

PermaStruct® Composite Piles and Fenders

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1 WHAT ARE PERMASTRUCT[®] COMPOSITES PILES

PermaStruct[®] Composite Piles are a series of piling systems suitable for the harshest marine systems. Each system is suited for different applications and locations.

Why Choose PermaStruct® Composites Piles?

- ✓ High Strength
- ✓ Light Weight
- ✓ Low Environmental Impact
- ✓ Corrosion Resistant
- ✓ Superior Energy Absorption
- ✓ No Maintenance
- ✓ Low Drilling Cost

PermaStruct[®] Composite Piles consist of three main types, each designed to suit their respective applications.

- 1. **PermaStruct® FRP Dock Piles** which are primarily used for minor marine infrastructures such as harbours, docks, jetties.
- 2. **PermaStruct® Heavy Duty FRP Piles** which are primarily used for major marine infrastructures such as oil depots and ports.
- 3. **PermaStruct**[®] **FRP Sheet Piles** which are primarily used for applications that require additional asset protection and cover.

Please Note:

- Design Life: 80 Years
- Warranty: 20 Years
- Piles are standard coated for UV protection and can be coated with pollyurea upon request.



1.1 PERMASTRUCT® FRP DOCK PILES

PermaStruct[®] Dock Piles are Fibre Reinforced Polymer Piles that have been specifically designed for marine infrastructures, such as marinas canals docks, harbours, jetties & pontoons. Each pile is manufactured with a specific thermoset UV stabilised resin. PermaStruct[®] Dock Piles, incorporate exceptional strength and stiffness attributes, that can match steel or timber equivalents. Perma Struct Dock Piles stand out due to their ability to not rot, decay or succumb to marine borers. PermaStruct[®] Dock Piles are projected to last up to 80 Years and provide a huge advantage for marine designers and infrastructure owners. A good example, where PermaStruct[®] Dock Piles can be used is for substituting existing treated /timber piles, with much improved resistance to storms and long-term deterioration.



1.1.1 PERMASTRUCT[®] FRP DOCK PILES CONNECTIONS

PermaStruct[®] FRP Dock Piles can be integrated into existing projects as a hybrid solution where the FRP pile is installed in the water and splash zone with existing sub-frame used above. Naturally, the fixing detail size will be dependent upon the wind and wave loadings specific to a project.



Figure 1: Typical Dock Connection to Sub-Frame Connection



Alternatively, Perma Struct FRP Dock Piles can be combined with new FRP Sub-Frames, for full existing site replacements, with a hybrid of PermaStruct[®] FRP Decks & Jetties and FRP Piles.

An important aspect to consider for all connections, is the use of FRP Shear Washers, that are required to be sandwiched between the sun frame braces or stringers and is to be used as a washer on the backside of the connection.

Figure 2: Typical FRP Shear Washer



The FRP shear washer distributes bolted connection compression forces over an area of the pile, as opposed to the tangential loading without the washer. The FRP shear washers can be bonded to the pile for increased bearing capacity. Bonding of the FRP shear washers to the pile should be performed using the following procedure.

- 1. Scrape both the pile and washer using a 100-grit sandpaper. All gloss must be removed from the pile surface.
- 2. Clean the sanded areas using isopropyl alcohol-soaked cloths.
- 3. Apply a recommended epoxy adhesive to one of the bonding surfaces.
- 4. Use a putty knife or body filler scraper to spread the adhesive to a uniform thickness over the entire bonding area.
- 5. Self-drilling screws should be installed to hold the FRP washer in position while the adhesive cures.
- 6. Holes for the dock joint should be drilled after the washer is bonded to the pile to ensure the bearing surfaces of the holes are aligned.

FRP shear washers are produced in 3m lengths. Therefore, washers can be supplied in custom lengths to provide full support of the adjoining member.

Although, PermaStruct[®] FRP Dock Piles bolted connections, are project specific, they have typical characteristic strengths for typical bolt sizes as below, based on a standard 254 x 9.5mm PermaStruct[®] FRP Round Dock Pile without any FRP washers.

