



TRANSNET SOC LTD

**DCT BERTHS 203 TO 205 - RECONSTRUCTION, DEEPENING AND
LENGTHENING**

PORT OF DURBAN

SPECIFICATION – STEEL SHEET PILING

1785-CO-000-C-SPC-0009 Rev T-01

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1.0 SCOPE

1.1 Project

This specification is a project specific technical specification for the DCT Berths 203 to 205 Reconstruction, Deepening and Lengthening Project in the Port of Durban.

1.2 Scope

The scope of this specification covers the *Employer's* requirements for the supply, delivery, handling and installation of steel sheet piles, which includes the following:

- a) Construction of the return quay cellular caissons using straight web sheet piles, bent piles and junction piles.
- b) Construction of temporary sheet piling.

2.0 NORMATIVE REFERENCES

2.1 Reference Documents

The *works* shall be carried out as specified in the following documents:

- a) This Specification
- b) Industry Codes, Standards and Specifications as listed in Section 2.2
- c) *Employer's* Project Specific Technical Specifications as listed in Section e)
- d) Project Drawings:
 - 1785-CO-070 series of drawings – Return Quay
 - 1785-CO-080 series of drawings – Temporary Sheet Piling
- e) Method statement prepared by the *Contractor*, as described in Section 4.1
- f) Project Geotechnical Reports, included in Part 4 - Site Information.

2.2 Standard Specifications

The *Contractor* shall provide and maintain current copies of all the standard specifications referred to herein below on the site for reference by both parties.

The governing standard for this specification shall be:

- a) BS EN 12063:1999. Execution of special geotechnical work. Sheet pile walls;

which shall apply in its entirety except for the variations and additions detailed in the specification clauses below.

The supply, delivery, handling and installation of steel sheet piles shall also comply with the following standard specifications:

- a) BS EN 1993-5:2007. Eurocode 3. Design of steel structures. Piling.
- b) BS EN 16228:2014. Drilling and foundation equipment. Series on Safety.
- c) BS 7121-1:2016. Code of practice for safe use of cranes - Part 1: General.
- d) BS EN 10248-1:1996. Hot rolled sheet piling of non alloy steels. Technical delivery conditions.
- e) BS EN 10248-2:1996. Hot rolled sheet piling of non alloy steels. Tolerances on shape and dimensions.
- f) BS EN 10060:2003. Hot rolled round steel bars for general purposes. Dimensions and tolerances on shape and dimensions.
- g) BS EN 12699:2015. Execution of special geotechnical *works*. Displacement piles. Section 10. Records.

2.3 *Employer's* Project Specific Specifications and Standards

The supply, delivery, handling and installation of steel sheet piles shall also comply with the following Project Specific Specifications and Standards:

- a) 1785-CO-000-C-SPC-0002 – Caisson Construction and Placement
- b) 1785-CO-000-C-SPC-0004 – Dredging and Reclamation (Including Vibro Compaction)
- c) 1785-CO-000-C-SPC-0017 – Corrosion Protection
- d) Project Environmental Specifications (PES) as contained in the Works Information and annexures.

3.0 DEFINITIONS

All definitions of responsibilities shall be in accordance with the NEC Engineering and Construction Contract (ECC) for the construction of the *works*.

Where the standard specifications referenced in this specification refer the “Engineer”, replace this term with the term “Supervisor”.

For the purpose of this specification, the technical definitions and abbreviations given in SANS-1200-F-1983 and BS EN 12063:1999 and as appropriate, together with the definitions given below shall apply:

3.1 Chart Datum Port

Chart Datum Port refers to the reference level used in the Port of Durban, which is 0,900 m below Mean Sea Level. All levels referred to in this document are relative to Chart Datum Port (CDP).

3.2 Co-ordinate System

The co-ordinate system to be used for all setting out and survey shall be World Geodetic System 1984 (WGS84), L031, referred to as WG31.

3.3 Tidal Levels

The Astronomical Tide Predictions as defined by the SA Navy Hydrographer and Chart SAN 2006 are as follows:

Table 3.1 – Tide Data

Tide	Abbreviation	Level m, Chart Datum Port
Highest Astronomical Tide	HAT	2.287
Mean High Water Springs	MHWS	1.997
Mean Level	ML	1.097
Mean Low Water Springs	MLWS	0.197
Lowest Astronomical Tide	LAT	-0.013

3.4 Method Statements

Method statements shall be compiled by the *Contractor* for all activities. The method statements shall be submitted to the *Supervisor* for acceptance three weeks in advance of the particular activity being undertaken. Full details of all proposed Equipment (including temporary *works*) and methods shall be provided for acceptance by the *Supervisor*.

