DRILLING METHODS

Dr. Bruce, ECO Geosystems, Inc., U.S.A.

Papers

Methods of overburden drilling in geotechnical construction – a generic classification

By DA Bruce, BSc PhD, CEng. MICE, MASCE, MAEG, MHKIE, FGS

A users' classification system for overburden drilling is presented which cuts across individual manufacturers' categories so as to clarify the confusing array of equipment on the market.

Background

The construction of specialist ground improvement and support systems usually involves the drilling of holes 60mm to 250mm in diameter and to maximum depths of 100m. It is very rare that these limits are exceeded in drilling for ground anchorages, grout holes, minipiles (pinpiles) and in situ reinforcing.

The methods available for drilling in rock – or other materials which will provide an open hole without the need for simultaneous wall support – are well known and easily classified (eg McGregor 1967)[1]. Thus, depending on the geologic conditions, the purpose of the drilling, the economic implications and the proclivities of the interested parties, rock drilling is most commonly conducted by purely rotary methods (from diamond coring to blind tricones) or by rotary-percussive systems featuring either top hammers or down-the-hole hammers (Bruce, 1989)[2]. Within each broad category there is, of course, a wealth of options with respect to equipment, flushing characteristics and operational techniques. However, the field remains fundamentally simple and relatively finite.

In marked contrast, the various methods currently available for drilling overburden present a substantially different picture. Overburden offers intrinsically far more problematical variability to the the driller: to rock masses' hardness and abrasiveness must be added many other relevant properties for consideration. Contractors and manufacturers have thus developed different systems to optimise drilling performance and economics, often specially designed to combat particular local conditions. As a result, there is currently on the market a potentially bewildering range of overburden drilling systems, and it would seem that the promotion of any given system often owes less to the ground conditions than to the experience and resources of the contractor in question.

The purpose of this paper is therefore to provide a generic classification of the methods used to drill holes in soils generally. In some cases the soil characteristics or hole geometry may permit the open holing referred to above. In other cases it may be possible to temporarily stabilise holes by using a mud foam flush. This review, however addresses conditions which necessitate hole stabilisation by the use of some form of casing, typically retrieved at a later stage and reused. Seven basic categories of systems are identified.

It should be noted that only contemporary production methods have been considered, thereby excluding options synonymous with high cost (eg diamond drilling) or restricted geological compatibility (eg vibrodriving). As a final word of introduction, it will become clear that numerous references have been made to specific companies, systems and products. No endorsement or favouritism should be implied, although care has been taken to name reputable and representative sources.

Methods of overburden drilling

The following classification is offered broadly in terms of increasing compexity, with the exception of Type 7 (hollow stem auger).

Type 1: Single tube advancement

In appropriate ground conditions with the proper equipment this is the cheapest and fastest method. There are two variants:

- Drive drilling and
- External flush (wash boring)

Drive drilling. This is, in principle, a percussive system in which the steel casing is drilled with the leading end terminating in either a knock off drive shoe or bit *Fig. 1.* No flush is used. A little rotation is necessary to prevent the string uncoupling during driving and to reduce deviation potential (recorded for the 76.1mm size being as much as 1 in 7.5).

Rarely however, are sizes over 101.6mm practical, except in particularly loose, gravelly or sandy conditions, and the 76.1mm system appears to be the optimum in terms of cost effectiveness.

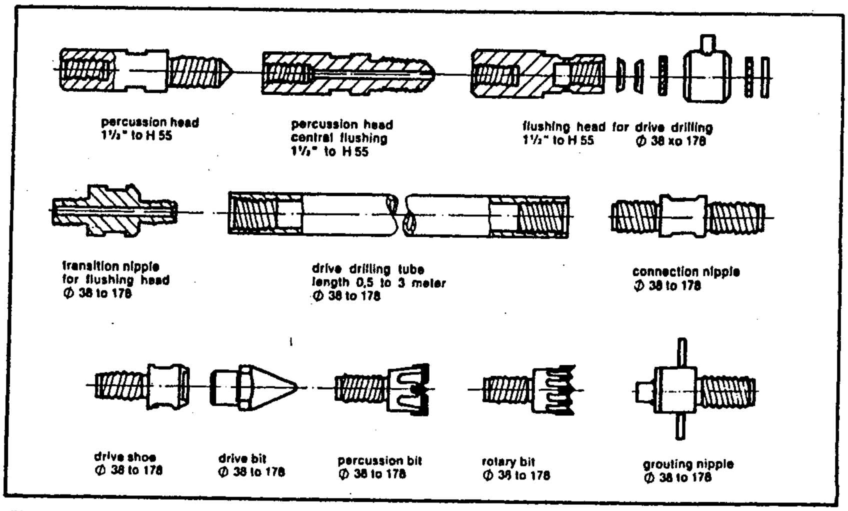
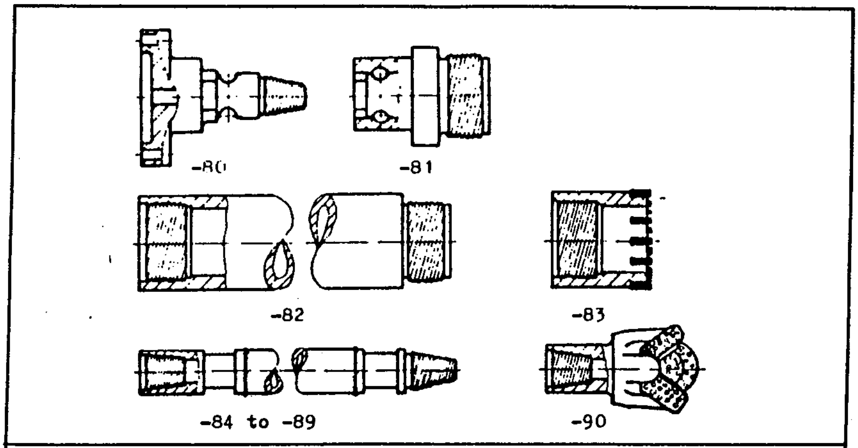


Fig. 1. Components of drive drilling system (Hutte).



