Technical Specification

Transport and Main Roads Specifications MRTS64 Driven Tubular Steel Piles (with reinforced concrete pile shaft)

November 2020

Queensland Government

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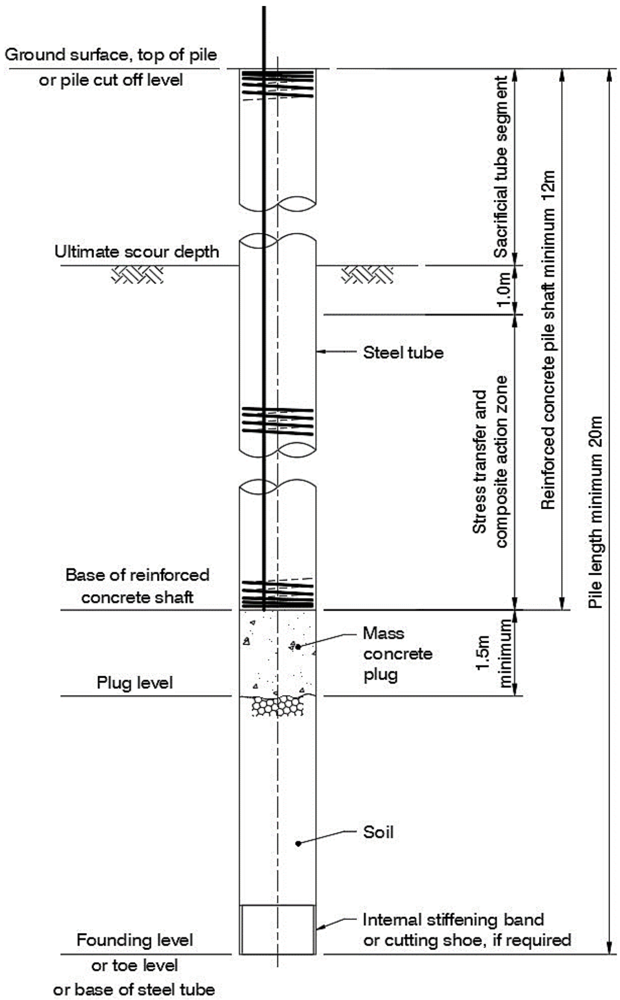
1 Introduction

This Technical Specification applies to the construction of driven tubular steel piles with reinforced concrete pile shafts. These are essentially large diameter (not less than 1.2 m) thick walled (≥ 20 mm thick) steel tubes, driven to a predetermined level (Founding Level), partially excavated, and capacity-checked. A short mass concrete plug is then cast from the base of the excavation (Plug Level). A reinforced concrete pile shaft is then cast from the top of the plug to the top of the pile (typically the underside of pile cap or headstock).

Load transfer between the steel tube and the reinforced concrete shaft is via adhesion and shear connection between the concrete and steel, and between the steel tube and the soil by friction. Design axial capacity of the pile is based primarily on the friction between the steel tube and the ground (refer to Transport and Main Road's *Geotechnical Design Standard* for details). The concrete plug does not contribute to the design geotechnical capacity of the pile in end bearing. Steel tubes shall be driven to the required level. Rotating or vibrating the steel tubes to level is not acceptable. Figure 1 shows a typical schematic diagram of a driven tubular steel pile.

Figure 1 – Schematic diagram of a steel tubular pile



The intention of this pile construction is that the reinforced concrete pile shaft is cast in dry conditions. Wet conditions for placing the reinforced concrete pile shaft shall only be permitted when all reasonable methods to achieve dry conditions have been unsuccessful. This requirement does not apply to the casting of the mass concrete plug.

This pile type may be considered in situations where the depth to competent rock is such that it is not practical to extend the steel tube to competent rock and then form a rock socket to construct an MRTS63 *Cast-In-Place Piles* compliant pile. Hence for this reason that a minimum reinforced concrete shaft length of 12 m is included in this specification. This will result in an effective minimum steel tube length in the ground of 20 m.

It is not a requirement to drive the steel tube to competent rock (although this may occur), rather the pile capacity is achieved essentially through friction between the steel tube and the soils, commencing from a point 1 m below the base of the ultimate scour level to the base of the steel tube. Where design and geotechnical analysis indicates that competent rock may be encountered the use of a cast in place pile conforming to MRTS63 *Cast-In-Place Piles* is the preferred option.

Steel tubular piles are not recommended in situations where the pile is used to resist essentially bending moment loads rather than vertical loads. In such situations, typically sign gantries and similar structures, MRTS63A *Piles for Ancillary Structures* type pile is more appropriate.

The following foundation methods / types are not permitted for use on Department of Transport and Main Roads projects:

a) piles consisting of driven, closed-end tubes that are later filled with concrete except in some specific marine applications

b) piles using enlarged bases formed by extruding a concrete plug from the base of a liner with an internal drop hammer

c) piles constructed with bentonite or polymer slurry, and

d) the use of temporary liners that are subsequently removed.

This Technical Specification shall be read in conjunction with MRTS01 *Introduction to Technical Specifications*, MRTS50 *Specific Quality System Requirements* and other Technical Specifications as appropriate (refer Clause 3).

The requirements for the manufacture of steel tubular piles include the use of suppliers and products for the items listed in Table 1 that are registered by Transport and Main Roads.

Table 1 – Items requiring the use of registered suppliers and products

Clause	Category of Work
7	Reinforcing steel
8	Steelwork fabricator
12	Reinforcing spacers

For information regarding registered suppliers and approved products for the above items refer to the departmental website https://www.tmr.qld.gov.au/business-industry/Business-with-us/Approved-products-and-suppliers or email TMRStructuralMaterials@tmr.qld.gov.au.

2 Definition of terms

The terms used in this Technical Specification shall be as defined in Clause 2 of MRTS01 *Introduction to Technical Specifications*.

Terms listed in Table 2 are also applicable to this Technical Specification.

Table 2 – Definitions of terms

Term	Details
AINDT	Australian Institute of Non-Destructive Testing
base of shaft	The base of the reinforced concrete pile shaft. This level corresponds to the top of the mass concrete plug.
cleanliness inspection	An inspection typically involving the lowering of a camera down the pile to confirm that the top of the concrete plug is clean and free of debris and that the internal wall of the steel tube is clean, particularly in the load transfer and composite action section and that all load transfer (shear connection) devices are undamaged and clean.
competent rock	Rock material generally moderately weathered or better, into which a socket could be formed.
founding level (or pile toe level)	The final level of the bottom of the steel tube at the time of pouring the pile shaft. The design founding level is the design level of the same point.
High Strain Dynamic Testing (PDA)	A device, commonly known as a PDA, which monitors a range of parameters including, but not limited to, hammer input energy, pile penetration per blow, pile temporary compression, and stress wave parameters.
steel tube	A heavy walled steel tube which can be driven to a predetermined depth and capacity and which contains a stress transfer and composite action section over all or part of its internal length and is adequately reinforced to take the stresses imposed during driving.
load transfer section (external)	That section of the steel tube between a point 1 m below the base of the ultimate scour zone to the toe of the steel tube where loads are transferred from the steel tube to the surrounding soil or weathered rock by friction.
load transfer section (internal)	The internal wall of the steel tube from the bottom of the concrete plug to the toe of the steel tube, where loads are transferred by friction from the steel tube to the soil or weathered rock contained within the steel tube.
plug	A short mass concrete plug, not less than one pile diameter long, nor more than two pile diameters long cast towards the base of the pile which separates the soil contained within the steel tube following driving and partial excavation from the pile shaft.
plug level	The level of the base of the plug at the time of casting the pile. The design plug level is the same level shown on the design plans of the pile.
PM	Pile Monitor, a device which monitors the blows of the pile hammer and records at least the following pile driving parameters: hammer input energy, pile penetration per blow, pile temporary compression.
rake	For non-vertical piles, the deviation of the pile from the vertical. Rake may be in the plane of the pier / abutment, or at some specified orientation from the plane of the pier / abutment.
shaft	A reinforced concrete shaft cast within the steel tube (full diameter of the steel tube) from the top of the plug to the top of the pile.

