



*A division of Gilmore Engineers Pty Ltd
Research and Development

Our Ref: RLH:VLK:213306

Your Ref: JW

8 May 2013

REPORT

TO

Patented Foundation Systems Pty Ltd
ACN 156 530 497
c/- STA Consulting Engineers
241 Milton Road
Milton, QLD 4064

Attention: Mr Justin Williamson
Senior Geotechnical Engineer

RE: KATANA SCREW PILE CORROSION REVIEW

ON

VOID SLAB SYSTEM

Prepared by:

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1 INTRODUCTION

Patented Foundation Systems Pty Ltd have requested e3k review appropriate Australian Standards, or other Standards relevant to corrosion of steel screw piles, to determine the potential effects and limitations of use of the Katana pile in soils of varying pH, up to a depth of 500 mm, for an expected lifetime of 50 years. Patented Foundation Systems Pty Ltd have also requested e3k investigate measures to protect the Katana pile against corrosion in soils of varying pH, up to a depth of 500 mm, for an expected lifetime of 50 years.

I understand that the “Void slab system” is primarily intended for use in areas with expansive clay foundation soils.

In the preparation of this report, I have read and used the following information:

- a) Katana Pile Product Guide, including drawings, from STA Consulting Engineers, dated 7th May (see Appendix 1).
- b) Void Slab System, preliminary edition, from STA Consulting Engineers, dated 16th March 2013.
- c) Australian Standard AS 2159-2009 Piling – Design and installation (incorporating amendment No.1).
- d) Australian / New Zealand Standard AS/NZS 2312:2002 Guide to the protection of structural steel against atmospheric corrosion by the use of protective coatings (incorporating amendment No.1).
- e) Australian Standard AS 2832.2-2003 Cathodic protection of metals Part 2: Compact buried structures.
- f) Australian Standard AS 2832.3-2005 Cathodic protection of metals Part 3: Fixed immersed structures.
- g) Data sheet for Denso PVC SA tape (see Appendix 2).
- h) Data sheet for Denso Rigspray Micro (see Appendix 3).

This report details our review of the relevant Standards and our recommendations.

2 AS 2159-2009 PILING – DESIGN AND INSTALLATION

Australian Standard AS 2159-2009 Piling – Design and installation, contains specific information on the durability design of piling. Section 6.5, of AS 2159-2009, “Design for durability of steel piles”, contains exposure classifications for steel piles in different environments.

The exposure classification of the surface of a steel pile is to be determined from Tables 6.5.2 (A), (B) & (C) from AS 2159-2009. For the range of chemical conditions of piles in soil, the condition leading to the most severe aggressive conditions shall be allowed for and consideration shall be given to possible changes in groundwater levels.

TABLE 6.5.2(A)
EXPOSURE CLASSIFICATION FOR STEEL PILES—
PILES IN WATER

Exposure conditions	Exposure classification
Sea water—submerged	Severe
Sea water—tidal/splash zone— Cold water (south of 30°S)	Severe
Sea water—tidal splash zone— Tropical/Subtropical water (North of 30°S)	Very severe
Fresh water—soft running water	Moderate

TABLE 6.5.2(B)
EXPOSURE CLASSIFICATION FOR STEEL PILES—
PILES IN REFUSE FILL

Exposure conditions	Exposure classification
Domestic waste	See Note 2
Industrial waste	See Note 2

TABLE 6.5.2(C)
EXPOSURE CLASSIFICATION FOR STEEL PILES—PILES IN SOIL

Exposure conditions			Exposure classification		
pH	Chlorides Cl		Resistivity ohm.cm	Soil condition A*	Soil condition B†
	In soil ppm	In groundwater ppm			
>5	<5000	<1 000	>5 000	Non-aggressive	Non-aggressive
4–5	5000–20,000	1 000–10 000	2 000–5 000	Mild	Non-aggressive
3–4	20,000–50,000	10 000–20 000	1 000–2 000	Moderate	Mild
<3	>50,000	>20 000	<1 000	Severe	Moderate

* Soil conditions A—high permeability soils (e.g., sands and gravels) that are in groundwater

† Soil conditions B—low permeability soils (e.g., silts and clays) or all soils above groundwater

NOTES TO TABLES 6.5.2 (A), 6.5.2 (B) AND 6.5.2 (C):

- Where high levels of sulfates exist (>1000 ppm), sulfate-reducing bacteria may be present and active, sometimes leading to microbiologically induced corrosion. In such cases, classify as 'mild' for low permeability soils and 'moderate' for high permeability soils.
- Contamination by the tipping of mineral and domestic waste or by spillage from mining, processing or manufacturing industries presents special durability risks due to the presence of certain aggressive acids (both organic and inorganic), salts and solvents, which can chemically attack steel. In the absence of site-specific chemical information, the exposure condition should be assessed as 'severe' for domestic refuse tips and 'very severe' for industrial/mining waste tips. Chemical and microbiological analysis of the latter may, however, lead to lower risk classification.
- For piles in disturbed soil, consider the assumption of soil A conditions where accelerated corrosion is possible.

Based on table 6.5.2 (C) from AS 2159-2009, it is recommended to test the chloride level and resistivity at each installation site, as well as measuring the pH. Measuring of the sulphate level in clay is not required as even high levels above 1000 ppm will only result in a “mild” classification for low permeability soils.

Table 6.5.3, from AS 2159-2009, gives uniform corrosion allowances for loss of section under the five exposure classifications. Section 6.5.3 of AS 2159-2009 states “corrosion on the internal faces of a fully sealed closed-form pile may be assumed to be negligible”.

TABLE 6.5.3
CORROSION ALLOWANCES FOR STEEL PILES

Exposure classification	Uniform corrosion allowance (mm/year)
Non-aggressive	<0.01
Mild	0.01–0.02
Moderate	0.02–0.04
Severe	0.04–0.1
Very severe ³	>0.1

NOTES:

- 1 The allowances in Table 6.5.3 may be reduced, as appropriate, where adequate corrosion protection systems (coatings or cathodic protection) are to be used. Coatings will reduce corrosion allowance while they remain in good condition. Coating damage, deterioration and breakdown will result in the corrosion rate increasing and, in such circumstances, the corrosion allowances in Table 6.5.3 shall apply.
- 2 To allow the implementation of cathodic protection after construction it is good practice to provide electrical continuity throughout the piled system at the time of construction. In providing electrical continuity, consideration shall be given to the likelihood of stray current corrosion, especially if the completed structure is of significant length and adjacent to a cathodically protected system or within close proximity to direct current electrified traction or power supply systems.
- 3 For very severe conditions a site-specific assessment should be sought.