No activity shall commence until the method statement has been accepted by the *Supervisor*.

Further details of the requirements of particular method statements are provided in Section 4.

3.5 Bent Piles

Bent piles are straight web sheet piles pre-bent at the mill and can be used to set up structures or parts of structures with small radii.

3.6 Cellular Caisson

A caisson structure made up of a series of relatively closely spaced circular cells linked by connecting arcs. The circular cells and linking arcs are formed by a series of individual straight web sheet piles. Each cell is a self-supporting structure.

3.7 Followers

A steel member placed between the pile hammer and pile that allows the pile to be driven below the reach of the leader.

3.8 Jetting

Jetting is the use of pressurised fluid to temporarily reduce the toe resistance of the piles to be inserted. Depending on the soil and jetting method the skin friction and interlock friction can also be reduced by rising water.

3.9 Junction Piles

Junction piles and bent piles are modified straight web sheet piles that are used to join circular cells and intermediary arcs. Junction piles have additional straight web sheet piles welded to a standard straight web sheet pile at connecting angle of 35 degrees.

4.0 REQUIREMENTS

4.1 Method Statements

The *Contractor* shall prepare method statements that shall include *inter alia*, the following information:

- a) Details of all the Materials and Equipment as per Section 4.2 and Section 4.3.
- b) Descriptions and ratings of other installing Equipment not covered here including cranes and power packs.
- c) Details of the methods and procedures for the safe use of all of the Equipment for all of the piling activities.
- d) Details of the methods and procedures for transport, handling and storage of all of the Materials and Equipment.
- e) Details and calculations of the template design for the main cell and arc wall of the cellular caissons.
- f) Details of the methods and procedures for the installation of the various piling templates and any other temporary *works*.
- g) Details of the pile driving wave equation analysis demonstrating pile drivability.
- h) Details of the methods and procedures for driving the piles.
- i) Details of the methods and procedures to help facilitate driving in the event of an obstruction.
- j) Details of the methods and procedures used to reduce piling vibration and noise.
- k) Details of the methods and procedures for cutting and trimming piles.
- l) Details of any pile driving trials to be undertaken.
- m) Details of the methods and procedures for pile driving monitoring.
- n) Details of the methods and procedures for monitoring the new and existing structures during construction.
- o) Details of the method and procedures for ensuring the piles are installed to the tolerances specified in Section 5.7.

4.2 Materials

4.2.1 General

All sheet piles shall be fabricated in accordance with BS EN 10248. The piles for the cellular caisson shall be corrosion protected in accordance with 1785-CO-000-C-SPC-0017.

All welding shall be in accordance with EN 12063.

All sheet piles and connectors shall be submitted to inspection and testing in accordance with EN 10248. Inspection document “type 3.1” based on specific inspection shall be issued by the manufacturer declaring that the products are in compliance with the requirements of the order (EN 10248-1, clause 10, option 8).

The *Supervisor* reserves the right to carry out inspections of the finished product at the manufacturers *works* prior to shipping to South Africa (EN 10248-1, clause 10, option 9). The *Contractor* shall inspect the sheet piles jointly with the *Supervisor* after offloading in Durban, and any damaged items or defects shall be replaced or repaired by the *Contractor* to the satisfaction of the *Supervisor*.

One product analysis shall be carried out for each cast for the determination of the chemical composition of the product as specified in Table 1 of EN 10248-1 (EN 10248-1, clause 10, option 10).

All sheet piles shall be supplied by the manufacturer with colour markings defining sheet pile, length and steel grade (EN 10248-1, clause 10, option 11).

All sheet piles shall be supplied with a 50 mm diameter lifting hole on the centreline of the sheet pile through the web, 250 mm from the head of the pile.

Sheet piles shall conform to the dimensional and mass tolerances specified in EN 10248-2; where there is a conflict between these two tolerances, the dimensional tolerances shall apply.

All profiling and strengthening of the pile toes shall be made using material of the same grade as the pile.

The required sheet pile materials are shown on the drawings. No provision has been made for additional piles that may be required (e.g. due to damage). If the *Contractor* for whatever reason requires additional piles over and above those shown on the drawings, then the *Contractor* will be responsible for procuring and supplying the additional piles. All costs related to procuring and supplying of these piles will be for the *Contractor's* account.

4.2.2 Straight Web Sheet Piles

The straight web sheet piles, bent piles and junction piles shall be fabricated from steel grade S430GP. Detailed sections of these piles are shown on the drawings. Table 4.1 details the characteristics of the straight web sheet piles.