Force Direction	1 x M16 Bolt	2 x M16 Bolts	1 x M20 Bolt	2 x M20 Bolts	1 x M25 Bolt	2 x M25 Bolt
Parallel to Pile Axis	2,951 Kg	5,901 Kg	3541 Kg	7,082 Kg	4,721 Kg	9,442 Kg
Perpendicular to Pile Axis	1,762 Kg	3,525 Kg	2,115 Kg	4,230 Kg	2,820 Kg	5,639 Kg

All loads based on single shear loading & typical timber capacities.

With FRP Washers now added in, a significant increase in capacities can be seen.

Force Direction	1 x M16 Bolt	2 x M16 Bolts	1 x M20 Bolt	2 x M20 Bolts	1 x M25 Bolt	2 x M25 Bolt
Parallel to Pile Axis	5,295 Kg	10,589 Kg	6,354 Kg	12,707 Kg	8,471 Kg	16,943 Kg
46 Degrees to Pile Axis	4,345 Kg	8,691 Kg	5,214 Kg	10,429 Kg	6,953 Kg	13,905 Kg
Perpendicular to Pile Axis	3,877 Kg	7,754 Kg	4,652 Kg	9,305 Kg	6,203 Kg	12,406 Kg

All loads based on single shear loading, use of recommended epoxy adhesive & typical timber capacities.

Figure 3: Typical FRP Piles Load Directions



In addition to above data, PermaStruct[®] FRP Dock Piles have a typical pull out strength of the washer using a 152 x 9.5 mm Square Radius Washer of up to 6719 Kg, as well as maximum allowable torque of up to 68 Nm.

1.1.2 PERMASTRUCT[®] FRP DOCK PILES MATERIAL AND PHYSICAL PROPERTIES

PermaStruct[®] FRP Dock Piles have the following material and physical properties. These properties are based on data obtained on a typical pile size of 254mm x 9.5mm.

Property	Value			
Mechanical Properties				
Flexural Strength	453 MPa			
Compressive Strength	453 Moa			
Average In-Plane Shear Strength	74 MPa			
Typical In- Plane Shear Strength	65 MPa			
Average Shear capacity	27,753 Kg			
Typical Shear Capacity	24,317 Kg			
Average Torque Strength	67 Knm			
Typical Torque Strength	58 Knm			
Axial Compressive Strength	453 MPa			
Axial Compression Capacity	338 Кg			
Modulus of Elasticity	43.5 Gpa			
Bending Stiffness	2.43 x 10 ^11 Kg/mm^2			
Moment Capacity	195 Knm			
Average Pin Bearing Strength Cross Wise	132 MPa			
Typical Pin Bearing Strength Cross Wise	114 MPa			
Average Pin Bearing Strength Length Wise	219 MPa			
Typical Pin bearing Strength Length Wise	191 MPa			
Physical Properties				
Diameter	254 mm			
Wall Thickness	9.5 mm			
Moment of Inertia	4.31 x 10 ^6 mm ^4			
Radius of Gyration	87 mm			
Weight	15.3 Kg.m^2			
Coefficient of Thermal Expansions	9 x 10 ^10^-6 mm/mm/°c			
Water Absorption Rate- 24 Hrs	1 %			
Fibre Volume Fraction	>= 50%			
Cross-Sectional Area	7290 mm^2			
Surface Area	M^2/m			

1.1.3 PERMASTRUTC FRP DOCK PILES LOADING CAPABILITIES

PermaStruct[®] FRP Dock Piles have typical load capacities based on a typical FRP Dock Pile. These capacities are based on the Pile Moment Capacity.

Top of Pile to Point	Allowable Lateral	Lateral Load Producing the Exposure to Deflection (L/D) Ratio (Kg)			
of Fixity	Load (Kg)	120	240	360	
1.524 m	5226	2614	1306	871	
1.828 m	4355	1815	907	605	
2.133 m	3733	1333	666	444	
2.438 m	3266	1021	510	340	
2.743 m	2903	806	403	268	
3 m	2613	653	326	217	

Single Pile (Braced)- Lateral Load Capacity at Joint Location

Based on a FOS of 2.5 for allowable lateral loads.

