sliding doors, or mesh nets are examples. The shelves themselves must be firmly fixed so they cannot be vibrated out of place and allow shelf contents to fall.

Installation of seismic lips of proper height on shelving areas can prevent stored items from falling during a seismic event. *The seismic lip must be at least as high as the center of gravity of the restrained items.* For bookshelves, friction matting may be substituted upon consultation with EH&S.

(25) All equipment requiring anchoring, whether installed by a contractor or the University, shall be anchored, supported, and braced to the building structure in accordance *with applicable code and standards or good engineering practice as indicated in the ProtectSU Seismic Restraint Manual. For example, any equipment attached to light gauge steel stud walls should be attached directly to the steel studs or using a system such as uni-strut to span horizontally between studs.*

(26) Cabinets must be equipped with positive locking door latches.

Examples include barrel bolts, safety hasps, and childproof locks. These latches will not allow the cabinet door to open unless the locking mechanism is triggered. Magnetic or pinch- grip catches are not considered “positive locking” and hence should not be used.

9. APPENDICES

APPENDIX A: BSE-1N AND BSE-2N RESPONSE SPECTRA

Table 4: Horizontal and Vertical BSE-2N/MCE$_R$ and BSE-1N/DE Response Spectra Values
5% Damping

Zone 0 Spectra				
Period	**Horizontal MCE$_R$ /BSE-2N per ASCE 7-16**	**Vertical MCE$_R$ /BSE-2N per ASCE 7-16**	**Horizontal DE/BSE-1N per ASCE 7-16**	**Vertical DE/BSE-1N per ASCE 7-16**
(sec)	**(g)**	**(g)**	**(g)**	**(g)**
0.01	0.96	0.81	0.64	0.49
0.02	1.10	0.95	0.74	0.57
0.03	1.25	1.35	0.83	0.80
0.05	1.54	2.35	1.03	1.35
0.065	1.76	2.92	1.17	1.65
0.075	1.90	2.98	1.27	1.68
0.084	2.03	2.95	1.35	1.65
0.10	2.03	2.61	1.35	1.46
0.15	2.03	1.86	1.35	1.05
0.20	2.03	1.41	1.35	0.81
0.30	2.36	1.11	1.57	0.66
0.40	2.66	0.99	1.77	0.61
0.50	2.33	0.74	1.56	0.48
0.75	1.85	0.54	1.24	0.36
0.90	1.69	0.50	1.13	0.33
1.00	1.63	0.49	1.09	0.33
1.50	1.14	0.36	0.76	0.24
2.00	0.88	0.29	0.59	0.19
3.00	0.51	0.17	0.34	0.12
4.00	0.38	0.14	0.25	0.090
5.00	0.31	0.11	0.20	0.073
7.50	0.20	0.072	0.14	0.048
10.00	0.15	0.054	0.10	0.036

Table 5: Horizontal and Vertical BSE-2N/MCE$_R$ and BSE-1N/DE Response Spectra Values

5% Damping

Zone 1 Spectra				
Period	Horizontal MCE$_R$/BSE-2N per ASCE 7-16	Vertical MCE$_R$ /BSE-2N per ASCE 7-16	Horizontal DE/BSE-1N per ASCE 7-16	Vertical DE/BSE-1N per ASCE 7-16
(sec)	(g)	(g)	(g)	(g)
0.01	0.94	0.86	0.63	0.51
0.02	1.09	1.01	0.72	0.59
0.03	1.23	1.46	0.82	0.84
0.05	1.52	2.62	1.01	1.45
0.065	1.73	3.29	1.16	1.80
0.075	1.88	3.38	1.25	1.83
0.083	2.00	3.36	1.33	1.81
0.10	2.00	2.96	1.33	1.59
0.15	2.00	2.12	1.33	1.14
0.20	2.00	1.60	1.33	0.87
0.30	2.00	1.05	1.33	0.60
0.40	2.00	0.81	1.33	0.48
0.417	2.00	0.79	1.33	0.47
0.50	1.74	0.60	1.16	0.37
0.75	1.67	0.51	1.11	0.32
1.00	1.68	0.51	1.12	0.33
1.50	1.30	0.39	0.87	0.26
2.00	1.06	0.32	0.70	0.21
3.00	0.81	0.26	0.54	0.17
4.00	0.65	0.21	0.43	0.14
5.00	0.42	0.14	0.28	0.093
7.50	0.20	0.066	0.13	0.044
10.00	0.15	0.049	0.10	0.033

