SOLUTIONS FOR THE BUILT WORLD

Fall 2015 Iowa DOT Vibration Seminar

Effects of Soil Type on Vibration – Liquefiable Soils

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Effects of Soil Type on Vibration

- Generally,
  - Vibrations attenuate at a greater rate in soft soil than hard soil, or rock.
  - High frequency vibrations attenuate at a greater rate than low frequency vibrations.
  - Not all soils are susceptible to liquefaction.
- Questions?

Effects of Soil Type on Vibration

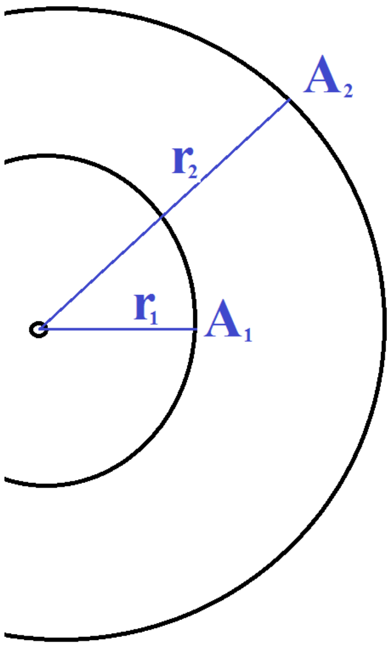
- Vibration Attenuation
  - Geometric (radiation) damping

    $A_2 = A_1(r_1/r_2)^n$

    n = 0.5 for Rayleigh waves

    n = 1 for body waves

    n = 2 for surface waves



Effects of Soil Type on Vibration

- Vibration Attenuation
  - Material (hysteretic) damping

    $A_2 = A_1(r_1/r_2)^n e^{[-\alpha(r2 - r1)]}$

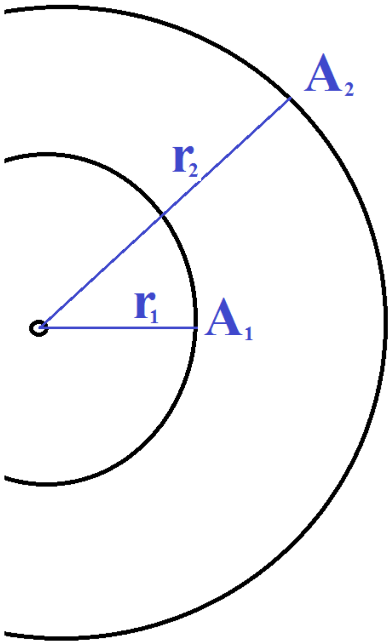
    α is greater in soft soils

    α is a frequency dependent coefficient of attenuation

  Attenuation at one frequency can be computed from the attenuation at another:

    $\alpha_2 = \alpha_1 (f_2/f_1)$:

  α Increases with increasing frequency



Effects of Soil Type on Vibration

Class	Attenuation Coefficient α (1/m) at 5 Hz	Description of Material
I	0.01 to 0.033	***Weak or Soft Soil*** – shovel penetrates easily, N < 5. Lossy soils, dry or partially saturated peat and muck, mud, loose beach ***sand***, dune sand, recently plowed ground, soft spongy forest or jungle floor, organic soils, and topsoil.
II	0.0033 to 0.01	***Competent Soils*** – can dig with shovel, 5 < N < 15. Most sands, sandy clays, gravel, silts, weathered rock.
III	0.00033 to 0.0033	***Hard Soils*** – cannot dig with shovel, 15 < N < 50. Dense compacted sand, dry consolidated clay, consolidated glacial till, some exposed rock.
IV	<0.00033	***Hard Competent Rock*** – N < 50. Bedrock

