Wagners Pinkenba Wharf Project

Design Validation Of GFRP Materials

For Use In An Innovative Wharf Structure

ACIC 2019 – University of Birmingham

WWW.WAGNER.COM.AU

Todays Presentation

- Wagners Background
- Bridge Beam Development
  - Development of composites in bridge applications
- Pinkenba Wharf
  - Design
  - Design Validation
  - Fabrication and QA
  - Installation
- Future Developments

Wagners CFT
Building the Future

- Head Office Toowoomba, Queensland Australia
- Manufactures and Fabricates 1400 tonne of Fibre Composite Material per annum
- Australia's only Pultruder
- Publicly Listed on Australian Stock Exchange – ASX:WGN

WAGNERS

Pull Wound Sections

SQUARE HOLLOW SECTIONS – WCFT Grade GV35-S

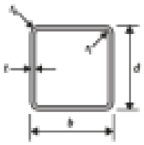
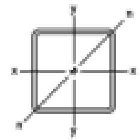


Table 2.1

DIMENSIONS & SECTION PROPERTIES

SQUARE HOLLOW SECTIONS
WCFT Grade GV35-S
Fibre Reinforced Polymer (FRP)



DIMENSIONS					SECTION PROPERTIES							
Designation Depth d x Width b x Thick. t	Outside Corner Radius r_o	Inside Corner Radius r_i	Mass per m	External Surface Area per m	Gross Section Area A_g	About x- and y-axis I_x	Z_x	r_x	About n-axis I_n	Z_n	Torsion Constant J	Torsion Modulus C
mm mm mm	mm	mm	kg/m	m²/m	mm²	10^6mm⁴	10^3mm³	mm	10^6mm⁴	10^3mm³	10^6mm⁴	10^3mm³
WCFT 125 x 125 x 6.4 SHS	10.0	4.75	5.85	0.483	2970	6.89	110	48.2	6.90	81.9	10.9	48.2
WCFT 100 x 100 x 5.2 SHS	10.0	4.75	3.75	0.383	1905	2.80	56.1	38.4	2.81	42.3	4.55	58.4

RECTANGULAR HOLLOW SECTIONS – WCFT Grade GV35-S

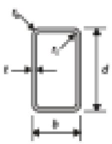
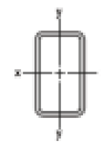


Table 2.2

DIMENSIONS & SECTION PROPERTIES

RECTANGULAR HOLLOW SECTIONS
WCFT Grade GV35-S
Fibre Reinforced Polymer (FRP)



DIMENSIONS					SECTION PROPERTIES								
Designation Depth d x Width b x Thick. t	Outside Corner Radius r_o	Inside Corner Radius r_i	Mass per m	External Surface Area per m	Gross Section Area A_g	About x-axis I_x	Z_x	r_x	About y-axis I_y	Z_y	r_y	Torsion Constant J	Torsion Modulus C
mm mm mm	mm	mm	kg/m	m²/m	mm²	10^6mm⁴	10^3mm³	mm	10^6mm⁴	10^3mm³	mm	10^6mm⁴	10^3mm³
WCFT 100 x 75 x 5.0 RHS	10.0	4.75	3.12	0.333	1584	2.14	42.8	36.8	1.37	36.5	29.4	2.76	59.2

BONDED RECTANGULAR BEAMS – WCFT Grade GV35-S

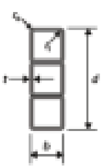
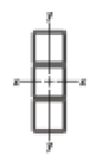


Table 4.1

DIMENSIONS & SECTION PROPERTIES

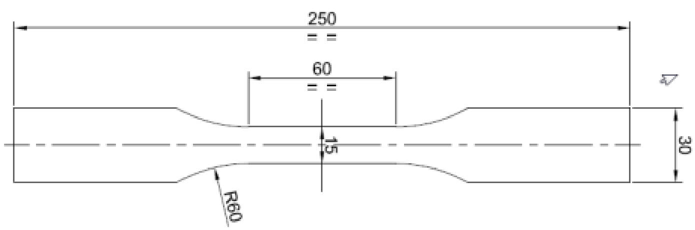
BONDED RECTANGULAR BEAMS
WCFT Grade GV35-S
Fibre Reinforced Polymer (FRP)

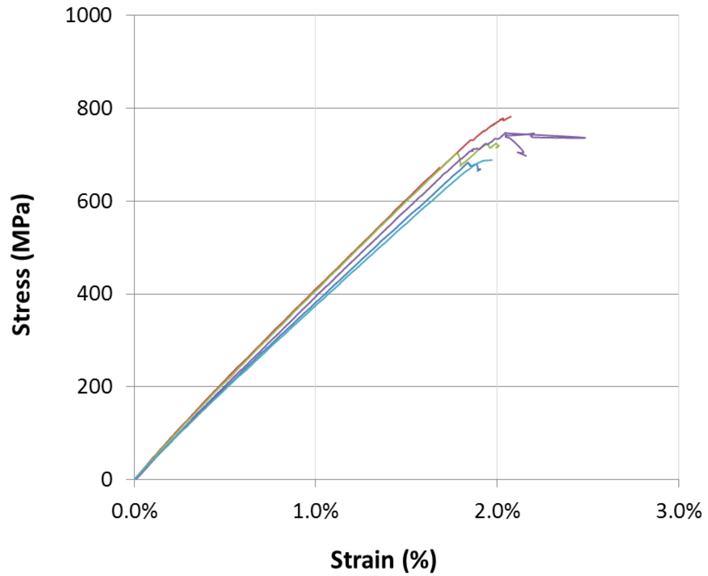


DIMENSIONS					SECTION PROPERTIES							
Designation Depth d x Width b x Thick. t	Outside Corner Radius r_o	Inside Corner Radius r_i	Mass per m	External Surface Area per m	Gross Section Area A_g	About x-axis I_x	Z_x	r_x	About y-axis I_y	Z_y	r_y	Torsion Constant J
mm mm mm	mm	mm	kg/m	m²/m	mm²	10^6mm⁴	10^3mm³	mm	10^6mm⁴	10^3mm³	mm	10^6mm⁴
WCFT 625 x 125 x 6.40 BRB	10.0	4.75	29.3	1.57	14840	490	1595	183	34.4	551	48.2	54.6
WCFT 500 x 125 x 6.40 BRB	10.0	4.75	23.4	1.30	11879	260	1038	148	27.5	441	48.2	45.7
WCFT 375 x 125 x 6.40 BRB	10.0	4.75	17.6	1.05	8909	113	605	113	20.7	330	48.2	32.8
WCFT 250 x 125 x 6.40 BRB	10.0	4.75	11.7	0.756	5939	37.0	296	78.9	13.8	220	48.2	21.8
WCFT 500 x 100 x 5.20 BRB	10.0	4.75	18.8	1.27	9527	205	818	147	14.0	280	38.4	22.8
WCFT 400 x 100 x 5.20 BRB	10.0	4.75	15.0	1.05	7621	106.5	532	118	11.2	224	38.4	18.2
WCFT 300 x 100 x 5.20 BRB	10.0	4.75	11.3	0.828	5716	46.5	310	90.2	8.41	168	38.4	13.7
WCFT 200 x 100 x 5.20 BRB	10.0	4.75	7.51	0.606	3811	15.1	151	63.0	5.61	112	38.4	9.11