Table 6: Horizontal and Vertical BSE-2N/MCE$_R$ and BSE-1N/DE Response Spectra Values

5% Damping

Zone 2 Spectra				
Period	**Horizontal MCE$_R$/BSE-2N per ASCE 7-16**	**Vertical MCE$_R$ /BSE-2N per ASCE 7-16**	**Horizontal DE/BSE-1N per ASCE 7-16**	**Vertical DE/BSE-1N per ASCE 7-16**
(sec)	**(g)**	**(g)**	**(g)**	**(g)**
0.01	0.92	0.83	0.61	0.48
0.02	1.06	0.97	0.70	0.56
0.03	1.19	1.39	0.80	0.80
0.05	1.47	2.48	0.98	1.38
0.065	1.68	3.12	1.12	1.71
0.075	1.82	3.210	1.22	1.74
0.083	1.94	3.180	1.29	1.72
0.10	1.94	2.81	1.29	1.51
0.15	1.94	2.01	1.29	1.08
0.20	1.94	1.53	1.29	0.84
0.30	1.94	1.01	1.29	0.58
0.40	1.94	0.78	1.29	0.47
0.416	1.94	0.76	1.29	0.45
0.50	1.71	0.58	1.14	0.36
0.75	1.63	0.49	1.08	0.31
1.00	1.63	0.49	1.09	0.32
1.50	1.26	0.38	0.84	0.25
2.00	1.02	0.31	0.68	0.21
3.00	0.77	0.25	0.52	0.17
4.00	0.63	0.21	0.42	0.14
5.00	0.40	0.14	0.27	0.090
7.50	0.19	0.064	0.13	0.043
10.00	0.14	0.047	0.10	0.032

Table 7: Horizontal and Vertical BSE-2N/MCE$_R$ and BSE-1N/DE Response Spectra Values

5% Damping

Zone 3 Spectra				
Period	**Horizontal MCE$_R$/BSE-2N per ASCE 7-16**	**Vertical MCE$_R$ /BSE-2N per ASCE 7-16**	**Horizontal DE/BSE-1N per ASCE 7-16**	**Vertical DE/BSE-1N per ASCE 7-16**
(sec)	**(g)**	**(g)**	**(g)**	**(g)**
0.01	0.66	0.54	0.44	0.32
0.02	0.72	0.59	0.48	0.35
0.03	0.77	0.79	0.51	0.46
0.05	0.87	1.25	0.58	0.720
0.065	0.95	1.48	0.63	0.83
0.075	1.00	1.48	0.67	0.83
0.10	1.13	1.37	0.75	0.76
0.15	1.39	1.21	0.92	0.67
0.18	1.53	1.15	1.02	0.64
0.20	1.53	1.03	1.02	0.58
0.30	1.57	0.73	1.05	0.43
0.40	1.71	0.63	1.14	0.39
0.50	1.65	0.53	1.10	0.33
0.75	1.56	0.46	1.04	0.29
1.00	1.56	0.46	1.04	0.30
1.50	1.19	0.36	0.80	0.23
2.00	0.97	0.29	0.65	0.20
3.00	0.74	0.24	0.49	0.16
4.00	0.60	0.20	0.40	0.13
5.00	0.38	0.13	0.25	0.086
7.50	0.18	0.061	0.12	0.040
10.00	0.14	0.045	0.090	0.030

Table 8: Design Acceleration Parameters

	Zone 0	**Zone 1**	**Zone 2**	**Zone 3**
S_S	2.12	2.08	2.02	1.92
S_1	0.76	0.75	0.72	0.68
S_{DS}, Site-Specific	1.60	1.20	1.16	1.03
S_{D1}, Site-Specific	1.17	1.72	1.68	1.59
S_{MS}, Site-Specific	2.39	1.80	1.75	1.54
S_{M1}, Site-Specific	1.76	2.59	2.51	2.38
PGA_M	0.84	0.82	0.80	0.76