Figure 4: Single Pile (Braced)- Lateral Load Capacity at Joint Location



Top of Pile to Point	Allowable Lateral	Lateral Load Producing the Exposure to Deflection (L/D) Ratio (K			
of Fixity	Load (Kg)	120	240	360	
1.524 m	10454	5228	2614	1743	
1.828 m	8711	3631	1815	1210	
2.133 m	7467	2667	1334	889	
2.438 m	6534	2042	1021	681	
2.743 m	5808	1613	807	538	
3 m	5227	1307	654	435	
3.352 m	4752	1080	540	360	
3.657 m	4356	908	454	303	
3.962 m	4021	773	386	258	
4.267 m	3734	667	333	222	
4.5 m	3484	581	290	194	

Two Piles (No Braces)- Lateral Load Capacity At Joint Location

Based on a FOS of 2.5 for allowable lateral loads. Based on pile moment and shear strengths only.

Figure 5: Two Piles (No Braces)- Lateral Load Capacity At Joint Location



Top of Pile to	Pile Spacing,	Allowable Lateral	Lateral Load Producing the Exposure to Deflectio teral Ratio (Kg)		
Point of Fixity(z)	within Bent, (y)	Load (Kg)	120	240	360
3 m	1.219	17423	9986	4993	3329
3 m	2.438	19454	-	13135	8757
3.658	1.219	13067	5624	2812	1875
3.658	2.438	19454	-	10086	6724
4.267	1.219	10454	3499	1750	1167
4.267	2.438	17423	11900	5950	3967
4.267	3.658	19454	-	12597	8398
4.877	1.219	8711	2358	1179	786
4.877	2.438	13067	6930	3465	2310
4.877	3.658	19454	-	10390	6927
5.486	1.219	7467	1686	843	562

Two Piles (X Brace)- Lateral Load Capacity at Joint Location

Based on a FOS of 2.5 for allowable lateral loads. Based on pile moment and shear strengths only. Standard timber capacities used. Bracing assumed to be standard blackbutt timber.

Figure 6: Two Piles (X Brace)- Lateral Load Capacity At Joint Location



1.1.4 PERMASTRUCT® DOCK PILES VERSUS TIMBER PILES

PermaStruct[®] Dock Piles offer many advantages over traditional Timber Piles, with the following charts comparing their performance.





1.1.5 PERMASTRUCT® DOCK PILES INSTALLATION

PermaStruct[®] FRP Dock Piles can be efficiently driven with a vibrating hammer. When utilizing a vibrating hammer, an adaptor is used to connect the pile to the vibratory hammer. The adaptor includes an interior steel pipe that fits into the PermaStruct[®] FRP Dock Pile to guide the pile. The interior tube is between 12.7 mm to 50.8 mm less than the interior diameter of the FRP pile. The interior pipe is welded onto a fat steel plate. The steel plate applies the compression force into the top of the pile.

It is also important to note that the pile may require an FRP insert for added compression or pin bearing strength. Therefore, the interior diameter of the pile will change. In the event a pile needs to be pulled, a vibratory hammer can be utilized to pull the piles.

Diesel and air impact hammers can also be successfully utilized to drive the PermaStruct[®] FRP Dock Pile. A pipe insert driving head or steel pipe cap is required for driving the hollow FRP piles. It is important that the piles are impacted so that the driving force is dissipated over the cross section of the top of the pile. Applying of wood or composite material pile cushion is recommended to reduce driving stresses.



PermaStruct FRP Dock Piles can also be driven into rock formation. However, it is often up to the Geotechnical & structural engineer as to how they want to approach the installation, but typical installation techniques would be as below:

- 1. Pre-drill the hole or rock socket. A hole is drilled slightly larger than the pile OD and the pile is fit into the hole.
- 2. Steel H-pile stinger. A steel H-pile is welded to a collar and the pile is bolted to that coupler and then driven to elevation.
- 3. Open shoe or Steel Tip. Piles driven in softer rock formations using a shoe or tip.

1.2 PERMASTRUCT® HEAVY DUTY FRP PILES

PermaStruct[®] Heavy Duty FRP Piles, are primarily used for larger marine structures, where high wave/Wind loads are present. They are also useful for dealing with impact loads from ships, due to its high energy absorption capabilities. Normally, PermaStruct[®] Heavy Duty Piles form a hybrid with PermaStruct[®] FRP Whales to form fender systems. This is where Perma Struct Heavy Duty FRP Piles stand out, due to the reduce stiffness, that allows for less rigidity and higher absorption. This allows vessels to impact the piles without any damage, as the piles deflects, absorbing the load in the process. PermaStruct[®] Heavy Duty FRP Piles are made of High strength, directional fibreglass with vinyl ester resin.

