

Ground stabilisation is an important factor at any construction site. Carly Lovejoy looks at the products available from several key manufacturers and their application

Atlas Copco

Atlas Copco offers complete equipment solutions to increase customer productivity in many types of ground-stabilising applications, including: micropiling; foundation drilling; underpinning; anchoring and tunnelling.

Mikael Wester, communications manager at Atlas Copco geotechnical drilling and exploration, comments: "As global redevelopment of urban areas continues, contractors and drillers face new challenges. The demand for application-tailored solutions to meet the challenges is increasing; the Atlas Copco systems are easily customised to the specific application at hand."

Atlas Copco produces three ranges of rock bolts for stabilisation applications – MAI Self Drilling anchors, Swellex rock bolts and Roofex rock bolts.

MAI SELF-DRILLING ANCHOR

The MAI SDA is a bolting solution for unstable ground conditions such as sand, gravel, silt and clays, and fractured rock formations. Using MAI as the drill rod during drilling and utilising a sacrificial bit, then grouting the anchor in place, makes a safe and productive solution. MAI can also be installed using simultaneous drilling and grouting to boost productivity even further.

When used for slope stabilisation, MAI anchors are suitable for most rock or soil formations that are normally benched prior to the installation of 'soil nails'. The unconsolidated or weathered ground conditions favour the use of self-drilling hollow core anchors. The MAI SDA R32-R38-R51 models are recommended.



For micropiling applications, MAI bolts can be injected with grout and used to replace small-diameter drilled piles. MAI micropiles can be installed in sites with limited headroom and restricted access with light drilling equipment. They require minimal site preparation and can be installed in most ground conditions, including rock, and are suitable for tension and compression loads.

MAI anchors can also be used to reinforce the circumference of tunnels and for advanced roof support in tunnel excavation in overburden and soft, fractured rock, as well as in unconsolidated ground.

Mr Wester adds: "European Technical Approval has recently been granted to the Atlas Copco MAI SDA range, making us the first supplier within the EU to have a range of CE-Approved self-drilling anchors."

SWELLEX ROCK BOLTS

Swellex rock bolts are built from a welded tube, folded on itself and sealed at one extremity. The operator drills a hole in the rock, inserts the bolt and then inflates it to a predetermined pressure using a dedicated inflation system.

Swellex bolts are available in two versions: the Swellex Premium line, which is a stiff rock bolt for moderate stress conditions; and the Swellex Manganese line, which is highly deformable for areas that experience large rock movements.

The Premium range are connectable and consist of three components: a blind segment, which guides the bolt into the hole (a standard Swellex bolt with a threaded connector); a middle segment with a connector at both ends (the length and number of these segments dictates the final full length); and an inflatable segment, with a connector at one end and an inflation bushing at the other where a Swellex chuck can be connected. The inflatable segment can be connected to the blind segment and a long rock bolt is created by connecting several segments together. The patented connector connects and seals the bolts while facilitating pressurised water flow throughout the segments.

Atlas Copco upgraded the Swellex line in 2009, making them faster, easier and safer to use. The firm makes a line of corrosion-resistant bolts – Plasticcoated Swellex – for highly corrosive environments. For special applications such as hangers and deep reinforcement, Atlas Copco has developed specialised versions of Swellex bolts. With the Swellex Hanger Pm24H, operators can install a service hanger in conjunction with the primary support method, while the Connectable Pm24C is a modern replacement for medium-length cable bolts, with high productivity, quality control and safety components.

A typical application in tunnelling is to use Swellex as pattern bolts to support, reinforce or consolidate the periphery of an excavation. Density

Casagrande rig with rod-handling carousel





Boart Longyear's DB95 drill rig, specifically designed for tieback, soil nail drilling and micropiling applications

of bolting depends on the size of the excavation and the self-supporting qualities of the rock mass.

ROOFEX ROCK BOLT

Atlas Copco produces the Roofex range of supporting and monitoring rock bolts, designed to dissipate and control large amounts of energy. The bolt is made from a high-quality steel bar, encased in a smooth, plastic sheath, which is fixed inside the borehole with cement or resin grout. A patented energy absorber acts as a sliding element over the steel bar, allowing the bolt to extend outwards under load while ensuring the load capacity remains constant. In this way, the bolt can absorb sudden displacements such as rock burst or seismic events, making it particularly suitable for use in poor quality rock or areas that experience high levels of deformation.

The Roofex concept offers two types of monitor bolts (static and dynamic), which monitor rock mass movements directly and provide predictability to the rock-reinforcement system. Usually, once bolts are installed, deformation can only be determined using geodetical survey methods. This is not always an indication that the bolts work properly or that they are well bonded to the rock mass, but by using Roofex monitor bolts the effective movement of the



SonicSampDrill's MidSonic rig anchor-drilling in Speyer Rhineland, Germany



Soilmec rig in action

inner, steel bar through the energy absorber can be clearly monitored.

