SUBSURFACE CONDITIONS DO IMPACT YOUR DRILL FLUID

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Drill fluid is a key component of HDD project success

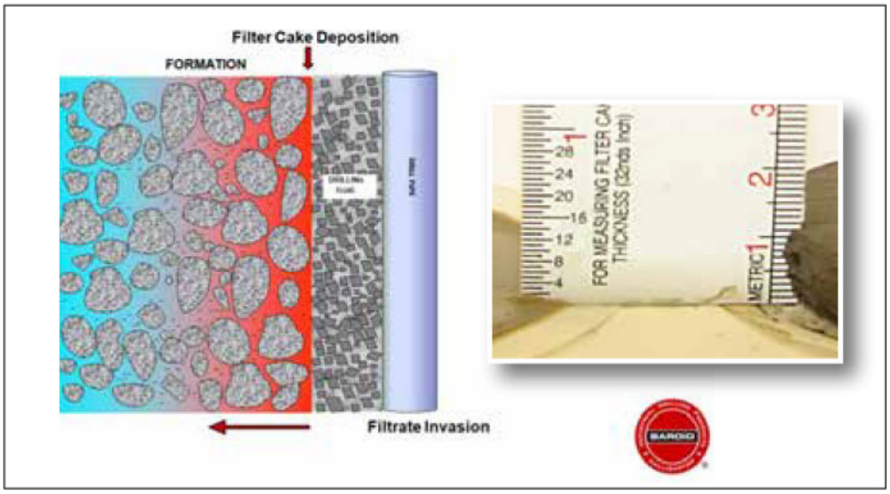
Drill fluid support must last until carrier pipe is in place

Drill fluid is a key component for project success. Initially, the ground at all sites is stable. Excavation destabilizes soil leading to collapse over time. Some conditions collapse rapidly while others may remain open for extended periods. Excavation instability is caused by the difference between the external soil and groundwater pressure at the edge of the hole and the internal drill fluid pressure. The excavation is unstable unless the internal pressure can apply the same pressure as applied by the excavated material. Because drill fluid typically does not provide full replacement of the original supporting pressure, it only extends the time that the hole will stay open. However, this temporary support must last until the carrier pipe permanent support is in place.

Excavation in HDD bores requires spoil removal at the same rate as the excavation progresses. The Horizontal Directional Drilling (HDD) process consists of fluid assisted mechanical excavation with a drill bit, spoil removal by drill fluid and temporary support of the hole by drill fluid pressure acting on the mud cake. Subsurface conditions will interact with the drill fluid performance. The wide variety of soil types in New England encountered along most bores means that there is no single drill fluid suitable for all conditions. Understanding the data produced by drill fluid testing provides the information necessary to properly optimize performance of the fluid, thus optimizing daily production rates.

Important to properly optimize fluid performance

"NOT KNOWING SUBSURFACE CONDITIONS MEANS YOU ARE AGREEING TO BE PART OF THE PROBLEM."



Optimal filter cake thickness is 2/32 inch

Drill fluid must be adaptable to react in a predictable manner to support the HDD process over multiple types of subsurface conditions. New England soils can react unfavorably to basic drill fluid without proper additives. Basic drill fluid to soil reaction problems may include the following:

1. **Flocculation:** Brackish groundwater, low pH swamp water, hydrogen sulfide, and road salt chlorides chemically react with bentonite drill fluid causing flocculation of the bentonite, a cottage cheese appearance. The reaction makes the fluid much harder to push along the bore annulus resulting is less load carrying capacity and higher pressure in the annulus.
2. **Thick filter cake:** Jetting fluid needs sufficient pressure and turbulence to generate the differential pressure required to create a filter cake. Pressure is fully contained within a few feet of the drill bit. Differential pressure between the bore and the surrounding ground 'squeeze' the water out of the fluid leaving the bentonite flakes behind creating a mud cake around the hole. Ideally, the pressure in the bore annulus is completely confined by the filter cake to the bore annulus leaving surrounding ground fluids unaltered and unpressurized. The filter cake should form a balloon like structure to isolate the inside from the outside. Filter cakes have an optimal thickness of about 2/32 inch. Poor quality drill fluid can make the filter cake too thick or too weak to support the surrounding soil.

