CHAPTER

11

USE OF CLAYS AS DRILLING FLUIDS AND FILTERS

11.1 DRILLING FLUIDS

In geotechnical engineering, drilling fluid is a fluid used to drill boreholes into the earth. In drilling rigs, drilling fluids help to do drill for exploration of oil and natural gas. Liquid drilling fluid is often called drilling mud. The three main categories of drilling fluids are:

Water-based mud: which can be dispersed and non-dispersed.
Non-aqueous mud: usually called oil-based mud.
Gaseous drilling fluid: in which a wide range of gases can be used.

The main functions of drilling fluids include providing hydrostatic pressure to prevent formation fluids from entering into the well bore, keeping the drill bit cool and clean during drilling, carrying out drill cuttings, and suspending the drill cuttings while drilling is paused and when the drilling assembly is brought in and out of the hole. The drilling fluid used for a particular job is selected to avoid formation damage and to limit corrosion.

11.2 TYPES OF DRILLING FLUID

Many types of drilling fluids are used on a day-to-day basis. Some wells require that different types be used at different parts in the hole, or that some types be used in combination with others. The various types of fluid generally fall into a few broad categories (Table 11.1).

On a drilling rig, mud is pumped from the *mud pits* through the drill string where it sprays out of nozzles on the drill bit, cleaning and cooling the drill bit in the process. The mud then carries the crushed or cut rock (“cuttings”) up the annular space (“annulus”) between the drill string and the sides of the hole

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Table 11.1: Brief descriptions of different drilling fluids

Drilling fluid	*Description*
Air	Compressed air is pumped either down the bore hole's annular space or down the drill string itself.
Air/water	The same as above, with water added to increase viscosity, flush the hole, provide more cooling, and/or to control dust.
Air/polymer	A specially formulated chemical, most often referred to as a type of polymer, is added to the water and air mixture to create specific conditions. A foaming agent is a good example of a polymer.
Water	Water by itself is sometimes used.
Water-based mud (WBM)	A most basic water-based mud system begins with water, then clays and other chemicals are incorporated into the water to create a homogenous blend resembling something between chocolate milk and a malt (depending on viscosity). The clay (called "shale" in its rock form) is usually a combination of native clays that are suspended in the fluid while drilling, or specific types of clay that are processed and sold as additives for the WBM system. The most common of these is bentonite, frequently referred to in the oilfield as "gel".
Oil-based mud (OBM)	Oil-based mud can be a mud where the base fluid is a petroleum product such as diesel fuel. Oil-based muds are used for many reasons, some being increased lubricity, enhanced shale inhibition, and greater cleaning abilities with less viscosity. Oil-based muds also withstand greater heat without breaking down. The use of oil-based muds has special considerations.
Synthetic-based fluid (SBM) (Otherwise known as Low Toxicity Oil Based Mud or LTOBM)	Synthetic-based fluid is a mud where the base fluid is a synthetic oil. This is most often used on offshore rigs because it has the properties of an oil-based mud, but the toxicity of the fluid fumes are much less than an oil-based fluid. This is important when men work with the fluid in an enclosed space such as an offshore drilling rig.

being drilled, up through the surface *casing,* where it emerges back at the surface. Cuttings are then filtered out with either a shale shaker, or the new shale conveyor technology, and the mud returns to the *mud pits*. The mud pits let the drilled "fines" settle; the pits are also where the fluid is treated by adding chemicals and other substances.

The returning mud can contain natural gases or other flammable materials which will collect in and around the shale shaker/conveyor area or in other work areas. Because of the risk of a fire or an explosion if they ignite, special monitoring sensors and explosion-proof certified equipment is commonly installed, and workers are advised to take safety precautions. The mud is then pumped back down the hole and further re-circulated. After testing, the mud is

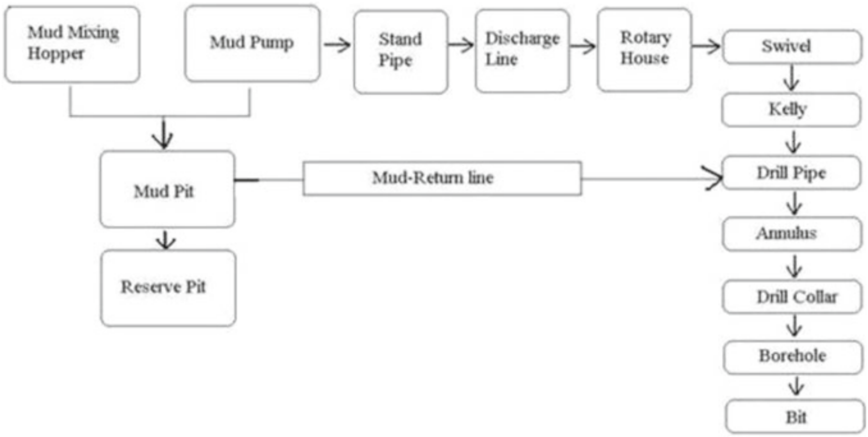

Fig. 11.1: Flow chart of drilling process.

