MAIN ROAD WESTERN AUSTRALIA

Fremantle Traffic Bridge 0916

PIER 15 EMERGENCY REPAIR

CONFIDENTIAL

JUNE 2016

WSP | PARSONS BRINCKERHOFF

Fremantle Traffic Bridge 0916

PIER 15 EMERGENCY REPAIR

Main Road Western Australia

Confidential

Project no: 2113438A-TPT-REP-0001 RevD
Date: June 2016

REV	DATE	DETAILS
A	13/05/2016	Draft
B	26/05/2016	Revision 1
C	27/05/2016	Revision 2
D	01/06/2016	Revision 3

AUTHOR, REVIEWER AND APPROVER DETAILS

Prepared by:	Wolfram Schwarz	Date: 01/06/2016	Signature:	
Reviewed by:	Kris Hird	Date: 01/06/2016	Signature:	
Approved by:	Jon Williams	Date: 01/06/2016	Signature:	

WSP | Parsons Brinckerhoff
Level 5, 503 Murray Street
Perth WA 6000
PO Box 7181
Cloisters Square WA 6850

Tel: +61 8 9489 9700
Fax: +61 8 9489 9777

www.wsp-pb.com

Our ref: 2113438A-TPT-REP-0001 RevD.docx

Level 5, 503 Murray Street
Perth WA 6000
PO Box 7181
Cloisters Square WA 6850

Tel: +61 8 9489 9700
Fax: +61 8 9489 9777

www.wsp-pb.com

1 June 2016

Confidential

Adam Lim
Senior Engineer Structures
Main Roads Western Australia
Don Aitken Centre
Waterloo Crescent
East Perth WA 6004

Dear Adam

Fremantle Traffic Bridge 0916
Pier 15 Emergency Repair

I have the pleasure in enclosing the Fremantle Traffic Bridge 0916 – Pier 15 Emergency Repair Report – Revision 3, including associated documents.
Should you have any queries regarding the works, we would be pleased to discuss these with you.

Yours sincerely

Wolfram Schwarz
Principal Engineer, Transport Structures

TABLE OF CONTENTS

ABBREVIATIONS

MRWA	Main Roads Western Australia
GVM	Gross Vehicle Mass

EXECUTIVE SUMMARY

MRWA commissioned WSP | Parsons Brinckerhoff to assess the timber piles of Pier 15 of the Fremantle Traffic Bridge (Bridge 0916) after a localised reduction to the level of the river bed level was recorded during recent inspections.

The assessment of the piles identified significant safety concerns around the ongoing operation of the bridge, and therefore suggested closure of the bridge to all traffic. In order to return the bridge to operation, a temporary bracing system was developed and installed to improve the assessed pile capacities. With bracing installed, the bridge was reopened to traffic with existing load restrictions in place,

As part of a longer-term strategy, WSP | Parsons Brinckerhoff has suggested a permanent solution that is currently being developed and is planned to be installed within the next 6 months. The temporary bracing system will be removed as part of these permanent works.

1 ANALYSIS

1.1 Background

MRWA commissioned WSP | Parsons Brinckerhoff to assess the timber piles of Pier 15 of the Fremantle Traffic Bridge (Bridge 0916) after a localised reduction to the level of the river bed level was recorded during recent inspections.

Two spans and the pier were modelled in SpaceGass as 3-dimensional frames (refer to Plate 1), based upon available as-constructed records.

1.2 Assumptions

The following assumptions have been made and consequently used to derive the results reported in Table 1 & Table 2:

- The timber grade of all piles is F17 in accordance with AS1720-1988.
- Piles are in good condition.
  - Pile capacities and ratings were revised with measurements taken by divers whilst undertaking underwater inspections.
  - Where piles could not be measured at the base an average taper of 4.5mm/m (average of all measured tapers available from the diving reports from water level to river bed level) was applied; reducing the measured diameter at water level over the length of the pile to estimate the diameter at the river bed level.
  - The member capacity of the individual timber pile was calculated based on the average diameter at mid length.
- Pile lengths from river bed level to the concrete walers were based on direct measurements by the underwater inspectors.
  - The unsupported length of each pile was increased by 4× the pile diameter to cater for the additional length required in the ground to activate some restraint by the soil. This equated to a pile length of 13.9m + 1.6m = 15.5m for Pile 9A & 9B and 12.9m + 1.6m = 14.5m for the remainder of the piles before applying the effective length factor.
- Piles are fully restrained at the concrete walers and below the river bed level. Originally an effective length factor (sk) of 1.2 was applied in accordance with AASHTO LRFD 2012, Table C4.6.2.5-1 to allow for sway of the pier at the concrete walers. As older literature (e.g. AASHTO LRFD 2007) allows an effective length factor of 1.0 for restrained base, sway and restrained top, the lower values were applied.
- Presented load rating results are based upon axial loads only. Neither moments from eccentric axial loads, nor moments from tidal loading were considered in the analysis (see Tables 1 and 2).
  - Generally, construction tolerances during pile driving result in additional eccentricities, which generate bending effects in the piles. These effects were not taken into account in the analysis.
- Drag forces from tidal flows (3 knots – tidal flow velocity in winter taken from records provided by the Port of Fremantle) were included in the 3D model. Axial effects resulting from these loads were included in the analysis.
- A 3.5 kN/m^2 uniform distributed load was applied to multiple lanes of the bridge (in various configurations) to model the effect of vehicles with a gross vehicle weight of up to 5t. A dynamic load

allowance factor of 0.1 was applied to these light vehicle loads. No lane reduction factor was applied if multiple lanes have been loaded.

