Piloting the Shively Interceptor

Brad Ream and Joseph Butor report on the completion of the Shively Interceptor, the third-largest US pilot-tube microtunnel, which negotiated difficult sandy soils, some below the water table

Akkerman 4812 set-up in sheeted cell with casing and backstop in place

MIDWEST Mole recently completed a project in Louisville, Kentucky, US, which utilised pilot-tube microtunnel (PTM) technology. The project comprised the installation of 3,050m of clay pipe in sands above and below the groundwater table, with blow counts ranging from five to 15. There is approximately 372m of 27in (685mm) vitrified clay pipe (VCP); 320m of 21in (533mm) VCP; 1,308m of 18in (457mm) VCP; and 1,347m of 15in (381mm) VCP.

Indiana-based Midwest Mole used an Akkerman 4812 guided boring machine (GBM) to install the 27in VCP and 177m of the 21in VCP. An Akkerman 308 installed all the 15in and 18in VCP, as well as a short crossing of 21in VCP.

The shafts were designed to allow for the installation of 1m lengths of 15in, 18in, and 21in VCP and 1.82m lengths of 27in VCP. The crossing lengths ranged from 46m to 112m, and were designed at extremely flat grades, ranging from 0.068% to 0.143%. Due to the flat grades, low blow counts and overcut of the machine, we had to engineer most of our lines to ensure they came out within the acceptable tolerances.

Shafts on the project were, on average, 7.5m deep, with the deepest shaft having a depth of around 10m.

A great deal of effort was expended in the design and implementation (and quality control) of injecting bentonite into the annulus of the pipe and excavated earth to reduce skin friction while jacking the product pipe into place. Soil conditions, along with the length of the crossings and the diameter of the pipe, introduced the potential for jacking-force issues, as the 308 can only produce 100t (US) of thrust and the 4812 can only produce 200 tons (US).

Pipe string before installation

METHOD OF CHOICE

When most companies are undertaking a tunnel or bore project, they would not consider being off by one-tenth of a foot (30mm) as a bad outcome. Midwest Mole had to be within one-tenth of a foot on this project, 35 times.

On top of that, we were working in wet, loose sand with blow counts ranging from 1 to 19, and at times several feet below the water table. With these challenging ground conditions and strict grade requirements, PTM was the only economical choice.

The 27in VCP required the use of the Akkerman 4812 due to the pipe diameter. We also chose to use the 4812 on two of the 21in crossings, considering their length and the pipe diameter, to eliminate any possible thrust issues. The 4812 provides 200t (US) of thrust with four cylinders, which would allow us to provide additional thrust if jacking forces increased. We used the Akkerman 308 and 240 for the 15in and 18in crossings, and also for the shorter 21in. The 308 and 240 can provide up to 100t (US) of thrust with two cylinders.

Project details

Project owner:	Louisville MSD
Engineer:	Louisville MSD
Contractor:	Midwest Mole
Microtunnelling cost:	US$4.3 million

SHAFTS

The 4812 is designed to work out of 3.65m-minimum ID shafts. We used secant pile shafts when installing the 27in clay pipe. Each secant pile was 915mm in diameter and overlapped the adjacent one by 150mm.

We had the general contractor core out three holes in the secant piles based on centreline elevation to allow for the entry of the tooling. The first hole was 8in-diameter for the pilot tubes, the second hole was 16in-diameter for the 11in temporary casings, and the third hole was 36in in diameter for the powered cutting head (PCH).

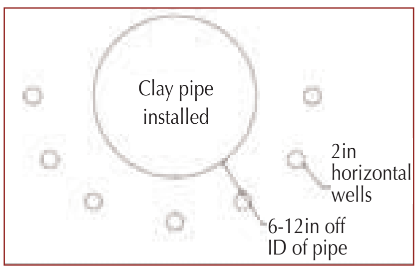
The 36in core was the biggest core we were able to get, which made it tight when using the PCH28.5 due to the outer diameter being 863mm and having an overcut of 38mm. On the first shaft we removed the 8in core and installed the pilot tubes. Once the pilot tubes were across, we chipped out the 16in core to allow for the casings, and once the casings were across, we chipped out the 36in core. This was unable to make it all of the way through the secant piles due to the diameter and offset of the piles.


The view from the work shaft looking towards the receiving shaft

We ended up letting the PCH cut through the last couple of inches of the piles, which worked out very well. The general contractor elected to install a square sheet pile shaft for the last 4812 work pit. We used the square shaft adapters, installed a bulkhead in the front and used a piece of casing to allow the three passes to go through. We filled the bulkhead up with flowable fill around the casing to make it easy to remove and allow the general contractor to remove the sheeting easily. We installed a backstop utilising steel plates and ½in (13mm) aggregate.

The Akkerman 308 GBM is designed for 8ft-diameter shafts, but Midwest Mole elected to

Groundwater pouring into shaft



Location of horizontal wells installed in relation to the main clay pipe

➔ use 9ft-diameter to allow for more working room in the shafts. We added a 12in extension to the frame rails to allow them to fit tight in the shafts. The general contractor installed a galvanised corrugated can for the work shafts and receiving shafts.