The Katana pile drawings are shown in Appendix 1 of this report. The main tube of the pile is a 350 Grade 76 x 4.0 Circular Hollow Section (CHS). I understand that the minimum required wall thickness for an 80 kN Safe Working Load (SWL) is 2.0 mm. Thus the 4.0 mm wall thickness CHS has a steel corrosion allowance of 2.0 mm.

It can be seen from the drawings in Appendix 1 of this report that the top of the piles can be sealed with the threaded edge beam connector. However, this will not provide an air tight seal. The bottom ends of

the piles are open, and as the pile screws into the ground, the pile will fill with soil, which may seal the bottom end of the pile. However, this seal will most likely not be water tight. Thus in my opinion, the provided design would not be considered a fully sealed closed-form pile.

3 RECOMMENDATIONS

Table 1 of this report shows the estimated design life and recommendations for the Australian Standard exposure classifications.

I understand that the "Void slab system" is primarily intended for use in areas with expansive clay foundation soils. I note that Table 6.5.2 (C) from AS 2159-2009 indicates for use in clays, soil condition B is used, and that it has a maximum exposure classification of "Moderate". The only exception is if the site has been contaminated by domestic or industrial waste. Thus most sites where the "Void slab system" will be used will be classified as "Non-aggressive", "Mild" or "Moderate".

3.1 Non-Aggressive and Mild Environments

To be conservative, it is assumed that for the basic design the uniform corrosion allowance acts on both the inside and outside of the CHS. With this assumption, the basic design is expected to have a design life of 50 years or more in environments classified as "Non-aggressive" and "Mild".

3.2 Moderate Environments

To achieve a design life of 50 years or more in environments classified as "Moderate", it is recommended that the inside of the CHS be fully sealed air tight by welding, thus limiting corrosion to the outside surface.

3.3 Severe Environments

To achieve a design life of 50 years or more in environments classified as "Severe", it is recommended that the inside of the CHS be fully sealed air tight by welding. Additionally the wall thickness will need to be increased to at least 7.0 mm or extra corrosion protection will be required. AS 2159-2009 allows for either coating protection systems or cathodic protection.

3.3.1 Coating Protection Systems

Section 6.5.4 of AS 2159-2009 states "Coating systems should comply with the requirements of AS/NZS 2312". Appendix C of AS/NZS 2312:2002 deals with coating systems for non-atmospheric and hot environments. Table C1 in AS/NZS 2312:2002 recommends three different coating systems for soil environments. These are: ultra-high build two-pack epoxy, fusion bonded epoxy, or wrapping tapes.

Appendix 2 and 3 of this report show typical examples of coating protection systems available on the market. Other systems from other manufacturers are also available and may be more suitable.

Appendix 2 of this report contains a data sheet for Denso PVC SA tape. This is an example of a possible coating protection system.

Appendix 3 of this report contains a data sheet for Denso Rigspray Micro, a 2-component isophalic Polyester resin reinforced with micro glass flakes. This was recommended by Denso as a possible coating protection system for the screw piles.

For any coating protection system, it is recommended that the manufacturer's advice on suitability for the environment, surface preparation and application, be followed.

If a coating protection system is used, it is recommended that any coating protection system be tested to ensure it remains adhered to the piles after screwing into the ground. At least five tests are recommended where the piles are coated, screwed into the ground and then removed from the ground to check for damage to the coating protection system.

3.3.2 Cathodic Protection

Section 6.5.5 of AS 2159-2009 requires cathodic protection systems to conform with AS 2832.2 or AS 2832.3. After reviewing both AS 2832.2 and AS 2832.3 it is my opinion that cathodic protection systems will not be reliable in the clay environment and are not suitable for the "Void Slab System".

3.4 Very Severe Environments

For environments classified as "Very severe", it is not recommended that the metal Katana pile be used.

3.5 Recommendations Summary

Exposure Classification	Uniform corrosion allowance (mm/year)	Uniform corrosion over 50 year life (mm)	Recommendation	Estimated Life (Years)
Non-aggressive	<0.01	<0.5	Basic design ok	100 + (Corrosion inside & outside)
Mild	0.01 – 0.02	0.5 – 1.0	Basic design ok	50 – 100 (Corrosion inside & outside)
Moderate	0.02 – 0.04	1.0 – 2.0	Fully Seal	50 – 100 (Corrosion outside only)
Severe	0.04 – 0.1	2.0 – 5.0	Fully Seal + increase wall thickness to 7mm or + Coat	50 – 125 (7mm wall thickness) 20 – 50 (4mm wall thickness) + Coating allowance (Corrosion outside only)
Very severe	> 0.1	> 5.0	Not Recommended	< 20 (Corrosion outside only)

Table 1. Estimated design life and recommendations for the Australian Standard exposure classifications for a 350 Grade 76 x 4.0 CHS Katana plie (with 2.0 mm steel corrosion allowance).

4 CONCLUSIONS

Based on my review of the documents listed in Section 1, I am able to provide the following conclusions:

- a) It is recommended that the pH, chloride level, and resistivity at each installation site be measured to determine the exposure classification of the site as per table 6.5.2 (C) from AS 2159-2009.
- b) I understand that the "Void slab system" is primarily intended for use in areas with expansive clay foundation soils. I note that Table 6.5.2 (C) from AS 2159-2009 indicates for use in clays, soil condition B is used, and that it has a maximum exposure classification of "Moderate". The only exception is if the site has been contaminated by domestic or industrial waste. Thus most sites where the "Void slab system" will be used will be classified as "Non-aggressive", "Mild" or "Moderate".
- c) The basic Katana pile design, shown in Appendix 1, is expected to have a design life of 50 years or more in environments classified as "Non-aggressive" and "Mild".
- d) To achieve a design life of 50 years or more in environments classified as "Moderate", it is recommended that the inside of the CHS of the Katana pile be fully sealed air tight by welding, thus limiting corrosion to the outside surface.
- e) To achieve a design life of 50 years or more in environments classified as "Severe", it is recommended that the inside of the CHS of the Katana pile be fully sealed air tight by welding. Additionally the wall thickness will need to be increased to at least 7.0 mm or extra corrosion protection will be required (see Section 3.3.1 of this report).
- f) For environments classified as "Very severe", it is not recommended that the metal Katana pile be used.