treated periodically in the mud pits to ensure properties which optimize and improve drilling efficiency, borehole stability, and other requirements listed below.

11.3 FUNCTION

The main functions of a *drilling mud* can be summarized as follows:

(a) Remove Cuttings from Well

Drilling fluid carries the rock excavated by the drill bit up to the surface. Its ability to do so depends on cutting size, shape and density, and speed of fluid travelling up the well (annular velocity). These considerations are analogous to the ability of a stream to carry sediment; large sand grains in a slow-moving stream settle to the stream bed, while small sand grains in a fast-moving stream are carried along with the water.

Other properties include:

- Higher annular velocity improves cutting transport. Transport ratio (transport velocity/lowest annular velocity) should be at least 50%.
- High density fluids may clean hole adequately even with lower annular velocities (by increasing the buoyancy force acting on cuttings). But it may have a negative impact if mud weight is in excess of that needed to balance the pressure of surrounding rock (formation pressure), so mud weight is not usually increased for hole cleaning purposes.
- Higher rotary drill-string speeds introduce a circular component to annular flow path. This helical flow around the drill-string causes drill cuttings near the wall, where poor hole cleaning conditions occur, to move into higher transport regions of the annulus. Increased rotation are the best methods in high angle and horizontal beds.

(b) Suspend and Release Cuttings

- Must suspend drill cuttings, weight materials and additives under a wide range of conditions.
- Drill cuttings that settle can cause bridges and fill, which can cause stuck-pipe and lost circulation.
- Weight material that settles is referred to as sag; this causes a wide variation in the density of well fluid, which occurs more frequently in high angle and hot wells.
- High concentrations of drill solids are detrimental to:
  - Drilling efficiency (it causes increased mud weight and viscosity, which in turn increases maintenance costs and increased dilution)
  - Rate of Penetration (ROP) (increases horsepower required to circulate)

(c) Control Formation Pressures

- If formation pressure increases, mud density should also be increased, often with barite (or other weighting materials) to balance pressure and keep the well-bore stable. Unbalanced formation pressures will cause an unexpected influx of pressure in the well-bore; possibly leading to a blowout from pressured formation fluids.
- Hydrostatic pressure = density of drilling fluid × true vertical depth * acceleration of gravity. If hydrostatic pressure is greater than or equal to formation pressure, formation fluid will not flow into the well-bore.
- Well control means no uncontrollable flow of formation fluids into the well-bore.
- Hydrostatic pressure also controls the stresses caused by tectonic forces. These may make well-bores unstable even when formation fluid pressure is balanced.
- If formation pressure is subnormal, air, gas, mist, stiff foam, or low density mud (oil base) can be used.

(d) Seal Permeable Formations

- When mud column pressure exceeds formation pressure, mud filtrate invades the formation, and a filter cake of mud is deposited on the well-bore wall.
- Mud is designed to deposit thin, low permeability filter cake to limit the invasion.
- Problems occur if a thick filter cake is formed in tight hole conditions, poor log quality, stuck pipe, lost circulation and formation damage.
- In highly permeable formations with large pore throats, whole mud may invade the formation, depending on mud solids size.

  - Use bridging agents to block large opening, then mud solids can form seal.
  - For effectiveness, bridging agents must be over the half size of pore spaces/ fractures.
  - Bridging agents (e.g. calcium carbonate, ground cellulose).
- ➔ Depending on the mud system in use, a number of additives can improve the filter cake (e.g. bentonite, natural and synthetic polymer, asphalt and gilsonite).

