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Seismic Risk Assessment El Mirador 1820 Avenida del Mundo, Coronado, CA 92118

May 2010



Prepared for:

CORONADO SHORES ASSOCIATION #9
1820 Avenida del Mundo
Coronado, CA 92118

Project Number: 2365670

Executive Summary

**Table E-1
 Summary of Data and Risk**

MMI Shaking Intensity	Soil Classification	Drawings Available	Soils Report Available	Engineers			
VII	Sd	Yes	No	I. Robertson			
Property Data						Risk ¹	
Name	Asset Type	Constr. Type	Year Built	No. of Stories	Area (sq. ft.)	Risk Level	PML ²
Coronado Shores Association #9 1820 Avenida del Mundo. Coronado, CA 92118	Condominium Building	Concrete Shear Wall	1977	17	335,000	High	39%

1. Based on ABS Consulting's proprietary state-of-the-art loss analysis software, *USQUAKE™*.
2. Represents a 90% confidence of non-exceedance for a 475-year event.

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1. Introduction

PURPOSE

The purpose of this report is to estimate the potential damage to the structures in the event of strong ground shaking at the subject site. The probable maximum loss (PML) percentage for the structures was projected based on the following factors: type of construction; configuration of the building; design code used; seismic-resistant system;

structural design and details; local geology and seismicity; distance from faults; site earthquake history and performance of similar structures in previous earthquakes.

SCOPE OF WORK

The scope of work for this review consisted of the following tasks:

1. Review available structural and architectural drawings for the buildings to determine the nature of the design and primary structural characteristics, and to assess strengths and weaknesses of the vertical and lateral force (earthquake) resisting systems.
2. Review available geotechnical information for the site and general geological information and fault maps of the area to determine the seismic hazard.
3. A site visit was performed at the building on May 27, 2010. A site visit is performed to visually review the buildings and assess the general condition of the structures, note obvious deficiencies, and confirm that available drawings generally correspond with observed conditions.
4. Determine the loss percentage for the buildings using ABS Consulting's proprietary computer program software for seismic risk assessments. The loss percentage will be developed for a 475-year Design Basis Earthquake (DBE) on the governing fault affecting the site and will be expressed as a percentage of the replacement value of the buildings.
5. Prepare a brief report for the property summarizing our findings.

LIMITATIONS

Our professional services have been performed using that degree of care and skill ordinarily exercised, under similar circumstances, by reputable engineers practicing in the structural field in this or similar localities at this time. No other warranty, expressed or implied, is made as to the professional advice included in this report. This report has been prepared for the indicated client to be used solely in their evaluation of the subject property. The report has not been prepared for use by other parties and may not contain sufficient information for purposes of other parties or other uses.

RELIANCE

This assessment was performed at the request of Coronado Shores Association #9 utilizing methods and procedures consistent with good commercial or customary practices designed to conform to acceptable industry standards. This report may be distributed to and relied upon by Coronado Shores Association #9, their successors and/or assigns with respect to a loan upon the project, together with any rating agency or issuer or purchaser of any security collateralized or otherwise backed up by such loan. The independent conclusions represent our best professional judgment based on the conditions that existed and the information and data available to us during the course of this assignment. Factual information regarding operations, conditions, and test data provided by Coronado Shores Association #9, owner, or their representative has been assumed to be correct and complete.

2. Seismic Hazard

GENERAL

The seismic hazard of a site is dependent upon: frequency and magnitude of earthquakes in the region, the proximity of the site to the earthquake sources (i.e. faults) and local site conditions such as soil type, depth and slope.

The building is located in one of the highest earthquake regions in the United States. It is assigned to Seismic Design Category D by the 2007 California Building Code (CBC). Multiple earthquake faults are located within the vicinity of the site including those summarized in Table 2-1 below.

Table 2-1
Summary of Major Nearby Faults, Magnitude and Distance to Site ¹

Fault Name	Maximum Magnitude	475-Year Magnitude	Distance to Site (miles)	475 Year MMI
Rose Canyon	7.10	6.80	0.5	X
Coronado Bank	7.60	7.08	11	VIII
Elsinore (Julian Segment)	7.10	7.10	44	VII
San Andreas	8.10	7.70	92	VII

1. See Appendix A for discussion of earthquake magnitude.

GROUND SHAKING INTENSITY

Earthquake property damage can result from shaking or direct damage due to seismically induced soil failure. Ninety percent of all earthquake damage is due to shaking. Intensity describes the effects of shaking in terms of damage at a particular location. The Modified Mercalli Intensity scale (MMI) is commonly used to measure this intensity. See Appendix A for a description of the MMI scale.

The intensity of shaking was determined through the use of ABS Consulting's proprietary software program, *USQUAKE*[™]. *USQUAKE*[™] employs a database of California seismicity, which includes location and recurrence data for more than 170 faults and fault segments (approximately 200,000 events). The program computes the closest distance from each site to each fault and computes the intensity of shaking (MMI) through the application of the attenuation model developed by Campbell (1994). It then computes the site intensity of a range of possible earthquake magnitudes for each fault and develops the annual probability of each event. A seismic hazard curve for the site is produced, which relates the expected intensity of shaking to the appropriate return period.