Roofex can be used as a primary bolting support or as a secondary support system. A typical application of the latter is where a tunnel has been reinforced with rock bolts, such as Swellex, and a wire mesh is then applied and sealed with shotcrete. Roofex can then be installed as a secondary precaution.

SUPPORTING PRODUCTS

Atlas Copco offers three casing advancement systems for ground stabilisation: Symmetrix; Elemex and Odex. With these systems a casing pipe is installed while the hole is drilled. The casing stops the hole collapsing. The systems offer high productivity for foundation works or well drilling in urban areas, even if the ground contains boulders, concrete blocks or old foundations that are hard to penetrate.

When used for micropiling, cased piles can accommodate large load concentrations, also from lateral forces. The drilling principle is based on a pilot bit and a reamer bit, which, together, drill a hole larger than the external diameter of the steel casing. This enables the casing pipe to follow the drill bits down the hole. Odex has an eccentric reamer bit while Symmetrix and Elemex feature a concentric reamer called a ring bit.

Atlas Copco also produces Mustang geotechnical drill rigs, Unigrout grouting platforms and compressors. The range is based on four families – the Mustang 4, 5, 9 and 13; each one designed for a range of uses and environments. Thanks to its modular design, the Mustang rig can be used in virtually all geotechnical drilling operations.

Unigrout grouting systems are designed to seal, strengthen, or consolidate formations and structures by preparing and injecting grout. The platforms are operated by fully hydraulic power units, with electric or diesel drive. For urban applications, the range includes a set of very compact, high-performance grouting units, which are safe to operate, highly reliable, and easy to clean and service. In micropiling operations the Logac electronic grout recorder can be added to monitor grouting parameters.

Casagrande

Casagrande Group has two ranges of drilling rigs available for ground stabilisation; one sold under the Casagrande brand and the other under the Hutte brand, a company acquired some years ago.

Michael Finch, managing director of Casagrande,

explains: "Generally speaking, all Casagrande and Hutte rigs can be used for tieback, anchor and soil-nailing applications, but there are models in each range that have been specifically designed for this purpose. In the Casagrande range, the M6A-1 and M9-1 drilling rigs are targeted at this particular market as they have sophisticated mast-articulation arrangements, which allow easy across-tracks drilling, with the rig and mast in various different positions. In the Hutte range, the HBR504, 605 and 609 models offer a similar across-tracks and angle hole-drilling capability."

All of these rigs are offered with a wide range of rotary and rotary percussive heads, including double-head systems, which are suitable for applications where both drill rods and casings have to be used. The rigs are available with a variety of mechanised rod and casing handling systems, which are becoming increasingly popular with the greater focus on drill rig safety in some markets.

A degree of customisation is available on all Casagrande and Hutte rigs. There is a large range of accessories available including different mast types, clamp types, flushing pumps and handling winches. All rigs are designed on a modular basis for easy transport and the factory production line is organised to accommodate different build specifications for every rig. Casagrande can also offer a degree of bespoke customisation for specific applications, although this may result in longer delivery times.

Mr Finch comments: "Casagrande Group drill rigs and machinery are sold all over the world in virtually every market. Our established markets are in Europe and the US, but, increasingly, South America and Asia are becoming important to the company. In the UK, Casagrande and Hutte rigs have been sold to most major drilling contractors, including the Keller Group, Cementation Foundations and Bachy Soletanche.

Soilmec

Soilmec's range of products for the installation of anchors and soil nailing consists of seven multi-purpose rigs from 3-23t in weight: the SM-3; SM-5; PSM-8 (including 8B); SM-14; SM-18; PSM-20 and SM-21. All are suitable for executing micropiles and jetting works.

The SM-3 is a new micro-drilling rig, specially designed for customers who need high-range performance, even in narrow and constrained spaces. The main unit comes with a separated,

GROUND STABILISATION

2.5t-weight power pack (75kW electric, 85kW diesel, or 115kW diesel) and includes: expandable crawlers (780mm-1130mm); outriggers; telescopic zoom; mast tilting capabilities of $\pm 15^\circ$, and a slew ring working area of $\pm 180^\circ$. It can be equipped with a range of rotary heads up to 2,000Nm to meet different drilling requirements.

The SM-3's modular mast offers the chance to have three different strokes for 1m, 1.5m and 2m length rods and is complete with a hydraulic-motor-crowd-system (a cylinder-crowd-system is also available). The rig can also be fitted with a special mast extension, allowing it to use jet-grouting rods up to 90mm in diameter.