11.4 MAINTAIN WELL-BORE STABILITY

- Well-bore instability = sloughing formations, which can cause tight hole conditions, bridges and fill on trips (same symptoms indicate hole cleaning problems).
- Well-bore stability = hole maintains size and cylindrical shape.
- Chemical composition and mud properties must combine to provide a stable well-bore. Weight of the mud must be within the necessary range to balance the mechanical forces.
- If the hole is enlarged, it becomes weak and difficult to stabilize, resulting in problems such as low annular velocities, poor hole cleaning, solids loading and poor formation evaluation.
- In sand and sandstones formations, hole enlargement can be accomplished by mechanical actions (hydraulic forces and nozzles velocities). Formation damage is reduced by conservative hydraulics system. A good quality filter cake containing bentonite is known to limit bore-hole enlargement.
- In shales, mud weight is usually sufficient to balance formation stress, as these wells are usually stable. With water based mud, chemical differences can cause interactions between mud and shale that lead to softening of the native rock. Highly fractured, dry, brittle shales can be extremely unstable (leading to mechanical problems).
- Oil (and synthetic oil) based drilling fluids are used to drill most water sensitive shales in areas with difficult drilling conditions.

11.5 MINIMIZING FORMATION DAMAGE

- ➔ Most common damage:
  - Mud or drill solids invade the formation matrix, reducing porosity and causing skin effect
  - Swelling of formation clays within the reservoir, reduced permeability
  - Precipitation of solids due to mixing of mud filtrate and formations fluids resulting in the precipitation of insoluble salts
  - Mud filtrate and formation fluids form an emulsion, reducing reservoir porosity

- Specially designed drill-in fluids or workover and completion fluids, minimize formation damage.

11.6 COOL, LUBRICATE AND SUPPORT THE BIT AND DRILLING ASSEMBLY

- Cool and transfer heat away from source and lower to temperature than bottom hole.
- If not, the bit, drill string and mud motors would fail more rapidly.
- Lubrication based on the coefficient of friction. Oil- and synthetic-based mud generally lubricate better than water-based mud (but the latter can be improved by the addition of lubricants).
- Heat is generated from mechanical and hydraulic forces at the bit and when the drill string rotates and rubs against casing and well-bore.
- Amount of lubrication provided by drilling fluid depends on type and quantity of drill solids and weight materials and chemical composition of system.
- Poor lubrication causes high torque and drag, heat checking of the drill string, but these problems are also caused by key seating, poor hole cleaning and incorrect bottom hole assemblies design.
- Drilling fluids also support portion of drill-string or casing through buoyancy. Suspend in drilling fluid, buoyed by force equal to weight (or density) of mud, so reducing hook load at derrick.
- Weight that derrick can support is limited by mechanical capacity; increase depth so weight of drill-string and casing increases.

11.7 ENSURE ADEQUATE FORMATION EVALUATION

- Chemical and physical mud properties and well-bore conditions after drilling affect formation evaluation.
- Potential productive zone are isolated and performed formation testing and drill stem testing.
- Mud helps not to disperse of cuttings and also improve cutting transport for mud loggers determine the depth of the cuttings originated.
- Oil-based mud, lubricants and asphalts will mask hydrocarbon indications.
- So mud for drilling core is selected based on type of evaluation to be performed (many coring operations specify a blend mud with minimum of additives).

11.8 CONTROL CORROSION (at Acceptable Level)

- Drill-string and casing in continuous contact with drilling fluid may cause a form of corrosion.
- Dissolved gases (oxygen, carbon dioxide, hydrogen sulfide) cause serious corrosion problems:

- Cause rapid, catastrophic failure
- May be deadly to humans after a short period of time

- Low pH (acidic) may be the cause of corrosion and aggravates, so 'corrosion coupon' is essential to monitor the type of corrosion and simultaneously can suggest the right material (chemical inhibitor) to resist it.
- Mud aeration, foaming and other O_2 trapped conditions cause corrosion damage in short period time.
- When drilling in high H_2S, elevate the pH fluids + sulphide scavenging chemical (zinc).

11.9 FACILITATE CEMENTING AND COMPLETION

- Cementing is critical to effective zone and well completion.
- During casing run, mud must remain fluid and minimize pressure surges so fracture induced lost circulation do not occur.
- Mud should have thin, slick filter cake, well-bore with no cuttings, cavings or bridges.
- To cement and complete operation properly, mud is displaced by flushes and cement.

11.10 COMPOSITION OF DRILLING MUD

Water-based drilling mud most commonly consists of bentonite clay (gel) with additives such as barium sulphate (barite), calcium carbonate (chalk) or hematite. Various thickeners are used to influence the viscosity of the fluid, e.g. guar gum, glycol, carboxy methylcellulose, polyanionic cellulose (PAC), or starch. In turn, deflocculants are used to reduce viscosity of clay-based muds; anionic polyelectrolytes (e.g. acrylates, polyphosphates, lignosulphonates (Lig) or tannic acid derivates such as Quebracho) are frequently used. Red mud was the name for a Quebracho-based mixture, named after the colour of the red tannic acid salts. Some other common additives include lubricants, shale inhibitors and fluid loss additives (to control loss of drilling fluids into permeable formations). A weighting agent such as barite is added to increase the overall density of the drilling fluid so that sufficient bottom hole pressure can be maintained.