Figure 5: Horizontal MCE$_R$/BSE-2N

Site-Specific Response Spectra for Zones 0, 1, 2, and 3

5% Damping

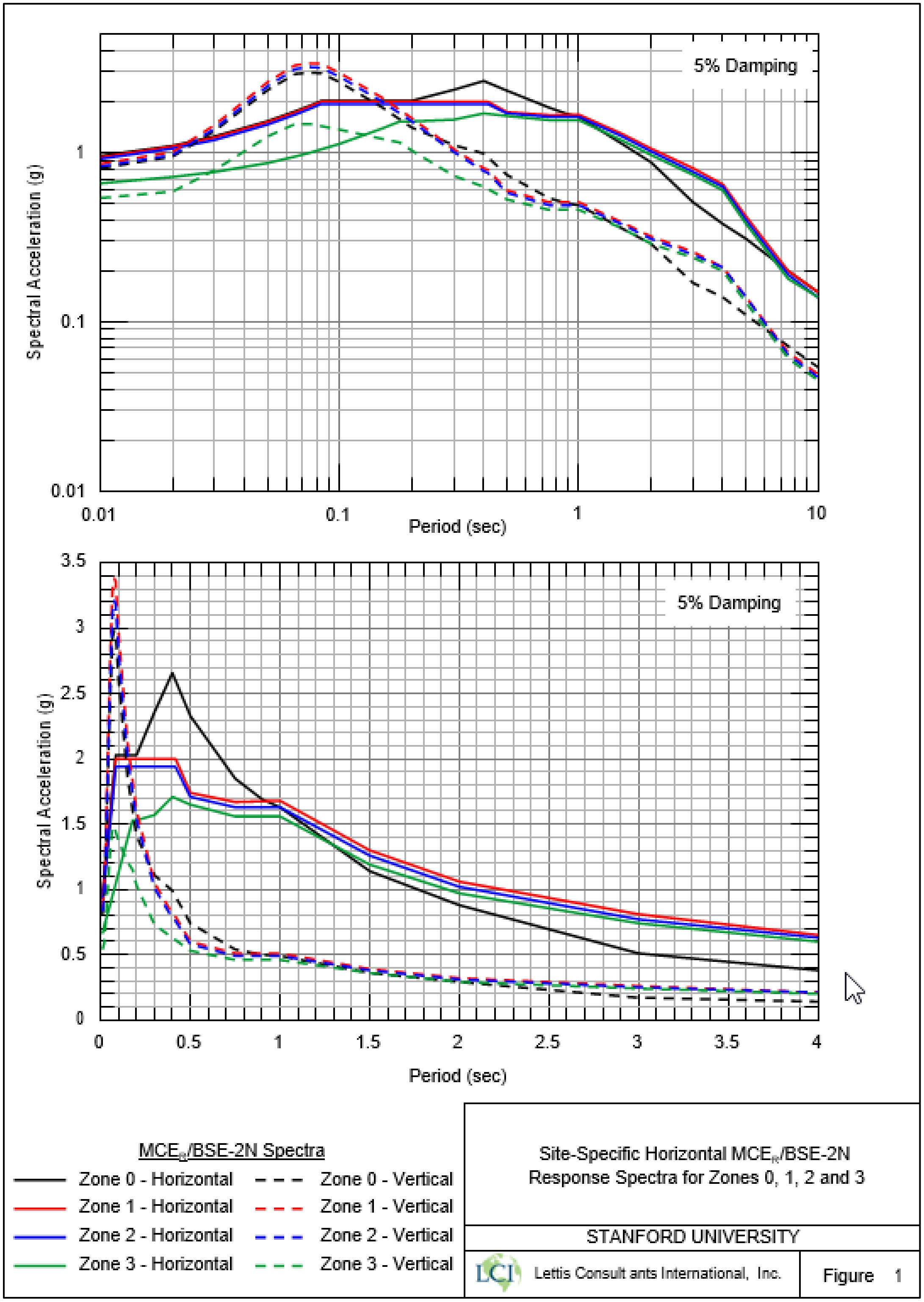
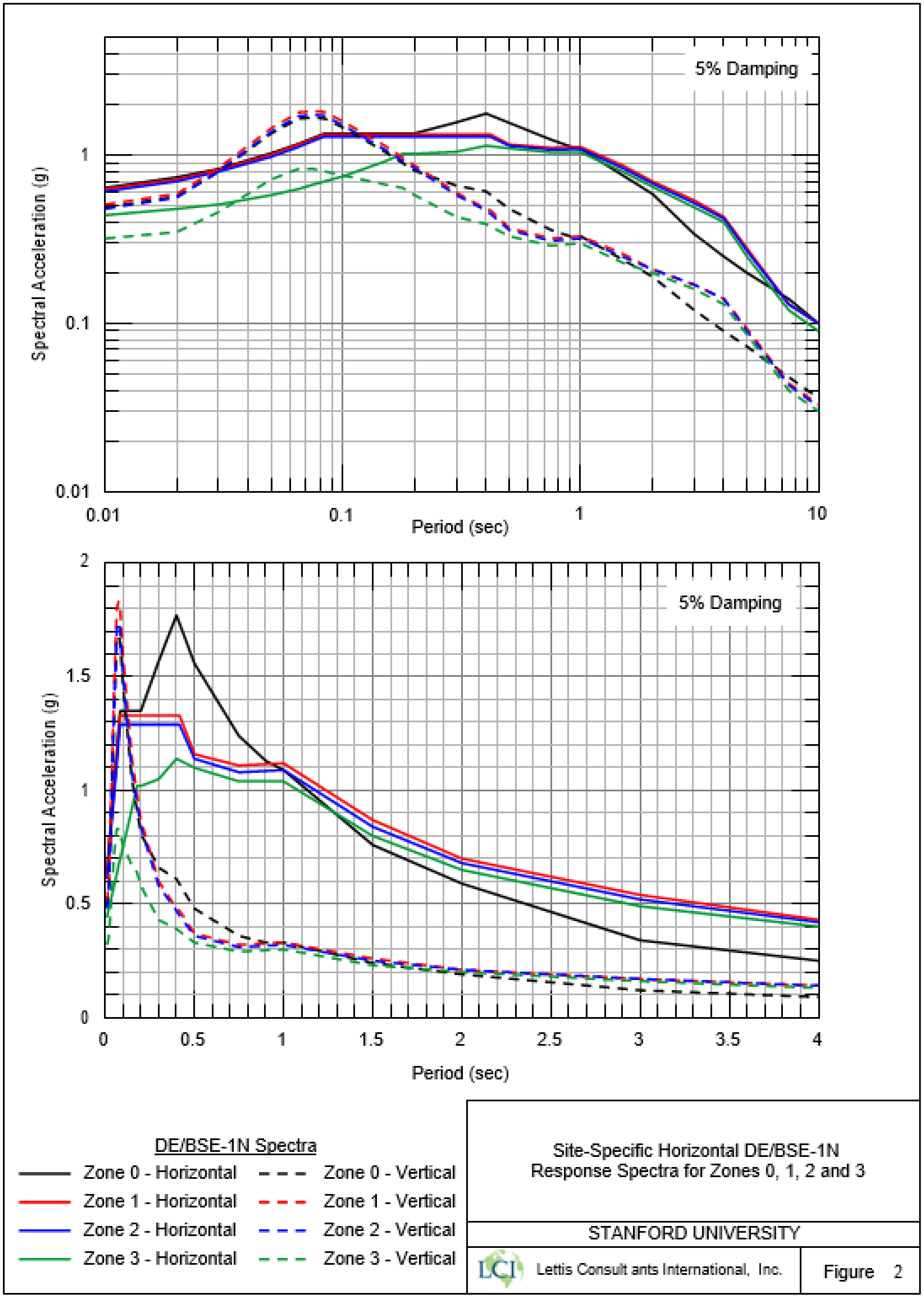