- A M-Truck load model modified to reflect 17t gross vehicle mass was applied as a moving load on top of the 3.5 kN/m^2 uniform distributed load. A dynamic load allowance factor of 0.3 was applied to the M-Truck loads. Lane reduction factors were applied in accordance with AS5100.7 where multiple lanes were loaded.
- A Group 1 Vehicle 1 load model was applied as a moving load. A dynamic load allowance factor of 0.3 was applied to the Group 1 Vehicle 1 loads. Lane reduction factors were applied in accordance with AS5100.7 where multiple lanes were loaded.
- The following load duration factors (k1) in accordance with the MRWA Timber load rating and refurbishment design manual and AS1720-1988 were used:
  - k1-factor = 1.0 for permanent loads only
  - k1-factor = 1.4 for timber bridges on main roads (local roads with traffic volumes exceeding 500 vehicles per day are treated as main roads) loaded with a combination of rating vehicles and dead load
- Stabilising effects from the concrete collars encapsulating the timber piles have not been taken into account.

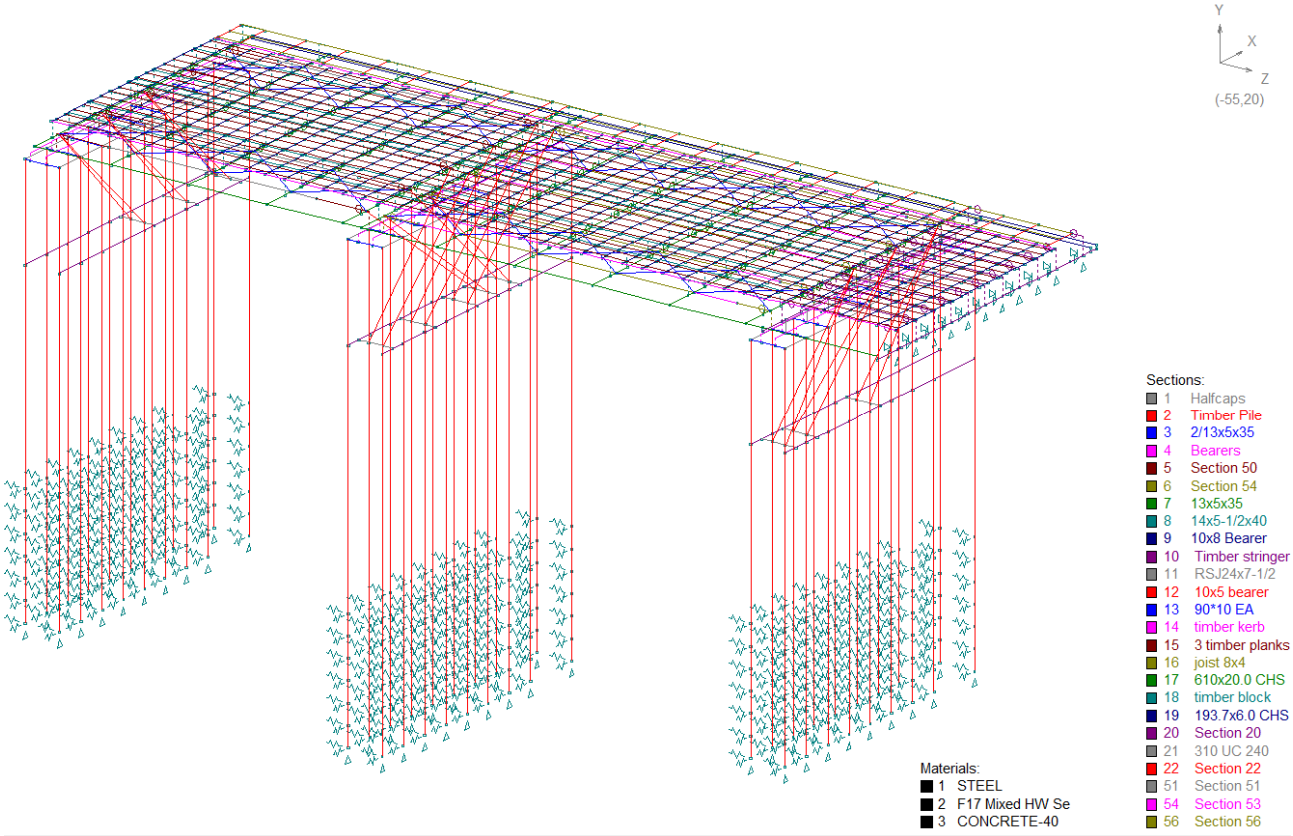


Plate 1: 3D Space Gass model – 1 timber span, 70ft & 56ft navigation spans

1.3 Results

The theoretical capacity and associated utilisation for permanent effects and load rating results for a combination of permanent effects and live loads of each individual pile of Pier 15 was calculated using loads derived from the 3D Space Gass model based on the above assumptions. The results are shown in Table 1 and Table 2 respectively.

Table 1: Dead load rating including revised pile length and diameters based on latest diving records

PIER 15		DEAD LOAD ONLY	
	DIA [MM]	PILE CAPACITY [KN] (F17, K1=1.0, SK= 1.0)	UTILISATION[1]
P1A	473.6127	188.9	86%
P1B	417.5	156.5	97%
P2A	397.5	128.6	123%
P2B	397.2183	128.2	115%
P3A	381.3029	108.9	139%
P3B	413.1338	150.3	94%
P4A	340 Timber; (560 Grout)	*adequate	
P4B	425.8662	169.4	81%
P5A	385	113.2	130%
P5B	397.5	128.6	107%
P6A	387.2183	115.8	133%
P6B	417.5	156.5	92%
P7A	397.5	128.6	124%
P7B	377.5	104.6	142%
P8A	407.5	142	116%
P8B	381.3029	108.9	141%
P9A	375	89.1	195%
P9B	417.5	136.9	116%

* Pile 4A has been strengthened with a 560 concrete annulus which increases the member capacity.