Reduced bit life and inefficiency

> **"THE HIGH VARIABILITY OF NEW ENGLAND SOIL OFTEN FAVORS A BASIC DRILL FLUID BLEND AND THE USE OF APPROPRIATE ADDITIVES."**

3. **Bit balling in clay:** Jetting fluid needs sufficient pressure and turbulence and proper additives to help control sticky clay to clean a drill bit. Improper tooling for jetting makes for inefficient use of the jets for cleaning resulting in bit balling in clay.
4. **Bit wear from re-grinding abrasive granular soil:** High pressure jets quickly remove bit excavated material from the excavation face. The faster this material can be removed the more efficiently the bit can operate. Basic fluid with enhanced suspension properties can assist in abrasive quarts and some metalic mineral cuttings removal from the bit. Inefficient cutting removal from the face reduces bit life and efficiency.
5. **Cuttings clogging the hole:** Thicker drilling fluid is not a good idea. Thick drilling fluid removes less cuttings as the fluid can only support a percentage of its volume in cuttings. The result is a buildup of excess cuttings in the bottom of the bore often at joint upsets that chokes the circulation, increases annular pressure, and prevents the bit from cutting efficiently.
6. **Blinding screens or low cutting load on recycler:** HDD operations that use drill fluid recycling systems can have screens blinded and cutting loads that cannot be cost effectively removed thus requiring costly replacement of the drill fluid, or additional methods for cutting removal such as centrifuges. Additionally, sending contaminated drill fluid back into the hole will cause significant abrasion wear on your pumps and mud motor whenever sand content increases above 0.5 percent.
7. **Over excavation/sinkholes:** Unit weight will indicate over or under excavation. This will also show up in filter cake test.

Each of these drilling problems can be solved by designing a basic drill fluid program enhanced with appropriate additives suited for the soil. Besides being flexible in composition, drill fluid needs to bring the following attributes to the table:

- Low unit weight to carry the optimal cutting load without over-pressurizing the bore walls.
- Sufficient Yield Point (YP) low enough to allow low annular pressure to initiate fluid movement.
- Sufficient gel strength and short gel time to keep cuttings in suspension during rod changes at low flow or no flow.
- Ability to transmit high pressure at a design constant volume and density to ASSIST with mechanical excavation and to power down hole tools.
- Low Plastic Viscosity (PV) which is resistance to free flow to have the ability to carry excavated material in suspension at lower annular pressure then enable mechanical cleaning tools such as screens and cyclones to remove the cuttings.
- Ability to quickly form a filter cake with sufficient strength to support the hole and prevent fluid to ground contamination.
- Ability to carry additives to enhance drill fluid properties.

Basic drill fluid can be either a bentonite based or bentonite/with polymer additives fluid. In some scenarios an all polymer system might be applicable. Both can work but at different costs and care in mix design. Every supplier has technical support to assist you with developing a base fluid plus an assortment of additives necessary to adjust the drill fluid to your soils. Additives are used to enhance the basic drill fluid to address site specific soil conditions. Additives like polymers, xantham gum, PHPA's and others are often the critical factor in handling site specific soil related problems. Discussion of additives is a whole different topic from basic drill fluid understanding therefore will not be covered further. There are engineers that specialize in drill fluids that provide mix design, design modification, or full-time assistance with variable subsurface conditions that can provide recommendations for both basic drill fluid design and the application of various additives to enhance drill fluid properties when encountering various site-