WAGNERS

Derivation of Characteristic Material Properties

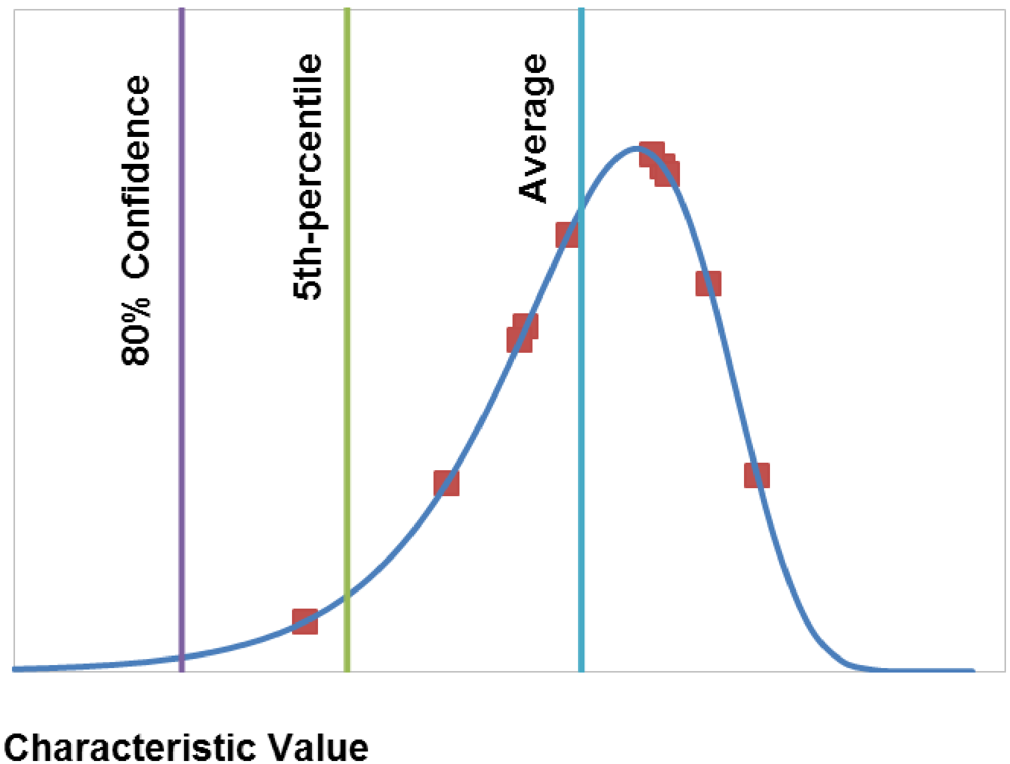




Sampling → **Material tests** → **Characteristic Values** → **Design strength**

- ASCE (2010) *Pre-Standard for Load and Resistance Factor Design (LRFD) of Pultruded Fiber Reinforced Polymer (FRP) Structures (Final)*, American Society of Civil Engineers

Characteristic Values



Weibull function

ASTM D7290

- Statistically determined values
- Considering two parameters – Shape and Scale
- Representing 80 % lower confidence bound on a 5th percentile of specific population

WAGNERS

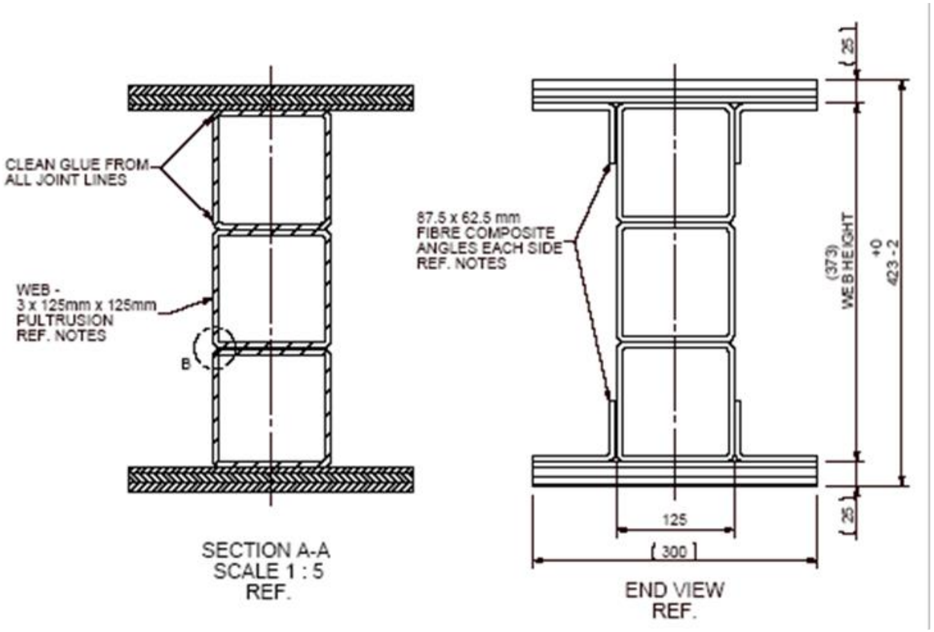
Application to Pedestrian Structures

- Wagners development process continued with Pedestrian Infrastructure
- Over 500 Structures around Australia, USA, NZ, UK and UAE Coastline


120

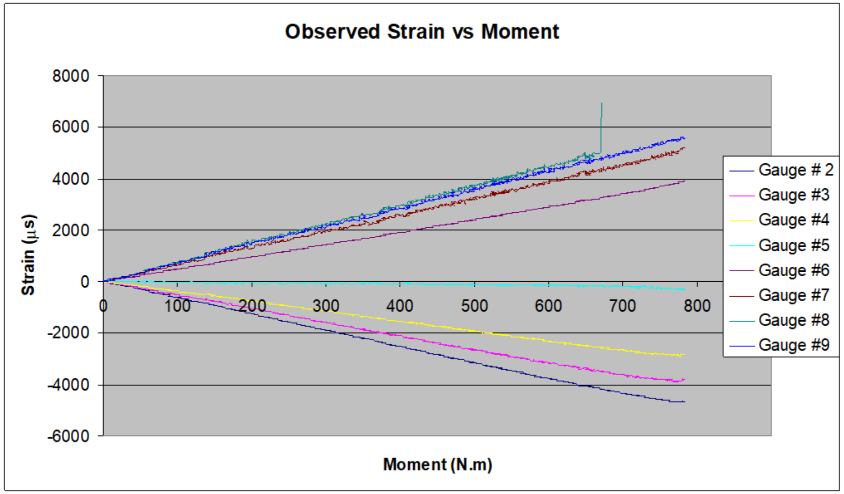
- Little Malop St Bridge – Geelong
- Raked Truss + Throw Screens
- 23m Span
- Designed for Horizontal Impact loading to AS5100
- Large vertical curve – Architectural and clearance to rail

