Concrete Pipe Jacking

CPAA

Concrete Pipe Association of Australasia

Technical Brief

Introduction

Concrete pipe jacking is a method of installing pipelines without disrupting existing surface facilities or activities. Pipe jacking has been used to install concrete pipelines for drainage and sewerage projects throughout Australasia since the late 1960's. Where pipelines are laid at depths greater than five metres for lengths longer than 50 metres, concrete pipe jacking is always considered as an economic alternative to trenching.

With increasing growth in Australian and New Zealand cities and towns and the consequent need to refurbish, renew and upgrade existing facilities, concrete pipe jacking is seen to be a growth industry. The formation of the Australasian Society for Trenchless Technology is recognition of increased activity in pipe jacking in the region and a belief that pipe jacking will become a large part of pipeline installation in the future.

To date, many thousands of kilometres of concrete pipelines have been installed throughout Australia and New Zealand. The largest pipelines to be jacked in Australia were 3000mm in diameter at many locations in Brisbane, Sydney and Melbourne, and 2500mm in Auckland with lengths generally less than 50 metres. Among the longest jacked pipelines in Australia are the Bulimba Creek Trunk Sewer,1650mm in diameter, and the Cabbage Tree Creek Trunk Sewer, 1200mm in diameter, both 3000m long, for the Brisbane City Council. Both pipelines have rubber ring in-wall joints and were successfully completed on time. In New Zealand some 200 metres of 1650mm diameter have been jacked for Waitakere City.

Although the basic methods of concrete pipe jacking are similar for all pipeline applications, Australasian contractors have developed their own individual techniques to achieve accuracy during jacking, to lengthen the jacked distance and control varying ground conditions. The methods developed allow tolerances normally acceptable for sewer and storm water construction in most ground conditions. The recent introduction of tunnel boring machines (TBM's) by contractors and authorities allows small diameter (900mm diameter) concrete pipe jacking to be successfully employed with an even higher degree of directional accuracy.

Method Of Installation

Concrete pipe is jacked from a jacking pit to a receiver pit usually located at pipeline access chambers. The main jacks in the jacking pit are used to push the concrete pipes into the cavity excavated ahead of the progress- ing pipeline. The main jack's capacity and stroke depend on the size of pipe, length of pipeline and type of ground in which it is being jacked. There are typically two or four jacks, with capacities up to 300 tonnes and stroke up to 1200mm.

The jacking force is resisted by the thrust block in the jacking pit and applied to the concrete pipeline end through the steel thrust ring. The concrete pipe end is protected against spalling by softwood or chipboard joint packers between the thrust ring and the concrete surfaces.

The steel cutting shield fitted to the lead pipe gives protection to the workers and allows steering and alignment adjustments.

Generally the shield and lead pipe are pushed into the receiving pit and removed for reuse. Intermediate jacking stations may be required in long lengths (>1 Dam) and stiff ground conditions. Alternatively bentonite injection may be used to reduce pipe/soil friction.

The work method generally follows a repetitive sequence of excavation at the face, pushing the pipeline into the excavated cavity and removing the spoil by muck cart on rails in the pipe invert.

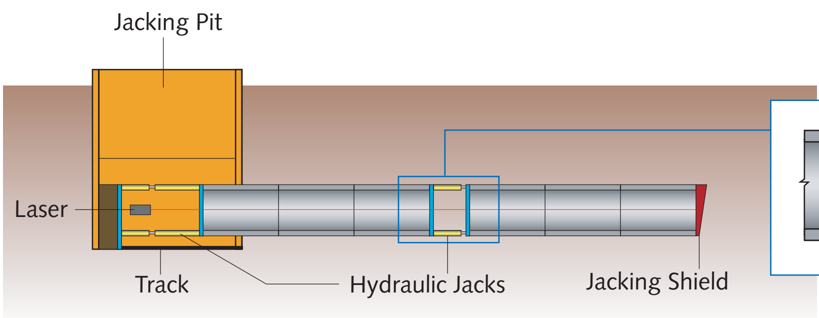
The critical period of installation occurs as the first two to three pipe lengths are advanced into the jacking pit walls and subsequently as the lead pipe and shield approach and break through the receiving pit walls. As the lead pipe and shield is pushed into the jacking pit wall, it leaves the support tracks and is supported by the ground at the pit walls. The ground adjacent to the jacking

pit commonly is disturbed from the pit excavation and may need to be improved by grouting and timber lagging.