APPENDIX 1



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Website: <http://www.staconsulting.com.au>

Katana Pile Product Guide :

Standard Katana Pile Product :

Product Code	Item Description	Pile Length (m)
SP-010	80 kN Pile, CHS 76 x 4.0 wall, 250 x 6 Helix - 350 Grade	1.0
SP-015	80 kN Pile, CHS 76 x 4.0 wall, 250 x 6 Helix - 350 Grade	1.5
SP-020	80 kN Pile, CHS 76 x 4.0 wall, 250 x 6 Helix - 350 Grade	2.0
SP-025	80 kN Pile, CHS 76 x 4.0 wall, 250 x 6 Helix - 350 Grade	2.5
SP-030	80 kN Pile, CHS 76 x 4.0 wall, 250 x 6 Helix - 350 Grade	3.0
SP-040	80 kN Pile, CHS 76 x 4.0 wall, 250 x 6 Helix - 350 Grade	4.0

Katana Attack Pile Product :

Product Code	Item Description	Pile Length (m)
AP-010	80 kN Pile, CHS 76 x 4.0 wall, 200 x 6 Helix - 350 Grade	1.0
AP-015	80 kN Pile, CHS 76 x 4.0 wall, 200 x 6 Helix - 350 Grade	1.5
AP-020	80 kN Pile, CHS 76 x 4.0 wall, 200 x 6 Helix - 350 Grade	2.0
AP-025	80 kN Pile, CHS 76 x 4.0 wall, 200 x 6 Helix - 350 Grade	2.5
AP-030	80 kN Pile, CHS 76 x 4.0 wall, 200 x 6 Helix - 350 Grade	3.0
AP-040	80 kN Pile, CHS 76 x 4.0 wall, 200 x 6 Helix - 350 Grade	4.0

Katana Pile Extension Product :

Product Code	Item Description	Pile Length (m)
EXT-010	80 kN Pile Extension, CHS 76 x 4.0 wall - 350 Grade	1.0
EXT-015	80 kN Pile Extension, CHS 76 x 4.0 wall, 350 Grade	1.5

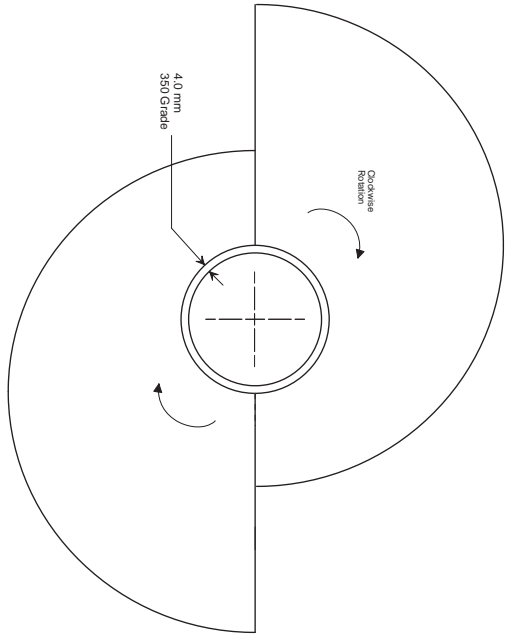
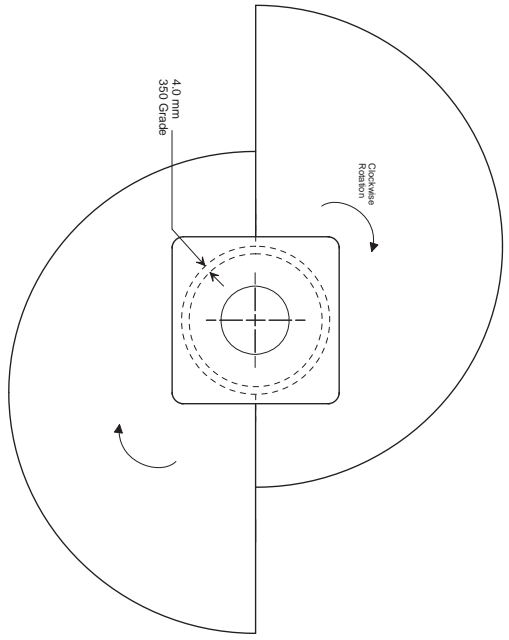
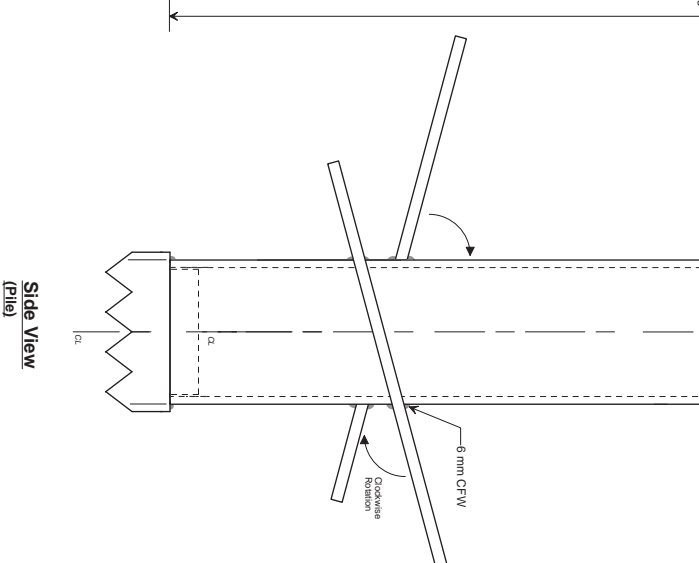
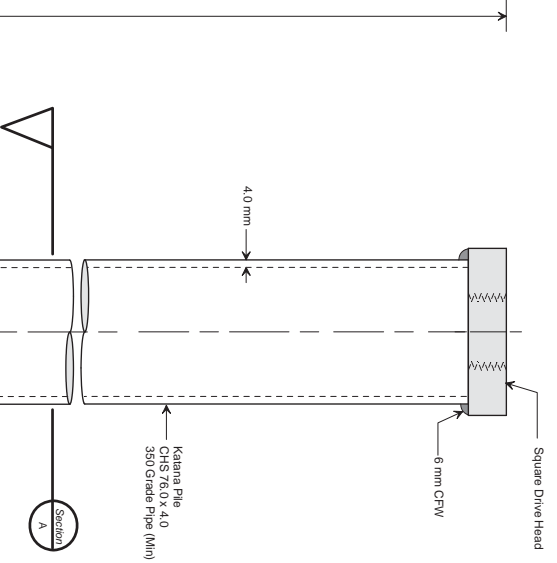
Katana Pile Connector Product :