GROUNDWATER

The use of a corrugated metal pipe shaft presented challenges in sealing off the entry and exit portals against flowing sands and groundwater. The corrugations of the can created an irregular shape against which to mount a standard seal, which in turn left voids between the seal and the CMP that allowed flowing material to enter the shaft. Therefore, we had to get creative with the way we were cutting the can and how we were going to lower the groundwater table. We encountered groundwater elevations up to 1.5m above the crown of the product pipe.

The pilot tubes could be successfully installed with minimal issues related to groundwater and flowing sands, as the pilot-tube steering head does not have an overcut band – the steering head is the same diameter as the pilot tubes.

The pilot-tube steering head was able to pierce through the can in such a manner that the entry point was essentially the same diameter as the tubes, and formed a seal around the pilot tubes. When it was time for the reaming head to enter and exit the shafts, we would cut along the reaming head's anti-roll 'fins' and allow the reaming head to push the can open.

This approach did not allow for a tight seal around the auger casings due to the overcut on the reaming head. In an effort to minimise ground loss, Celsior (artificial straw) was inserted into the area around the reaming head at the entry/exit portals to create a seal to limit the amount of soil entering the shaft.

The PCH presented similar challenges to the reaming head, except that we were able to cut out a pie-shape in the CMP and let the PCH push the flaps into the soil matrix. These flaps provided a little support for the soil, but typically Celsior would also be required to minimise soil flow into the shaft. Cutting the can this way allowed us to support each pass on the can without worrying about any of the passes settling. Were we to end up cutting out too much, we would weld a support across the bottom to prevent them from settling.

In some cases, the groundwater and soil pressure was so great that deep wells were required on the outside of the shaft for entry/exit of the tooling. Chemical grout stabilisation products from De Neef Construction Chemicals were successfully used in some cases. However, this approach did not prove to the best economical choice.

Another technique for dewatering the soils immediately outside the shafts that proved to be successful and cost-effective was the use of horizontal wells. We drilled 2in holes down from the spring line following the circular shape of the pipe, and installed perforated PVC pipe as 2in well points to draw the water table down to a manageable elevation.

While the soils were not completely dewatered at the entry/exit portals, the ability to relieve some of the water pressure at these locations proved to be an adequate solution.

SETTLEMENT

While engineering and pushing the pilot tubes, we had to anticipate the crossing settling into the overcut of the casings and the PCH. With an overcut of 1½in (38mm) on both the reaming head and PCH, we were required to anticipate the line dropping 0.12ft (37mm) in total. We would set up at a couple of hundredths of an inch (0.127mm) high at the work pit, and on

Akkerman 308 guided boring machine set up in 9ft-diameter corrugated metal pipe uphill crossings, we would install them at a steeper grade, while on downhill crossings we would install them on a flatter grade.

We would set the machine in the shaft and, once the machine was on line and grade, we would install our theodolite stand in the back using concrete anchor bolts.

We requested that all concrete seals in the work pits be 49in (1,245mm) below the centreline in the work pit, and 24in (610mm) below invert in the receiving pits. This allowed for tolerance when setting up the machine in the event that the seal elevation was not exact. The concrete seals were installed in the wet, which led to the seal quality being poor in most cases. The additional tolerance in seal elevation allowed for an additional 6in (150mm) of concrete to be poured to cap the mud seal and allow for a rigid surface on which to mount the theodolite stand.

We could not afford the theodolite moving, and so we took every precaution we could. We started welding angle-iron underneath the machine's front plates to set the machine on, so that it was not resting on and possibly moving the seal, which in turn would move the theodolite. As a precaution, we screwed the legs down, so that if the angle happened to break, the legs were there to prevent the machine from falling. This allowed us to make our set-up quicker and reduce the overall time for installation.

Mini excavator handling hoses at work shaft

TRAFFIC

The majority of our shafts were installed in the centre of the road while it was open to local traffic. On one section of the job, we would average around 50 cars an hour, with the worst time of the day being between 5pm and 7pm. Due to the equipment we used, we were able to allow traffic to pass through in most instances. Temporary gravel roads were installed at each location to allow traffic to pass through. ➔


Equipment layout at the receiving shaft

THRUST

Thrust pressure is always a concern when pushing through sand, especially when total thrust available is limited. To ensure we did not have any issues with jacking pressure in ground conditions that were highly variable across the project, we had to use several different bentonite mixes throughout the project.

We had dry, fine sand on the north side of the project and coarse-grained material with a substantial amount of groundwater on the south side. While installing the casings, we attached ½in (13mm) plastic pipe to their top and let it follow them the length of the crossing.

Each batch of bentonite was tested with a marsh cup and funnel to ensure proper viscosity; bentonite usage was monitored while pushing the clay pipe to ensure that we were injecting enough lubrication into the overcut. Our average thrust force was 60t for the crossings installed with the 308 GBM and 120t with the 4812 GBM. Of course, there were a few sleepless nights when thrust pressures were at the maximum tonnage.

CONCLUSION

Midwest Mole had three crossings remaining on the project, which were completed three weeks ahead of schedule. The use of remotely controlled lifting equipment, superb trenchless equipment, an understanding of bentonite and, most importantly, a crew of dedicated employees with the technical ability to use the equipment properly, were the keys to success on this extremely challenging project.

Brad Ream and Joseph Butor are engineers at Midwest Mole, Indiana, US. This paper was presented by the authors at the NASTT 2012 No-Dig Show –