COUNTY OF LOS ANGELES
DEPARTMENT OF PUBLIC WORKS
GEOTECHNICAL AND MATERIALS ENGINEERING DIVISION

LIQUEFACTION/LATERAL SPREAD

These guidelines address the geotechnical review of "Projects" (see SP117A, Table 1) in areas that have been designated by the California Geological Survey (CGS) to have a potential for liquefaction in accordance with the provisions of the Seismic Hazard Mapping Act of 1990 and the 2014 County of Los Angeles Building Code Section 1803. These guidelines may be used to address the geotechnical review of non-Projects when directed to do so by the Building Official. Supporting documents for these guidelines are as follows:

- CGS Special Publication SP117A; 2008.
- State of California Seismic Hazard Mapping Act of 1990 (Public Resources Code, Chapter 7.8, Division 2).
- Recommended Procedure for Implementation of DMG Special Publication 117, Southern California Earthquake Center (SCEC); 1999.

Per SP117A, "The State Mining and Geology Board recommends that engineering geologists and civil engineers conduct the assessment of the surface and subsurface geological/geotechnical conditions at the site, including off-site conditions, to identify potential hazards to the project. It is appropriate for the civil engineer to design and recommend mitigation measures. It is also appropriate for both the engineering geologist and civil engineers to be involved in the implementation of the mitigation measures – engineering geologist to confirm the geological conditions and civil engineers to oversee the implementation of the approved mitigation measures."

Prior to performing a quantitative assessment, a screening investigation should be conducted in accordance with SP117A. If the screening investigation clearly demonstrates the absence of a liquefaction hazard and the Geotechnical Development Review Units concur, the screening investigation will satisfy the site investigation report requirement. Otherwise, a quantitative evaluation is required to assess the liquefaction hazard.

The following screening criteria may be used to determine if specific layers or the maximum investigative depth explored may be excluded from further quantitative evaluation of liquefaction hazard:

1. Estimated maximum past, current, and future groundwater levels are determined to be deeper than 50 feet below the existing ground surface, finished grade, or 20 feet below the proposed bottom of foundations, whichever is deepest.

2. Bedrock or other similarly dense, lithified formational material underlying the site need not be considered liquefiable. Analysis of their liquefaction potential is not required. The presence of bedrock or other similar lithified formational material must be substantiated by either encountering refusal or by providing boring log(s) showing that at least 5 feet of such materials exist. It should be noted that hand augered refusals will not be accepted as adequate exploratory effort.

3. Corrected Standard Penetration Test (SPT) blow counts $(N_1)_{60}$, greater than or equal to 30. A sufficient number of tests shall be conducted to provide at least one SPT blow count record for every 5 feet of depth explored. If nonstandard samplers or penetration tests are used, conversion to SPT blow counts shall incorporate conservative conversion factors (e.g., conversion from California modified split spoon to field SPT blow counts is typically 0.67 to 0.7). Conversion of blow counts from nonstandard samplers or penetration tests, such as the Becker Penetration Test, to SPT blow counts will require supporting calculations and discussions.

4. Cone Penetration Test (CPT) results of discrete coarse-grained soil layers with corrected CPT tip resistances (q_{c1N}) greater than or equal to 160 tsf (156 kg/cm^2 or 16 MPa).

5. Soils that behave like clays and do not undergo severe strength loss during ground shaking may be generally considered not susceptible to liquefaction. To determine if soils are susceptible to liquefaction, the Plasticity Index (PI) and in-situ moisture content must be determined. Soils considered to be potentially susceptible to undergoing seismically induced deformation during liquefaction are classified in the following manner; **(1)** P1<12 and moisture content greater than 85 percent of the liquid limit, or **(2)** soils with a P1>18 and a degree of sensitivity (S_t) greater than 6.

Typically the S_t is determined as the ratio of undisturbed to remolded compressive strength. Similar tests may also be conducted to determine the S_t such as, ratio undisturbed to remolded shear strength and a consolidated undrained triaxial stress relaxation tests (for additional S_t references, see *Soil Mechanics in Engineering Practice* 3rd Edition by Terzaghi, Peck, and Mesri or *An Introduction to Geotechnical Engineering* by Holtz and Kovacs).

Note: Use of Soil Behavior Type Index (I_c) values may not be used as screening criteria and may not be used to exclude layers from the seismically induced settlement calculations.

If the screening investigation cannot clearly demonstrate the absence of a liquefaction hazard at the site, an engineering geology and/or soils engineering report that addresses the potential for liquefaction and associated settlement and lateral spreading will be required. The report(s) must, at a minimum, include and consider the following:

1. A description of the proposed project's location, proposed grading, drainage, topographic relief, and subsurface geologic conditions.

2. A site plan of the subject site showing the location of all exploratory work, including test pits, borings, penetration tests, and soil/rock samples obtained. The site plan shall also include the direction of north, plan scale, and location of proposed site improvements and property lines.

3. Logs of borings, CPT soundings, test pits, and other subsurface data obtained. Boring logs shall provide raw (unmodified) N-values if SPT's are performed; CPT probe logs shall provide raw qc-values and plots of raw sleeve friction values. It is required that subsurface data be collected and analyzed to a minimum depth of 50 feet below ground surface or finished grade, whichever is deeper. When a structure may have subterranean construction or deep foundations, the minimum depth of exploration must be extended to a minimum of 20 feet below the lowest expected foundation level (bottom of caisson or pile), or 50 feet below ground surface, whichever is deeper. Also, when proposed developments are within several hundred feet of a free face of slope, the depth of exploration shall be adequate to evaluate the site's lateral spreading capacity.