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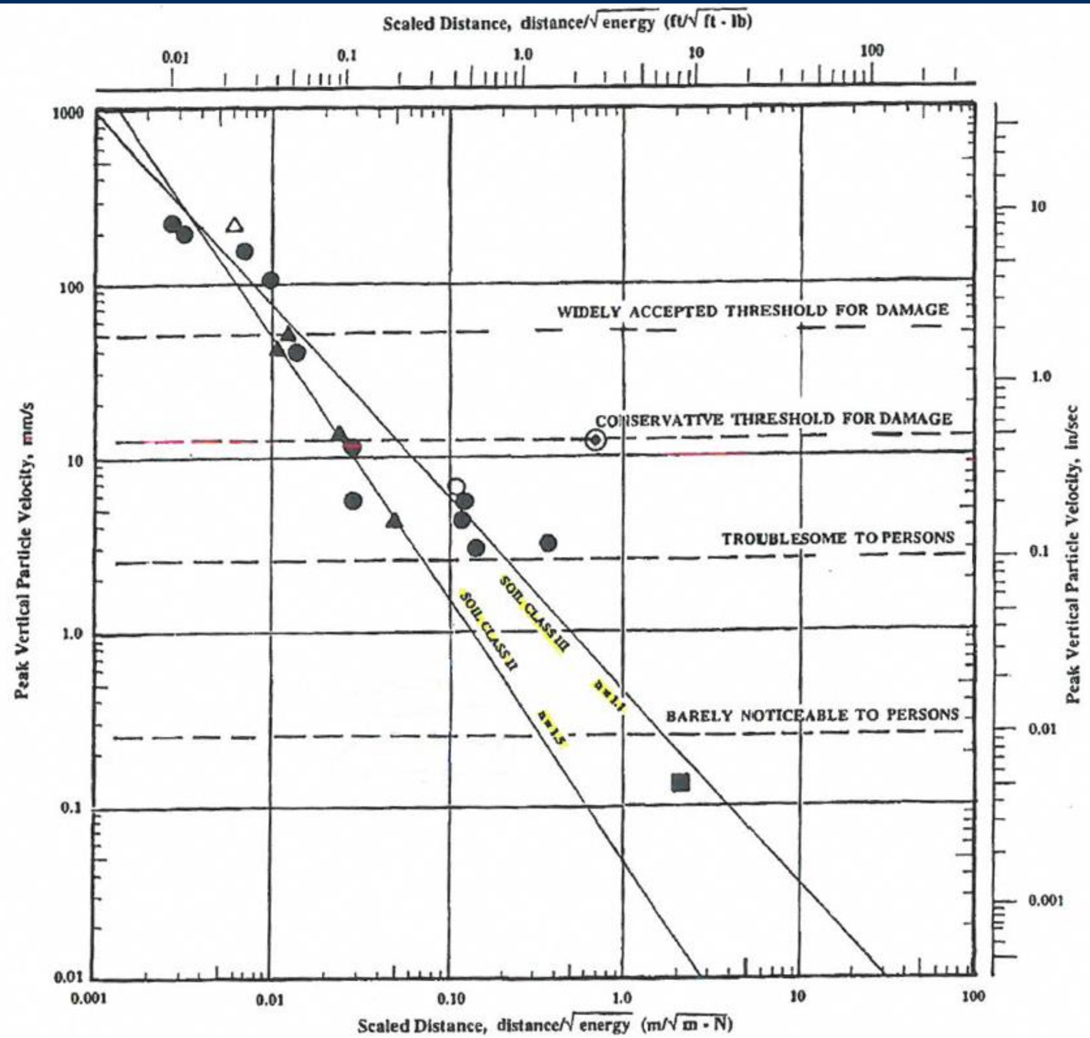
Effects of Soil Type on Vibration



Peak vertical particle velocity versus scaled distance

Effects of Soil Type on Vibration

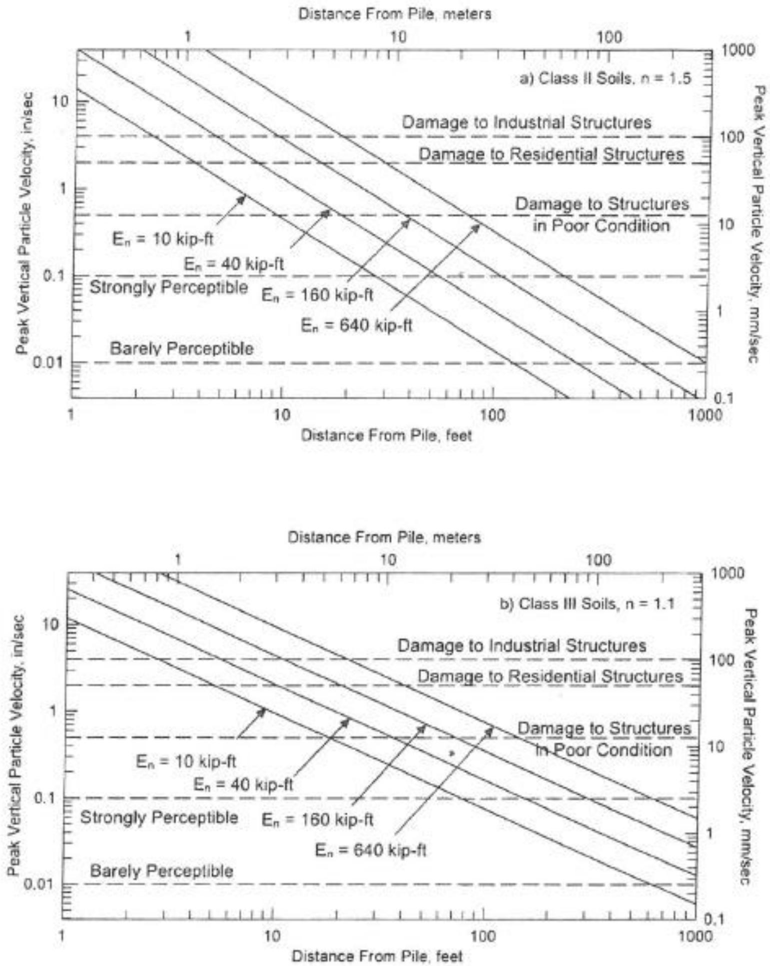


Figure 9.80 Predicted Vibration Levels for Class II and Class III Soils (after Bay, 2003)