Order-no.	Name
178-80	transition flange with Wirth-thread 63,5
178-81	ejection flushing head 63,5 x 177,8
178-82	tube 177,8 x 900mm
178-83	casing crown button type 178 x ø 180mm
178-84	tube 63,5 x 900mm
178-85	tube 63,5 x 1500mm
178-86	tube 63,5 x 2000mm
178-87	tube 63,5 x 2500mm
178-88	tube 63,5 x 3000mm
178-89	tube 63,5 x 3500mm
178-90	rotary bit ø 149,2mm with transition to tube 63,5

Fig. 2. Components of 177.8mm rotary duplex system (Hutte).

Production figures of up to 250m/day are claimed for this size in favourable conditions, to maximum depths of 40m. This system was used recently in the saturated fluvial deposits in Cairo, with great distinction.

External flush. Again a single casing tube is advanced to the final depth, but in this case the drilling mechanism is rotary (and not percussive), and the casing terminates in an open crown, or bit, and not a closed point. Water flush of proper volume and pressure is passed continuously down through the casing during drilling and washes debris out and away from the leading end. The water born debris then typically escapes to the surface around the outside of the casing, but may equally be 'lost' into especially receptive upper horizons. Depending on the purposes of the drilling, this system may be especially useful or potentially dangerous. For example, if ground anchorages are to be formed by subsequent pressure grouting through the casing during its withdrawal, the washing will have helped promote a bulb of larger diameter, and so a fixed anchorage of higher load bearing potential. Conversely, if the drilling is to be conducted through highly sensitive soils under particularly delicate structures, the uncontrolled washing of the soil may prove inadvisable. However, even in this case, the system should not be rejected if good practice and commonsense can together verify its applicability.

All sizes of casing can be used with this approach, but the most common applications of anchoring, minipiling and in situ reinforcement usually involve diameters of 100mm to 200mm.

Type 2: Rotary duplex

In the most common situations, when ground conditions and job requirements combine to eliminate the easy option of single tube advancement, some method featuring the simultaneous advancementof internal rod (with bit) and external casing (with crown) must be adopted. Such methods may collectively be referred to as duplex.

The basic method, which most frequently carries the term duplex, is purely rotary. It relies for its penetration performance on variations of rig thrust, head torque and rotational speed, and flushing characteristics, other factors being equal. The major components are illustrated in ***Fig. 2*** for a typical size, and are

- Outer casing (rotated)
- Casing crown
- Inner drill rod (rotated)
- Drill bit (usually tricone)
- Duplex head/transition flange, connecting to the rotary head of the rig

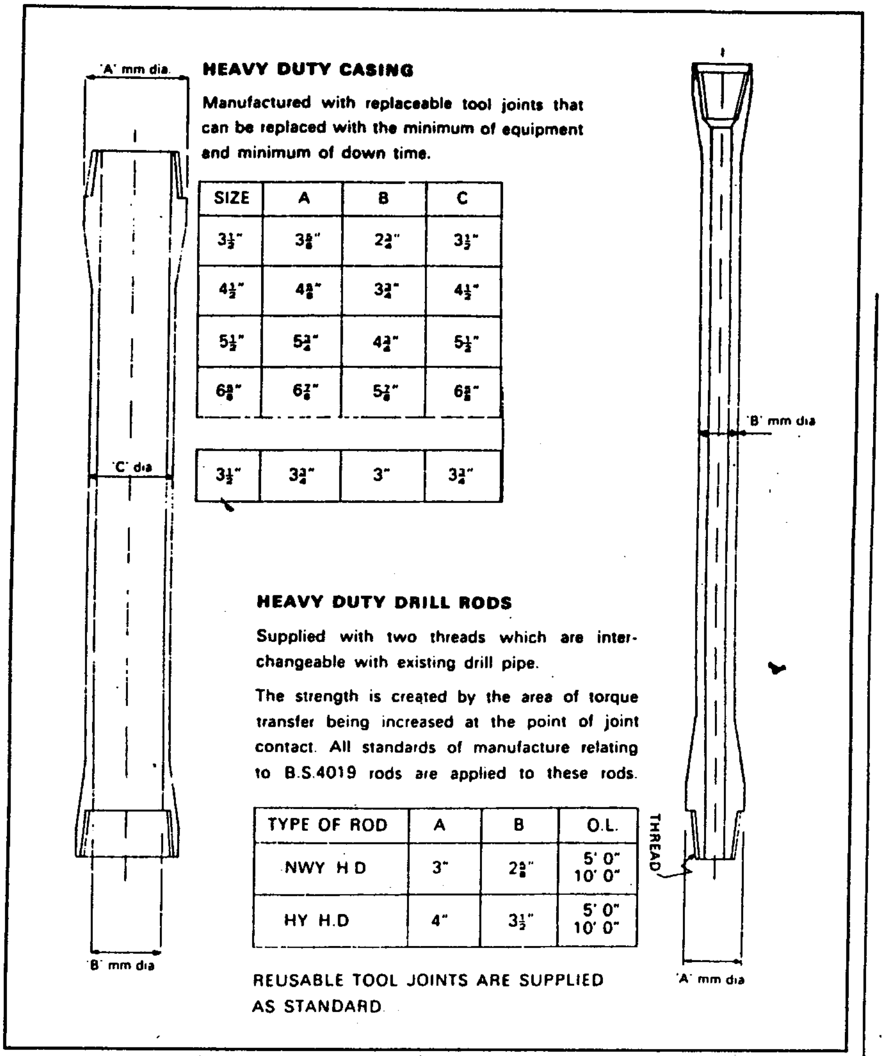
If a large number of hard obstructions is foreseen, it is possible to exchange a down-the-hole hammer for the tricone bit, to hopefully fragment the obstruction and so permit the casing to be rotated down with less resistance (eg) Bruce and Yeung, 1983)[3]. Equally, in especially difficult ground conditions, reverse circulation may be used. Duplex is most commonly used as a high production tool in soft and variable ground conditions, and usually with powerful hydraulic rotary heads. As a consequence, many contractors may favour rather more robust systems than illustrated in ***Fig. 2*** and, as example, ***Fig. 3*** shows the heavy duty range manufactured by Euro-Drill. However, where conditions are less onerous, or environmental restraints are significant, standard flush coupled or jointed casing, or water well casing with appropriate rod types may be used, in accordance with local national standards.