Figure 6: Horizontal DE/BSE-1

Site-Specific Response Spectra for Zones 0, 1, 2, and 3

5% Damping



APPENDIX B: SEISMIC DESIGN FLOW CHARTS

Figure 7: Flow Chart A - New Construction

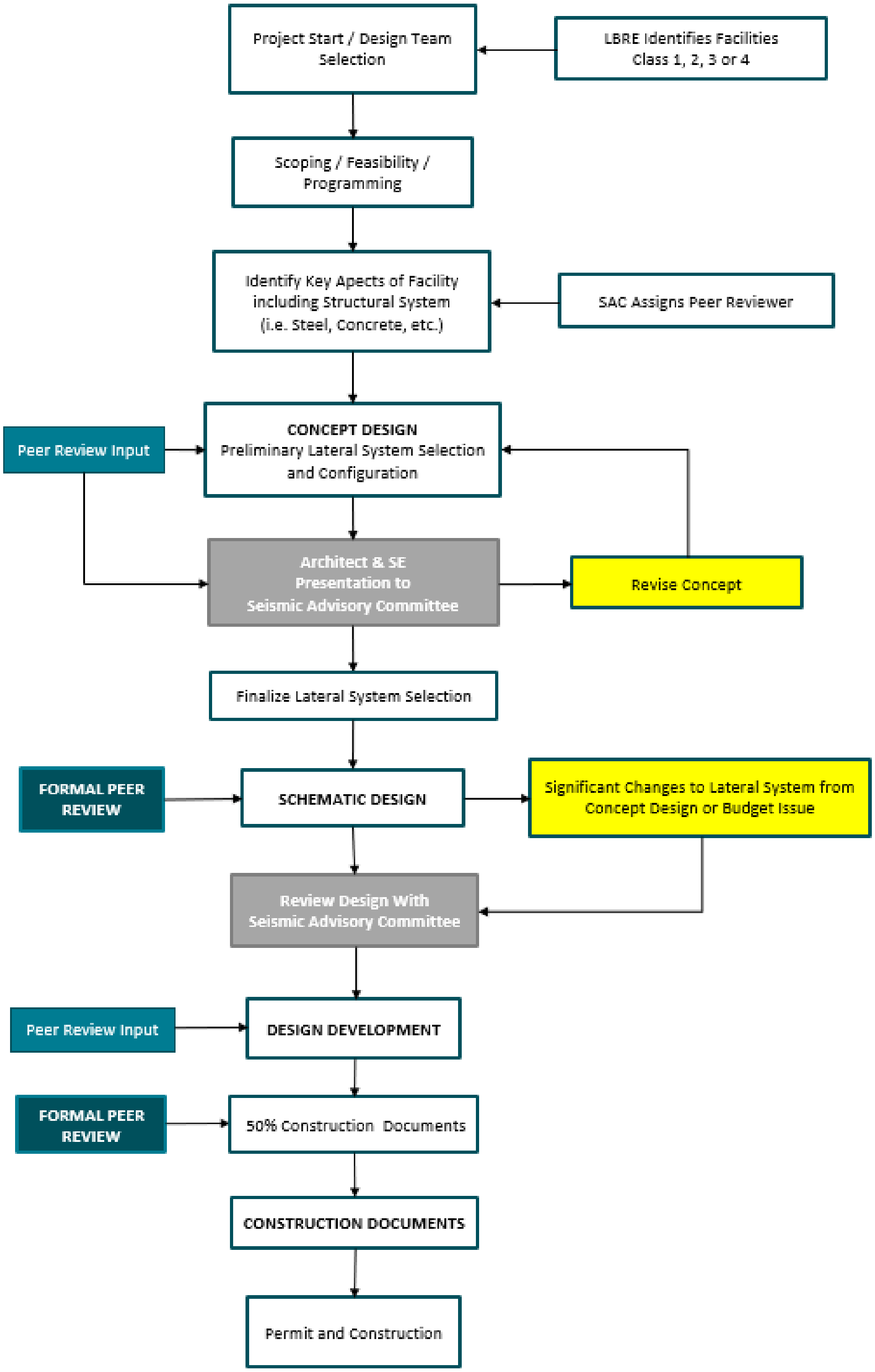


Figure 8: Flow Chart B - Retrofit

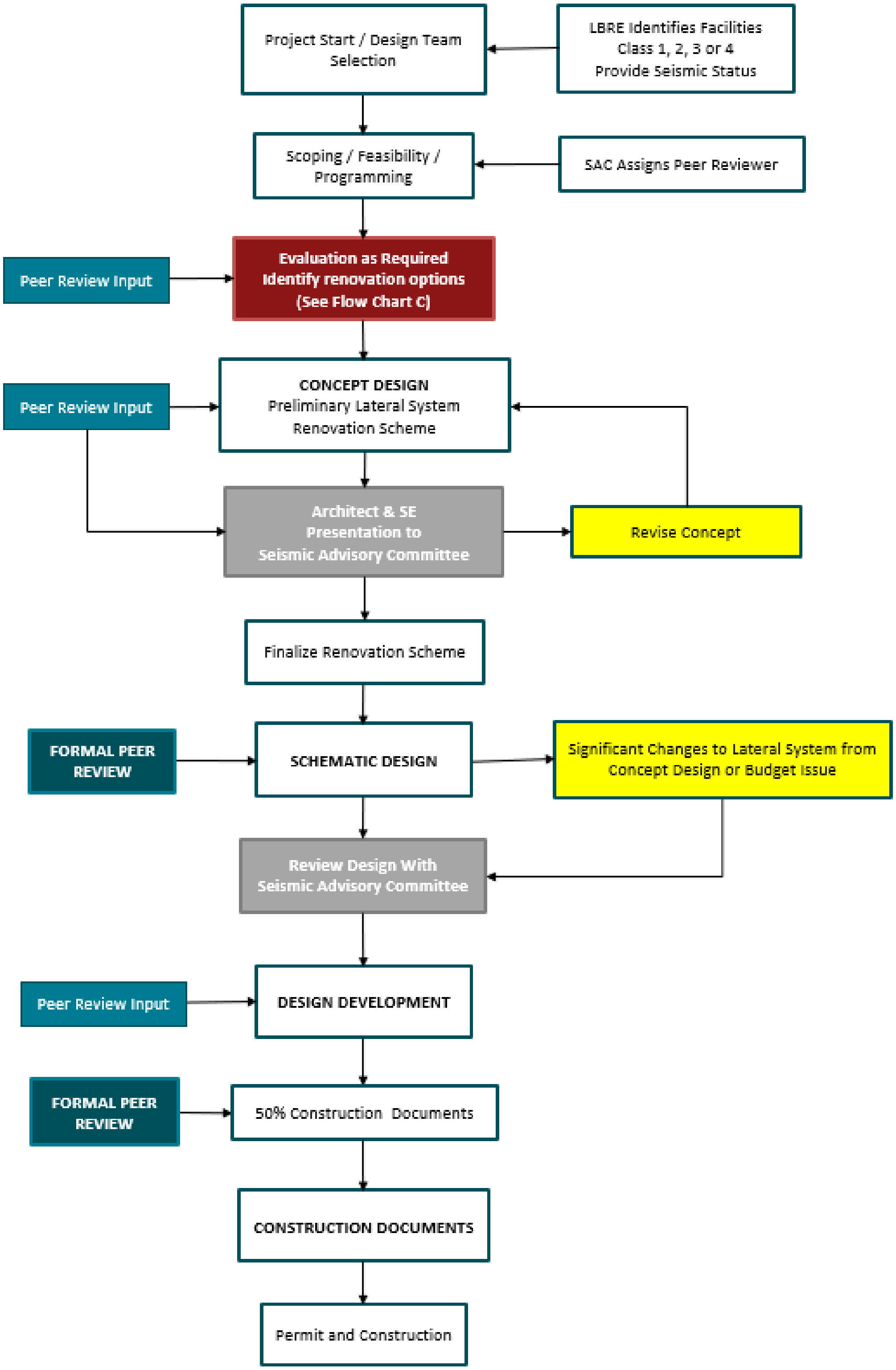
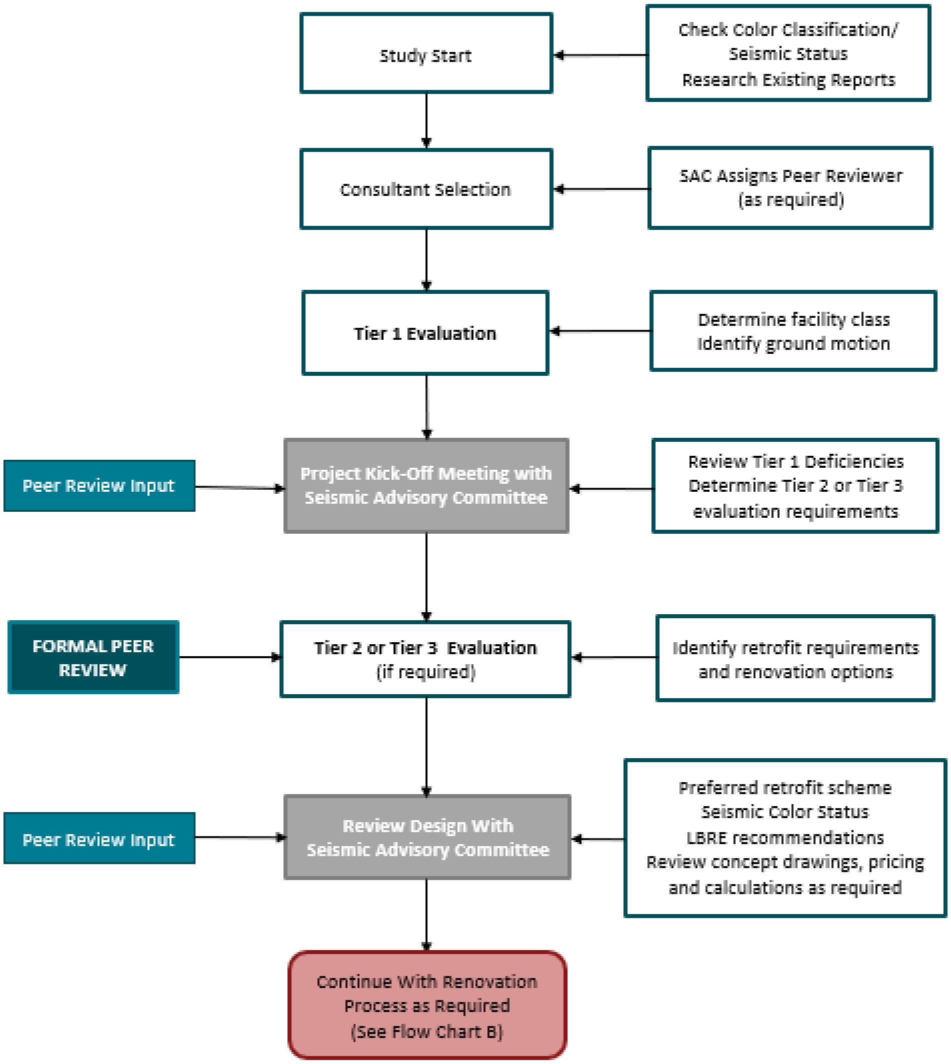