The PSM-5 rig features an optimised tilting system and can be used with a range of rotary drill heads to suit: anchoring and tie-backs; micropiles; jet grouting; coring; and waterwell drilling applications. The new kinematic system, comprising two slew rings, allows a large range of slewing and mast positions to be used. The first slew ring fitted on the base of the machine enables drilling parallel to the tracks up to $\pm 90^\circ$; the second kinematic device allows an overall mast rotation equal to $\pm 180^\circ$. In order to increase the versatility of the drilling unit, the PSM5 is also equipped with a telescopic boom and a sliding mast.

The SM-18 was developed using a fusion of Trevi Group job-site experience and Soilmec technological research. It offers greater drilling depths thanks to a higher hoist force, and features a load-sensing control system and over 500 litres/min oil flow provided by twin piston pumps. For safety, the rigs feature an emergency stop for drilling functions, a safety light for active drilling mode, and a telescopic counterweight and stabilisers. Soilmec rigs can also be customised to meet clients' needs.

The company's main markets are Italy, Europe, the US and United Arab Emirates. Over the past two years, Soilmec has worked to consolidate its presence in established micropile markets such as Europe, and is looking to improve its presence in emerging markets such as Brazil and China.

In Italy, a multifunctional PSM-20, recently acquired by Geocostruzioni, is currently operating in Bologna, where it is installing clay tie rods with 220mm-diameter augers at a depth of 30m. Along the Salerno-Reggio motorway section in Calabria, a SM-14 rig bought by Dott Angelo Sicilia is performing consolidation works and has reached a daily production of 260m. Meanwhile, a PSM-20 rig, purchased from Soilmec by the Gruppo Marchese, is also carrying out anchoring works along the new 'quadrilateral' motorway link, which will connect Perugia and the Adriatic Coast.

A spokesperson for the company says: "Soilmec has received a number of orders in the first few months of 2010, especially following the introduction of two new models into its range – the SM-3 and SM-5. We are feeling confident going in to 2011. In Italy, Impregilo has just won a contract for nailing works to be performed in tunnels, for which it has decided to use a PSM-8 rig complete with a kinematic device and a 360° slew gear."

Boart Longyear

The Boart Longyear DB95 drill rig was specifically designed for tieback, soil nail drilling and micropile applications, featuring enhanced mast articulation and power. Its patented MasterLink mast articulation design enables fast on-hole set-up, and maintains



Atlas Copco Swellex rock bolts

precise and consistent drilling angles as the mast articulates.

The drill system is mounted on an independent pendulum crawler which is capable of handling extreme terrain without the need for stabilisation jacks. The DB95 is highly portable and compact. It weighs 10t and features a 105kW power pack. The hydraulic power pack has load-sensing technology which provides power on demand, thus saving fuel, maximising energy efficiency and extending engine life. Oversized hydraulic hoses ensure efficient power transmission and reduce power loss.

In addition, the mast of the DB95 has a maximum torque rating of 15,000Nm and a pullback capacity of 7t, providing contractors with the strength to manage a wide range of foundation applications.

Zach Keller of Two Rivers Marketing comments:



Casagrande M9-1 rig

"The DB95 is particularly popular for road construction projects. Slope stabilisation is typically done using retaining walls or other boundaries anchored deep in the slope, micropiles or a soil-nailing technique. This requires a drill capable of good performance in extreme grades and the DB95 is perfect for this."

The DB95 is available with a range of single rotary-head or single hydraulic drifter configurations (with optional side-shift) to meet most common drilling requirements. It can also be fitted with a double rotary-head system on request. Radio remote-driving controls are standard features of the rig, designed to enhance site safety and driller productivity. The DB95 is also available in a geothermal format for geothermal drilling.

Tracto Technik

Tracto Technik's current Grundomat soil-displacement hammer P-generation of rigs replaces the previous Z-version. The new range was developed to meet customers' requests for easier reversing and higher efficiency. The Grundomat features an improved chisel-head system, with two-stroke percussive action for better accuracy and penetration.

The Grundomat is ideal for piling applications and was used by Mott MacDonald to improve stability on a section of London's Northern Line tube system, just south of Mill Hill East Station, which was experiencing ground movement on the embankment above the line.

Mott MacDonald approached tube maintenance firm Tubelines to drive 14 steel minipiles, each 114mm in diameter, into the embankment to allow them to carry out load tests. A 95mm Grundomat rig was chosen for the job. The piles had to be driven from 2-4m in depth; seven vertically and seven at a 45° angle. Each pile had 300mm of fill material at the base, allowing it to support the concrete beams that retain the embankment.

The project was completed successfully and the

piles were filled with concrete in readiness for tension-capacity tests, conducted by a specialist company. On average it took 17min to drive a 3-5m pile, including the welding time.