Table 4.1: Characteristics of Straight Web Sheet Piles

Section	Width	Web thickness	Deviation angle	Perimeter	Sectional area	Mass	Mass per m ² of wall	Moment of inertia	Section modulus
	b	t	δ						
	mm	mm	°	cm	cm ²	kg/m	kg/m ²	cm ⁴	cm ³
AS-500-12.5	500*	12.5	4.5**	139	97.2	76.3	153	201	51
<p>* The effective width taken for layout purposes is 503 mm for all straight web sheet piles</p> <p>**This angle has been limited to 3° and where deviation angles exceed this value in the arc walls bent piles have been used to maintain this value.</p>									

All straight web sheet piles, bent piles and junction piles shall be able to interlock with each other. The minimum strength of all interlocks shall be 5500 kN/m (EN 10248-1, clause 10, option 7).

Standard junction piles shall be fabricated with a connecting angle of 35 degrees by welding in accordance with EN 12063. Bent piles shall be fabricated with a bend angle of 6 degrees. All junction and bent piles shall be pre-welded and pre-bent at the mill.

The straight web sheet piles, bent piles and junction piles shall be rolled in the mill to the lengths shown on the drawings. The Contractor shall not weld two or more sheet piles together to achieve the lengths shown on the drawings.

4.2.3 HZ and AZ Sheet Piles

HZ and AZ sheet piles shall be fabricated from steel grade as indicated below. The RH, RZD and RZU connectors shall be fabricated from steel grade S430GP. The C9 connectors shall be fabricated from steel grade S355GP.

Where the HZ sections are longer than the maximum rolling length, either longer sections may be requested from the mill or two HZ sections shall be welded together in accordance with Section 4.5.4

HZ sheet piles are to be supplied with RH, RZD and RZU connectors pre-welded to the sheet piles as applicable. The connectors are the same length as the sheet piles. The welds shall be 6 mm discontinuous fillet welds applied over 10% of the length (100mm/m), over the whole connector length; and 500 mm continuous welds at the top and toe of the connector.

Where two HZ sheet piles form a corner, special C9 connectors shall be welded onto the main sheet pile at the appropriate location and angle.

HZ sheet piles shall have a shaped toe with flange and web plates welded to the section to provide additional strength.

AZ piles shall be supplied as double piles (clutched together in pairs) in standard Form I. Pairs shall be crimped together with at least 4 crimping points per meter.

The HZ and AZ sheet piles and RH, RZD and RZD connectors shall be used to form the following Arcelor Mittal designation combination walls:

Berth 203 Extension:

- a) HZ 880M C – C1 (Steel grade S430 GP)

Berth 205 Extension:

- a) HZ 880M C – C23 (Steel grade S355 GP)
- b) HZ 880M C – 12 / AZ 18-700 (Steel grade S355 GP)
- c) HZ 880M C – 24 / AZ 18-700 (Steel grade S355 GP)

A modified combination wall shall be fabricated onsite by cutting and welding together three HZ 88M C – C1 sections as shown in detail three on drawing 1785-CO-080-C-DWG-0002-01.

4.2.4 Anchorage

The anchorage system shall comprise tie bars, walings, bearing plates, link plates, turnbuckles and couplers, washers and nuts in accordance with the Anker Achroeder ASDO 355 M115/90 system or similar approved. The tie bars are fabricated from ASDO 355 steel grade 355 ($f_y = 350 \text{ MPa}$).

The anchor tie bars shall conform to the dimensional and mass tolerances specified in EN 10060.

Two combinations anchor systems are required. These are shown on the drawings and are described as follows:

- a) Type 1 anchor system transfers the forces from the sheet pile to the anchor bar through waling sections that run the length of the wall. Both horizontal and vertical articulations are possible.
- b) Type 2 anchor system comprises machined and factory welded tension plates placed either side of the HZ web and passed through burnt holes in the flange. Forces are transferred from the HZ sheet piles to the forged eye anchor bar through a pin connection with articulation in the vertical plane.

The required anchor system components are shown on the drawings. No provision has been made for additional tie bars or other accessories that may be required (e.g. due to damage). If the *Contractor* for whatever reason requires additional tie bars or accessories over and above those shown on the drawings, then the *Contractor* shall be responsible for procuring and supplying the additional materials. All costs relating to procuring and supplying of these additional materials shall be for the *Contractors* account.

Tie bars and other accessories shall be handled, transported and stored with all necessary precautions to prevent damage and bending. The *Contractor* shall supply the necessary supports and protectors to enable safe handling and stacking.

All anchor and coupling components shall be from a single propriety anchor system supplier, subject to the approval of the *Supervisor*.

4.3 Equipment

4.3.1 General

The *Contractor* shall take full and entire responsibility for the sufficiency of his Equipment to provide the *works*. The *Contractor* shall submit details of all Equipment to be used to the *Supervisor* for acceptance at least 3 weeks prior to the execution of this work commencing.