Table 2-2 below presents a summary of the maximum ground shaking intensity anticipated at the site for a deterministic 475-year event.

**Table 2-2
 Summary of Deterministic Site Intensity**

Site Address	475-Year MMI ¹
1820 Avenida del Mundo Coronado, CA 95361	X

1. See Appendix A for discussion of the intensity scale.

SITE STABILITY

In addition to shake damage, buildings and contents can be damaged due to localized soil-induced failures such as fault rupture, landsliding, liquefaction and soil compaction. The vulnerability of the site to this type of damage is presented in Table 2-3. See Appendix A for a description of the types of soil stability concerns and resulting consequences. This site is not located within an Alquist-Priolo Special Studies Zone.

**Table 2-3
 Site Vulnerability Potential ¹**

Site Address	Fault Rupture	Landsliding	Liquefaction ²	Compaction / Settlement
1820 Avenida del Mundo Coronado, CA 95361	Low	Low	Moderate	Low

- Legend:
 High - Recommend site hazard study be performed to determine extent of vulnerability.
 Moderate - Recommend site hazard study be performed to confirm and quantify vulnerability.
 Low - Damage due to hazard is judged not significant.
- Area contains liquefiable layers of soil; however this risk is mitigated by the building being on driven piles.

3. Building Description

The El Mirador Condominiums are located at 1820 Avenida del Mundo in Coronado, California. The site is level on the Coronado Peninsula in San Diego County (Figure 3-1). The building is 17 stories tall, 15 levels of residential over two levels of parking. The buildings are very irregular in plan due to the recessed entry areas at each side of the building. The building has an "H" shaped plan. However the drawings indicate adequate detailing to accommodate these irregularities.

The drawings are dated September 17, 1976 and the building was likely designed to the 1973 Uniform Building Code (UBC). The building's outside dimensions are approximately 140 feet x 140 feet resulting in a total plan area of approximately 247,000 square feet each. The height to the roof peak is approximately 132 feet above the pedestal slab. Total building area for all 17 floors is 335,000 square feet.

The building is concrete shear wall construction with concrete columns and post tensioned concrete slabs, reinforced concrete slabs at the parking level and driven

precast concrete piles. Exterior walls are metal stud non-bearing walls finished with stucco on the exterior and gypsum board at the interior. Interior walls are also metal stud with gypsum board finishes.

The vertical load-carrying system consists of 9 inch post-tensioned concrete flat slabs at the upper 15 levels and 8 inch reinforced concrete slabs with concrete beams at the parking levels. These loads are transferred to a combination of concrete walls and columns to pile caps and driven precast concrete piles. The ground floor of the parking area is a reinforced concrete slab-on-grade.

The lateral load-resisting system for the building includes concrete roof and floor diaphragms, transmitting the loads to the four 20 inch thick concrete shear walls in each direction, and from there to the concrete piles and surrounding soil. Drawings indicate as many as 18 #18 (2 1/4" diameter) vertical bars at each end of each wall at the lower levels with multiple #3 (3/8" diameter) ties at 10 inch spacing. Drawings also indicate concrete columns have #4 ties at 4 inch spacing at the top and bottom 22 inches of each column, but only #3 ties at 10 inch spacing at the middle section of each column. A summary of the building vertical and lateral load-resisting elements is presented in Table 3-1.



Figure 3-1 – Aerial View of the Site, Looking East
(Microsoft Maps)

**Table 3-1
 Vertical and Lateral Load-Resisting Elements**

Building Name	Vertical System	
El Mirador Condominiums 1820 Avenida del Mundo, Coronado, CA	Penthouses	Metal joist and studs w/ stucco and gyp board
	Residential Levels and Roof:	9" P.T. Concrete Slab.
	Parking Levels	8" slab with concrete girders.
	Ground Floor:	Reinforced concrete slab-on-grade
	Walls and Columns:	Reinforced concrete
	Foundation:	Driven concrete piles, 105 kip capacity.
	Lateral System	
	Diaphragms:	P.T. concrete slabs
	Vertical Elements:	20 inch thick x 20 foot long concrete shear walls.

SEISMIC VULNERABILITIES

Building seismic vulnerabilities can result from irregular configurations, both in plan (such as "L" shaped or "U" shaped) and elevation (such as "stepped back" or "overhanging" floors). They can also be a result of an incomplete or inadequate load path for transferring lateral forces from all parts of the building to the ground. Vulnerabilities can also be the result of type and detailing of the construction, whether the construction materials and connections are stiff or flexible, and whether they are brittle (i.e. can suddenly lose load-carrying capacity under moderate deformation) or ductile (i.e., will retain load carrying capacity after significant deformation). Pounding from adjacent buildings can also result in seismic vulnerabilities. Table 3-2 presents a summary of the vulnerabilities for this building based on a brief review of the drawings.

**Table 3-2
 Building Vulnerabilities**

Building Name	Configuration	
El Mirador Condominiums 1820 Avenida del Mundo, Coronado, CA	Plan:	H-shaped plan at each of the entries can produce large stresses at these interior corners. Design appears to have accommodated these stresses.
	Vertical:	No significant concerns.
	Lateral-Force-Resisting System	
	Horizontal:	No significant concerns.
	Vertical:	Inadequate horizontal ties in the mid height region of both the concrete columns and shear walls.
	Connections:	No significant concerns.
	Foundations:	No significant concerns.
	Adjacency	
	Pounding:	No significant concerns. No adjacent buildings.