Term	Details
toe of steel tube	The level of the toe of the steel pile tube shown on the design plans for the pile.
stress transfer and composite action zone	The designated section of the steel tube which has a number of load transfer (shear connection) devices welded into the inner surface of the steel tube to facilitate the transfer of pile loads from the reinforced concrete pile shaft to the steel tube. Steel tubes may be partially or completely manufactured out of ribbed steel in which case the potential stress transfer section may extend to the full length of the pile. The drawings shall show the design length and location of the stress transfer section and the minimum length of the stress transfer section.
top of pile	Generally, the soffit of the pile cap or headstock. Where a pile changes from a pile to a column, the top of the pile can be considered as being the point where the design changes from a pile to a column.
top of soil transfer	The point, taken as 1 m below the base of the ultimate scour level below which loads are transferred from the steel tube into the soil by friction.
f_{sy}	Yield stress for the steel used to manufacture the steel tube.

3 Referenced documents

Table 3 lists documents referenced in this Technical Specification.

Table 3 – Referenced documents

Reference	Title
AS 1379	*Specification and supply of concrete*
AS 1579	*Arc-welded steel pipes and fittings for water and wastewater*
AS 2159	*Piling – Design and installation*
AS 2207	*Non-destructive testing – Ultrasonic testing of fusion welded joints in carbon and low alloy steel*
AS 5100.3	*Bridge design, Part 3: Foundation and soil-supporting structures*
AS ISO 9934.1	*Non-destructive testing - Magnetic particle testing – Part 1: General principles*
AS ISO 9934.2	*Non-destructive testing - Magnetic particle testing, Part 2: Detection media*
AS ISO 9934.3	*Non-destructive testing - Magnetic particle testing, Part 3: Equipment*
AS ISO/IEC 17025	*General requirements for the competence of testing and calibration laboratories*
AS/NZS 1554.1	*Structural steel welding, Part 1: Welding of steel structures*
AS/NZS 3678	*Structural steel – Hot-rolled plates, floorplates and slabs*
MRTS01	*Introduction to Technical Specifications*
MRTS50	*Specific Quality System Requirements*
MRTS56	*Construction Surveying*
MRTS63	*Cast-In-Place Piles*
MRTS63A	*Piles for Ancillary Structures*
MRTS68	*Dynamic Testing of Piles*

Reference	Title
MRTS70	*Concrete*
MRTS71	*Reinforcing Steel*
MRTS71A	*Stainless Steel Reinforcing*
MRTS78	*Fabrication of Structural Steelwork*
Z17	*Recommended Practice: Tremie Concrete for Deep Foundations.* Concrete Institute of Australia, 2012
–	*Geotechnical Design Standard (minimum requirements)* – Transport and Main Roads
–	*Technical Note 11 Commentary on the Structural Steel Welding Standard AS/NZS 1554* – Weld Australia (2018)
–	*Welding Steels Without Hydrogen Cracking*, 2nd Edition Abington Publishing and ASM International – Bailey N., Coe F.R., Gooch T.G., Hart P.H.M Jenkins N, Pargeter R.J. (1973)
–	*Workplace Health and Safety Act,* 2011

4 Quality system requirements

4.1 Hold Points, Witness Points and Milestones

General requirements for Hold Points, Witness Points and Milestones are specified in Clause 5.2 of MRTS01 *Introduction to Technical Specifications*.

The Hold Points and Milestones applicable to this Technical Specification are defined in Table 4.1. There are no Witness Points defined.

Table 4.1 – Hold Points, Witness Points and Milestones

Clause	Hold Point	Witness Point	Milestone
7.2	1. Acceptance of procedure for construction, excavation, inspection, certification and concreting of piles		Submit procedure for construction of piles (28 days prior to driving steel tubes)
8.1	2. Welding procedures for shop fabrication of steel tubes		
8.2.1	3. Welding procedures for field splice welding of steel tubes		
8.2.2	4. Submission of non-destructive weld test reports for field splice welding of steel tubes		
9.1	5. Approval of steel tube driving procedure		
11.1 13.1	6. Certification of pile capacity and cleanliness of base and steel tube wall. Approval to insert reinforcement cage		
11.9.3			Supply of a suitable camera for cleanliness inspection

Clause	Hold Point	Witness Point	Milestone
13.1	7. Approval of the tremie for underwater concreting including continuous supply and placing of concrete		

4.2 Construction procedures

The Contractor shall prepare documented procedures for all construction processes in accordance with the quality system requirements of the Contract.

Construction procedures for those activities listed in Table 4.2 shall be submitted to the Administrator in accordance with the quality system requirements of the Contract.

Table 4.2 – Construction procedures

Clause	Procedure
7.2	Prebore depth and diameter.
7.2	Driving of steel tubes including details of the pile frame, pile hammer and packing materials. Note where the proposed hammer differs from that specified in Annexure MRTS64.1 the contractor shall provide revised set calculations for the proposed hammer.
7.2	Monitoring procedures, during at least the last 10 blows to ensure that the pile has adequate geotechnical capacity.
7.2	Procedures for cleaning and excavating the pile, to the required depth and casting the mass concrete plug.
7.2	Procedures for cleaning the pile, particularly in the stress transfer and composite action zone and the base of the shaft.
7.2	Construction of the reinforced concrete pile shaft in dry conditions, cleaning, inspection and certification of the cleanliness of the steel tube and concreting. Modified procedure for pouring the reinforced concrete pile shaft in wet conditions, including inspection and certification of the cleanliness of the steel tube and concreting.
13.5.3	Procedure for placing concrete underwater with a tremie including continuous supply of concrete.

4.3 Lot size for testing

The minimum lot size for cast-in-place pile work covered by this Technical Specification is each pile.

4.4 Conformance requirements

The conformance requirements which apply to each pile for work covered by this Technical Specification are summarised in Table 4.4.

Table 4.4 – Conformance requirements

Clause	Conformance
8	Damage to steel tubes
9.1	Pile capacity and foundation level for each pile
9.1	Pile founding level, damage, location and tolerances
9.2	Hard driving and buckling of steel tube

Clause	Conformance
9.7	Failure of the mass concrete plug
10	Pile tolerances
11.1	Supply of PDA (Pile Driving Analyser) and PM (Pile Monitoring) data and analysis. Minimum of one pile per pier or abutment.
11.4	Position, length and cleanliness of the transfer zone and base of the shaft
13.5.3.2	Resolution of the issues following the tremie being pulled out
MRTS70	Concrete conformance

5 Assessment of foundation information

In assessing the foundation information provided in the tender documents, the Contractor's attention is drawn to the provisions of the Contract with respect to:

a) the need for the Contractor to be self-informed of all available information pertaining to the physical conditions upon and below the surface of the Site, and

b) latent conditions.

