Australasian Society for Trenchless Technology

Standard for Microtunnelling & Pipe Jacking

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1.0 BACKGROUND

The Australasian Society Trenchless Technology has developed this Standard to assist industry users in Australia and New Zealand in utilising Microtunnelling and Pipe Jacking.

This document does not replace any existing relevant manuals or standards. It remains the user's responsibility to ensure that all relevant laws, standards and specifications are adhered to during the course of a Works.

Additional Microtunnelling and Pipe Jacking can be obtained from the Australasian Society Trenchless Technology website, they are:

- Guideline for (Horizontal Directional Drilling, Pipe Bursting, Microtunnelling and Pipe Jacking). Document number
- Specification for Microtunnelling and Pipe Jacking.
- National Utility Contractors Association Trenchless Assessment Guide, which is a web based tool that can be used for identifying trenchless construction methods that are suitable for a particular set of project attributes(i.e. diameter, length, depth, geological conditions, and so on).

NUCATAG

2.0 DEFINITIONS

A number of abbreviations and technical terms have been used in this standard:

ASTT - Australasian Society for Trenchless Technology, (www.astt.com.au).

Auger - A method of moving material by use of rotating helical fighted screw conveyor. The auger drill can also be used to excavate or drill through material.

Client - Person or company requiring the Works to be undertaken.

CCTV - Closed Circuit Television - The use of video cameras to visually inspect the installation. Often used where manual entry is not feasible or possible.

Contractor - Person or company undertaking the Works required.

Cutter Head - The part of the MTBM that is responsible for excavation. Contains the cutter face, which is responsible for breaking, cutting and otherwise removing earth to form the desired bore.

Environmental Impact Assessment - assessment of the possible impact—positive or negative—that a proposed project may have on the environment; considering natural, social and economic aspects.

Entry Shaft - Also called insertion or launching shaft. An entry point constructed for lowering the MTBM into the ground to start the MTBM process.

Exit Shaft - Also called reception shaft. An exist point in the ground where the MTBM exits when the MT process.

EPBM - Earth Pressure Balance Machine. Mechanized excavating equipment similar to the MTBM relies on excavated spoil to pressurise the machine and balance forces exerted upon it during excavation.

GBR- Geotechnical Baseline Report for all anticipated conditions.

GDR

MT - Microtunnelling. Method for installing an underground service conduit to a high accuracy using a Microtunnelling machine. Generally guided by a laser and most often used for the installation of gravity flow systems- ie sewer and stormwater or for other services where high accuracy is required.

MTBM - Microtunnelling Boring Machine. Mechanized excavating equipment that is remotely operated, steerable, connected to and thrust forward by the jacking system. The common range of pipe diameters is from 600mm to 1200mm.

NUCA TAG - National Utility Contractors Association Trenchless Assessment Guide.

Pipe Jacking - Method for installing pipe that serves as initial construction lining and tunnel support, installed for stability and safety during construction. Pipe is shoved forward (or jacked) as the tunnel is advanced. The pipe is jacked forward as the tunnel is advanced.

PTMT – Pilot Tube Microtunnelling. A MT method that involves drilling a pilot bore prior to tunnel excavation.

Shield - Often comprised of circular lining and the cutter head, protects the internal workings of the MTBM from ground water, spoil and debris. Sometimes referred to as part of the MTBM, the shield is pushed forward through the intended bore path by the jacked pipe.

Specification - A document that specifies, in a complete, precise, verifiable manner, the requirements, design, behaviour, or other characteristics of a system, component, product, result, or service and, often, the procedures for determining whether these provisions have been satisfied.

Spoil - Material removed in the course of excavation.

Standard - A document that provides uniform technical criteria, methods and processes. Often establishes an engineering norm.

Works - The project or task to be completed by the Contractor on behalf of the Buyer.

3.0 SYSTEM DESIGN CONCEPT AND PARAMETERS CONSIDERATION

Many MT and PJ design parameters and processes need to be tailored to suit each the specific Work requirements.