Concrete Shear Construction

The performance of reinforced concrete shear wall buildings is highly dependent on the number of walls, their location within the building, their configuration, the size and number of openings in the walls, and steel reinforcing details. Well-designed concrete walls have adequate reinforcing throughout (both horizontally and vertically) as well as special reinforcing around openings and at edges. For walls greater in height than width, vertical reinforcing steel at edges should be provided with horizontal steel ties that wrap around this steel and the concrete within to hold it together.

Shear wall buildings with abrupt changes in lateral resistance have often performed poorly in earthquakes. Damage tends to be located in weak or flexible stories, or at locations where shear walls at upper levels do not continue to the foundation level. Buildings with walls distributed primarily at only two or three sides are subject to large torsional displacements (twisting) and have been severely damaged in past earthquakes.

Due to the small ties in the ends of the walls and in the columns, and the large spacing of the ties at mid height of the walls and columns, significant damage appears possible for the relatively high expected level of ground shaking at the site.

4. Seismic Risk

The seismic risk of a building is the combination of the seismic hazard at the site (presented in Section 2) and the seismic vulnerabilities of the building (presented in Section 3).

DETERMINISTIC ANALYSIS

The Probable Maximum Loss (PML) is a financial measure of the seismic vulnerability of the building and is estimated to be the cost to restore the structure to pre-earthquake condition, expressed as a percentage of total replacement value. A PML with a 90% confidence level has been provided (i.e., there is only a 10% chance that actual losses experienced would be exceeded). The Normal Expected Loss (NEL) represents a 50% probability that the given hazard will not be exceeded (i.e. there is a 50% chance that actual losses experienced would be exceeded). The designated time-period for this assessment is 475 years, which is a common measure of seismic risk for this type of report and the basis for structural design in modern building codes.

The NEL and PML loss estimates for the building are **39%** and **23%**, respectively. In addition, a contingency for cleanup and recovery assumed as 10% of the loss and a demand surge 13% of the loss should be included in estimating the total expected loss for the building. Business interruption caused by damage to the building or surrounding area typically represent a significant portion of the total expected loss and should normally be included in the overall loss estimate for the building. If these were rental units, approximately a 4 month loss of rental income would be expected while repairs are being made.

The term PML has been misused in recent years and without standard definitions, the PML for the same building could vary considerably depending upon which definition is used. The PML referred to in this report is also referred to as an SUL or SUL₉₀ (scenario upper loss with a 90% confidence that it will not be exceeded) in ASTM 2026, which was written to standardize the definitions of various potential loss numbers. This has been the commonly accepted definition of PML for over 25 years. ASTM 2026 defines SEL as the scenario expected loss. This is the expected loss from a specified event, but with only a 50% confidence that the damage will not be exceeded. Another commonly used term from ASTM 2026 is the PL, which is expressed as a damage ratio based on a probabilistic analysis rather than a scenario analysis. The PL is more of a mean damage level for the approximate repair cost divided by the replacement cost.

PROBABILISTIC ANALYSIS

Losses from probabilistic analyses include consideration of all earthquakes (approximately 200,000) in the *USQUAKE*TM hazard database. Each probabilistic event in the hazard database is established using available geologic and paleoseismic fault data. An annual probability of occurrence is established for each probabilistic event and all of these probabilistic events are used in a probabilistic analysis. This is different from a deterministic analysis in that a deterministic analysis determines a controlling event, and then all calculations are based on that single event.

Losses from these events are then ranked in ascending order of their loss amounts. The annual probability of non-exceedance for a selected loss amount in this ranking is determined by summing the annual probabilities of all events whose loss amounts are equal to or lower than the selected loss amount. For example, the level of loss that has an annual probability of non-exceedance of 99.8% (or a 2% annual probability of exceedance) is expected to be exceeded once in a 500-year timeframe.

These levels of loss are expected to be exceeded once in 500 years, or it has 0.2% (1/500) of being exceeded in any given year or, the level of loss is expected to be exceeded once in 250 years and has 0.4% (1/250) of being exceeded in any given year. A 100 year return has a 1% chance of being exceeded in any given year. The probabilistic loss estimate for the building for an annual probability of non-exceedance of 99.8% (500-year) is 2%.

Figure 4-1 shows probabilistic losses for other non-exceedance percentages, which can be translated into other return periods for the building. The 99.80% probability of not exceeding a 15% loss in any given year is the 500 year return and the 99.00% probability of not exceeding a 6% loss in any given year is the 100 year return. 90% probability of non-exceedance is approximately a ten year return. This graph does not include demand surge for this building or the contingency for cleanup and recovery.

