Bridge over Hawkesbury River at Windsor
Load Testing

Test Report

Prepared For:

NSW Roads and Traffic Authority

June 2011

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Document Information

Title:	Bridge over Hawkesbury River at Windsor Load Testing - Test Report
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Client:	NSW Roads and Traffic Authority
Client Contact:	Peter Ton
Client Reference:	O/N 4510276450

Revision/Checking History

Rev. No.	Description	Author	Reviewer	Approved	Date
0	Issued to client	BM	BH		24/06/11

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1. Introduction

1.1 General

Endurance Consulting was engaged by the NSW Roads and Traffic Authority (RTA) to provide structural measurements of Windsor Bridge over Hawkesbury River at Windsor. Performance load testing (static testing) and measurement of ambient traffic (dynamic testing) for a minimum period of 6 months is required. This document outlines the installation and presents the results of load testing.

1.2 Bridge Description

The Reinforced Concrete (RC) Beam Bridge consists of eleven spans and was built in 1931. 10 sets of 3'6" diameter wrought iron piers extend to the river bed. Figure 1-1 shows the instrumented piers.

1.3 Requirements

Measurements at piers 4, 5, 6 and 7 are required for the analysis of static load testing and ambient traffic monitoring. Bending strain in the piers is of concern, so at each location a strain gauge installed on both the south and north side allows bending to be resolved. A sampling frequency above 200 Hz is expected sufficient to capture bridge dynamic events.

Figure 1-1. RTA Bridge – Windsor Bridge Piers

2. Instrumentation

2.1 Instrumentation Layout

Figure 2-1 below shows the numbering conventions for the installed strain gauges at piers 4 to 7.

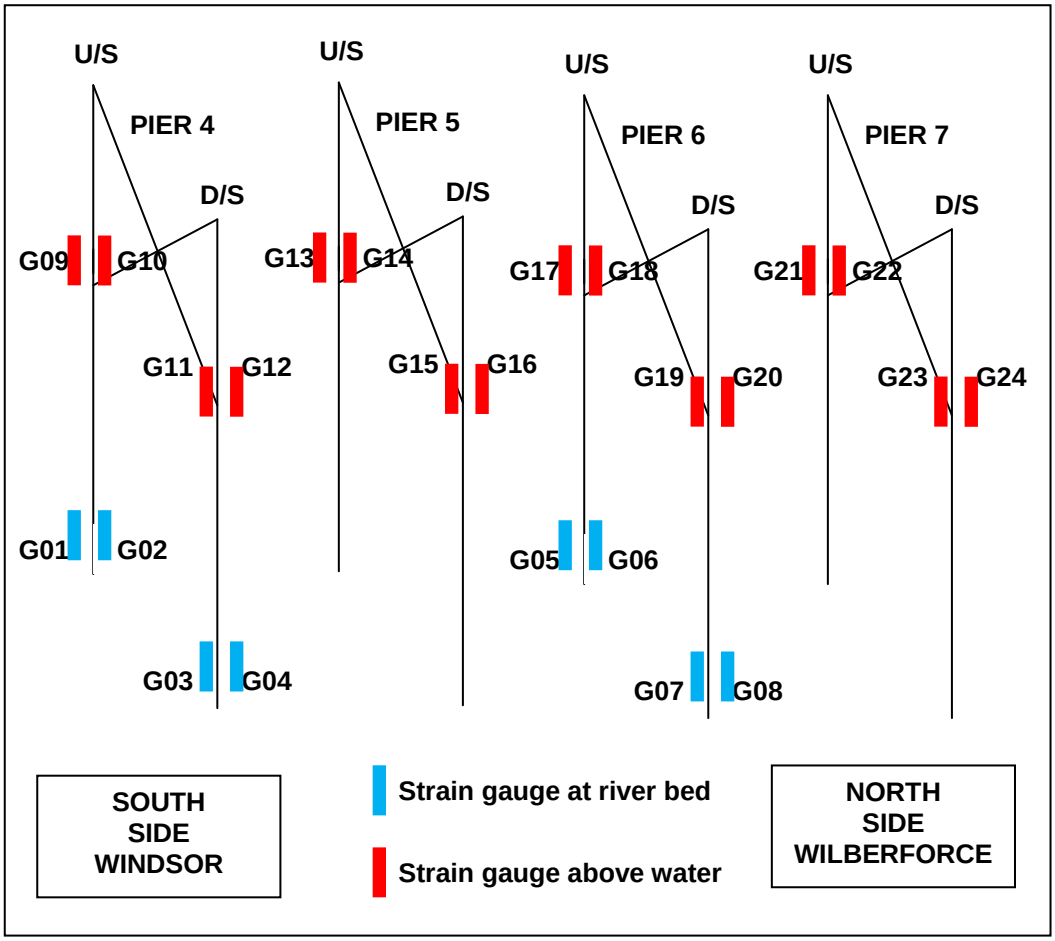

Figure 2-1. Instrumentation Layout

Table 2-1 below further indicates the positioning of the strain gauges.

Table 2-1. Sensor Locations

Transducer	Name	Pier	Side / Depth*
Demountable Strain Gauge at River Bed	**G01**	P4 U/S	S/S 7.49m
	G02	P4 U/S	N/S 7.49m
	G03	P4 D/S	S/S 6.72m
	G04	P4 D/S	N/S 6.72m
	G05	P6 U/S	S/S 7.14m
	G06	P6 U/S	N/S 7.14m
	G07	P6 D/S	S/S 6.45m
	G08	P6 D/S	N/S 6.45m
Foil Strain Gauge	**G09**	P4 U/S	S/S 1.65m
	G10	P4 U/S	N/S 1.65m
	G11	P4 D/S	S/S 1.65m
	G12	P4 D/S	N/S 1.65m
	G13	P5 U/S	S/S 1.65m
	G14	P5 U/S	N/S 1.65m
	G15	P5 D/S	S/S 1.65m
	G16	P5 D/S	N/S 1.65m
	G17	P6 U/S	S/S 1.65m
	G18	P6 U/S	N/S 1.65m
	G19	P6 D/S	S/S 1.65m
	G20	P6 D/S	N/S 1.65m
	G21	P7 U/S	S/S 1.65m
	G22	P7 U/S	N/S 1.65m
	G23	P7 D/S	S/S 1.65m
	G24**	P7 D/S	N/S 1.65m
Displacement	**DDT01****	P4 D/S	kerb

U/S – Upstream, D/S – Downstream, S/S – South Side, N/S – North Side

**All depth measurements are taken from the underside flange of the bolted pier connections*

***G24 was replaced with DDT01 during testing only*

2.2 Data Acquisition Hardware

National Instruments hardware acquired all channels at a sampling frequency of 2000Hz. This data was then re-sampled to 200Hz employing appropriate anti-aliasing filters. Labview software was used for data processing. Figure 5-1 shows the location of the hardware.

2.3 Expansion Joint Transducer

For the period of the static testing a dynamic displacement transducer was installed at the Pier 4 expansion joint. The sensor was mounted on the downstream kerb as shown in photo Figure 5-4.

2.4 Strain Gauges

The following strain gauges were used to obtain the required measurements:

- Strap-On Strain Gauges – 8 off, 300mm gauge length, 350 ohm full bridge strain sensing elements fastened between two 50x5mm flat bar rings. Installed by CDS Pty Ltd. Straps were initially manufactured to a circumference of 3730mm whereas the actual pier circumference was 3370mm. On-site modifications took place resulting in the strain elements now aligning 180mm to the outboard side on the centreline.
- Foil Strain Gauges – 16 off, TML WFCA-6 120 ohm half bridge gauges.

Figures 2-2 and 2-3 below show two types of strain gauges

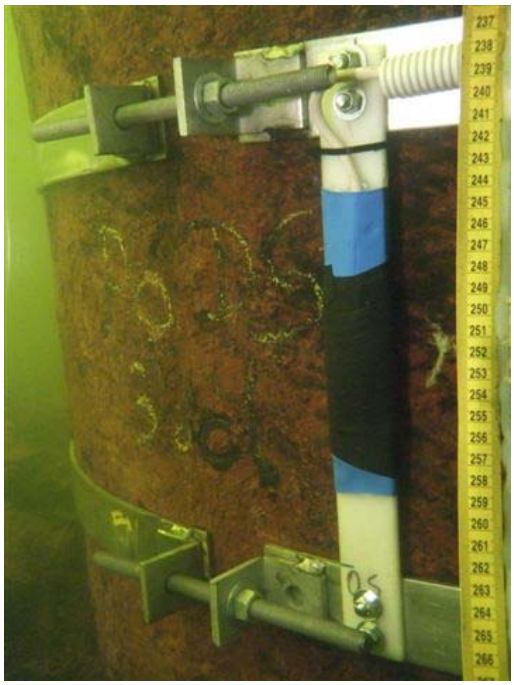

Figure 2-2. Instrumentation – Strap-On Gauge

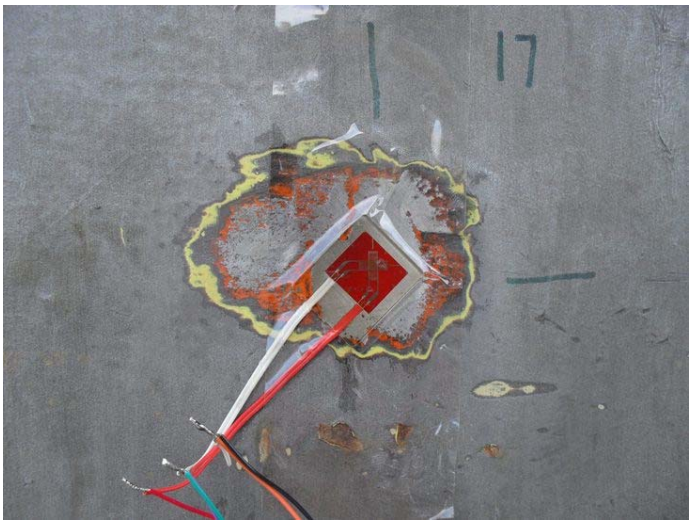

Figure 2-3. Instrumentation – Foil Strain Gauge

3. Static Test Results

3.1 Test Conditions

Planned load testing with the RTA Test Truck was carried out on the night of 8 June 2011. Normal carriageway was used for all tests. Three load levels were tested during the crawl tests as indicated in Table 3-1. Braking tests were also conducted on approach to Pier 4 and Pier 7 from both directions.

3.2 Test Vehicle and Loadings

The planned load testing was conducted by using an RTA dedicated test vehicle as shown in Figure 3-1.

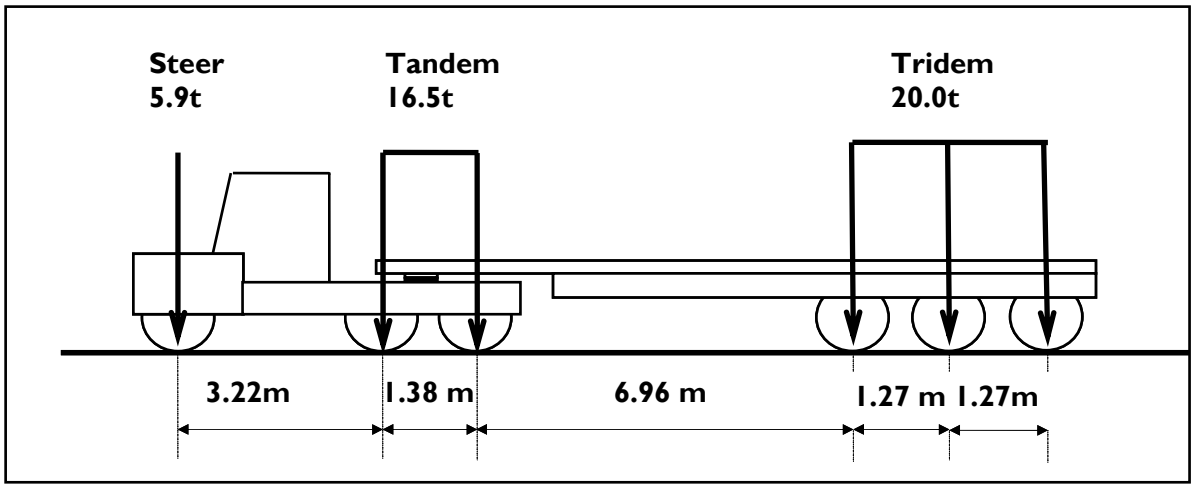

Figure 3-1. RTA Test Vehicle

The three loading levels used in performance load testing are shown in Table 3-1.