Type 3: Rotary percussive concentric duplex

This method, historically typified by the Atlas Copco OD72 system, is a duplex method wherein both rods and casings are simultaneously percussed and rotated ***Fig. 4.*** In its early years of use it was driven by mainly air hammers with relatively restricted torque capacity. Therefore, the applicability was regarded as limited, and other methods, notably ODEX, with far less emphasis on rotational power were developed. More recently, however, there is clear evidence of a resurgence of the method as a result of the increasing availability of higher torque hydraulic top hammers. By way of illustration, it may be noted that rotary percussion duplex was the preferred production drilling tool of all major contractors on Mass Transit Railway Corporation related works in Hong Kong. Ground conditions were extremely onerous, featuring gritty decomposed granites with large fresh rock relicts. This market for grout hole installation alone, was conservatively estimated at about 200 000m of drilling per year, in the late 1970s and early 1980s.

Although the Atlas Copco system is available in only one size, other manufacturers can supply sizes as in ***Table 2.***

The casings are, of necessity, high quality steel, and have modified rope form threads and wall thicknesses of around 12mm (as opposed to 6mm for ODEX). One consequence is that the unit weight is high, and normally 2m casing lengths are used in the larger sizes. Drilling on with the rods into rock or other stable strata is accomplished without the necessity to change the bit. Both insert and button



HEAVY DUTY CASING

Manufactured with replaceable tool joints that can be replaced with the minimum of equipment and minimum of down time.

SIZE	A	B	C
3½"	3⅝"	2¾"	3½"
4½"	4⅝"	3¾"	4½"
5½"	5¾"	4¾"	5½"
6⅝"	6⅞"	5⅞"	6⅝"
3½"	3¾"	3"	3¾"

HEAVY DUTY DRILL RODS

Supplied with two threads which are interchangeable with existing drill pipe.

The strength is created by the area of torque transfer being increased at the point of joint contact. All standards of manufacture relating to B.S.4019 rods are applied to these rods.

TYPE OF ROD	A	B	O.L.
NWY H D	3"	2⅜"	5' 0" 10' 0"
HY H.D	4"	3½"	5' 0" 10' 0"

REUSABLE TOOL JOINTS ARE SUPPLIED AS STANDARD.

Fig. 3. Heavy duty rotary duplex system. Note that the recommended rock bit maximum sizes for the four major casing types are 2⅝", 3½", 4½", and 5¾" respectively (Euro Drill).

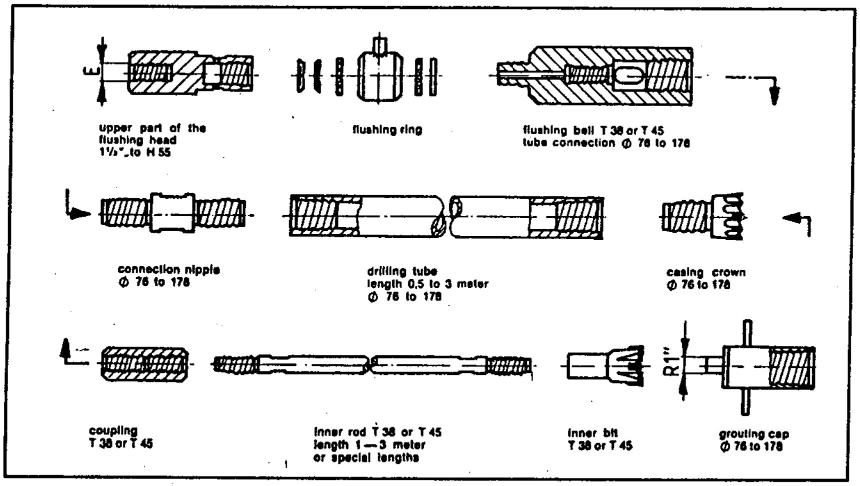


Fig. 4. Components of rotary percussive duplex system (Hutte).

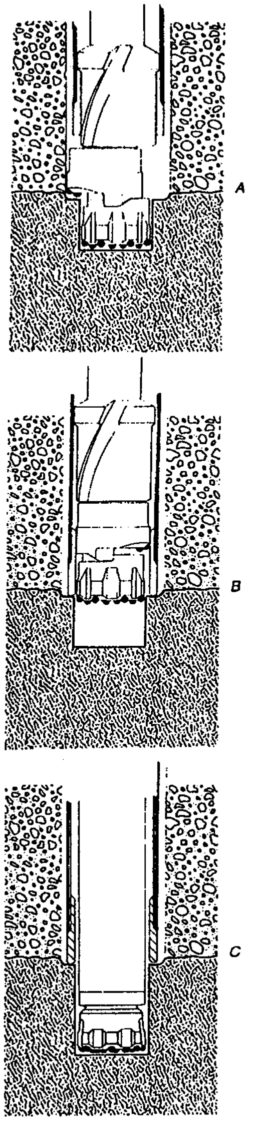
types are available for bits and casing shoes. As with other forms of concentric duplex, in especially sensitive ground, the bit can be retracted up into the casing behind the casing shoe, to minimise cavitation of the ground and promote good flush return. The opposite is done in particularly competent ground. Flushing water is best introduced via an external flushing device and should have a minimum rate of about 100 litres/minute – at up to 2N/mm^2. To improve flush return further, sleeving can be inserted between adjacent couplers on the rod string to present a constant annular volume and reduce local pressure drops and resultant blockages.