4. Groundwater level to be used in the liquefaction analysis. SP117A requires that the analysis of hydrologic conditions consider the current, historical, and potential future depth of subsurface water. The historic high groundwater level shall be used in the liquefaction analysis unless a shallower level (higher elevation than historic high) is determined to be appropriate.

5. Description of seismic setting, historical seismicity, and methods and/or sources used to determine earthquake ground-motion parameters used in the liquefaction analysis. SP117A indicates that either a Probabilistic or Deterministic Seismic hazard Analysis must be performed in order to obtain a peak horizontal ground acceleration and earthquake magnitude for use in a quantitative analysis. To determine which evaluation is most appropriate to the proposed site improvements, please refer to the following.

   Probabilistic

   Probabilistic Seismic Hazard Analysis must utilize at least a hazard level of 2 percent probability of exceedance in 50 years.

   County reviewers will review the seismic parameters submitted in the site-specific hazard analysis by utilizing the national earthquake source database at http://geohazards.usgs.gov/deaggint/2008/. The peak horizontal ground acceleration and mean magnitude will be compared against the acceleration and magnitude values utilized in the submitted quantitative evaluation of liquefaction resistance.

Seismic parameters utilized in the consultant's quantitative evaluation will be accepted if they are equal to or more conservative than the parameters obtained by the County reviewer. Seismic parameters that do not meet the values obtained by County reviewer must be justified by the consultant and approved by the reviewer.

-OR-

Deterministic

Earthquake magnitudes based upon the current United States Geological Survey/CGS database of earthquake sources are readily available and should be utilized in determining a peak horizontal ground acceleration and magnitude. The deterministic earthquake event for any fault should be a maximum value that is specific to that seismic source.

Attenuation equations and values must use current literature and site conditions.

Geotechnical consultants should utilize the average ground motion obtained from the three attenuation relations in the quantitative liquefaction evaluation. For high occupancy structures, it is common practice to use a deterministic seismic hazard analysis with a median-plus-one-standard-deviation (84th percentile) in developing ground motion estimates.

Seismic parameters that do not meet values obtained by County reviewers must be justified by the consultant. County reviewers must concur with the justification and/or findings in order for lower seismic parameters to be used in the quantitative evaluation.

6. Consideration of the geologic factors that may control or affect the severity of potential hazards (e.g., site-specific response characteristics due to amplification of soft soils, deep sedimentary basins, topography, near-source affects, etc.).

7. The geotechnical report must comply with and contain a finding in accordance with Section 111 of the County of Los Angeles Building Code.

8. Discussion of proposed mitigation measures, if any, necessary to reduce potential damage caused by liquefaction.

9. Specific commentary and supporting data provided for every layer excluded from liquefaction assessment and settlement analyses.

10. Depth of exploration to a minimum of 50 feet below ground surface, finished grade, or 20 feet below the lowest expected foundation level (bottom of caisson or pile), whichever is deepest.

11. When using the CPT, provide a confirmation boring to meet the minimum required depth of exploration (see Item No. 2 above). The CPT and confirmation boring shall be conducted in close proximity to each other, but not be spaced so closely that stress relief may affect the results.

12. A factor of safety (FS) of 1.30 shall be used in the quantitative liquefaction hazard evaluation to determine the exclusion of layers from settlement calculations. The FS is the ratio of the magnitude corrected cyclic resistance ratio (CRR) to the cyclic stress ratio (CSR) or simply FS = CRR/CSR. Layers that do not have a FS greater than (>) or equal to 1.30 shall be included in the seismically induced settlement calculations.

13. Quantitative analysis shall not combine layers of raw data regardless of data similarity (for example: converting 50 CPT layers of 0.1-foot thickness into a 5-foot thick average layer).

14. All acceleration values must be magnitude weighted in accordance with magnitude scaling factors after Youd and Idriss, 1997.

15. All correction factors applied to raw SPT blow counts and CPT soundings shall be discussed and sufficiently justified.

16. Consistent values must be used throughout the analyses, or they must be adequately explained and supported with substantiating data.

17. Bridging of non-liquefiable soil layers above liquefiable layers is not considered an adequate explanation or justification for exclusion of those layers in the seismically induced settlement calculations.

18. Total seismically induced settlement must be the sum of seismically induced settlements of both the saturated and unsaturated soils.

19. Differential settlement shall be taken at least half of the total seismically induced settlement over a horizontal distance of 30 feet. In order to use less than half of the total settlement, there must be additional borings onsite that confirm the uniformity of the soil stratigraphy and relative density.

20. Assessment of lateral spreading must be conducted when gently sloping ground or free faces (e.g., marina seawalls, drainage channels) are within or in close proximity to the site. Soil layers having equivalent $(N_1)_{60}$ blow counts less than 15 should be evaluated to assess the lateral spreading hazard.

21. Structural mitigation alone is acceptable for: (1) up to 1 inch of seismically induced differential vertical displacement over a horizontal distance of 30 feet, (2) up to 4 inches of total seismically induced settlement, and (3) up to 12 horizontal inches of lateral ground displacement. Anything in excess of the aforementioned values requires ground modification. A combination of ground modification, piles, and structural mitigation may be acceptable on a case by case basis.

22. A "Project" and applicable non-Projects will be approved only when the nature and severity of liquefaction potential at the site has been evaluated in a geotechnical report and appropriate mitigation measures have been proposed and incorporated into the plans.

23. If CPT data is used in quantitative liquefaction analysis, submittal of the electronic version of CPT data in a spreadsheet format, on a compact disc, will aid in the review process.

24. A copy of all submitted geotechnical reports and review sheets approving the "Project" must be sent to the State Geologist within 30 days of recommending the plan for approval.

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