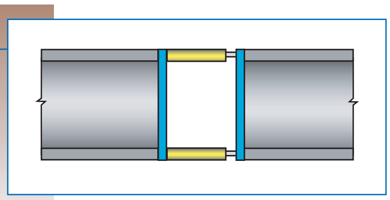
As the lead pipe and shield approaches the receiving pit, vertical ground pressures are reduced and control of vertical alignment becomes critical. Generally alignment control is assisted by maintaining a sealed vertical face in the receiver pit by timbers or sheet piling which are removed when the shield is positioned up against the vertical face.

Pipeline alignment is continually monitored and adjusted during jacking by laser light from the jacking pit to a target fixed to the inside crown of the lead pipe or shield. Gradual adjustments are continuously made to avoid over-stressing the concrete pipe joints.

Generally, pipe jacking is carried out during two daily shifts of 8-10 hours per shift and progress, dependent on pipe size and ground conditions, can vary from 1-6 pipes per shift. Typical labour resources required are two on the surface (including crane driver), and three in the pipe and jacking pit, (two at the face and one in the pit). For smaller projects this number has successfully been reduced to three.



Typical Jacking Arrangement



Detail - Intermediate Jacking Station

Concrete Pipe Design

Reinforced concrete pipe design for vertical soil loads is determined from AS/NZS3725 "Loads on Buried Concrete Pipes" (1) Clause 6.3.7. The formula in the standard contains a soil parameter which reduces the load on the pipe through arching. Care should be taken in applying this parameter since varying soil conditions along the pipeline may cause the load to increase or decrease. Without extensive soils investigations it is recommended that the value of the parameter be taken as zero.

The formula in the standard is based on that for trench installation with the width of trench being the pipe outside diameter or the width of excavation, usually only marginally greater than the pipe outside diameter. For the typical installation, in the appendix, 1500mm pipe with eight metres of cover, the class of pipe required is Class 3. For the same installation, in a trench of minimum width and Type HS2 installation (a typical installation under a road), a. Class 4 would be required.

Concrete jacking pipe horizontal loads from jacking forces induces stresses in the pipe cross-section. For butt ended jacking pipes a minimum pipe wall for a standard Class 3 pipe is recommended. A Class 4 pipe wall thickness is, however, typically adopted. Since concrete jacking pipes are manufactured to the project's requirements, it is not unusual to specify a Class 3 strength pipe with Class 4 pipe wall thickness.

Design of the pipe wall thickness for jacking loads is carried out based on the Concrete Pipe Association of Australasia manual "Pipe Jacking" (2). The' wall thickness required is based on a pipe joint having softwood or chipboard joint packers, continuous around the circumference of the pipe joint surface. The formula in the manual, although appearing complicated, when applied using recommended values for pipe wall thickness, packer type and thickness, pipe concrete allowable stresses and standard pipe lengths, becomes simple and easy to arrive at a workable solution.

