ASTT

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).
- 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).

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 flighting, a 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.

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.

Exit Shaft - Also called reception shaft.

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 other wise removing earth from the desired bore path.

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

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 shoved forward by the jacked pipe or mechanical rods.

NUCA TAG - National Utility Contractors Association Trenchless Assessment Guide.

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

PTMT - 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.

TBM - Tunnel Boring Machine. Mechanized excavating equipment that is steerable, guided and articulated, connected to and pushed by the jacked pipe.

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

3.0 SYSTEM DESIGN CONCEPT AND PARAMETERS

Many MT and PJ design parameters and process 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]

(i) Perform all, required feasibility studies, environmental surveys, site and works protection plans, geotechnical reports, 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,

(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),

(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) 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 and onsite disposal, and a disposal plan 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:

- Service fluid type (i.e. potable water, sanitary, or storm sewer),
- Internal operating fluid pressure,
- External ground and live loads,
- External water load (groundwater),
- Method of installation,
- Material handling loads,
- Owners history with pipe material,
- Construction costs, and
- Lifetime Expectancy.

Typical processes require the following components:

- Installation method (MT or Pipe Jacking),
- Jacking system,
- Spoil transportation system,
- Guidance and direction control system,
- Jacking pipe.

4.2 Installation Method

4.2.1 Microtunnelling Methods

<u>Microtunnelling Boring Machine (MTBM)</u>

An MTBM can be described as a mechanised excavating piece of equipment that is remotely operated, steerable, connected to and shoved forward by the jacked pipe. It can have a variety of cutter heads, shields, and soil excavation methods, applicable to the type of terrain likely to be encountered.

MTBM's are used mainly for the installation of gravity pipelines, such as sanitary or storm sewers, and is normally no bigger than 900 to 1000mm in diameter. These machines are generally categorised into two types, being either 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.

Auger

The simplest form of MT is the auger MT method, where the spoil is transported from the cutter face to the surface 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 chain of simple auger screw conveyors running through the newly jacked pipe. The mud skip, once nearing capacity, is emptied as a new segment of pipe is lowered into the drive shaft. As the cutting head is not pressurised, the auger method is not suitable for harder, more granular soils, or soils with high water tables.

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 filtered from the slurry and the slurry is recycled into the system.[3] Slurry disposal arrangements will need to be made 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).

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 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 and can be injected into the spoil via auger flights.[5]

The EPBM is pushed forward on jacked pipes, which simultaneously form the new pipeline. Spoil is removed via a screw auger system and transported to a mud skip, which is periodically emptied as new pipe segments are inserted. 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 grounds or soils with boulders and cobbles.

Pilot Tube

Pilot Tube Microtunnelling (PTMT) utilises concepts similar to Horizontal Directional Drilling (HDD), with the drilling of the pilot tube. This provides a pilot bore which plots the intended course of the new pipeline and establishes line and grade. The steering head is often shoe shaped, which provides a reactant force from the soils to help steer the front of the drill pipe.[7] The head is pushed from the entry to the exit shaft. After the boring of the pilot tube, excavation for the product pipe is carried out using auger boring and casings. The product pipe is then jacked into place behind the auger system.

This method is highly accurate, achieving alignment control to within 25mm.[7] PTMT has been used to install pipelines with exceptional accuracy to over 100m, and with diameters ranging from 100mm to 1200mm.[6] 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.

<u>Vacuum Extraction</u>

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 recycling, treatment, then on-site disposal or off-site disposal. Drilling in a downhill direction causes the ground water to flow to the face which also needs to be managed.

4.2.2 Jacking System

Jacking systems are comprised of jacks and a jacking frame. They are designed to be able to provide the level of pressure required by the tunnelling process. On longer and more complex drives, an interjacking system must be considered.

An interjack is a set of hydraulic jacks within a steel frame that is inserted at specific points into the pipe string. Each interjack is independently controlled. Incorporation of interjack systems dramatically reduces the potential for pipe failure by separating the pipe string into smaller lengths.

4.2.3 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 where it is relocated to the surface.

An MT process has an automated means of transporting the excavated spoil away from the cutting head. Often the spoil system transports the spoils to a mud skip under the jacking frame. When the mud skip is nearly full, it is hoisted to the surface to empty. If the MT process involves inserting the new pipe in segments, then this would occur when the mud skip emptying process is carried out, effectively reducing further pauses in the operation.

4.2.4 Guidance and Direction Control System

Laser guidance systems (most commonly used) give accurate line and grade. The laser installed in the entry shaft creates a point of reference, whilst 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 laser targeting systems, a CCTV monitors the target grid mounted in the steering head, and gives visual feedback to an operator at a control panel. Active systems use photocells installed on the target for digital feedback.

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 role, inclination, attitude, rate of advance, installed length, thrust force, and cutter head torque.[3]

4.2.5 Jacking Pipe

The jacking pipe shall be able to resist the high jacking forces. The pipes must also have smooth uniform surfaces and watertight joints as per the manufacturer's specifications. Pipe ends must be square and smooth and pipe joints must not extend past the main barrel of the pipe, to ensure loads are evenly distributed and to reduce jacking friction.

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

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 shaft diameter must be sufficient for the MT or PJ method chosen, and must meet the equipment manufacturer's area specifications.

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 pressure tests will also be performed on the pipeline.

CCTV inspection should be undertaken to ensure the internal pipe is integrally 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 Works.

The construction sequence shall be as follows:

(i) Pre-construction planning, environmental assessments, and public relation initiatives/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 requirement 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, in other process spoil is 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 tunnel;

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

(xx) Project completion.

7.0 REFERENCES

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