Product Code	Item Description
EC-250	Edge Beam Connector, 250 N12 Bar 500 Grade, M36 Thread
TP-200	Load Transfer Plate 200 x 200 x 4 350 grade, M36 Thread

Katana Pile Adaptor Product :

Product Code	Item Description
PT-010	Pile Adaptor to suite - 80 kN Pile, CHS 76 x 4.0 wall - 350 Grade

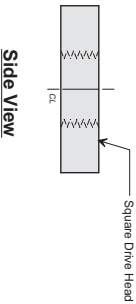
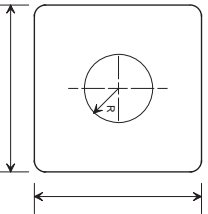
Katana Pile Specifications



Plan View

Section View

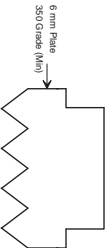
Square Drive Head Details



Plan View

Side View

Cutting Comb



Side View



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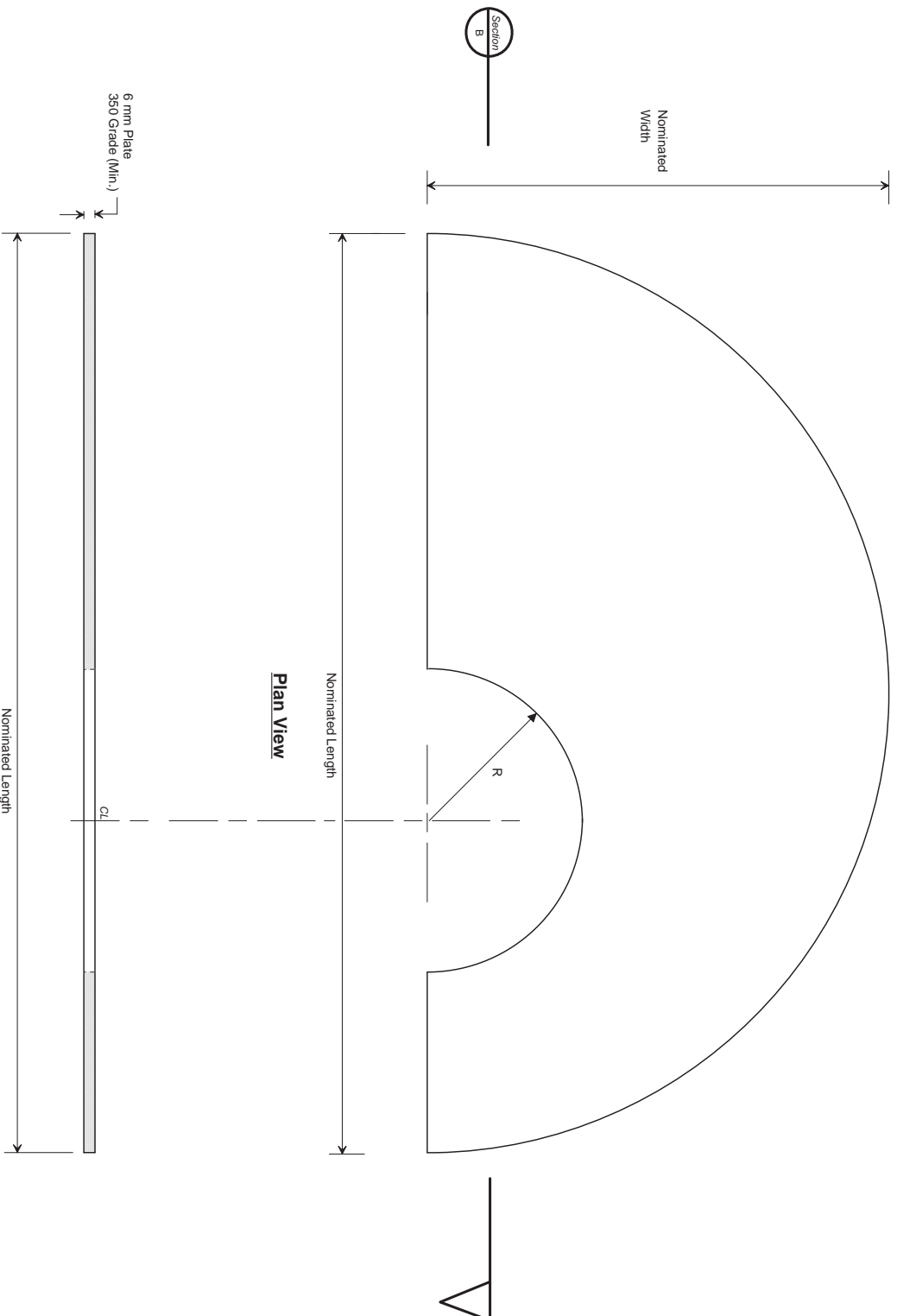
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DRAWING TITLE