Table 3-1. Approximate Loadings

Test Truck	Load Level	Group Loads (t)			Equivalent GVM (t)
		Steer	Tandem	Tridem	
RTA	1	5.9	16.5	20.0	42.4
	2	5.9	16.5	25.0	47.4
	3	5.9	16.5	30.0	52.4

3.3 Results Presented

For each test the maximum strain relative to the unloaded strain has been calculated and presented in tabular form (Section 3.4). Section 3.5 displays selected example waveform (time series). Bending results for each pair of gauges are calculated as:

Bending Strain = (North Side Strain – South Side Strain) / 2

The bending strains are generally low so only the absolute maximum has been reported for each test.

3.4 Tabulated Static Test Results

Tabulated results are found in Tables:

- 3-2. Results for test with no braking
- 3-3. Results of test with braking on approach to Pier 4.
- 3-4. Results of tests with braking on approach to Pier 7.

The following abbreviations are used in the tables:

P# Pier#

US Upstream

DS Downstream

RB River Bed

AW Above Water

SS South Side

NS North Side

DDT Dynamic Displacement Transducer

Table 3-2. Non- Braking Test Results

TRIDEM LOAD LEVEL		20t	20t	20t	20t	25t	25t	30t	30t
SPEED (km/hr)		Crawl	Crawl	40	40	Crawl	Crawl	Crawl	Crawl
BRAKING		NO	NO	NO	NO	NO	NO	NO	NO
DIRECTION		South	North	South	North	South	North	South	North
TIME		10:28	01:10	11:03	11:04	11:29	11:36	11:58	12:05
Gauge #	Location	Compressive Strain (microstrain)							
G01	P4 US RB SS	2.9	9.9	4.2	10.7	3.5	11.1	3.6	12.0
G02	P4 US RB NS	2.6	6.7	3.3	8.1	3.4	7.3	3.7	8.2
G03	P4 DS RB SS	7.0	3.4	8.2	2.6	8.0	3.7	9.0	3.9
G04	P4 DS RB NS	7.5	2.9	7.6	3.1	8.6	2.4	9.9	3.3
G05	P6 US RB SS	5.8	19.4	7.3	21.3	7.0	23.0	7.4	25.6
G06	P6 US RB NS	6.9	19.8	7.3	22.2	9.1	22.7	9.6	25.4
G07	P6 DS RB SS	17.1	6.0	18.0	5.4	19.0	5.7	21.3	6.5
G08	P6 DS RB NS	23.3	8.2	23.3	7.9	26.5	7.1	29.2	8.3
G09	P4 US AW SS	6.7	15.2	6.9	17.6	7.4	16.8	8.9	18.9
G10	P4 US AW NS	6.3	15.6	6.7	18.7	6.6	19.4	7.2	22.1
G11	P4 DS AW SS	18.5	8.3	19.7	6.7	21.9	7.5	25.5	9.1
G12	P4 DS AW NS	12.6	6.6	12.0	7.0	13.9	7.6	15.5	8.3
G13	P5 US AW SS	6.9	19.6	7.7	22.3	8.8	21.7	10.1	24.5
G14	P5 US AW NS	6.5	17.6	7.6	19.9	6.1	21.7	8.0	25.0
G15	P5 DS AW SS	10.0	4.9	9.2	4.8	12.0	4.8	13.9	5.3
G16	P5 DS AW NS	16.3	6.2	15.1	5.8	13.4	7.6	18.6	8.8
G17	P6 US AW SS	7.4	17.9	8.0	19.5	7.3	19.8	10.7	22.7
G18	P6 US AW NS	6.1	15.1	6.6	14.5	6.8	18.6	7.3	21.6
G19	P6 DS AW SS	19.2	7.9	20.0	8.7	18.8	7.9	26.0	7.9
G20	P6 DS AW NS	21.4	8.0	20.2	7.4	22.5	8.8	25.2	10.8
G21	P7 US AW SS	7.8	19.7	9.0	21.4	9.8	21.6	11.1	24.7
G22	P7 US AW NS	6.0	17.5	8.1	18.4	7.0	20.7	7.7	23.6
G23	P7 DS AW SS	19.3	7.7	19.5	8.7	22.2	7.6	25.9	8.4
DDT (mm) Min	P4 DS Kerb	-0.24	-0.13	-0.27	-0.11	-0.28	-0.08	-0.26	-0.09
DDT (mm) Max	P4 DS Kerb	0.69	0.31	0.67	0.32	0.76	0.31	0.87	0.35
Bending Strain	Absolute Max	7.7	6.2	8.9	7.7	9.3	7.0	11.0	8.2

Table 3-3. Braking at Pier 4 Test Results

TRIDEM LOAD LEVEL		20t	20t	20t	20t	20t	20t	20t	20t
SPEED (km/hr)		20	20	30	30	40	40	50	50
BRAKING		@ P4	@ P4	@ P4	@ P4	@ P4	@ P4	@ P4	@ P4
DIRECTION		South	North	South	North	North	South	South	North
TIME		12:52	12:54	12:58	01:00	01:05	01:07	01:15	01:17
Gauge #	Location	Compressive Strain (microstrain)							
G01	P4 US RB SS	3.7	9.9	4.3	10.3	10.5	4.4	4.9	10.0
G02	P4 US RB NS	3.8	6.4	3.8	6.6	8.0	2.8	3.7	6.6
G03	P4 DS RB SS	7.6	3.3	8.2	3.3	2.9	8.9	9.2	2.9
G04	P4 DS RB NS	9.3	3.8	9.1	4.1	5.3	7.5	8.3	3.8
G05	P6 US RB SS	7.5	21.4	6.7	21.2	21.3	7.7	7.8	20.1
G06	P6 US RB NS	7.9	21.4	7.9	20.5	21.1	7.3	8.5	20.7
G07	P6 DS RB SS	16.9	6.1	17.0	5.8	6.2	17.4	16.7	5.8
G08	P6 DS RB NS	23.5	7.4	22.9	7.5	7.9	22.5	23.2	8.8
G09	P4 US AW SS	7.3	15.4	6.9	15.3	15.9	6.8	7.3	15.5
G10	P4 US AW NS	6.7	15.9	7.1	16.5	15.7	6.4	6.9	15.6
G11	P4 DS AW SS	20.1	8.3	19.2	8.0	8.2	20.4	19.0	7.2
G12	P4 DS AW NS	12.7	6.9	13.7	6.6	6.4	13.2	12.9	6.3
G13	P5 US AW SS	7.4	19.6	8.1	19.7	20.3	7.2	7.4	18.8
G14	P5 US AW NS	7.7	17.7	7.8	17.4	18.1	7.5	7.8	17.4
G15	P5 DS AW SS	9.9	4.8	10.1	4.4	4.7	9.0	9.2	4.6
G16	P5 DS AW NS	15.5	6.4	15.8	5.8	6.6	15.4	15.0	6.1
G17	P6 US AW SS	7.8	17.6	8.0	17.5	17.9	7.6	8.6	18.3
G18	P6 US AW NS	8.3	15.2	7.4	15.9	15.1	7.0	7.9	15.2
G19	P6 DS AW SS	19.8	7.7	20.8	7.9	7.7	19.8	19.4	8.1
G20	P6 DS AW NS	22.4	8.4	21.2	8.5	9.0	20.9	20.4	8.5
G21	P7 US AW SS	9.4	20.3	9.1	19.8	20.0	9.4	10.0	19.3
G22	P7 US AW NS	7.9	17.7	7.2	16.7	16.6	7.1	7.6	20.5
G23	P7 DS AW SS	20.6	8.9	19.0	8.8	8.2	18.8	20.4	8.0
DDT (mm) Min	P4 DS Kerb	-0.21	-0.13	-0.22	-0.10	-0.15	-0.26	-0.22	-0.10
DDT (mm) Max	P4 DS Kerb	0.67	0.30	0.64	0.29	0.28	0.60	0.61	0.29
Bending Strain	Absolute Max	8.7	6.4	8.2	6.4	6.2	8.4	8.5	7.4

Table 3-4. Braking at Pier 7 Test Results

TRIDEM LOAD LEVEL		20t	20t	20t	20t	20t	20t	20t	20t
SPEED (km/hr)		20	20	30	30	40	40	50	50
BRAKING		@ P7	@ P7	@ P7	@ P7	@ P7	@ P7	@ P7	@ P7
DIRECTION		South	North	South	North	South	North	South	North
TIME		01:20	01:22	01:26	01:27	01:30	01:33	01:35	01:37
Gauge #	Location	Compressive Strain (microstrain)							
G01	P4 US RB SS	3.8	9.8	3.5	9.8	3.6	9.8	3.7	10.0
G02	P4 US RB NS	3.4	6.6	2.9	7.1	3.3	7.0	2.9	6.9
G03	P4 DS RB SS	7.2	2.9	7.2	2.9	7.6	2.7	7.5	3.0
G04	P4 DS RB NS	8.5	3.0	8.0	2.7	8.8	3.2	7.9	3.1
G05	P6 US RB SS	6.9	20.2	7.5	22.4	8.5	20.4	11.4	21.9
G06	P6 US RB NS	7.4	21.6	7.9	23.1	7.4	22.3	8.1	24.4
G07	P6 DS RB SS	17.3	6.3	17.5	8.1	17.7	8.6	20.4	9.2
G08	P6 DS RB NS	22.9	7.8	24.2	8.8	23.2	9.2	22.7	10.2
G09	P4 US AW SS	8.0	16.0	7.3	15.0	8.5	14.7	7.3	16.2
G10	P4 US AW NS	6.9	16.7	6.5	16.3	6.2	16.6	6.0	16.4
G11	P4 DS AW SS	22.8	8.4	21.7	7.7	23.8	7.5	21.8	7.9
G12	P4 DS AW NS	13.0	6.9	13.5	6.7	13.3	6.6	13.1	6.6
G13	P5 US AW SS	7.7	19.7	7.9	20.5	7.8	21.7	8.1	19.8
G14	P5 US AW NS	8.0	18.7	6.8	19.9	7.1	20.0	7.4	19.2
G15	P5 DS AW SS	11.0	4.7	10.6	4.6	10.4	5.6	10.5	4.5
G16	P5 DS AW NS	17.0	6.2	16.0	6.5	15.4	6.3	15.6	6.3
G17	P6 US AW SS	7.9	17.9	7.4	18.4	7.5	19.0	7.9	19.0
G18	P6 US AW NS	6.5	15.3	6.9	17.5	7.0	16.6	7.5	17.0
G19	P6 DS AW SS	20.4	7.9	18.9	8.6	18.4	9.6	19.1	8.5
G20	P6 DS AW NS	21.2	8.0	21.4	9.6	21.8	10.3	21.8	10.1
G21	P7 US AW SS	8.5	20.4	9.6	21.1	8.3	20.5	8.5	20.2
G22	P7 US AW NS	7.7	17.1	7.2	17.3	6.8	17.1	8.0	17.0
G23	P7 DS AW SS	18.8	7.3	21.0	8.0	19.4	8.0	18.6	7.4
DDT (mm) Min	P4 DS Kerb	-0.23	-0.14	-0.27	-0.22	-0.28	-0.23	-0.51	-0.27
DDT (mm) Max	P4 DS Kerb	0.67	0.30	0.66	0.27	0.70	0.29	0.64	0.31
Bending Strain	Absolute Max	9.5	6.7	9.1	6.8	10.8	7.2	9.1	6.9

3.5 Results Discussion

The following observations can be made from the test period and the presented results:

- Bending strain is not the dominant strain in the piers. All strain gauges go into compression under loading in all test instances.
- The braking tests did not increase bending strain results or expansion gap openings.
- The expansion gap opening is due to the method of measurement being sensitive to the flexure of the spans. Braking tests did not increase the values so it considered that they did not contribute to the expansion joint opening.
- Pier 4 river bed gauges on both upstream and downstream display less axial compression then the corresponding above water gauges.
- Pier 6 river bed gauges correlate well with the results from the above water gauges.

3.6 Graphical Static Test Results

Figures 3-2 to 3-9 graphically represent a sample of the above data. Plots are shown for tests at times 10:28PM and 11:03PM. (Negative indicates compressive strain).