> The borehole drilling logs, cores and the associated reports should be available for the Contractor to make an assessment of the nature of the material when determining the equipment and plant needed.
>
> The borehole data represents subsurface information at a specific location only. Information on strata between boreholes is the subject of interpretation and also of the inherent variability of soil and rock strata. Departures from the strata conditions indicated by the borehole information are inevitable.
>
> In regard to the available foundation information, this will generally include items other than just those included in the contract documents, for example; further reports, test results and samples. It is the responsibility of the Contractor to make their assessment based on all the information not just that which is bound into the contract documents.
>
> In regard to latent conditions the Contractor needs to be aware that these only apply where a material difference exists between what should reasonably have been anticipated by the Contractor and what is found on the Site.

The Contractor shall be deemed to have allowed for the departures as could reasonably be expected. This statement applies particularly in regard to location of the mass concrete plug and achieving the minimum transfer length in the reinforced concrete pile shaft.

6 Design

This pile type should not be considered as a 'normal' or 'standard' pile type to be used for bridge applications. It is a relatively expensive pile type to construct. As such it should be limited to situations beyond the limits for a MRTS63 *Cast-In-Place Piles* compliant pile. The following limitations have been placed on its use. Note the quoted figures are all minimum values.

The required values shall be determined during the pile design process:

a) Minimum reinforced concrete pile shaft length: 12 m, including at least 5 pile diameters below the ultimate scour level.

b) Minimum mass concrete plug length: one pile diameter or 1.5 m, whichever is greater.

c) Minimum steel tube length in the ground of 20 m.

d) Minimum steel tube diameter of 1.2 m.

e) Minimum length of stress transfer and composite action zone: 5 m.

f) Minimum steel tube thickness (excluding cutting shoe if required): 20 mm. Corrosion of the steel tube shall be assessed using AS 2159 and AS 5100 whichever provides the highest allowance for corrosion. A minimum steel tube thickness of 10 mm shall remain after 100 years of corrosion for the steel tube below the top of the stress transfer and composite action zone. Below the level of the concrete plug corrosion is to be considered on the inside and outside of the steel tube.

g) Thickness of steel tube not to be considered in the design of the reinforced concrete shaft.

h) Cutting shoe, if required, shall be placed internally to the steel tube (this is the reverse of the requirements for a MRTS63 *Cast-In-Place Piles* steel liner).

i) External friction between steel tube and soil or weathered rock shall be limited to the length of the tube from 1 m below the design ultimate scour level to the toe of the pile.

j) Internal friction between the steel tube and soil or weathered rock shall be limited to the length of the steel tube from the bottom of the concrete plug level to the toe of the pile. The internal skin friction per unit area shall be no more than 50% of the external skin friction per unit area if no cutting edge is used and no more than 25% if a cutting edge is used.

k) The geotechnical axial pile capacity provided by the combined external skin friction discounting the friction from the surface to 1 m below the design ultimate scour level, and the internal skin friction combined after the excavation of the internal soil to the bottom of the concrete plug level shall be no less than 85% of the geotechnical axial pile capacity. If for some reason the pile is driven to competent rock and the skin friction capacity is less than 85% then the designer shall be consulted and the pile may need to be redesigned and converted to a pile type in accordance with MRTS63 *Cast-In-Place Piles* or MRTS63A *Piles for Ancillary Structures* depending on the application.

l) The self weight of the reinforced concrete shaft and the steel tube shall be considered when calculating the geotechnical pile capacity both in design and for determination of the geotechnical capacity of the completed pile. Further information on this calculation can be found in the *Geotechnical Design Standard*. The required pile capacities given in Annexure MRTS64.1 shall clearly state whether the self weight of the pile has been included or excluded.

m) The grade of concrete used for the concrete plug shall be the same as that used for the reinforced concrete pile shaft. The contribution of the concrete plug in end bearing is not to be considered in calculating the geotechnical capacity of the pile.

n) The load transfer devices (shear connectors) shall be a square steel section minimum 10 mm by 10 mm or round steel section minimum of 10 mm diameter, fillet welded on both sides to the inner surface of the steel tube. Gaps can be designed in the shear connectors to allow passage of reinforcing spacers. Cover to reinforcement can be reduced at the location of the shear connectors from the design cover.

o) The design scour level for the pile shall be the ultimate limit state design scour level noting that this scour level may not necessarily occur at the highest flood level.

The design of these piles shall conform to the relevant requirements of *Geotechnical Design Standard* and AS 2159 with the *Geotechnical Design Standard* taking precedence.

7 Materials and processes

7.1 General

Materials and processes shall conform to the following standards:

a) Steel for steel tubes - as stated on the Drawings but not less than AS/NZS 3678 Grade 250.

b) Structural steel welding AS 1554.1 - all welding shall be designated SP.

c) Reinforcing steel - MRTS71 *Reinforcing Steel*, and

d) Concrete - MRTS70 *Concrete* together with Clause 13 of this Technical Specification.

All reinforcing steel shall be sourced from a Transport and Main Roads registered supplier of reinforcing steel (refer to Clause 1).

7.2 Construction procedures

The Contractor shall submit a procedure for construction, inspection and certification of the piles. The procedure shall give details of the following:

a) Any preboring proposed shall be detailed and the reasons for such preboring stated. The material is to be stable and safe for preboring. The procedure shall detail the method of grouting the gap between steel tube and the prebored hole from the base up. The depth of preboring shall not exceed that shown on the drawings, or 3 m if no depth is shown on the drawings.

b) The proposed method of driving, and the equipment to be employed, including the means of holding the steel tube in position during the driving shall be detailed. The proposed method shall also include an analysis of the maximum hammer input energy of the proposed hammer system, driving stresses to ensure buckling of the steel tube is avoided. Note that the use of vibration, oscillation or rotation is not accepted for the installation of the steel tube in the ground.

   Note details of the design hammer are included in Annexure MRTS64.1, should the contractor use a different hammer from that listed in the Annexure, the contractor shall provide to the Administrator revised set and driving stresses appropriate for the alternative hammer system.

> Procedures which could be considered include limiting the height of drop of the hammer or limiting the mass of the hammer.
>
> Alternative methods of inserting the steel tubes such as vibration or rotation are not acceptable as they have been shown to decrease the geotechnical capacity of this pile type.

c) The proposed method for excavating the pile to the required depth.

d) The proposed method of plug construction including details of equipment to be employed.

e) A statement of the information required to facilitate the certification of pile capacity.

f) Procedure for monitoring and certification of the pile capacity including the methods of cleaning and inspection. The procedure shall include the methods of inspection (or certifying cleanliness of the steel tube), to be used for both dry and wet piles. How the Contractor proposes to ensure that an adequate length of transfer zone is available should the plug be cast at a different level to that shown on the drawings.

g) The equipment and methods for supplying and placing concrete in dry conditions and underwater if seals cannot be achieved including full details of the tremie and the method of operation.