Katana Pile Specifications

**Typical Katana Pile
Fin Details**



Section View - B



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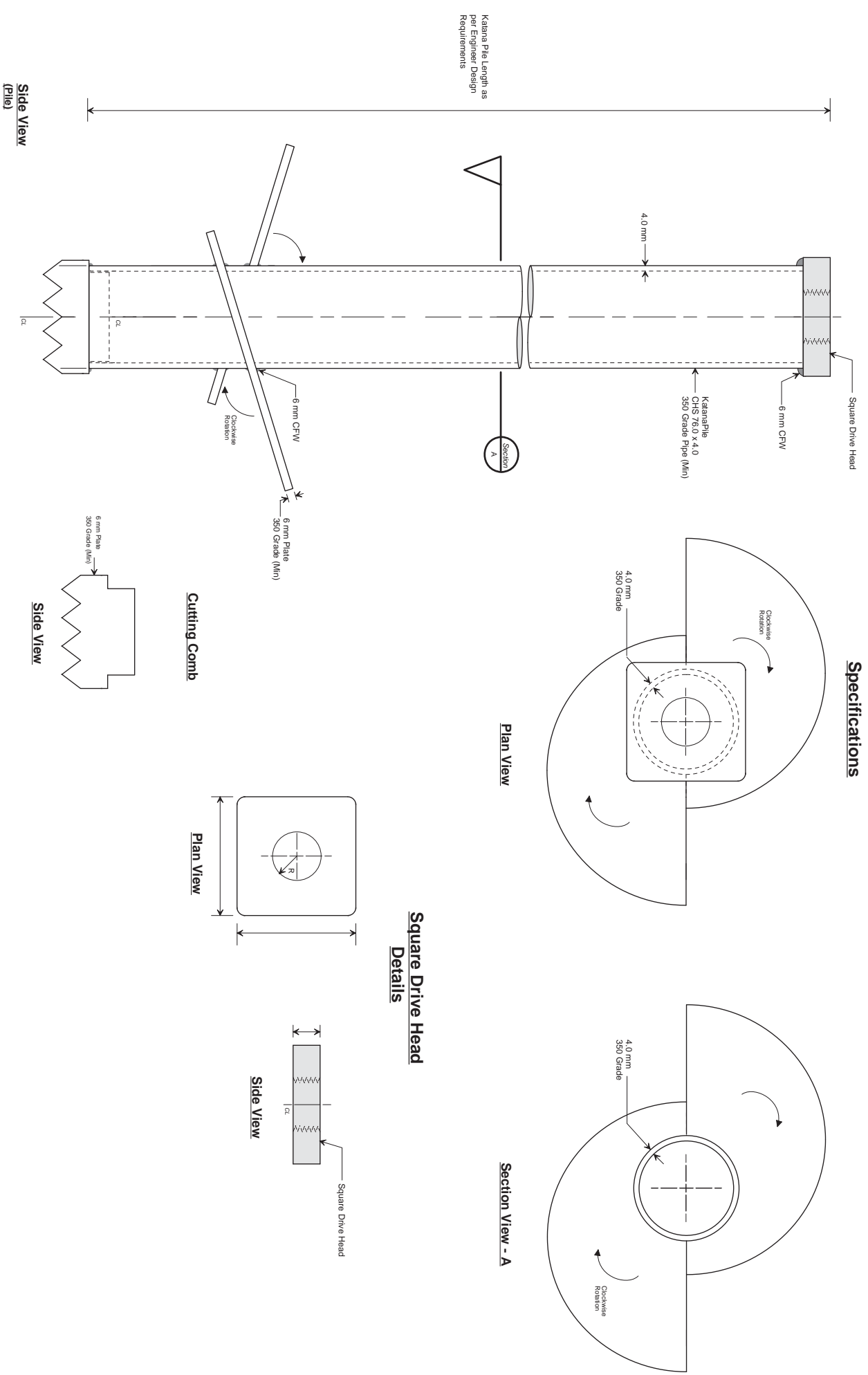
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 Katana Pile Specifications

Katana Attack Pile Specifications



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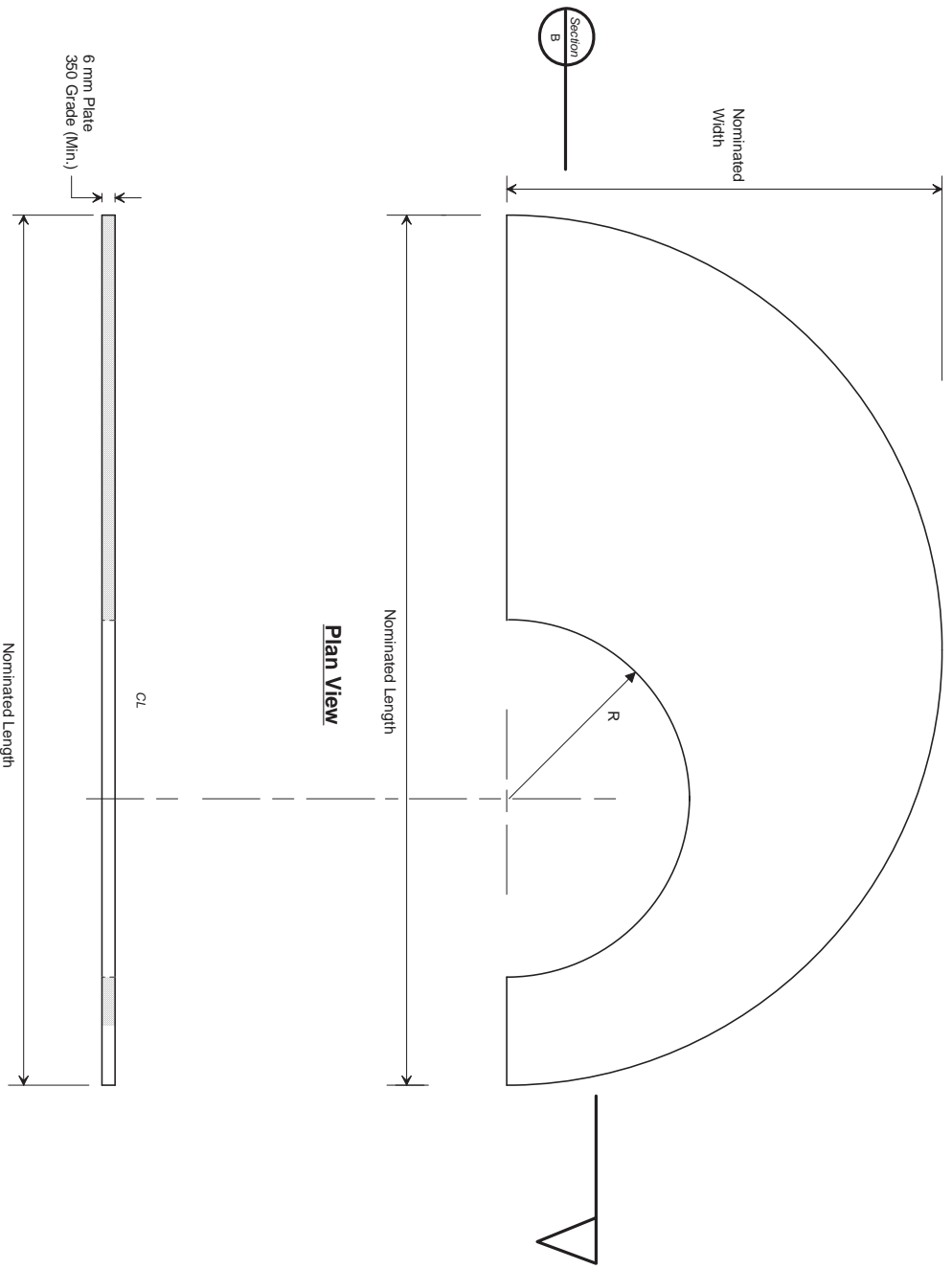
ADELAIDE
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 Katana Pile Specifications

