6 Soils

Soil properties can significantly impact manufactured homes exposed to flooding. Properly determining soil type and allowable bearing capacity is important for the selection and performance of the foundation. It is recommended that a geotechnical engineer make these determinations. For example, highly erodible soils are not desirable as fill for elevating a structure in a high velocity area because it can be washed away by moving floodwaters. Other soils lose strength as moisture content increases, reducing a foundation's load capacity. This chapter discusses the effect of flooding on soil properties.

6.1 Bearing Capacity

Bearing capacity is a soil's capability to support load without catastrophic failure. Bearing capacity is derived from the soil shear strength, which is expressed as:

$$s = c + \rho\ (\tan \phi)$$

Where s = soil shear strength

c = soil cohesive strength

ρ = lateral confining pressure

ϕ = soil angle of internal friction

The general bearing capacity equation is:

$$q = (\gamma b/2)N_\gamma + cN_c + \rho N_\rho$$

Where q = soil bearing capacity

γ = unit weight of soil

b = footing width

N_γ = bearing capacity factor for soil density and footing size

N_c = bearing capacity factor for cohesion

N_ρ = bearing capacity factor for surcharge

As previously discussed, soil strength frequently changes as a function of moisture content. In granular soils, as moisture content approaches saturation (i.e., intergranular voids are 100 percent filled with water), the effective unit weight is reduced, thus reducing the confining pressure (ρ).

For preliminary design purposes, allowable bearing capacities can be established based on national model codes, local building codes, and soil surveys. Local officials may also have information on soil types and soil bearing capacities.

Soil classifications of a general nature and a typical range of their maximum allowable bearing capacities can be found in publications such as the IBC (2009 Edition), NFPA 5000 (2009 Edition), and NFPA 225 (2009 Edition). These documents can provide the allowable bearing pressures considered sufficient to support foundations at well drained sites. Excessive foundation movement or settlement may occur where unusual soil or moisture conditions are encountered. A geotechnical engineer should be consulted when unusual soil or moisture conditions are present.

6.2 Effects of Flood Duration and Frequency on Soil

For granular soils located below the water surface, the effective confining pressure (ρ') is used to determine the effective shear strength'. The effective confining pressure is calculated using the effective unit weight of the soil where:

$\gamma' = \gamma_s - \gamma_w$

γ' = effective unit weight of soil

γ_s = total unit weight of soil and

γ_w = unit weight of water

The submerged weight can be estimated as about half of the total weight of many granular soils. The angle of internal friction (ϕ) is not appreciably changed by submergence. Therefore, if the water table rises from a depth greater than the width of the footing to the ground surface, as can be the case of flooding, the bearing capacity of the soil is reduced by approximately 50 percent.

Cohesive soils (silt and clay) are bound together by electrochemical bonds between individual particles. Increasing the moisture content can change the distance between particles, decreasing the strength of the inter-particle bonds. The decrease in bond strength results in a decrease in cohesion and a loss of shear strength.

6.3 Soil Liquefaction

Seismic soil liquefaction is an important consideration for earthquake design because soil liquefaction can be a major cause of damage in a seismic event. Liquefaction is defined as the significant loss of strength resulting from an increase in soil pore pressure. Seismic vibrations act to realign soil particles into a denser configuration. The realignment decreases the inter-particle void space, thus increasing the water pressure in the voids. The increase in water pressure has the effect of decreasing the effective strength of the soil. A sufficient increase in pore pressure can reduce the effective strength to zero, at which time the soil mass behaves as a liquid. The loss of shear strength in soils supporting buildings can be catastrophic. Building foundations can slide or unevenly settle, bridges can collapse, and empty fuel tanks buried under ground can rise to the surface.

Liquefaction-induced soil movements can push foundations out of place to the point where the manufactured home will lose support.

Loose clean sands with relatively few fines, and silty soils with little or no clay, are vulnerable to seismic induced liquefaction. It is necessary to identify the presence of liquefaction susceptible soils expected to support building foundations, and design the manufactured home foundation accordingly.

To reduce liquefaction hazards, the best approach is to avoid construction on soils susceptible to liquefaction. Other options such as making the structure liquefaction resistant or improving the strength, density, and/or drainage characteristics of the soil are probably not economical for most manufactured home sites.

6.4 Recommended Soil Testing and Criteria for Manufactured Home Installations

Shallow subsurface investigations should be conducted to evaluate the soil bearing conditions at the proposed manufactured home site. An experienced geotechnical engineer can conduct an appropriate investigation using hand augers, field strength tests, and visual classification methods. Field strength testing includes dynamic cone penetration tests, pocket penetrometer tests for cohesive soils, and torvane tests for granular soils. The investigation should evaluate soils to a depth of twice the width of the bearing surface or 5 feet, whichever is greater. The investigation will provide information on soil type and bearing capacity.

When footings are eccentrically loaded, the effective bearing area is reduced so footing sizes must be increased accordingly. Eccentric loading occurs when piers are not centered over footings and when a manufactured home frame is not centered on its pier. Eccentrically loaded foundation conditions should be avoided.

Ground anchors consist of a specific anchoring device designed to transfer home anchoring loads to the ground (24 CFR 3285.5). Axially loaded ground anchors support loads by mobilizing soil shear strength along a subsurface shear plane. Ground anchors loaded non-axially resist loads through both the axial shear strength and passive soil resistance against the horizontal component of the non-axial load. Development of passive soil resistance requires some soil movement. The required movement will generally result in larger total movement in non-axially loaded anchors than axially loaded anchors in the same soil conditions.