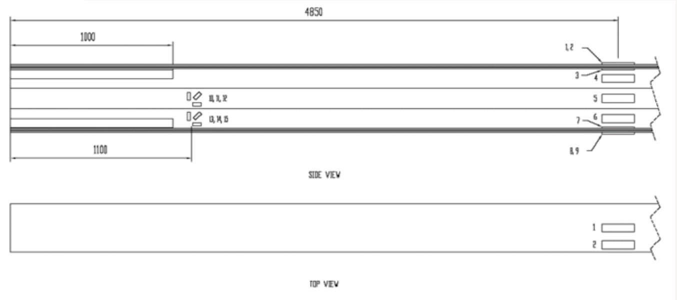
Beam Development

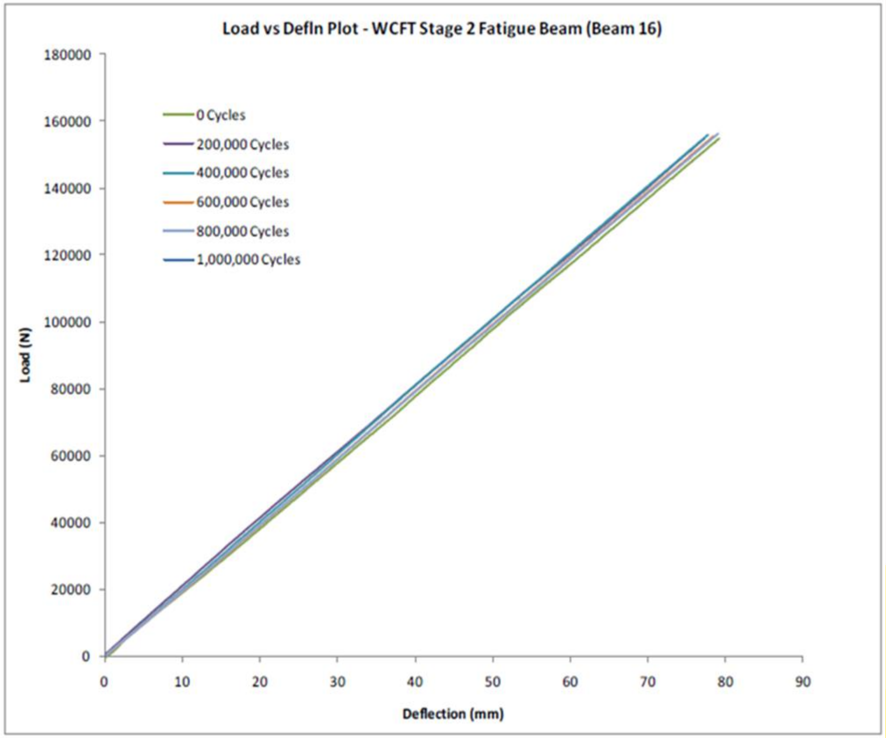


Beam Property	Requirement	Tolerance	Wagners Beam	Requirement Met?
Max width	350 mm	+0	300mm	Yes
Max depth	425 mm	+0	424mm	Yes
Mmax at failure	660 kNm	-0	780kN	Yes
EI of girder	29.6×10^{12} Nmm^2	+/- 10%	27.4×10^{12} N.mm^2	Yes
Working live load capacity	109 kNm	NA	NA	NA
Shear Capacity	350 kN	-0	435 kN	Yes
Max Deflection (at ultimate = 350kN)	170 mm	+/- 10%	172.4mm	Yes

Beam Testing - Fatigue







WAGNERS

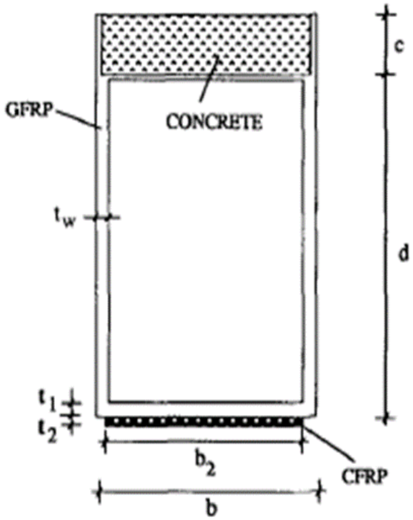
Timber Bridge Rehabilitat

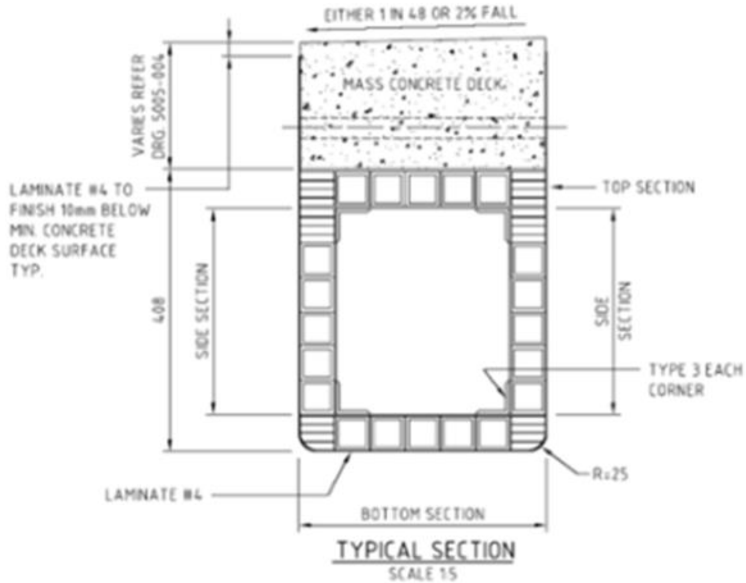
Replacement of timber structures
With FRP Piles, girders and decks

Concrete / FRP Bridge Superstructures

- Erie County Department of Public Works oversees 1200 lane mile of road, upon which 24 feet of snow falls every year. The county dumps 96,000 tonne of de-icing salts on their roads each year.

Evolution of a Hybrid Bridge Deck





- Early Concept - Triantafillou and Meier (1992)