**Katana Attack Pile
Fin Details**



Section View - B



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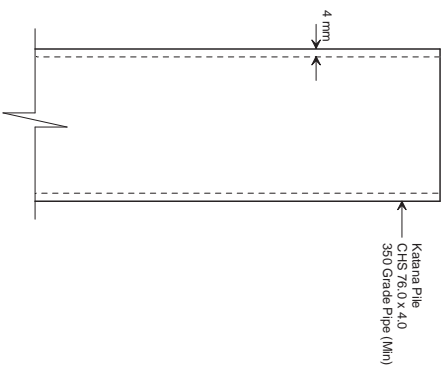
ADELAIDE
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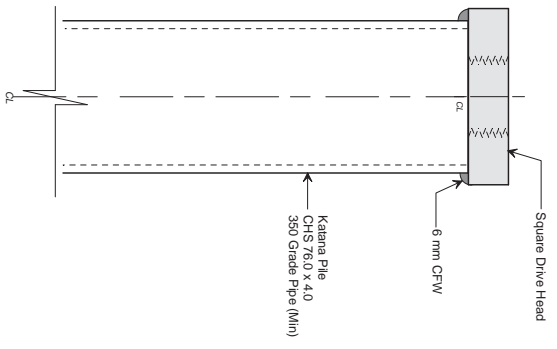
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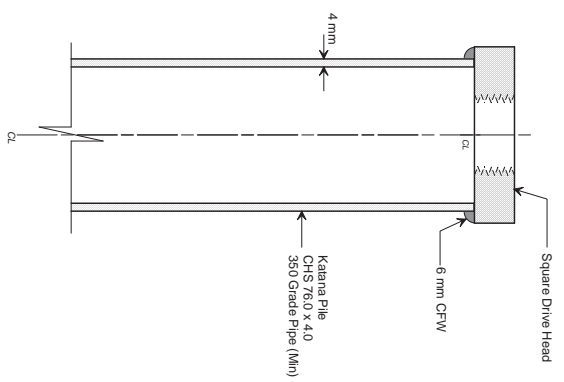
Typical Katana Pile Specifications



**Side View
Pile Top (No Drive Head)**

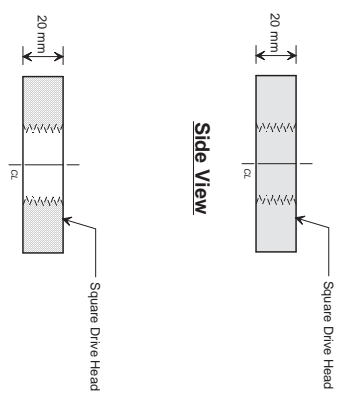
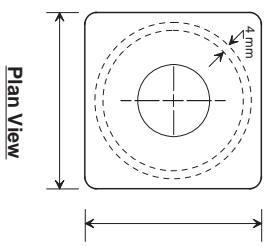


**Side View
Pile Top (with Square Drive Head)**



**Section View
Pile Top (with Square Drive Head)**

Square Drive Head Details



Section View



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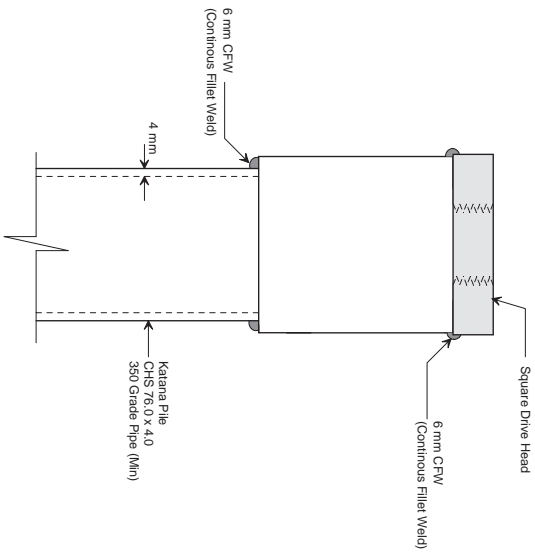
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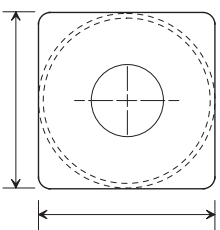
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 Katana Pile Specifications