Due to the very low identified capacities of individual piles heavy vehicle loads have not been included in ratings presented in Table 2. The purpose of ratings presented in Table 2 was used for risk management purposes and guidance during the decision making process.

[1] Utilisation <100% indicates that the member is adequate for load effects

Ratings presented in Table 2 were undertaken to review if any two traffic lanes could be kept open for vehicles with a maximum gross weight of 5t to manage peak hour traffic. Load cases 7 to 12 represent different traffic loading scenarios.

Table 2: Dead load plus 3.5 kPa live load rating occupying 2 lanes. Ratings include revised pile length and diameters based on latest diving records

PIER 15		DEAD LOAD PLUS 3.5KPA LIVE LOAD						
	DIA [MM]	PILE CAPACITY [KN] (F17, K1=1.4, SK= 1.0)	LOAD CASE 7 (LINEAR): UDL 3.5KPA LHS AND RHS	LOAD CASE 8 (LINEAR): UDL 3.5KPA CENTRE LANES	LOAD CASE 9 (LINEAR): UDL 3.5KPA LHS LANES	LOAD CASE 10 (LINEAR): UDL 3.5KPA RHS LANES	LOAD CASE 11 (LINEAR): UDL 3.5KPA LHS CENTRE RHS	LOAD CASE 12 (LINEAR): UDL 3.5KPA RHS CENTRE LHS
P1A	473.6127	264.46	284%	524%	188%	10731%	239%	806%
P1B	417.5	219.1	201%	391%	132%	3261%	169%	615%
P2A	397.5	180.04	66%	87%	43%	344%	54%	120%
P2B	397.2183	179.48	104%	140%	67%	638%	86%	196%
P3A	381.3029	152.46	2%	2%	1%	4%	2%	3%
P3B	413.1338	210.42	261%	241%	164%	526%	206%	319%
P4A	340; (560)	*adequ.	*100%+	*100%+	*100%+	*100%+	*100%+	*100%+
P4B	425.8662	237.16	422%	298%	275%	454%	324%	380%
P5A	385	158.48	43%	28%	33%	32%	34%	33%
P5B	397.5	180.04	185%	117%	141%	135%	145%	141%
P6A	387.2183	162.12	31%	21%	32%	20%	28%	23%
P6B	417.5	219.1	308%	210%	324%	194%	278%	227%
P7A	397.5	180.04	69%	59%	117%	43%	79%	53%
P7B	377.5	146.44	-9%	-8%	-17%	-6%	-11%	-7%
P8A	407.5	198.8	109%	118%	365%	68%	163%	87%
P8B	381.3029	152.46	-2%	-2%	-8%	-1%	-3%	-2%
P9A	375	124.74	-149%	-323%	-953%	-96%	-573%	-124%
P9B	417.5	191.66	109%	255%	570%	70%	470%	91%

* Pile 4A has been strengthened with a 560 concrete annulus which increases the member capacity.

Negative ratings indicate no live load capacity.

1.4 Conclusion

Results in Table 1 and 2 represent the theoretical utilisation and rating respectively. Reducing safety factors such as allowing higher stress grades for timber which would increase pile capacities has been considered as too high risk and therefore has not been included in the rating results in this report.

The analysis indicates that, based upon site measurements and other assumptions made as mentioned under 1.2, there is an increased risk of failure of piles to Pier 15 due to the localised reduction in river bed level.

It was concluded that the bridge should be temporarily closed to all traffic and pedestrians, and the northern navigation span closed to river traffic, pending development and implementation of strengthening or repair works.

It was suggested that temporary strengthening works be considered as an interim measure to reduce the risk of structural failure. Two options were presented for this:

1. Temporary propping of the superstructure to provide alternative load paths;
2. Temporary bracing works of the piles to reduce the effective length of the piles.

Potential risks associated with these options were assessed in consultation with Main Roads, and it was concluded that the most appropriate form of temporary strengthening consisted of a temporary bracing system. This system could be implemented quickly, and would allow the bridge to be operational within the shortest possible time.

2 TEMPORARY STRENGTHENING

As the length of an unrestrained compression member (e.g. pile) increases, the slenderness of the member increasingly impacts upon its load carrying capacity. As this slenderness increases, the capacity of compression members become increasingly sensitive to increased unrestrained length.

The reduction in bed level at Pier 15 has increased the unrestrained length of the piles only slightly, but this has had a significant impact upon their capacity. In order to improve this capacity, it is necessary to reduce the slenderness of the piles by providing additional lateral restraint.

Installation of a horizontal plan bracing to all timber piles at a point below the concrete walers would result in the larger diameter piles with spare capacity providing some lateral restraint to the smaller diameter piles which would otherwise be at risk of buckling. If the plan bracing could be tied to a very stiff member – ideally a fixed point – it would provide a greater lateral restraint to all timber piles connected to the plan bracing. A stiff lateral restraint decreases the effective length of the individual compression members which reduces the slenderness of the piles and results in an increase of the member capacity.

At Pier 15 of the Fremantle Traffic Bridge the recently installed fender system to protect the bridge piers from vessel impact has been identified to be stiff enough to act as this “fixed point’ to tie the plan bracing to.