Figure 9: Flow Chart C – Seismic Evaluation



APPENDIX C: PEER REVIEW SAMPLE FORMS

It is suggested that this form be produced in Excel format to facilitate tracking and reporting. Projects with multiple buildings and/or structures should provide the following information for each building/structure to be designed.

Figure 10: Peer Review Report - Sample Form

EXPECTED PERFORMANCE LEVEL

Building Structure	Facilities Class	EQ Level	Performance Level	Importance Factor	Interstory Drift Limit
Building 1 Name	Class 3 (?)	BSE-1N	3 (?)	1.0 (?)	2% (?)
		BSE-2N	4 (?)	1.0 (?)	
Building 2 Name					

LATERAL LOAD RESISTING SYSTEMS

Identify the building lateral systems and provide basic information regarding the building

- ISC Structural System A:
- ISC Structural System B:
- Seismic Design Code:

The Peer Review Report shall indicate irregularities as noted below:

<u>BUILDING IRREGULARITIES (AS DEFINED IN THE CBC)</u>

Horizontal:	Torsional	☐
	Re-entrant Corner	☐
	Diaphragm Discontinuity	☐
	Out-of-Plane Offset	☐
	Nonparallel System	☐
	No Irregularities	☐
Vertical:	Soft Story	☐
	Mass	☐
	Geometric	☐
	In-Plane	☐
	No Irregularities	☐
	Discontinuity	☐

