OMAN WASTEWATER SERVICES COMPANY S.A.O.C

الشركة العمانية لخدمات الصرف الصحي ش.م.ع.م

OMAN WASTEWATER SERVICES COMPANY

TECHNICAL STANDARD SPECIFICATION

CIVIL WORKS

SECTION 08 MICROTUNNELING

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1. GENERAL

1.1 Micro-tunneling is one method of construction of buried pipelines which does not involve excavation of trench from ground surface. It shall involve excavation using a remotely guided computer controlled tunnel boring machine (TBM) and the subsequent installation of pipes by jacking.

1.2 Micro-tunneling work shall be undertaken by a specialist subcontractor, to be approved by the Engineer, who can demonstrate a history of successful completion of similar work in the Gulf region.

1.3 The Contractor shall provide all necessary geotechnical information to the specialist subcontractor.

1.4 All references to the contractor in the following clauses in this section of the specification shall be deemed to include the specialist subcontractor.

1.5 Any lengths of pipe indicated in the documents to be constructed “in trench” may be constructed by micro-tunneling at no additional cost, subject to the approval in writing of the Engineer. The Contractor will not be permitted to construct in trench any pipelines indicated to be constructed by micro-tunneling.

2. SURVEY

2.1 The Contractor shall record ground levels prior to commencement of shaft sinking and tunneling works. Reliable bench marks and references stations shall be established. The locations of these shall be agreed with the engineer. Four reference stations shall be set around each shaft. Levels shall be taken along the center of the pipeline and the offsets of 5 meters and 10 meters each side of the pipeline at 15 meter intervals between shafts.

2.2 In Case of any adjacent structures to the tunneling works the Contractor shall carry out a survey on all buildings and structures located within the zone of influence shall be taken to be a distance in plan from the center line of the works equal to the depth to invert of that part of the works below ground level.

2.3 Levels shall be taken and recorded on all of the above points at daily intervals during micro-tunneling works, again one week before issue of a completion certificate, and finally at the end of the maintenance period.

2.4 As built survey for each micro-tunnel drive shall be taken at the end of each drive.
E The Contractor is responsible for the protection of the Works and adjoining properties. It shall be the responsibility of the Contractor to determine what additional areas to those specified above are required to be recorded by condition surveys to satisfy the Contractor's obligation.

2.5The Contractor shall submit a method statement for setting out and controlling the alignment of the tunnels and shafts for agreement by the Engineer prior to commencement of work. Adequate opportunity for checking of the survey and setting out shall be given to the Engineer.

2.6Details of all setting out readings and calculations shall be maintained at the site and be set out in a clear and orderly fashion to allow for ease of checking.
H The Contractor shall provide all necessary lines and levels together with all necessary equipment to enable the works to be constructed to the required tolerances. The setting out lines and levels shall be carefully preserved, and where necessary replaced, throughout the period for which they are required.

2.7 The primary setting out system shall be used for the main control of the excavation , tunnel lining and shafts , including checking and recording of the " as-built" position of the lining at intervals.

3 SUBMITTALS

3.1 The Contractor shall submit the following:

a) Description and specification of pipes and design calculations.
b) Details of proposed manufacturer of pipes with relevant literature and details of manufacturer's Quality control system.
c) Description of tunneling equipment, relevant literature.
d) Details of the specialist subcontractor's qualifications and experience in micro-tunneling together with project references including the client's name and current contact details.
e) Detailed curriculum vitae of the proposed tunneling machine operator including details relevant experience in Gulf countries and the Middle East.

f) Plan at 1: 50 scale showing working plant positions , spoil removal facilities, materials storage facilities, launch and reception shafts, fencing, offices, discharge lines, ground water removal facilities ,etc.
g) Working program, including anticipated production rates.
h) Anticipated jacking loads.
i) Structural design of thrust walls.
j) Detailed method statement for spoil disposal.
k) Bentonite injection system details.
l) Groundwater control details including launching seal details.
m) Detailed method statement for disposal of ground water arising from micro-tunneling works.
n) Detailed method statement for all other aspects of micro-tunneling works.
o) Where appropriate for the size of machine proposed, details of man access into the tunnel and tunnel boring machine.
p) Details of safety measures.
q) Details of records and machine protocols to be kept and submitted.

3.2 The Contractor shall not commence the micro-tunneling works until he gets the Engineer's written approval of the above submissions.

3.3As part of the Contractor's tender, preliminary details of pipes, equipment, program, method statement and safety measures shall be submitted together with details f the previous experience of the proposed subcontractor.

4. SHAFTS REQUIRMENTS

4.1 Dimensions

The working shaft shall be designed to withstand the force applied by the main jacking station and of adequate dimensions to fully cater for the underground installation of all necessary Microtunnelling equipment. This will include the jacking frame and thrust ring assembly, slurry pumping equipment and guidance system. Consideration must also be given to safe access and working space for the pit bottom crew.
The design of the shaft base shall incorporate the requirements of a thrust block for the jacking frame to bear upon and a tunnel launching eye and sealing ring through which the TBM is launched. The design of these structures will depend on the type of ground and jacking pressures envisaged. They are normally considered to be temporary structures, being removed on completion of the drive, but consideration may be given to incorporating them in the permanent works wherever possible.