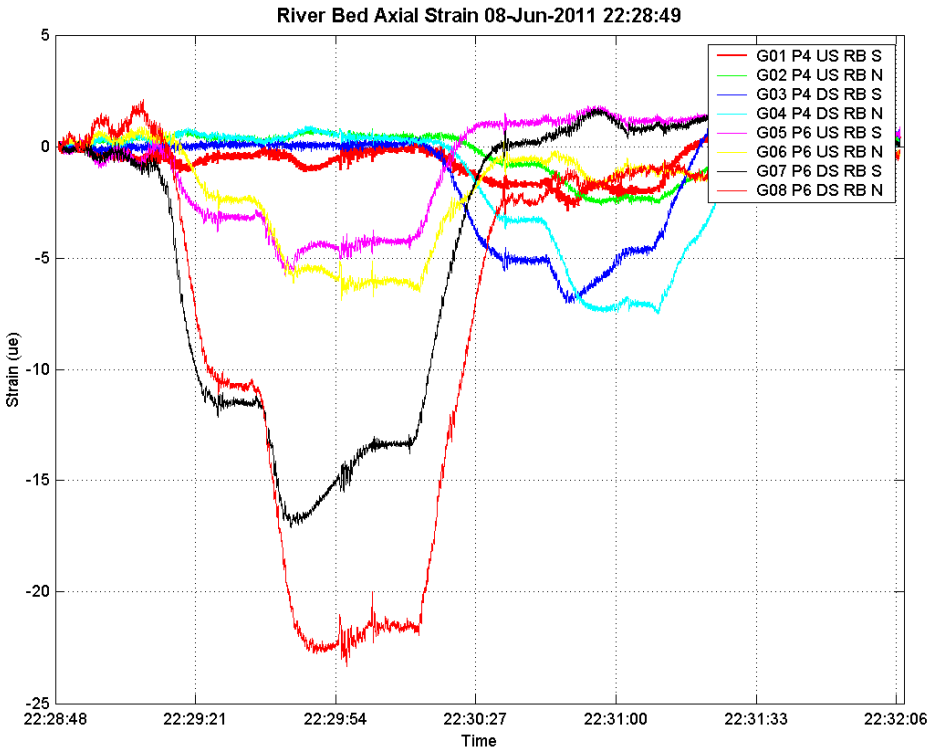

Figure 3-2. 10:28PM Axial Strain (RB)

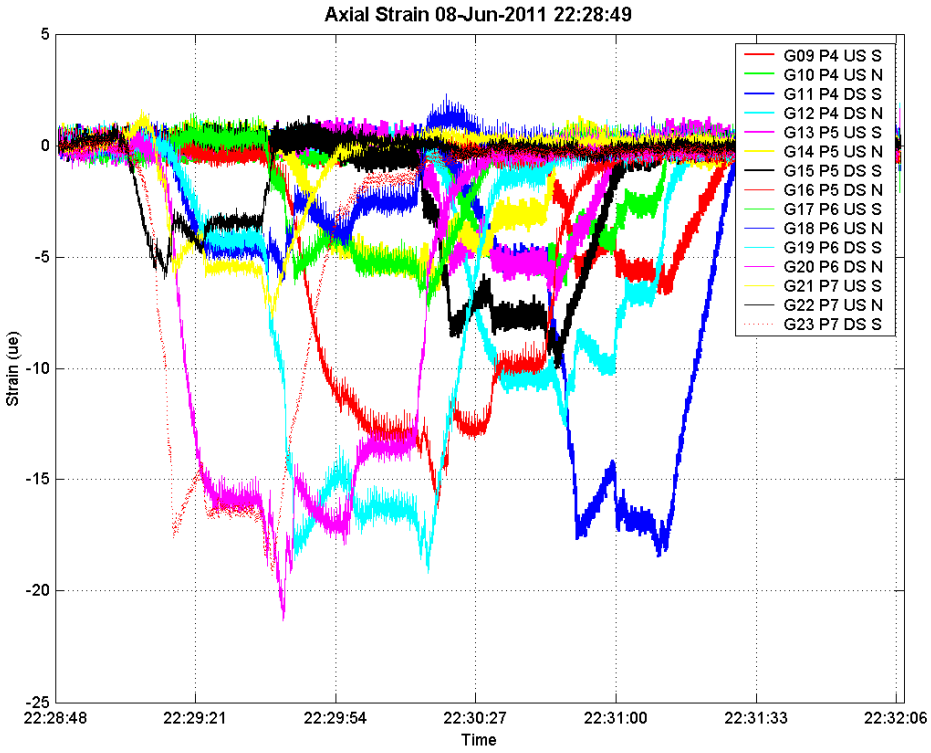

Figure 3-3. 10:28PM Axial Strain (AW)

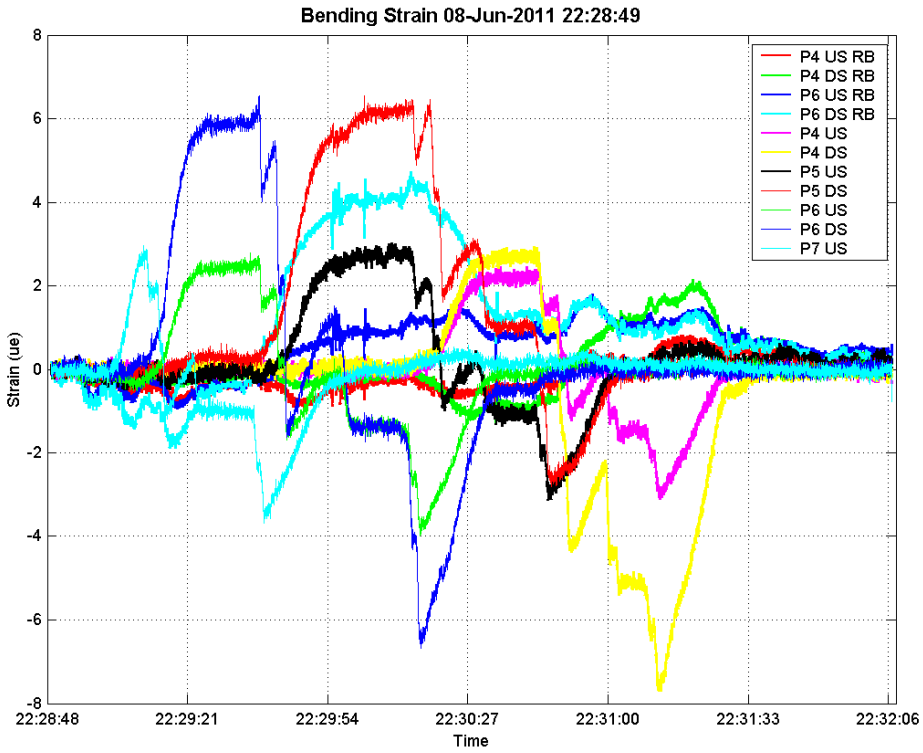

Figure 3-4. 10:28PM Bending Strain

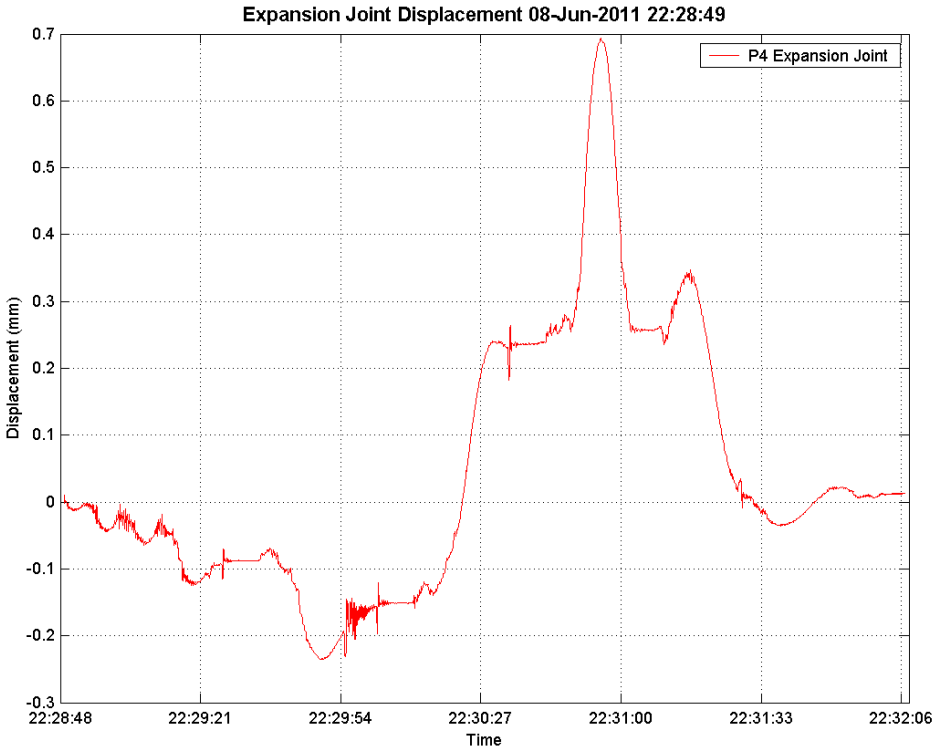

Figure 3-5. 10:28PM Expansion Joint

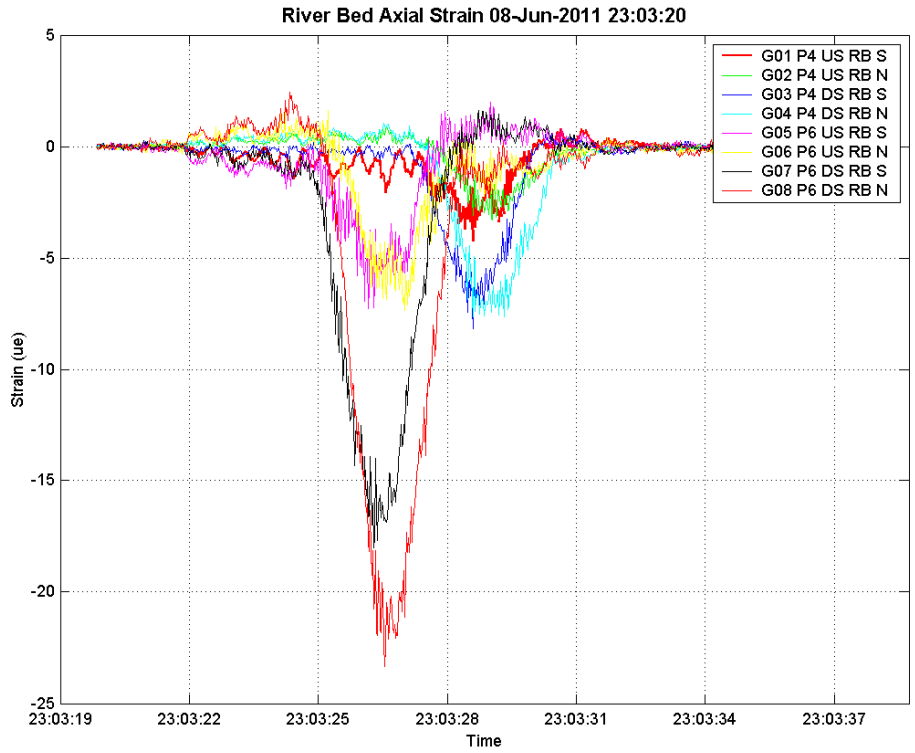

Figure 3-6. 11:03PM Axial Strain (RB)