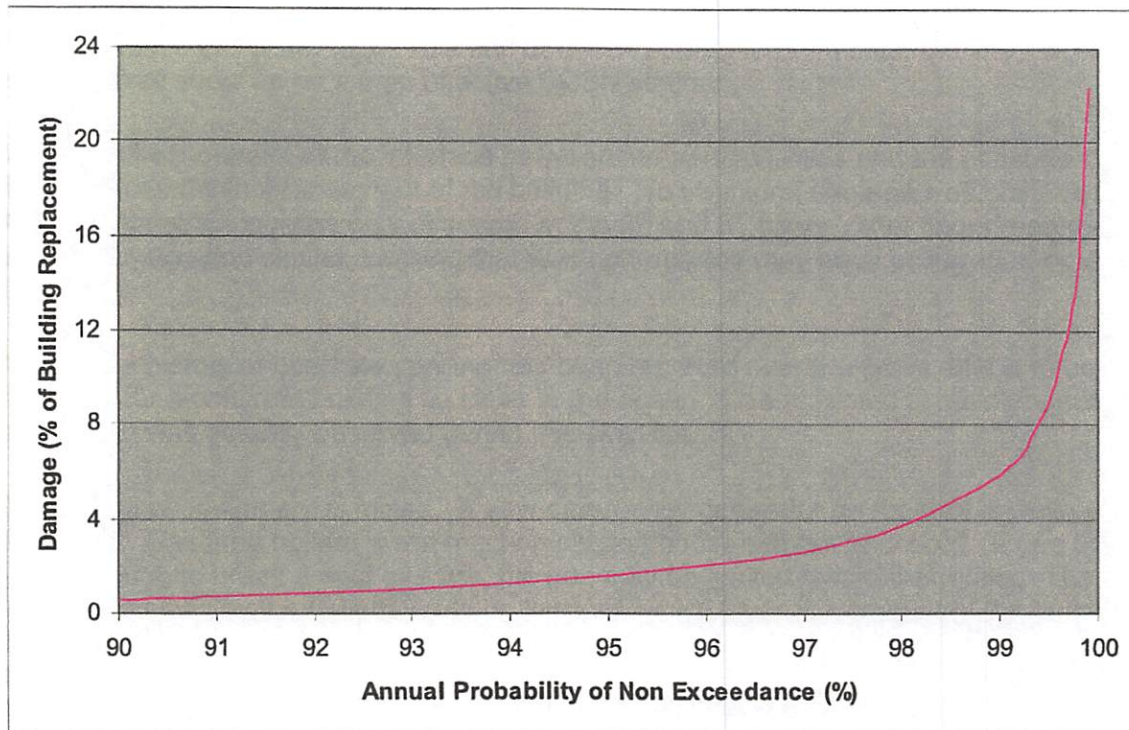


Figure 4-1 – Annual Aggregate Damage and Loss Distribution

DEMAND SURGE

Demand surge represents the expected rise in the cost of construction, materials, and services following a major earthquake. From experience it is clear that such a surge is likely, and can be significant, but it is not clear that the surge effect can be determined reliably. However, for the controlling event for this building, demand surge is expected to be 13. Demand surge has not been included in the potential loss calculations presented in this report in Table E-1.

CONTINGENCY FOR CLEANUP AND RECOVERY

Following a major earthquake, it will be important to restore a damaged facility to normal operations as soon as possible. This cost is shown as a contingency for cleanup and recovery in developing the expected loss and is estimated as 10% of the total expected cost. Cleanup and recovery consists of reorganizing office space and production areas, removing debris, and engineering services related to damage inspections and repairs.

SITE OBSERVATIONS

Minor damage was reported following the magnitude 7.2 Mexicali Earthquake of April 4, 2010, 39 miles south of Mexicali and 112 miles east-south-east of Coronado. 203 people from the Coronado Zip Code reported feeling the earthquake to USGS and from the information they provided, USGS determined the MMI intensity in Coronado was approximately V.

An accelerometer that appears to be part of the Southern California Seismic Network (SCSN) was found at the roof. This unit does not appear to be maintained any longer and does not show up on a map of active SCSN stations.

Minor cracking of paint at the interface between the partition walls and the concrete floors indicated minor movement of the building. No structural damage was observed. Although the cracking was only observed at the 3rd and 8th floors, other floors reported similar damage and similar cracking that was not reported may have occurred at other floors.

Although a history of concrete spalling has been reported over the years, this is to be expected for a concrete building so close to the ocean. Due to remedial maintenance, no spalling was actually observed during this site visit.

Anchorage of equipment is mixed. A new emergency generator on the roof is well anchored. Gas fired boilers in the mechanical penthouse are not anchored. If one boiler shifts enough to break a rigid gas line, the gas may be ignited by another boiler. The risk is minimized by the boilers being on the roof, which limits the amount of the building that may burn, and the building has a seismic gas shutoff valve at the ground floor. The boilers should be checked following an earthquake as the amount of gas contained in 15 floors of pipe between the shutoff and the boilers could burn for some time.

Sprinkler piping appeared to be adequately braced and other piping at the parking level had flexible rubber couplings. A 25,000 gallon (estimated) water storage tank at grade could not be adequately observed to determine adequacy of anchorage.