The completed procedure shall be submitted to the Administrator at least 28 days prior to the date for driving of the steel pile shafts. **Milestone** Work shall not commence until acceptance from the Administrator has been received in writing. **Hold Point 1**

8 Shop fabrication and on Site splice welding of steel tubes

8.1 Shop fabrication

Steel tubes shall be fabricated in accordance with MRTS78 *Fabrication of Structural Steelwork*, by a Transport and Main Roads registered steel fabricator (refer to Clause 1).

Steel tubes shall conform to the dimensions and thicknesses shown on the Drawings.

Steel tubes shall be fabricated using welded plate segments with all welds either perpendicular to or parallel to the long axis of the steel tube. The leading edge of the steel tubes shall be reinforced as shown on the Drawings.

The inside diameter of the steel tube shall not be less than the nominal diameter shown on the Drawings, nor shall the out-of-round tolerance exceed 5% of the diameter of the steel tube. The outside circumference of the steel tube shall not be less than the nominal circumference calculated from the pile diameter and the steel tube thickness. Steel tubes shall not exceed a bow of 1% of the length of the pile in any direction. Steel tubes shall be free of any internal steps or ridges, other than the shear connectors, which may interfere with drilling equipment, buckets or personnel during inspections.

Welding shall be carried out in accordance with the provisions of AS/NZS 1554.1. All welding shall be SP category. A Welding Procedure Specification shall be submitted to the Administrator for approval prior to welding steel tubes. **Hold Point 2**

All longitudinal and transverse steel tube welds shall be made with full penetration butt welds carried out using the submerged arc process. The outside surface of welds perpendicular to the long axis of the tube shall be finished flush with the surface of the tube either through the welding process or by mechanical means such as grinding. The finished surface of the weld (reinforcement) shall not protrude or exceed 1 mm above the outside surface of the steel tube.

Steel tubes shall be supplied to the Site in the longest lengths possible, commensurate with the overall length of the pile, transport facilities available, and the steel tube driving process.

The load transfer devices (shear connectors) shall be welded to the inside of the steel tubes and the attachment of the stiffening bands or cutting shoes shall all be conducted in the fabrication shop.

Steel tubes shall be stored and transported in such a manner as to prevent damage. Damaged steel tubes shall be repaired or replaced by the Contractor at no additional cost to the Principal. **Nonconformance**

8.2 On Site splice welding of steel tubes

8.2.1 Requirements

Field splice welding of steel pile tubes to be conducted in accordance with AS 1554.1 and the following additional requirements:

a) A Welding Procedure Specification shall be submitted to the Administrator for approval prior to splice welding steel tubes. **Hold Point 3**

b) Welds shall be Category SP full penetration butt welds.

c) The weld shall be finished flush with the outside of the steel tube either through the welding process or by mechanical means such as grinding. The finished surface of the weld (reinforcement) shall not protrude or exceed 1 mm above the outside surface of the steel tube.

d) Individual steel tube segments shall be rotated 90 degrees to each other so that longitudinal welds along the steel tube are staggered.

e) Hydrogen controlled welding process and consumables shall be used (i.e. Classification H10 or better). The hydrogen content of the deposited weld metal shall not exceed 10 ml of H_2 per 100 g demonstrated by a material test certificate for the welding consumable.

f) Welding consumables to be kept clean and dry and stored in accordance with the manufacturer's instructions.

g) Heat input from the welding process shall not exceed 3 kJ/mm.

h) Metal surfaces to be welded shall be clean, dry and free of condensation. Welding not permitted where the metal temperature is below 10°C.

i) The welder, the consumables and the working area to be protected from wind and rain. Gas shielded welding not permitted where wind speeds exceed 10 km/h.

j) No accelerated cooling of the welding shall be permitted.

k) Time delay between end of welding and commencement of non-destructive testing to be as listed in Clause 8.2.2 below.

l) Non-destructive testing shall include Visual Inspection, Ultrasonic Testing (AS 2207) and Magnetic Particle Testing (AS ISO 9934).

m) Non-destructive testing shall only be performed by NATA registered laboratories with third party accreditation to AS ISO/IEC 17025 with a NATA endorsed test report to be produced. All non-destructive examination reports shall be prepared as required by AINDT qualified and certified non-destructive testing technicians. The report shall identify both the technician responsible for carrying out the test and the technician responsible for the test report. AINDT details to be included on the test report. The report is to include a photograph of the weld, including time and date of completion of welding and time and date of inspection.

n) Welds containing imperfections exceeding the limits in Table 6.2.1 and Table 6.2.2 of AS/NZS 1554.1 shall be repaired. The full length of the repaired weld together with 300 mm of weld on each side of the repaired weld shall be non-destructively tested.

8.2.2 Prequalification

Field splice welding of pile tubes shall be prequalified for each welder by non-destructive testing of the first splice weld on the project commencing no less than 48 hours after the weld has cooled to ambient temperature. The first splice weld may be conducted insitu on an actual pile splice to be incorporated into the works, or on sections of tube not less than 1 m in length, of the same diameter and material grade and thickness as the pile tubes located in representative field conditions which are not to be incorporated into the works. If no hydrogen induced cracking is found from the non-destructive testing of the first splice weld, then the welder and welding process are deemed to be prequalified for the project provided there is no change in the steel material or grade. If hydrogen induced cracking is found, then the welder and welding process is deemed to not be prequalified.

Test requirements for a welder and welding process that is not prequalified is for all further field splices to be non-destructively tested with the testing commencing no less than 16 hours after the weld has cooled to ambient temperature.

Test requirements for a welder and welding process that is prequalified is for all further field splices to be non-destructively tested with 10% of the welds to be tested no less than 16 hours after the weld has cooled to ambient temperature, and the remaining 90% of welds tested after the weld has cooled to ambient temperature but not less than two hours from the completion of welding. If hydrogen induced cracking is found in any of the splice welds, then the prequalification process needs to be repeated or the contractor defaults to the non-prequalified testing process.

Changes to the welder, welding process, welding consumables, steel grade, or steel thickness shall require the prequalification process to recommence.

All test reports to be submitted to the Administrator for approval prior to any further driving of steel tubes. **Hold Point 4**

> The outside surface of welds perpendicular to the long axis of the steel tubes made in the fabrication shop and any on Site splice welds are finished flush with the outside of the tube so that there is no loss in the friction between the outside surface of the steel tube and the surrounding ground during the driving process which may reduce the geotechnical capacity of the pile.
>
> Non-destructive testing of splice welds is required as in this pile type the steel tube is a structural component of the pile compared to an MRTS63 Cast in place pile or an MRTS63A pile where the steel tube is effectively a sacrificial component and is not part of the permanent structure.
>
> Prequalification is only valid for the project duration as different projects may use different steels which will affect the welding process and results.

For further information on Hydrogen Induced Cracking in welds please refer to:

- Weld Australia (2018). *Technical Note 11 Commentary on the Structural Steel Welding Standard AS/NZS 1554*
- Bailey N., Coe F.R., Gooch T.G., Hart P.H.M Jenkins N, Pargeter R.J. (1973). *Welding Steels Without Hydrogen Cracking*, 2nd Edition Abington Publishing and ASM International

9 Construction

9.1 Driving of steel tubes – General

The founding levels shown on the Drawings are provisional levels and have been determined using foundation information available prior to construction. Details of the required driving hammer and set are contained in Annexure MRTS64.1.