Requirements for launching the TBM assembly, which may comprise multiple units of varying length, shall also be taken into consideration when deciding upon the overall size of the shaft base.

4.2 Verticality

The working shaft shall be constructed within 75mm for verticality through its full depth. Where design considerations require any localized reduction of the shaft section or change in shape then sufficient dimensions shall be maintained to enable access to all items of tunneling equipment and jacking pipes slung in their normal attitude.

4.3 Water Tightness

The construction of the working shaft shall be by such method as to minimise the water ingress in the shaft bottom hence ensuring security of all the underground workings and equipment during tunnelling activities. Any unavoidable ingress of water through the shaft walls shall be collected and directed to an adequate sump in the shaft bottom for removal by submersible pump to the surface.
The provision of headwork's shall be made around the shaft to avoid surface water seeping or flowing into the shaft.

4.4 Filling of Voids

Any overbreak or loss of ground encountered during sinking of the working shaft shall be recorded and where appropriate be backfilled / grouted as work proceeds to ensure no voids remain in the vicinity of the jacking zone.

4.5 Shaft Bottom Jacking Requirements

Prior to work commencing on the construction of the working shaft due consideration shall be taken of the space requirements for pipe jacking from the shaft bottom. This shall in particular include all requirements for the safe launching of the tunnelling machine assembly and for safe working of the operating crew. The shaft invert shall be cast at such level and in such manner as to facilitate the installation and operational needs of the jacking frame and ancillary equipment to be installed in the shaft bottom.
A sump pit shall be incorporated in the shaft bottom for the installation of submersible pumping equipment. The size of the sump shall be adequate for the depth of the shaft and ingress volume of water in addition to any requirements for pumping during jacking operations and shall include the facility of a standby pump.

5 PIPES

5.1 General

a) This specification covers design, material requirements, dimensions, inspection and factory testing of a composite GRP-concrete sewer pipe and joints, in nominal diameters of 1200, 1400,1600,1800,2000 and 2200mm pipes for the use of underground gravity sewer applications, buried by micro-tunnelling method of installation.

b) The manufacturer of jacking pipes will be required to show :
• Third party certified quality assurance and control programme to ISO 9000
• Compliance with the British and other relevant standards regarding materials, mixing and placing, curing and storing of pipe constituents.

c) A certificate issued by the pipe manufacturer shall be provided to the Engineer to confirm that the jacking pipes comply in all respects with the relevant standards. The certificate shall also confirm the allowable distributed and deflected jacking loads.

d) The manufacturer's premises and methods shall be open to inspection by the Engineer for the purpose of checking the quality of manufacture. The Contractor shall ensure that all necessary assistance is provided to the Engineer on each visit.

e) Jacking pipes shall be of precast concrete, designed and manufactured to meet the requirements of:

•BS5911 Specification for reinforced concrete jacking pipes with flexible joints.
•BS EN ISO 9002 Manufacturing.
Or equivalent standards as appropriate.

f) The Contractor shall demonstrate that the reinforced concrete pipes for jacking are designed to resist all loads and damage from the construction process, including crushing of the material due to load transfer at the joint. The proof-design shall be carried out using a design procedure in common use in Europe and around the world , such as ATV rules and standards A 161: static calculation of driven pipes, DVGW Specification GW 312: Static computation of driving pipes , etc. and using ,wherever applicable, published codes and standards.
g) The concrete surround shall be designed to withstand the maximum jacking force. The design shall also ensure the GRP is not subjected to forces during installation

h) As well as the construction loads, the jacking pipes shall be designed to withstand the external loads and hydrostatic water pressure.
i) Pipes shall be factory tested.

5.2 Nominal Diameter

The Nominal diameter (ND) indicated on the contract drawings and documents shall mean the inside diameter (ID) of the GRP inner pipe.
C Jacking pipe wall thickness shall be determined by the Contractor and is a function of the following:
• Maximum Jacking forces.
• Length of drive.
• Dead and live loads and hydrostatic pressure.
• Designed jacking forces at maximum angular deflection.
• Dead and live loads and hydrostatic pressure.
• Pipe stiffness requirements.
• Handling and positioning of pipe.

5.3 Class of jacking pipes

a) All pipes shall be manufactured by a supplier approved by the engineer. The process of manufacture may be by centrifugal or vertical casting subject to submission and approval by the Engineer. All pipes shall be cast with a minimum of 3 grout holes of minimum dimension ¾" BSP. Each hole shall have provision for taking a steel connector for lubricant injection during jacking operations; such provision being cast in.

b) Pipes shall be designed to withstand the maximum axial thrust with a factor of safety of (2.5) based on the full effective areas of the joint surface and the ultimate compressive strength of the pipe material. For reinforced concrete pipes the full effective area at the joint shall be used in accordance with the BS.

c) The Minimum Jacking pipes strength class 120 according to BS 5911- 1:2002.

d) The concrete shall be of minimum characteristic compressive strength of 50 MPa determined in accordance with ISO 4012.
e) Reinforced concrete pipe joints shall be flexible consisting of a fixed stainless steel Grade 316S11 or S31 collar with an EPDM or other elastomeric seal (rubber ring) complying with BS 2494, such approved material shall be incorporated in each pipe joint, including joints between pipes and interjacks / TBM. The design of the seal

shall be commensurate with the detailing of the pipe joint. Seals may be fitted either at the place of manufacture or on site prior to placing of the pipe below ground. In either case the seals shall be fitted in accordance with the manufacturer's instructions. Seals shall be inspected for damage by the surface crew immediately prior to pipe use and any damaged seals replaced. Pipe seals shall be suitably lubricated with a soap solution or other such compound in the pit bottom immediately prior to closing the joint with the jacking frame. The collar shall be a fixed steel band, at least 5mm thick.