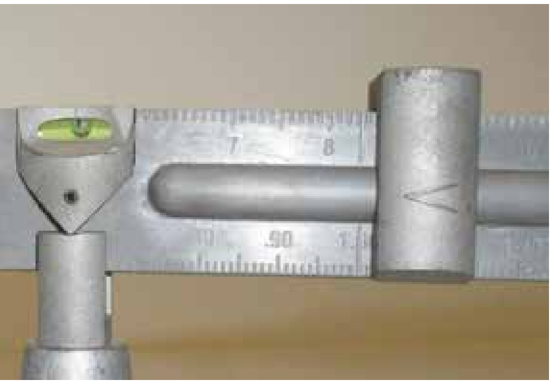
“NEW ENGLAND SOILS CAN REACT UNFAVORABLY TO BASIC DRILL FLUID WITHOUT PROPER ADDITIVES.”

specific soil conditions. It is important to understand the proper use of additives so you do not become the source of drilling problems. Use your available resources wisely.

Planning and maintaining a basic drill fluid system includes field confirmation measurements recorded daily. **This data may be one of the drillers’ best records for recognizing and documenting changed conditions**.

Understanding what the drill data means can provide significant information as to a cause of drilling problems.

- Soil description is possibly the most important piece of information in the selection of a drill fluid system. Not knowing subsurface conditions means you are agreeing to be part of the problem. No single drill fluid can perform efficiently for all soil conditions just like soil duckbill drill bits do not work well in rock. Basic information includes grain size to determine if soil is granular or cohesive, pH and hardness of soil and groundwater, and moisture content of the soil. Note that grainsize can provide an excellent indicator as to how the soil will perform during excavation. If the #200 sieve material is more than 20 percent and has a plastic index (PI) determined by Atterberg limits greater than 10 then the material will react like clay, otherwise it reacts as a granular material. Additionally, the Atterberg liquid limit (LL) provides a moisture content where a clay is at a boundary of acting like a clay solid (stable) or a clay liquid (unstable). When the formation moisture content is less than the Atterberg plastic limit then the formation clay will start to suck the water out of your drill fluid possibly swelling resulting in a smaller than drilled annulus.
- Match your pump and drill bit to optimize drill fluid circulation. Select a bit and pumping rate to clean the bit and remove the cuttings. Drill fluid needs velocity in the annulus to move suspended cuttings. A good rule of thumb is to have an up-hole fluid velocity around 80 feet per minute for a pilot hole. However, reaming enlarges the hole annulus thus significantly reducing return fluid annular velocities as a square root function of diameter; sometimes to less than 5 feet per minute. Annular Flow = 24.512*(Pump)/(Dh^2 – Dr2) with Pump in gpm and Dh and Dr equal to hole diameter and rod diameter in inches. Circulating time in minutes is Length of hole in feet/Annular Flow. Basically, it will take longer to clean a larger hole as you always need about 3 to 5 gallons of drill fluid to remove 1 gallon of excavated hole volume.



Drill fluid most efficient when transporting 8 – 12% solids

Keep marsh funnel readings between 45 – 75 seconds

Sand content significantly reduces equipment life

- pH and hardness: ALWAYS check mix water prior to making any drill fluid. Do not underestimate the value of soda ash or sodium carbonate (not bicarbonate) pH conditioning to get the best yield and efficiency out of your drill fluid. Hardness means that you have calcium in the makeup water. Calcium prevents the bentonite from fully yielding therefore you do not have the properties you need unless you add more bentonite (cost) to your drill fluid. Desirable mix water pH 8.5 to 9.5 and hardness less than 100 ppm.
- Unit Weight of both reconditioned supply and return fluids – As Baroid's Frank Canon asks: Are you cleaning the hole? Water is 8.3 ppg, fresh mud 8.5ppg about 1 percent. Everything above 8.5 percent may be considered as solids. Drill fluid is most efficient when it transports between 8 to 12 percent solids.
- Unit weight is the drill fluid property that provides internal support of the hole. The amount of support (pressure, P in psi) may be calculated by ((Drill fluid density in pcf)/144)*Vertical depth of hole below entry.
- The following procedure/example by Frank Canon lets you know if you are cleaning the hole:

  1. Hole area (in^2)/24.5 = Gallons of soil per foot of hole
  2. Gallons of soil per foot * Rod Length = Gallons of soil per rod
  3. Pump rate (gpm) * Minutes per rod = Gallons of drill fluid pumped per rod
  4. Gallons of soil per rod + Gallons of slurry per rod = Total slurry volume per rod
  5. Calculated % Solids (%Sc) = Gallons of soil per rod/Total slurry volume per rod
  6. Measure return fluid unit weight (ppg) = UW_m
  7. Actual percent solids content (%Sa) = UW_m * 8
  8. RESULT: If %Sc ~ %Sa 'Life is Good'
     If %Sc > %Sa Where did the solids go?
     If %Sc < %Sa Where are the extra solids coming from?
- Marsh funnel provides an indication of drill fluid viscosity, thickness and ability to suspend cuttings. A simple test is to put return fluid in a glass jar and watch to see if the cuttings stay in suspension (good) or collect in the bottom of the jar (bad). Low viscosity allows your pump to work as designed and relates to how much pump pressure and annular pressure is required to move drill fluid. High marsh funnel readings indicate that higher annular pressure is required to move the drill fluid increasing risk of uncontrolled drill fluid loss and eventually damage to the pump should the intake stroke cause cavitation. There will be a 'sweet spot' between low and high readings to effectively remove cuttings. Charge pumps help but are not the right answer. Pumps typically operate best when inflow to the pump is in the range between 1 and 3 feet per second. Typically try to keep marsh funnel readings between about 45 to 75 seconds. Water is 26 seconds.

When running mud motors, or when encountering highly abrasive soil, the following testing may be recommended by your drill fluid specialists:

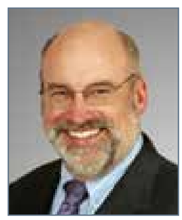
- Sand Content significantly reduces pump, mud motor, and equipment life. (Less than 1 percent by volume)
- Filtrate 30 min test water loss reading between 6 ml to 8 ml, 2/32 thick cake, AND fold paper to observe for plastic or cracking in filter cake.
- Plastic Viscosity, PV = Rheometer Fann 600 – Fann 300, Desire PV ~20 for working drill fluid.
- Yield Point, YP = Rheometer Fann 300 – PV, Desire as close to PV as possible but typically ~15. Typically (as a rule of Thumb) YP for proper hole cleaning will be 1.5 to 2 times your bit size.
- Gel Strength (Lb/100 ft^2) at 10 seconds, ability of drill fluid to suspend cuttings in a timely manner after circulation has stopped. Excessive gel strength requires high pump pressure to restart circulation which can

cause high annular pressure possibly resulting in fracturing the hole and uncontrolled drill fluid loss. Low gel strength can cause cuttings to build up on the bottom of the hole resulting in restricting of the annulus size which again can cause high annular pressure and uncontrolled drill fluid loss. Gel Strength is calculated from a Rheometer by rotating at 1,100 RPM for 10 seconds; stop and wait 10 seconds, rotate at 3 RPM and take a Fann reading which will be the 10 second gel strength.

Basic drill fluid often needs help from additives to enhance the properties to drill effectively in New England soils. Additives are used to tailor the basic fluid to site-specific subsurface conditions. Each drill fluid manufacturer has additives that they use to enhance their drill fluid. The high variability of New England soil often favors a basic drill fluid blend and the use of appropriate additives. Proper interpretation of drill fluid data will tell you how the drill fluid is reacting to the soil.

Match your drill fluid to anticipated subsurface conditions. Take advantage of manufacturer's technical specialist to properly enhance the properties of your drill fluid for anticipated subsurface conditions. For high-risk projects, consider hiring independent certified drill fluid specialists to help setup a drill fluid program and/or provide full time services to manage your drill fluid system. In all situations, the drill fluid that best addresses the encountered subsurface conditions will provide the best daily production rates with the least amount of tool wear.

ABOUT THE AUTHORS:



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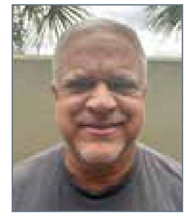

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