A simple system which could be handled by divers to form a plan bracing system was developed. The plan bracing consists of strut and tie members connecting all pier piles forming a stiff horizontal diaphragm at approx. 3m below the concrete walers. This diaphragm was connected to the Fender Piles 15A and 15D using the same strut and tie members. As constructed drawings can be found in Appendix A.

A 3D model of Pier 15 (refer to Plate 2) was used to determine the effectiveness of the plan bracing and to confirm the reduction in effective length for each individual pile.

The member capacities of the timber piles were assessed with the reduced effective length. It was found that due to the lower river bed level at Pile 9A, bracing at one level was insufficient. The capacity of this pile was improved with the installation of a second plan bracing system installed to Piles 9A and 9B and connecting to the stiff fender pile at a further 3m below the first plan bracing level.

2.1 Results

The theoretical capacity and associated utilisation for permanent effects and load rating results for a combination of permanent effects and live loads of each individual pile of Pier 15 was calculated using loads derived from the 3D Space Gass model based on assumptions in 1.2 and the temporary bracing designed. The results are shown in Table 3 and Table 4 respectively.

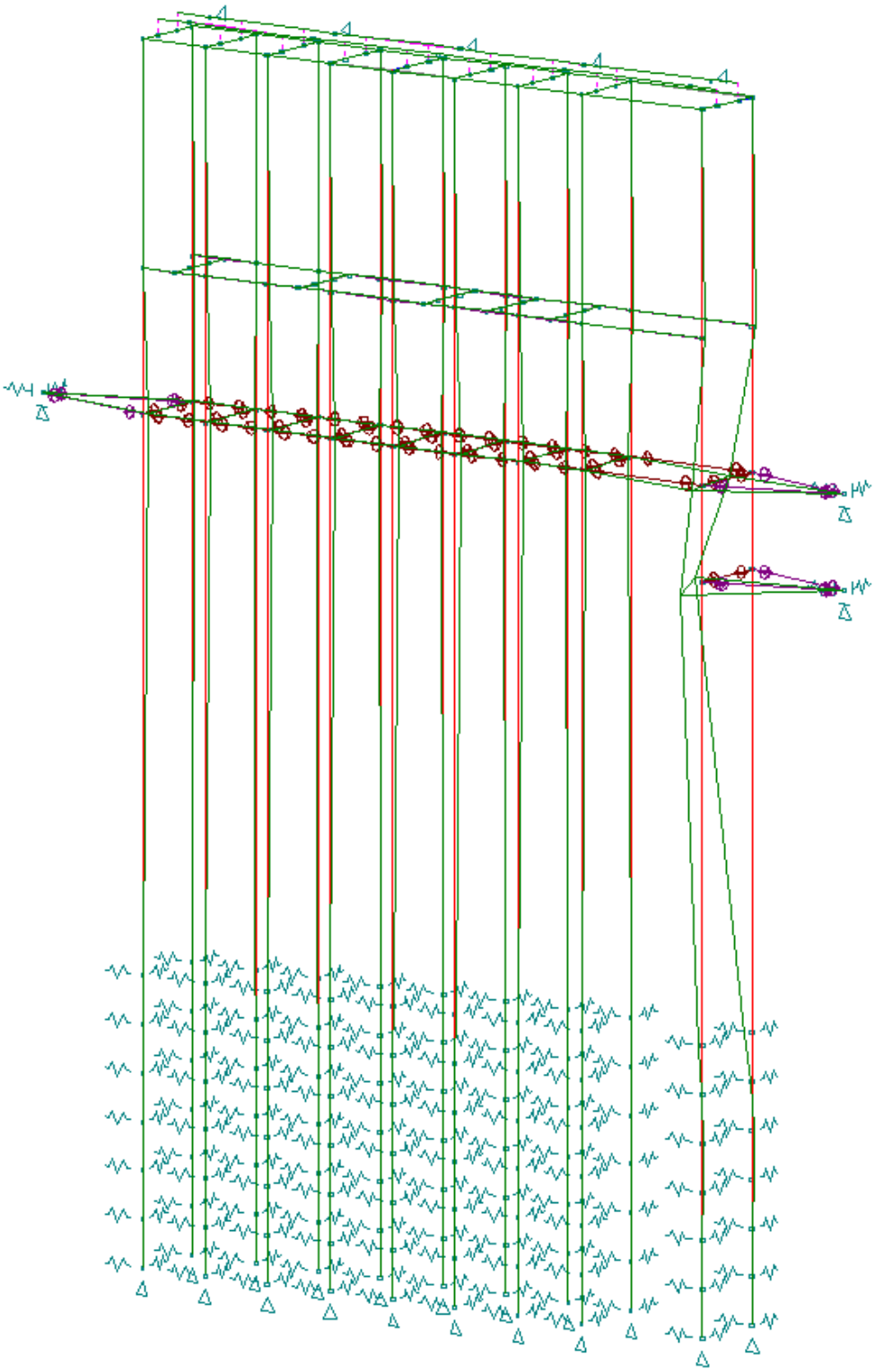


Plate 2: Pier 15 buckling model

Table 3: Dead load rating, bracing system installed

PIER 15		DEAD LOAD ONLY	
	DIA [MM]	PILE CAPACITY [KN] (F17, K1=1.0, SK= 1.0)	UTILISATION[2]
P1A	473.6127	392	41%
P1B	417.5	271.9	56%
P2A	397.5	223.4	71%
P2B	397.2183	222.3	66%
P3A	381.3029	189.2	80%
P3B	413.1338	260	54%
P4A	340; (560)	*adequate	*100%+
P4B	425.8662	292	47%
P5A	385	196.6	75%
P5B	397.5	223.4	62%
P6A	387.2183	200	77%
P6B	417.5	271.9	53%
P7A	397.5	223.4	72%
P7B	377.5	181.7	82%
P8A	407.5	323.5	51%
P8B	381.3029	262.4	58%
P9A	375	214	81%
P9B	417.5	406.1	39%

* Pile 4A has been strengthened with a 560 concrete annulus which increases the member capacity.