Assuming that sufficient torque (say to 6000Nm) is available at the hammer, and adequate pull-out force can be applied (say around 40kN) then rotary percussive duplex may be regarded realistically as a viable and robust production method for holes to 60m depth. Clearly, however, for the deeper drilling associated with water wells or mineral prospecting it may not be the most cost effective option.

Type 4: Rotary percussive eccentric duplex

Restricted in terms of torque availability and faced with the increasaing demand for a system to penetrate the difficult Scandinavian glacial deposits reliably, Atlas Copco and Sandvik jointly developed the very successful ODEX system in 1972. This percussive duplex variant features a pilot bit with eccentric reamer, which cuts a hole of diameter slightly larger than the casing. The manufacturer states that its performance is not impaired by gross changes in the ground from loose soil to fresh igneous rocks; the method cuts straight through obstructions or shoulders them aside. Early experience in Britain (Patey, 1977)[4] also confirmed its ability to deal with artificial obstructions such as slag and other foundry spoil, typical of fill deposits in old industrialised areas. Good results in loose scree type deposits, rip rap, and through old piled foundations have also been confirmed.

The principle of the operation is illustrated in ***Fig. 5.*** In (a), the single piece pilot bit (concentric) is shown drilling beneath the casing; rotation has been applied to the rod string, swinging out the reaming device (eccentric) which is enlarging the hole so facilitating the advancement of the casing (percussed only). The reamer is held in the correct position by stop lugs during drilling. Cuttings are transported upwards past the guide device, inside the casing to exit via ports at the driving cap. Flush is usually water, although air can be used, and foam is common for depths over 30m. When drilling is complete ***Fig. 5 (b)*** the rods are counter-rotated, so closing the reamer and permitting the withdrawal of the rod and bit assembly. Drilling on into rock must then be done with a suitable rock bit ***Fig. 5 (c).*** ODEX is available with



A When drilling, the reamer of the ODEX bit swings out and drills a hole larger than the external diameter of the casing tube.

B When the required depth has been reached, the drill is reversed and the reamer swings in to its minimum diameter, allowing the bit to be lifted up through the casing, which is left in the hole.

C Drilling can continue with an ordinary DTH drill bit.

Fig. 5. Operating principle of ODEX (Atlas Copco).

both top hammer and down-the-hole options and selection reflects ground conditions, hole diameter, hole purpose, and the type of rig and head available. In the former case, ***Fig. 6 (a),*** part pf the percussive energy is transferred from the top hammer, via a shank adaptor, to a driving cap above the casing. For down-the-hole drilling, ***Fig. 6 (b),*** the percussive energy is transferred to the casing from the hammer by a special bit tube with a driving (or impact) shoe. The casing is therefore pulled down, again without rotation, from its lower end. In both cases, however, the steel must be strong enough to resist the percussive energy of the hammer either in compression (top hammer), or in tension (down-the-hole). Also, where it is to be extracted, the threaded casing must also have sufficient tensile strength, particularly in the threaded zones, and this parameter often dictates the practical depth to be drilled under any given conditions. Indeed, where ODEX 76 has been employed as a producton drilling tool under adverse conditions, the typically thin-walled rotary casing of the standard system has had to be altered by specialist contractors, within, of course, the limits imposed by the geometry of the other elements of the system.

Regarding the anticipated longevities of the key components of the ODEX and OD systems (for comparison), Atlas Copco has published the indicative guidelines reproduced in ***Table 3.*** It should be noted, however, that the relatively recent developments of high torque rotary and percussive drill heads have breathed new life back into conventional and simpler concentric duplex systems, as described above. Therefore the use of top drive eccentric duplex is becoming rarer. On the other hand, the demand remains strong especially in the water well industry for the drilling of large diameter holes in which the casing may be left in permanently. In such cases the down-the-hole variants still have much to offer especially when the driller has available only a standard medium sized drill rig with rotary head, and has experience in down-the-hole drilling.

Most recently Halco has developed its own eccentric duplex system called Sim Cas ***Fig. 7.*** As the reaming device is in only two pieces, the operation is claimed to be simpler and more robust than the three piece ODEX equivalent. A similar system is also offered by Hutte and by Weaver & Hurt (Bulroc overburden drilling system).

System Designation: o.d. (mm)	i.d. (mm)	Recommended tube lengths (must be portable by 2 men)
42.4	15	3.0m
51.0	18	3.0m
63.5	35	3.0m
76.1	50	3.0m
88:9	64	2.5m
101.6	72	2.0m
108.0	82	2.0m
114.3	88	2.0m
133.0	108	2.0m
177.8	150	1.5m

Table 1. Standard drive drilling sizes (Hutte).

ODEX System	
Pilot Bit	200- 600 drilled metres
Reamer	100- 300 drilled metres
Guide	400-1200 drilled metres

The various items are normally consumed in the following ratios: 1 guide; 2 pilot bits; 4 reamers.

OD System	
Extension Tube	1000-1500 drilled metres
Tube Coupling	800-1000 drilled metres
Ring Bit	150- 400 drilled metres
Adaptor Sleeve	1000-1200 drilled metres
Cross-Bit	300- 500 drilled metres

ODEX and OD Systems	
Shank adaptor, flushing head, driving cap	800-1000 drilled metres
Extension Rods	1000-1500 drilled metres
Coupling Sleeves	800-1000 drilled metres

Table 3. Indicative guidelines on life of Atlas Copco OD and ODEX components (Atlas Copco).