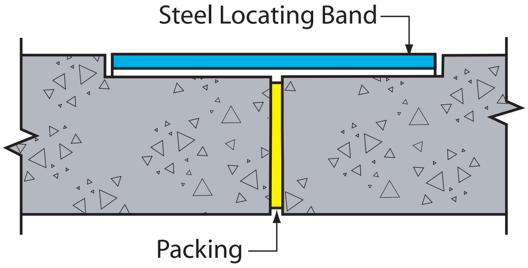
Concrete Pipe Joints

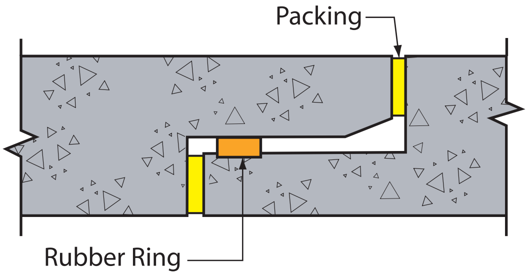
Pipe joint types are typically butt end type with mild steel locating band or socketed in-wall rubber ring joint type, depending on the pipeline application. Most commonly t butt joint type is used for culvert and stormwater applications and the in-wall rubber ring joint type for sewer and pressure pipe applications.

The mild steel band on the butt joint pipe is a construction requirement and ensures no lateral displacement of the pipe joint during jacking. The band is a snug fit to the recess in the pipe, and is fitted to the trailing end of the pipe and overlaps the following pipe in the pipeline.

Flush joint drainage pipes have been successfully jacked but only for short jacking lengths «20m), with low to moderate jacking forces expected.

Concrete jacking pipe in-wall rubber ring joints are typical for pipe 1200mm in diameter and above. A wall thickness of 135mm allows the in-wall joint to be made. However, a minimum of 150mm is recommended for trouble-free use. The joint is fitted with softwood or chipboard joint packers which distribute the jacking loads across both the internal and external socket and spigot profiled ends.
A mild steel band may be fitted (if required) to the socket outside diameter to overlap the following pipe. This ensures no soft ground ingress into the joint which may dislodge the rubber ring from its correct location.





Additional Features

Pinning of joints between pipes at the head of the advancing pipeline should be considered to avoid opening of the joints as the progressing pipeline moves into and through soft ground conditions. Jacking pipes in Japan are supplied with this feature which has been proven to be an assurance against stoppages in soft ground commonly encountered in Tokyo and surrounding areas. This joint feature has been successfully used in Australia, but contractors have not yet commonly adopted its use.

Jacking pipe lubrication points are also not commonly required by jacking contractors, however, they should always be considered when planning a jacking project. 2 Ducts for this purpose can be a formed within the concrete pipe wall. An alternative to lubrication points, intermediate jacking stations may be used to reduce the main jacks' required capacity or extend the jacked pipeline length. II Intermediate jacking stations 6 typically have a capacity of 30% 4 of the main jacking station and are located at approximately one third the pipeline distance back from the lead pipe. Commonly a maximum of two intermediate stations are used since their inclusion extends the push time. Intermediate jacks typically have 200mm stroke and consequently are required to be activated more regularly than the main jacks with stroke up to 1200mm.

Reinforced concrete jacking pipe is normally supplied in 2.44m lengths. Shorter lengths down to 600mm and longer lengths up to 4.88m can be supplied if required to suit jacking pit layouts.

Ground Conditions

Ground conditions determine the viability and selection of jacking pipe installation methods. Long jacking lengths are particularly suitable for tunnel boring machines. The economics of the reduced number of jacking and receiver pits, however, need to be compared with the additional costs associated with long muck cart travel times, additional ventilation and longer service lines and the cost of tunnel boring equipment. Tunnel boring machines are not suitable for mixed face conditions.

The best ground for concrete pipe jacking is clay with a minimum 100KPa unconfined compressive strength. The higher the percentage of silt or sand in the clay, the higher the value of soil/pipe friction and consequent jacking loads. Pipe jacking is most successful in shales with good stand-up times and which turn to clay immediately around the progressing pipeline. Difficult ground conditions include squeezing clays and running sands or gravels. Soil/pipe friction can be excessive where these materials are stable and stand at the excavation face.

Compressed air chambers at the work face have been used successfully overseas to ensure a stable work face, however, the use of this method considerably reduces work progress and increases costs. Stabilisation of the ground ahead of the pipeline by grout or chemical injection from the surface is a better alternative in terms of costs.