The desired properties of the tunnelling and pipe jacking Works shall include, but are not be limited, to the following:[1]

[a1]

(i) Perform all, required feasibility studies, Environmental Impact Assessment, site and works protection plans, geotechnical reports or (GBR), risk assessments and contingency planning;

(ii) Selection of suitable tunnelling rig and related MT system specifications including but not limited to shaft construction, thrust wall, anchoring system, spoil removal systems and jacking forces,

(iii) Proposed type of new pipe, including all relevant specifications

(iv) Details of each step taken including mobilisation, excavation, rig installation and operation procedures, drilling of pilot hole (if required), jacking operations, depth of cover, entry angle, groundwater, and any other pertinent data,

(v) Description of drilling fluid used, recycling system employed, rates of operation, pumps, control system and any other equipment used,

(vi) Proposed water supply for operation,

(vii) Boring pipe description (size, grade, quantity etc),same as (iii)

(viii) Proposed guidance and steering system, include limitations and access requirements,

(ix) Pressure monitoring and electric recording systems, if required,

(x) Boring Fluid mitigation plan including:

  (a) Description of fluid together with manufacturer's specifications material data sheets(MDS) and authorisation from appropriate agencies for the use of the fluid.

  (b) Emergency response plan with notification procedures, emergency equipment onsite, emergency containment plans and descriptions of cleaning and recycling systems.

  (c) Disposal plan complete with estimate of volume and composition of waste, method of containment, disposal methodology consisting of either a mix and bury onsite plan or an offsite disposal plan, with written authorisation from appropriate agencies (e.g. landfill owners).

4.0 MATERIALS AND EQUIPMENT

4.1 Equipment Requirements

The key criteria to be considered in the selection of the pipe process for any MT and PJ Work includes:

- Type of services to be apply for (i.e. potable water, sanitary, or storm sewer),
- Internal operating fluid pressure acting on the pipe,
- External ground and live loads acting on the pipe,
- External water load (groundwater) acting on the pipe,
- Method of installation,
- Material handling loads,
- Owners experience with the chosen pipe material,
- Construction costs, and
- Lifetime Expectancy.

Typical MT&PJ processes require the following component parts:

(1) 1 Excavation
- Borehole excavation method(MT or PJ),
- Thrust excavation method (Jacking system),

(2) 2. Guidance
- - Steering direction jacks control system, normally by laser,

(3) 3 Spoil removal
- - Spoil transportation system

(4) 4 Pipe installation
- - Trust system normally incorporating with hydraulic

4.2 Installation Method

4.2.1 Excavation Methods

4.2.1.1 Microtunnelling Boring Machine (MTBM)

An MTMB is a small-mechanised machine used for the excavation of boreholes. It normally operated by remote control. The method of excavation is by mechanical, rotating cutter head. The MBTM does not self propel, unlike a TBM. The thrust necessary to drive the MTBM farwards is generated by the pipe jacking system at the entry shaft.

MTBM's are used mainly for the installation of gravity pipelines, such as sanitary or storm sewers, and are normally no larger than 900 to 1200mm in diameter. MTBM's are used for this purpose due to the capability of the MTBM to achieve high accuracy in maintaining its gradient during the installation process. These machines are generally categorised into the related type of spoil removal system employed- pressurised, slurry or auger. The decision on which method to use for removal of the spoils is normally dependant on the groundwater level, productivity, length of drive, and costs.

4.2.1.2 Thrust excavation method (see above)

4.2.2 Spoil Removal Systems

4.2.2.1 Auger

The simplest form of MT spoil removal is the auger method. The spoil is transported from the cutter face to the collection point by a series of auger flights. The cutter face itself is often a large unit directional auger that excavates the earth. The spoil is transported from the face to a mud skip by a series of simple auger screw conveyors running through the newly jacked pipe. The mud skip, once full is hoisted to surface for emptying. This is normally done in the planned sequence related to the lowering of the new section of pipe into the drive shaft. The auger method is not suitable for harder, more granular soils, or dround condition with high water tables.

4.2.2.2 Slurry

This MT method uses a slurry mixture to pressurise the cutter head and to transport the spoil back to the entry shaft. This pressurised slurry is used to balance the soil or groundwater against the pressure on the cutter face.[2] The slurry is a mix of water and Bentonite and/or polymer additives. Slurry is pumped through to the cutter head via hoses running through the jacked pipe.

Spoil is transported suspended in slurry to the solids separation system. Here the spoil is removed by screening and filtration from the slurry. The filtered slurry is then recycled into the system.[3] Some slurry will be wasted due to carryover with the spoil. Disposed of this waste water will need to be arranged prior to commencing the Works. The slurry MT method is required if difficult ground conditions are present or if there are high groundwater heads (greater than 4m). Please refer to table 5.2 of Guideline for HDD, PB, MT and PJ.(document number)

4.2.2.3 Earth Pressure Balance

Earth Pressure Balance (EPB) is a mechanised boring method that utilises the excavated spoil to maintain the required pressure balance at the excavating head [a3]to prevent the ingress of any unwanted material to the shield. Excavation is carried out using an Earth Pressure Balance Machine (EPBM).