- Australian Approach – Van Erp et al 2002
- Funding from Wagners

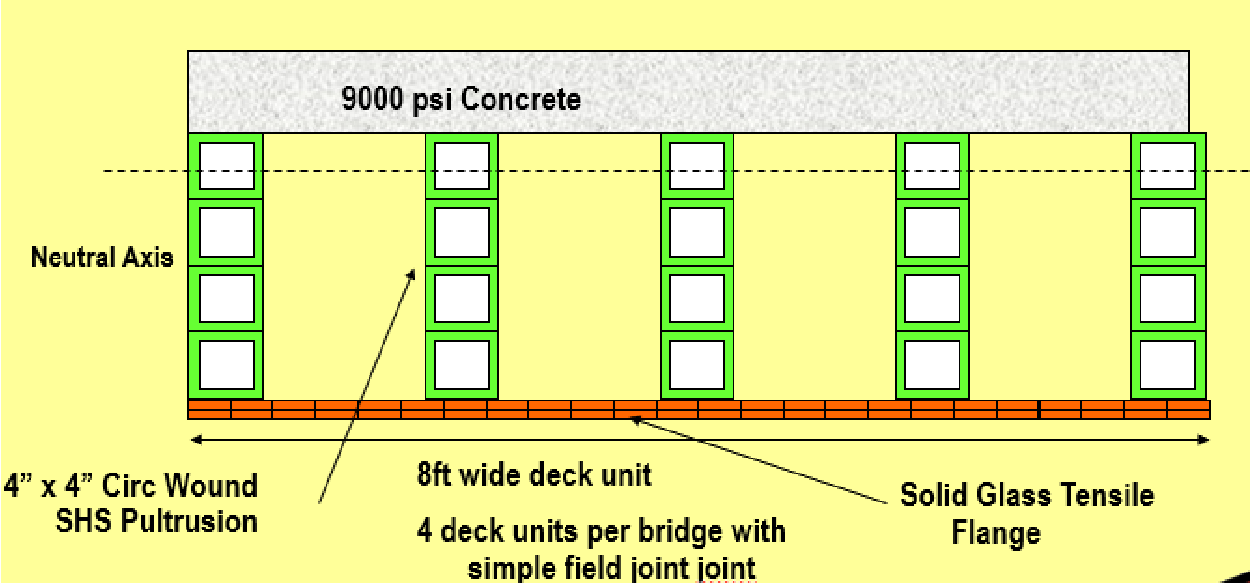
WAGNERS

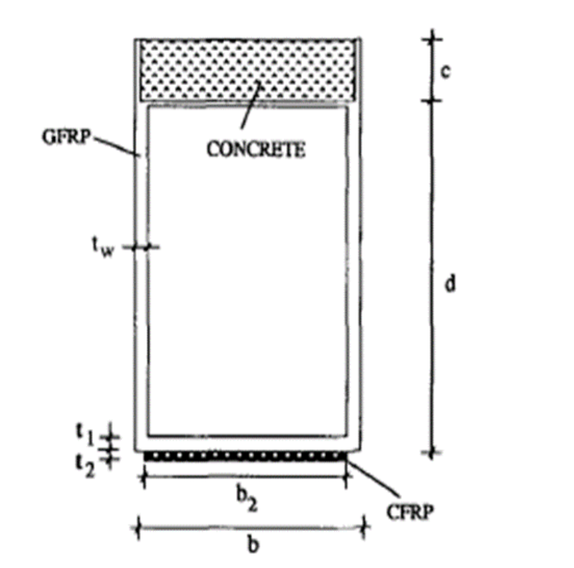
Evolution of a Bridge Deck

Australia’s First FRP Deck

Coutts Crossing, Grafton NSW

Erie County Concept Section

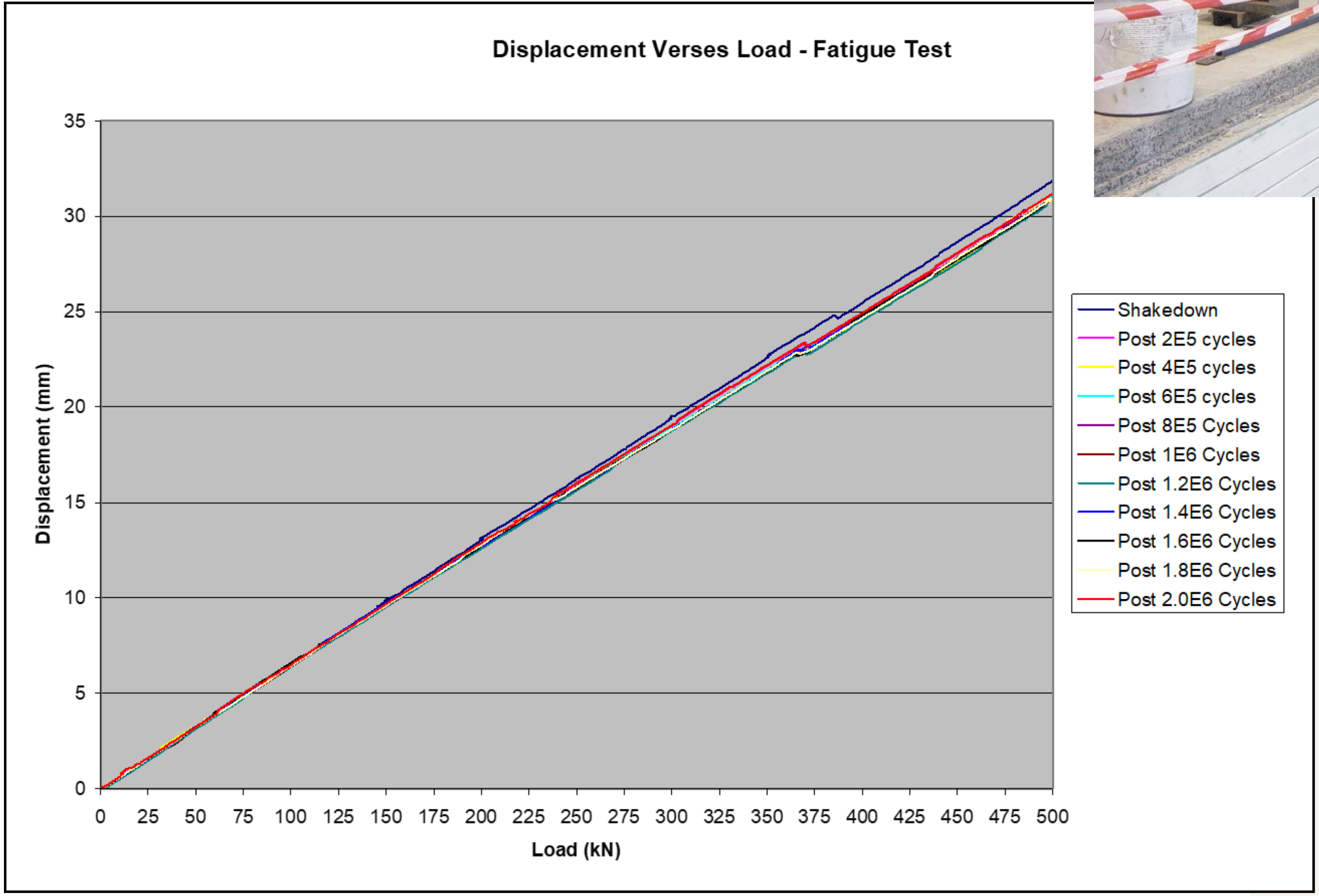


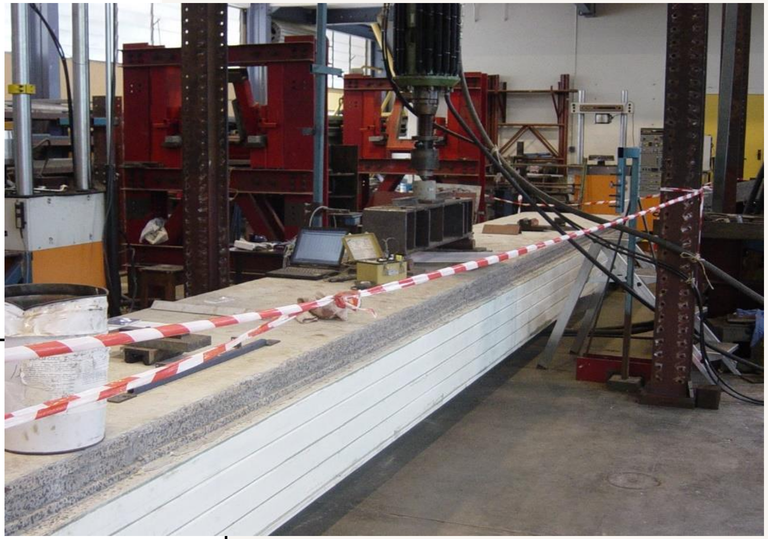


- AASHTO HS25 Design Vehicle
- L/500 allowable deflection under Live Load

- Early Concept - Triantafillou and Meier (1992)

Testing and Analysis
Fatigue





- 2 Million Cycles
- 4-Point Bending
- 2x 56,000 lb Point Loads (250kN)
- Average 1 ¼" Deflection (32mm)
- No loss of stiffness across test

WAGNERS


WAGNERS
TRALIA


WAGNERS
AUSTRALIA
www.wagner.com.au
WAGNERS

14 Years of Service

After 14 years of service the following observations are made:

- No deck surface deterioration
- No Corrosion of FRP materials
- No Structural failures
- No damage from debris (underside)

