How to drill by cable percussion: D.V. Allen, C.Eng. MICE

FORAGER-55
CABLE PERCUSSION DRILL RIGS
The techniques and tools available to users of a Consallen Forager-55 Cable Percussion (shell & auger) drilling machine.

(Best read in conjunction with our video showing setting up & use of the Forager-55)

INTRODUCTION

A cable percussion drill-rig lifts and drops a string of heavy tools in the hole it is drilling. The falling tools break up the material being drilled, allowing it to be removed, and the hole to advance. Different tools are used, depending on the type of material. A crushing tool breaks rock, and mixes it with water to form mud, which can be removed using a bailer. A clay cutter rapidly removes clay by cutting and extracting a solid plug, rather like an apple corer. Other tools combine the attributes of both crushing and clay cutting. Additional weight may be provided using sinker bars that can be screwed together, and a sliding hammer can be used to drive tools by repeated blows.

The Forager-55 has a free-fall winch, with which the tools are lifted, then allowed to fall freely, so they are travelling as fast as possible when they strike, for maximum impact. Both 'long drop' and 'short stroke' techniques may be employed. The 'long drop' suits the directly controlled winch, allowing use of a wide range of tools and methods.

The most basic method of drilling by cable percussion involves using a suitable heavy tool to break up the earth in a hole, and then removing this material using either the tool itself in the case of 'stubbers', 'clay cutters', drive tubes or 'bailers' to bail mud. Depending on the nature of the material being drilled, the addition of some water may help the material either flow into a bailer, or to form mud that the bailer can remove. In any material exhibiting cohesion (containing clay), a stubber or a clay cutter will cut and retain a core that can be hauled out, and quickly removed from the tool at ground level. Stubbers and clay cutters employ the long drop technique with the addition of one or more sinker bars for additional force; they are also be used with a sliding hammer in some conditions, and an occasional cup of water will serve to lubricate the cutting shoe.

The hole may, or may not, require support during drilling operations. Many materials will support themselves, but techniques are available if this is not the case. Keeping a head of water in the hole is a very successful method of preventing collapse when ground such as saturated sand and silt will not stand unsupported.

Traditionally, the driving of steel casing, and then excavating the plug of material formed in the bottom has been used in certain types of ground. After this has been cleared, further progress is made with repeated cycles of driving and excavating. The casing provides protection against any collapse of the hole, and maintains a clearance, allowing the tools to work freely in the pre-formed space. If the stage is reached where heavy driving of the steel casing makes no further advance, a smaller casing can be telescoped inside the first. This 'reduction' may be required several times to complete a hole in some formations.

A variation on this technique is where excavation takes place in advance of the casing as it is lowered down. This is used where the ground will stand unsupported for part of the hole. The casing may be quite loose and not require heavy driving, but performs the task of reaming and maintaining the hole size and straightness for the free fall of the tools. An oversized shoe is often used with this technique, ensuring some clearance between the outside of the casing and the hole. This clearance allows the

casing to be lifted and dropped as a means of drilling and reaming after a pilot hole has been opened with the drilling tools. The 'loose casing' method is frequently used in conjunction with clay cutters and stubbers, which are also called 'dry' drilling tools – mostly this technique is used with flush jointed temporary casing, often referred to as "shell & auger" drilling. Loose casing may sink under it's own weight when bailing below the shoe in saturated sands and silts

Techniques involving the use of a driven steel casing are utilised where either the casing is temporary and is to be removed on completion of the well, using another permanent screen and casing, or where the driven casing is also permanent. Temporary steel casing is expensive, usually is flush butt thread jointed, and must be removed for re-use whenever possible. The cost of this equipment is so high that it cannot normally be allowed to remain in the ground. The methods of driving and recovery of steel casings are 'heavy weight' methods but can be used with light drilling machines like the Forager-55, where the weight of casing being handled does not exceed about 80% of the safe working load of the winch. In good conditions this may be the equivalent of 30 metres of 6-inch or 45 metres of 4-inch flush jointed steel casing on a direct pull. Additional weights of casing can be hoisted using snatch blocks to provide two, or more, falls of wire in a multi-part tackle. Some very thick-walled plastic tube can be forced down as the hole is drilled ahead of the leading edge, protected by a steel shoe and with a suitable steel cap, but this is not the same as the heavy driving which can be sustained by a steel casing.