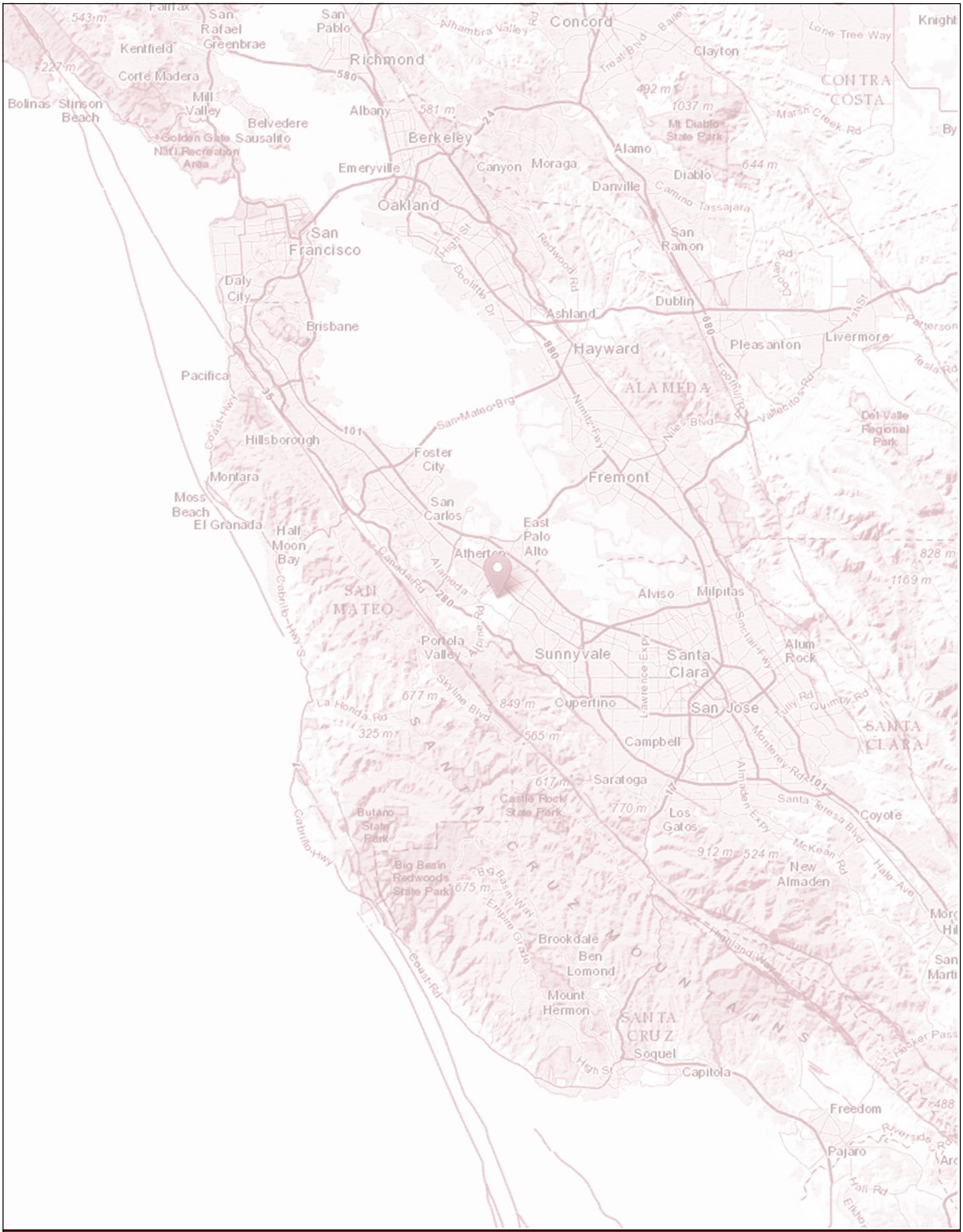
The review comments shall be addressed to the EOR and organized according to the following categories:

- Type 1: Potential structural design concerns and code violation.
- Type 2: Missing information, coordination problems or constructability concerns.
- Type 3: Suggestion, drawing error or discrepancy (no response required)
- Type 4: Value engineering and/or seismic performance issue.

The EOR shall provide written responses to all Type 1, 2 and 4 comments. All comments and responses shall be forwarded to the project manager and SAC at each peer review. The record of the peer review comments and responses should be maintained according to the format below. This form shall include all comments from all phases.

Figure 11: Peer Review Comments and Responses - Sample Form

Item	Type	Location	Peer Reviewer Comment	Engineer of Record Response
1	2	Sheet #	**DATE – COMMENT FROM PEER REVIEWER** Follow-up until resolution is indicated	**DATE – ANSWER FROM EOR** Follow-up until resolution is indicated; when resolution is reached, indicate "ISSUE RESOLVED"
2	1	Sheet #	**DATE – COMMENT FROM PEER REVIEWER** Follow-up until resolution is indicated	**DATE – ANSWER FROM EOR** Follow-up until resolution is indicated; when resolution is reached, indicate "ISSUE RESOLVED"
3			**DATE – COMMENT FROM PEER REVIEWER** Follow-up until resolution is indicated	**DATE – ANSWER FROM EOR** Follow-up until resolution is indicated; when resolution is reached, indicate "ISSUE RESOLVED"
Etc.			(Continue accordingly through completion of the peer review process)	
Etc.				



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