5.4 Reinforcing Steel

a) The reinforcing steel shall be grade 500 and shall comply with BS 4449:2005 and where appropriate with BS 4482, 4483. No elliptical reinforcement will not be allowed in any circular pipe.

b) Reinforcement shall be obtained from a certified Authority for reinforcing steel Quality Assurance approved supplier and the Contractor shall provide copies of the manufacturer's certificates of test results relating to the steel reinforcement to be supplied.

c) Steel reinforcement shall be cut and bent in accordance with BS 8110 Part 1. Cold bending shall be used.

5.5 Concrete

a) The jacking pipe concrete shall comply with BS EN 206-1:2000 /BS 8500.

b) Materials and concrete for the manufacture of jacking pipes shall comply with the following Standards:
I. Cement BS EN 197-1; BS 146; BS 4027
II. Aggregates BS EN 12620
III. Mixing Water BS EN 1008
IV. Admixtures BS EN 934-2
V. Additions BS 3892-1;BS 6699

c) The jacking pipe's concrete shall pose low slump values, in the order of 30-50mm.

5.6 GRP Inner Pipe

a) The GRP internal liner shall have a design life of 100 years when used for gravity flow applications.

b) Pipes shall have spigot and socket joints .The joints shall make a watertight connection when the external concrete pipe surrounds are in their final position after jacking. The GRP joints shall be able to withstand an external water pressure of 4 bars.

5.7 Packing Material

An 18mm thick Medium Density Fibreboard (MDF) packer shall be fitted to the socket face of each pipe prior to the pipe being used in the tunnel. The packer, comprising several segments to form the 360% annulus, shall be firmly glued to the socket end and in such manner as to be 15mm inset from the intrados of the pipe. These packers may be fitted on either at the factory or on site, however it should be noted that in wet weather conditions suitable protection may be required in cases of lengthy exposures.

5.8 Damaged Pipes

No damaged pipes shall be permitted to be used in the permanent works. Pipes damaged in the casting and handling process in the factory shall not be permitted on site. Repairs to cast pipes, either in the factory or on site shall be confined to minor cosmetic repairs only. All repairs shall be subject to the approval of the Engineer and carried out to an approved procedure. Any pipes identified as being unfit for use in the tunnel shall either be removed from site and destroyed or clearly marked and quarantined for later inspection and possible repair.

5.9 Handling

Pipes shall only be lifted on site using a cast in lifting hole and/or a purpose made lifting device. Such device shall be fully tested and carry relevant certification. Pipes shall be stored in an orderly fashion in a designated area, not more than three pipes high and on purpose made timber supports.

5.10 Jacking

Pipes shall be power lowered by crane or gantry down the working shaft and set on a purpose made cradle comprising the base of the jacking frame assembly. The cradle shall have been set true to line and level prior to commencement of the jacking and secured to

the shaft bottom. The thrust wall assembly behind the jacking frame shall also be set at right angles to the line of drive to ensure that no misalignment occurs at the pipe joint on closure. The lifting device shall be removed from the pipe prior to the joint being closed and jacking of the pipeline recommenced. The lifting hole shall be sealed with a precast concrete plug and rapid setting mortar prior to the hole location passing through the eye seal. Jacking of the pipeline shall be carried out in such manner as to limit any deflection at a joint to the manufacturer's recommended maximum. Pipe loadings shall normally be limited to 50% of the design load (or similar as agreed) whereupon an interjack assembly shall be installed.

6 Jacking Equipment General

6.1 Reference List

The method to be employed for micro tunneling shall be selected by the Contractor using a slurry TBM to suit the ground conditions and ground water pressure.
All tunneling machines for pipe jacking shall be robust with adequate safety margins for the anticipated duty , designed and manufactured to comply with all safety standards. The machine shall be capable of excavating , controlling and negotiating the envisaged ground conditions.

6.2 Project Specification Micro-Tunneling

The external diameter of the tunneling machine shall be designed to produce minimum overbreak and the least necessary clearance for the proper construction of the works.
Design shall take into account the horizontal and vertical alignment to be negotiated.
Provision shall be made to limit and correct roll of the machine.
The contractor shall demonstrate by means of the provision of the TBM manufacturer reference lists illustrating the suitability of the proposed TBM and experience relevant to the contract.
TBM equipment manufacturer sales reference lists are to be submitted using the attached forms: -
a. For all tunnelling systems manufactured in the last 5 years
b. For all slurry type equipment of outside diameters from 1.80m to 4.00m, without any restriction on year of manufacture.
The Contractor shall be responsible for the quality of materials used to present within the tunneling machine and shall ensure that all materials used or present are adequate for the task they are to perform.