**Katana Pile Specifications
On Site Pile Adaptor (PT)**

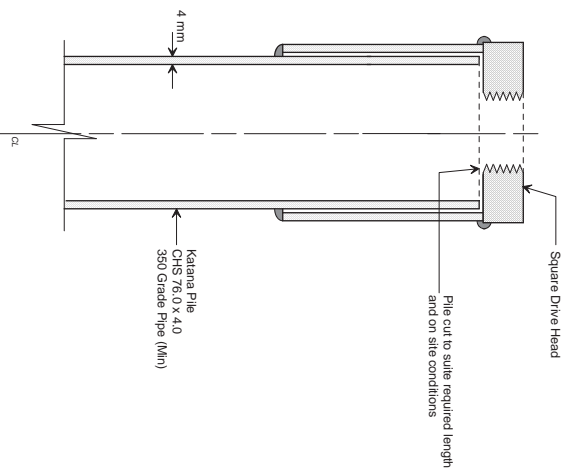


**Side View
Pile with On Site Pile Adaptor**

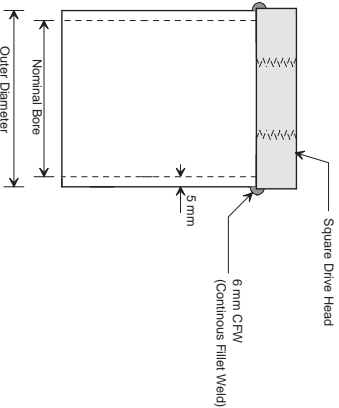
Square Drive Head Details



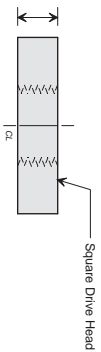
Plan View



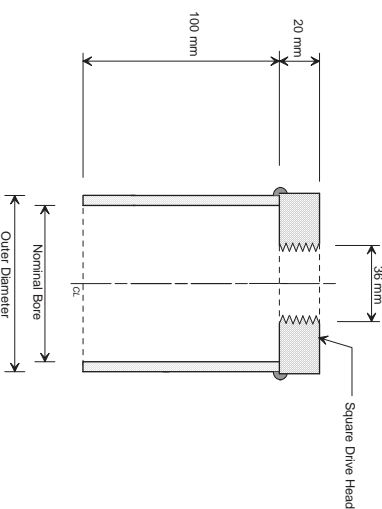
**Section View
Pile with On Site Pile Adaptor**



**Side View
Pile Adaptor**

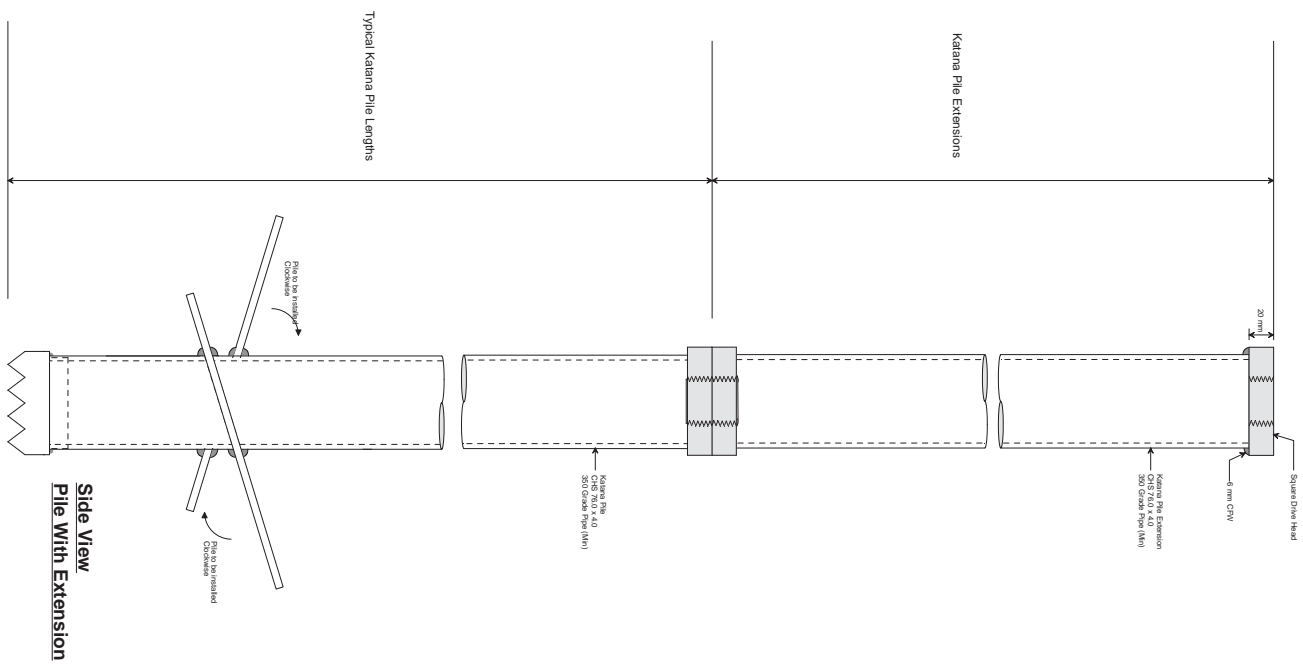
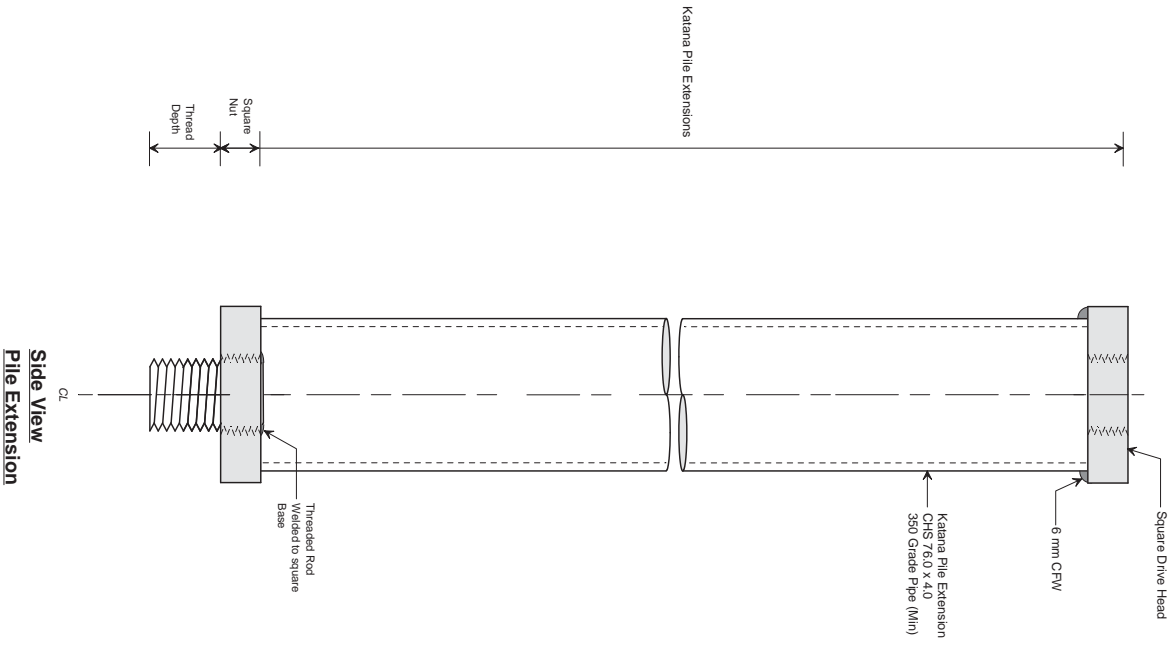