Sizes	NW Casing	HW Casing
Pilot Hole or Bit Diameter	73.0 mm	95.2 mm
Underreamed Hole Dia (Max)	92.0 mm	117.4 mm
Pin Connection	"NW" Rod	"HW" Rod
Pilot Bit Connection Box	"NW" Rod	$2^3/_8$ API
Feed Pressure to Operate	29.1kg/sq cm	65.8kg/sq cm
Optional Feed Pressure	14.0kg/sq cm	32.4kg/sq cm

Assembly	Size NW		Size HW	
Description	*Part No*	*Weight*	*Part No*	*Weight*
Underreamer (less Pilot Bit)	21145	12.2kg	21144	18.5kg
Optional Underreamed Hole Dia's	To 111.1 mm		To 152.4 mm	

Table 4. Specifications for casing underreaming system (Acker Drill).

Casing			
o.d (mm)	min i.d. (mm)	Crown o.d. (mm)	Bit dia. (mm)
88.9	64	92	60
101.6	72	104	67
108.0 *	82	112	77
114.3	88	116	83
133.0 *	108	135	103
177.8 *	150	182	146

Table 2. Standard percussive duplex sizes (Hutte) (*denotes common sizes for double head drilling section).

Hole dia. (mm)	Stem o.d. (mm)	Stem i.d. (mm)
140	76.1	50
155	88.9	64
170	101.6	72
190	108.0	82
230	114.3	88

Table 6. Hollow stem augers (Hutte).

In summary, a major attraction of ODEX type systems is that the effective efficient depth of penetration is not primarily dependent on driving torque, since the presenter of the greatest steel/ground contact area, ie the casing, is not rotated. However, the system remains relatively sophisticated, and its success is very sensitive not only to operator skill and expertise, but to the quality of the casing and its joints, and the efficiency of the flush.

Type 5. Rotary or driven duplex underreaming

Several such systems have been conceived and employed with varying degrees of technical and commercial success in recent years. One of the more successful – the casing underreamer, of

Table 5. Specification for double head drill, with either rotary or rotary percussive option for inner drill string (Krupp).

OPERATING METHOD	OUTER CASING INNER ROD	OPTION A Rotated * Rotated *	OPTION B Rotated * Percussed/Rotated *
Service weight including base plate	kg	630	700
Oil flow rate (front/rear rotary mechanism	max. l/min	160/170	160
Oil flow rate (percussive mech. for inner string)	max. l/min	-	-/85
Operating pressure (front/ rear rotary/percussion mech.)	max. bar	210/260/-	210/170/170
Torque (front/rear rotary mechanism)	max. Nm	8000/4000	8000/4000
Number of revolutions* (front/rear rotary mechanism)	max. rpm	110/145	110/110
Number of blows	max. min^{-1}	-	-/1800
Connection thread outer/inner drill strings		to be specified	to be specified
Hole diameter	mm	100-300	100-300
Flushing medium		air/water	air/water

* Clockwise or counterclockwise, but inner and outer drill strings always counter rotating.

Type*	Rock drill	Recommended casing dimensions metric standard (mm)	American standard (in)	Drill tube diam. mm	(in.)	Reamed diam. mm	(in.)
For top hammers							
ODEX 76 W/T	BBE 57 COP 1238	W: max. O.D. 89 min. I.D. 78 min. wall thickness 4.5 mm T: 88.9 × 77.8 R.H. thread	$3\frac{1}{2}$ $3\frac{1}{16}$ $3\frac{1}{2} \times 3\frac{1}{16}$	R 38	($1\frac{1}{2}$)	96	($3\frac{25}{32}$)
ODEX 127 W/T	BBE 57 COP 1238	W: max. O.D. 142 min. I.D. 128 min. wall thickness 5 mm T: 140 × 128 R.H. thread	$5\frac{10}{16}$ $5\frac{1}{16}$ $5\frac{1}{2} \times 5\frac{1}{32}$	R 38	($1\frac{1}{2}$)	162	($6\frac{3}{8}$)
For DTH hammers							
ODEX 90 W/T	COP 32 A 30–15	W: max. O.D. 115 min. I.D. 102 min. wall thickness 5 mm T: 114.3 × 101.6 L.H. thread	$4\frac{1}{2}$ 4 $4\frac{1}{2} \times 4$	76	(3)	123	($4\frac{13}{16}$)
ODEX 115 W/T	COP 42 DHD 24 DHD 340 A A 34–15	W: max. O.D. 142 min. I.D. 128 min. wall thickness 5 mm T: 140 × 128 L.H. thread	$5\frac{10}{16}$ $5\frac{1}{16}$ $5\frac{1}{2} \times 5\frac{1}{16}$	76 or 89	(3) ($3\frac{1}{2}$)	152	(6)
ODEX 140 W	DHD 15 DHD 350 A 43–15	max. O.D. 171 min. I.D. 157 min. wall thickness 5 mm	$6\frac{5}{8}$ $6\frac{1}{8}$	89 or 114	($3\frac{1}{2}$) ($4\frac{1}{2}$)	187	($7\frac{3}{8}$)
ODEX 165 W	COP 62 DHD 16 DHD 360 A 53–15	max. O.D. 196 min. I.D. 183 min. wall thickness 5.5 mm	$7\frac{3}{4}$ $7\frac{1}{4}$	114	($4\frac{1}{2}$)	212	($8\frac{11}{32}$)
ODEX 215 W	DHD 380 A 63–15	max. O.D. 257 min. I.D. 241 min. wall thickness 6 mm	10 $9\frac{1}{2}$	114 or 140	($4\frac{1}{2}$) ($5\frac{1}{2}$)	278	($10\frac{15}{16}$)