6.3 TBM

In order to optimize face support during excavation and minimize possible ground settlement a Slurry mode tunnelling machine shall be used incorporating fine regulation of the face support pressure.
The tunnelling equipment shall be capable of excavation in hard rock conditions at face pressures of up to 3.0 bars and under the predicted static ground loadings. The shield, slurry system, interjack system, pipe lubrication and main jacking station shall constitute a complete tunnelling system designed and manufactured specifically for this project and the existing conditions. The complete system should support excavation rates of up to 50mm / minute.

6.4 Shield

The shield structure shall be designed to withstand the worst case combination of the support pressure at 3.0 bars, the active ground pressure and the jacking forces without distortion.
The shield provides a housing for all the systems required to support the excavation. A stone crusher shall be included in the excavation chamber behind the cutting wheel.
The shield shall be equipped with steering jacks and such beads, ploughs and copy cutters as may be required for adjusting the alignment of the pipes .In machines where man access to the pressure chamber is possible, unless otherwise agreed with the Engineer , they shall be replaceable from within the chamber.

7. PROJECT SPECIFICATION MICRO-TUNNELLING

A pressure bulkhead shall be incorporated to provide a compressed air system for face pressure regulation along with a compressed airlock system to allow for man access to the excavation chamber under compressed air.
Multiple lubricant injection points shall be provided within the shield in order to provide immediate ground support when necessary.

7.1 Cutting Wheel

The shield shall be equipped with a hard rock cutting wheel equipped with disc cutters. The design of the cutter head shall incorporate the facility to replace the disc cutters with soft ground picks to cope with any cohesive ground. The wheel shall be capable of excavation in either direction of rotation for correction of machine roll.

The cutting wheel / shield configuration should allow for sufficient lateral overcut to allow the negotiation of the curves in the tunnel alignment without introducing excessive over excavation to the tunnel invert. All cutting tools shall be changeable from the rear of the cutterwheel.

7.2 Cutting Wheel Drive

The cutter wheel drive shall be hydraulic and of a robust construction providing a bi–directional steplessly variable speed drive . The available driving torque shall be enough to over come the encountered various types of soil envisaged plus an adequate working and safety margin in the lower speed range.The main bearing shall be of triple axis design with a design life of 10,000 hours. The main bearing shall be protected by a seal system of proven design incorporating a leakage chamber for seal condition indication.
The pressure control system shall automatically maintain the required pressure on the face at all periods when the machine is advancing, and when standing. Control shall be such that the pressure can be adjusted to suit changing face conditions and can be maintained at all times within + 10% of the required pressure.

7.3 Airlock Systems

The shield shall incorporate compressed airlock systems in accordance with EN 12110. Work in compressed air shall comply with section 401 of the 2000 edition of the specification for tunnelling prepared by the British Tunnelling Society and Institution of Civil Engineering allowing access to the cutter wheel for maintenance by a team of 3 persons under compressed air conditions. The system should also allow for the possible entry of medical personnel in the case of emergency.

7.4 Jacking System - TBM

The shield itself shall be capable of transmitting the required cutter head thrust forces from the pipe jack to the face.
The shield shall incorporate a telescopic section at the rear end to enable constant thrusting on the face during excavating in rock conditions. Under such conditions advancing the shield by direct shoving from the jacking rig or interjacks shall not be permitted.

8. PROJECT SPECIFICATION MICRO-TUNNELLING

8.1 Slurry System

The excavation and disposal arrangements shall be capable of dealing with the full range of materials expected. Generally the disposal system shall accommodate materials produced by the tunnelling machine .
System incorporated into slurry machines shall be provided with means of accurately controlling and adjusting the density and viscosity of the medium supplied to the pressure chamber and introducing additives where required. Pipework, pumps and separation plant shall be designed to accommodate the maximum rate of advance at which the machine will be progressed. The separation plant shall be such that assessment of the nature and volume of excavated material can be made.
Slurry feed and return pumps shall be supplied complete with their necessary control systems linked to the operators console in the shield.

8.2 Bentonite Injection

An automatic bentonite injection system shall be provided for lubrication of the annular space around the pipeline. It shall allow programmed and controlled injection of bentonite at 15m centres along the pipe jack and through ports in the tunnelling machine. The control of the system shall be programmable and operatable from the TBM operator control station.

8.3 TBM Operator Control Station

The TBM operator control station shall include controls and monitors for all main functions of the TBM including but not limited to: -

- Cutting Wheel Speed of rotation
- Direction of rotation
- Drive operating pressure
- Steering Cylinder Operating Pressure
- Stroke
- Slurry Circuit Position indication for all valves (feed, discharge and bypass)
- Slurry Pumps Flowmeters for discharge and feed pumps
- Slurry discharge pump speed of rotation
- Slurry feed pump speed of rotation
- Slurry pressure at cutting head

- Main Jacking Station Operating pressure
- Remote pendant for jacking rig operation outside control container
- Interjack station operation
- Telescopic section Operating pressure
- Variable advance speed
- Automatic Bentonite Lubrication System
- Injection pressure
- Injection volume
- Injection sequence
- General All equipment start and stop controls
- Emergency stop control
- Hydraulic oil temperature – container
- Auto Shut Down Oil temperature too high
- Oil level too low
- Oil cooler trip
- Supply voltage incorrect

8.4 Data Logging

All main operational data shall be logged on an industrial standard computer. Where applicable this function can be carried out by the guidance system computer. As a minimum the following shall be continuously recorded: -
Total drive length
Deviation from line and level
Roll angle
Steering cylinder stroke
Main jacking station thrust
Interjack station thrust
Cutting wheel torque
Date / time
Provision for operator to add comments to the protocol
All of the above figures shall be available as a tabular printed record and deviation from line and level as graphical printed record.