11.11 USE OF CLAYS AS FILTERS

Filtering is the screening processes for removal of contaminants present in a bulk sample. Due to its adsorption properties and large surface area, clays have enormous use as filters. With the addition of suitable organic substances, the adsorption properties can be altered. Such synthetically produced clays are called inorgano-organo clays. To remove pollutants these clays have wide applications, some of them are described below.

To purify water, use of clay pots is a very well known old process. With time, variation of filtering materials and methods have been developed as needed. This purification process of water varies according to the scale of purification and also the amount and type of contaminants present e.g. the water purification for household need is quite different from the waste water purification processes or removal of oils and fat or colour contaminants. The purification of waste water from various industries is an acute problem. To tackle such widely varied problems, clays with a combination of suitable organic compounds were synthetically developed to alter the filtering properties and processes as needed.

A brief division of filtering using clay types are: (1) Water filtration for household purpose, (2) Large scale filtration for waste waters from Industry and sewerage, (3) Desalination of water, (4) Use of bleaching clays in processing edible oils and (5) Filter materials for smoking items like cigars etc. to reduce health hazard problems.

11.12 WATER FILTRATION FOR HOUSEHOLD PURPOSE

These filters produce small amounts of water per day to meet the daily needs of 25 to 30 litres per person. Use of clay pot filters is a very well known old process.

Clay-saw Dust Filter

A paste with mixture of the clay and saw dust (of about 20 micron size) with different proportions (depending on the plasticity of clay used) is given the needed shape and fired to make it hard porous solid ready for filtration. This very simple type filter can only filter out the particles and colour out of water but is unable to remove bacteria.

Ceramic Water Filters (CWF)

These rely on the small pore size of the ceramic material, are inexpensive and more effective water filter, to filter dirt, debris, and bacteria, protozoa, and microbial cyst etc. out of water. But again, this is not effective against viruses since they are of smaller size than the pores and can pass through to the other "clean" side of the filter. To overcome this, CWF are treated with silver in a form that will not leach away helps to kill or incapacitate bacteria and prevent the growth of algae in the body of the filter.

A high-performance activated carbon core inside the ceramic filter cartridge is used that reduces organic and metallic contaminants and some chemical compounds such as chlorine etc. for the absorbing property of Active Carbon. These filters need to be replaced periodically because the carbon becomes clogged with foreign material.

CWF systems consist of a porous ceramic filter that sits on top of a plastic or ceramic receptacle. Contaminated water is to pass through the filter into the receptacle below. The receptacle usually is fitted with a tap.

When used to treat turbid water, the filter needs to be frequently scrubbed clean to remove the retained material. This abrasive treatment rapidly wears away the ceramic. Care has to be taken to prevent cracking of the ceramic as short circuiting of the filter by pathogens can occur.

Main risks to the success of all forms of CWF are hairline cracks and cross-contamination. If the unit is dropped or otherwise abused, the brittle nature of ceramic materials can allow fine, hard to see hairline cracks, and pass contaminants through the filter.

11.13 LARGE SCALE FILTRATION FOR PURIFYING WATER

Removal of contaminations from the waste waters (from different Industries, sewerage etc.)

Removal of even trace level of pollutants from very large volume of waste water is a micro separation process. For such applications, the adsorbents need to be cost effective.

Clay adsorbents are modified by combining organic substances, produced synthetically, and these inorgano-organo clays are of vital importance to remove pollutants from industrial waste water. The basic material of inorganic clay phase is varieties of expanding clays, like montmorrilonite, bentonite etc.

Removal of Coloured Organics from Aqueous Solutions

For removing the coloured organic substances in various aqueous systems, use of Anion Clay Hydrocalcite is a very effective method. The coloured substances can be adsorbed on the surface or enter the inter-layer region of clay by anion exchange. Adsorption capacity of hydro calcite is a little more than the commercially activated carbon. By heating at 723°K all the adsorbed organics can be removed and the used sorbent can be reused again with greater adsorbing capacity. This sorbent is becoming very useful and environmental friendly for water purification process.