It is the *Contractor's* responsibility for selecting a suitable installation method to provide the *works*. The *Contractor* shall evaluate the *in situ* material conditions as discussed in Section 4.4 and select suitable Equipment.

4.3.2 Storage and Handling Equipment

4.3.2.1 Support packing and spacers

When storing the sheet piles the *Contractor* shall support the piles on timber dunnage or similar product to avoid sagging. Additionally, timber or steel spacers and support packing shall be used to separate individual bundles and provide stability to the stack.

4.3.2.2 Lifting beams, slings, hooks and protectors

Depending on the lifting methodology the *Contractor* shall use lifting beams, lifting slings and lifting hooks. When handling with chains or steel cable slings the *Contractor* shall use protectors to avoid damage to the sheet pile interlocks.

4.3.3 Pile Driving Equipment

4.3.3.1 General

All pile driving Equipment, including the pile driving hammer, hammer cushion, helmet, and other accessories to be furnished by the *Contractor* shall be approved by the *Supervisor* before any driving can take place. In this regard the *Contractor* shall submit a description of all pile driving Equipment to the *Supervisor*. The description shall contain sufficient detail so that the proposed driving system can be evaluated by wave equation analysis.

Approval of pile driving Equipment shall not relieve the *Contractor* of responsibility to drive piles, free of damage, to the required pile toe level shown on the drawings.

In selecting the driving Equipment to be used, the *Contractor* shall take cognisance of nearby marine structures and shall select a driving method which will not destabilise or cause damage to nearby structures or piles.

Noise levels during pile installation shall be limited to the maximum allowed by the Project Environmental Management Plan (EMP).

The *Contractor* is made aware of the low flexural stiffness of the straight web sheet piles, and shall select suitable Equipment for handling, pitching and driving to the required depths without the sheet piles declutching or being damaged.

4.3.3.2 Hammers

Piles shall be driven with an impact or vibratory hammer, or both. This Specification is non-specific regarding the type of hammer to be used and it left to the experience of the *Contractor* to select suitable Equipment to provide the *works*. The *Contractor* shall conform to the hammer manufacturer's recommendations and shall ensure the following minimum requirements are met when selecting a suitable hammer:

Drop Hammer:

- a) Drop hammers shall not be used for sheet pile driving whose nominal resistance exceeds 600 kN.
- b) The ram shall have a weight not less than 10 kN and the height of the drop shall not exceed 3.7 meters.
- c) The ram weight of the drop hammers shall not be less than the combined weight of the helmet and pile.

Air/steam Hammers:

- a) The Equipment furnished for air-hammers shall have sufficient capacity to maintain, under working conditions, the pressure at the hammer specified by the hammer manufacturer. The hose connecting the compressor with the hammer shall be at least the minimum size recommended by the hammer manufacturer.

Diesel Hammers:

- a) Double acting diesel hammers shall be equipped with a bounce chamber pressure gauge, mounted near ground level so as to be easily read. The Contractor shall provide a correlation chart of bounce chamber pressure and potential energy.

Hydraulic Hammers:

- a) Hydraulic hammers shall be equipped with a built-in system for determining the ram velocity just prior to impact.

Vibratory Hammers:

- a) Vibratory pile driving methods may be used for pile driving and extraction.
- b) Vibratory drivers shall have an operating frequency range suited to the onsite ground conditions.

4.3.3.3 Driving Accessories

Hammer Cushion:

All impact pile driving equipment shall be equipped with a suitable thickness of hammer cushion material to prevent damage to the hammer or pile. Hammers designed such that the hammer cushion is not required shall be excluded from this requirement.

Where applicable, hammer cushions shall be made from durable manufactured material that will retain uniform properties during driving. Wood, wire rope, or asbestos hammer cushions shall not be used. A striker plate shall be placed on the hammer cushion to ensure uniform compression of the cushion material. The hammer cushion shall be replaced by the *Contractor* before driving is permitted to continue whenever there is a reduction in the hammer cushion thickness exceeding 25 percent of the original thickness or, for air hammers, when the reduction in thickness exceeds the manufactures recommendations.

Driving Cap:

Piles driven with impact hammers shall be fitted with a driving cap to distribute the hammer blow uniformly and concentrically to the pile head. The surface of the driving cap in contact with the pile shall be plane and smooth and

shall be aligned parallel with the hammer base and the pile top. It shall be guided by the leads and not be free-swinging. The driving cap shall fit the pile head in such a manner as to maintain concentric alignment of hammer and pile.

For special types of piles, appropriate driving heads, mandrels, or other devices shall be provided so that the piles may be driven without damage.

