4.7 Procedures for Geologic Site Hazards and Foundations

This section provides Tier 2 evaluation procedures that apply to foundations and supporting soils: geologic site hazards, condition of foundations and capacity of foundations.

Commentary:

A thorough seismic evaluation of an existing building should include an examination of the foundation, an assessment of the capability of the soil beneath the foundation to withstand the forces applied during an earthquake, and consideration of nearby geologic hazards that may affect the stability of the building during an earthquake.

To fully assess the potential hazard presented by local geologic site conditions, and to establish soil engineering parameters required for analysis of these hazards, it may be necessary to consult with a geotechnical design professional. The evaluating design professional is strongly urged to seek consultation with appropriate professionals whenever site conditions are beyond the experience or expertise of the design professional.

4.7.1 Geologic Site Hazards

Commentary:

Certain geologic and local site conditions can lead to structural damage in the event of an earthquake. Large foundation movements due to any number of causes can severely damage otherwise seismic resistant building. Potential causes of significant foundation movement include settlement or lateral spreading due to liquefaction, slope failure, or surface ruptures. An evaluation of the building should include consideration for these effects and the impact they might have on the superstructure.

4.7.1.1 LIQUEFACTION: Liquefaction susceptible, saturated, loose granular soils that could jeopardize the building's seismic performance shall not exist in the foundation soils at depths within 50 feet under the building for Life Safety and Immediate Occupancy.

Tier 2 Evaluation Procedure: The potential for liquefaction and magnitude of differential settlement shall be evaluated. An analysis of the building in accordance with the procedures in Section 4.2 shall be performed. The adequacy of the structure shall be evaluated for all gravity and seismic forces in combination with the forces induced by the potential differential movement in the foundation.

Commentary:

Soils susceptible to liquefaction may lose all vertical load bearing capacity during an earthquake. Loss of vertical support for the foundation will cause large differential settlements and induce large forces in the building superstructure.

These forces will be concurrent with all existing gravity loads and seismic forces during the earthquake.

4.7.1.2 SLOPE FAILURE: The building site shall be sufficiently remote from potential earthquake-induced slope failures or rockfalls to be unaffected by such failures or shall be capable of accommodating any predicted movements without failure.

Tier 2 Evaluation Procedure: The potential magnitude of differential movement in the foundation shall be evaluated. An analysis of the building in accordance with the procedures in Section 4.2 shall be performed. The adequacy of the structure shall be evaluated for all gravity and seismic forces in combination with the forces induced by the potential differential movement in the foundation.

Commentary:

Steep slopes are susceptible to slides during an earthquake. Slope failures are possible in rock or other on non-liquefiable soils on slopes that normally exceed 6 percent. Slopes that exhibit signs of prior landslides require the most attention.

The concern for buildings on the uphill side of slopes is lateral spreading of the downhill footings. The concern for buildings on the downhill side is impact by sliding soil and debris.

4.7.1.3 SURFACE FAULT RUPTURE: Surface fault rupture and surface displacement at the building site is not anticipated.

Tier 2 Evaluation Procedure: The proximity of the building to known active faults shall be determined. The potential for surface fault rupture and magnitude of rupture shall be determined. An analysis of the building in accordance with the procedures in Section 4.2 shall be performed. The adequacy of the structure shall be evaluated for all gravity and seismic forces in combination with the forces induced by the potential differential movement in the foundation.

Commentary:

In the near field of active faults there is a potential for large fissures and differential movement to occur in the surface soils. Foundations of buildings located above these ruptures will be subjected to large differential movements that will induce large forces in the building superstructure.

These forces will be concurrent with all existing gravity loads and seismic forces during the earthquake.

4.7.2 Conditions of Foundations

Commentary:

Foundation elements are usually below grade and concealed from view. Evaluations, however, should still include consideration of the foundation and the condition of the elements. Often signs of foundation performance are visible on the surface in the form of existing differential settlement, sloping floors, out-of-plumb walls, and cracking or distress in visible portions of the footings.

4.7.2.1 FOUNDATION PERFORMANCE: There shall be no evidence of excessive foundation movement such as settlement or heave that would affect the integrity or strength of the structure.

Tier 2 Evaluation Procedure: The magnitude of differential movement in the foundation shall be evaluated. An analysis of the building in accordance with the procedures in Section 4.2 shall be performed. The adequacy of the structure shall be evaluated for all gravity and seismic forces in combination with the forces induced by the potential differential movement in the foundation.

Commentary:

The integrity and strength of foundation elements may be reduced by cracking, yielding, tipping, or buckling of the foundation. Such weakening may be critical in the event of an earthquake.

Lower level walls, partitions, grade beams, visible footings, pile caps, and similar elements shall be visually examined for cracking, yielding, buckling, and out-of-level conditions. Any such signs should be identified and further evaluated.

4.7.2.2 DETERIORATION: There shall not be evidence that foundation elements have deteriorated due to corrosion, sulphate attack, material breakdown, or other reasons in a manner that would affect the integrity or strength of the structure.