[2] Utilisation <100% indicates that the member is adequate for load effects

Ratings presented in Table 4 demonstrate that the capacity of each individual pile at Pier 15 could be increased to allow unrestricted reopening of the bridge once the bracing was installed. With the bracing installed, the critical loading occurs with more than two lanes of traffic running, rather than the restricted loading shown in Table 2.

Table 4: Dead load plus live load combinations, bracing system installed

PIER 15		DEAD LOAD PLUS LIVE LOAD					
	DIA [MM]	PILE CAPACITY [KN] (F17, K1=1.4, SK= 1.0)	UDL 3.5KPA 4 LANES	17T M-TRUCK LANE 1+2+3 (FROM LHS)+UDL 3.5KPA 4 LANES	17T M-TRUCK LANE 2+3+4 (FROM LHS) + UDL 3.5 KPA 4 LANES	G1V1 LANE 1+2+3 (FROM LHS)	G1V1 LANE 2+3+4 (FROM LHS)
P1A	473.6127	548.8	766%	396%	607%	436%	1421%
P1B	417.5	380.66	496%	257%	399%	277%	1014%
P2A	397.5	312.76	294%	156%	218%	176%	425%
P2B	397.2183	311.22	340%	180%	253%	198%	498%
P3A	381.3029	264.88	209%	112%	138%	132%	221%
P3B	413.1338	364	448%	239%	296%	272%	467%
P4A	340; (560)	*adequ.	*100%+	*100%+	*100%+	*100%+	*100%+
P4B	425.8662	408.8	529%	287%	317%	340%	429%
P5A	385	275.24	222%	124%	124%	163%	160%
P5B	397.5	312.76	328%	184%	183%	231%	227%
P6A	387.2183	280	216%	129%	116%	181%	144%
P6B	417.5	380.66	438%	260%	235%	353%	279%
P7A	397.5	312.76	270%	174%	142%	272%	170%
P7B	377.5	254.38	200%	130%	105%	199%	121%
P8A	407.5	452.9	539%	381%	280%	686%	322%
P8B	381.3029	367.36	436%	308%	225%	548%	251%
P9A	375	299.6	290%	235%	148%	610%	155%
P9B	417.5	568.54	1055%	870%	539%	2507%	556%

* Pile 4A has been strengthened with a 560 concrete annulus which increases the member capacity.

3 CONCLUSION

After the divers had installed the plan bracing, a site inspection to review the works was conducted by the designer and MRWA representatives using live CCTV transmission technology.

It was concluded that bracing members were installed in accordance with the design drawings; allowing the bridge to be re-opened, pending development and implementation of permanent strengthening works.

4 RECOMMENDATIONS

It is recommended that a full inspection and measurement of all submerged timber components of Pier 15 is undertaken to develop appropriate permanent strengthening options.

Inspection should include intrusive investigations to determine the condition of the residual timber contained within the concrete collars.

4.1 Permanent Strengthening

A long term solution to increase the pile capacity would be to encapsulate all piles with a reinforced cementitious grout annulus of 750mm outside diameter. This would involve removing the original installed concrete collars before applying the encapsulation. This would also provide an opportunity to inspect all piles fully and assess their condition. It is understood that this is the preferred option and will be further pursued.

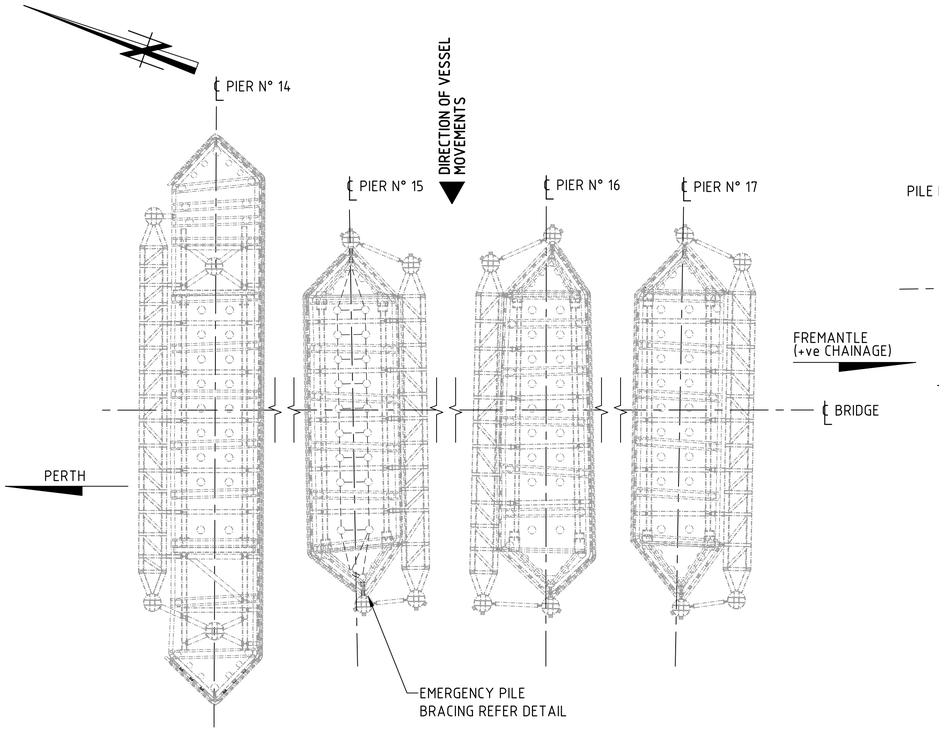
4.2 River Bed Protection

Findings from current underwater inspections (April/May 2016) indicate the river bed level is 600mm lower compared with the survey from mid-late 2015. It is therefore recommended to increase the river bed levels by at least 2m around Pier 15 and protect the fill with scour protection measures to avoid recurrence of this.