*T = threaded casing tubes W = welded casing tubes

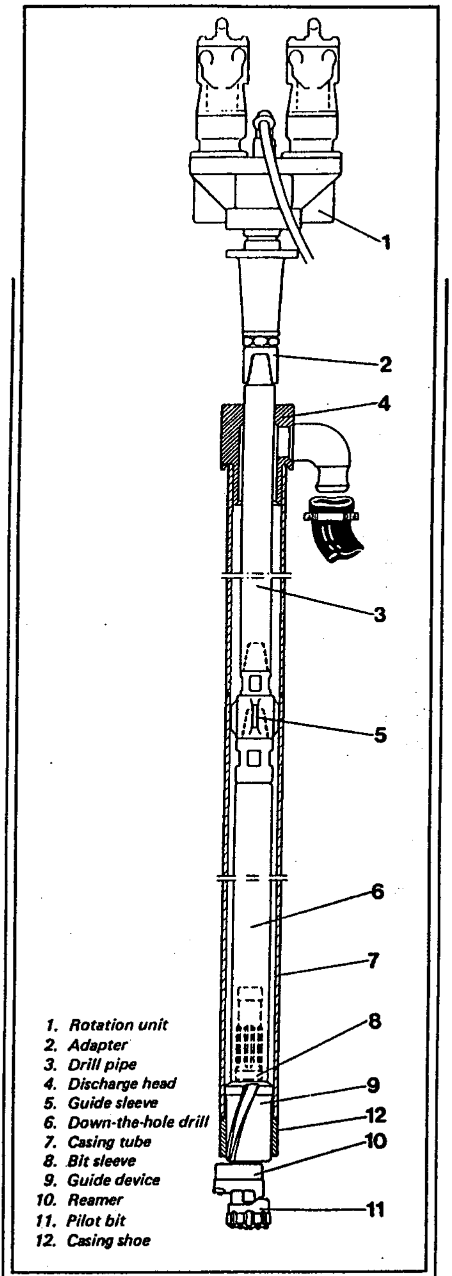


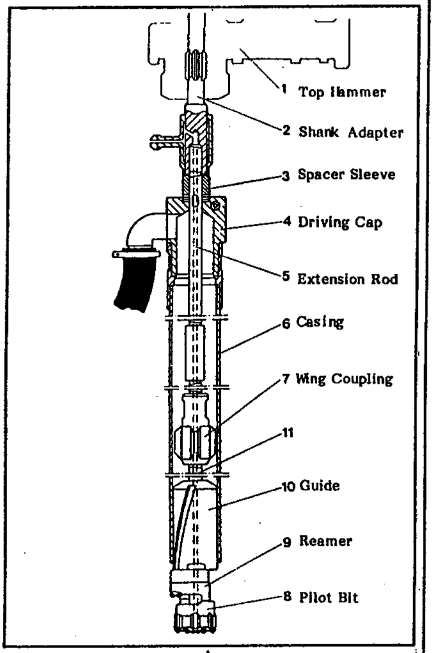
Fig. 6. Comparison of (a) top hammer (left), and (b) down-the-hole ODEX system (right), and data on system sizes (Atlas Copco).

Acker Drill – is taken as a typical example. In principle, an oversized hole is cut by a bit, and the following casing is either driven or rotated. As shown in ***Fig. 8*** the underreaming is not conducted by the eccentric bit system of ODEX, but by activating outwards cutting blades above the pilot bit. Thus if the overburden is soft, resistance is low, the blades remain retracted and the casing advances in the simple duplex manner. However, when hard layers are encountered the blades open and cut the clearance necessary for the advancement of the casing. At final depth, thrust is removed from the drill string, the underreamer blades fall in, and the string can be extracted. The system permits either subsequent or concurrent advancement of the casing, relative to the rods.

Two sizes (***Table 4***) are available, designed for heavy duty applications and the installation of NW or HW flush jointed drill casing. Diamond faced cutter blades are available for replacing the twin carbide insert blades when drilling extremely hard material. Diamond pilot bits are also commonly used to replace roller, rock or drag type pilot bits commonly used for drilling average overburden materials.

The underreamer is operated at speeds normally used for tricone or drag bits. The thrust required for the 117.4mm underreamer is about 4000N and for the 92.0mm model is about 2000N. The water requirements are similar to those for normal rotary drilling. The system is capable of penetrating boulders, rock debris, timber and steel.

Type 6: Double head duplex drilling



This rotary duplex method is claimed to be especially quiet, and to ensure minimal ground disturbance, and consistent cost effective penetration to over 80m in even the most difficult ground conditions. It is distinguished from conventional rotary duplex by the fact that the rods, and casings, are simultaneously rotated but in opposite senses. The inner drill rods, with right hand rotation carry either a down-the-hole hammer (air or water activated) in hard conditions, or some form of rotary bit in soft ground. Typical rotary energy requirements are 2500N torque at 40rpm to 60rpm.

The casing, with left hand rotation, terminates in a substantial crown which cuts a slightly oversized hole, thus reducing casing/ground resistance. Rotational speeds are lower than in conventional duplex drilling (15rpm to 30rpm) the advantage of the torque availability (to 8000Nm).

However, the benefits of the counter rotation are that the combined action of the casing and rod cutting is enhanced, and the prospect of flush debris blockages in the casing/rod annulus is minimised due to its dynamic boundaries. Water flush is typically 40 litres/minute to 60 litres/minute at $1{\cdot}5N/mm^2$. In addition, the counter rotation helps to offset natural tendencies for holes to deviate and, in conjunction with the stiff, thick walled casing used ***Table 2***, holes of exceptional straightness (say within 1 in 100) can be routinely formed.

