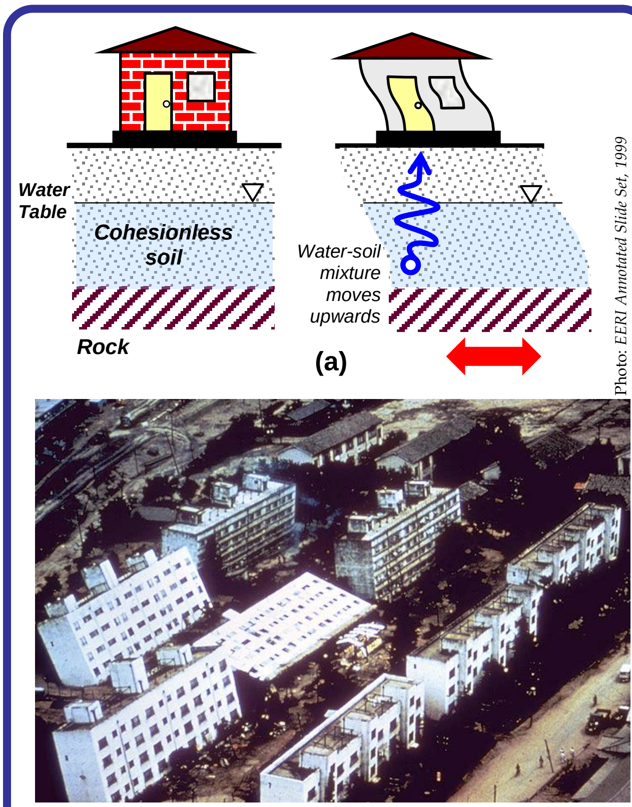
IITK – BMTPC Earthquake Tip 31

*Learning Earthquake Design and Construction*

# Why do Buildings Sink into the Ground during Earthquakes?

## What is Liquefaction of Soils?

A special situation arises during earthquake shaking in sandy (cohesionless) soils that are loose and saturated with water. Horizontal shaking of the earth at the bedrock level is transmitted upwards to overlying layer(s) of soil. Saturated loose cohesionless soils have voids between soil particles filled with water. During strong ground shaking, loose sand tends to densify; this tends to compress water, but because water is incompressible, it tends to escape out. Water cannot drain out quickly from the soil (Figure 1a), and therefore *pore water pressure* increases in soil; this reduces the *effective stress* between soil particles. At some stage the *effective stress* may become almost zero. In that situation, since soil strength depends on this *effective stress,* the soil may loose its shear strength completely and behave like a liquid; this phenomenon is called *liquefaction*. Buildings and structures rested on such soils can topple and sink into the ground (Figure 1b). Depending on soil properties and ground motion characteristics, the earthquake may impose *shear stress demand* in soil at some depth that exceeds *shear strength capacity* of soil; soil liquefies over this depth (Figure 2).




(b)

**Figure 1: Soil liquefaction during earthquake shaking** – *(a) Process of liquefaction, and (b) Collapse of buildings during 1964 Niigata Earthquake, Japan*

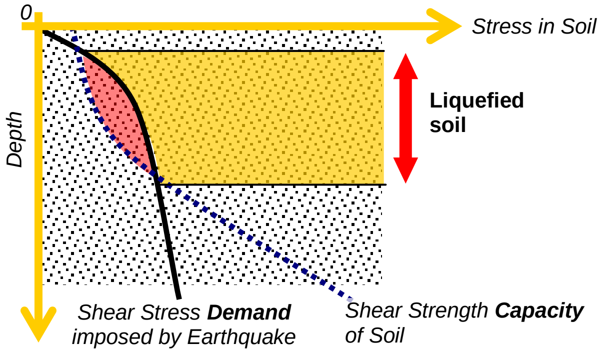


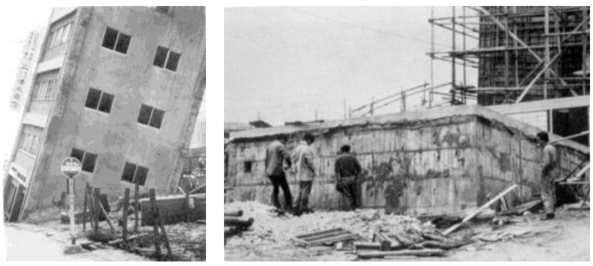

**Figure 2: Liquefaction of soil layer** – liquefied soil layer may be embedded at a depth beneath the ground surface

## Physical Consequences of Liquefaction

During liquefaction, *cohesionless soil-water mixture* tends to behave like a liquid, and hence the ground tends to flatten out. For instance, embankments may collapse while the depth of ponds may reduce. This can have serious detrimental effects on structures.

(1) *Sinking and uplifting of structures*

As the *cohesionless soil-water mixture* liquefies, structures tend to settle or sink into the ground (Figure 3). In many cases, some parts of the building may sink more than the others, leading to tilting of the building. Similarly, buried structures tend to uplift and float up to the surface, because their overall density is lower than the *liquefied* soil.



(a) (b)

**Figure 3: Sinking and uplift of structures** – (a) Sinking of a building, and (b) uplift of sewage tank, during 1964 Niigata Earthquake, Japan

(2) *Slope failures and lateral spreading*

When soil at a lower level looses its strength to hold any load, the overlying soil layer may slide laterally, especially when slope is steep (>~5%) and the original soil is loose. This can cause landslides extending over hundreds of meters of motion of soil mass (Figure 4a). In both loose and dense soils, when the slope is gentle (<~3%), forward movement of a large soil mass can cause disintegration of the large soil mass behind it. Therefore, structures may sink and destabilize, if supported by such soil (Figure 4b). Soil movement due to lateral spreading can exert significant stresses and damage in foundations and bridge abutments causing damages.