Driving of steel tubes shall not commence until approval of the driving procedure has been obtained from the Administrator. **Hold Point 5**

Following driving and excavation to the level of the bottom of the plug, and before the plug is cast, the capacity of the pile shall be checked against the design requirements. The founding level may be varied (subject to minimum requirements shown on the Drawings) to achieve the design geotechnical capacity. However, if founding levels are changed, the minimum load-transfer length (both internal and external) shall still be achieved. Failure to achieve any of these requirements shall constitute a **Nonconformance** and may require the pile to be redesigned.

The driving of the steel tube shall be performed from firm ground, temporary supports, a spudded barge, or a fixed platform.

Whatever the method used, it shall provide sufficient rigidity to ensure accuracy of driving under all conditions.

The steel tube length shall be marked on the tube at no less than 1 m intervals from the toe of the tube before driving the tube so that the depth of penetration of the tube into the ground can be clearly seen.

Any steel tube which is incorrectly located, or damaged, or which has insufficient load transfer length to an extent that it results in a decrease in the load carrying capacity of the pile or reduced durability, may be rejected, removed and replaced, or repaired. **Nonconformance** Proposed remedial measures shall be submitted by the Contractor for the approval of the Administrator. Replacement of any rejected pile or other remedial work shall be at no cost to the Principal.

9.2 Driving

Steel tubes shall be driven (hammered, but not vibrated, oscillated or rotated except for the first 2 pile diameters), open-ended using a driving rig capable of achieving penetration of the steel tube to the required founding level and mobilising the design ultimate geotechnical strength, after excavation of the pile to the bottom of the plug level, without damaging the steel tube.

Vibration, oscillation or rotation methods are not permitted for installation of the steel tube because these methods disturb the pile soil interface and significantly reduce the skin friction between the pile and the surrounding soil thus reducing the geotechnical capacity of the pile.

Preboring of steel tubes is only permitted in certain circumstances as stated in Clause 9.4.

The steel tube shall be driven to the required founding level provided that driving shall not continue at penetrations less than nominal refusal (2 mm/blow). If upon reaching the nominated founding level the steel tube has not achieved the required geotechnical resistance (as determined by PDA or PM testing) the pile may be driven further or the Contractor may elect to undertake a restrike.

Material inside the steel tube shall be excavated progressively to the bottom of plug level by air lift, grab or percussion breaking equipment, rotary drilling or other approved means. Unless specifically allowed elsewhere in the Contract, explosives shall not be used.

Under no circumstances shall the excavation advance below the steel tube during the driving process. The steel tube shall not be driven for extended lengths at resistances equal to or greater than nominal refusal.

The Contractor shall ensure that the driving stresses do not exceed 0.8 f_{sy}. If driving stresses are approaching this level, driving shall cease and advice from the Designer and Administrator sought.

If hard driving or continual driving after refusal results in damage to the steel tube, the Contractor shall at no cost to the Principal, repair and, if necessary, reinforce the top of the steel tube to ensure transfer of the driving forces from the helmet to the steel tube. **Nonconformance**

> The Contractor may request from the Designer the basis for the design of the steel tube, including design hammer size or input energy. Should the Contractor wish to use alternative methods this may necessitate a different steel tube thickness or design.

If the steel tube buckles or is damaged during installation, the Contractor shall propose remedial action that shall be subject to approval by the Administrator. No additional payment will be made to the Contractor in the event of any necessary remedial action undertaken. **Nonconformance**

If it is elected to optimise the proposed construction procedure by increasing input energy over and above that necessary, as detailed on the drawings, to drive steel tubes, then a heavier steel tube is to be used to sustain the application of such increased driving energy. Any change to the nominated steel tube design is to be approved by the Administrator and no additional cost will be borne by the Principal as a consequence of this change to the steel tube thickness.

9.3 Restrike

If the design pile penetration has been reached or exceeded but set (or geotechnical capacity including the requirement for 85% of the capacity to be achieved by skin friction as defined in Clause 6(k)) has not yet been attained, the Contractor may request a restrike of the pile. In this case driving shall cease for at least 12 hours, and the pile restruck using the nominated driving energy as detailed in Annexure MRTS64.1. If the required set is then achieved during the restrike the pile shall be accepted. Alternatively, the field splicing of additional steel tube followed by further driving may be required.

9.4 Steel tubes in prebored holes

Steel tubes shall not be placed in prebored holes beyond 3 m in depth without both the Designer's and Administrator's approval.

Preboring is only permitted where the material in situ is of a consistency, cohesion and strength such that the hole shall be self-supporting until such time as the steel tube is inserted, and it is safe to work around the top of the unlined hole. Preboring is not allowed in strata with sand or gravel layers.

The diameter of a prebored hole shall be of a minimum size to facilitate driving of the steel tube.

Preboring shall be included in the cost of pitching or driving and not paid as a separate item. No additional payment will be made by the Principal for prebored holes.

Any resultant space between the steel tube and the prebored hole shall be backfilled using flowable fill or other approved material after completion of the driving, using a method that fills the void around the steel tube completely. Flowable fill shall be piped to the base of the prebored hole and the gap filled from the base upwards. Fill shall be inserted at a minimum of three points equally spaced around the steel tube circumference.

9.5 Construction limitations

No driving or excavation work shall be undertaken on a pile located within 9 m (clear distance) of a pile which has had the reinforced concrete pile shaft concreted within the last 12 hours.

A pile which is located within 2.5 m clear distance from a newly concreted pile shall not be worked on until 18 hours after the initial set of the concrete in that adjacent pile.

The top of a newly concreted (within 48 hours of placing the concrete) pile shall not be in contact with the driving platform while another pile is being driven or excavated from that platform.

> For this class of piles, it would be expected that all piles at the one location (Pier or Abutment) would be driven, excavated and the plug cast prior to concreting of the pile shaft. If a pile is to be completed prior to the driving of a subsequent pile at the adjacent position, than these time limitations are applicable.

9.6 Excavation of steel tubes and casting the concrete plug

Steel tubes shall be excavated to the level of the base of the concrete plug. The internal steel tube wall over the section of the steel tube into which the plug is to be cast shall be cleaned prior to casting of the plug. The plug shall be cast within 48 hours of excavation of the steel tube. Immediately prior to casting, the depth of the excavation shall be checked to ensure that the base of the excavation is still at the required level. If this is not found to be the case the steel tube shall be further excavated and cleaned. See also Clause 13.2.

> The concrete plug is essentially an item of temporary works or a construction expediency as such it may be cast in either the wet or dry condition to suit the Contractors work method. In this regard the critical dimensions are the level of the top of the plug and the length of the plug is not less than that specified.

9.7 Casting of the Reinforced Concrete Pile Shaft

Prior to casting of the reinforced concrete pile shaft, the level (or depth) to the top of the concrete plug shall be recorded. The top of the plug and wall of the steel tube shall be thoroughly cleaned and the pile dewatered without damaging the shear connectors. Before dewatering, the concrete plug shall be of a minimum concrete strength to maintain its integrity under the hydrostatic head at the level of the plug. If the plug fails, then the remainder of the plug shall be excavated and the plug recast. **Nonconformance**

The pile shall be inspected for certification (see Clause 11), and the rate of inflow of water into the pile shall then be determined (see Clause 13.5.3). After the pile is certified the reinforcing cage (see Clause 12) shall be inserted and the reinforced concrete pile shaft cast (see Clause 13).