9. Guidance System (including Long Distance and Curved Pipejacking Applications)

9.1 General

In mechanical tunnel driving, it is vitally important to have a permanent check on the position of the tunnel-boring machine (TBM) with respect to the designed tunnel axis (DTA) to allow corrective action to be taken well in advance of any deviation and prevent the TBM drifting out of tolerance.
In pipe jacking, it is essential to avoid sudden changes in direction and in point loading the outer edges of the pipe, as damage in the area of the seal cannot be tolerated if the water tightness of the drive is to be maintained. Changes in direction cause more resistance to the movement of the machine and all the following pipes that in turn require greater hydraulic forces to overcome the increased friction. Although no tunnel keeps precisely to the DTA, the aim must be to keep any deviations to an absolute minimum.
An appropriate laser guidance system, including , where appropriate, the ability to predict ahead of the face, will be installed on tunnelling machines which will be provided with a display to show the position , orientation, altitude and roll of the machine at all times. The display should be positioned to enable the machine operator to have a clear view at all times.

In the case of long distance or curved pipejacking however, there is one fundamental difference in the supply of the guidance information to the machine operator. This is the positioning of the laser reference in a stable position once the machine has advanced to a point where the laser beam can no longer activate the Target from the start shaft. At this point the laser reference must be positioned within the moving pipe. As soon as the laser reference is no longer in a stable position it is necessary to accommodate this fact. Control surveys shall be taken in static situations. This absolute measurement shall be applied to the guidance of the machine in the dynamic situation where the hydraulic forces used and varying geological conditions cause short-term anomalies in the position of the elements of the pipeline and components within it.

9.2 References

Reference shall be made to contract documents for required accuracy and tolerances and other matters affecting the operation of the system.

9.3Technical Aspects

The tunnelling system shall be designed to maintain a clear space for the guidance system and laser beam, irrespective of shield / TBM orientation.
The guidance system, including cabling and connectors, shall be robust. It shall be capable of sustained, safe operation within the onerous environmental conditions of a tunnel under construction, where dust, water, high humidity, varying quality of power supply, sustained vibration and repeated shocks are to be expected.
The guidance system shall be self-checking, with redundancy in essential components, and shall generate and record appropriate status messages for delivery when remotely or locally interrogated and to alert the operator to fault conditions immediately they occur.
Loss of primary power to the guidance system in the tunnel shall not result in data loss, which would prevent the system self-starting on resumption of primary power supply.
During forward movement of the shield or TBM, the guidance system shall provide as a minimum the following real-time data for the shield or TBM, with reference to the designed tunnel alignment at the machine head: -

- Station (chainage)
- Horizontal / line displacement
- Vertical / level / grade displacement
- Left or right lead / yaw
- Overhang or look-up / pitch
- Main axis rotation / Roll

This information shall be presented in numerical and graphical form, refreshed every 20 seconds or faster.With historical tendency diagram for analysis of machine steering characteristics.
The system shall have an accuracy of at least ± 50mm over a self-referenced jacking range of 100m.
The data shall be presented on displays at the Machine Operators position and if required at the offices on surface of the Contractor and the Owner's Representative. Facilities to download data electronically (for further transmission) and for paper printout, independently of the current display, shall be provided.
Data shall be recorded in a medium unaffected by primary power loss in a store of sufficient capacity to hold the entire tunnels production records.

9.4 Procedural Aspects

The operation of the guidance system shall be a specific feature of the Contractor's Quality Plan. This should clearly address: -
Definition of responsibility and authority of personnel maintaining and operating the guidance system.
Intervals between manual checking of data produced by the guidance system .
Intervals at which control surveys are to be carried out, based upon tunnel geometry, rate of advance and tolerance requirements, but not greater than 100m.
Detection and correction of trends to non-conformance, (requiring long-term data storage)

It shall be clearly stated that the guidance system must be fully operational whenever the shield or TBM is advancing.

The guidance system shall permit the following operations: -
Input of machine and project parameters
Standard geometric elements of tunnel alignment and subsequent computation of alignment data for stations at 1m intervals.
Fully computed Designed Tunnel Alignment data
Input of initial survey data, control survey data and reference line data, clearly recording each input for future reference.
Automatic determination of Target position and orientation with respect to the laser reference.
Control of the motorised laser theodolite, capable of continuously maintaining its operation during the forward advance of the pipeline
Verification of laser reference position in the advancing pipeline with Manual or Automatic initiation of the survey measurement cycle.
Automatic measurement of the pipe advance.
Automatic input of measurement cycle data into reference line editing program for easy smoothing.