Leader:

Pile driving leaders that align the pile and the hammer in proper positions throughout the driving operation shall be used as required. Leaders shall be constructed in a manner that affords freedom of movement of the hammer while maintaining alignment of the hammer and the pile to ensure concentric impact for each blow.

Leaders may be either fixed or swinging type. Swinging leaders, when used, shall be fitted with a pile gate at the bottom of the leader. The leader shall be adequately embedded in the ground or the pile constrained in a structural frame such as a template to maintain alignment.

Followers:

When present the follower and pile shall be maintained in proper alignment during driving. The follower shall be of such material and dimensions to permit the piles to be driven to the blow count determined to be necessary.

4.3.3.4 Jetting Equipment

Jetting Equipment shall be capable of providing the desired volume of water at the required pressure. The Equipment shall be able to vary the jetting pressure to suit the ground conditions.

4.3.3.5 Monitoring Equipment

The *Contractor* shall provide an “Energy Saximter (E-Sax)” or equivalent monitoring Equipment for each piling operation where piles will be driven and blow counts will be recorded. The monitoring Equipment shall document the installation process of each pile or pair of piles to assure that the driving criterion are met.

The monitoring Equipment shall allow a manual or automated collection of blow count per unit penetration and shall measure the ram velocity at impact, and kinetic energy.

The monitoring Equipment shall display the acquired data in real time, and shall store data electronically for transmission and permanent storage. The device shall have enough memory available for storage and download of data at a later time.

The monitoring Equipment shall be able to record, pile name, date with start/stop times of all pile driving, blow rate, stroke (for open end diesel hammers only), blow count versus depth, and impact velocity and kinetic energy.

4.3.3.6 Pile Driving Guides and Templates

The *Contractor* shall employ suitable temporary wales, templates, guide frames or bracing as required to ensure that the piles are installed to the required tolerances, do not declutch during driving and the pile is not damaged.

The *Contractor* shall design a template frame that can accommodate several HZ and AZ sheet piles at one time, and that provides a rigid guiding system when driving the sheet piles.

A piling template shall be used for the cellular caisson construction. The template design shall take into consideration, but not be limited to, the stability of the template structure, installation on land, number of cells to be constructed, accuracy of template for intended use, reuse of template, length of the sheet piles, capacity of the lifting equipment, and safety consideration for the work crew.

The exact template diameter shall be calculated to ensure correct pile positioning. The effective width of the piles shall be taken into account in determining the dimensions of the template. The template design shall allow for adjustment of the alignment of the structure. In this regard, the dimensions of the template shall be smaller (gap \approx 30 mm) than the nominal dimensions of the cellular structure.

The templates shall have at least two guiding levels with sufficient distance from each other to assure proper sheet pile alignment. The lower guide shall be positioned as close to the ground as possible. It shall be moveable to allow easy handling during installation. Similar conditions apply to the upper guides. Additionally, the upper guide shall provide a safe working platform for the crew.

An additional template shall be designed for the arc walls with similar design requirements as discussed above.

The templates shall be designed by professional engineers with prior experience in template design for cellular structures. The design shall comply with Eurocode 3 or a similar national design standard.

4.4 Nature of In Situ Material

Details of the nature of the in situ material are provided in the Project Geotechnical Reports, included in Part 4 - Site Information. The *Contractor* is responsible for interpreting these reports and selecting a suitable methodology and Equipment for installing the sheet piles.

The *Contractor* is made aware of the presence of existing foundation trench material. The *Contractors* Equipment shall be capable of penetrating this material without deviating out of tolerance. The foundation trench material shall not be classified as an obstruction.

4.5 Methods and Procedures

4.5.1 General Precautions

The *Contractor* is advised that the piling operations will take place within an operational port and that he must take all the necessary precautions to work safely within the port and not disrupt port operations. In addition, the piling operation will take place below seawater level, within the tidal range and in close proximity to existing structures. In this regard the *Contractor* shall take all the necessary precautions when working below the seawater level, or to deal with seawater as required and to protect and minimise damage to existing structures and natural features such as the Central Sandbank and "Little Lagoon" areas during piling operations.

Piles are to be installed in close proximity to the foundation blocks of the existing blockwork wall and existing foundation trench (Refer to Section 4.4). The *Contractor* shall monitor the existing wall in accordance with Section 5.6, and notify the *Supervisor* immediately should any movement, settlement or rotation occur during pile installation.

4.5.2 Safety

The *Contractor* shall take all the necessary safety precautions during the execution of the sheet pile walls. The safe use of the Equipment shall be in accordance with the recommendations of BS EN 16228 series. For the various lifting and driving operations the *Contractor* shall adhere to BS 7121-1 which gives recommendations for the safe use of cranes in a work environment.

