EFFECT OF EARTHQUAKE ON SHEAR STRENGTH OF SOIL

First of all, let us take a look on soil

What is soil consisted of?

Normal natural soil (not problematic soil) consists of the following:

Gravel (abbreviated as G) <may be coarse, medium, or fine>

Sand (abbreviated as S) <may be coarse, medium, or fine>

Silt (abbreviated as M, to differentiated from sand), and

Clay (abbreviated as C) <high plasticity or low>

:---- 60 mm
GRAVEL
:
:
:----------------------- <2.00 TO 4.75 mm>
:
:
SAND
:
:
:---------------------- <0.060 TO 0.074 mm>
:
:
SILT
:
:
:--------------------- <0.001 TO 0.005 mm> with 0.002mm
:   most common
:
CLAY
:--- To several sheet thickness, knowing that each sheet
thickness is about 7.2 A.

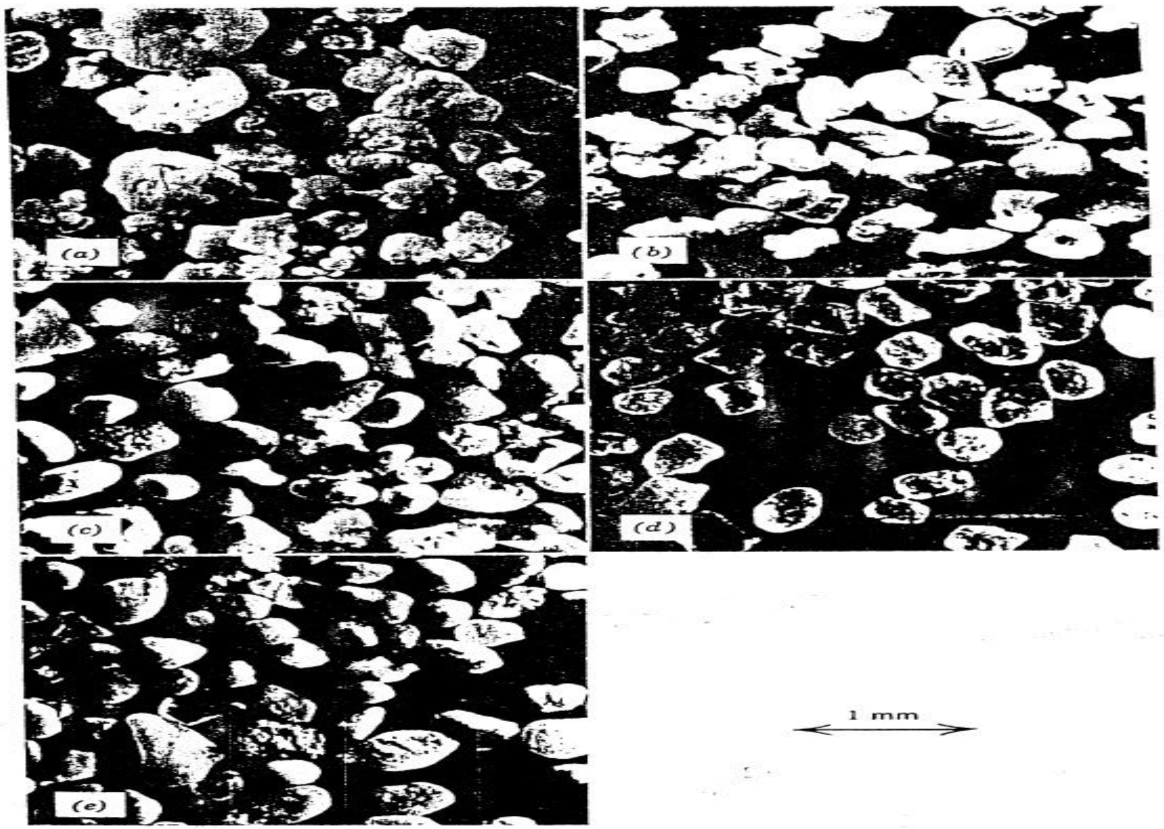


Fig. 4.3 Sands from Libya (0.15 to 0.25 mm fraction). (*a*) Plant site, Brega. (*b*) Harbor bottom, Brega. (*c*) Gas plant, Brega. (*d*) Raguba. (*e*) Crude tank farm, Brega. (Sands supplied by ESSO Libya; Photos by R. T. Martin, M.I.T.)