Although widely used in the UK for drilling to chalk aquifers, the use of steel for permanent casing in the majority of tropical countries is deprecated since they corrode in the mostly acidic groundwater, giving a bad taste to the water as well as having a relatively short useful life. Techniques most suited to drilling in tropical African conditions, use plastic permanent well casing, which can not be driven by traditional percussion methods. Plastic is light in weight, cheap enough to be regarded as disposable, is available almost everywhere for local purchase, and will not corrode nor impart taste & impurities to potable water. However, successful forcing requires the use of a steel shoe, and a cap designed to distribute the stresses employed in pulling down against ground anchors. The pull-down provided by the Forager-55 is equal to the winch hoist, and this can be increased using snatch blocks in multi-part tackles. Plastic casing employed in this way may be recovered in some conditions, but is generally regarded as permanent, or sacrificial. In water well drilling this is usually not a problem, but may not be an acceptable practice for site investigation work. Shoes for plastic casing may need to be stainless in aggressive groundwater. Double thickness "stove-pipe" plastic casing is very strong, is flush jointed, and requires no glue or adhesive. This material is made in such a way that considerable force is needed to push the two elements together. The result is a casing, which can be used in a manner similar to the loose casing technique described above. The shoe is larger than the casing pipe, giving some small additional space for the plastic tube, thus minimising friction.

The TOOLS

Bailers

A bailer is an elongated bucket with a bottom valve allowing water and cuttings to enter, and then not escape. Bailers are used for to remove water, mud and cuttings arising from the drilling activity. Heavy weight bailers can be fitted with a cutter bar, and used as a drilling tool in suitable ground. Bailers are made in a variety of sizes to suit the casing in which they will work. The size used to describe a bailer is the casing size in which it operates, but in fact it is at least one size smaller. So a 4-inch bailer is 3½" (90mm) diameter for free movement – allowing water to escape round the sides – in a casing having a nominal bore of 4 inches (100mm). The nomenclature is the same whether casing is steel or plastic. Bailers are fitted with several types of shoes and valves, depending on the use and materials being drilled. Better quality (more expensive) bailers have replaceable screw-on shoes, and some heavy weight universal types can also be used as sinker bars. A Sand Pump is a bailer into which has been fitted a piston and rod. On hoisting, the rod pulls the piston up, causing a partial vacuum in the bailer shoe, sucking in loose sand and water. Some valved drive tubes perform a similar function.

Drilling Bits

A wide variety of bits may be employed to suit the material being excavated. Hard material like rock requires a bit which will crush, and less hard materials need chopping bits to cut and crush.

CLAY CUTTERS

Any material having some cohesion (containing clay) can be excavated using either a clay cutter or a stubber bit. These operate in the dry, cutting extruded cores of clay or clayey sand – they also work with some sand/silt mixtures with suitable moisture content. The impact of these tools causes material to be extruded into the body for easy removal at ground level. Rapid progress is possible if the correct tools are applied to suitable materials. Both clay cutters and stubbers work well in some materials using a sliding hammer to drive the tool by repeated small blows. Multiple drops of about ½m will drive the tool into the material and allow a longer core to be withdrawn than a single long fall. The use of the sliding hammer in this way also allows catching devices to be used in clay cutters to retain sands and gravel, which would normally drop out of the tool. Plastic basket catchers and Valvate discs work well in dry granular materials, in both high and low window clay cutters. Retaining devices are placed with appropriate support rings above the shoes of clay cutters. In some sands, the rings themselves will be sufficient to cause material to form a bridge and be retained in the tool.