5. References

1. California Division of Mines and Geology (CDMG) (1991), *Fault Rupture Hazard Zones in California*, California Division of Mines and Geology Special Publication 42, Point Loma Quadrangle.
2. Jennings, C.W. (1994), *Fault Activity Map of California and Adjacent Areas*, California Division of Mines and Geology, Geologic Data Map No. 6.
3. Jennings, C.W. and Saucedo, George J. (1999, revised 2002), "Simplified Fault Activity Map of California, Map Sheet 54."
4. County of San Diego, Department of Planning and Land Use (SanGIS), "Draft – Liquefaction County Of San Diego Hazard Mitigation Planning" 2009
5. Youd, T.L., and D.M. Perkins (1987), "Mapping of Liquefaction Severity Index," *Journal of Geotechnical Engineering*, American Society of Civil Engineers, Vol. 113, No. 11, pp. 1374-1392.
6. American National Standard, "ASTM E 2026, Standard Guide for the Estimation for Building Damageability in Earthquakes," 1999 and 2007.
7. Thiel, C.C., Zsutty, T.C., "Earthquake Characteristics and Damage Statistics," *Earthquake Spectra*, Vol. 3, No. 4, November 1987.
8. Applied Technology Council, "Earthquake Damage Evaluation Data for California," ATC-13, Redwood City, California, 1985.
9. California Building Standards Commission, "2007 California Building Code", 2007.
10. International Conference of Building Officials, "1973 Uniform Building Code"
11. Krisel/Shapiro & Associates, AIA, "Coronado Shores, Silver Strand Boulevard, Coronado, California," Permitted 9/17/76.

Appendices

- A. EARTHQUAKE HAZARDS**
- B. LATERAL FORCE DESIGN FOR BUILDINGS**
- C. RISK AND PROBABLE MAXIMUM LOSS**
- D. ABS CONSULTING QUALIFICATIONS**

APPENDIX A: EARTHQUAKE HAZARDS

MAGNITUDE AND INTENSITY SCALES

Earthquakes and their effects are measured and reported using a number of different scales. This section provides information on the most commonly used scales and their significance.

Magnitude scales are a well known, but typically misunderstood, means of describing the energy released during an earthquake. Magnitude scales are intended to be objective, instrumentally determined ratings of the size of an earthquake. The smallest-felt earthquakes have a magnitude of about 2.0, while the largest recorded range up to approximately 9.0. An increment in magnitude of 1.0 represents an increase of approximately 32 times the amount of energy released.

A number of different magnitude scales are commonly used. The Richter (or local) magnitude scale, M_L , is the most well known magnitude scale and, historically, the most commonly used in California.

While magnitude describes the size of an earthquake, intensity describes the effects of shaking in terms of damage at a particular location. Intensity is governed by the magnitude of an earthquake, the distance from the site to the fault rupture, and local geologic conditions. Even a small or moderate earthquake may generate strong ground shaking, but the region affected by this shaking will be substantially less than that generated by a major earthquake. The 1931 Modified Mercalli Intensity (MMI) Scale (Table A-1) is commonly used to measure intensity. The scale comprises 12 categories of ground motion intensity, from I (not felt, except by a few people) to XII (total damage). The MMI Scale is somewhat subjective; it is dependent on personal interpretations and, to some extent, quality of construction in the affected area.

EARTHQUAKE SITE EFFECTS

The earthquake effects that are most likely to cause damage to structures include direct ground fault rupture, ground shaking, liquefaction, lateral spreading, compaction, and landsliding. The propensity for a site to experience these hazards is directly related to the types of soils present, their density and slope, and the presence of ground water. Site-specific soils data, obtained from borings and supplemental laboratory testing of extracted samples are typically required to accurately define the probability and severity of these hazards at a specific site.

Ground Fault Rupture

Ground fault rupture is the direct manifestation of the movement that has occurred along a fault, projected to the ground surface. It consists of a concentrated, permanent deformation of the ground surface, and in major earthquakes, can extend along the trace of the fault for many miles. This deformation can be in either a horizontal and/or vertical direction. Depending on the type of soils present at the site, the zone of ground

deformation associated with fault rupture may be limited to a band a few inches wide, located directly over the fault, or it may be spread out over several hundred feet. A ground-surface rupture involving more than a few inches of movement within a concentrated area will cause major damage to structures that cross it. Fault displacements associated with great earthquakes may be as large as 30 feet. In general, the precise location and total length of faults are not known because they are covered by alluvium. Fault displacements produce forces so great that the best method of limiting damage to structures is to avoid building in areas close to ground traces of active faults.

Ground Shaking

Ground shaking is the primary and best-known hazard associated with earthquakes. It is the mechanism by which most energy released in an earthquake is dissipated. Ground shaking includes both horizontal and vertical motions that can last up to several minutes during major earthquakes. Generally, sites located remotely from the zone of fault rupture experience less severe ground motion than do sites located close to the fault. However, local soil conditions can amplify and modify the character of ground motion to produce more intense effects at individual sites. It is estimated that ground shaking causes more than 90% of all earthquake-related damage to buildings.

Landsliding

A landslide is the downhill movement of masses of earth under the force of gravity. Earthquakes can trigger landslides in areas that are already landslide prone. Slope gradient is often a clue to stability. Landslides are most common on slopes of more than 15° and can generally be anticipated along the edges of mesas and on slopes adjacent to drainage courses. In the 1964 Alaska earthquake, landslides in Anchorage caused destruction and total loss of many residences and commercial buildings, including an entire subdivision.