4.5.3 Storage and Handling

The storage of the sheet piles onsite shall be at the designated site camp area as shown on the drawings. The sheet piles and auxiliary materials shall be handled, transported and stored with all the necessary precautions to prevent damage to the piles and auxiliary materials. The recommendations of BS EN 12063 shall be followed.

4.5.4 Welding

When the steel is to be welded, the welding procedure shall be suitable for the grade of steel and intended use or service. All welding and weld testing shall be in accordance with EN 12063.

The required weld testing and frequency of testing is described in Section 5.4

4.5.5 Pile Toe Modification

The profiling and strengthening of the toe of the piles shall be made using material of the same grade as the pile. Welding shall be in accordance with Section 4.5.4.

4.5.6 Guides and Templates

The *Contractor* shall employ suitable temporary wales, templates, guide frames or bracing as required to ensure that the piles are installed to the required tolerances, do not declutch during driving and are not damaged.

Guiding frames shall be used to install all the sheet pile combination walls.

With regard to the cellular caisson template construction, the following general installation procedure shall be followed for the:

- a) Position and secure the template by installing supporting piles.
- b) Level and position the supporting piles with reference to the cell axis.
- c) Secure the template against lateral shifting or tilting by driving the supporting piles some distance into the ground.
- d) Positioned and fix the platforms at the required elevations ensuring correct alignment.

4.5.7 Pile Driving

4.5.7.1 Driving procedure

All sheet piles shall be installed such that, after driving, they fulfil the following requirements to the required tolerances:

- a) Parallelism: Every pile must stand vertically and adhere to the specified inclination.
- b) Alignment: The required driving alignment must be achieved to the required tolerances.
- c) Distortion/distorting: Distorting and twisting increases the risk of interlock declutching and therefore must be prevented.
- d) Spacing: The distance between the piles must be equal over their entire length, matching the system dimension.

These requirements can only be fulfilled accurately by guiding the piles during pitching and driving as specified in Section 4.5.6 above.

4.5.7.2 Installation sequence for straight web sheet piles

Once the template is positioned and securely anchored as described in Section 4.5.6, the following general procedure for pitching and driving the junction piles and straight web sheet piles shall be followed:

Phase 1:

- a) Install template for main cell.
- b) Pitch junction piles as shown on the drawings.
 - Marks shall be placed at the circumference of the working platform of the template, in order to indicate whether the sheet piles are spaced properly.
 - The exact position of the junction piles shall be determined by survey.
 - Verticality of the junction piles shall be checked.

Phase 2:

- a) The straight web sheet piles shall be pitched alternately from two junction piles using the centre pile or pair of piles to complete the arc.
 - Thread sheet piles on either side of junction piles.
 - Install symmetrically by threading additional piles working away from the junction piles.
 - Close the cell at the same distance from the junction piles.
- b) All piles shall be fixed temporarily to the template.

Phase 3:

- a) Remove temporary fixation of the first pile or pile pair for driving.
- b) This shall be one of the junction piles.
- c) Driving shall be done in stages of 0.5 m.
- d) The driving shall proceed in one direction from this point on until the first junction pile is reached again.
- e) The driving direction shall change between driving intervals to prevent leaning of the piles in one direction.
- f) This procedure is repeated until the design depth is reached.
- g) The upper guide of the template shall move stepwise with the piles (Or a suitable alternative employed i.e. special follower).

Phase 4:

- a) Pitch the connecting arcs between two completed main cells, using the arc template.
- b) Drive the connecting arcs.
- c) Pitching and driving procedures shall be similar to those for the main cells.

4.5.7.3 Refusal

The selection of a refusal blow count limit or penetration rate limit depends on the hammer manufacturer limitations to prevent hammer damage. The refusal criteria shall be the more critical of the hammer manufacturer's recommendations and the following:

- a) For impact hammers the blow count shall not exceed 400 blows/m.
- b) For vibratory hammers the pile penetration rate shall not be less than 5 mm/sec.
- c) In no case shall driving continue for more than 100 mm at refusal driving conditions.

4.5.7.4 Limiting driving stresses

The compressive driving stress shall not exceed 90 percent of the yield point of the pile material.

4.5.7.5 Design founding depths

The founding levels of the piles shall be as shown on the drawings and shall not be a function of driving refusal. The *Contractor* shall inform the *Supervisor* immediately when unforeseen underground obstructions are encountered or if the nature of the strata should vary significantly from that indicated in the Site Information.

4.5.7.6 Obstructions

If the piles encounter unforeseeable, isolated obstructions, the *Contractor* shall notify the *Supervisor* immediately. The *Contractor* and the *Supervisor* shall agree on the method that shall be used to help facilitate driving past the obstruction as discussed in Section 4.5.7.7 and Section 4.5.7.8.