10 Tolerances

The completed pile shall be located as shown on the Drawings within the following tolerances:

a)	Top of pile, in plan	75 mm in any direction
b)	Top of pile, vertically	5 mm in height
c)	Variation from vertical or designated rake	20 mm per metre
d)	Bow of pile	1% of the length of the pile in any direction
e)	Diameter of steel tube and socket	0, + 5% of nominal diameter at any position, and
f)	Length of concrete plug	Not less than the specified length.

Any piles which are outside these tolerances shall be corrected by the Contractor to the satisfaction of the Administrator at no additional cost to the Principal. **Nonconformance** Correction may include additional reinforcement or increased dimensions of pile caps or additional piles.

> Any design changes consequent to out of tolerance piles will need to be approved by the Designer and the Administrator and will be at no cost to the Principal. This includes design costs if applicable.

11 Geotechnical certification

11.1 General

The purpose of the geotechnical certification is to confirm that the design requirements have been achieved, and the foundation is safe, adequate and durable. This means that the steel tube has been driven to the correct level, the geotechnical capacity achieved, the base of the shaft (top of plug) is clean, the steel tube walls are clean, the shear connectors are clean and undamaged, and that the location and length of the transfer zone is compliant with the design requirements.

Prior to geotechnical certification of the concrete pile shaft, the Geotechnical Assessor shall certify that the foundations are at the required level and have achieved at least the design geotechnical resistance as assessed by PDA or PM testing. Failure to deliver the data to facilitate the certification shall constitute a non-conformance. **Nonconformance**

Where the Geotechnical Assessor issues a conditional certificate, for example the shaft base or steel tube walls need to be further cleaned then the certifier shall release the condition prior to moving to the next stage of the construction process. The Geotechnical Assessor shall ensure all issues are resolved prior to the next stage of construction.

The Contractor shall forward a copy of the geotechnical certification of the foundation to the Administrator for approval. Insertion of reinforcement and concreting of the pile shaft shall not commence prior to the Administrator's approval of the certification. **Hold Point 6**

As-constructed records of all driving and excavations including the final toe Height of the steel tube, the Height of the base of the concrete plug, and the Height of the base of the reinforced concrete shaft all determined in accordance with MRTS56 *Construction Surveying,* and the basis upon which the Geotechnical Assessor issued the certificate shall be maintained and forwarded to the Administrator.

11.2 Geotechnical assessor

The Geotechnical Assessor shall be either a civil or geotechnical engineer who is also a Registered Professional Engineer of Queensland (RPEQ) with at last 10 years' experience in heavy civil engineering foundation design, assessment procedures and high strain dynamic testing of piles.

Unless otherwise permitted by the Administrator, the Geotechnical Assessor shall be independent from the pile designer, pile driver, and pile testing organisations or companies.

The name and qualifications of the Geotechnical Assessor shall be submitted to the Administrator at least 28 days prior to commencing pile construction. **[Refer to Hold Point 1]**.

> The role of the Geotechnical Assessor is critical to the process of constructing the pile. The Assessor's certification cannot be over ridden by the Contractor. Should an issue arise between the Assessor and the Contractor then this should be referred to the Administrator who may need to obtain independent expert advice regarding the issues.

11.3 Safe access

As part of the construction procedures, the Contractor shall undertake a safety and hazard assessment to ensure all procedures are in accordance with the *Workplace Health and Safety Act,* 2011.

11.4 Dewater and clean

Following casting of the plug, and sufficient delay for the plug to gain adequate strength, the Contractor shall attempt to pump the hole dry using an appropriate pump arrangement and clean the concrete shaft base (top of the plug) and steel tube walls, this applies particularly in the load transfer zone to allow full assessment. If the pile cannot be pumped dry, concrete shall be cast in the wet in accordance with Clause 13.5.3.

While the criterion for dry concreting a pile is an inflow rate which causes a rise in the water level of less than 12 mm / minute, to facilitate inspections much greater rates of inflow can be tolerated. It would be expected that the Contractor would have adequate pumping equipment to remove water at these higher inflow rates.

11.5 Assessment methods

The Geotechnical Assessor shall utilise sufficient processes to obtain the information necessary to certify the foundations using the original geotechnical investigation data and/or reports and any additional investigation data. The geotechnical capacity of the pile shall be assessed at end of drive (or restrike) and be based on the driving records (PDA and/or PM) and geotechnical data for obtaining data on foundation capacity. As a review of the geotechnical investigation data is fundamental to any assessment, a copy of the bore logs and geotechnical report shall be kept on the Site until all foundations are completed.

Dewatering and cleaning of steel tubes for the formation of the reinforced concrete pile shaft shall occur prior to the Assessor attempting to certify the pile. If an excavation cannot be dewatered, then the Assessor shall determine how the cleanliness of the steel tube walls, load transfer devices and top of concrete plug can be verified to permit the pile to be certified prior to pouring of the reinforced concrete shaft.

The Geotechnical Assessor is expected to use their professional judgment in determining the acceptability of the foundation. A range of tools may be used by the Assessor, these may include a review of the Geotechnical Report and PDA and/or PM records obtained during driving.

The tools / procedures used shall be adequate to enable the Geotechnical Assessor to come to a conclusion regarding the adequacy of the foundation.

11.6 Minimum information needed to assess pile capacity

11.6.1 General

The following factors shall be assessed using information gathered on the Site prior to certification of pile capacity.

11.6.2 High Strain Dynamic Testing

A minimum of one pile per pier or abutment shall be subjected to high strain dynamic (PDA) testing over the full length of the drive to determine driving stresses, impact energy and geotechnical capacity.

The geotechnical capacity of the pile shall be assessed at end of drive after excavation to bottom of plug level (or restrike) and be based on the driving records (PDA and/or Pile Monitor) and geotechnical data for obtaining pile axial capacity. As a review of the geotechnical investigation data is fundamental to any assessment, a copy of the bore logs and geotechnical report shall be available to the Geotechnical Assessor and also kept on the Site.

The procedure for PDA testing shall be in accordance with the requirements of MRTS68 *Dynamic Testing of Piles*. However, where there are conflicts between this specification MRTS64 *Driven Tubular Steel Piles (with reinforced concrete pile shaft)* and MRTS68 *Dynamic Testing of Piles*, the requirements of MRTS64 *Driven Tubular Steel Piles (with reinforced concrete pile shaft)* take precedence.

A detailed methodology related to PDA testing and wave matching procedure shall be provided by Designer / Contractor as per MRTS68 *Dynamic Testing of Piles*.

11.6.3 Pile monitoring of the last 10 blows

The last 10 blows of each pile after excavation to bottom of plug level (including those tested using a PDA) shall be monitored using a pile monitoring device to determine set and temporary compression.

This data shall be used to assess the geotechnical capacity of the pile at end of drive on the basis of the Hiley formula. The results of PDA and PM should be correlated in order to more accurately assess the static geotechnical capacity of the piles.

11.6.4 Seepage of water into pile excavation

Where an inspection indicates water is leaking into the pile excavation, the rate of leakage shall be measured.