Why Choose PermaStruct Heavy Duty FRP Piles?

- ✓ Same Strength as Steel
- ✓ Low Maintenance
- ✓ Reduced Stiffness Allows for Minimal Damage on Impact
- ✓ Superior Energy Absorption to Steel & Concrete
- ✓ Acoustic Properties
- ✓ Low Drilling Cost

1.2.1 PERMASTRUCT[®] HEAVY DUTY PILE ACCESSORIES

A wide range of accessories are available to compliment the PermaStruct Heavy Duty Pile range, this includes;

- ✓ Pile caps for covering piles
- ✓ HDPE sleeves for added wear protection in vessel strike zone
- ✓ Prefabricated pile slices for low overhead clearance applications



1.2.2 PERMASTRUCT[®] HEAVY DUTY PILE DESIGN

PermaStruct[®] Heavy Duty FRP Piles can be engineered to suit various structural requirements, with a wide range of piling options available. PermaStruct[®] Heavy Duty FRP Piles are manufactured in a unique way, using a proven vacuum infusion process. This allows more control over variables that affect resin flow, laminate permeability, and pressure differentials, which results in more consistent production outcomes. PermaStruct[®] Heavy Duty FRP Piles, also have a unique closed moulding method, that allows a higher fibre to resin ratio (up to 54%) to be produced, allowing for a stronger and lighter product, than other moulding methods.

	Overall Diameter	Wall Thickness (mm)	Weight	Ultimate Limit State Capacities	
Part Number	(mm)		(Kg/m)	Moment (KNm)	Shear (KN)
PHDP1850	457.2	12.7	36.3	768.7	1276.6
PHDP1862	457.2	15.9	45.1	939.6	1574.7
PHDP1875	457.2	19.1	53.7	1105.0	1863.8
PHDP18100	457.2	25.4	70.5	1411.4	2419.8
PHDP2475	609.6	19.1	72.3	2027.0	2539.9
PHDP24100	609.6	25.4	95.5	2618.1	3313.9
PHDP24112	609.6	28.6	106.9	2900.1	3692.0
PHDP24125	609.6	31.8	118.0	3171.3	4061.2
PHDP24150	609.6	38.1	140.2	3686.5	4772.9
PHDP30100	762	25.4	120.4	4196.3	4212.5
PHDP30125	762	31.8	149.3	5114.2	5182.2
PHDP30150	762	38.1	177.5	5983.2	6111.9
PHDP36125	914.4	31.8	180.4	7522.1	6303.1
PHDP36150	914.4	38.1	214.9	8837.2	7459.7
PHDP36175	914.4	44.5	248.8	10095.4	8585.1
PHDP42150	1066.8	38.1	252.2	12248.5	8807.5
PHDP48150	1219.2	38.1	289.6	16215.6	10155.3

1.2.3 FENDER SYSTEM

A major advantage of PermaStruct[®] Heavy Duty Piles is the ability to absorb a high amount of impact energy, due to its flexibility, where on impact from a vessel, they bend and deflect and return back to its original shape with no damage on the fender and in most cases the vessel. Fender systems are developed with the use of PermaStruct[®] FRP Wales. Although, the main core strength of the fender comes from the piles, PermaStruct[®] FRP Wales have a higher stiffness, making it ideal for applications where protection of piers and waterfront is required. These wales are stiffer than alternatives like timber, allowing distribution the forces of impact across the piling system. PermaStruct[®] Fender systems are also suitable for areas where narrow channels or structures are in close proximity due its tight knit design.



Our PermaStruct FRP Fender System can be seen in action Below:

https://youtu.be/jy3vkFSxBC4

1.2.4 PERMASTRUCT[®] HEAVY DUTY PILE TOLERANCES

During manufacturing, there are always slight discrepancies in values due to tolerance levels. This applies also to PermaStruct[®] Heavy Duty FRP Piles.