Conclusion –

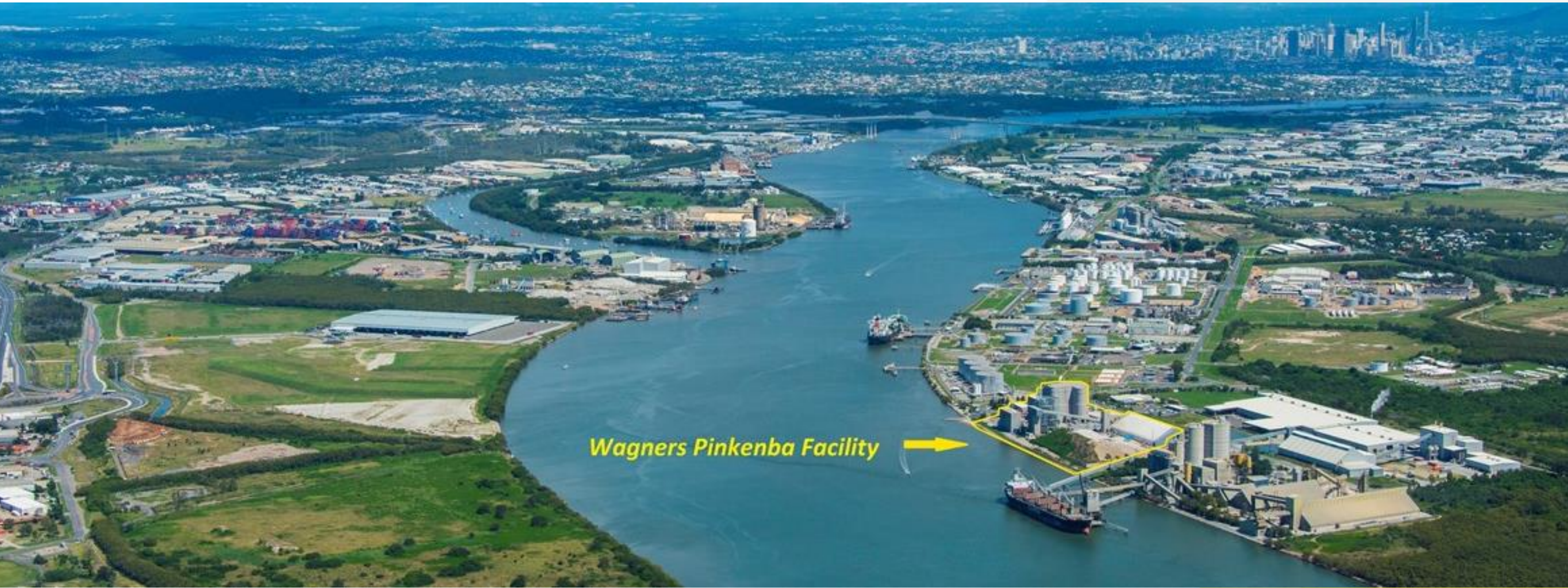
FRP Materials are living up to the reputation!

WAGNERS

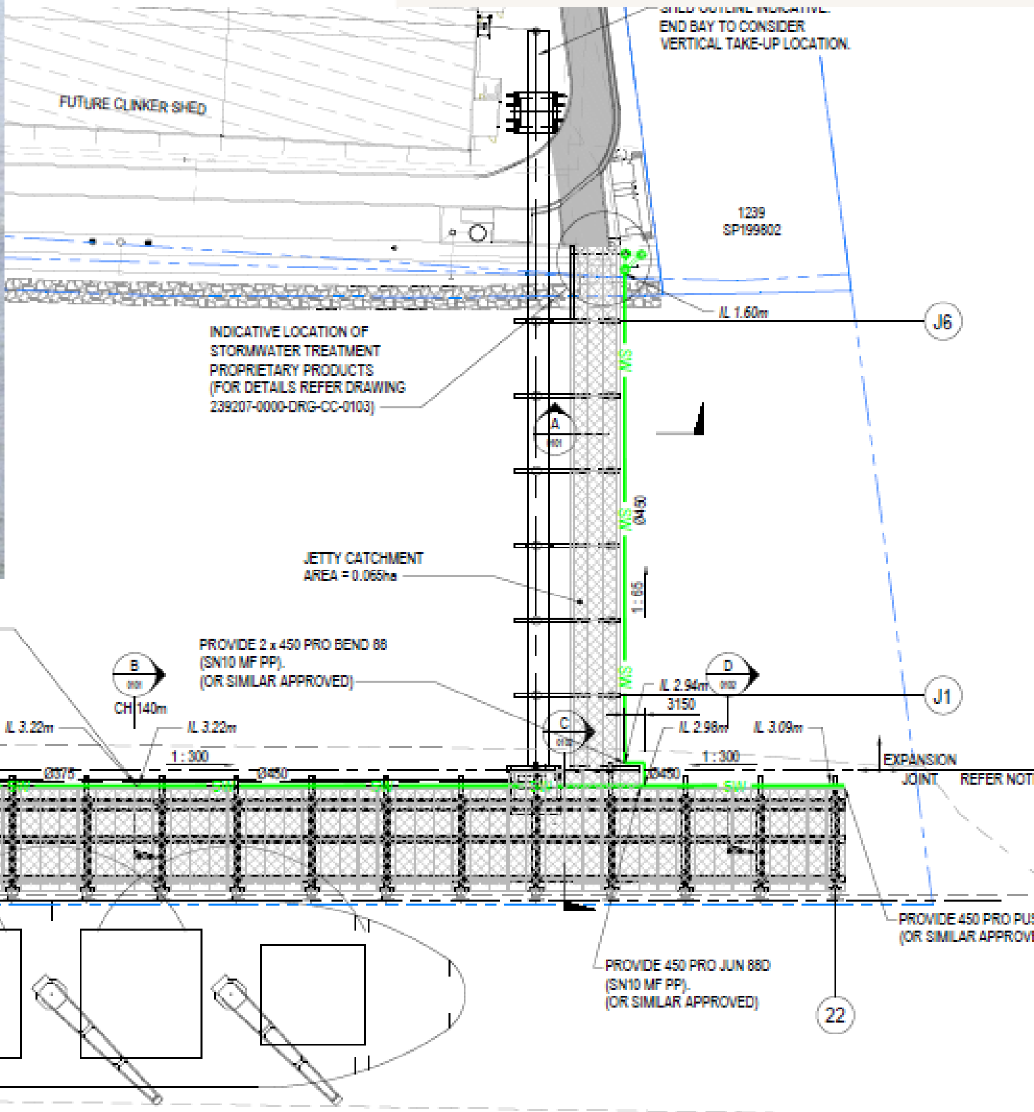
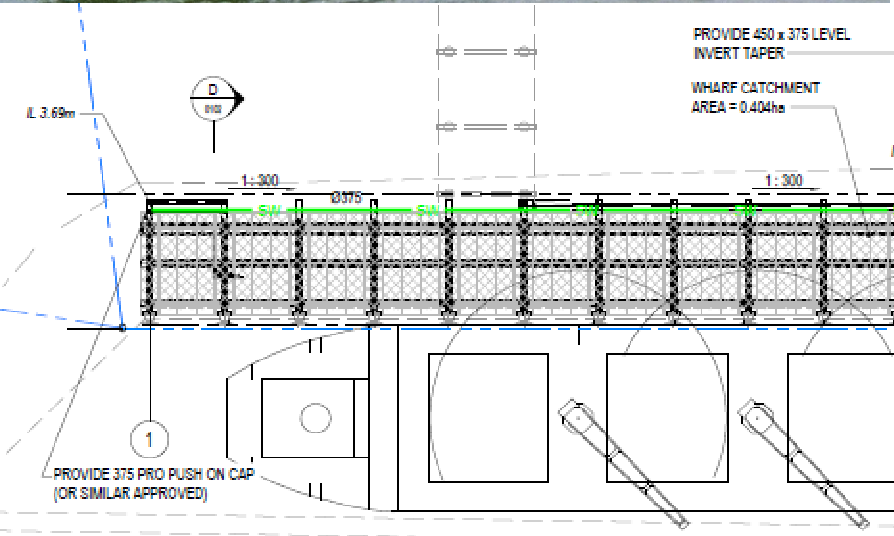
Pinkenba Wharf