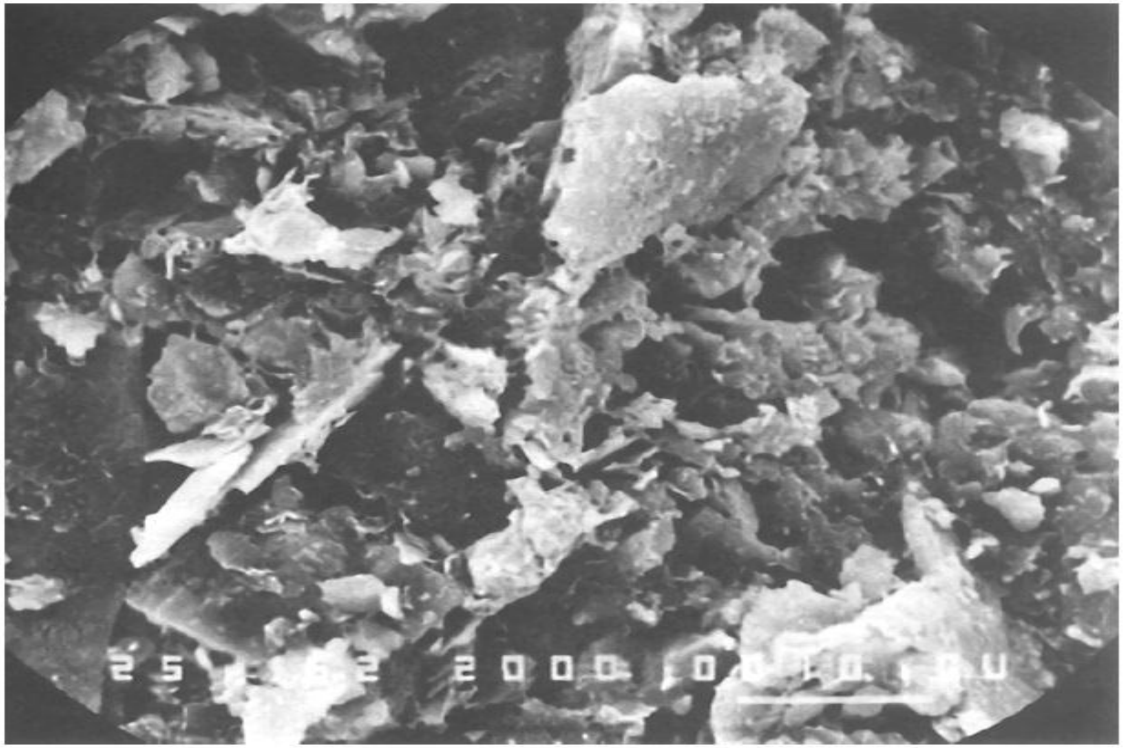
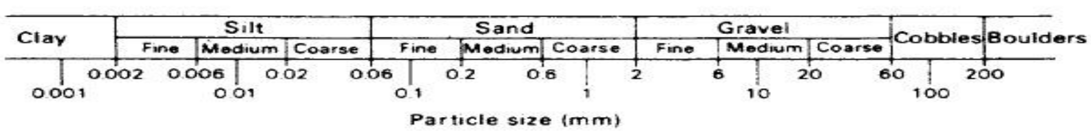


Figure 1.5 Structure of Errol Clay.



The Effects of Soil Type on Earthquake Damage

When thinking about the dispersion of effects of an earthquake, many people think of it like dropping a pebble in a lake. The pebble hits the water and it creates a uniform ripple effect getting weaker as it travels from the center. The earth's surface, however, is not uniform like the water in this comparison.

Now please care for the following facts;

During an earthquake one area can experience over ten times the effects as a neighboring area that is the same distance from the fault line.

This is because of what are called "site effects". Site effects are variations that occur in the geologic conditions of a particular location.

There are two main conditions that account for these variations: The softness of the soil or rock, and the total thickness of the sediment above the bedrock. The softer and thicker the sediment is, the greater the effects of an earthquake will be amplified.