4.5.7.7 Jetting to facilitate driving

Jetting shall only be permitted when approved by the *Supervisor*. Jetting shall be used with impact driving and vibrating in order to:

- a) Achieve the necessary embedment depth under early refusal conditions or in the event an obstruction is encountered.
- b) Prevent overloading of the plant and overstressing of the sheet piles.
- c) Reduce vibrations in the ground

Jetting shall not be used generally for facilitating pile installation and to reduce costs through shortening installation times, reducing power requirements and/or enabling lighter equipment to be used.

The *Contractor* shall determine the number of jets and the volume and pressure of water necessary to freely erode the material adjacent to the pile. The *Contractor* shall dispose of all jet water in manner satisfactory to the *Supervisor*. Jet pipes shall be removed before or when the pile toe is 1.5 meters above the final toe level, and the pile shall be driven without jetting to the final toe level.

4.5.7.8 Predrilling to facilitate driving

Predrilling to facilitate driving shall only be permitted when approved by the *Supervisor*. The *Contractor* and *Supervisor* shall agree on the size and depth of hole prior to predrilling. Any void space remaining around the pile after completion of the drilling shall be filled with sand or other approved material. Material resulting from predrilling holes shall be disposed of as approved by the *Supervisor*.

4.5.8 Vibration and Noise Control

Noise levels during pile installation shall be limited to the maximum allowed by the Project Environmental Management Plan (EMP).

The *Contractor's* chosen installation methodology shall take into consideration the effects of vibrations from pile driving or extraction on existing structures. The *Contractor* shall monitor the effects of vibrations on existing structures as discussed in Section 5.6.

4.5.9 Cutting and Trimming Piles

Piles driven to a predetermined depth shall be stopped at the required level within the specified tolerances. Any protruding section of pile shall be cut off at the required level. In addition to being trimmed at the required level, sheet piles shall be cut off to allow installation of such items as the service tunnels, storm water pipes and the crane rail beam as shown on the 1785-CO-070 series of drawings.

4.5.10 Anchorage

4.5.10.1 General precautions

During the installation of the anchor system over the backfill area there is no support for the tie rods as the backfill will be no higher than +1.85mCD. The *Contractor* shall ensure that the tie rods are adequately supported at all times, so that there is no sagging (see Tolerances).

4.5.10.2 Anchor installation

After driving the HZ piles, the *Contractor* shall cut openings in the HZ pile flanges (as detailed by the supplier) to accommodate the tie rod eye connector. The remaining components are then assembled and connected. The *Contractor* shall ensure that the tie bars are adequately supported at all times, so that there is no sagging (see Section 5.7). Initially the tie bars shall be lightly tensioned by turning up the turnbuckle and the end nut using hand tools.

4.5.11 Temporary Sheet Piling

Temporary sheet piling is required during construction of the permanent works, but does not form part of the permanent works. In the event that temporary sheet piling is left in place, the sheet piles will need to be cut off at a level below the permanent layer works to facilitate further construction work. Once no longer required, temporary sheet piling may be extracted or left in place. Ties holding the sheet piling will need to be removed to allow layer and drainage works to progress. Where temporary sheet piling extraction may disturb existing foundations, the temporary sheet piling should be left in place.

4.6 Record Keeping

4.6.1 Pile Driving

Site records and records of driving observations shall be kept in general accordance with EN 12699 section 10 "Records". Additionally, the following shall be recorded for impact and vibratory pile driving.

4.6.1.1 Impact hammers

The hammer make, model, energy, stroke, pile and hammer cushions and other driving equipment as described in Section 4.3.3 shall be recorded in the pile driving record. During driving the *Contractor* shall record pile name, date with start/stop times, blow rate, stroke (for open end diesel hammers only), blow count versus depth, and impact velocity and kinetic energy.

4.6.1.2 Vibratory hammers

The hammer make, model, weight, dynamic force, frequency or range of frequencies, maximum eccentric moment, clamping method as described in Section 4.3.3 shall be recorded in the pile driving record. During driving the *Contractor* shall record pile name, date with start/stop times, driving rate and frequency.

4.6.2 Monitoring of New Sheet Pile Structures

Monitoring records of the displacement of the sheet pile walls during execution shall be as per Section 5.6.

4.6.3 Monitoring of Existing Structures

Monitoring records of the displacement of the existing structures shall be as per Section 5.6.

5.0 COMPLIANCE WITH REQUIREMENTS

5.1 Pile Driving Wave Equation Analyses

The *Contractor* shall submit to the *Supervisor* results of a wave equation analysis to show that the piles are drivable. With regards to simulations of vibratory pile driving by the wave equation model, the software used shall implement the necessary modifications to this model to produce reasonable results. All analysis assumptions shall be listed.