Liquefaction

Liquefaction is the sudden loss of bearing strength that can occur when saturated, cohesionless soils (sands and silts) are strongly and repetitively vibrated. The consequences of liquefaction can include lateral spreading, landslides, a quick condition (loss of bearing capacity or tilting), and differential settling of the ground. The 1964 Niigata, Japan, earthquake led to liquefaction over a large area, causing many apartment buildings to tilt as much as 70°. Many structures settled more than a meter, and buried structures floated to the surface. In the 1971 San Fernando earthquake, liquefaction nearly resulted in the loss of the Van Norman Dam. Liquefaction in the Marina District of San Francisco contributed to the severe damage and collapse of many residential structures in the 1989 Loma Prieta earthquake. Liquefaction typically occurs in loose sand deposits within 15 feet of the ground surface when there is subsurface groundwater above a depth of 20 feet. Shallow groundwater and loose soil are usually localized conditions, resulting either from natural or human-made causes. As a result, site-specific data are necessary to accurately determine if liquefaction may occur at a location.

Lateral spreading is a secondary effect of liquefaction. When soils located on a sloping site liquefy, they tend to flow downhill in an uneven manner. A site that has experienced

lateral spreading will typically exhibit a series of parallel cracks in the ground, oriented along the sloping face. Structures founded on sites experiencing lateral spreading can be severely damaged, and sometimes collapse.

Compaction

Compaction of loose soils and poorly consolidated alluvium can occur as a result of strong seismic shaking, causing uniform or differential settlement of building foundations. Buildings supported on deep pile foundations are more resistant to such settlements. (Piles are long, slender columns usually of timber, steel, or reinforced concrete driven into the ground to carry a vertical load.) However, in the 1985 Mexico earthquake, buildings supported on piles experienced substantial damage due to differential settlements between pile-supported buildings and non-pile-supported slabs-on-grade. Substantial compaction may occur in broad flat-valley areas recently depleted of groundwater.

Table A-1 MODIFIED MERCALLI INTENSITY SCALE	
I.	Not felt. Marginal and long-period effects of large earthquakes.
II.	Felt by persons at rest, on upper floors, or favorably placed.
III.	Felt indoors. Hanging objects swing. Vibration like passing of light trucks. Duration estimated. May not be recognized as an earthquake.
IV.	Hanging objects swing. Vibration like passing of heavy trucks; or sensation of a jolt like a ball striking the walls. Standing motor cars rock. Windows, dishes, doors rattle. Glasses clink. Crockery clashes. In the upper range of IV wooden walls and frames creak.
V.	Felt outdoors; direction estimated. Sleepers wakened. Liquids disturbed, some spilled. Small unstable objects displaced or upset. Doors swing, close, open. Shutters, pictures move. Pendulum clocks stop, start, change rate.
VI.	Felt by all. Many frightened and run outdoors. Persons walk unsteadily. Windows, dishes, glassware broken, knickknacks, books, etc., off shelves. Pictures off walls. Furniture moved or overturned. Weak plaster and masonry D cracked. Small bells ring (church, school). Trees, bushes shaken (visible, or heard to rustle).
VII.	Difficult to stand. Noticed by drivers of motor cars. Hanging objects quiver. Furniture broken. Damage to masonry D, including cracks. Weak chimneys broken at roof line. Fall of plaster, loose bricks, stones, tiles, cornices (also unbraced parapets and architectural ornaments). Some cracks in masonry C. Waves on ponds; water turbid with mud. Small slides and caving in along sand or gravel banks. Large bells ring. Concrete irrigation ditches damaged.
VIII.	Steering of motor cars affected. Damage to masonry C; partial collapse. Some damage to masonry B; none to masonry A. Fall of stucco and some masonry walls. Twisting, fall of chimneys, factory stacks, monuments, towers, elevated tanks. Frame houses moved on foundations if not bolted down; loose panel walls thrown out. Decayed piling broken off. Branches broken from trees. Changes in flow or temperature of springs and wells. Cracks in wet ground and on steep slopes.
IX.	General panic. Masonry D destroyed; masonry B seriously damaged. (General damage to foundations.) Frame structures, if not bolted, shifted off foundations. Frames racked. Serious damage to reservoirs. Underground pipes broken. Conspicuous cracks in ground. In alluviated areas sand and mud ejected, earthquake fountains, sand craters.
X.	Most masonry and frame structures destroyed with their foundations. Some well-built wooden structures and bridges destroyed. Serious damage to dams, dikes, embankments. Large landslides. Water thrown on banks to canals, rivers, lakes, etc. Sand and mud shifted horizontally on beaches and flat land. Rails bent slightly.
XI.	Rails bent greatly. Underground pipelines completely out of service.
XII.	Damage nearly total. Large rock masses displaced. Lines of sight and level distorted. Objects thrown into the air.

Source: Richter, C.F. Elementary Seismology. San Francisco CA: W. H. Freeman Co., 1957.

Note: To avoid ambiguity, the quality of masonry, brick, or other material is specified by the following lettering system. (This has no connection with the conventional classes A, B, and C construction.)

Masonry A. Good workmanship, mortar, and design; reinforced, especially laterally, and bound together by using steel, concrete, etc.; designed to resist lateral forces.