10. Interjacks

10.1 Design of Interjacks

Interjack stations shall be designed to provide sufficient jacking force to overcome the frictional resistance to pipe motion over the distance between them.
Interjack stations shall have a capacity enough to overcome the envisaged forces during the tunnelling operation. The seal shall be adjustable to exclude the ingress of ground

water and bentonite and shall be capable of withstanding working pressures in excess of 4bar.
The envisaged number of intermediate jacking stations shall be agreed in advance of the commencement of jacking operation. At least one intermediate jacking assembly shall be available at the start of pipe jack unless otherwise agreed.

10.2 Operation of Interjacks

Hydraulic power to operate the interjack stations shall be provided by powerpacks situated in both the TBM and in the launch shaft. In order to minimise hose lengths and subsequent power losses, the forward interjacks shall be fed from the TBM powerpack and the rear interjacks, from the shaft powerpack.

10.3 Closure of Interjack

On completion of tunnelling operations all interjack cylinders and seal assemblies shall be removed. The exposed steelwork shall be cleaned and treated with epoxy paint and the pipes shall be closed to eliminate the gap. The adjustable interjack sealing systems shall be manufactured to facilitate easy removal by hand within the tunnel.

11. Main Jacking Station

11.1Main Jacking Station Construction

The main jacking station shall be of robust construction, and comprise a thrust ring and cylinders fixed firmly to a backwall and slide rails.

11.2 Main Jacking Station Operation

The thrust ring only shall be used for advancing pipes. A local control shall be provided at the pit bottom for use by the shaft bottom crew during pipe extensions only. During normal advance the main jacking station is controlled from the TBM operators console. Cylinder pressures are available to the operator at all times.
The Contractor shall limit the jacking load applied to pipelines such that damage to them is avoided. The jacking load shall be transferred to the pipes through a thrust ring, which shall be sufficiently rigid to ensure even distribution of the load. The Contractor shall be responsible for deciding whether intermediate jacking stations are required but as a 14 general rule they shall be installed where jacking forces are approaching 67% of the maximum allowable forces.

The Contractor shall maintain site records of jacking loads, line and level measurements, the distance moved and the relationship between them. Copies of all records shall be provided to the Engineer's representative within 48 hours of Jacking.
An interlock arrangement shall exist to transfer control between the operator's console and the shaft, whereby only the operator in ownership of the control can make the transfer at the time.

12. Slurry System

12.1 Slurry System Design

The slurry system shall be designed to be capable of functioning with bentonite slurry where required as a support medium. The slurry circuit shall be designed for a minimum flow rate that is capable to transport all the excavated material during the tunnelling machine advancing.The slurry circuit shall include flowmeters on both feed and discharge lines.
Automatic valves shall be included at the shaft top to allow for immediate closure by the operator in the event of burst system hoses.
The separation plant shall be sized to be 25% over capacity to account for any possible flow surges within the slurry circuit.

12.2 Slurry System Operation

All controls and indicators for running the slurry system shall be available at the TBM operator's console. A telephone system shall be installed to allow direct communication between the TBM and the separation plant.

13. Bentonite Lubrication System

13.1 Bentonite Lubrication System - Design

The equipment shall include an automatic bentonite injection system to enable both the lubrication of the pipe wall and the support of loose ground to be maintained. The system shall be such that the annulus around the pipe is kept full of lubricant at all times including periods of downtime.
Lubrication holes shall be threaded to enable plugs to be screwed into the socket and to withstand external pressure. A non-return valve shall be fitted where opening a lubrication hole would permit ground loss. upon completion of grouting the plugs shall be covered with a material similar to that of the jacking pipes.

All formed holes in the GRP inner pipe shall be repaired on completion of the installation of the pipe by skilled craftsmen in accordance with the GRP pipe manufacturer's recommendations.
Documentation shall be provided of the successful use of the proposed system on other pipejacking projects.
Injection of bentonite shall be at a minimum of three points spaced equally around the pipe wall and at centres not exceeding 15m along the pipe line.
The frequency and duration of injection at any given point shall be programmable and controlled from the TBM operator's console. The point of operation and system pressure shall be displayed to the operator.

13.2 Bentonite Lubrication System - Operation

The system shall be used continuously whilst pipe advance is taking place.
On completion of the drive it is not intended to displace the lubricant, which shall remain as the permanent void filler around the pipeline. The two ends of the pipeline will be secured with cement grout to prevent any displacement of bentonite lubricant around the pipeline.

14. Work in Compressed Air

14.1 General Requirements

Provisions shall be made on the tunnelling machine to facilitate entry into the face of the machine under compressed air for inspections and maintenance. These provisions shall comply in all respects with all relevant statutory regulations governing work in compressed air. The airlocks and other equipment fitted to the machine shall comply with the requirements of EN12110.
All equipment and personnel necessary to perform such interventions for inspection or maintenance shall be available throughout the pipejacking operations.
The Contractor shall submit details of the compressed air installation for the Engineer's approval, along with details of the qualification and previous experience of lock attendants, medical lock attendants, compressor attendants and supervisory staff.
The installed capacity of the compressed air supply plant to be provided shall be agreed with the Engineer after inspection of the available site investigation information.
In highly permeable ground where air losses might be excessive, arrangements shall be made to inject a thick bentonite slurry into the face prior to an intervention to form a cake on the exposed face in order to limit air loss.

