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HDD and Vertical Drilling Fluids: Understanding the Differences

When it comes to drilling fluids for horizontal directional drilling (HDD) and vertical drilling, such as geothermal loop installation or water well drilling, there are a lot of similarities. Bentonite is used as a base or starting point for drilling fluids in each drilling application, and polymers and additives are used, along with varying the amount of bentonite, to help adjust drilling fluids to various soil conditions. In each drilling application, drilling fluid characteristics, such as pH, viscosity, velocity, density, solids content, fluid-loss and gel strength, are important, and should be closely monitored and properly maintained. A lot of the same types of polymers and additives are used in vertical and horizontal directional drilling to control down-hole conditions such as reactive clays and/or fluid-loss in coarse soils. Yet, with all of the similarities between HDD and vertical drilling fluids, there are some important differences between the two that drilling contractors must understand in order to maximize their success rate.

Significant Physical Differences Downhole

Flow characteristics between vertical and horizontal directional drilling differ dramatically, and play a key role in the design of drilling fluids for each application. In a vertical drilling application, such as water well drilling, the annular ascending velocity of drilling fluid is somewhere between 85 feet to 125 feet per minute, in comparison to horizontal directional drilling where fluid moves at a snail's pace, due to larger-diameter boreholes and the direction of flow.

In vertical drilling applications, the direction of return flow (carrying drill cuttings) is the 180 degrees, or opposite the direction from which gravity is pulling the solids down, making it much easier to suspend drill cuttings. One must simply move the drilling fluid with cuttings up out of the hole faster than the settling rate of the drill cuttings. For horizontal directional drilling, the direction of flow is in a 90-degree angle from the direction in which gravity is trying to pull the cuttings, making it much more difficult to transport cuttings. In vertical drilling applications, cuttings may have hundreds of feet to drop before settling on bottom, as opposed to inches or less for horizontal directional drilling applications.

Hydrostatic head also has a big impact on how horizontal directional drilling fluids interact with downhole conditions vs. vertical drilling applications. A horizontal directional drilling fluid that weighs 8.5 pounds per gallon will exert around 13.26 pounds per square inch of hydrostatic head pressure on a formation at a depth of 30 feet, while a vertical drilling fluid of the same density will exert 110 pounds per square inch of hydrostatic head on a formation at a depth of 250 feet.

For both vertical and horizontal drilling applications, it's important to keep flow characteristics in mind. Photo courtesy of Atlas Copco.

Gel Strength and Fluid Loss

A simple demonstration that illustrates the difference in gel strength requirements for HDD and vertical drilling fluids is to use a clear plastic tube containing water and glitter. If one shakes up the glitter and holds the tube in a vertical position, the glitter seems to stay in suspension forever, due to the distance the glitter must travel through the fluid to get to the bottom, whereas when the tube is shaken and held in a horizontal position, the glitter settles to the bottom almost instantly. Bentonite drilling fluids are non-Newtonian, which means viscosity changes with shear, whereas with a Newtonian drilling fluid such as oil, viscosity changes with temperature.

The faster you move a bentonite drilling fluid, the thinner it gets, and when a bentonite drilling fluid is at rest, such as making a connection, bentonite drilling fluid gels up and suspends drill cuttings. Because of the slower annular ascending velocity flow rates and the high amount of drill cuttings generated by horizontal directional drilling fluids, especially when reaming large-diameter holes, it is imperative to have a drilling fluid that has high gel strength at the lowest possible viscosity.

Specialty HDD fluids can have as much as three times the amount of gel strength or solids-carrying capability than high-yield bentonite, which is most commonly used in water well drilling. One simple way for a horizontal directional drilling contractor to determine if the gel strength in a drilling fluid is adequate to suspend the drill cuttings encountered is to take some of the drilling fluid in a clear container and stir in soil from the entry or exit pit. If solids settle in a container, they will definitely settle downhole; therefore, gel strength must be increased to prevent stuck or stretched product line from occurring.

Many HDD contractors attempt to save money by using high-yield bentonite products, but end up paying more by having to add gel-strength-enhancing additives, which are among the most expensive drilling fluid additives, or pay a penalty in the way of higher viscosities and problems associated with high-viscosity drilling fluids, such as increased frac-out, reduced pump efficiency and slower pull-back speeds. HDD reamer pull-back speed is determined primarily by the amount of drilling fluid that can be delivered to the reamer, and an 80-second funnel viscosity drilling fluid, for example, can cut a reciprocating pump's performance in half.

Along with much higher gel-strength, a good HDD specialty drilling fluid will have soda ash mixed in to help the product perform better in hard water or low pH conditions, as well as containing additives to enhance fluid-loss for increasing borehole stability in coarse soil conditions. In order for a drilling fluid to create borehole stability in coarse soils such as sand, the drilling fluid must be capable of building a low-permeable filter cake (low fluid-loss) on the walls of the formation, and hydrostatic head pressure is applied against the filter cake to keep the formation from collapsing. The hydrostatic pressure need not be high; it just needs to be a positive pressure, especially in zones where ground water is encountered.

Field Applications

Specialty HDD drilling fluid products can work great in vertical drilling applications as long as one has a mechanical means of removing the drill cuttings, such as hydrocyclones (desilting or desanding cones) and/or drilling fluid recycling systems. The additional gel strength provided by specialty HDD bentonite drilling fluid products will not allow drill cuttings to settle out in a tub, resulting in a high-solids drilling fluid that will create a multitude of problems, including excessive wear on drilling fluid circulation equipment, formation damage, loss circulation and slower penetration rates.

High-yield bentonite normally used in water well drilling can work in horizontal directional drilling applications if the correct additives are used. Soda ash must be used to pre-treat the mix water in order to maximize yield, gel strength and fluid-loss any time high-yield bentonite is used. Fluid-loss polymers are required when using high-yield bentonite in coarse soils for horizontal directional applications, in order to keep the hole open. Gel-strength-enhancing polymers are necessary when using high-yield bentonite for horizontal directional drilling fluids in order to build sufficient gel strength to carry drill cuttings out of the hole at a lower viscosity.

Conclusion

As previously mentioned, bentonite is used as a starting point in both vertical and horizontal directional drilling fluids, and polymers and additives are used (along with varying the amount of bentonite) to help adjust drilling fluids to various soil conditions. Knowledge is power, and having the ability to match drilling fluids to varying soil conditions and different drilling applications – be it vertical or horizontal – means having more control over the success rate of drilling projects. ND

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