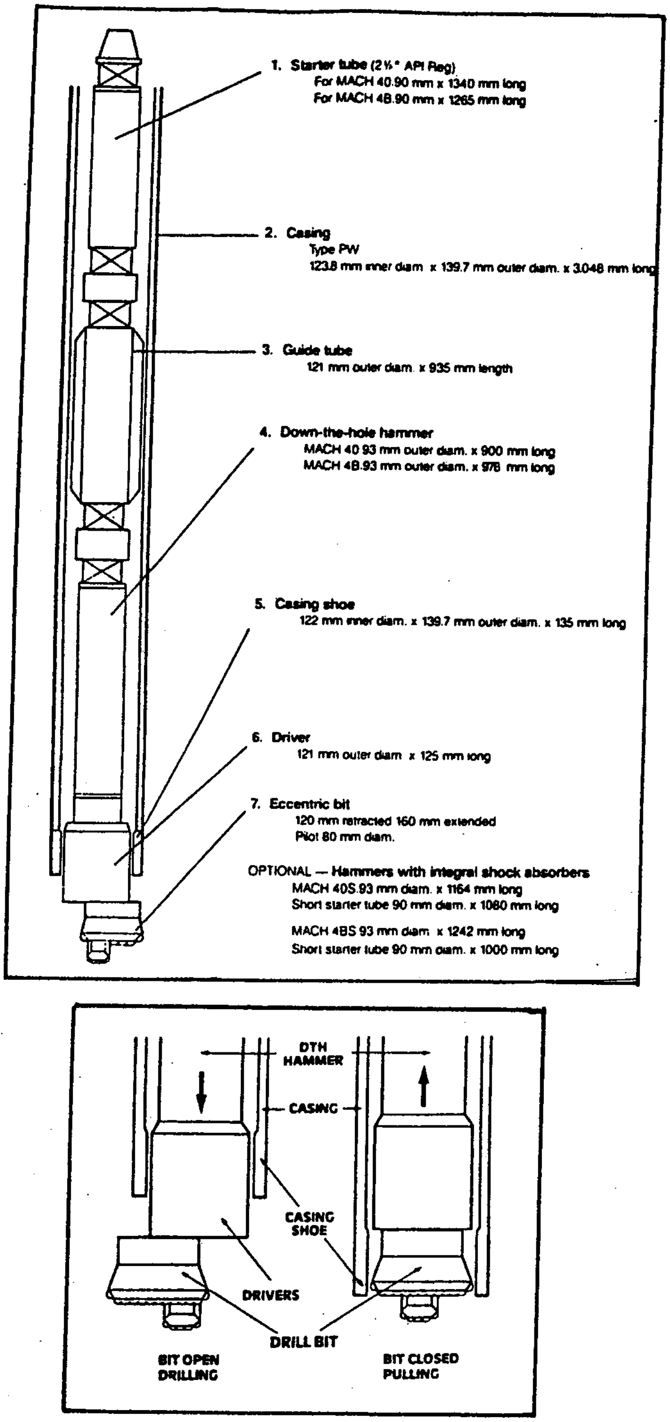
This system is driven by special double heads with both Klemm and Krupp *Table 5* being prime examples. These heads can be mounted happily on relatively small and mobile track rigs of sufficient hydraulic output *Pic 1.* A particular feature is the facility to move coaxially the upper rotator (turning the rods) about 300mm relative to the casing rotator. This affords the driller extra scope in selecting the relative advancement of rod bit and casing shoe in response to ground conditions. The lower rotator can also work in high gear (say 30rpm), low torque range) or low gear (say 15rpm, twice the torque previously available). In addition the upper rotator can be replaced with a rotary percussive head and the down-the-hole hammer omitted, as noted in Table 5. As with other percussive duplex variants, a retrievable underreamer can be used to precut the soil to a diameter just larger than the casing shoe.

Double head duplex is common on European sites with particularly difficult ground but restricted access. It was also used under similar conditions recently at the Hines Auditorium in Boston (Bruce, 1988, 1989)[6] while its use is growing – with the increasing popularity of diesel hydraulic track rigs – on both coasts of the United States. In Canada, a project has recently been completed underground in North Ontario where the 133mm casing has been drilled, straight, to 60m depth through loose mine backfill containing large boulders of up to 500N/mm^2 compressive strength, in headroom of 4m, at outputs equivalent to over 50m/shift.

Type 7: Hollow stem auger

Auger drilling is a long established method of drilling cohesive soils with the minimum of hard inclusions, and features the rotation of what is basically a screw into the ground. The continuous flight auger may be in one part (as used in bored piling works) or in connecting sections. The basic method uses a solid stem (or core) to excavate the hole, which, when the auger is withdrawn, will remain only due to the natural competence of the ground and the absence of groundwater pressures. As noted earlier, such open hole methods are not the subject of this discussion.

Much recent development has focused on hollow stem augers, which permit water and/or grout to be pumped to the bottom of the hole, allow placing of anchor bars or



	Sim-Cas 3	Sim-Cas 4	Sim-Cas 5	Sim-Cas 6
Casing O.D.	114mm	140mm	167mm	194mm
Casing I.D.	101.6mm	125.5mm	149.2mm	178mm
Maximum drill-through dia.	98mm	120mm	146mm	172mm
Halco down-the-hole hammer types	Mach 30B	Mach 4B/40B	Mach 5V/50V	Mach 6V/60V

Fig. 7. Details of Sim Cas system (Halco).

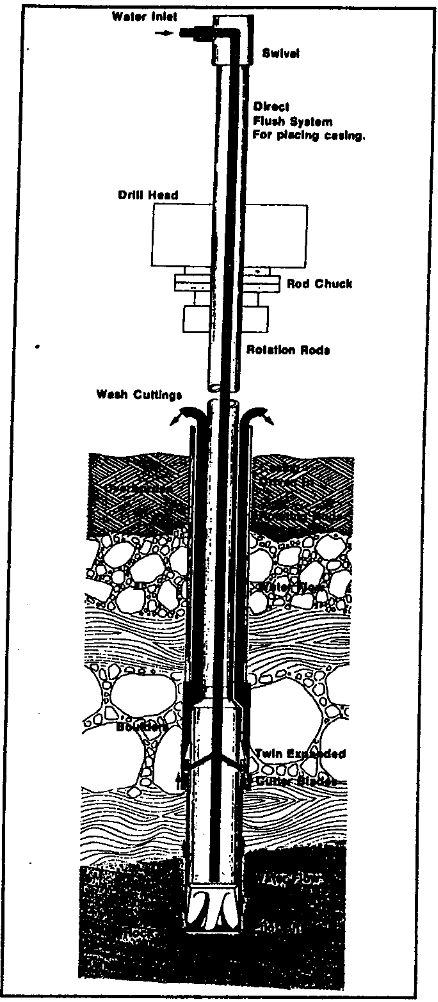


Fig. 8. Operating principle of casing underreamer system (Acker).