The following hammer efficiencies shall be used in a wave equation analysis unless better information is available.

Table 5.1: Hammer Efficiencies

Hammer Type	Efficiency
Drop 25 to 40	%
Single-acting air/steam	67
Double acting air/steam	50
Diesel	80
Hydraulic or diesel with built in energy measurement	95
Vibratory	100

For the piles to be deemed drivable they shall not refuse as per the criteria in Section 4.5.7.3 and the compressive driving stress shall not exceed 90 percent of the yield point of the pile material.

5.2 Pile Driving Trials

The *Contractor* shall be responsible for determining the driving conditions as described in Section 4.4, and undertaking on site pile driving trials as may be required.

5.3 Pile Inspection Tests

Before accepting and removing the piles from the designated storage area, the *Contractor* shall inspect the sheet piles, carrying out sufficient assessment of pile lengths, clutch tolerances, and any other dimensions, in order to assure himself that the piles comply with the tolerance requirements of EN 10248-2.

5.4 Testing and Inspection of Welds

One X-ray test according to ISO 1106-1:1984 on 10 % of the sheet piles and 100 % visual inspection, or Ultra sonic tests on 10 % of the sheet piles over the whole length of the weld and 100 % visual inspection.

5.5 Pile Driving Monitoring

During installation of the sheet piles, the position and condition of the sheet piles must be checked and suitable measurements carried out to ascertain when the intended embedment depth has been reached. Together with the correct starting position, adherence to tolerances must be checked in sufficient intermediate phases. This shall make it possible to detect small deviation from required position or deformations of the pile head so that early corrections can be made and, if necessary, suitable countermeasures initiated.

The *Contractor* shall monitor the pile driving operations using monitoring Equipment described in Section 4.3.3.5, and shall submit records to the *Supervisor* as described in Section 4.6.1.

The pile driving monitoring Equipment shall be installed prior to driving of the piles, and shall be maintained during the installation of all piles unless otherwise directed by the *Supervisor*. In the event that the monitoring device is not fully operational, the *Contractor* shall notify the *Supervisor*. For the duration the device is not operational, the *Contractor* shall manually record blow counts, start/stop times, and blows per unit penetration or rate of penetration as directed by the *Supervisor*.

5.6 Monitoring of the New Sheet Pile Wall, Existing Quay Wall and North Substation

Procedures for monitoring of the existing quay wall movement during dredging have been set out in specification 1785-CO-000-C-SPC-0004 – Dredging Reclamation and Sandbank Extension. The *Contractor* shall undertake the same monitoring procedure of the existing quay wall during piling operations adjacent to the existing structures. The same base line set out for the dredging shall be used.

The *Contractor* shall monitor the movement of the new sheet pile walls during installation, excavation in front of the walls and final reclamation in front of the walls. The horizontal displacements of the top of the sheet pile walls shall be periodically measured with appropriate accuracy at predefined points. The *Contractor* and the *Supervisor* shall agree the frequency, accuracy and location of these measurements.

The *Contractor* shall monitor vibrations due to piling operations in the vicinity of the North Substation. Details of such monitoring systems and parameters shall be included in the *Contractor's* method statements.

5.7 Tolerances

5.7.1 Sheet Piles

The *Contractor* shall ensure that cumulative tolerances meet with tolerance requirements as defined within this specification.

Piling tolerances shall be in accordance with EN 12063. Notwithstanding the tolerance requirements in EN 12063 the, the following tolerances shall apply:

- a) Refer to figure 6 of EN 12063:1999
- b) Applies to both primary and secondary sheet piles
- c) The plan position of the sheet piles at cut-off level
 - Transverse tolerance (c): + 50 mm / - 50 mm
 - Longitudinal tolerance (d): + 50 mm / - 50 mm
- d) Verticality in all directions
 - 1.5% of the embedment depth measured over the top 1 m of pile
- e) Toe level and head level of piles
 - + 75 mm / - 0 mm
- f) The tolerances regarding position and verticality may be additive
- g) Any deviations greater than these tolerances, or any other rotation or leaning that may lead to de-clutching, is remedied by the Contractor by either:
 - Applying corrective external loads during further driving, such that the deviation is reduced to an acceptable level without damaging the piles, or
 - Extraction and re-driving of the pile(s).

5.7.2 Anchorage

Tie bars shall be supported at the turnbuckle/swivel position and required intermediate positions such that the deviation from a fish line stretched from one end of the anchor tie rod assembly to the other is less than 20 mm.

The level of the eye rod bar connector at the HZ pile shall not differ from the specified level by more than 25 mm.