Parameter	Value
Length	+-152.4 mm
Diameter	+-19.05 mm
Wall Thickness	+-4.76 mm
Weight	+-10 %
Fibre Volume	+-5%

1.2.5 PERMASTRUCT[®] HEAVY DUTY PILES INSTALLATION

PermaStruct[®] Heavy Duty FRP Piles can be efficiently driven using standard industry methods, such as use of vibrating & impact hammers. When using vibrating hammers, a hydraulic caisson clamp is to be attached directly to the pile. The clamping surface is level in order to minimize damage at the point of contact during driving. The size of the vibratory hammer should be selected based on site-specific soil conditions along with the diameter and weight of the pile. The maximum eccentric moment of the vibratory hammer recommended for PermaStruct[®] Heavy Duty FRP Piles is 0.4 KNm.

PermaStruct[®] Heavy Duty FRP Piles can be cut using most traditional concrete cutting equipment such as a diamond or abrasive grit blade. It is important that the cut line is accurately marked when cutting, and proper safety equipment is always to be worn during installation.

1.2.6 PERMASTRUCT[®] HEAVY DUTY PILES TRANSPORTATION

PermaStruct[®] FRP Heavy Duty Piles are shipped to site using flat bed trailers. The piles should be stored in an area or use blocks to prevent rolling of the piles. Nylon slings should be used to avoid damaging the surface of the pile. Straps need to be appropriately rated for the weight of the piles. It is also acceptable to tandem lift the piles with fork trucks or lulls that are utilizing nylon slings. PermaStruct[®] FRP Heavy Duty Piles should not be rolled over. Because of the way PermaStruct[®] FRP Heavy Duty Piles are manufactured, there are surface imperfections on the piles. These are a normal part of the processing and do not affect the pile's structural performance and should not be a concern

1.3 PERMASTRUCT® FRP SHEET PILES

PermaStruct[®] FRP Sheet Piles is ideal for projects, where asset protection is a major priority, not just in terms from impact but for security purposes as well. The sheet piles are formed by a pultrusion process using electric grade fibreglass and high strength resins. They offer also a form of UV protection to assets that would deteriorate when exposed to high volumes of violet rays from sunlight.

PermaStruct[®] FRP Sheet Piles are suitable for a wide range of applications, including;

- ✓ Wave Breaks
- ✓ Retaining Walls
- ✓ Water Control
- ✓ Land Stabilization
- ✓ Bridge Abutment's
- ✓ Erosion Control
- ✓ Flood Protection
- ✓ Containment/Security Boundaries

PermaStruct[®] FRP Sheet Piles are proven system used for various structural solutions where water protection is required. The sheets are aesthetically pleasing, and per weight, are stronger than steel, concrete & timber. There are easy and quicker to install with standard pile driving equipment only required, and its light weight allows for easy transportation. A major positive, is they are highly corrosive resistance allowing for minimal to no maintenance required. They are also inert to marine borers and are unaffected to marine life.



1.3.1 PERMASTRUCT[®] FRP SHEET PILES TYPICAL PROPERTIES

PermaStruct[®] FRP Sheet Piles have typical properties as below. These properties may change slightly with variances in sheet profiles.

Property	Value
Tensile Modulus Lengthwise	24.96 Gpa
Tensile Modulus Crosswise	3.59 Gpa
Compressive Modulus Lengthwise	24.96 Gpa
Compressive Modulus Crosswise	6 Gpa
Tensile Strength Lengthwise	440 MPa
Tensile Strength Crosswise	58 MPa
Compressive Strength Lengthwise	381 MPa
Compressive Strength Crosswise	131 MPa
In Plane Shear Strength	56 MPa
In Plane Shear Modulus	3.45 Gpa
Short Beam Shear Strength	21 MPa
Moment Capacity	271.3 Knm/m & 78.2 Knm/m
Shear Capacity	247 Kn/m & 71.1 Kn/m
Modulus of Elasticity	31.85 GPA
Web Buckling Capacity	186.7 Kn/m

BASED ON A STANDARD SHEET SIZE OF 812.8MM X 355.6MM X 8.6MM

1.3.2 PERMASTRUCT[®] FRP SHEET PILES ACCESSORIES

PermaStruct[®] FRP Sheet Piles comes with the following two accessories which are fit for purpose items.





Sheet Pile Caps

Sheet Pile Connectors