Wagners Clinker Grinding Facility

Servicing Brisbane and SEQ Cement Market

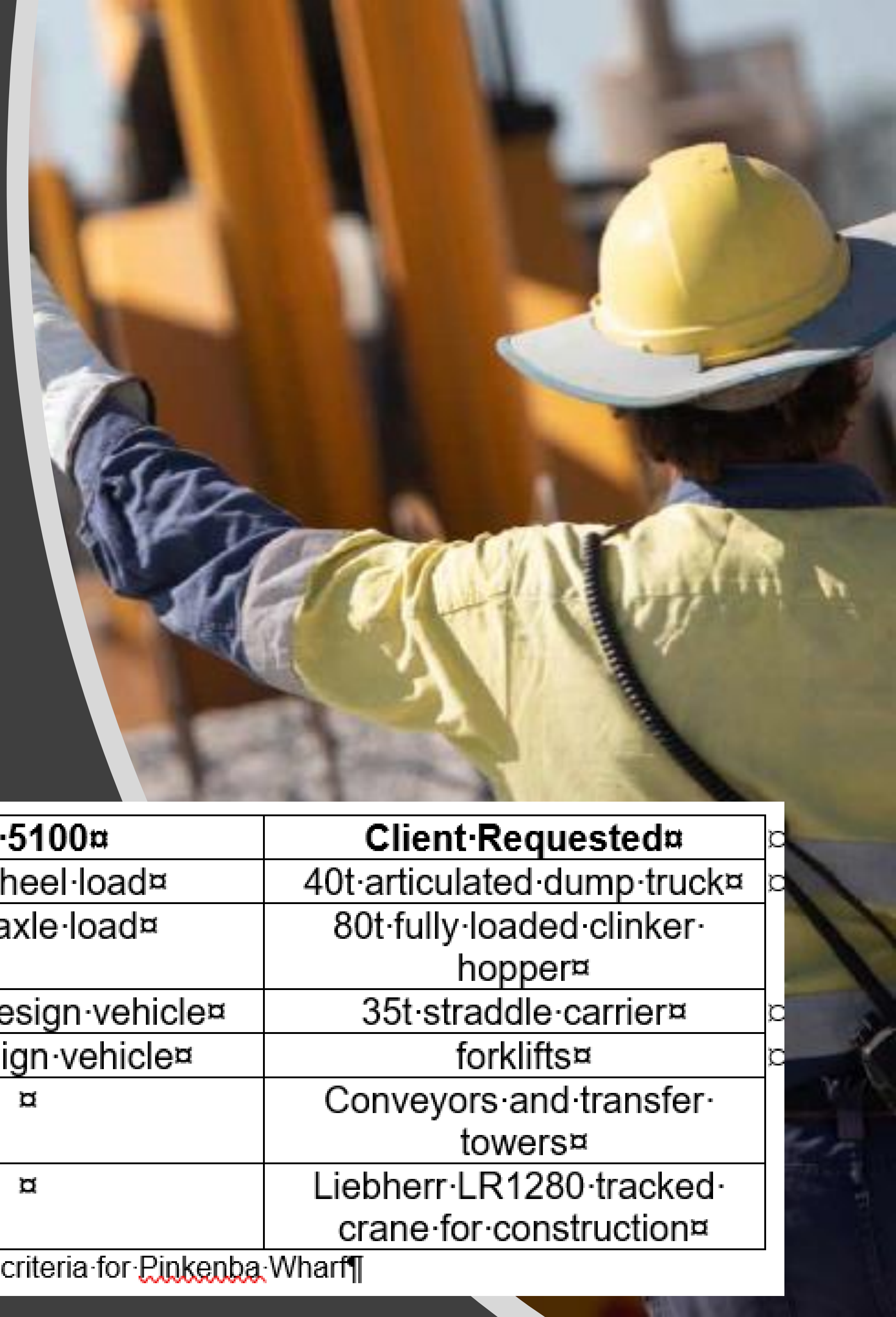


Pinkenba Wharf

Loading

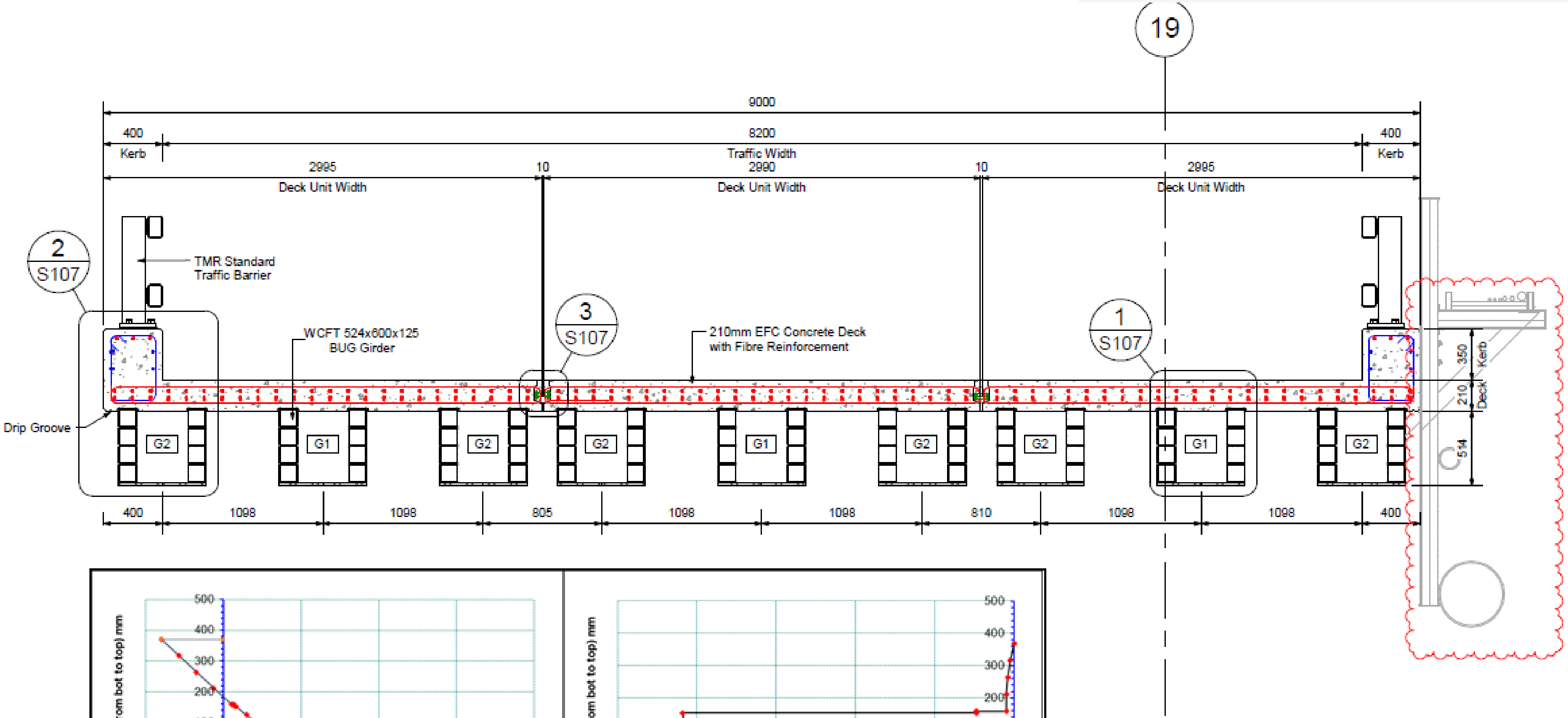
- Superstructure
  - FRP U-Girder Deck
  - Class 25 Wharf – 3.6psi deck UDL (25kPa) + 112,000 lb point load on 3ft square point load from Crane (General Purpose wharf)
  - Construction Load – Liebherr 1280 tracked crane
  - Concrete Top (Earth Friendly Concrete)
  - FRP Rebar in Concrete
  - No Corrosion in Deck

