16.5.1.2 Site Characterization for Drilled Shaft Foundations

The site characterization requirements for drilled shaft foundations are similar to those used for driven pile foundations. The following additional factors should be considered or evaluated during the investigation:

1. Cobbles and Boulders. Construction of a shaft can be affected by the presence of cobbles and boulders and, therefore, the site characterization effort should try to quantify these effects through the review of drilling information and geologic reviews. Because of the importance of cobbles and boulders to the shaft construction process, normal practice is to conduct a geotechnical exploration at center of each shaft location.

2. Gravel and Cobbles. Identify the presence of open gravel and cobble layers, as these materials may require the use of casing or special drilling muds to avoid hole collapse or excessive loss in drilling muds during construction.

3. Explorations. Explorations should extend at least 20 ft (6 m) or 5 shaft diameters, whichever is greater, below the likely toe of the shaft. If hard bearing material or rock is located less than 20 ft (6 m), the depth of exploration can be stopped 10 ft (3 m) into the hard bearing material.

4. Socketed. If the shaft is going to be socketed in rock, the exploration should extend at least 2 shaft diameters below the planned toe elevation of the shaft.

5. Groundwater. As part of the site characterization effort, it is also very important to establish the location of the groundwater table and whether groundwater is perched or involves artesian conditions. These conditions will have an important effect on the drilling methods selected by the shaft construction contractor.

16.5.1.3 Construction of Drilled Shafts

Details of the construction procedures are critical with regard to the performance of the drilled shafts. Therefore, construction methods must be carefully controlled in order for the foundation to function as designed. Different subsurface conditions warrant different methods of construction. Three methods commonly used in the United States include the dry method, the casing method and the wet method. Detailed descriptions of these methods, along with examples of possible construction problems, are described in FHWA *Drilled Shafts: Construction Procedures and Design Methods*.

16.5.1.3.1 Clay Sites

The effects of installing a drilled shaft into clay are different from those of installing a pile. If the clay is homogeneous so that the excavation will remain open and dry, the clay will creep toward the axis of the excavation accompanied by vertical subsidence of the ground surface. The creep and subsidence will be substantial if the clay is weak, but minimal for stronger overconsolidated clays. Disturbance and stress relief due to drilling will cause some loss of shear strength at the surface of the borehole, which must be addressed during design.

The placement of fluid concrete in the excavation will impose a lateral stress on the sides of the excavation, the magnitude of which is dependent on the fluidity and rate of placement of the concrete. If the excavation is drilled dry, moisture from the fluid concrete can migrate into the clay and cause some additional softening. This problem can be important in concrete that is mixed with a high water-cement ratio in which much more water than is needed to hydrate the cement is used in batching. Whether the excavation in the clay is wet or dry, there is evidence to show that there is an interaction between the clay and particles of cement and/or products of cement hydration, with a consequent strengthening of the bond between the concrete and the clay. This interaction results in a larger strength at the interface than the softened strength that exists just after the concrete placement.

16.5.1.3.2 Sand Sites

If the sand in a drilled-shaft excavation is prevented from collapsing by driving a casing into place, the behavior of the sand around the perimeter (shaft) of the casing will be similar to that of a driven pile. The sand will heave at the base of the excavation resulting in lower unit end bearing than for a driven pile. The end-bearing load-deformation behavior may be adversely affected by construction practices that fail to remove cuttings that have been suspended in drilling slurries during borehole excavation. The Drilled Shaft Special Provision limits the amount of loose or disturbed material in the bottom of the shaft to 1 in (25 mm) after cleaning.

The placing of concrete with high workability (cohesive mixes with high slump) will impose stresses against the sides and base of the excavation that are larger than those from the slurry. The fluid concrete could then cause a slight densification of the sand adjacent to the wall and base of the drilled shaft. Concrete with a low slump will bulk and not collapse under its own weight. In addition to producing potential defects (e.g., honeycomb; voids) in the concrete, this effect causes the lateral stress against the sides of the excavation to be less than would occur had the concrete been fluid. The resistance along the sides are to some extent dependent on this concrete pressure. Low-slump concrete can also have a negative effect on geomaterial resistance.

As with clay, the properties of sand around a drilled shaft can be very different from the in-situ properties. The subsurface investigation should be designed to reveal as well as practical the in-situ characteristics of the sands, especially its density and grain-size distribution. The parameters selected for the design of a drilled shaft in sand will then be adjusted by the design method according to the best estimate of the properties of the sand that exist around the drilled shaft as built.

16.5.1.3.3 Rock Sites

The requirement to bear on or penetrate rock strata often dictates the use of drilled shaft foundations. One of the important considerations of rock-socketed drilled shafts is the condition of the side of the borehole. High values of side shearing resistance can develop because of dilation that occurs between a rough surface at the boundary of the concrete and the mating surface in the rock. Upward or downward movement of the concrete shaft caused by applying axial loads produces lateral compression of the rock and, as a result, higher lateral stresses along the concrete-rock interface than existed after the concrete was placed. The increased