An alternative option to increase river bed levels to restore the original levels of 1938 when the bridge was constructed would restore sufficient pile capacity but the opportunity to assess pile condition would be lost. Restoring the river bed level without assessing the pile conditions is regarded as a high risk and is not recommended.

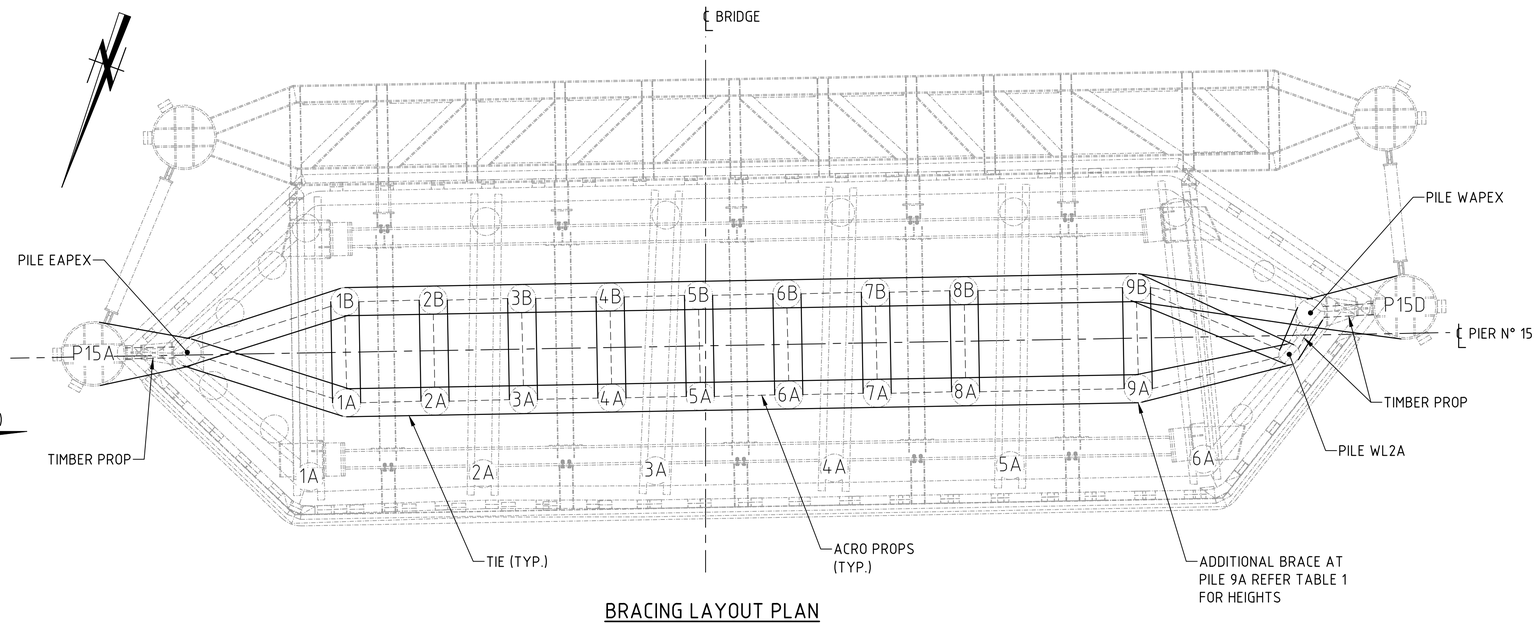
Appendix A

AS CONSTUCTED DRAWINGS PLAN BRACING



PIER LAYOUT PLAN

PIER No.'s 14 TO 17
1:200

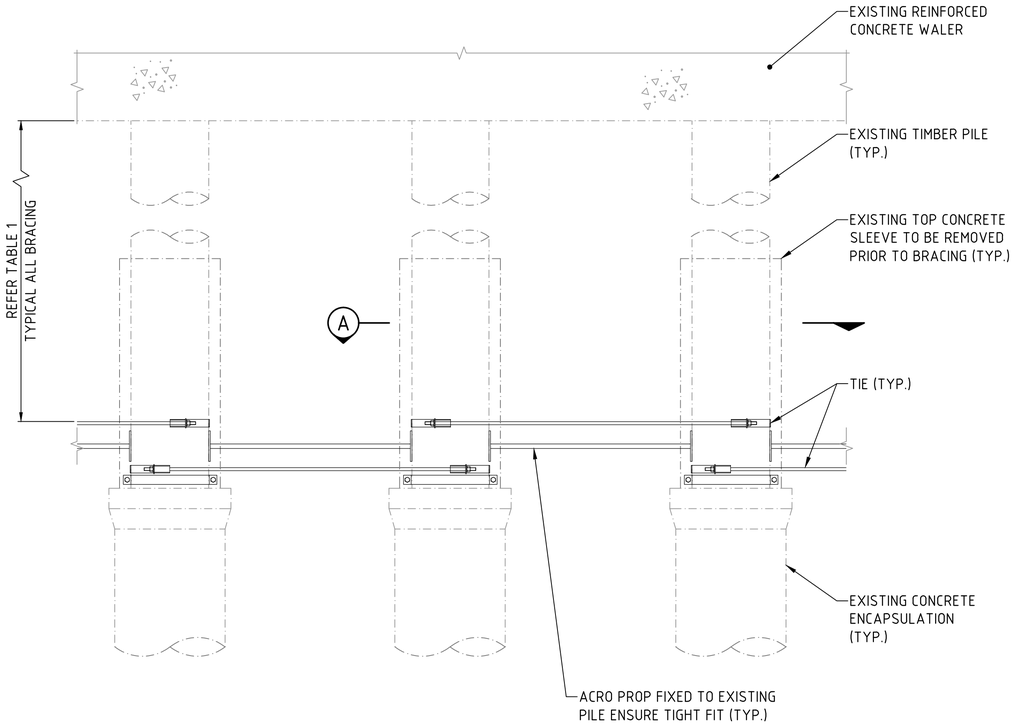


BRACING LAYOUT PLAN

PIER No. 15
N.T.S.

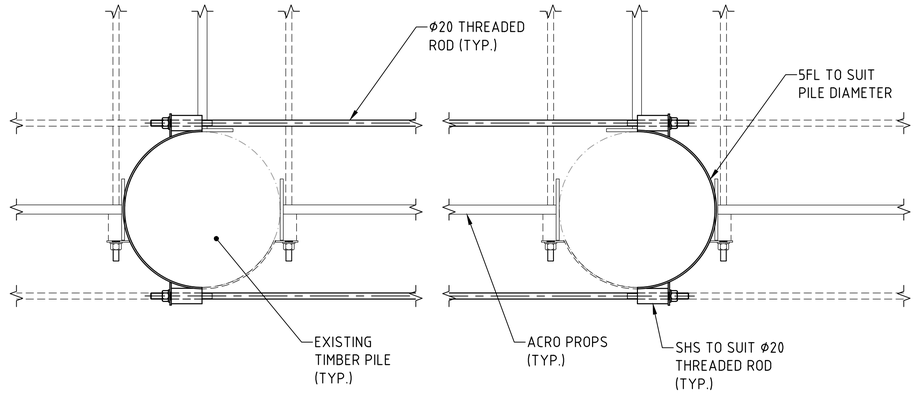
AS CONSTRUCTED

DATE: 05/2016



TYPICAL BRACING DETAIL

N.T.S



SECTION (A)

1:10

CONCRETE SOFFIT TO LOW BRACE			
PILE NUMBER	MEASURED HEIGHT	PILE NUMBER	MEASURED HEIGHT
P15A	3220	-	-
