12CVC082 - Geotechnical Engineering
'Trenchless Technology' - Techniques and Examples of Successful Practice

Most construction projects require new supply and waste disposal pipes to be laid or to replace the old ones present therefore trenchless technology has been developed to offer the ability to achieve this without disturbing the layers of ground underneath the topsoil which could be inhibited or used by traffic.

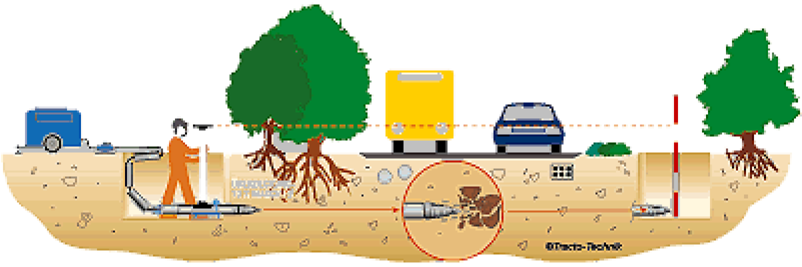

Image: Trenchless technology taking place as to not disturb traffic
http://www.hms-it.co.uk/trenchless_technology.htm

Trenchless Technology can be defined as 'the technology for placing new pipe, cable, or conduit in the ground between two defined points without continuous, open cut excavation between them, or for renovating, replacing, and rehabilitating.' (Kramer, Mcdonald et al. 1992) Trenchless technology emerged in such countries as Japan and Australia where modern sewer networks were needed as the population of the countries were increasing. The primitive technologies used in these countries were then adapted by UK pioneers in the 1970s and early 1980s. (Evans, n.d)

The advantages of using trenchless technology as opposed to open cut excavation methods are numerous such as minimising the environmental effects which open cut excavation methods cause due to disturbing the soil, organisms and water bodies. Minimal ground disturbance results in discovering fewer unknowns from the ground. Trenchless technology also saves the project time and excessive costs due to increased engineering from surveying and design calculations. It also minimises the installation time in comparison to open cut excavation methods as well as increasing the safety of the construction related to steep excavations. (Piehl, R. 2005)

There are various methods of trenchless technologies that may be used and the type of method chosen for a certain project is dependent upon the pipe size that needs to installed, the depth it needs to be installed to, the soil conditions of the ground and the overall cost of the method. The different methods have been outlined below:
Impact Moling: "a technique in which a percussive mole (soil displacement hammer) is launched from an excavation to displace the soil and form a bore. The new conduit is normally drawn in behind the mole or pulled back into the bore using the hammers reverse action." (Cambridge New Media, 2005)
Thrust Boring: "a solution for installing new pipes in virgin ground where accuracy is critical. Working from a compact launch pit a rod is thrust into the ground which pulls through a pipe into its proposed position." (Tomlinson Brothers (Hucknall) Ltd, 2012)

Method	Type of soil suitable for	Other comments
Pipe Jacking	All soil types soil classes 1 to 5 according to DIN 18300	Exception of non-displaceable hard soil and rock
Microtunnelling	All soil types	Very fast and reliable system
Impact Moling	Soft clays and silts	Minimum disruption
Auger Boring	(soils with sufficient stand-up time)	Suitable for shallower depths
Thrust Boring	All soil types	No limitation as to what can be achieved.

Table 1: trenchless methods used depending on ground soil

As can be seen from the table, the two main methods of trenchless technologies are pipe jacking and tunnelling/microtunnelling due to their wide range of use within soils. Whatever trenchless method is chosen though, the soil of the ground on the site has to have an adequate strength to remain withstanding within the shafts. The finer the grains and particles of the soil are the more effective these methods are, as using trenchless methods can prove difficult in hard rocks due to their displacement.

Pipe jacking

'Pipe jacking is used to describe the technique of installing man-entry pipes by adding sections of pipe at the drive pit and jacking the line forward to form the tunnel lining behind the cutting shield.' (Kramer et al. 1992) This method allows for man-entry-size pipes to be installed using hydraulic methods. Pipe jacking has developed widely throughout the years as the first use of this method was recorded in 1892 in USA for Northern Pacific Railroad Company. This method of trenchless technology is preferred over other methods due to its simplicity of installation and benefits such as avoided settlement of ground.

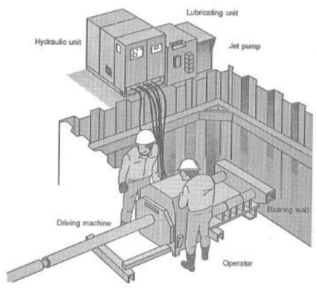

Image: Pipe jacking (Kramer, S. R. 1992)

Method:

1. The tunnelling machine has a thicker wall version with a female end fitted with a collar rimmed with a thin ring of fibre board and a male end fitted with a rubber seal. This connection forms a watertight seal between the two ends minimising friction.
2. Jacks are extended and released to push the tunnelling machine into the earth and the speed of movement is synchronised with the force of the jacks.
3. Lubricant is required between the annulus and surrounding earth to minimise friction acting at longer distances.
4. To complete, the manholes are built and the shafts are backfilled.