Masonry B. Good workmanship and mortar; reinforced, but not designed to resist lateral forces.

Masonry C. Ordinary workmanship and mortar; no extreme weaknesses, like failing to tie in at corners, but neither reinforced nor designed to resist horizontal forces.

Masonry D. Weak materials, such as adobe; poor mortar; low standards of workmanship; weak horizontally.

APPENDIX B: LATERAL FORCE DESIGN FOR BUILDINGS

BUILDING CODES

The minimum requirements for structural design of buildings are set by locally adopted and enforced building codes. Although most parts of the United States are now using the International Building Code (IBC), until recently most building codes in use in the United States were based on one of three model building codes: the *National Building Code (NBC)*, *Standard Building Code (SBC)*, and *Uniform Building Code (UBC)*. These codes were developed and published by industry associations representing building officials. The earthquake design provisions contained in these model codes are all similar and are based on recommendations developed by the Structural Engineers Association of California and the Building Seismic Safety Council. In the most seismically active regions of the United States, including Alaska, California, Idaho, Nevada, Oregon, Utah, and Washington, design has been based on the UBC for many years. In other regions of the nation, the other model building codes were commonly used. In many localities in these other regions, the seismic provisions of these codes are not enforced.

The UBC used in the past and the currently adopted IBC have adopted a seismic design philosophy intended to protect life safety, but allow for some structural and potentially significant nonstructural damage for earthquake levels as severe as can be expected at a site. The code implicitly sets forth the following three-level earthquake performance criteria:

1. Resist minor levels of earthquake ground motion (MMI less than or equal to VI) with no structural damage and with only minor damage to nonstructural features such as glazing, architectural finishes, and suspended ceilings. Such ground motion may occur many times during the economic life of a building and typically lasts only a few seconds. Ground motions experienced during the 1986 North Palm Springs and 1984 Morgan Hill earthquakes were typically of this severity.
2. Resist moderate levels of earthquake ground motion (MMIs of VII to VIII) with minor repairable structural damage, and possibly some extensive nonstructural damage. Such ground motion could occur once or twice during the economic life of a building. These motions may last up to 15 or 30 seconds. The 1994 Northridge earthquake produced this level of ground motion throughout the Los Angeles area. The 1989 Loma Prieta earthquake produced similar motion throughout the San Francisco Bay Area.
3. Resist major levels of earthquake ground motion (MMI greater than VIII), which has an intensity equal to the strongest either experienced or forecast for the building site, without collapse but possibly with some major structural as well as extensive nonstructural damage. Such ground motion may or may not occur during the economic life of a building. Ground motion of this intensity may last up to a minute or more. The 1906 San Francisco earthquake produced motions of this intensity throughout Northern and Central California.

The lateral force design regulations of the UBC and IBC primarily address requirements for building components and connections subjected to strong shaking during an earthquake. The design regulations do not address the effects of potential ground failures at a site, such as liquefaction, consolidation, landslides, and ground surface rupture. Any of these types of ground failures can result in excessive damage to a building, regardless of how well the building is constructed.

The intent of the seismic design provisions of the UBC and IBC is to prevent injuries and loss of life under the conditions discussed above, not to minimize property damage. Over the years, a few buildings have been designed to perform better. Such buildings are designed to substantially exceed the detailing, strength, and stiffness requirements specified by the building code as a minimum design basis. In some jurisdictions, schools, hospitals, fire and police stations, and communications centers are required to be designed to such enhanced criteria. However, most buildings are designed for the code minimums.

BUILDING EARTHQUAKE RESISTING SYSTEMS

Buildings are designed to resist wind and earthquake loads through the provision of a lateral-load-resisting system. The lateral-load-resisting system of a building typically comprises a combination of vertical and horizontal elements and their connections. Typical vertical elements are frames (beams and columns), braces, and walls. Typical horizontal elements are roofs, floors, and braces. Horizontal elements are usually termed diaphragms. Details of how these elements are constructed and interconnected are critical to a building's seismic performance.

Beams and columns with connections designed to resist bending and shear forces are termed moment-resisting frames. Typically, such frames are constructed of either monolithically placed reinforced concrete or structural steel. Recent codes require special detailing for these types of structures to ensure that they can behave in a ductile manner (able to absorb substantial amounts of energy and sustain extensive distress before collapse).

Walls designed to resist lateral loads are referred to as shear walls. Shear walls in buildings are composed either of reinforced concrete, reinforced or unreinforced masonry (concrete block or brick), or wood stud walls sheathed with plywood or gypsum board, or covered with stucco or plaster. In general, buildings with moment-resisting frames are more flexible than shear wall buildings and experience larger deformations in earthquakes. This commonly results in additional damage to architectural finishes.

When a building shakes back and forth, in response to ground motion, inertial lateral forces are generated at each point in the structure. Lateral loads generated within the roof and floors must be transferred to the vertical lateral-load-resisting elements. Typically, these loads are transferred to the vertical elements either by horizontal braces or by roof or floor diaphragms. (Diaphragms can be viewed as deep beams turned on their sides that resist horizontal loads by spanning between the vertical lateral-load-resisting elements.) Diaphragms can consist of plywood nailed to the floor framing, a reinforced concrete slab, or reinforced concrete over a metal deck.