Side View



**Section View
Pile Adaptor**

Stoddart Pile Specifications Extensions (EXT)



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DATE : 7th of May, 2013
 DWG NO. : STAC 007

DRAWING TITLE
 Katana Pile Specifications

APPENDIX 2



Approved Quality Management System
AS/NZS ISO 9001:2008
Lloyds Register-Certificate No. MEL 0927759

Technical Data Sheet
DENSO PVC SA TAPE
(Formerly "Denso MP/HD PVC Overwrap Tape")

Description:	A tough, multi-purpose, heavy duty, conformable, pressure sensitive adhesive PVC tape.
Composition:	Plasticised Poly Vinyl Chloride incorporating natural and synthetic rubber based adhesives and fungal inhibitor.
Characteristics:	<ul style="list-style-type: none"> • highly impermeable to water moisture and air • stable in composition and plasticity • non hardening and non cracking • accommodates vibration and movement of substrate • resistant to mineral acids, alkalis and salts • exhibits limited resistance to ultraviolet radiation (black only)
Uses:	For mechanical protection, sealing and water proofing of metal above and below ground as part of the Denso Petrolatum Tape system. Protection of pipelines, joints, fittings, cables, tensioning members.
Surface Preparation & Application:	<p>Prepare substrate to be protected as per the Denso Petrolatum Tape System. Clean metal surfaces with wire brush. Firmly adherent rust and scale need not be removed.</p> <p>Apply a thin film of Denso MP Primer, where needed use mastic to prepare profiles then apply tape.</p> <p>Wrap tape without overstretching. Apply heavily coated side of the tape to the metal surface.</p> <p>Smooth down and mould by hand especially all overlapped edges.</p> <p>A 55 % overlap of tape should be applied to provide a double layer of tape. Finally apply Denso PVC SA Tape ensuring a 55% overlap is maintained.</p>
Recommended Temperatures:	<p>Application: 0 to + 60 °C</p> <p>Service: - 20 to + 60 °C</p> <p>Peak: + 75 °C</p>
Storage:	In cool, dry, ambient conditions, in original cartons away from heat and direct sunlight.
Available Dimensions:	<p>Colours: Available in Black or Yellow</p> <p>Widths: 25, 50, 100, 150 mm.</p> <p>Length: 30 metre roll, minimum.</p> <p>Other sizes available by special arrangement.</p>

Physical Properties:	Test	Test Method	Units	Value
	Thickness	ASTM D751	mm	0.19 ± 0.02
	Weight	ASTM D751	g/m ²	245 ± 25
	Breaking Strength	ASTM D1000	N/mm	3.0 ± 0.6
	Elongation at Break	ASTM D1000	%	180 ± 40
	Breakdown Voltage - double layer	ASTM D149	kV	≥ 16
	Adhesion Strength -to steel	ASTM D1000	g/mm	18
	-to self			14

APPENDIX 3

Description

Archco-Rigidon Rigspray Micro is a 2-component medium duty brush, roller or spray applied lining. It is formulated from an isophthalic Polyester resin reinforced with micro glassflakes. The lining dry film thickness is normally 0.6mm. More than one coat can be applied if required.

Principal Characteristics

- * Excellent corrosion resistance
- * Very good abrasion resistance
- * Very good erosion resistance
- * Very low permeability
- * Good chemical resistance
- * Excellent application properties
- * Single coat application 300 to 600 micrometres
- * Excellent undercutting resistance
- * Lower styrene emissions
- * Rapidity of cure
- * Excellent UV resistance

Corrosion and Temperature Resistance

Archco-Rigidon Rigspray Micro is suitable for use in aggressive marine environments and resists some mildly aggressive chemicals at temperatures up to 65°C under immersion conditions.

Suggested Uses

Archco-Rigidon Rigspray Micro is used primarily to protect steel structures from corrosive attack.

Rigspray Micro is widely used for the protection of steel structures subject to the most aggressive marine environments, where abrasion and erosion are also a problem, i.e. splash zones, underdeck areas, helidecks and main deck surfaces.

How to Order

A full material system may be ordered by simply specifying **Archco-Rigidon Rigspray Micro (System 457)**.

Contact **Archco-Rigidon** engineers for further information.

Rigspray	Isophthalic Polyester
Operating Temperature Range	Min -50°C Max +65°C
Application Method	Spray, roller or brush
Surface Preparation	Gritblast to Sa2½ min
Colour	To specification
Catalyst Type	Archco-Rigidon C2
Volume Solids	98%-99%
Dry Film Thickness	300-600 Mic.
Min Substrate Temperature	10°C
Max Humidity during Application	90% Rh
Min Dewpoint/Substrate Differential (steel)	Dewpoint +3°C
Flash Point	31°C
Overcoating Times	Min 2 hrs - Max 36hrs @ 25°C
Tool Cleaning Solvent	T2 Cleaner
Storage Temperature Limits	10°C - 20°C
Specific Gravity	1.2
Shelf Life	6 Months

Estimated Coverages are as follows:	Theoretical Material Requirement	Practical Material Requirement
Component	Quantity m²/0.6mm DFT	Quantity m²/0.6mm DFT
457/04 Rigspray Micro Resin Mix	0.72 kg	1.0 kg
457/11 C2 Catalyst	0.01 kg	0.02 kg
457/16 T2 Cleaner	0.50 litres	0.50 litres

Rigspray Test Data		
Characteristic	Standard	Result
Abrasion Resistance	ASTM D 4060	0.035gm (smooth)
Adhesion Properties	ASTM D 952	8 Mpa
Cathodic Disbondment	BS 3900F11	Compatible