Steeper slope for Type II soil

Effects of Soil Type on Vibration

- Vibrations attenuate more in soft soils than in hard soils
- High-frequency vibrations attenuate more quickly than low frequency waves
  - Amplitude decreases in magnitude with each oscillation as the wave travels from the source
  - Over a given distance, the high frequency wave goes through more cycles

Effects of Soil Type on Vibration - Liquefaction

- **Inter-granular forces**
- The weight of soil and the surcharge above it push the grains against each other, locking them into position due to friction between grains.
- The confining pressure and resulting inter-granular friction serve to develop the bearing capacity of the soil.
- In a dry soil, the effective stress (grain-on-grain contact pressure) is based on the dry unit weight of the soil.
- In a saturated soil the effective stress is reduced by the unit weight of the water due to buoyancy of the solids.
- The inter-granular forces are lower in saturated soil

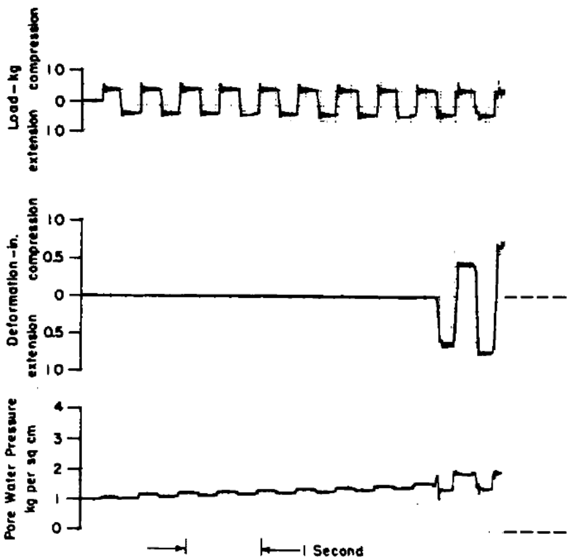
Effects of Soil Type on Vibration - Liquefaction

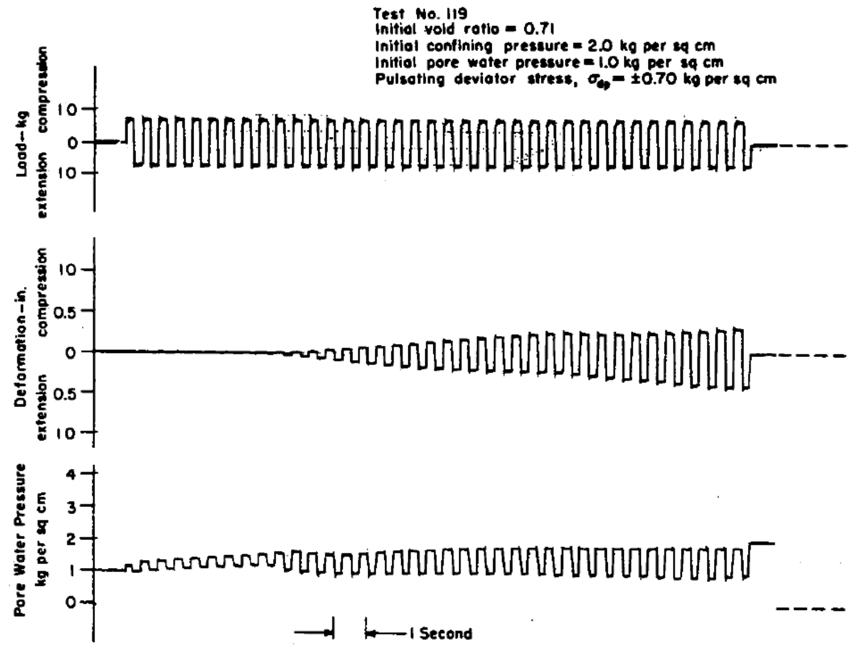
- Vibration waves travelling through the ground are pressure waves.
- The wave front applies short-term forces on the soil grains
- If the forces exceed the inter-granular friction, they become displaced and trend toward closer packing
- If the soil is saturated, the trend toward closer packing results in a transfer of the gravity load from the mineral skeleton to the pore water, increasing the pore water pressure.
- If the pressure does not have time to dissipate between impulses, the pore water pressure accumulates

Effects of Soil Type on Vibration - Liquefaction

- Increasing pore water pressure reduces the effective stress
  - Inter-granular forces decrease
  - Bearing capacity decreases
  - Settlement can occur if the applied forces exceed the bearing capacity.

