Give STPs respect

Michael Rowlinson of slurry treatment specialist Pigott Shaft Drilling (PSD) outlines the technology involved in slurry treatment plants (STP) and argues that as much importance should be placed on STP selection as on the selection of the slurry

PSD recently demobilised equipment from contract KDB200 on the Kowloon Southern Link, having achieved more than 99% availability of the STP throughout the project

IN SLURRY shield tunnelling, the slurry is required to fulfil a number of prime functions, which include face support in loose ground and maintenance of face cuttings. Other duties include lubrication of moving parts, wear reduction, cooling and suspension of cuttings.

The selection of an STP will depend upon many factors, including the type of ground, the diameter and length of the bore, the excavation rate and the slurry flow rate.

The 21st century has seen significant increases in tunnel diameter excavated using slurry TBMs. It is not uncommon for slurry TBMs to excavate tunnels of over 10m diameter, while in Shanghai, two TBMs are each excavating 15.43m diameter tunnels.

The larger the diameter of the bore, the larger the quantity of solids to be removed from the face, therefore the higher the flowrate and slurry pipe diameter needed. A larger slurry pipe has a higher potential to carry larger cuttings which necessitates a good quality bentonite slurry, capable of effectively suspending and transporting the large cuttings.

Secondly, a large-diameter bore requires a larger area of face to be supported and, in granular soils, face support is of great importance. In order to keep fluid loss under control, while maintaining the pressure required to support the face, it is necessary to use a good quality bentonite, capable of building an effective filter cake.

The choice of bentonite is important in these circumstances, as is the choice of slurry treatment plant. For a contractor to achieve sustained production safely, it is essential that the slurry treatment plant is extremely reliable and able to keep the slurry parameters within acceptable limits for challenging ground conditions.

Ground conditions will frequently vary and the STP selected will often have to balance the ability to handle differing ground conditions such as clays, rocks, sands and gravels. In less permeable ground, it may be possible to excavate without bentonite, however it should not be forgotten that one of the purposes of the slurry is to lubricate and to reduce wear on components. Good-quality bentonite slurry can result in significant reductions in the wear on cutters, pipework, pumps and the STP itself when mining through hard rock.

Testing equipment is essential to monitor the condition of the slurry. The parameters of the active slurry will be set by the engineer and will differ depending upon ground conditions and circumstances, but it is of great importance that tests are carried out and trigger levels identified so that an engineer can make changes in response to changing slurry parameters.

A typical STP for a large-diameter slurry TBM will include bentonite preparation equipment and slurry storage tanks, primary screening equipment, pumps, hydrocyclones, dewatering screens, fine particle separation and flocculation plant. It is possible that conveyors may be included to transport solids to a muck pit and the importance of the solids-handling conveyor as part of the system should not be forgotten. If the conveyor breaks down, the STP may be unable to run or may be able to run only at reduced capacity, thereby adversely affecting production.

Bentonite preparation equipment will include mixing equipment, storage tanks, pipework and pumps, and the system must be designed to allow flexibility. It is important that the preparation system and storage is capable of providing the active slurry system with sufficient 'fresh' bentonite as may be required at any time, plus the ability to introduce additives or pH modifiers. This may be to improve the properties of the active slurry, to replace a volume of slurry that has been disposed of, or to provide an 'infusion' of slurry to the head.

In the past, when variable speed pumps were required, a mechanical variator was used, but the increased affordability of reliable frequency inverters has meant that these can be used to drive the motor. This then leads on to possibilities for the use of automated control systems which use electronic signals to control the speed of pumps, for instance, in relation to the level of fluid in a tank.

Some suppliers have increased automation with a central control cabin, but while PSD progresses with automating certain aspects, the control of PSD's plants is not centralised, based

Bespoke programmable logic control for centrifuge

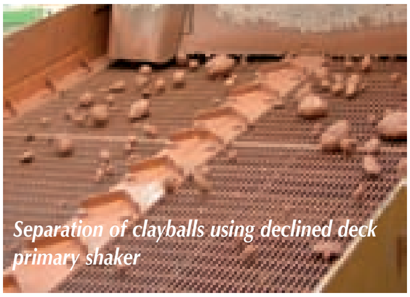
on the policy that an STP operator benefits from being in regular touch with all aspects of the plant including sights and sounds, rather than relying on a bank of warning lights.

The primary screen, which should ideally cope with different soil types, will be the first part of the STP to encounter the cuttings-contaminated slurry as it is pumped from the head of the TBM. The size, type, angle, motion and open area of the screen, as well as the material it is made from, will have a significant bearing on wear resistance and its ability to handle different soil types at a given flow rate and excavation rate.