The type of foundation used to support the structure can significantly influence its performance in areas that are potentially vulnerable to earthquake-induced ground failures. For example, buildings supported on well-designed piles driven to bedrock are generally not significantly affected by liquefaction or consolidation of soils directly under the structure. Footings, on the other hand, will not resist liquefaction or consolidation of soils because they depend directly on the soil for their support. Movement of the footings in this case generally results in large relative movements within the structure and the potential for extensive damage.

APPENDIX C: RISK AND PROBABLE MAXIMUM LOSS

Table C-1 Risk and Probable Maximum Loss		
Level of Risk	Probable Maximum Loss (% of total value)	Type of Damage
Low	0 – 10	Architectural damage; light, easily repairable
Moderately Low	10 – 20	Limited damage with some localized structural damage leading to short- term business interruption
Moderate	20 – 30	Substantial structural damage; structure may be closed for inspection and repair
High*	30 – 50	Severe structural damage possibly leading to partial collapse and critical economic loss
Very High*	>50	Severe structural damage leading to partial or total collapse and possibly to total economic loss of structure

* Possible life hazard

APPENDIX D: ABS CONSULTING QUALIFICATIONS

ABSG Consulting Inc. (ABS Consulting) provides **structural and earthquake engineering** services worldwide. ABS Consulting is the result of the recent consolidation of EQE International Inc. (EQE) and ABS Group Inc. Originally founded in San Francisco in 1981 to provide specialty earthquake engineering services, EQE grew to become a multinational firm with more than 500 employees and achieved international recognition in structural engineering and risk management consulting services relating to earthquakes, and other natural and operational hazards. ABS Group Inc., which provides a wide range of consulting services focused on improving the safety, quality and environmental impact of its clients' operations worldwide, is headquartered in Houston, TX.

In July of 2001, EQE and ABS Group completed consolidation of their operations. The two companies now have a combined force of more than 1,100 employees, operating in 32 countries, with annual revenues exceeding \$140 million. ABS Consulting is organized around four major divisions, one of which is Structural Risk.

Structural Risk staff consists of approximately 50 California licensed structural engineers and 50 licensed civil engineers. This Division has several regional offices located throughout the U.S. including Irvine (CA), Oakland, Seattle, Salt Lake City, and St. Louis.

Structural Risk consulting services include the following:

- Analysis and evaluation of existing buildings, structures, and bridges
- Structural retrofit design of buildings, structures, bridges, and equipment
- New facility design
- Plan check, design, and peer reviews
- Development of design criteria
- Earthquake damage investigation and repair
- Property acquisition due-diligence engineering studies
- Constructability reviews
- Construction management related to structural rehabilitation and retrofit
- Seismological criteria development
- Seismic and windstorm risk assessment for property portfolios
- Natural- and human-induced hazard preparedness/business recovery planning
- Vulnerability and reliability analyses of lifeline systems - power, water, gas, telecommunications

Earthquake Investigations. Our unique expertise in earthquake engineering is supported by investigations of nearly 100 major earthquakes worldwide and our knowledge of their impacts on buildings, equipment, infrastructure, lifelines, business operations, and preparedness planning. Information gathered from these events have been applied to resolving problems faced by private industry in protecting facilities of all types, and by government agencies in maintaining vital services. Senior structural engineering staff regularly participates in, and leads the periodic revision of, seismic design provisions of national codes for building and non-building structures.

Structural Engineering. Our structural engineers have completed a wide variety of projects, ranging in scale from structural conceptual studies to \$65 million medical and \$100 million industrial renovation projects. The wide range of facility types addressed includes schools, hospitals, low- to high-rise office buildings, R&D facilities, hotels, commercial and industrial buildings, manufacturing facilities, convention centers, museums, and parking and underground structures.

Our structural engineers actively participate across the whole spectrum of structural design, repair, retrofit and rehabilitation activities. We have also designed underground garages and basements, shoring, retaining structures, curtain walls, equipment supports, and bracing, anchorages and restraints for special equipment.

We also have extensive experience in the design of renovation and upgrades for unique structures of all types, including healthcare facilities and archaic structures. Our familiarity and experience with public agency requirements and state building codes (such as California's Office of Statewide Health Planning and Development - OSHPD) greatly benefit a project through expeditious plan-check reviews. Related projects (which underwent expeditious plan-checks) include an eight-story, 220-bed hospital, two large parking garages, several low-rise office buildings, a school theater and a state-of-the-art library/learning center, a high-security sonar testing facility for the US Navy, a 2,200 bed state correctional facility, buildings at a primary school, and four university buildings.

Seismic Retrofit Design. We have successfully upgraded or designed hundreds of structures, ranging from small-unreinforced masonry buildings to 40-story, steel-frame high rises. We have upgraded historical buildings that are on the National Register and applied innovative seismic retrofit techniques, such as base-isolation and energy-dissipating systems. With our extensive retrofit experience, we are able to develop rehabilitation programs that allow buildings to remain in use during construction, and preserve the existing architectural finishes and details when necessary. We have prepared seismic design and evaluation criteria for use by major corporations and government agencies, including the United States Department of Energy.

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