14.2 Compressed Air Plant

The air compressors may be powered from the mains electricity supply or from generators, or may be diesel powered.
In all cases a standby capacity of at least 50% shall be provided and this standby capacity shall be powered by an independent power source.
All essential parts of the compressed air system, including pipelines carrying compressed air to the face, shall be duplicated. All pipework, valves, guages, etc. must be protected from impact damage. Where flexible hoses are used to carry the compressed air through the pit bottom jacking arrangement they shall also be protected from entrapment. In the event of failure of one part of the system it should be possible to isolate that part without interrupting the air supply.
A safety valve shall be fitted to free air side of the pressure bulkhead of the tunnelling machine. This safety valve shall be set to relieve at marginally above the working pressure and shall be of adequate size to match the installed capacity of the air compressors.
Prior to any work in compressed air the system should be tested to working pressure.

14.3 Airlocks

Any airlock fitted to the tunnelling machine shall beat least 1.5 meters diameter. The air lock should be designed as a pressure vessel, subjected to a hydraulic test and issued with an appropriate test certificate.
Air lock doors should be at least 700 millimetres by 700 millimetres. Doors should normally be kept closed by the air pressure but the door opening to the front of the tunnelling machine should also be able to be locked shut whilst persons are being decompressed in the lock.
The airlock should be comprised of two chambers to allow access into the working chamber in case of emergency.
For use at pressures above one bar the lock should be fitted with seating for the persons being decompressed.
Where the working pressure is above 0.7 bar a medical lock shall be provided which shall be manned by a medical lock attendant whenever work in compressed air is in progress and for twenty four hours afterwards.

14.4 Air Quality

If necessary the quality of the compressed air supplied to the working chamber shall be improved by coolers and filters to ensure compliance with the specified requirements.
The supply of compressed air to the working chamber shall be sufficient to ensure that the level of any contaminant shall not exceed 10% of the short term exposure level when measured at atmospheric pressure.
Air quality should be monitored at least once per day.

14.5 Medical Supervision

The contractor shall appoint a registered medical practitioner experienced in compressed air work to advise on decompression methods to be adopted and on all other aspects of health relating to the work in compressed air.
All employees will be medically examined prior to working in compressed air.
Records will kept of all medical examinations and details of each compressed air exposure including working pressure, working time, decompression procedures, etc..
No person shall be allowed to work in compressed air if the contractor has reason to suspect that person is under the influence of drink or drugs such that his capacity is impaired.

14.6 Operational Requirements

No one shall be allowed to enter the compressed air working chamber alone.
An experienced lock attendant shall be on duty at the free air side of the air lock at all times when there are persons in the compressed air working chamber.
All valves gauges and controls at the lock attendant's station shall be clearly marked with their function and method of operation.
Smoking shall be banned in compressed air and no person shall take smoking materials into compressed air.
As far as is practicable no combustible material shall be taken into the air locks and or the working chamber.
The use of burning or welding equipment should be strictly limited and shall be subject to a permit to work system.
Fire extinguishers shall be provided in the air locks and the working chamber whenever work in compressed air is in progress.

15. Jacking operations

15.1Temporary Works

The Contractor shall be responsible for the design and integrity of all temporary works associated with the pipejacking operation including those required in the shaft bottoms. He shall submit for approval full details of all designs relating to such works including any checks required under the contract by independent engineers.

15.2 Alignment

Pipejacking shall be carried out in any material encountered true to line and level. The Contractor shall provide such continuous supervision as is necessary to maintain accuracy of line and level.
The position of the internal face of any pipe shall not deviate from that detailed in the Contract by more than the following permissible deviations in order to ensure no distress to the pipeline.

- Line 75mm
- Level 50mm
- Backfalls shall be avoided.

15.3 Misalignment Correction

The contractor shall submit proposals for realignment of the pipejack in the event, for whatever reason; the agreed parameters are exceeded. Such proposals shall be based on the principal of striking a new driveline as opposed to working with offsets from the original driveline, in order to ensure a gradual recovery.

16 Personnel

16.1 Previous Experience

Key personnel, including Site Manager, Tunnel Foreman, Shift bosses, Surveyor and Engineering staff shall have had appropriate previous experience in pipe jacking work. Details shall be submitted for approval prior to appointed personnel taking up positions on site.
TBM operators shall have a proven track record of a minimum of two years experience in driving similar TBMs in similar ground conditions.

16.2 Jacking crews

Key operatives in each jacking crew shall have appropriate prior experience including documented evidence in their ability to supervise and train the jacking crew in all aspects of the jacking operation.

16.3 Training

Appropriate on site training shall be provided to all locally employed new starters including a general induction on site safety.

17. Working Hours

17.1 Shift Work

The contractor shall make proposals for shift working of jacking operations subject to any local environmental requirements. Where restrictions on night or Friday work or any other such time related restrictions apply the Contractor shall ensure that all reasonable provision is made for preventing a freeze up of the line during such periods of standing. This may include the provision of additional acoustic enclosures and the like such as to allow minimal periods of working during the restricted hours.