Reamers

These are employed to ensure that drilling tools have space to operate without becoming trapped by suction, or having the speed of fall impeded by trapped air or water. They are cutters, which shave or enlarge a hole made by other tools, to at least one size greater than the tool nominal diameter. Generally they do not excavate material, but allow cuttings to fall into the space previously made by other bits and cutters. Reamers have air/water ways to prevent suction or resistance, and clearance angles to avoid entrapment. Some stubbers can also be employed as reamers.

Slugs of clay pushed out of a clay-cutter.

Sinkers

In order to drive drill bits a certain amount of weight is required; this is supplied by sinker bars. They normally have threaded connections, and can be coupled together to supply any weight required for the materials encountered. Sinkers are supplied in sizes and weights to suit the drilling machine capability, in units that are easy to handle. The maximum tool weight for the Forager-55 is 250 Kg. As an example of a sinker bar, a 3½" (90mm diameter) bar weighs 60 Kg per metre, and the Forager-55 rig allows a drill string of 3.58 metres. This maximum can be made up of bits and sinkers, but allowance must be made for the height of any casing protruding from the ground, which the drill string must clear for removal from the hole. We supply sinkers having a weight of up to about 100 Kg, and up to 140mm Ø.

Drilling Jar (Sliding hammer)

A sliding hammer, can be used to cause a snatch to the drill string if it should be temporarily stuck. When used as a sliding hammer, repeated blows can be delivered to a tool without pulling it out between blows or falls. They are often used with stubbers, clay cutters or drive tubes to obtain a bigger sample than can normally be obtained by the long drop technique. They also allow dry drilling in granular materials if a suitable retainer device is used in the drilling tool – see under Clay Cutters above.

CASING

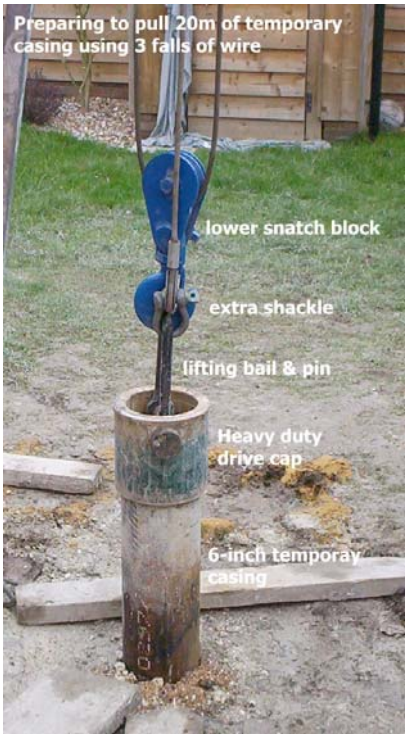
Flush jointed temporary steel water well casing to BS 879 (Flush butt)

This material is available in different lengths, but is most useful in 1.5m (5-foot) lengths for 'shell & auger' drilling by light cable percussion rigs. For the Forager-55, 6-inch nominal bore casing is the

usual starting size. This allows the use of tools based on the next pipe size down – 5-inch sized bailers, clay cutters stubbers etc. The casing is flush jointed inside and out. The threads butt to one another, allowing heavy driving if necessary. A leading shoe is used, which may be either the same size as the casing outer diameter, or oversized. A drive cap is used of a heavy section, allowing heavy driving without damage to either cap or casing threads. The drive cap is supplied with a cross-hole to take a bail and pin for lifting the casing string. A typical 1.5m length of this material weighs about 60 Kg. (132 lbs) Casing shoes may be made oversize by adding hard-face welding – which can also be removed by grinding.