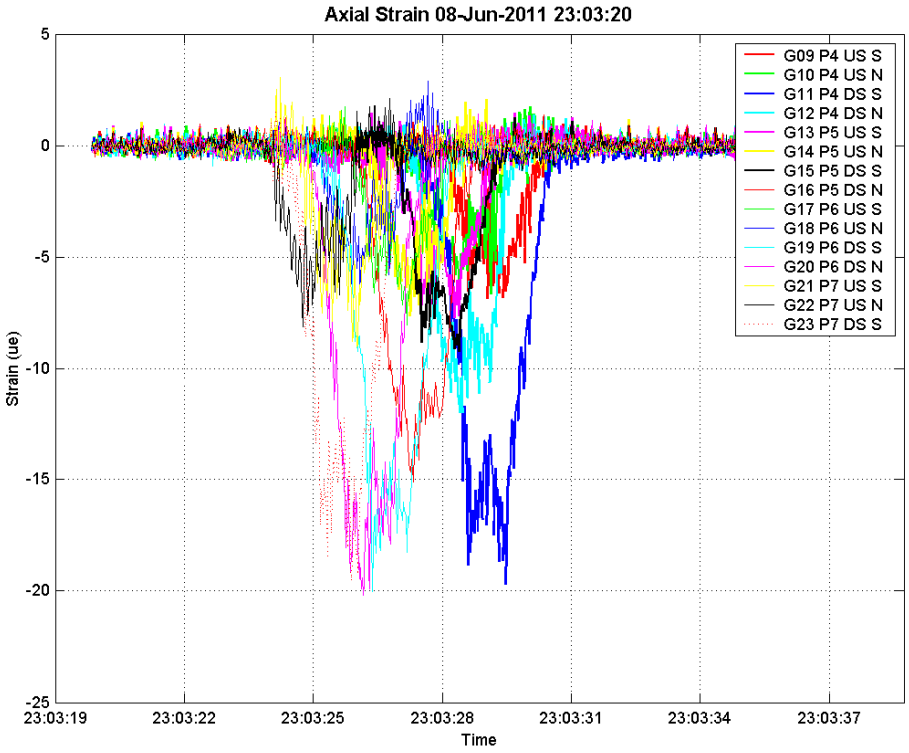

Figure 3-7. 11:03PM Axial Strain (AW)

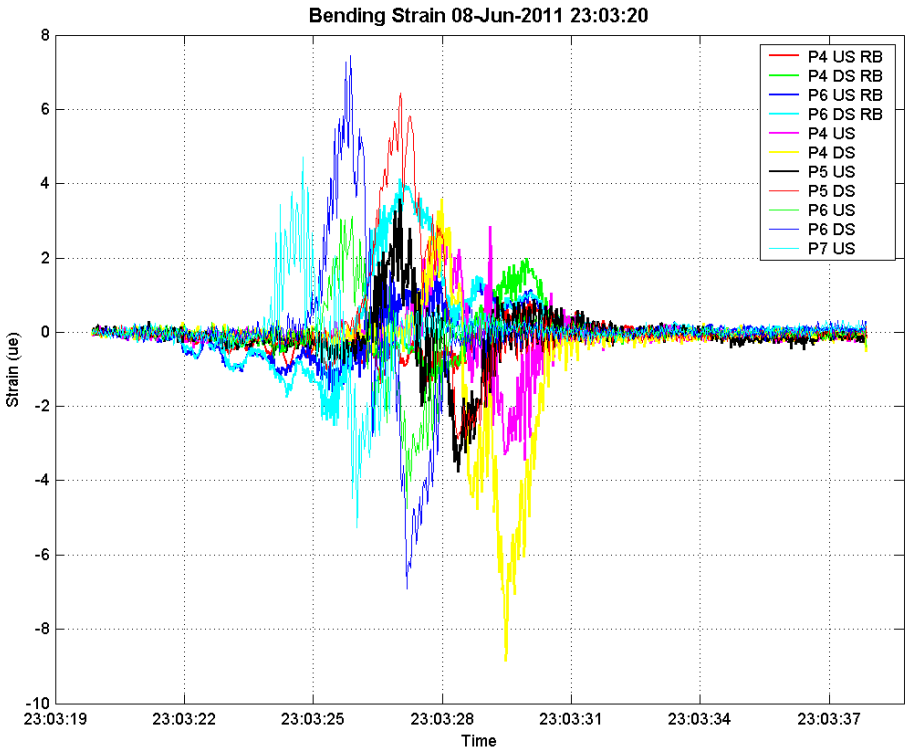

Figure 3-8. 11:03PM Bending Strain

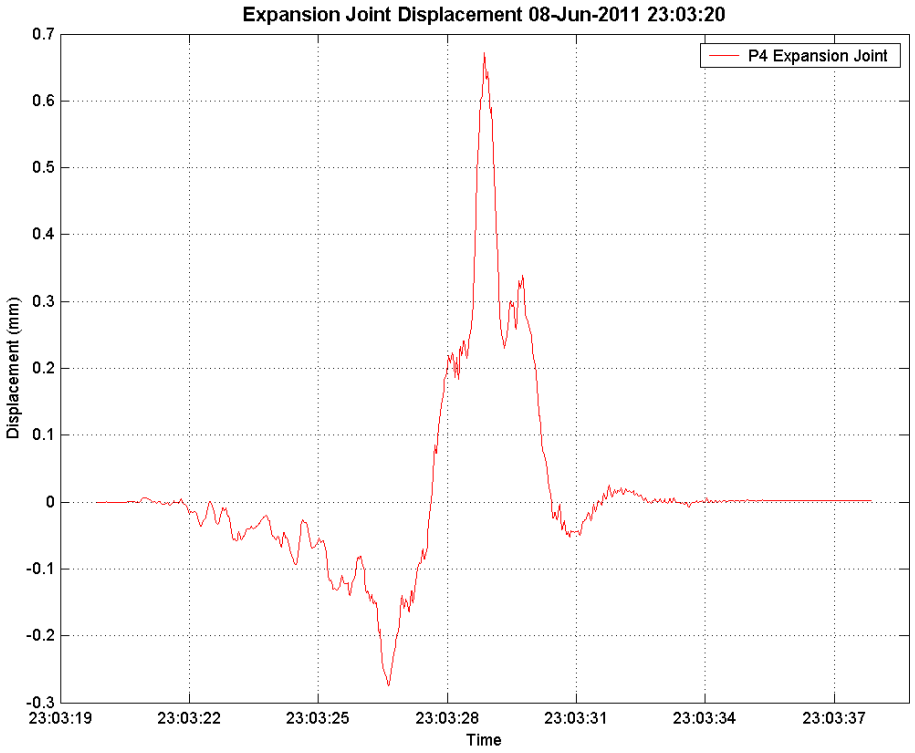

Figure 3-9. 11:03PM Expansion Joint

4. Dynamic Test Results (Monitoring of Ambient Traffic)

4.1 Test Overview

Installation of continuous power via solar panels was completed on 17 June 2011 and dynamic testing of ambient traffic was initiated that day. Data from 17 to 24 June is presented in this section. A 40 second period of time series data is acquired to enable full post-processing.

4.2 Results Processing

Traffic events which cause strain deviations above a set point have been logged and are presented in Sections 4.3. The nominal trigger set points used were G18 - 15 με, and G20 -20με for axial strains. Waveforms of peak events were viewed to confirm that the event fitted the expected profile and was indeed a vehicle.

Additional data can be viewed on the website www.endcon.com.au/clients/nswrta/bn415 .

4.3 Scatter Plots

Figure 4-1 to 4-12 show axial strain scatter plots for each pier upstream and downstream with a red line mark indicating the load level 1 test at 40kph results from Section 3.3. Figure 4-13 to 4-24 show bending strain scatter plots for each pier upstream and downstream.

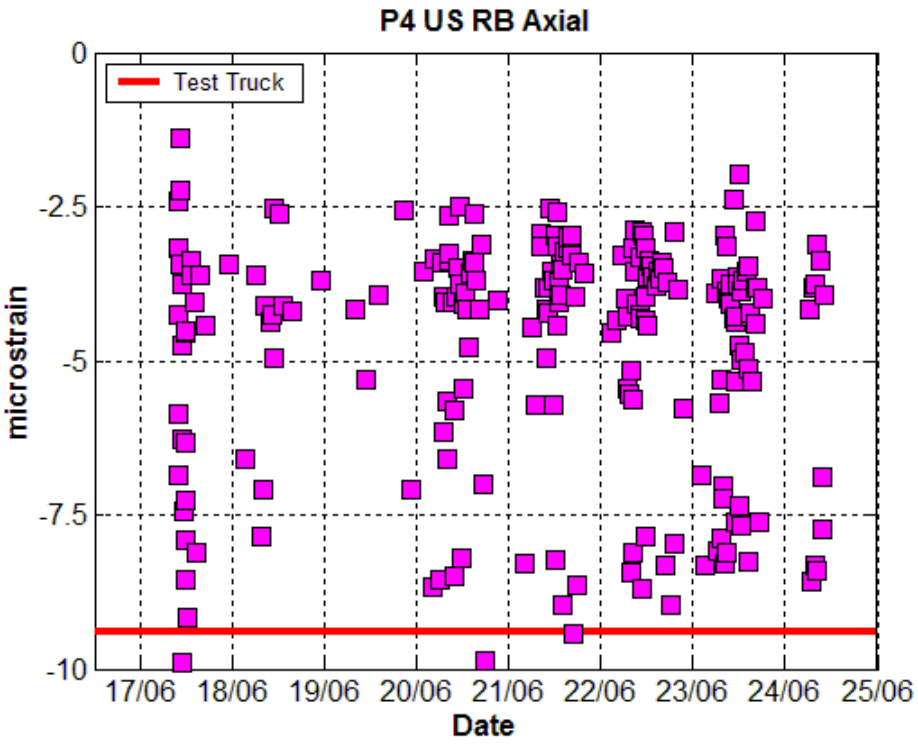

Figure 4-1. Scatter Plot - Pier 4 Upstream Axial Strain (RB)

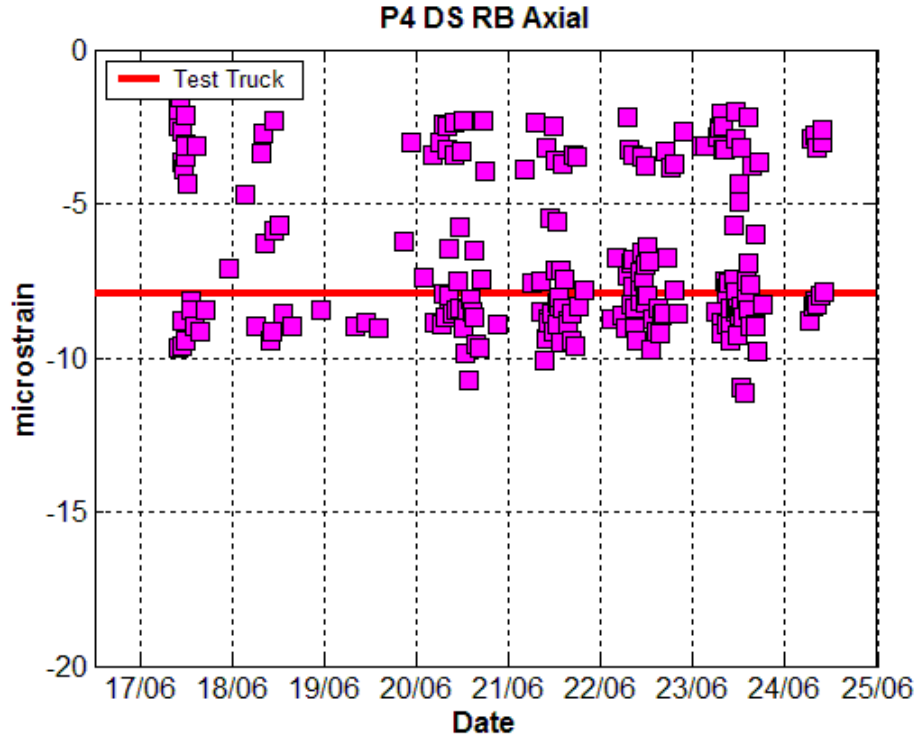

Figure 4-2. Scatter Plot - Pier 4 Downstream Axial Strain (RB)