As well as having many advantages, pipe jacking can acquire many disadvantages such as its cost. Due to the technology used its cost may be quite high however it is able to save on other engineering costs. The pipes used for jacking need to possess the correct strength otherwise the method might fail. If a fail does occur, there is great difficulty in replacing those damaged pipes. To achieve a fully functioning system, the pipes must align perfectly which can also help with the water tightness of the tunnel. (Perco Engineering Services Ltd, 2012)

Pipe jacking Case Study:

The increase in urbanization on Route 63 in Macon, Missouri led to upstream flooding which initiated the need for two additional culvert pipes. These were to be installed into the ground using the pipe jacking method. After a thorough site investigation it was concluded that the soil was mostly lean clays scattered with sand and gravel, with no boulders. Post construction analysis of the successful installation indicated the need for more culvert pipes to further decrease the amount of flooding. (Najafi et al. 2005)

Image: Microtunnelling
https://perco.co.uk/services/microtunnelling.aspx

Microtunnelling

This method entails installing pipes into the ground through hydraulic methods without the aid of personnel, as opposed to tunnelling, which are remotely controlled from the outside. It requires the use of a microtunnelling boring machines and Kramer defines it as 'those methods that install pipes with a diameter of less than 36 inches (900mm) to a predetermined line and level by remotely controlling the cutting head.'(Kramer et al. 1992)

Method: Microtunnelling uses two shafts to and hydraulic jacks to fit the tunnelling system underground allowing the utility pipes to be placed inside it permanently. This is done by the following method:

1. Shafts are sunk in at each end of the intended drive usually at man-hole positions, one end drive shaft and one reception shaft. The shafts must be long enough to accommodate the tunnelling equipment.
2. The microtunnelling machine is then lowered on the guide tracks by a crane allowing it to be thrust forward by hydraulic jacks. It is guided by a laser which projects onto the target surface.
3. The excavated material at the front is crushed by the head of the machine and any slurry is brought to the surface by slurry shafts in the tunnelling machine. Any ground movements are eliminated due to the counterbalanced ground pressures. Its journey is monitored by screens above the ground.
4. After the machine has penetrated the other shaft, excavation is halted and the pipes are disconnected.

Microtunnelling Case Study

'The project mentioned involved the installation of about 2.5 km of reinforced concrete pipes with diameters ranging from 600 to 1000 mm at an average depth of 5 m below surface.' (Jebelli et al. 2010) Sewer lines were installed using micro tunnel boring machines and hydraulic pipe jacking. Problems encountered during the construction were face instability, shaft failure and groundwater issues. These problems were faced due to the low stability of small grained soils such as sand, therefore the mistakes learnt from this case study can be implemented on other similar situations.

Comparison between Microtunnelling and Pipe jacking

Essentially both methods use the same technique however pipe jacking allows for bigger diameters of pipes to be installed 'Microtunnelling has more limitations than Pipe jacking in terms of ground conditions. The smaller diameters and remote aspect of the operation make Microtunnelling more prone to problems where soil conditions change rapidly or when obstructions are encountered.' (Kim et al. 2008)

Case studies: Trenchless technology methods are used mostly for installing utility pipes especially those running under busy roads or rivers. Treatment works for sewage pipes in Poland's Vistula River in Poland have been installed in record time using pipe jacking. (Environmental Protection, 2012)

Formerly, site investigations and trial pits were used to investigate ground conditions however over the years this has evolved to virtual visualisation which can be seen in the TUNCONSTRUCT project in the UK. This project illustrates a successful case study in which state of the art technology was used to construct underground without the need for digging trenches. The use of software tools, visual prototyping and robotic devices have allowed trenchless technology to develop from the use of tunnelling machines and devices therefore reducing the overall time, cost and risk endured in a project. (Beer, 2010)

Another case where trenchless technology was used underground was for the build of Victoria underground station in London, UK. Jet grouting was the method chosen for this as it creates less potential for heave compared to other methods such as ground heave. This was important to achieve due to the excessive use of the ground above the station, and any disturbance in the ground below may cause high risks. (Symes, 2012)

Critical risks can occur from trenchless technology such as pipes bursting underground as seen in the Yorkshire, Asquith, Birkett and Reynard case study. Other risks include settlement of the ground which is caused by the ground movement during the installation of the tunnelling machines. This can be prevented firstly by maintaining stability of the excavation face and secondly by avoiding inadvertent loss of soil in the tunnel. Microtunnelling is able to avoid this consequence as the pressure acting on the pipe is always counterbalanced with the volume of soil being moved. Another problem that the use of trenchless technology may cross is the flowing of groundwater into the shafts and tunnels formed by the machines. This can cause flooding of the trenches, and may disturb the project overall therefore adequate ground investigation and site surveys are required to fully comprehend the water table beneath the ground of that specific site.

Obstacles such as boulders can be encountered during underground works and this can lead to excessive excavations which can over cost the project. This affected the progress of a project mentioned in ((Jebelli et al. 2010)) which was remedied by removing boulders without losing the face, and the upper part of the face had to be breasted from within the excavation. Some cases of rock encounter can be so severe that the trenchless method has to be elapsed and a full open cut excavation method used to carry out the required work.

Discussion and Conclusion: Trenchless technology has been in development since it was first used; nevertheless the innovation of technology itself in the twenty first century has allowed the use of software and databases to predict the ground beneath the surface which was one of the preventions for these methods before. Gaining access to the history of the ground usage of a site has proved difficult in the past however with the emergence of such databases as the Underground Construction information System (UCIS) this aspect of trenchless methods could be implemented on most projects in the future, therefore benefitting the environment by minimising disruption to the ground.

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