As seismic waves travel though the ground, they travel faster through hard rock than soft soil. As a result, when the waves move from hard rock to soft soil, the amplitude (largeness) of the waves needs to increase to be able to carry the same amount of energy, creating stronger shaking. This same principle accounts for the site effects of sediment thickness. The deeper the sediment above bedrock, the more soft soil there is for seismic waves to travel through, therefore creating stronger amplifications.

THE NATIONAL EARTHQUAKE HAZARDS REDUCTION PROGRAM (NEHRP) HAS DEFINED SIX DIFFERENT SOIL AND ROCK TYPES BASED ON THEIR SHEAR-WAVE VELOCITY, IN ORDER TO DETERMINE AMPLIFICATION EFFECTS:

Type A, hard rock (igneous rock).

Type B, rock (volcanic rock).

Type C, very dense soil and soft rock (sandstone).

Type D, stiff soil (mud).

Type E, soft soil (artificial fill).

Type F, soils requiring site-specific evaluations.

As such;

Type A having the least amplification and Type E the most.

Although soil type is a significant indicator of how specific locations will be affected by an earthquake, other factors can also contribute to “hotspots”, which are unique to each earthquake. The orientation of the fault, irregularities in the rupturing fault surface, and dispersion of waves as they hit subsurface structures can all have an influence in creating hotspots.

Soil Types and Shaking Amplification:

One contributor to the site amplification is the velocity at which the rock or soil transmits shear waves (S-waves). Shaking is stronger where the shear wave velocity is lower. The National Earthquake Hazards Reduction Program (NEHRP) has defined 5 soil types (before six) based on their shear-wave velocity (Vs). Source reference has modified these definitions slightly, based on studies of earthquake damage in the Bay Area. The modified definitions are as follows:

Soil type A	Vs > 1500 m/sec	Includes unweathered intrusive igneous rock. Occurs infrequently in the bay area. We consider it with type B (both A and B are represented by the color blue on the map). Soil types A and B do not contribute greatly to shaking amplification.
Soil type B	1500 m/sec > Vs > 750 m/sec	Includes volcanics, most Mesozoic bedrock, and some Franciscan bedrock. (Mesozoic rocks are between 245 and 64 million years old. The Franciscan Complex is a Mesozoic unit that is common in the Bay Area.)
Soil Type C	750 m/sec > Vs > 350 m/sec	Includes some Quaternary (less than 1.8 million years old) sands, sandstones and mudstones, some Upper Tertiary (1.8 to 24 million years old) sandstones, mudstones and limestone, some Lower Tertiary (24 to 64 million years old) mudstones and sandstones, and Franciscan melange and serpentinite.
Soil Type D	350 m/sec > Vs > 200 m/sec	Includes some Quaternary muds, sands, gravels, silts and mud. Significant amplification of shaking by these soils is generally expected.
Soil Type E	200 m/sec > Vs	Includes water-saturated mud and artificial fill. The strongest amplification of shaking due is expected for this soil type.

EARTHQUAKE WILL AFFECT SOIL STRENGTH BY TWO ASPECTS:

For sand there will be the liquefaction phenomena

For clay the effect will be experienced through quick clay

FIRST

Soil Liquefaction

Soil liquefaction describes a phenomenon whereby a saturated or partially saturated soil substantially loses strength and stiffness in response to an applied stress, usually earthquake shaking or other sudden change in stress condition, causing it to behave like a liquid.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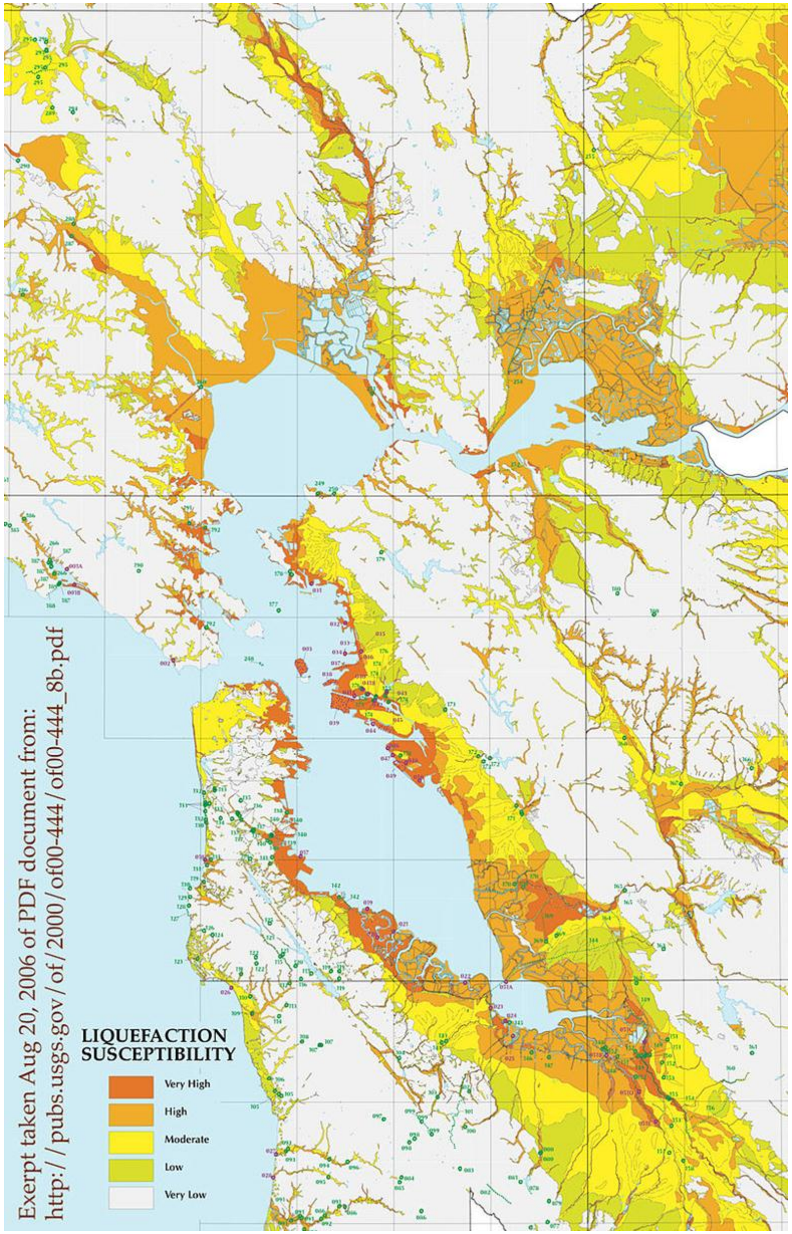
In soil mechanics the term "liquefied" was first used by Allen Hazen in reference to the 1918 failure of the Calaveras Dam in California. He described the mechanism of flow liquefaction of the embankment dam as follows:

"If the pressure of the water in the pores is great enough to carry all the load, it will have the effect of holding the particles apart and of producing a condition that is practically equivalent to that of quicksand...As such, the initial movement of some part of the material might result in accumulating pressure, first on one point, and then on another, successively, as the early points of concentration were liquefied."

Occurrence:

Liquefaction is more likely to occur in loose to moderately saturated granular soils with poor drainage, such as silty sands or sands and gravels capped or containing seams of impermeable sediments. During wave loading, usually cyclic undrained loading, e.g. seismic loading, loose sands tend to decrease in volume, which produces an increase in their pore water pressures and consequently a decrease in shear strength, i.e. reduction in effective stress.



A liquefaction susceptibility map—excerpt of USGS map for the San Francisco Bay Area. Many areas of concern in this region are also densely urbanized.

SECOND

Quick clay

Quick clay, also known as Leda Clay (in Canada), is a water-saturated gel, which in its solid form resemble a unique form of highly sensitive clay. This clay has a tendency to change from a relatively stiff condition to a liquid mass when it is disturbed. This gradual change in appearance from solid to liquid is a process known as spontaneous liquefaction. The clay retains a solid structure despite the high water content (up to 80% by volume), because surface tension holds water-coated flakes of clay together in a delicate structure. When the structure is broken by a shock or sufficient shear, it turns to a fluid state.