Effects of Soil Type on Vibration - Liquefaction





Test No 114
Initial void ratio = 0.87
Initial confining pressure = 2.0 kg per sq cm

Test No. 119
Initial void ratio = 0.71
Initial confining pressure = 2.0 kg per sq cm
Initial pore water pressure = 1.0 kg per sq cm
Pulsating deviator stress, σ_{dp} = ±0.70 kg per sq cm

Effects of Soil Type on Vibration - Liquefaction

- Not all soils are sensitive to liquefaction
- Sensitive soils
  - Recent geologic deposits (saturated)
  - Saturated sandy soils without cohesive fines
  - Uniformly grains sands

Effects of Soil Type on Vibration - Liquefaction

- Not all soils are sensitive to liquefaction
- Sensitive soils

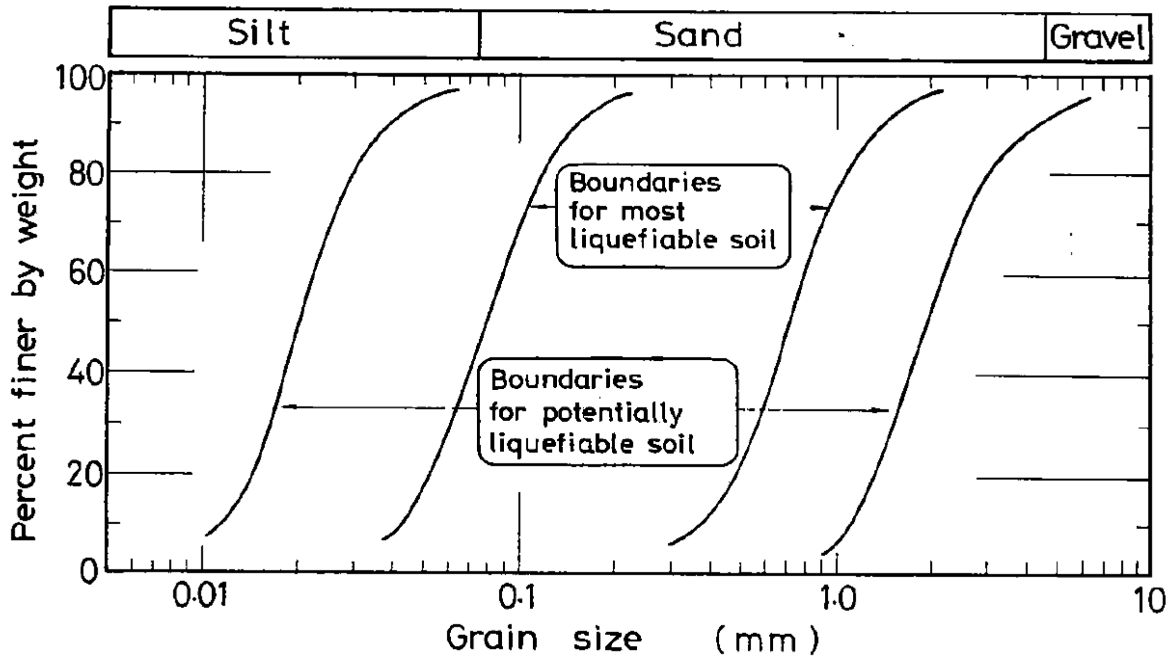


FIGURE 2-19 Limits in the gradation curves separating liquefiable and unliquefiable soils. Source: Tsuchida (1970).

Effects of Soil Type on Vibration - Liquefaction

- Not all soils are sensitive to liquefaction
  - Clay in the mix tends to prevent pore pressure buildup
- Non-Sensitive Soils
  - Dry soil
    - Could still be consolidated, but not liquefied
  - Clay/Silt
  - Well-graded soils
  - Dense sands (already consolidated)

Effects of Soil Type on Vibration - Liquifaction

- Example

- The Pierre Condominium
  - 12-story building in Chicago
  - Mat foundation, or mat on timber piles
  - 40-ft of soft saturated sands, silts and sandy silt
- Repeated impacting for hours approximately 30 feet away
  - Vibration amplitudes reportedly less than 0.5 in/s
- Settlement-related distress noticed the next day
  - Eventually 1.5 inches of settlement