The rate of water ingress per minute shall be recorded over at least 15 minutes.

Where the rate of water ingress exceeds 12 mm per minute rise in water level the pile shall be regarded as a 'wet' pile.

11.7 Stronger strata than expected in design

If during driving, the pile achieves a resistance of nominal refusal or greater for a length of 1 m, and the pile toe level is above the underdrive allowance, pile driving shall cease. Such a situation may necessitate a change in design or driving procedure. Any such changes shall be referred to the Designer and shall have approval of the Designer and the Administrator prior to finalising the new foundation design.

11.8 Weaker strata than expected in design

If during driving the pile achieves less than the design resistance at the design steel tube toe level driving shall cease and restrike testing conducted to assess pile capacity after setup. Depending on the outcome of restrike testing, such a situation may necessitate a change in design or driving procedure. Any changes shall be referred to the Designer and shall have approval or concurrence of the Designer and the Administrator prior to finalising the revised foundation design. If a decision is made to continue driving, consideration shall be given as to how this decision affects the location of the load transfer section within the pile.

11.9 Camera for inspections

11.9.1 Features and capability

To obtain adequate information, the camera used for pile inspections shall have at least the following features:

a) robust, high resolution and water resistant/waterproof (as appropriate) colour video camera controlled by a display monitor at the surface with the capacity to record data for QA records (pile identifier, date, time, operator’s name, pile depth and so on)

b) equipped with variable-intensity light source that can be adjusted to give true colour images of the inside of the steel tube, or concrete plug, and

c) able to be moved to view horizontally (steel tube wall) and vertically (top of the concrete plug) by means of a telescopic or articulated pole, push rod or some other controlling device.

The camera shall be operated by an experienced person who can obtain a clear stable image with high definition.

11.9.2 Calibration

Remote camera inspections shall use a means of calibrating depth and position on the circumference, such as a calibrated rod or tape measure lowered to the base.

11.9.3 Availability on the Site

The camera to be used for inspection shall be available on the Site at least two weeks before completion of the first pile excavation and the Contractor shall demonstrate compliance to the Administrator before it is used in pile assessment. **Milestone**

11.10 Underwater inspection

Where a pile cannot be dewatered, an inspection of the cleanliness of the steel tube walls, load transfer devices and top of concrete plug shall be carried out using a waterproof camera. Cloudy and turbid water shall be replaced with clean water to improve visibility for the camera operation under water.

> While for concreting purposes a pile is classified as 'wet' when the rate of inflow is 12 mm per minute, for assessment / certification purposes, inflow rates well in excess of this figure can be handled and the pile still certified using the same procedure as a 'dry' pile. It would be expected that the Contractor would have adequate pumps to permit pumping out of piles to permit certification of piles at high flow rates.

12 Steel reinforcing

Steel reinforcing shall be supplied and placed in accordance with the requirements of MRTS71 *Reinforcing Steel*. Steel reinforcing shall be assembled as detailed on the Drawings to form a rigid cage capable of being lowered into the excavation without disintegration.

> MRTS71 *Reinforcing Steel* requires the use of Transport and Main Road's registered suppliers of reinforcement.

Cover to steel reinforcing shall be maintained using registered spacers, or stainless steel nibs welded to the longitudinal reinforcement. The spacers shall be located on the periphery of the pile cage 90 degrees apart at a maximum of 2.5 m centres axially, as shown on the Drawings. Spacers shall be in accordance with MRTS70 *Concrete* or MRTS63 *Cast-In-Place Piles*. Stainless steel nibs shall be in accordance with MRTS71A S*tainless Steel Reinforcing*.

Where welded cages with a continuous spirally wound helix are used, the distance between spacers may be increased to 4 m provided that there are always at least two sets of spacers on each cage.

Prior to lowering the reinforcing cage, the steel tube wall and the top of the plug shall be cleaned of all loose material and the pile certified. If there is any evidence of spacers crushing or being displaced after lowering the reinforcement cage into the steel tube, the cage shall be withdrawn and alternative stronger spacers fitted.

Note that care must be exercised during the placement of the reinforcement to avoid conflicts with other reinforcement such as that required for the pile caps or headstocks or anchors.

13 Concreting

13.1 General

After excavation has been completed, the plug cast, and the pile foundation certified by the Geotechnical Assessor and the certificate accepted by the Administrator, **[refer to Hold Point 6]** the reinforcement shall be inserted and concreting operations shall commence without delay.

Where there has been a delay of more than 48 hours between certification and when the Contractor is ready to start concreting or when the foundation has been observed to deteriorate significantly, the foundation shall be recleaned (if required) and re-certified. **Hold Point 6**

If water flow into the pile exceeds 12 mm per minute, concrete shall be placed underwater as stated in Clause 13.5.3. It shall not be placed until the inflow has ceased. This can be achieved more quickly by pumping fresh water into the steel tube until internal and external water levels are equal.

All concrete shall be placed in accordance with MRTS70 *Concrete* except as otherwise specified in Clauses 13.2 to 13.5. The Contractor shall observe all relevant Milestones and Hold Points in MRTS70 *Concrete*. Placement of concrete underwater shall only commence after the tremie and the placing procedure has been accepted for use by the Administrator. **Hold Point 7**

13.2 Concreting of the plug

Since the plug is effectively only a 'temporary' item the procedures for casting the plug do not necessarily parallel those for casting the reinforced concrete pile shaft. The plug shall be cast using the same grade of concrete as that to be used for the shaft. The plug may be cast under water using a tremie.

13.3 Concrete

Concrete shall comply with the requirements of MRTS70 *Concrete*, except where specifically stated in Clause 13 and Clause 13.5.3.

The concrete mix shall be designed to limit excessive bleeding of water, which is likely to occur in deep concrete pours and be tested for water retention in accordance with MRTS70 *Concrete*.

> Attention is drawn to the requirement in MRTS70 *Concrete* to conduct the water retention test on all piling concrete mixes.

The mix design shall include the selection of suitable combined aggregate grading curves (particularly in the sand component), the use of appropriate admixtures and the need to retain adequate workability during placement.

13.4 Slump or spread of concrete

The target slump or target spread of the concrete shall be selected from the ranges in MRTS70 *Concrete*.

Slump / spread tests on delivery shall conform to the target slump / spread and the tolerances given in MRTS70 *Concrete*.

Concrete with a slump / spread suitable for a wet concrete pile may be used in a dry concrete pile subject to the approval of the Administrator.

13.5 Placement and compaction of reinforced concrete pile shaft

13.5.1 General

Concrete shall be placed in dry conditions except where ingress of water into the hole is too great to ensure a homogeneous mass of concrete of the specified strength. Where the rise of water in the bottom of the pile exceeds 12 mm per minute, measured over at least 15 minutes, concrete shall be placed using underwater techniques after the water level has stabilised (refer to Clause 13.5.3).

Prior to the commencement of concreting the length of shaft from the top of the plug to the top of the steel tube shall be measured and the socket walls and shaft base checked for cleanliness.

To assist compaction by hydraulic head, the rate of placing the concrete shall not be less than 10 m of pile length per hour.

Concrete supply shall be effectively continuous with delays between concrete delivery trucks of 15 minutes or less, unless an approved specific retarded mix design has been developed to allow for longer delays, as in remote areas. In the case of concrete being placed in wet conditions, the concrete shall maintain adequate slump / spread for a period equal to the time taken to pour the pile so that the concrete in the pile remains workable.