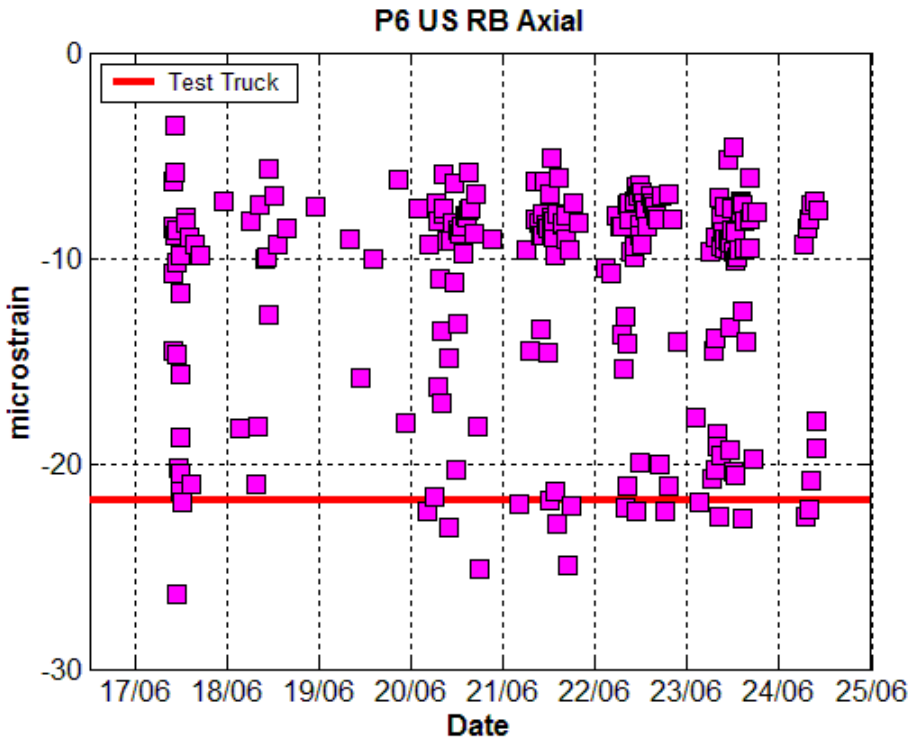

Figure 4-3. Scatter Plot - Pier 6 Upstream Axial Strain (RB)

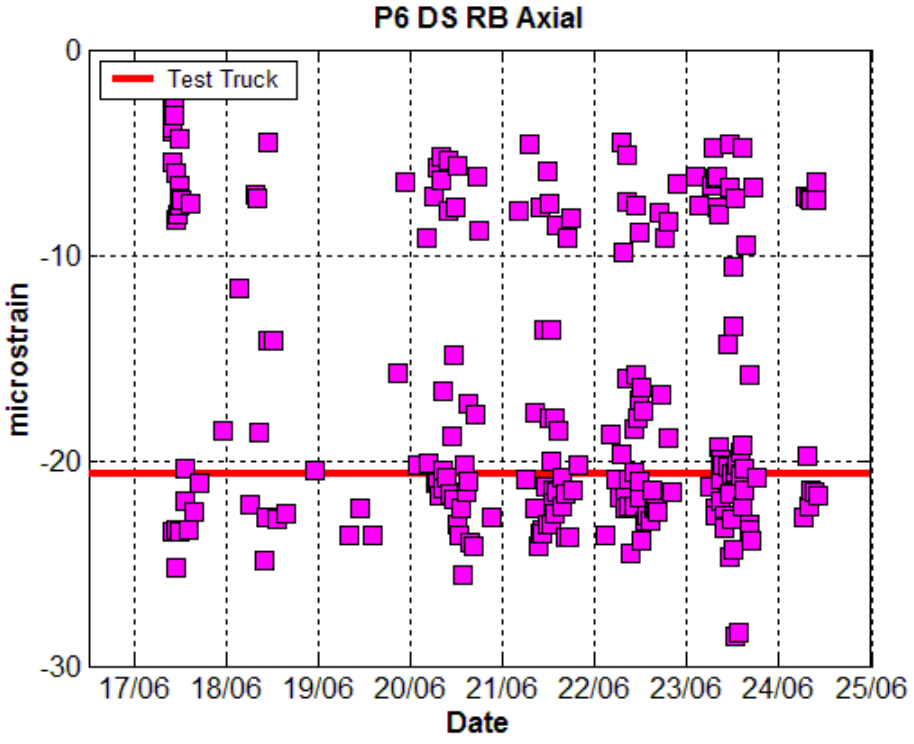

Figure 4-4. Scatter Plot - Pier 6 Downstream Axial Strain (RB)