EAPEX	3220	-	-
1A	3220	1B	3260
2A	3090	2B	2960
3A	3060	3B	3030
4A	3100	4B	3030
5A	3100	5B	3100
6A	3000	6B	3100
7A	3390	7B	3430
8A	3480	8B	3400
9A	3450 & 6900	9B	3200 & 6900
WL2A	3450 & 6900	WAPEX	3200 & 6900
P15D	3450 & 6900	-	-

TABLE 1

No.	DATE	DESCRIPTION	AUTHORISED
A	11.05.16	AS CONSTRUCTED	

AMENDMENTS

CLIENT

METROPOLITAN REGION

Telephone (08) 9311 8333 Fax (08) 9311 8383

APPROVED FOR IMPLEMENTATION

FILE NUMBER	FOLIO	DATE	APPROVAL NUMBER
AUTHORISED			
APPROVED			

CONSULTANT

WSP | PARSONS BRINCKERHOFF
Level 5
503 Murray Street
Perth WA 6000
Telephone +61 8 9489 9700
Facsimile +61 8 9489 9777
Email: perth@pb.com.au

DOC No.	2113415A-0916-ST-DRG-1630-0075-A		
FILE No.		JOB No.	
DRAWN	J. DYE MAY '16	DESIGNED	W. SCHWARZ MAY '16
CHECKED		VERIFIED	
APPROVED			