Temporary casing is used as a means of holding a hole open, or as a method of keeping a hole straight and reamed to size, while allowing drilling tools to work in a protected open space. It may also be required in order to seal off unwanted water yielding horizons. When possible, the 'loose casing' method of drilling is used, with heavy driving only if unavoidable. The 'loose casing method' operates by drilling ahead of the casing shoe. The self-weight of the casing is then allowed to ream the hole as lengths are added. Temporary casing also allows the installation of uncontaminated gravel packs of an even thickness around permanent screens & casing, before being pulled back.

A jacking system may be required for removal of temporary casing after the permanent casing, gravel pack etc. has been placed. This consists of hydraulic jacks and pump, arranged to give an upward force appropriate to the casing size. 20-ton and 30-ton sets for use with 6-inch casing are available. A hand-operated 20-ton version can be used to lift casing at about 2 metres per hour. The set applies an equalised force to the drive cap totalling 20,000 Kg. A power pack can be used in place of the hand pump; it requires a deliverable oil capacity of at least 5 litres and an operating pressure of 200 Bar. Having started the upward movement, casing can often be pulled by the rig using a multi-part tackle. The Forager-55 can employ a 7-part tackle to provide about 8 Tonnes of extraction force. The photo (right) shows a 3-part tackle being used. When using multi-part tackles, all the leg braces should be in place and the tripod feet prevented from spreading.



3-part tackle being used with a Forager-55 to hoist out 20m of 6-inch temporary casing.

Plastic permanent casing

Usually threaded, flush, butt jointed and may be in uPVC or Polyethylene. This is the best for water well casing, but glued uPVC pipe can also be used. Glued pipe has O-Gee joints which are not flush, but formed by re-heating one end of a pipe and forming it into a socket with an inside about the same as the normal outside diameter of the pipe. The pipe's wall thickness is not critical for most shallow wells, and pipes made for drainage purposes can often be used. Pipes made for pressure purposes are better quality and strength, and should be used for heavier duty applications, deeper holes and in unstable ground.

Glued jointed uPVC casing, while being cheap, has the disadvantage that the joint protrudes from the general line of the pipe outer wall. UPVC plastic casing cannot be driven, so when glue jointed pipe is used as casing, it must be placed in a drilled hole which is big enough to avoid problems with inserting the stepped joints. This is not usually a problem if the hole is designed for a gravel pack and surface cementing for hygienic protection. Careful joint surface preparation, cleanliness and correct use of the glue (solvent cement) is essential if the joints are to hold while the casing string is installed

Flush jointed screwed casing in plastic, when fitted with a suitable (stainless) steel shoe, can be pushed and bumped – not driven – down a hole close in size to it's outside diameter. In some conditions it can be used in the same way as the loose steel casing discussed in the Introduction above, by drilling ahead

of the shoe position and then pushing or pulling the casing down. Pulling a casing down requires the use of ground, or 'dead man', anchors.

The pull-down technique also works with 'stovepipe' casing. This is made by cutting cheap drainage pipe into short lengths, to form both inner and outer components of a composite tube. The inner component is slit lengthways and a suitable width strip removed. This allows it to be forced half way into a normal un-split similar length. If the lengths are uniformly about 2 feet each (600mm, say), the composites can be pushed as the hole progresses 2 feet at a time. Some glue can also be used with both the makeup of the composite shells and when placing them as casing. Slitting can be done with normal hand metal (tinsmith's) shears, and cutting into lengths with a hack saw.

Flush butt threaded casing has a limited allowable pullback force stated by the maker. None of the other plastic casing types have capacity for pulling back whatever. Neither glued joints, nor the push together stovepipe joints have any reliable resistance in tension, and the protrusions of the glued system of O-Gee joints makes pull-back virtually impossible unless the hole has been drilled very oversize in suitable material.