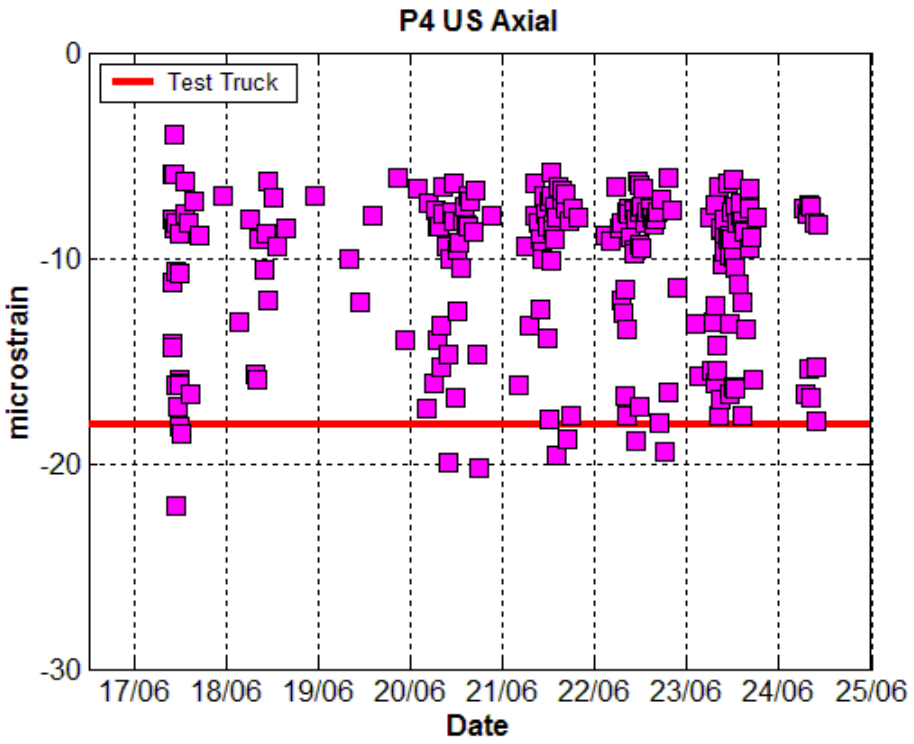

Figure 4-5. Scatter Plot - Pier 4 Upstream Axial Strain

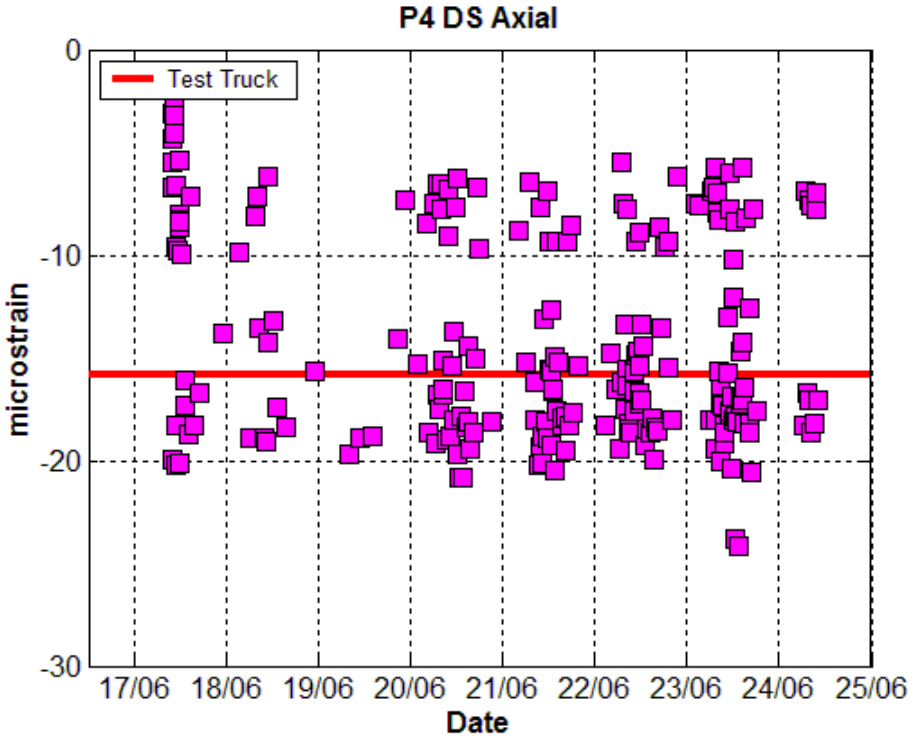

Figure 4-6. Scatter Plot - Pier 4 Downstream Axial Strain

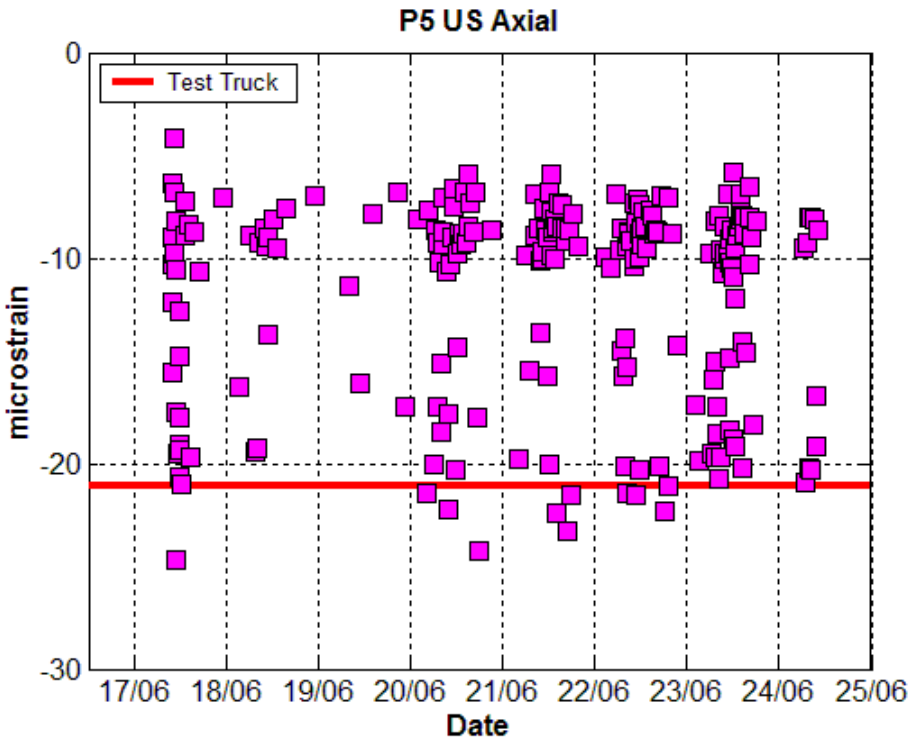

Figure 4-7. Scatter Plot - Pier 5 Upstream Axial Strain

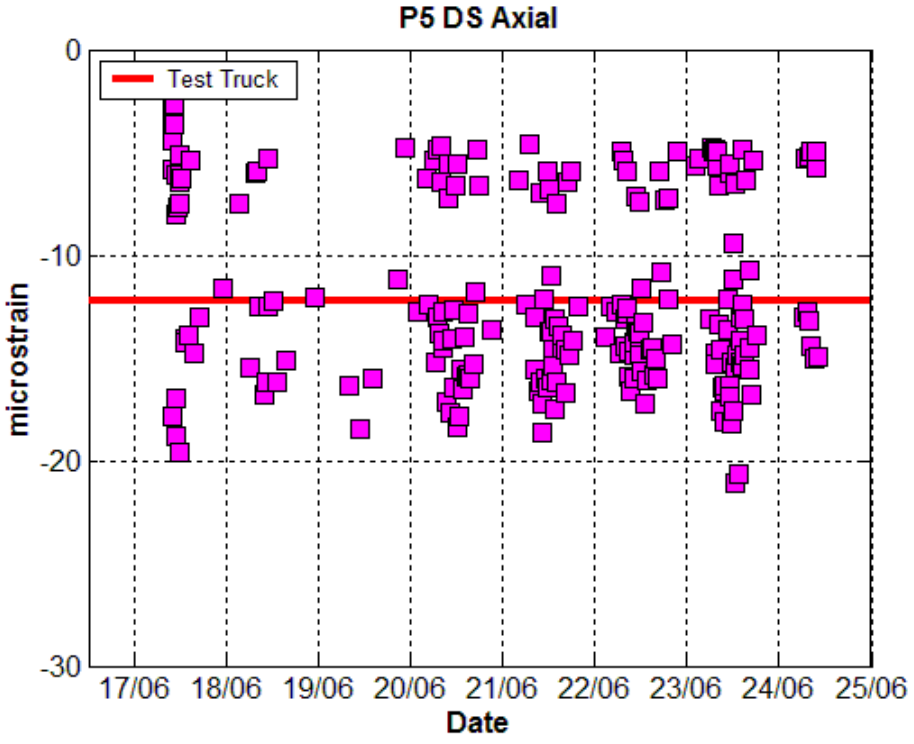

Figure 4-8. Scatter Plot - Pier 5 Downstream Axial Strain

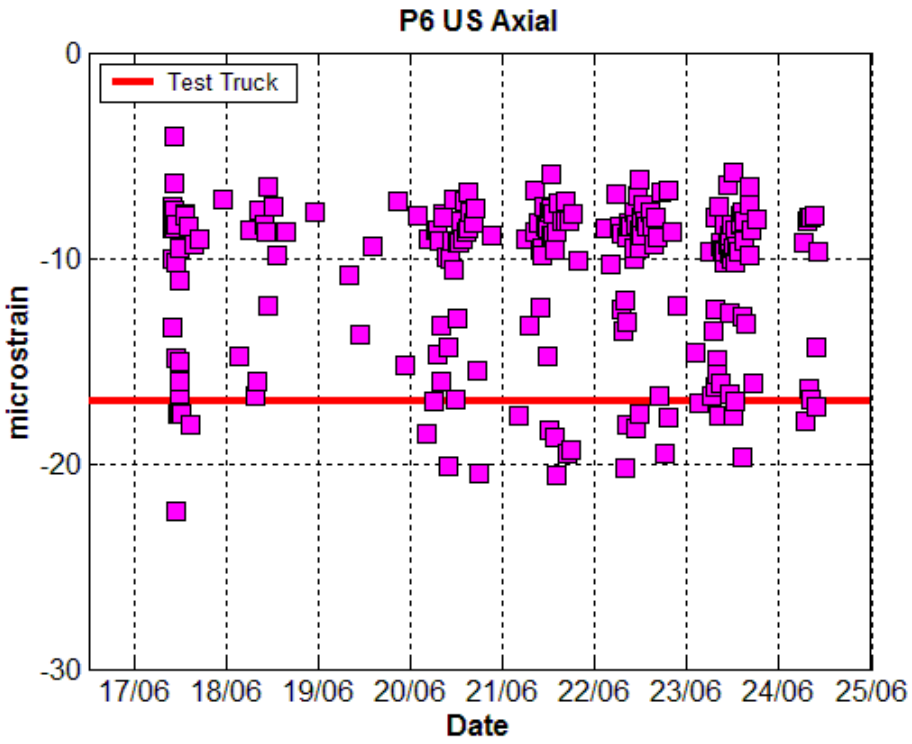

Figure 4-9. Scatter Plot - Pier 6 Upstream Axial Strain

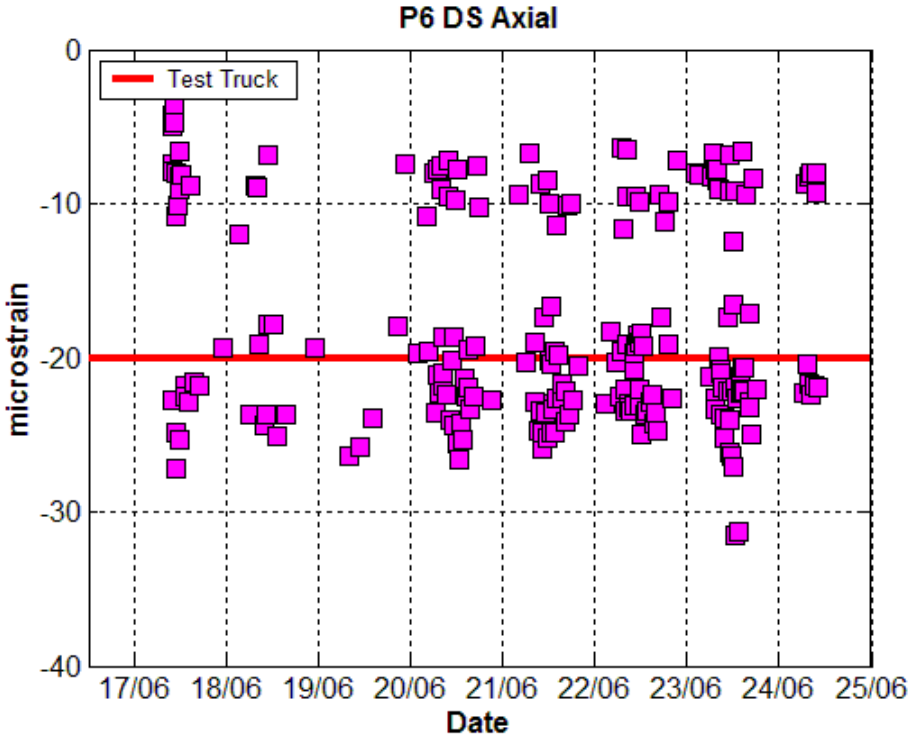

Figure 4-10. Scatter Plot - Pier 6 Downstream Axial Strain

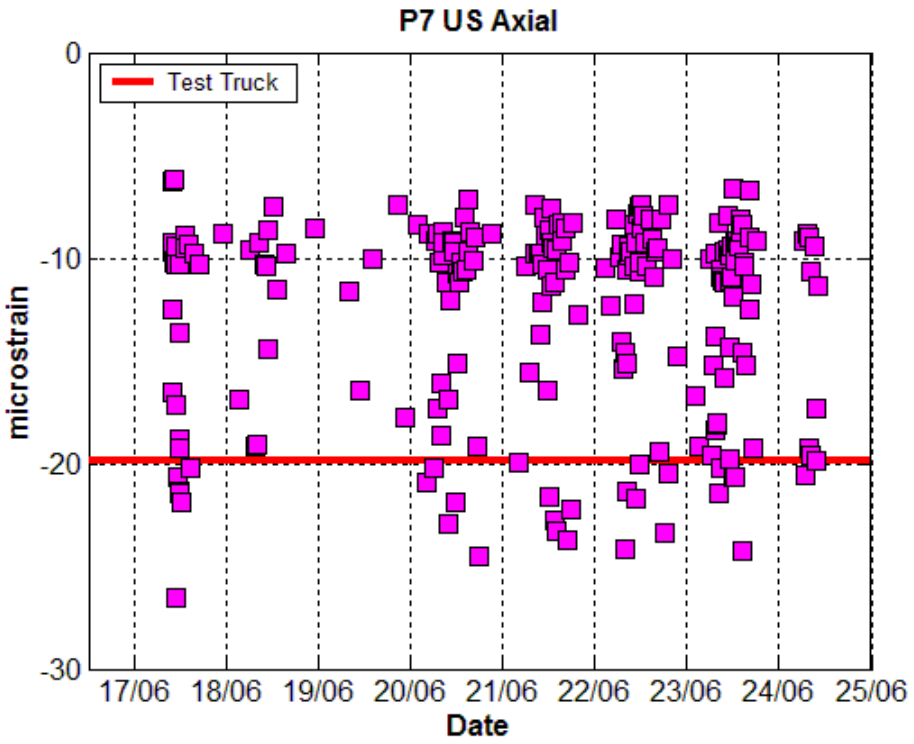

Figure 4-11. Scatter Plot - Pier 7 Upstream Axial Strain

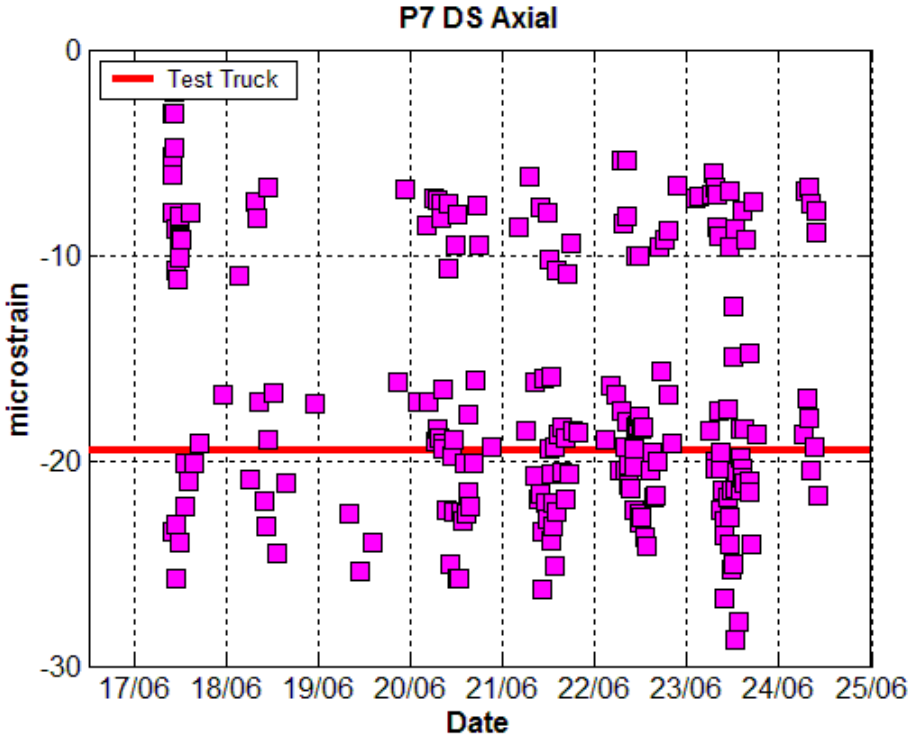

Figure 4-12. Scatter Plot - Pier 7 Downstream Axial Strain

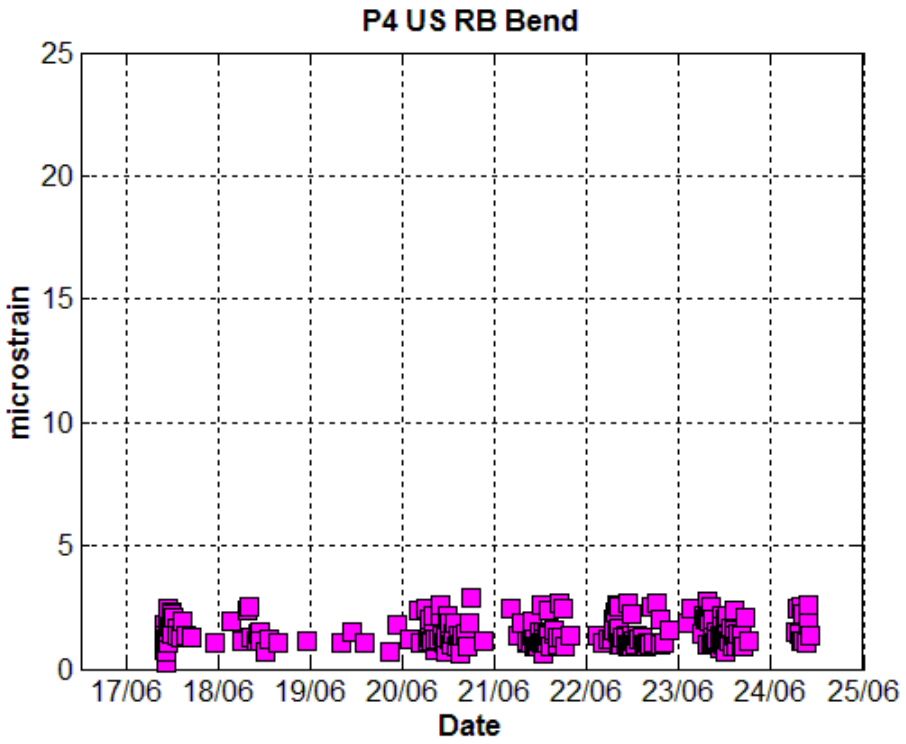

Figure 4-13. Scatter Plot - Pier 4 Upstream Bending Strain (RB)