The excavated material is stored in a plenum chamber within the cutter head behind the cutter face. The spoil is transferred from the cutter face to the plenum chamber by a screw auger. The pressure is monitored using pressure sensors that are controlled by an operator who controls the EPBM's speed and discharge rate.[4] Conditioning agents may be required to achieve the desired pressurised material properties. These agents are often polymers that can be injected into the spoil via auger flights.[5]

The EPBM is thrust forward on jacked pipes. Spoil is removed via a screw auger system and transported to a mud skip at the entry shaft EPB is ideal for fine cohesive soils and soils with low ground water levels. However, difficulties will arise if the EPB method is attempted in hard rock or soils with boulders and cobbles as the cutter head may not be able to excavate those ground conditions.

4.2.2.4 Pilot Tube

Pilot Tube Microtunnelling (PTMT) is a process which begins with the drilling of a pilot borehole. The method of drilling is very similar to HDD. The major difference between HDD and PT related to the design of the steering head. In PT, the steering head is often shoe shaped, which provides a reaction force from the soils to help steer the front of the drill pipe. The PT drill head is pushed from the entry to the exit shaft.

After the pilot tube borehole is completed, the borehole is taken to final diameter using auger boring. The new pipe is then jacked into place behind the auger system. The pilot bore plots the intended course of the new pipeline and establishes line and grade.

PTMT has been successful in the installation of pipelines from 100mm to 1200mm diameter over drive lengths of up to 100m. This method is highly accurate, achieving alignment control to within 25mm. It utilises relatively low technology and works from small shafts, e.g. using existing access chambers. For these reasons, the construction costs associated with the PTMT method are generally lower than those associated with other MT and PJ methods.

4.2.2.5 Vacuum Extraction

The use of vacuum extraction for the removal of spoil from the cutting head is used in firm soil ground –clayey sands, clays- to rock. It is not suitable for soft soil below the water table. All ground water made by the microtunnel and the shaft needs to be managed by treatment, recycling, then on-site disposal or off-site disposal. Drilling in a downhill direction causes the ground water to flow to the face, which is undesirable and needs to be properly managed.

4.2.3 Jacking System

Jacking systems are normally comprised of hydraulic cylinders, a thrust wall, a thrust rig and bench. They are designed to be able to provide adequate thrust force for the tunnelling process. On longer and more complex drives, an interjacking system must be considered.

The pipe jacking system is limited by the amount of thrust that can exerted onto the first pipe section, adjacent to the thrust ring at the entry shaft. If the pipe cannot safely transmit the required thrust force without failure, then the pipeline requires additional intermediate jacking stations. Intermediate jacking stations are introduced in order to limit the effective length of drive and as a result, the thrust force required at the start of each section.

The intermediate drive station comprises of a steel frame housing a number of hydraulic cylinders, capable of producing the required amount of thrust force for the pipe station ahead. Each intermediate drive station is independently controlled.

4.2.4 Spoil Transportation System

The spoil transportation system shall be suitable for the MT or PJ technique being considered. The process involves the transportation and disposal of spoil from the excavation face to the entry shaft and then to the surface.

MT process has an automated means of transporting the excavated spoil away from the cutting head. The spoil system transports the spoils to a mud skip under the jacking frame. When the mud skip is full, it is hoisted to the surface to be emptied.

4.2.5 Guidance and Direction Control System

The guidance and directional control system most commonly used in MT is laser alignment. Laser guidance systems give accurate line and gradient. The laser installed in the entry shaft creates the point of reference. A laser target installed in the MTBM gives a target reference. Both active and passive laser targeting guidance systems are used in MT. In passive manual control laser targeting systems, a CCTV monitors the target grid mounted in the steering head, and gives visual feed back to an operator at a control panel who takes appropriate corrective action. Active automatic systems use photocells installed on the target to provide digital feedback to the controls.