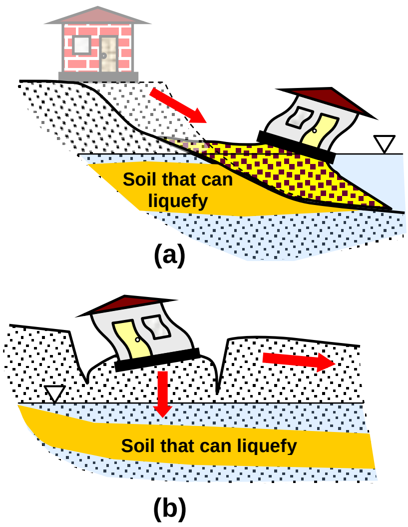



**Figure 4: Lateral spreading of slopes** – (a) steep slopes slide, and (b) gentle slopes subside

## Parameters Influencing Liquefaction

Susceptibility of a site to liquefaction depends on following factors:

(1) *Soil properties*: Uniformly-graded, fully-saturated cohesionless (sandy) soils are more prone to liquefaction than well-graded soils. Also, fine sands are more susceptible to liquefaction than coarse sands, gravelly soils, silts or clays. Sands with some clay content also can liquefy. Loose sands have much higher tendency to liquefy than dense sands.

(2) *Earthquake shaking characteristics*: As shaking intensity increases, soil is subjected to higher stresses and strains, and is more susceptible to liquefaction. Also, strong shaking with longer duration causes a larger number of stress and strain cycles in soil; this increases chances for liquefaction.

(3) *Geologic conditions*: Some geologic processes sort soils into uniform grain size and deposit them loosely, as in *Aeolian*, *Fluvial* and *Colluvial* deposits; such soils are candidates for liquefaction.

## Measures to overcome Liquefaction

To overcome liquefaction one may:

(a) *Increase* liquefaction-resistance of soil, *e.g.*, densify loose deposits (by vibro-compaction, impact compaction and pressure grouting) or replace susceptible soil (by vibro-replacement) (Figure 5a);

(b) *Reduce* earthquake demand on soil, *e.g.*, release of pore water pressure by allowing drainage of water (by stone columns), or increase confinement by adding a surcharge (Figure 5b);

(c) *Remove* soil layers that can liquefy, or use anchored piles as foundations going through liquefiable soil layers (Figure 5c).

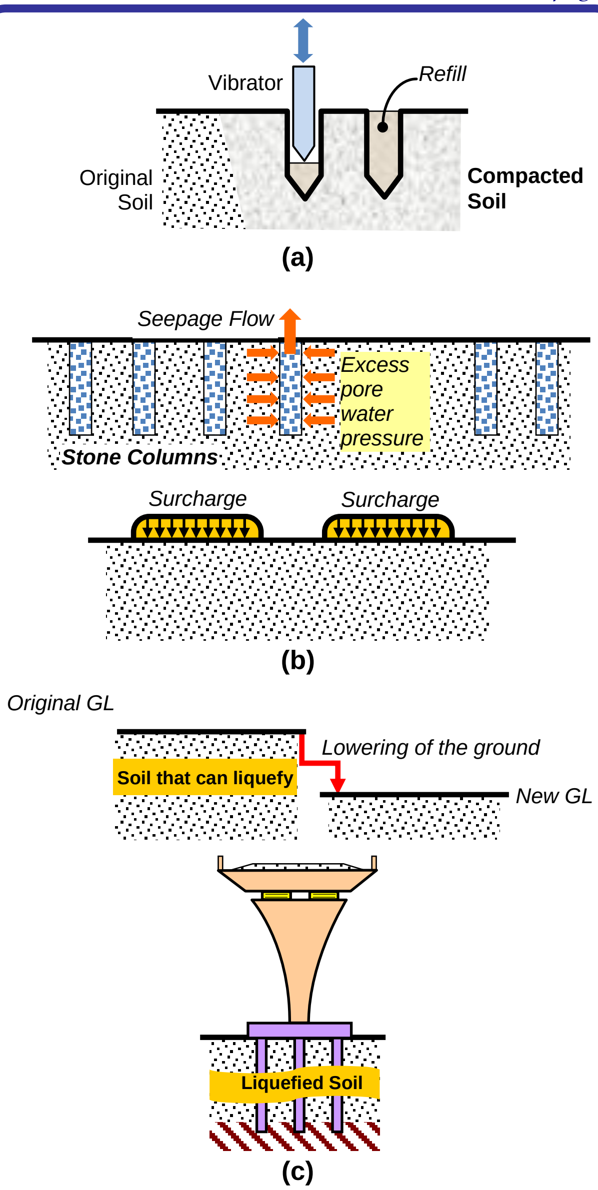



**Figure 5: Measures to overcome liquefaction** – three options

## Related IITK - BMTPC Earthquake Tip

*Tip 31: What is important in foundations of earthquake-resistant buildings?*

## Resource Material

Kramer,S.L., (1996), *Geotechnical Earthquake Engineering*, Prentice Hall, Inc., New Jersey, USA

Towhata,I., (2008), *Geotechnical Earthquake Engineering*, Springer-Verlag, Berlin

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