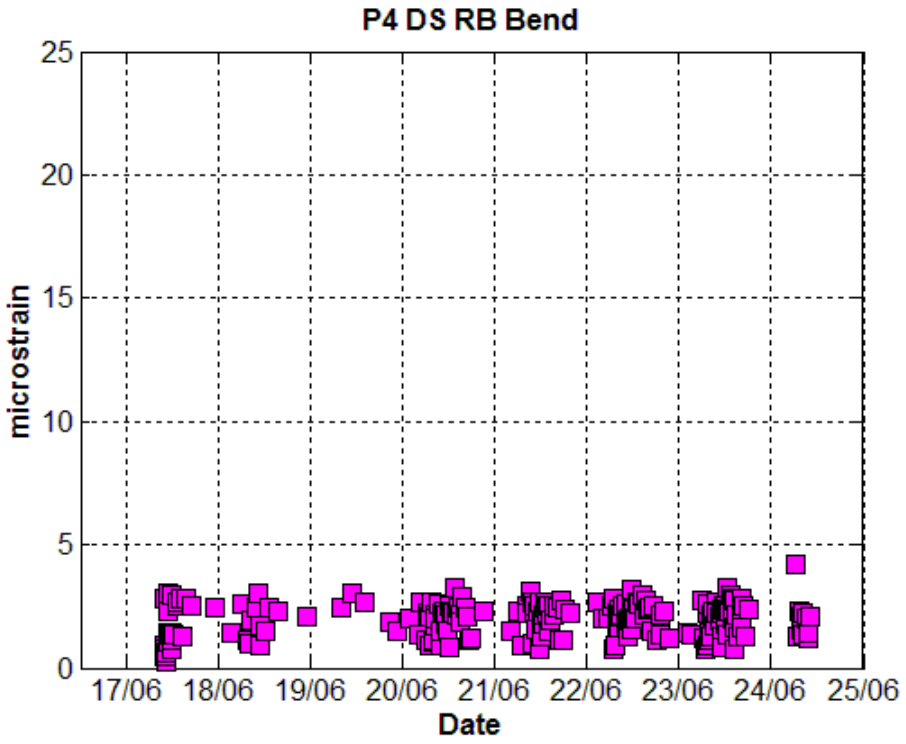

Figure 4-14. Scatter Plot - Pier 4 Downstream Bending Strain (RB)

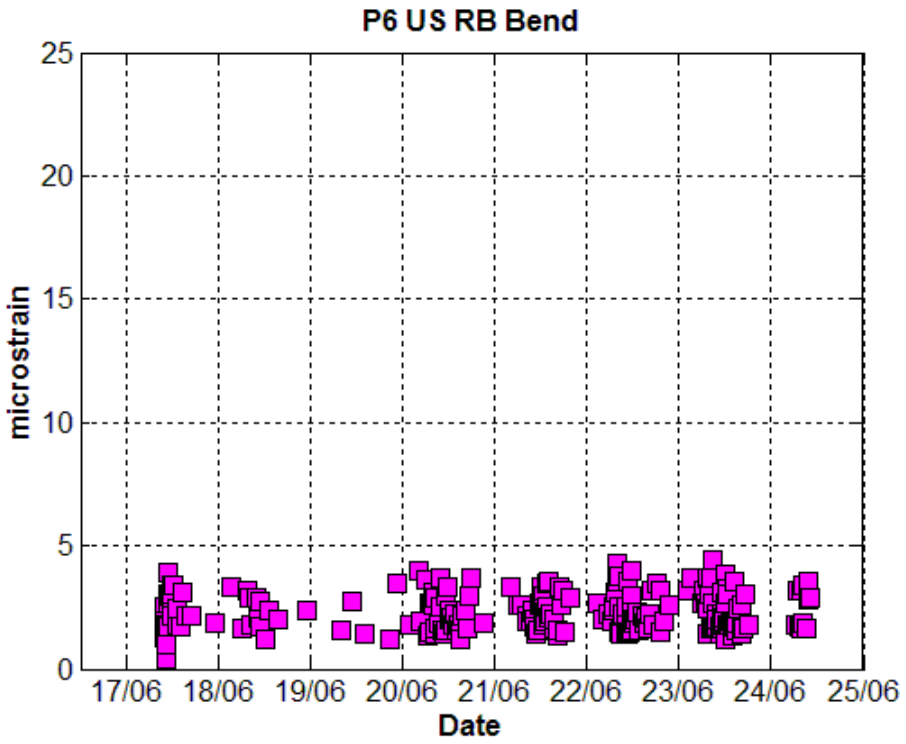

Figure 4-15. Scatter Plot - Pier 6 Upstream Bending Strain (RB)

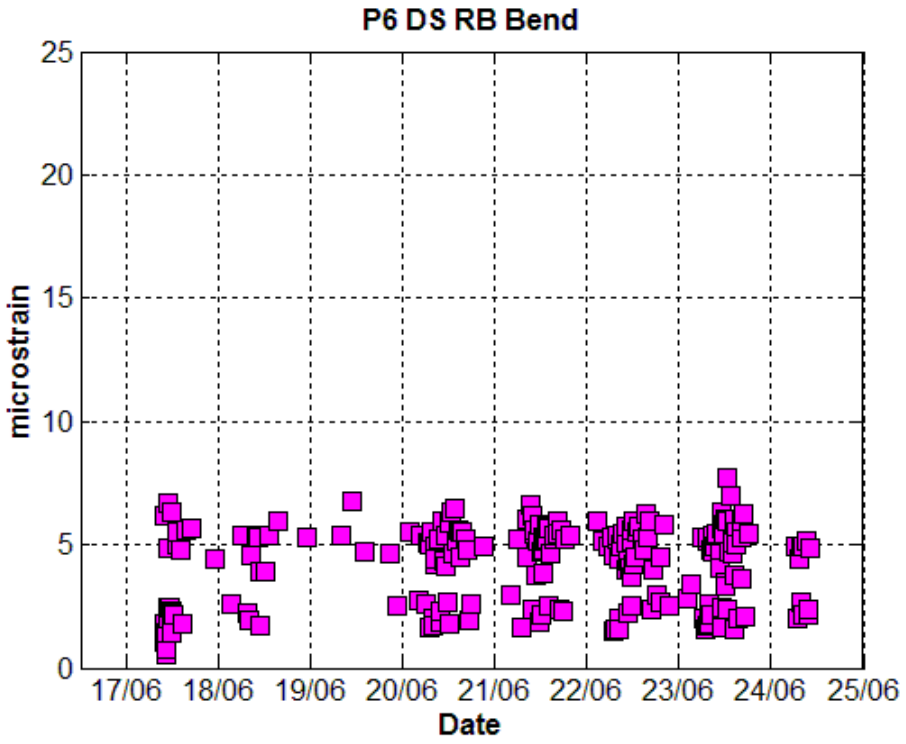

Figure 4-16. Scatter Plot - Pier 6 Downstream Bending Strain (RB)