17.2 Continuous Working

Generally continuous working shall be mandatory in the event that the jacking pressures exceed 70% of the main jacking station capacity.

17.3Tunnel services

The installation of all tunnel services shall be progressively carried out as the work proceeds. Services shall be supported on purpose made brackets bolted to the pipe wall. Electric cables shall be hung on the opposite side of the pipes to any water lines. Slurry lines may be mounted on blocks in the invert to facilitate access in case of blockage or leakage. On pipejacks larger than 2metre internal diameter and longer than 100metres a 450mm gauge track, or similar such devise, shall be provided to facilitate movement of men and equipment in the tunnel . Care shall be taken not to damage the pipes during the installation and handling of services in the tunnel. All fixings shall subsequently be removed and the holes plugged with a suitable mortar.

18. Safety and Environment

18.1 Regulations

The contractor shall carry out all works to the requirements outlined in all current appropriate Regulations, Codes of Practice.
The following recognized documents shall form the basis for guidance and development of the safety plan and site procedures: -

- BS 6164 Safety in Tunnelling (Code of Practice)
- Guide to best practice for the installation of pipejacks and microtunnels

18.2 Safety Procedure

The contractor shall develop a safety plan to encompass all aspects of safety and environmental requirements prior to commencement of the work. This plan shall be a working document and be subject to continuous review throughout the period of the contract.

18.3 Selection of Pipejacking Equipment

The method of pipejacking and the equipment shall be selected to control groundwater and water table movements to prevent damage to adjacent roads, utilities and structures. All machinery, including hoists shall be suitable for quiet and efficient operation and shall be installed and maintained to an acceptable safety standard.

18.4 Safety culture

A site safety culture shall be instigated on site prior to work commencing and be developed throughout the course of construction. The culture will comprise of the use of key management tools by the site management (and outlined in the site safety plan) in educating the site operatives in all aspects of best safety practice and awareness in their work

18.5 Induction

An induction session shall be given to all operatives and staff irrespective of their discipline and experience. This should, in particular outline all local requirements relating

to the contract, actions to be taken in event of emergencies, and an overview of the site and its personnel. The content of the induction may be varied to suit the recipients.

18.6 Job descriptions

Each operative shall receive training, together with any appropriate examination or documentation, to ensure he is completely aware of the requirements of each aspect of his job and the hazards which are inherent in its execution.

18.7 Risk/hazard analysis

The contractor shall produce a risk/hazard analysis of the key elements of the pipejacking operation and utilise the results of the analysis in reducing such risks that remain to a minimum. Such hazards shall be communicated to workers through induction, tool box talks and the like.

18.8 Tool box talks

The contractor shall ensure that a minimum of two toolbox talks are given by supervisors to each operative on a weekly basis. These shall be given at the place of work when practical. Content of such talks shall be agreed with the site manager and a record kept of all talks given and attendees.

18.9 Plant

Appropriate training and certification shall be given to all operators of plant. This shall be carried out only by engineering staff competent in the use and hazards associated with the particular item of plant concerned.

19. Surface operations

19.1 Site compound

Where practical the whole of the working area for each working shaft shall be enclosed by a secure fence or hoarding, 2metres high. Watchmen shall be employed during times when work is not in progress. Adequate lighting and warning notices shall be provided around the site. Suitable drainage and desilting tanks shall be provided to cater both with surface and underground water. The shaft top shall be secured with a robust barrier around its perimeter to a height of 1.2metres minimum.
Jacking pipes shall be stored clear of water and excavated material and shall not be used for storing plant and equipment.

19.2 Electrical Equipment

All electrical equipment shall be appropriately IP rated for its intended underground use. It shall be installed and maintained by a suitably qualified electrician.

19.3 Lighting

Tunnels requiring man access, even on an occasional basis, shall be adequately lit by 110v lighting. Naked lights shall not be used below ground.

19.4 Ventilation

The contractor shall supply and maintain a fresh air supply to all places underground where work is being carried out. When work is being carried out in the tunnel a fan shall be situated locally in the tunnel not more than 5metres from the location of the work.

19.5 Air Quality

In addition to providing air as described above the quality of the air shall comply with the following: -
less than 0.5% carbon dioxide content by volume
not less than 20% oxygen content by volume
no more than 0.25 milligrams/cubic metre of respirable dust
no more than 0.25 milligrams/cubic metre of respirable quartz
total concentration of inflammable gas not to exceed 25% of the lower explosive limit of the mixture by volume in air.

19.6 Tunnel Entry

No person shall be allowed to enter the pipejack without the authority of the supervisor.

19.7 Gas Detection

The contractor shall provide at least one automatic gas detector at each working shaft location. Continuous monitoring shall take place during working periods.

19.8 Underground Evacuation

The Contractor shall develop and implement a plan for immediate underground evacuation in the event that the presence of toxic / inflammable gas is identified in the excavation or if the particular gas requirements to do meet with those identified in 6.4f. In such case the Contractor shall identify and take appropriate action to rectify such hazard prior to allowing work to recommence.