Removal of Oils from Contaminated Water

For oil removal, use of organoclay is used in water treatment technology since 1995. Organo clays are developed using basically bentonite clays (mostly montmorillonite) mixing with quaternary amines (organic compounds derived from ammonia (NH_3), where the hydrogen atom is replaced by CH_3 or CH_5) under suitable temperature and pressure and pH-conditions. This modified bentonites or other organo clays are used (as filter candles or granules) to remove the oils, grease or other sparingly soluble organics from water.

11.14 DESALINATION OF WATER (in Large Scale)

To make saline water usable, removal of salinity is essential. This is called desalination and during this process some other minerals are also removed. The methods of desalination are listed below.

Distillation

Three types of distillation processes are used to desalinate water, but none of them use clay. These three methods are:

(i) **Multistage Flash Distillation** (MSF): Almost 85% of world's desalinated sea water is obtained using this method. This is essentially a countercurrent heat exchange process where flashing a portion of the water into steam in multiple stages distillation is processed.

(ii) **Multiple-effect Distillation** (MED): In this process, repeated distillation of the feed water system through tubes is performed. These tubes are either submerged inside or the feed water is being spread on the steam tubes. Evaporation of water by steam in multiple stages ensures increased volume of distilled water which is collected from the bottom of the distillation apparatus.

(iii) **Vapour Compression:** It is a distillation process where the heat is supplied by compressed vapour. In this method, the latent heat of the vapour is used during condensation to get extra heat (compression of the vapour increases both pressure and temperature).

Ion Exchange

These processes are widely used for water purification, decontamination and water softening. Being a reversible process, the ion exchanger can be reused with desirable ions.

Use of Membranes

Separation/desalination/purification using membranes is essentially a mechanical process and usually no heating is needed but sometime operates using pressure, thus consumes less energy. The main division of this method are: (i) Electro-Dialysis Reversal (EDR), (ii) Reverse Osmosis (RO), (iii) Nano-Filtration (NF) and (iv) Membrane Distillation.

11.15 USE OF BLEACHING CLAYS IN PROCESSING EDIBLE OILS

For bleaching of oils and fats, bentonite clays are used. These commercial bleaching clays are of two types e.g. natural (bentonites) and activated (montmorrilonites of suitably enriched ions by chemical processing) clays. The bleaching clays are intimately mixed with oils for specified time and predecided temperature with suitable agitation conditions. This bleaching process may need repeated operating cycles for desirable result. The used clay will be precipitated at the bottom of the chamber and can be reused. The oil will be collected in a different chamber.

11.16 FILTER MATERIALS FOR SMOKING ITEMS LIKE CIGARS

For reducing the harmful content of tobacco smoke filters are used. Filter materials are produced using a suitable mixture of clays with zeolites and used in cigarettes, cigars, tobacco pipes, cigar holders etc. Clays have enormous uses as filters due to its adsorption properties and large surface area.

QUESTIONS

1. Give a schematic diagram on flow chart of drilling process.
2. What are the types of drilling agent?
3. Choosing of drilling agent, how does it depend on pressure.
4. How can the formation damage be minimized.
5. What are the usages of filter?
6. Explain the following terms:
   Shortpass, Longpass, Bandpass, Dichroic filter, Absorptive.

FURTHER READING

Alther, George R. (1995). Organically modified clay removes oil from water. *Waste Management*, **15:** 623-628.

ASME Shale Shaker Committee (2005). The Drilling Fluids Processing Handbook. ISBN: 0-7506-7775-9.

Chilingarian, G.V. and Vorabutr, P. (1983). Drilling and Drilling Fluids. Elsevier.

Gray, G.R., Darley, H.C.H. and Rogers, W.F. (1980). The Composition and Properties of Oil Well Drilling Fluids. Gulf Pub. Co., Houston.

Greenlee, L.F., Lawler, D.F., Freeman, B.D. and Marrot, B. (2009). Desalination Plant and Water Technology. *Water Research*, **43(9):** 2317-2348.

Kate Van Dyke (1998). Drilling Fluids, Mud Pumps and Conditioning Equipment. ISBN: 10-0886981816.

Orthman, J., Zhu, H.Y. and Lu, G.Q. (2003). Use of Anion Clay...Aqueous Solutions. *Separation and Purification Technology*, **31(1):** 53-59.

Richardson, Louise I. (1950). Use of bleaching clays in processing edible oils. W Century Building, Los Alamos, CA 90045.

Srinivasan, K.R., Fogler, H.S. et al. (1985). Clays and Clay Minerals. Elsevier.