MODULE – 4

Dynamic Soil Properties
SOIL DYNAMICS

Liquefaction

- Strength and stiffness of a loose, saturated, cohesionless soil is reduced by earthquake shaking (or other rapid loading)
- Increase in pore water pressure during undrained shearing causes a reduction in effective stress which in turn reduces the shear strength
- Pore pressure is often released through sand or water boils
- The soil behaves more like a viscous fluid; heavy structures sink and light structures float

SOIL DYNAMICS

Liquefaction (contd.)

- Increase in pore water pressure during undrained shearing causes a reduction in effective stress which in turn reduces the shear strength

- Strength of a cohesionless soil is a function of overburden pressure and the angle of internal friction, only

\[ s = \sigma_{v0} \tan \phi \]
Liquefaction (contd.)

From Terzaghi’s principle of effective stress, if the pore water pressure \( u \) increases, the effective stress will decrease

\[
\sigma'_{v0} = \sigma_{v0} - u
\]

“Full liquefaction” is defined as excess pore water pressure ratio \( r_u \) equal to 1.0

\[
r_u = \frac{U_{\text{excess}}}{\sigma'_{v0}}
\]

Factors Influencing Liquefaction Susceptibility

- Earthquake intensity and duration
- Soil type
- Soil relative density
- Particle size distribution
- Presence or absence of plastic fines
- Groundwater table location (saturation)
- Hydraulic conductivity
- Placement conditions or depositional environment
- Aging and cementation
- Overburden pressure
- Structure load
- Historical liquefaction
Preliminary Screening for Liquefaction

1. Screening investigation
2. Quantitative evaluation

**Screening:** review of relevant topographic, geologic, soils engineering maps and reports, aerial photographs, groundwater contour maps, water well logs, agricultural soil survey maps, history of liquefaction in the area, other relevant published and unpublished sources.

**Is the soil saturated?**

If the estimated maximum-past, current and maximum-future-ground-water-levels (i.e. highest ground water level applicable for liquefaction analyses) are determined to be deeper than 50 feet below the existing ground surface or proposed finished grade (whichever is deeper), liquefaction assessments are not required. (Martin and Lew, 1999)

**Is the site underlain by bedrock?**

Bedrock or similar lithified formation material underlies site.

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**SOIL DYNAMICS**

Prof. Deepankar Choudhury, Department of Civil Engineering, IIT Bombay, Mumbai, India
SOIL DYNAMICS

Preliminary Screening for Liquefaction

- Is the corrected SPT $N_{L,60}$ value greater than 30 blows per foot in all samples for a sufficient number of tests?

  If so, liquefaction tests are not required. Similarly, if corrected CPT tip resistance, $q_{c1N_f}$ is greater than or equal to 160 in all soundings in sandy materials, liquefaction assessment is not required.

- Is site underlain by clayey materials?

  If the soil throughout the site clearly classifies as clay per the Chinese Criteria, Andrews and Martin (2000) and Seed et al. (2003), additional quantitative liquefaction assessments are not required.

SOIL DYNAMICS

Simplified Procedure for Liquefaction

→ Most basic procedure used in engineering practice for assessment of liquefaction potential is the “Simplified Procedure” originally by Seed and Idriss (1971), subsequently updated and refined (see Youd and Idriss, 1997, Youd et al. 2001 and Seed et al. 2003)

→ Compares a cyclic resistance ratio with the earthquake-induced cyclic stress ratio at a given depth for a specified design earthquake.

**CRR:** cyclic resistance ratio of the soil layer; cyclic stress ratio required to induce liquefaction for a cohesionless soil stratum of given properties at a given depth.
Simplified Procedure for Liquefaction

**CSR:** seismic demand on a soil layer; based on a peak ground surface acceleration and an associated moment magnitude.

→ Allows a factor of safety against liquefaction, $FS_I$, to be calculated for a soil stratum at a given depth.

$$FS_I = \frac{CRR_{7.5}}{CSR}$$

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**SOIL DYNAMICS**

Liquefaction (contd.)

Process by which zone of liquefaction is identified.
Liquefaction (contd.)

Process by which the zone of liquefaction is identified in the cyclic strain approach

Acceptable Factor of Safety

- 1.3 is recommended, but depends on severity of hazard, importance and vulnerability of structure, tolerable settlements or level of risk acceptable to owner or regulating body, confidence and certainty in underlying data and assumptions

- Lower factor of safety (1.1) may be acceptable for single family dwellings, for example, where potential for lateral spreading is low and differential settlement is hazard of concern, where post-tensioned floor slabs are specified.