SCALE 1:200 — MICROFILM DATE — A1

mainroads WESTERN AUSTRALIA

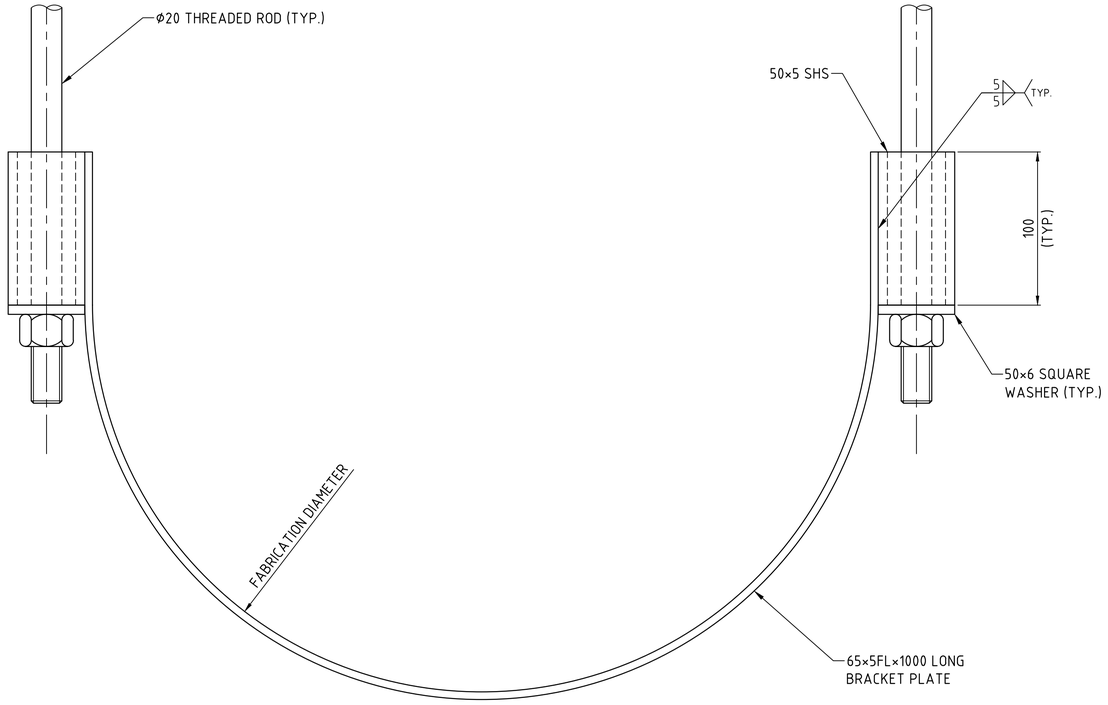
STRUCTURES ENGINEERING

QUEEN VICTORIA ST RD N° H031 (SLK 0.39)
BRIDGE N° 0916 OVER SWAN RIVER

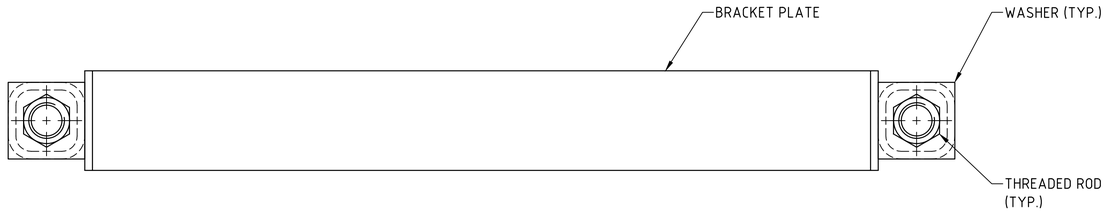
EMERGENCY BRACING REPAIR

LOCAL AUTHORITY (118) CITY OF FREMANTLE

DRAWING NUMBER 1630-0075-A AMEND. A



PLAN



ELEVATION

BRACING BRACKET - TYPE 1
1:5

NOTES:

1. ALL WELDING SHALL BE GENERAL PURPOSE IN ACCORDANCE WITH AS/NZS 1554 AND THE SPECIFICATION.
2. ALL BOLTS AND THREADED RODS SHALL BE SUPPLIED WITH NUTS AND WASHERS UNLESS OTHERWISE SPECIFIED ALL BOLTS, NUTS AND WASHERS SHALL BE HIGH STRENGTH GRADE 8.8 IN ACCORDANCE WITH AS/NZS 1252.
3. ALL THREADED RODS SHALL BE DIAMETER 20 UNLESS OTHERWISE SHOWN AND SHALL BE GRADE 300 IN ACCORDANCE WITH AS/NZS 3679.1.
4. UNLESS OTHERWISE SPECIFIED ALL STRUCTURAL STEEL SECTIONS SHALL BE MINIMUM GRADE 300 IN ACCORDANCE WITH AS/NZS 3679.1.
5. ALL STRUCTURAL STEEL HOLLOW SECTIONS SHALL BE MINIMUM GRADE C350 IN ACCORDANCE WITH AS/NZS 1163.
6. ALL STRUCTURAL STEEL PLATE SHALL BE MINIMUM GRADE 250 IN ACCORDANCE WITH AS/NZS 3678.
7. ALL STRUCTURAL STEEL FLAT (MERCHANT BAR) SHALL BE MINIMUM GRADE 300 IN ACCORDANCE WITH AS/NZS 3679.1.
8. FABRICATION SHALL COMPLY WITH THE REQUIREMENTS OF AS 4100.

AS CONSTRUCTED

DATE: 05/2016

No.	DATE	DESCRIPTION	AUTHORISED
A	11.05.16	AS CONSTRUCTED	

AMENDMENTS

CLIENT

METROPOLITAN REGION

Telephone (08) 9311 8333 **Fax** (08) 9311 8383

APPROVED FOR IMPLEMENTATION

FILE NUMBER	FOLIO	DATE	APPROVAL NUMBER
AUTHORISED			
APPROVED			

CONSULTANT

WSP | PARSONS BRINCKERHOFF
Level 5
503 Murray Street
Perth WA 6000
Telephone +61 8 9489 9700
Facsimile +61 8 9489 9777
Email: perth@pb.com.au

DOC No.	2113415A-0916-ST-DRG-1630-0076-A		
FILE No.		JOB No.	
DRAWN	J. DYE MAY '16	DESIGNED	W. SCHWARZ MAY '16
CHECKED		VERIFIED	
APPROVED			

mainroads WESTERN AUSTRALIA

STRUCTURES ENGINEERING

QUEEN VICTORIA ST RD N° H031 (SLK 0.39)
BRIDGE N° 0916 OVER SWAN RIVER

EMERGENCY BRACING REPAIR
BRACKET DETAIL - TYPE 1

LOCAL AUTHORITY (118) CITY OF FREMANTLE

DRAWING NUMBER: 1630-0076-A
AMEND.: A

SCALE 1:2
MICROFILM DATE
A1

PATH: \\apperl601\per3\WSP\Projects\01 - BDS Projects\BR 0916\05_CADD\01-SHEETS\Structural\As Constructed - Emergency Bracing Repair\1630-0076.dwg LAST SAVED BY: Dyejo DATE: 11 May 2016 4:05 PM