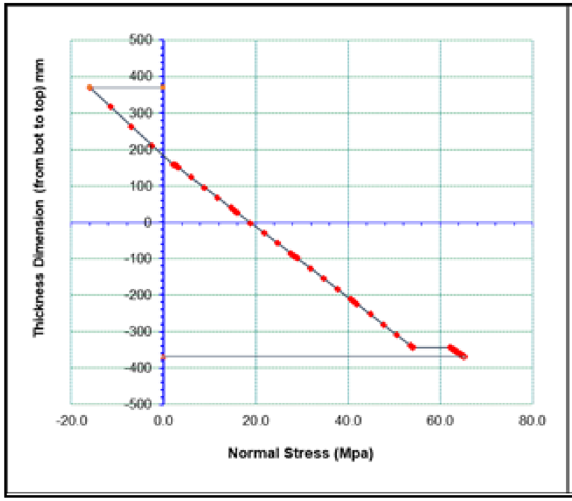


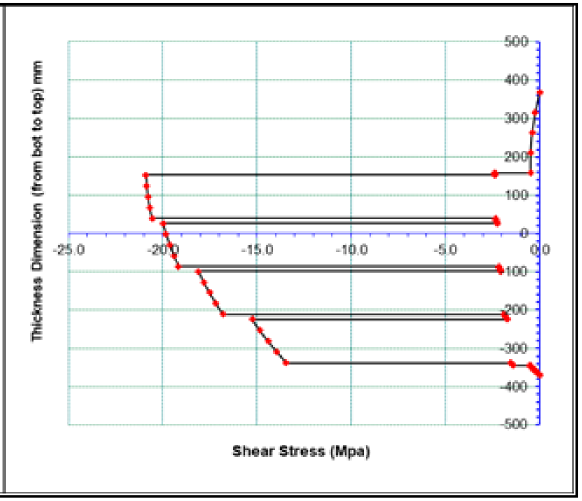
AS 4997	**AS 5100**	**Client Requested**
25 kPa UDL	W80 wheel load	40t articulated dump truck
500kN PL over 1200x1200mm sq.	A160 axle load	80t fully loaded clinker hopper
SM1600	SM1600 design vehicle	35t straddle carrier
HLP	HLP design vehicle	forklifts
50t SWL mobile crane		Conveyors and transfer towers
		Liebherr LR1280 tracked crane for construction

Table 1 Vertical loading criteria for Pinkenba Wharf

Proposed Section







Prototyping and Testing

- The testing program was broken up into five key tests:
  - **Test 1: aggregate shear key tension test**
    - To test tensile capacity and efflorescence of concrete
    - Ultimate tensile capacity of shear key from direct tension (wave uplift) loads
  - **Test 2: FRP reinforcing and concrete deck capacity**
    - Test ultimate moment capacity
    - Test ultimate shear capacity
    - Test ultimate punching shear capacity
    - Test ultimate bending capacity of slab
    - Test fatigue performance of slab over 2e6 cycles
    - Test long-term creep performance
    - Test longitudinal shear key capacity
    - Measure crack widths

Test 3: full scale U-girder and concrete deck test

Test ultimate moment capacity
Test ultimate shear capacity
Test ultimate bending capacity of slab
Test fatigue performance of slab over 2e6 cycles
Test long-term creep performance
Test longitudinal shear key capacity

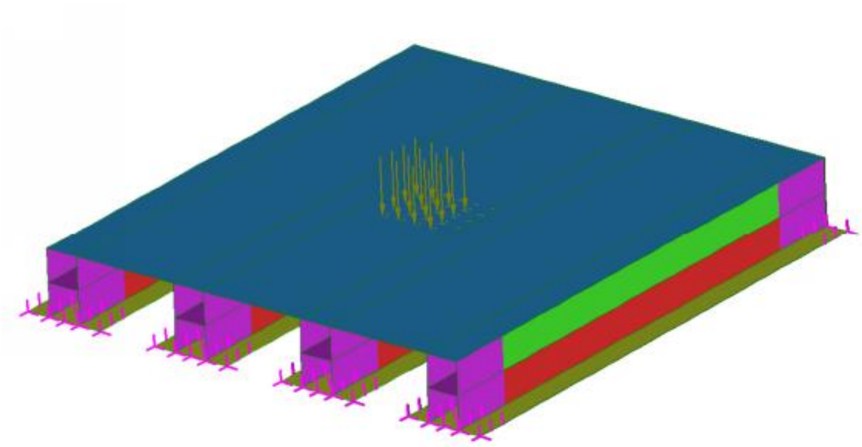
Test 4: FRP reinforcing bar tests

Test tensile modulus
Test elastic modulus
Test shear strength
Test ultimate tensile strength
Deriving GFRP bond coefficient