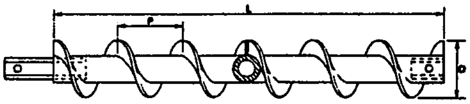
grout tubes, or enable drilling on into underlying strata for soil sampling or rock socketing. Generally, however, as emphasised by the range of standard sizes ***Fig. 9*** and the capacities of typical rotary head models, the whole concept of augering is still related to the larger diameter fields of cast in situ piles, prebored pile holes and sand drains.

To reduce power requirements and allow adequate clearance for the flights, auger bits (or cutting heads) cut a hole 10% to 12% larger than the auger diameter. The pitch of the flights is 60% to 80% of the outside diameter of the auger so as to reduce the tendency of the cuttings to roll back down the hole.

Expanding auger bits are available for use with continuous flight augers for boring inside casing. The auger bit has an outside diameter equal to the continuous flight auger, but expanding wings increase the cutting diameter to the outside diameter of the casing. During drilling the auger is positioned so that the wings are just below the lower edge of the casing which may then be advanced as cutting proceeds. Reversing the rotation causes the wings to fold back, enabling the auger and bit to be withdrawn without disturbing the casing.

	Continuous Flight Diameter (D)					Hole dia (Bit cutting dia)
	Auger Series					
	'125' mm (in)	'200' mm (in)	'250' mm (in)	'350' mm (in)	'400' mm (in)	mm (in)
	115 (4½)	– –	– –	– –	– –	130 (5)
	140 (5½)	140 (5½)	– –	– –	– –	155 (6)
	160 (6¼)	160 (6¼)	– –	– –	– –	180 (7)
	– –	205 (8)	205 (8)	– –	– –	230 (9)
	– –	255 (10)	255 (10)	– –	– –	280 (11)
	– –	305 (12)	305 (12)	305 (12)	305 (12)	340 (13½)
	– –	– –	355 (14)	355 (14)	355 (14)	395 (15½)
	– –	– –	405 (16)	405 (16)	405 (16)	460 (18)
	– –	– –	– –	460 (18)	460 (18)	510 (20)
	– –	– –	– –	510 (20)	510 (20)	570 (22½)
	– –	– –	– –	560 (22)	560 (22)	620 (24½)
	– –	– –	– –	610 (24)	610 (24)	690 (27)
	– –	– –	– –	– –	660 (26)	740 (29)
	– –	– –	– –	– –	710 (28)	800 (31½)
	– –	– –	– –	– –	760 (30)	850 (33½)
Hexagon Coupling Nominal size across flats	1⅝"	1⅝" or 1⅞"	1⅞" or 2"	2⅝"	2⅝"	

Note. Auger and hole diameters have been rounded to nearest ⅛".



Standard lengths (L) 1.0, 1.5, and 3 m (3.3, 5 and 10 ft); other lengths and auger diameters readily available

Hollow Stem Augers

Min i/d centre tube		o/d H.S. Auger Flight		o/d Auger Bit	
mm	(in)	mm	(in)	mm	(in)
60	(2⅜)	145	(5¾)	160	(6¼)
100	(4)	215	(8½)	240	(9½)
130	(5)	255	(10)	280	(11)
150	(6)	305	(12)	340	(13½)

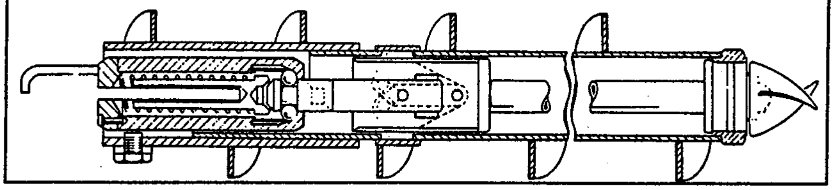


Fig. 9. Standard sizes of continuous flight, and hollow stem augers (Hands England).

For applications within our field of interest, **Table 6** shows typical sizes for hollow stem auger systems.

Final remarks

This classification has been proposed in an attempt to offer a dispassionate overview of overburden drilling methods – as distinct from commercially proposed systems. It is believed to encompass current practice in Western Europe and North America, while the research for the paper turned up no additional or alternate technologies *published* in other parts of the world. The author therefore hopes that the classification will prove useful for the non specialist, and a target of constructive criticism and embellishment by colleagues more knowledgeable and intimate with the business.

Acknowledgements

This concept of classification was developed out of presentations at Drillex, 1984, Toronto, and the annual grouting course at St. Louis, Missouri. It was nurtured by colleagues at Nicholson Construction Company, and friends in Britain. It was conceived out of necessity.

Technical and commercial brochures from

Acker Drill Co.	USA
Atlas Copco	Sweden
Bohler	Austria
Casagrande	Italy
Euro-Drill	UK
Halco	UK
Hands-England	UK
Hongdrill/FEDCO	Hong Kong
Hutte	West Germany
Klemm	West Germany
Krupp	West Germany
Montabert	France
Nicholson	USA
Rodio	Italy
Weaver and Hurt	UK
Wirth	West Germany

References

1. McGregor K (1967. The drilling of rock, 1st Ed. CR Books Ltd., London. 306 pp.

2. Bruce DA (1989). 'Contemporary practice in geotechnical drilling and grouting.' Keynote lecture, First Intl. Canadian grouting conference, Toronto, 18 April, 28 pp.

3. Bruce DA and Yeung CK (1983). 'Minipiling at Hong Kong Country Club.' *Hong Kong Contractor*, November, pp. 13-18.

4. Patey DW (1977). 'Grouting old mine workings at Merthyr Tydfill.' *Ground Engineering*, November, 4 pp.

5. Bruce DA (1988, 1989). 'Aspects of minipiling practice in the United States.' *Ground Engineering*, 21(8), pp. 20-33 and 22(1) pp. 35-39.