Tier 2 Evaluation Procedure: The cause and extent of deterioration shall be identified. The consequences of this damage to the lateral-force-resisting system shall be determined. The adequacy of damaged lateral-force-resisting elements shall be evaluated considering the extent of the damage and impact on the capacity of each damaged element.

Commentary:

Deterioration can cause weakening of the foundation elements, limiting their ability to support the building. Historical records of foundation performance in the local area may help assess the possibility of deterioration in the foundation of the building being evaluated.

4.7.3 Capacity of Foundations

Commentary:

Building foundation elements normally have a capacity at least two times the gravity loads. If there are no signs of foundation distress due to settlement, erosion, corrosion or other reasons, the foundations are likely to have adequate vertical capacity if the total gravity and seismic overturning loads do not exceed the allowable static capacity by more than a factor of two.

Foundations are considered to have adequate lateral capacity for seismic resistance if the allowable horizontal capacity of the foundation system exceeds the calculated seismic base shear of the buildings.

When the evaluation of foundation elements indicates significant problems, the evaluating design professional should consult with a qualified geotechnical design professional to establish rational criteria for foundation analysis and mitigation of unsatisfactory conditions.

4.7.3.1 POLE FOUNDATIONS: Pole foundations shall have minimumembedment of 4 ft. for Life Safety and Immediate Occupancy.

Tier 2 Evaluation Procedure: The lateral force resistance of embedded poles shall be checked using conventional procedures; the lateral force resistance shall be compared with conventional allowable pressures times 1.5.

Commentary:

Pole buildings are structures supported by poles or posts, usually found on rocky and hillside sites. Seismic resistance for a pole structure depends on the embedment depth of the poles and the resistance to active and passive soil pressures.

4.7.3.2 OVERTURNING: The ratio of the effective horizontal dimension, at the foundation level of the lateral-force-resisting system, to the building height (base/height) shall be greater than $0.6S_a$.

Tier 2 Evaluation Procedure: An analysis in accordance with the procedures in Section 4.2 shall be performed. The adequacy of the foundation including all gravity and seismic overturing forces shall be evaluated.

Commentary:

The concentration of seismic overturning forces in foundation elements may exceed the capacity of the soil, the foundation structure, or both.

For shallow foundations, the shear and moment capacity of the foundation elements should be evaluated for adequacy to resist calculated seismic forces. The vertical bearing pressure of the soil under seismic loading conditions due to the total gravity and overturning loads should be calculated and compared to two times the allowable static bearing pressure. For deep foundations, the ultimate vertical capacity of the pile or pier under seismic loads should be determined. The foundation capacity shall then be compared to the demands due to gravity loads plus overturning.

4.7.3.3 TIES BETWEEN FOUNDATION ELEMENTS: The foundation shall have ties adequate to resist seismic forces where footings, piles, and piers are not restrained by beams, slabs, or soils classified as Class A, B, or C.

Tier 2 Evaluation Procedure: The magnitude of differential movement in the foundation shall be determined. An analysis of the building in accordance with the procedures in Section 4.2 shall be performed. The adequacy of the structure shall be evaluated for all gravity and seismic forces in combination with the forces induced by the potential differential movement in the foundation.

Commentary:

Ties between discrete foundation elements, such as pile caps and pole footings, are required when the seismic ground motions are likely to cause significant lateral spreading of the foundations. Ties may consist of tie beams, grade beams or slabs. If the foundations are restrained laterally by competent soils or rock, ties are not required.

4.7.3.4 DEEP FOUNDATIONS: Piles and piers shall be capable of transferring the lateral forces between the structure and the soil. This statement shall apply to the Immediate Occupancy Performance Level Only. This statement shall apply to the Immediate Occupancy Performance Level only.

Tier 2 Evaluation Procedure: The lateral capacity of the piles, as governed by the soil or pile construction, shall be determined. An analysis of the building in accordance with the procedures in Section 4.2 shall be performed. The adequacy of the piles shall be evaluated for all gravity and seismic forces.

Commentary:

Common problems include flexural strength and ductility of the upper portions of piles or piers, or at the connection to the cap. Distinct changes in soil stiffness can create high bending stresses along the length of the pile.

For concrete piles, the design professional should check for a minimal amount of longitudinal reinforcement in the upper portion of piles or piers, and for hoops or ties immediately beneath the caps. The design professional should also check for confining transverse reinforcement wherever bending moments might be high along the length of the pile, including changes in soil stiffness.

4.7.3.5 SLOPING SITES: The grade difference from one side of the building to another shall not exceed one-half the story height at the location of embedment. This statement shall apply to the Immediate Occupancy Performance Level Only.

Tier 2 Evaluation Procedure: An analysis of the building in accordance with the procedures in Section 4.2 shall be performed. The adequacy of the foundation to resist sliding shall be evaluated including the horizontal force due to the grade difference.

Commentary:

The transfer of seismic force is more difficult when a permanent horizontal force is present.