There must not be any obstructions between the reference laser and target, in order to achieve the most accurate results. The active steering guidance system must be able to relay (as a minimum) the target position relative to the reference, including roll, inclination, and attitude. Additional information such as rate of advance, installed length, thrust force, and cutter head torque are sent to the control room on the surface.[3]

4.2.6 Jacking Pipe

The jacking pipe shall be able to resist the high jacking forces generated during the process. The pipe external surfaces must be smooth uniform ,watertight joints as per the manufacturer's. All joints should be watertight in accordance with the manufacturer's specification. Pipe ends must be square and smooth and pipe joints must not extend radially past the main barrel of the pipe, to ensure loads are evenly distributed and to minimize jacking friction.

The deflection of the pipe joint face shall not normally exceed 0.5 degrees. For curved drives, if required, cushioning materials are used at the joints[7] allowing deflections of over 1 degree to be achieved.

Considerations for jacking pipe selection include size and type of pipe, soil conditions, suitability for chosen MT method, and final use of the completed pipeline. Types of jacking pipes currently in use in MT are shown in Table 4.1:

PIPE MATERIAL	AVAILABLE DIAMETER	PIPE SECTION LENGTH
Reinforced Concrete Pipe (RCP)	300 to 3600 mm	0.9 to 3 m
Glass-fibre Reinforced thermosetting resin Pipe (GRP)	300 to 2700 mm	3 to 6 m
Vitrified clay pipe	150 to 1200 mm	0.9 to 3m
Ductile Iron Pipe	100 to 600 mm	Up to 6m
Steel Pipe	Up to 3600 mm	Up to 12 m

TABLE 4.1 - DIAMETER RANGES OF VARYING PIPE MATERIALS[7]

4.3 Entry and Exit Shaft

Prior to the commencement of any MT or PJ Work, an entry and an exit shaft needs to be properly designed and excavated. The size of these shafts can range from small pits to large excavations and are largely dependant on the sectional dimensions of the selected pipe to be installed and selected equipment specifications. The manufactures specifications for minimum shaft diameter should be used as a guideline. Tolerances to allow the MT or PJ process to be carried out safely must be accommodated. The shaft foundation must be adequately designed to withstand the masses and forces expected for the process.

All the equipment that will be utilised, both in the shafts, and externally, including spoil disposal and slurry treatment, must define the full MT or PJ process footprint.

5.0 INSPECTION AND TESTING

Pipe inspection and testing shall be performed to client's specification and the amount of testing required will be agreed to prior to commencing the Works.

The new pipe will be hydrostatically pre-tested prior to installation. Post installation hydrostatic pressure tests will also be performed on the pipeline.

CCTV inspection should be undertaken to ensure the internal pipe is structurally sound. Any defects that may be structurally detrimental to the completed installation shall be repaired or replaced.

Individual pipe joints shall be tested using low-pressure air methods in accordance with ASTM C828.

6.0 CONSTRUCTION

6.1 Construction Sequencing and Programming

All the necessary studies and assessments shall be completed prior to commencing any MT or PJ construction Works.

The construction sequence shall be as follows:[3]

[a4]

(i) Pre-construction planning, environmental assessments, and public relation initiatives and consultations;

(ii) Project sign off by the client;

(iii) Setting up controls and any auxiliary equipment;

(iv) Excavation of the reception and insertion pits;

(v) Set up jacking frame and hydraulic jacks;

(vi) Lower MT or PJ equipment into the driving shaft;

(vii) Set up guidance system;

(viii) In the Pilot tube process, the pilot tube is installed behind the steering head. The steering head bores from the drive shaft to the reception shaft. A cutter head and casing fitted with an auger inside are used after the steering head in the same manner to enlarge the hole if needed, and the product pipe is jacked through the tunnel;

(ix) In MT systems involving slurry, there are requirements of setting up slurry lines, pumps and hydraulic hoses;

(x) Progress MT or PJ method using hydraulic jacking system;

(xi) Disconnect Slurry lines and hoses, retract jacks and lower a new pipe into the shaft;

(xii) In an Auger process the mud skip is emptied as required, in other process spoil is continually removed to the surface;

(xiii) Reconnect slurry lines and hoses, jack new pipe into position;

(xiv) Repeat steps (viii) – (xi) until the MT or PJ method reaches exit pit;

(xv) Pipe inspection and testing;

(xvi) Remove MT or PJ method equipment, jacking frame and ancillaries from entry and exit pits;

(xvii) Dispose of any slurry or spoil accordingly;

(xviii) Grout annular space between exterior pipe surface and the borehole;

(xix) Restore site to pre-construction condition or better;

(xx) Project completion.

7.0 REFERENCES

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