SonicSampDrill

For ground-stabilisation applications such as anchoring, pile driving and soil nail drilling, SonicSamp supplies Compact and MidSonic drill heads with remotely controlled power packs and footclamps. The equipment can be mounted on various rigs and carriers to suit customers' needs, and utilises the Rotosonic sonic-drilling technique to penetrate the ground.

Gerard Van Dijk of SonicSamp explains: "Driving is by push-rotation only, but the 150Hz of sonic vibration generated greatly speeds up the drilling process and multiplies with penetration depth."

Sonic vibration allows rapid penetration of soft to medium-type soils without rotation. Soil is displaced by vibrations, which radiate from the drill string. Washing-up of cuttings can be achieved by coupling a sonic-resistant swivel in the drill string, and if the vertical vibration is assisted with a rotation and the drill cone is replaced by a drill bit, it is possible to penetrate hard layers or rock.

The efficiency of soil liquefaction caused by the vibration has allowed SonicSamp to create a rig with high drilling power, but a small footprint. The sonic vibration combined with rotation creates a perfectly straight borehole with a tight fit, if necessary under an angle.

The company is now working to improve drill-bit pressure control, and triple footclamps have been introduced on the CRS-V model to allow it to use more than one casing or sampler size. The tractor or powerpack-powered CompactRotoSonic masts can now be mounted with a double foot clamp and breaker arm, giving them the same capability as the crawler-rig version.

Mr Van Dijk adds: "On the ergonomics side, we are successfully testing a feature to lift and handle casing for the CompactRotoSonic rigs. We are currently testing the installation of Dywidag ground anchors in combination with the smaller CompactRotoSonic rig. The sonic vibration should increase both installation speed, as well as penetration depth. Both are critical factors in large-scale anchoring projects."

SonicSamp's main markets for rigs used in ground-anchoring applications are the US and Europe. BAM Netherlands is currently using three MidSonic units with power packs and footclamps for anchoring Dywidag GEWI bolts, and a large anchoring project was undertaken recently by a client using a MidSonic drill head, mounted on an existing Klemm rig, in Rhineland Germany.

Cubex

The Cubex QXW drilling system, coupled with Wassara water-hammer technology provides the enhanced drilling power and accuracy necessary for ground-stabilisation projects. The QXW series of track drills contain a frame-mounted feed system that uses a Wassara DTH hammer, complete with a high-pressure water feed from the on-board water-pump system. These drills have a deck-mounted pipe rack, capable of holding 44 drill pipes 3m in length, which are added to the feed by the on-board pipe arm.

Hydraulically-driven by two high-torque motors,



Tracto Technik's Grundomat soil-displacement hammer

the top drive has a torque capacity of 4,050Nm at 207bar. The drills have a slide-over of 406mm and can drill 15° from each direction off-vertical.

Kerry Falk, marketing manager at Cubex, says: "We have two scheduled deliveries coming up for QXW rigs for use in ground stabilisation. One is for the Thornton quarry near Chicago, which will be delivered in November or early December to Hayward Baker, and the second is to Alabama Power at the Logan Martin dam, to be delivered in September."

"The Thornton quarry is the world's second-largest commercial quarry, and is going to be part of the Chicago Tunnel and Reservoir Plan (TARP). Our



SonicSampDrill CRS-V crawler rig with tilting head

equipment was used for a similar project at the McCook Reservoir in Illinois in 2005. These are two of three reservoirs designed to protect the city of Chicago from flooding. There are underground tunnels that connect the reservoirs to the sewer system of the city, and water flow is regulated into the tunnels during heavy rainfall or spring run-off to ensure there is no overflow.

"The Thornton quarry is somewhat different than our previous projects because of the angles that must be drilled. To reach some of the areas that need to be grouted for the water-retention wall, the drill must be capable of operating at 65° angles. The previous drills allowed for 15° off-vertical drilling. We redesigned the drill mast and changed how the pipe is moved from the tub into the mast. This has made the drill approximately 60cm longer. It will have a reinforced front end and mast foot to allow it to take the increased load at the high angles. The grout curtain is 2.8km long, with a double row of holes extending the entire perimeter of the Thornton Reservoir. This rig will be a QXW1210 with an angle-drilling package."

The second delivery is for the Logan Martin dam. Due to poor ground conditions, drilling and grouting at the dam has been ongoing for almost 20 years. Cubex first supplied a 6200D drill rig for this application in 1994, and it is still drilling. However, following recent success using Wassara water DTH technology at other dam-reclamation sites in the US, Alabama Power decided to use a QXW at the site to improve results, and speed up the grouting process.

The goal is to finish the grouting project within two to three years. The hole size requirements of Alabama Power required Cubex to design a new rig with high water capacity to use a 12cm Wassara hammer. This upgrade required a new mainframe to accommodate the larger engine and water pump, as well as larger diameter rods. This has created the QXW1710 drill, which will be shipped to site in late September.