Here are some real footages showing the disaster:

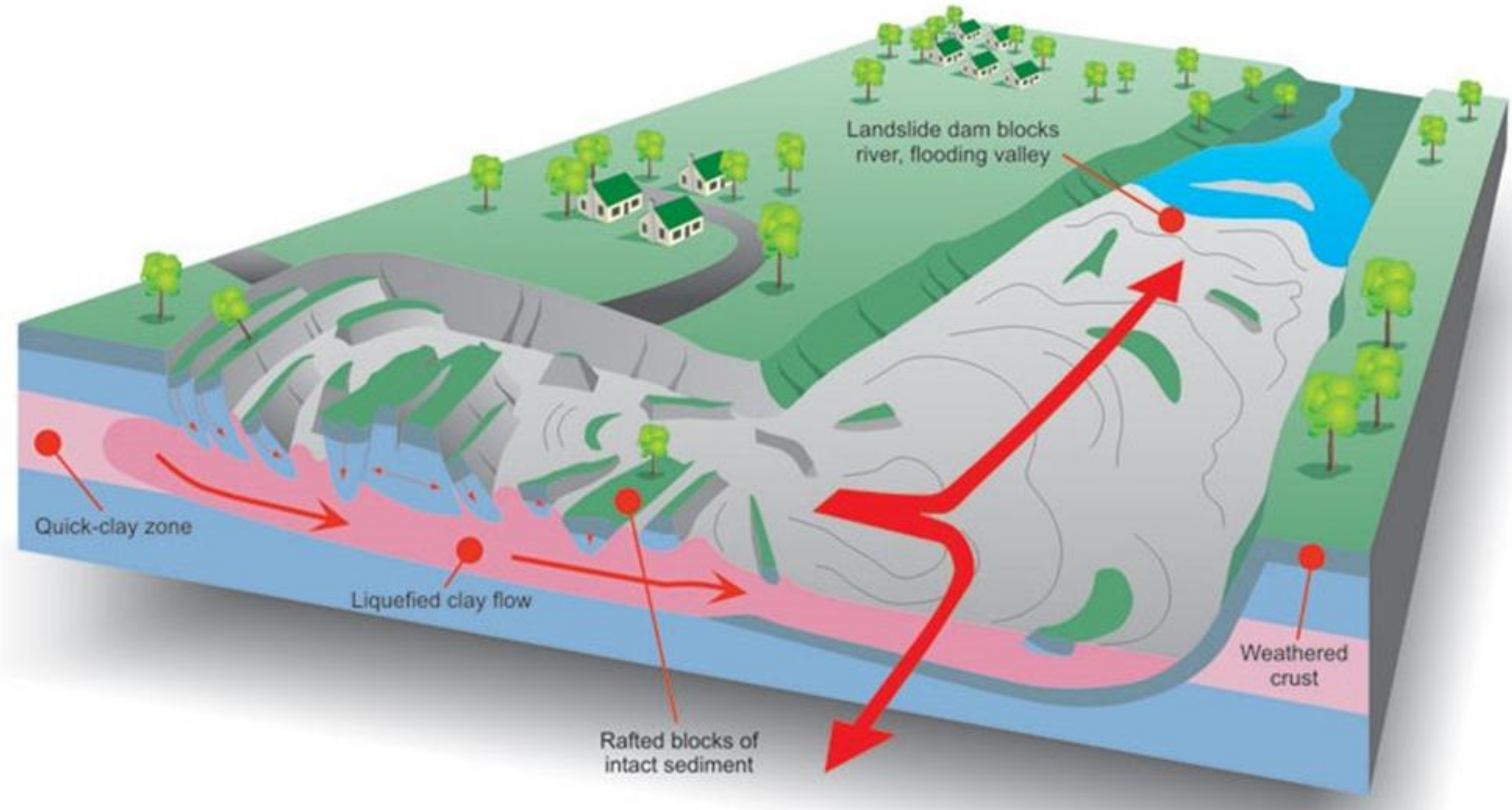
Quick clay disaster in Norway

Quick clay disaster in Norway as well

In Canada

Quick clay is only found in the northern countries such as Russia, Canada, Alaska in the U.S., Norway, Sweden, and Finland, which were glaciated during the Pleistocene epoch.

Quick clay has been the underlying cause of many deadly landslides. In Canada alone, it has been associated with more than 250 mapped landslides. Some of these are ancient, and may have been triggered by earthquakes.



Anatomy of a landslide

Thanks for you all