Florida Department of Transportation Research

Defining the Upper Viscosity Limit for Mineral Slurries used in Drilled Shaft Construction Project
BDK84-977-24

Many structures built on Florida's variable, sandy soils require deep foundations, such as pilings. Although pilings may be more familiar, drilled shafts are also often used. Drilled shafts require less expensive equipment and create less of the vibration that can disturb nearby structures and inhabitants. A drilled shaft foundation is created by drilling a hole of the correct diameter and depth. A steel reinforcing frame (cage) is placed in the hole, and concrete is added. The walls of the hole must remain intact during all phases of the installation. One means of doing this uses a clay-water mixture, called slurry, to fill the hole and stabilize the walls, especially where groundwater threatens wall integrity. After the cage is placed, concrete is pumped in, starting at the bottom; this displaces the slurry, which is captured for reuse.

Effect of slurry viscosity on concrete flow: left — 60 sec/qt; right — 90 sec/qt.

Slurry must be formulated to match soil conditions: looser soils require higher viscosity slurry, while more cohesive soils tolerate a slurry with lower viscosity. Often, slurry contains bentonite clay, and various polymer additives can be used to adjust slurry properties, especially viscosity. If the viscosity is too low, it may fail to maintain wall integrity, but if it is too high, it may not be sufficiently cleared during concreting and interfere with concrete-to-steel bonding. States provide guidelines for slurry properties, including minimum and maximum viscosities, but these are often based more on experience than science.

The Florida Department of Transportation (FDOT) specifies slurry in terms of viscosity, density, sand content, and pH tolerances. FDOT requires that mineral slurry for all primary structures remain within viscosity limits of 30 to 50 seconds per quart (sec/qt; Marsh funnel test). In 2010, FDOT research project BDK84-977-03 set a lower limit for slurry viscosity. In this project, University of South Florida researchers studied slurry viscosity in order to establish a maximum.

The effect of the upper viscosity limit on shaft performance was assessed with rebar pullout tests and side shear tests, which detect effects of slurry on structural and geotechnical performance, respectively. Based on these tests, the researchers concluded that the presence of any bentonite slurry at the time of concreting reduces the rebar bond, ranging from 25% (at 30 sec/qt) to 70% (at 90 sec/qt). Similar tests with polymer slurry showed smaller reductions.

Model-scale tests of a wide range of viscosities showed modest reductions in side shear for shafts cast with 50 sec/qt slurry, compared to 40 sec/qt slurry. Full-scale tests using mineral and polymer slurries showed that 60 sec/qt polymer slurry had no adverse effects on side shear, compared to 40 sec/qt.

Physical inspection of shafts poured in cages (with 6-in clear space) indicated potential durability issues as bentonite tended to become trapped at all rebar locations that extended from the rebar out to the soil/concrete interface. This effect was most pronounced for bentonite slurry with viscosity greater than 40 sec/qt.

Study findings support an upper viscosity limit of 40 sec/qt, not 50 sec/qt as recommended by the Federal Highway Administration. This study suggests that casting foundations within a lower range of slurry viscosity may result in stronger and more durable foundations.

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