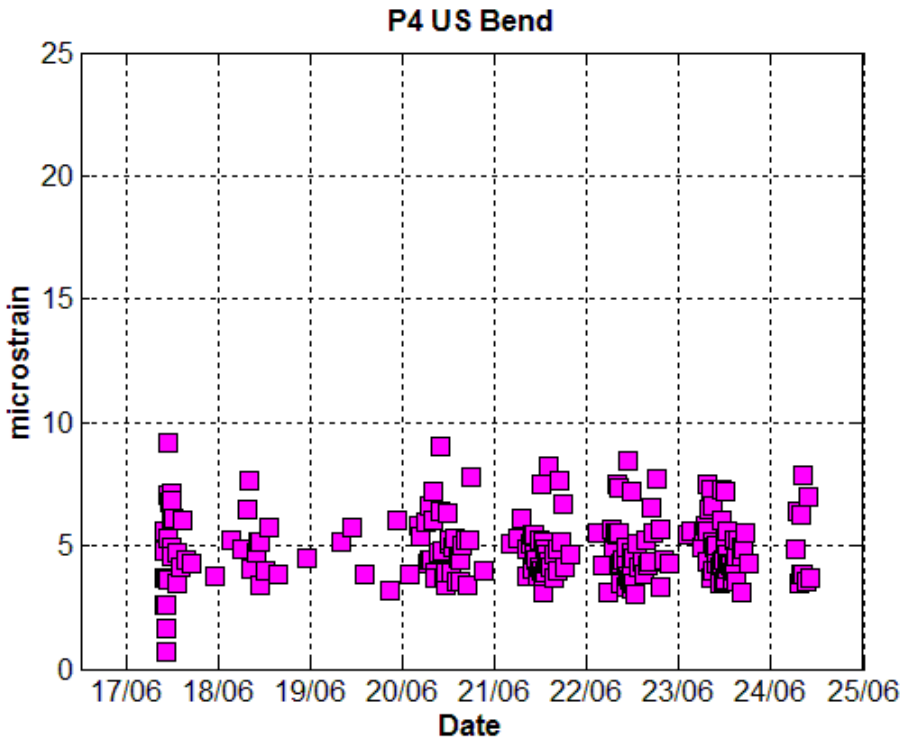

Figure 4-17. Scatter Plot - Pier 4 Upstream Bending Strain

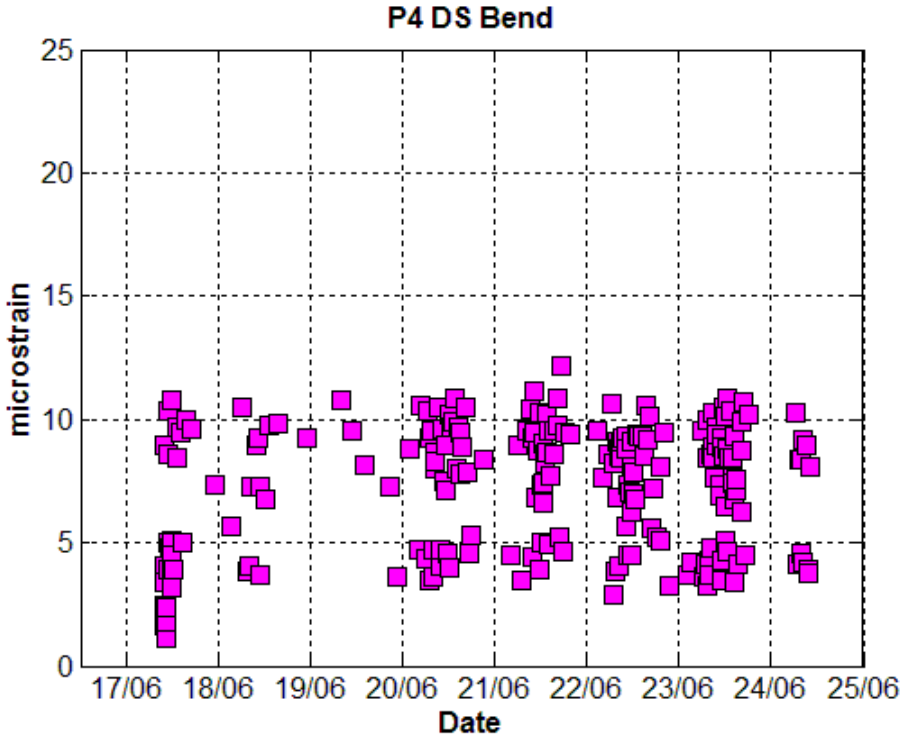

Figure 4-18. Scatter Plot - Pier 4 Downstream Bending Strain

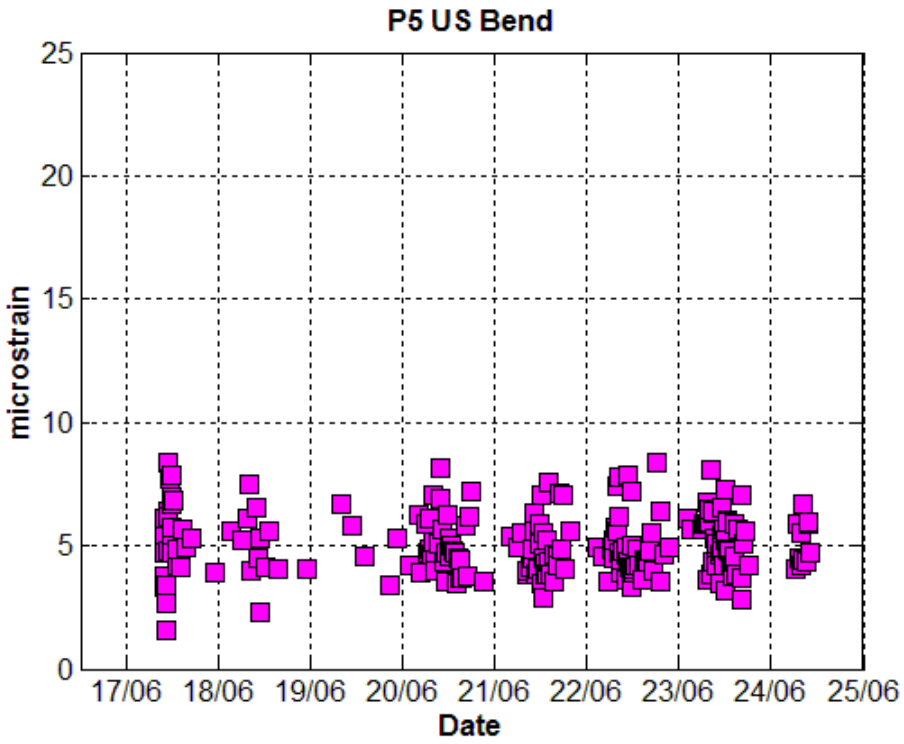

Figure 4-19. Scatter Plot - Pier 5 Upstream Bending Strain

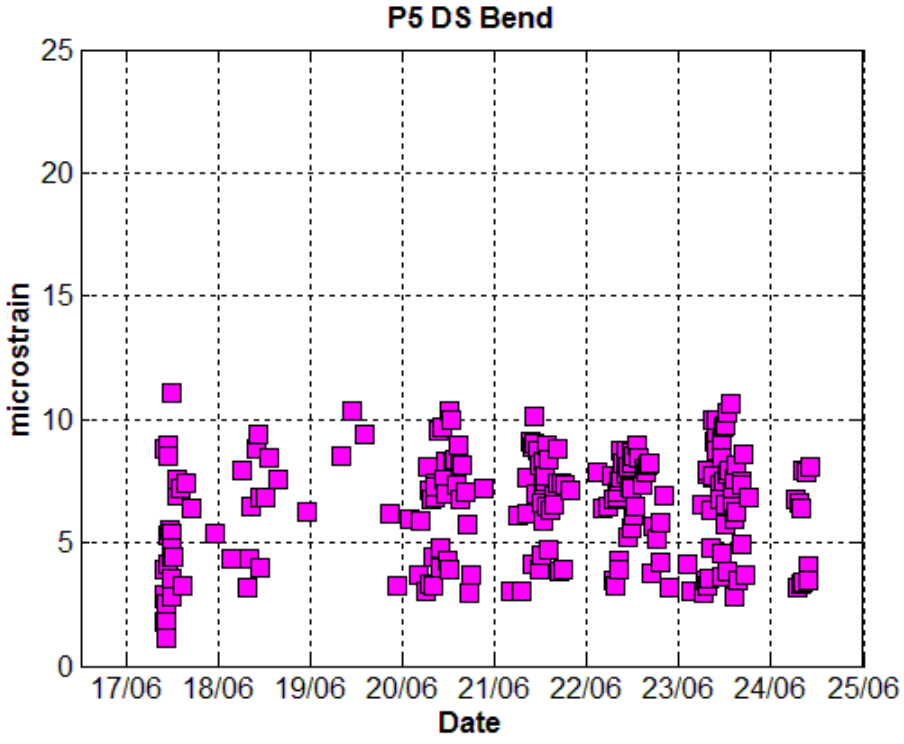

Figure 4-20. Scatter Plot - Pier 5 Downstream Bending Strain

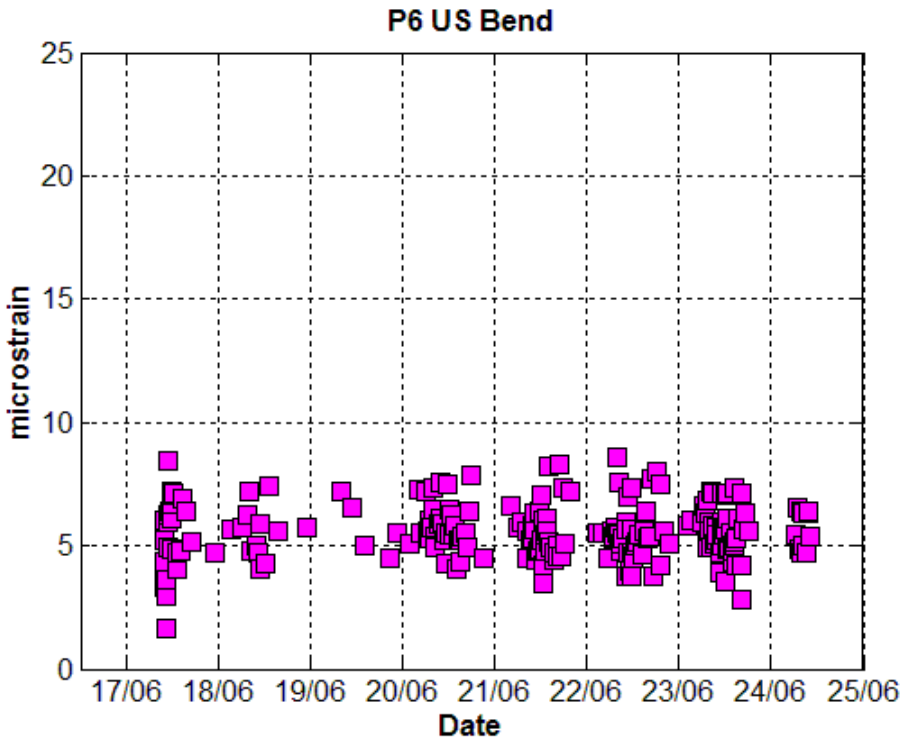

Figure 4-21. Scatter Plot - Pier 6 Upstream Bending Strain

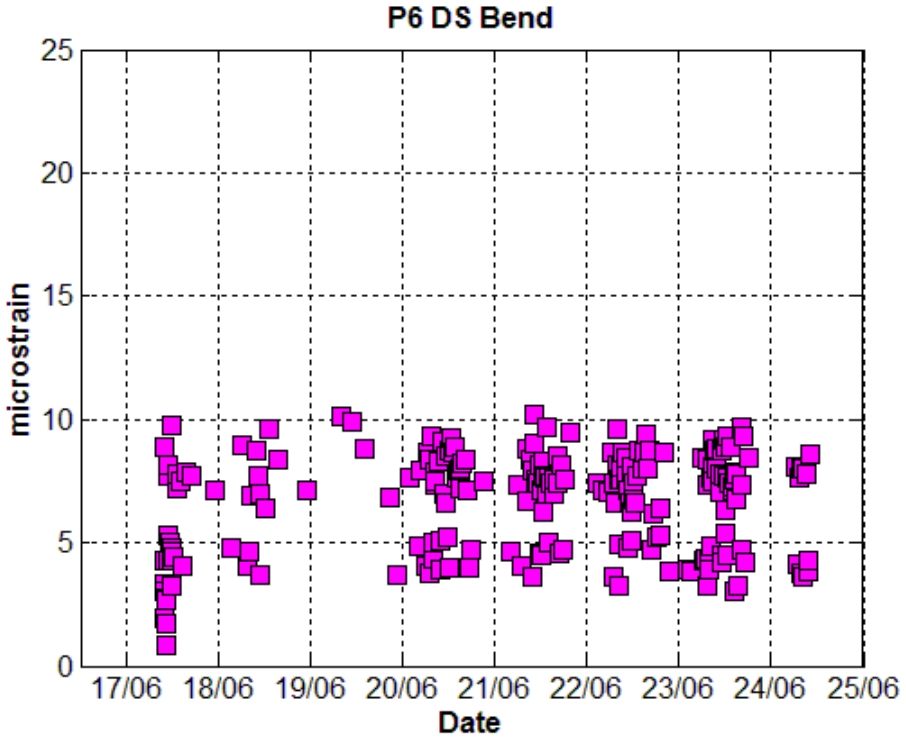

Figure 4-22. Scatter Plot - Pier 6 Downstream Bending Strain

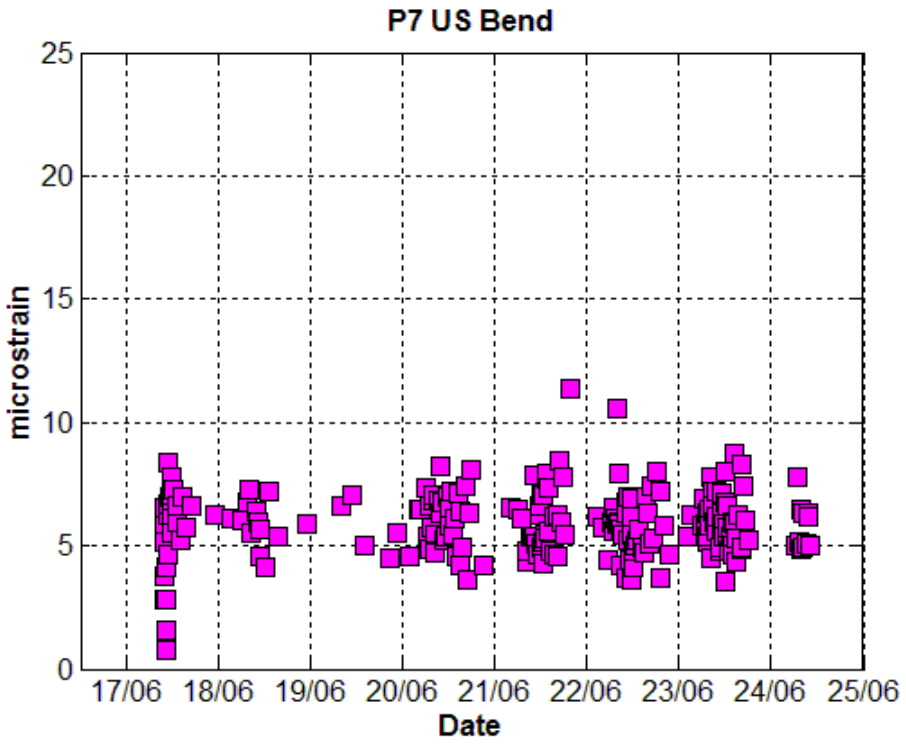

Figure 4-23. Scatter Plot - Pier 7 Upstream Bending Strain

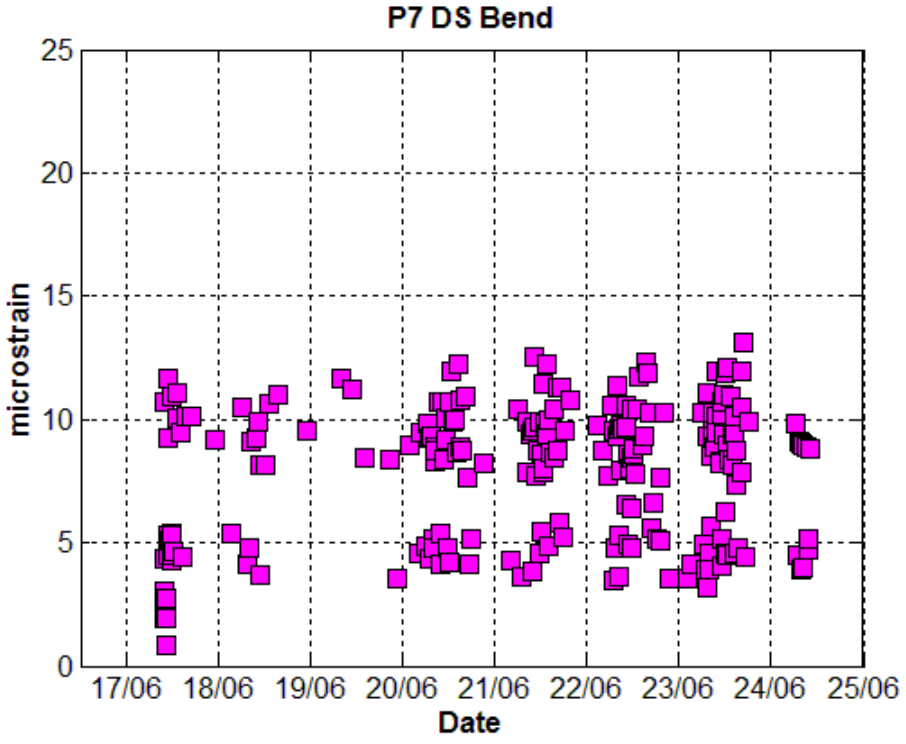

Figure 4-24. Scatter Plot - Pier 7 Downstream Bending Strain

5. Figures

Figure 5-1. Data Acquisition Location

Figure 5-2. Strap-On Strain Gauge for River Bed

Figure 5-3. Typical Pier Cabling

Figure 5-4. Expansion Joint DDT