DRILLING

Cable percussion drilling

The Consallen Forager-55 is designed for drilling water wells and other holes for completion using 4-inch plastic casing. This means that a drilled hole is required which may be up to 6½ inches clear diameter for installation of casing and the placing of gravel pack and cementing. The basic purpose for which the machine was developed is the construction of low cost water wells as an alternative to hand digging in the Developing world - generally for use with hand pumps. The depth to which holes can be drilled in suitable conditions and using suitable tools is about the same as the length of wire supplied with the winch. The maximum is usually 60 metres, which also coincides with the capability of most hand pumps designed for community use. In some circumstances the hole can be as much as 100 metres, which is the limit for small (3") submersible pumps. These latter can be used in casing with a nominal 3-inch inside diameter – externally about 90mm. Such casing is a useful reduction from 4-inch casing used in upper layers.

Drilling Clays, and sand with some clay content (very common materials) and Laterite

Most material like clay, or sands exhibiting cohesive qualities can be rapidly drilled using clay cutters and stubbers. The falling tools cause cohesive materials to extrude into the tool, where it is retained. The material is then easily removed from the tool on being brought to the surface. Stubbers work well with softer clays, and the ease with which the tools can be cleared make this method a rapid drilling technique.

Using Stubbers

One of the clay cutting bits, which operates by extruding cohesive material through the cutter ring into the spaces between the three legs. Stubbers operate by either the long drop method, or by using a sliding hammer in harder clays, and are simply and easily emptied at ground level.

This version has a threaded connection at the top allowing it to be screwed to a heavy sinker bar, which drives it into the material being drilled. This tool is 140mm diameter and is being driven by a 100 Kg. sinker bar of 125mm diameter.

Stiffer clays may require a clay cutter, with one or more sinker bars to deliver suitable force, depending on the available fall, and number of sinkers employed. Several falls may be needed to fill the cutter, while at times the cutter may fill readily with a single fall of the tools. Another method of using a clay cutter is to empty it after each fall, using a swan-neck clearing tool. Clay cutters also obtain excellent results in conjunction with sliding hammers.

Stubbers and clay cutters operating in clay require adequate clearance to prevent them and sinkers acting like pistons in a cylinder. Unless reaming follows the tools quite closely, the effect of a falling tool string can be neutralised by air trapped in the hole forming a cushion. Also, with the cushioning effect, suction may prevent easy removal of the tool string. Suction increases with water in the hole, which can also cause clays to swell, further impeding both the fall of the tools and their recovery.

Usually it will be necessary to ream a clay hole as soon as the hole advances more than a metre or so beyond the last reamed position. However, the driller will be aware of how the tools are performing and the need or otherwise to ream.

Stubbers may also work in some sands, which although having no cohesion, can behave as if they had, and will readily pack into the tool for removal at ground level.

Sands and Silt

Sands and silts, which are dry, can appear very hard. They can be drilled using a clay cutter, to which has been fitted a bailer valve. The added weight of a sinker bar allows the cutting shoe to drive into the material, which is then retained by the valve. As an alternative to a bailer valve, a plastic core retainer can be fitted and used very effectively. In other types of sand, a simple extrusion ring can be relied on to retain a plug of sand in a clay cutter. The tool can be emptied using a suitable scoop at ground level in the case of valves and core retainers, but an extrusion ring requires only the use of a swan-neck expressing tool. The technique also works in wet sand, and removes only small amount, of water from the hole. Loose sands can also be drilled using a bailer and sufficient water to allow entry through a leather clack valve. They may drill better with a cutter shoe on the bailer, and a sand pump can be tried if there the hole is making water.