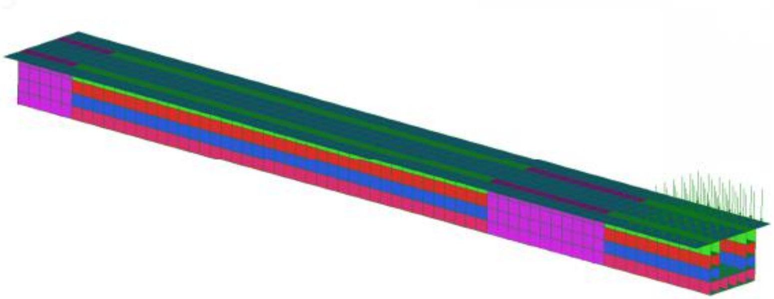
Test 5: U-Clip joint capacity

Test shear and tension across U-clips in construction joints between each

Testing – Point Loads through Deck

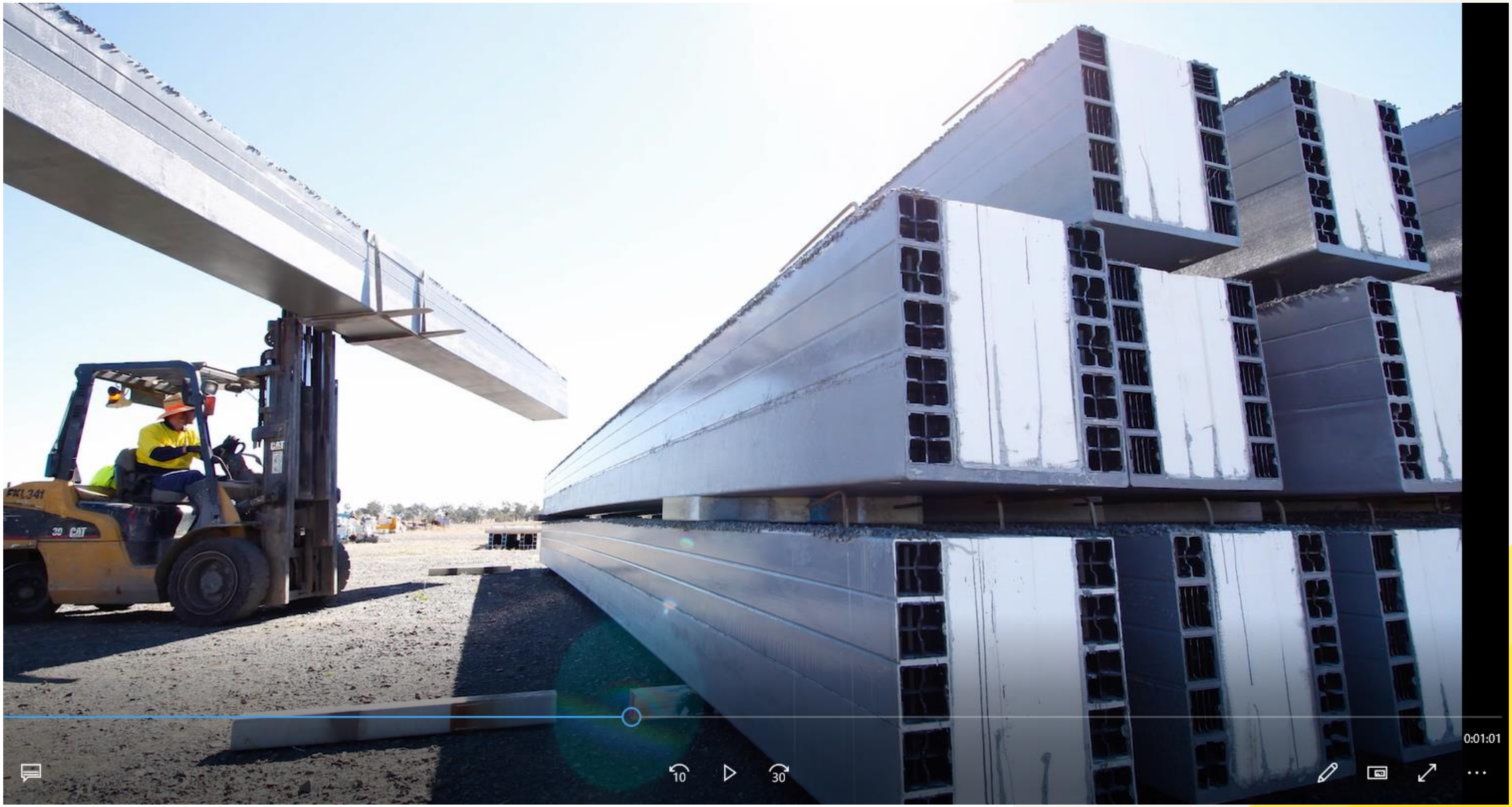


Testing – Full Scale Beam Bending



Fabrication

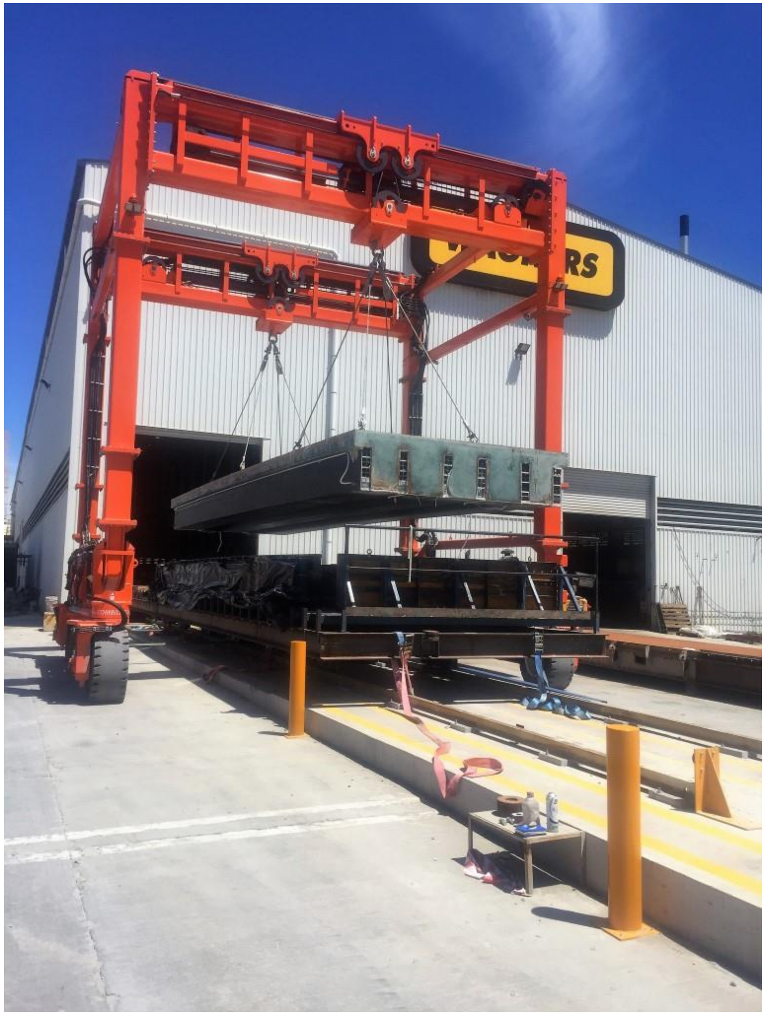
Fabrication



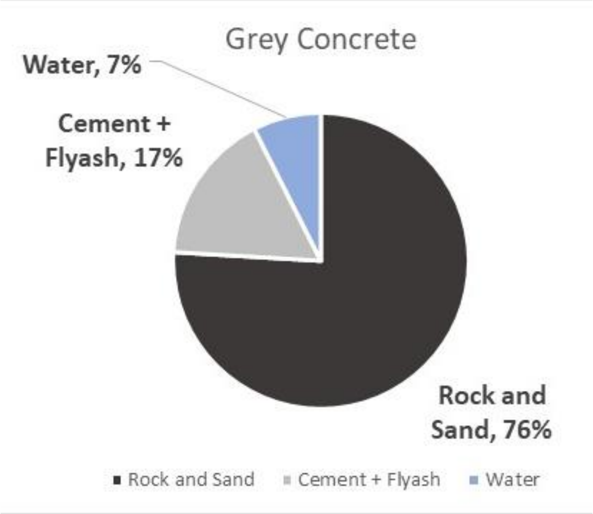
FRP Rebar

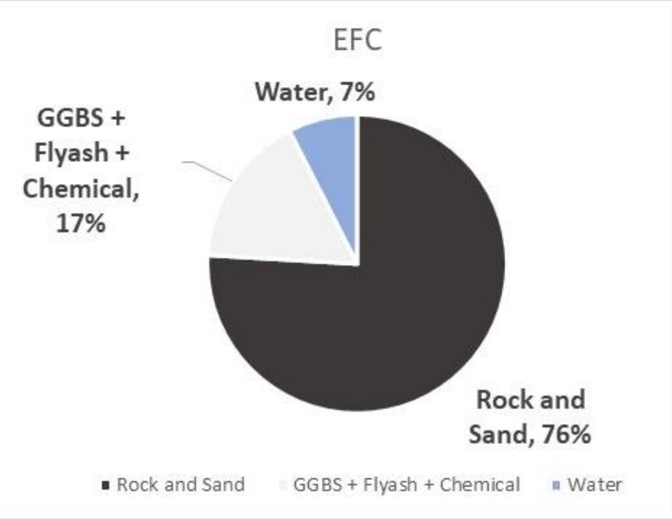
Rebar and U-Girders in Form

Deck Units



Geopolymer Concrete
Wagners Earth Friendly Concrete





Structural Performance (Compared to Portland cement concrete)	**Durability** (Compared to Portland cement concrete)
All commercial grades: 25 to 65 MPa	High acid resistance (sewer)
30% higher flexural tensile strength	High sulphate resistance
Low drying shrinkage – typ 350 $\mu\varepsilon$	High chloride ingress resistance (marine)
Similar modulus and poisons ratio	Low heat of reaction
High fire resistance	

WAGNERS


WAGNERS

Pinkenba Wharf

The first of its kind

Questions?

WAGNERS