From the primary screen(s) the slurry will be pumped to the desanding and desilting plant which normally comprises hydrocyclones and dewatering screens. Different manufacturers use different combinations of hydrocyclones and screens and these may be 'tuned' to suit the ground conditions.

Hydrocyclones used in STPs are commonly found in sizes from 75mm to 800mm diameter, and most can be fitted with different vortex finders, spigots and body extensions, with or without discharge regulators. The feed rate and pressure of the pre-screened slurry to the hydrocyclones will depend on the size and number of hydrocyclones in use, but generally speaking the smaller the diameter of the hydrocyclone, the lower the flowrate it is capable of handling and therefore the greater the number of hydrocyclones required.

The performance of a hydrocyclone is a function of many parameters, including the angle of taper and length of the parallel section. PSD typically uses a large 660mm-diameter hydrocyclone ahead of a number of smaller 125mm-diameter, high-performance, long-bodied, desilting hydrocyclones.These 125mm hydrocyclones perform better than the short-bodied 100mm oilfield types that are used by some suppliers.



Separation of clayballs using declined deck primary shaker

The quantity of solids being separated by any particular stage of an STP will vary as the ground conditions and advance rates vary; the better STPs incorporate flexibility to cope with this. PSD's operators typically choose to fine-tune the operation of the desilting hydrocyclones by changing the diameter of the spigots (the hole through which the hydrocyclone underflow discharges) and the depth of solids on the shaker, to suit differing ground conditions.

As with the primary screens, it is usually possible to use screens on the desanding and desilting stages of different aperture size, open area and material to suit different ground conditions. It is here that a balance must be struck between cost and performance.

One can employ desilters using pre-tensioned, fine-aperture, woven wire screens to obtain finer cut points, but this will often send screen costs soaring, as the finer the aperture, the finer the wire and therefore the quicker it is likely to wear out.

With good equipment, design and a knowledgeable operator, it is possible to achieve great results using heavy duty wedgewire screens of around 0.5mm aperture.

The processed fluid from the desanding and desilting stage is usually pumped back to the TBM. The primary screening and desanding plant should be capable of treating online the full flow of slurry from the TBM, which might typically be 1,000m^3/hr for a 6m diameter and 1,350m^3/hr for an 8m diameter TBM; this rises comparably as diameter increases, although some TBM manufacturers do specify lower flow rates.

A well-designed STP would be capable of removing nearly all of the particles down to sand size, as well as some of the silts, from the slurry before being returned to the active system. Not only is it important to keep the sand content to a minimum, but other properties of the slurry, such as density, are affected by silts and reactive clay particles that remain in the slurry after the desanding stage.

The next stage in a typical STP usually includes centrifuging and it is here that technology has moved most in recent years. Provided that the correct design of centrifuge with sufficient power is employed and that the control system allows it, the centrifuges can be used both for desilting and flocculation (where silts and clays are brought out of suspension).

The cost of heavy-duty civil engineering centrifuges is higher in relation to flowrate than that of desanding equipment; therefore, the centrifuge stage of the STP would not normally be specified to handle the full slurry flowrate, but to operate on a separate loop, taking its feed from the active system after the desanders.

STP at Durban Harbour Tunnel

When used in desilting mode, the centrifuge is able to remove particles down to about 10µm, but smaller particles and clays, including bentonite, remain in the slurry, thereby retaining many of the rheological properties of the slurry. In order to do this effectively, it is necessary to employ large centrifuges with very powerful backdrives.

When used in conjunction with a flocculation system, centrifuges can be used to remove clay particles, including bentonite, from the slurry. This system can be employed to remove contaminated slurry from the system in order for it to be replaced with 'fresh' bentonite or water. It is also possible to use equipment such as plate and belt presses for this function.

At the turn of the century, it was common for centrifuges to be hydraulically controlled, but again, partly due to the increased availability and affordability of reliable frequency inverters and programmable logic controllers (PLCs), it is now more usual for these to operate with PLC control.

The use of centrifuges is driven partly by environmental legislation which puts pressure on contractors, through rising disposal costs, to minimise the volume of waste that must be disposed of off-site and the difficulty of disposing of liquid waste. Through the use of centrifuge and flocculation system, it is usually possible to treat all of the liquid waste slurry to enable it to be disposed of as a clear fluid to the sewer and as a solid phase sludge, which may be re-usable on site.

A capable and reliable slurry treatment plant, with fast and effective support from a knowledgeable supplier, can contribute to the success of a project, but a poorly specified one can cause problems and delays to production.

The STP often plays second fiddle to the TBM, but a slurry TBM is not much use without an STP and it is arguable that as much importance should be placed on the selection of the STP as is placed on the selection of the TBM.

Further details from www.solidseparation.com