Most sands and silts will not stand below water level and some provision for casing must be made when water is found. Either casing must be installed, and/or sufficient water, or light mud, must be maintained to stabilise the section. If this is not the main water-bearing horizon, a casing will usually be required to isolate it, perhaps also with a cementing process. Further drilling will be at a reduced size. Sand pumps, and sampling tubes with suction valves can be used in sands and silts below water level. Often, bailing inside a screen or casing will allow the tube to sink under it's own weight in water-bearing sands. Good progress can often be made using a bailer and very short strokes to surge sand, silt and gravel into the tool. Using a clay cutter in the same way and in the same material removes less water from the hole, while removing the material. Removing less water reduces the risk of the hole collapsing, while making space for advancing the casing

Hard Ground

Indurated Laterite, Shale & Marls

Laterite is a material with a significant clay content, and may be drilled using stubbers and clay cutters. When it is dried out, the same material is more like marl or shale and needs drilling using a cross bit, chisel and some water to make slurry. Generally laterite will stand well and can be drilled easily. Marls and shale may slake, and absorb water. All three of these materials may swell on water absorption or relief of pressure, causing the hole to reduce in diameter; reaming is part of the solution.

Limestone, coral, dolomite & chalk

Use a chisel or a cross bit to fragment the rock and add sufficient water to mix into slurry, which can then be bailed out; no collapse problems in these materials. In some conditions, the bailer alone can be used both to break up the material, and bail it out of the hole. A stubber works well in chalk, as does a clay cutter – aided by a sliding hammer in some cases.

Granite, Basalt & other igneous rocks
These brittle rocks can be crushed with a blunt chisel bit, and combined with water into slurry. A California regular bit may be used, or a bit with tungsten carbide button inserts. A cross bit with hard faced edges also works well.

GENERAL

A successful driller needs to be resourceful & aware at all times of the way the tools are operating, and with an eye on rate of progress. Tools can get stuck, and he needs to know what resources are available to him to free them. The drilling cable has greater strength than the winch, the capacity of which can be multiplied by use of snatch blocks and a wire grip. A wire grip and levers can be used to quickly free tools, in addition to the effect of a sliding hammer. The tripod has a capacity exceeding that of the wire, but both can be hauled at more than the normal load if factors of safety are eroded. The breaking load of the 10mm wire we supply as standard is about 6500 Kg (6½ tons or 14,300 Lbs.).

KNOWN AFRICAN DRILLING PROBLEMS

The tropically weathered in-situ overburden to Basement Complex rocks
This material is generally easy to drill by cable percussion methods, and therein lies a possible trap for the unwary. The surface layers are often a firm to stiff lateritic clay, which stands well and is easy drilling. There may be 15 metres or more of this material, which may contain stones or rocks. Below is a softer clay material descending into silty sandy clay, frequently showing signs of water. This is the dangerous material because progress is rapid and the presence of some water leads the driller to think that he is close to completing the well. The danger is that there may be a sudden collapse of the soft wet material, which exhibits properties like a 'running sand'. This material may rise up a borehole, completely smothering the tools, and making them impossible to withdraw. The mixture of silt, sand and water under pressure may rise 6 or more metres up the hole.

One answer to the problem is to case the hole as far as possible upon first signs of water, and in the obvious presence of silty-sandy clay materials. Maintain at least 3 metres of water in the hole while drilling on, and advancing the casing at the same time. The casing will protect the hole and the drilling tools only while there is a sufficient head of water to prevent the running sand layer from collapse. Further drilling will take the hole into a cleaner sandier material that does not 'run', as it contains less clay and silt. At this point, the natural standing water level can be established in the hole, and bailing may determine the possible yield. If satisfactory, the screen and permanent casing can be installed, together with gravel pack & casing stabiliser.

There are occasions where the lateritic layers are either thin or completely absent, and the problems start close to ground level; the solutions are similar.

WIRE GRIP (Wire Puller)

The picture on the left shows a typical wire. The load is carried on the Load Point, which may be any distance below the grip, with the Hoist Point attached to the lower of a pair of snatch blocks. The upper snatch block would be attached to the rig frame near the apex at the strong-point provided.

The wire grip may also be used with a suitable lever as a quick means of giving an extra heave to stuck tools.

The Wire grip shown has a maximum safe working load of 2000 Kg, and can accommodate up to 5/8" (19mm) diameter wire.