Variable ground conditions across the face creates difficulties in steering due to differing ground pressures on each side of the pipeline. Some experience of rotation of the pipe has resulted in a recommendation by concrete pipe manufacturers to specify circular grid reinforcements in the pipe. For short lengths «20m) this requirement is not necessary.

To assist alignment control, removable fins have been used with some shields, and are a feature of some tunnel boring machines. The use of a single laser beam to indicate alignment is restricted to 300m lengths. Longer lengths require laser transfer stations.

Pipe jacking has been successfully carried out around large radius curves (>200m) overseas, but the operation is not popular and avoided wherever possible.

The use of bentonite or grout injection into the cavity between pipe and excavated ground is recommended in low ground cover, particularly under roadways where surface subsidence can cause major repair costs. Also, particular consideration should be given to the effects of ground dewatering as a result of the pipeline installation. Ground consolidation from reduced pore pressures may result and cause surface settlement or movement in adjacent building structures' foundations. Ground water tables should be monitored and if necessary be recharged during the jacking works.

Sub-surface investigations for pipe jacking projects will determine the feasibility of jacking and jack capacities. Identification of soft spots and sudden changes in ground materials along the proposed pipeline alignment is essential if problems and delays in work progress are to be avoided.

The organisation of the site operations is particularly important in pipe jacking projects where limited work areas and access are site conditions normally encountered. The site must be laid out to facilitate supply of pipe, removal of spoil and allow easy disconnection and additions to services with the addition of each pipe to the pipeline in the jacking pit.

Conclusion

Concrete pipe jacking has been proven by many hundreds of kilometres of successful installations across Australia and New Zealand. Contractors in all major cities have acquired the necessary skills from projects involving concrete pipe jacking in almost all pipe diameters and In varying lengths of pipeline through vastly different ground conditions. Although tunnel boring machines are less common, the only factor constraining their use is the cost of equipment and continuity of work.

As a city's infrastructure expands and existing sewer and drainage services in the central business district and inner metropolitan areas become inadequate, concrete pipe jacking in smaller diameters «900mm) requiring tunnel boring machines will increase rapidly. Concrete pipe manufacturers' experience both in Australasia and overseas places them in 'the position of being well prepared to advise project planners and work in consultation with project designers wherever pipe jacking is carried out.

Concrete pipe manufacturers today offer guidance and recommendations for the correct specification of concrete jacking pipe and where required can work alongside pipe jacking contractors to assist in the successful completion of the project.

Example 1 - Jacked pipe

Design of 1500 dia HI lacking Pipe Class
Refer AS/NZS3725-1989 "Loads on Buried Concrete Pipes"
Adopted soil mass = 18 kN/m3
Adopted soil parameter (c) = 0 kPa

Trench Condition
Depth to top of pipe (H) = 8.00 m
Excavation width (B) = 1.78 m
Earth load (Wg) = 140.3 kN/m
Adopted bedding factor, F = 2.0
Wg/F = 70.1 kN/m

Minimum test load = 70.1 kN/m

Adopt Class 3
Test cracking load = 81 kN/m
NOTE: Selected Class 3 (or Y) is 13.4% under stressed.

Example 2 - Excavated trench

Design of 1500 dia RRI Pipe Class
Design based on AS/NZS3725-1989 "Loads on Buried Concrete Pipes"

Adopted soil mass = 18 kN/m3 Installation type = HS2

Trench Condition
Depth to top of pipe (H) = 8.00 m
Trench width at top of pipe (B) = 2.40 m
Earth load (Wg) = 218.5 kN/m
Bedding factor, F = 2.5, Wg/F = 87.4 kN/m

Positive Projection check
Depth to top of pipe (H) = 8.00 m
Pipe outside diameter (D) = 1 714 mm
Earth load (Wg) = 325.3 kN/m
Bedding factor, F = 2.5, Wg/F = 130.1 kN/m

Trench condition controls
Minimum test load = 87.4 kN/m

Adopt Class 4 on type HS2 support
Test cracking load = 108 kN/m .
NOTE: Selected Class 4 is 19.1 % under stressed.

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