13.5.2 Concrete placement in dry conditions

The base of the pile shaft shall be clean and all water removed immediately prior to placing concrete. This shall be confirmed by direct observation or by using a camera.

The method of placement shall allow the following:

a) delivery hose or pipe to 2 m above the pile base, and

b) ability to lift and/or shorten the delivery hose / pipe quickly with delays no longer than 10 minutes.

Concrete shall be dropped 2 to 3 m from the end of the delivery hose / pipe onto the concrete surface to provide compaction or alternatively the concrete shall be compacted using vibration.

The delivery hose / pipe shall be positioned so that the concrete does not fall onto the reinforcement cage. For raked piles, the Contractor shall detail in the procedure for construction of piles the method of delivering concrete down the piles that minimises the risk of segregation. **[Refer to Hold Point 1]**

The top 3 m of concrete shall be well compacted with a concrete vibrator with a minimum diameter of 50 mm regardless of the slump / spread specification for the concrete mix.

13.5.3 Concrete placement underwater

13.5.3.1 General

Before placing any concrete underwater, the steel tube shall be full of water to a level at least equal to the external water level or to a stable level with no further inflow or out flow. In a salt water environment, the pile shall be pumped as dry as possible and then filled using fresh water to minimise the salt content of the pile water during concreting.

The placement of concrete underwater shall be effected by means of a watertight tremie which complies with the following requirements:

a) A tremie long enough to rest on the pile shaft base with watertight seals at all joints and a base that can be sealed. The seal shall be designed to break and allow discharge of concrete when the pipe and hopper are filled, and the tremie is lifted no more than 300 mm off the pile base. Suitable types of seals include balls, bags of vermiculite or similar materials or a plate attached to the base of the tremie which will break away when the tremie is full of concrete and lifted off the base.

b) A controlled means of carefully raising the discharge end so that it always remains embedded 2 m in the concrete.

c) Adjustable pipe length or removable segments, and

d) A supply of concrete that is effectively continuous and a rate of placing not less than 10 metres of pile length per hour.

Procedures shall comply with MRTS70 *Concrete* for underwater placement. The tremie shall remain in the concrete at all times.

A tremie pouring record shall be kept during the tremie pour, in which is recorded the following:

- the level or depth (from a point of known Height)
- depth of the base of the pile shaft
- time pour started
- arrival time of each truck
- depth at the start of delivery from each truck
- depth and time when the tremie is shortened
- the length of tremie kept within the concrete column during the shortening operation
- the estimated quantity of material allowed to flow to waste at the end of the process.

> Tremie placement of concrete is a high-risk procedure unless all staff are fully aware of the procedures to be followed. A concrete pump does not constitute a tremie and shall not be used as a substitute to a tremie.
>
> An example of a suitable tremie pouring record can be found in Appendix D3 of Z17.

13.5.3.2 Tremie lifted out of concrete

If the tremie base is lifted out of the concrete (a pull out) in the pile at any stage prior to completion, concrete placement shall stop and pull out resolved. **Nonconformance**

This can only be achieved while the concrete is still wet. If this process is delayed, then removal of even partially set concrete from within the pile becomes problematic, resulting in additional delay and cost.

All concrete shall be removed using a vacuum truck, grab or similar device for a distance not less than two pile diameters below the point where the pull-out occurred (the removal zone). This work may either be done immediately following the pull-out (preferably when the concrete is still wet), or following partial set of the concrete. Care shall be taken to ensure all concrete has been removed from the reinforcement and the area adjacent to the reinforcement in the removal zone. A construction joint shall be prepared at the revised top of the concrete surface, the surface levelled, cleaned and inspected. When approved by the Administrator, the rest of the concrete shall be placed using dry placement methods after removal of all water from the pile (refer Clause 13.5.2).

> Coring the pile is a last resort method for confirming the quality of the concrete in the affected zone. The excavation of wet or partially set concrete will require equipment small enough to fit within the reinforcement cage.

13.5.3.3 Significant delay in concrete placing

If the placement of concrete underwater ceases at any time before completion of the pile for a period of more than 45 minutes, concrete placement shall cease, and the concrete allowed to set for at least 8 hours. All water and contaminated concrete (typically the top 2 m or two pile diameters, whichever is the greater) shall be removed and the pile finished as stated in Clause 13.5.2.

13.5.3.4 Removal of contaminated concrete at completion of concrete placement (wet pours)

On completion of a wet pour the top section of concrete, the greater of 2 m or two pile diameters, shall all be removed and not be allowed to form part of the final structure.

When placing underwater, the pile steel tube shall be extended by at least 2 m above the design cut off level and subsequently cut back, or the steel tube shall be finished to level and the contaminated material allowed to overflow. This overflow shall be captured on the Site and not allowed to run off Site.

If the overflow method is used, concrete placement shall continue until the pile surface is all sound concrete with the same slump and consistency as the concrete out of the truck and then the top 3 metres of pile concrete shall be compacted with internal vibrators of 50 mm minimum diameter regardless of the slump / spread specification of the concrete.

Careful operation of the tremie will limit the volume of contaminated material.

After the concrete has hardened, the pile shall be cut back to the specified level or to the level of sound concrete, whichever is the lower. If any concrete below the specified cut off level is contaminated or lacks the normal proportion of coarse aggregate, it shall be removed. When cutting off, the Contractor shall take care to avoid shattering or otherwise damaging the rest of the pile. Cracked or defective concrete shall be broken away. The pile shall be repaired in an approved manner to provide a full and sound section at the cut off level.

All such repair and replacement shall be at no cost to the Principal.

14 Survey

After completion of pile construction and cutback to the specified level a survey of the pile shall be completed in accordance with MRTS56 *Construction Surveying.*

15 As Constructed records

The Contractor shall provide the following As Constructed records in relation to each pile, no later than 28 days after completion of piling:

1. The base Height and diameter of prebore if used.
2. Pile driving log at maximum interval of 0.25 m, showing the number of blows required for the interval, hammer type / model, hammer input energy or drop height, cushioning material type and thickness and when it was changed, date and time of start and end of pile driving.
3. In relation to the last 10 blows for each pile, for each blow the set, temporary compression, job hammer type and hammer input energy or drop height.
4. PM record for the entire section of pile driving where a PM was used (last 10 blows), both in graphical and tabular (digital) format.
5. Where a high strain dynamic test (PDA) has been undertaken, the test record shall include at least all the above data for example; job hammer details, energy input, set (to an accuracy of at least 1 mm), as well as the full pile driving record for each blow from start to finish. This record shall also include a depth or Height record accurate to 1 mm.
6. The base Height of both steel tube, concrete plug and reinforced concrete pile shaft.
7. Assessment of the pile capacity, cleanliness of the shaft wall and base and location of the transfer zone certified by an RPEQ.
8. Tremie Pouring Record for each pile.
9. All concrete test results.
10. As Constructed survey records in accordance with this Technical Specification and MRTS56 *Construction Surveying.*

16 Supplementary requirements

The requirements of MRTS64 *Driven Tubular Steel Piles (with reinforced concrete pile shaft)* may be varied by the Supplementary requirements given in Clause 3 of Annexure MRTS64.1.