navigable water, and they are very strict about maintaining uniform flow lines for such waters. They "sweep" the bottom intermittently to determine whether or not the required channel depth is available to navigation, and will require that corrections be made whenever and wherever necessary.

5-393.106 DRILLED SHAFTS

A drilled shaft foundation is a cylindrical excavation in soil or rock that is filled with concrete with the primary purpose of structural support. Reinforcing steel is installed in the excavation prior to placing the concrete. Drilled shafts are circular in cross section and may be belled at the base to provide greater bearing area.

Vertical load is resisted by the drilled shaft in base bearing or side friction or a combination of both. Horizontal load is resisted by the shaft in horizontal bearing against the surrounding soil or rock.

Other terminology commonly used to describe a drilled shaft includes drilled pier, drilled caisson, or auger-cast pile. Excavation of a "drilled" shaft may not utilize a drill or auger. Extraction of the soil or rock may be done by almost any method. For large diameter shafts, extraction is often done by clam shell. Drilled shafts are used because of their very high load capacities. Drilled shafts are becoming more common for river crossing bridges as they can be constructed to depths below predicted scour elevations, even in very dense soils or bedrock. The attention to detail in the construction of drilled shafts is critical to ensure a successful foundation. If proper procedures are used by an experienced contractor, drilled shafts can be installed successfully in a wide variety of subsurface conditions.

Certain limitations exist with regard to the geometry of a drilled shaft. Diameters of 300 to 360 millimeters (12 to 14.5 inches) can be used if the length of the shaft is no more than 2.5 to 3.0 meters (8 to 10 feet). Such small foundations are commonly used to support sign structures and high tower lighting.

As the depth of the excavation becomes greater, the diameter normally must increase. Several factors that influence the ratio of depth to diameter are: the nature of the soil profile, the position of the water table, whether or not a rebar cage is required, the design of the concrete mix, and the need to support lateral loading. The concrete may be placed by free fall in shafts if the mix is carefully designed to ensure that the excavation is filled and segregation is minimized. Free fall is defined as concrete falling through air. Therefore, the concrete must not fall through the rebar cage or strike the sides of the excavation.

Heavy, rotary-drilling equipment is available for large drilled-shaft excavations. Cylindrical holes can be drilled with diameters of up to 6 meters (20 feet) to depths of up to 60 meters (200 feet) and with under reamed bells up to 10 meters (33 feet) in diameter. Percussion equipment can make excavations of almost any size and depth. Typical sizes of shafts for bridge foundations have diameters in the range of 1 to 2 meters (3-6.5 feet).

The drilled shaft is most commonly constructed by employing rotary drilling equipment to drill a cylindrical hole. Auger methods are used in earth and soft rock and coring methods in hard rock. Three methods of keeping the excavated hole open are in general use: the dry method, the casing method and the slurry-displacement method. The dry method is generally used if the excavation can be made with little or no caving, squeezing or sloughing, and with little or no water collecting in the excavation. If the excavation will not maintain its dimensions, or if excessive water collects, the use of temporary or permanent casing may be required. An alternative to the use of casing is to drill the hole using a slurry to prevent caving or sloughing (the slurry-displacement method). After the cylindrical hole is excavated by augers, core barrels, or drilling buckets, an under reaming tool can be used to enlarge the base of the drilled shaft. A rebar cage is placed and the excavation is filled with concrete. Temporary casing, if used, is recovered as the concrete is placed. A concrete mix with a high workability (slump) is frequently required.

During placement of concrete into the shaft the inspector should carefully monitor the volume to determine if voids are present or if the walls are uncased, to determine if sloughing of the walls has occurred. To aid in monitoring the concrete volume a form has been developed (see figures A 5-393.106 and B 5-393.106). This form allows the inspector to compare the predicted volume with the actual volume at specific elevations during the placement. Large overruns or underruns in concrete volume may indicate large voids or sloughing of the walls.

After completion of *each* drilled shaft the Contractor is responsible for compiling an initial data report in a standard format furnished by the Engineer (see figure C 5-393.106). The report shall be furnished to the Engineer within 24 hours after concreting has been completed for that shaft. Upon completion and acceptance of all shafts by the Engineer, a final report for each shaft--in the same standard format--containing any additional data shall be furnished to the Engineer.

As there are many variations in the equipment and methods of excavation and construction for drilled shafts, this manual does not discuss detailed procedures. Personnel that are to be involved with projects having drilled shafts should carefully review the special provisions and obtain the following references available from the Federal Highway Administration and the International Association of Foundation Drilling which describe the detailed methods of construction that are used in a variety of subsurface and surface conditions:

Drilled Shaft Inspectors Manual
Published by: The International Association of Foundation Drilling
PO Box 280379, Dallas, Texas 75228 (214) 681-5994