SEAOC Seismology Committee
Position Statement- June 1999

<u>Seismic Design of Structures on Liquefiable Soils</u>

Soil Profile Types are described in Chapter 16 of the 1997 Uniform Building code in Table 16-J. Table 16-J notes that Soil Profile Type S_F is a soil requiring "site-specific evaluation" according to Section 1629.3.1. Section 1629.3.1 identifies four classes of soils corresponding to Soil Profile Type S_F. One of these classes is described as *"soils vulnerable to potential failure or collapse under seismic loading, such as liquefiable soils, quick and highly sensitive clays, and collapsible weakly cemented soils."* Such soil profiles, including those that have liquefiable soils, are required to have a site-specific evaluation to establish the Seismic Coefficients, C_a and C_v, according to Tables 16-Q and 16-R. These seismic coefficients are needed to establish the design base shear as given in Section 1630.2.1.

Section 1804.5 requires the evaluation of the potential for soil liquefaction and soil strength loss during earthquakes during the geotechnical investigation when required by Section 1804.2. Section 1804.2 states that the potential for seismically induced soil liquefaction and soil instability shall be evaluated in Seismic Zones 3 and 4, when required by the building official. Section 1804.5 states that the geotechnical report shall assess potential consequences of any liquefaction and soil strength loss, including estimation of differential settlement, lateral movement or reduction in foundation soil-bearing capacity, and discuss mitigating measures. These measures may include, but are not limited to, ground stabilization, selection of appropriate foundation type and depths, selection of appropriate structural systems to accommodate anticipated displacements, or any combination of these measures.

If there is liquefaction potential at a site identified by the geotechnical investigation, the possible consequences may define or limit the options available for mitigation of the effects of the liquefaction event. If it is determined that the consequences result in loss of soil strength and soil deformations that result in unacceptable behavior or structural instability, some process of ground stabilization may be appropriate for the site. If such a mitigation approach is used, and the area of improvement extends throughout the building area and beyond, it may be possible that the Soil Profile Type may be improved to a site class other than S_F. The determination of the appropriate site profile type should be based on the improved soil properties. The design base shear for the site can be determined using the procedure described above.

In some cases, however, although there is liquefaction potential, it may be determined that the consequences of liquefaction do not result in significant loss of soil strength and/or excessive soil deformations. To be more explicit, the soil deformations would result in small amounts of vertical settlement and there should be no horizontal lateral spreading or flow slides. This may allow for acceptable structural performance despite the event of liquefaction. In these cases, the Soil Profile Type will be S_F. To determine the design base shear for the structural design, the UBC requires a dynamic site response analysis.
It is now believed that site response analysis techniques are sufficiently developed to model the liquefaction behavior of soil sites. It is recognized that these techniques must be carefully and thoughtfully used to develop useful and realistic site response behavior. As an alternative to a site-specific response analysis for short period structures (structural period less than 0.7 sec) subject to liquefaction potential, the following conservative approach may be used.

The geotechnical investigation should be performed to obtain soils information to allow for the site to be categorized according to the procedures in Section 1636. The geotechnical investigation should obtain the soil properties needed that are given as the average shear wave velocities, standard penetration resistances, or undrained shear strengths.

The Soil Profile Type should be determined using the soil properties from the geotechnical investigation, assuming that liquefaction will not occur. The Seismic Coefficients C_a and C_v, may be determined from Tables 16-Q and 16-R using the Soil Profile Type determined in the step above.

The rationale for this alternative procedure is that during an earthquake, the soil profile will have different response or behavior before and after the on-set of liquefaction. Before the on-set of liquefaction, the soil profile may be considered to be non-liquefied and it may be expected that the ground motions will be characteristic of the behavior modeled by the Soil Profile Types for non-liquefied soils. For non-liquefied soils, it is expected that the short period spectral accelerations will be quite high. After the on-set of liquefaction, the soil will become much softer and result in a reduction of the short period ground motions and spectral accelerations. The longer period spectral response, however, may increase dramatically in terms of greater displacements. This approach is believed to be conservative for determining the design base shear for short period ($T<0.7$ sec) structures.

In lieu of the evaluation above to determine the Soil Profile Type in the absence of liquefaction, it would be conservative to determine the Seismic Coefficients C_a and C_v, assuming the worst case conditions using the highest values from an envelop using both Soil Profile Type S_D (for C_a) and S_E (for Cv).

This procedure does not apply to other soil profiles that may determined to be Type S_F. For example, soft clay soils may amplify the short period ground motions and spectral response, even for high levels of ground shaking.

It should be reiterated that this alternative procedure for determining the seismic coefficients and design base shear for a short period structure on a liquefiable site would only be applicable where the consequences of liquefaction can be demonstrated to not result in significant loss of soil strength and/or excessive soil deformations, and also not result in unacceptable structural behavior. The effects of differential settlement, lateral movement or reduction in foundation soil-bearing capacity should be considered in the structural design.