FAIRHURST

$\big(194\big)$

SUBMISSION FOR VOLUME 1, 2 AND 3 DEPARTURE FROM STANDARDS

DEPARTURE FROM STANDARDS

Name of Works:

Strengthening of End Link Brackets For N.E & S.E Towers

(Bridges and other Highway Structures)

Name of Bridge or Structure: Forth Road Bridge

Structure Reference Number: N/A

OVERSEEING ORGANISATION NAME: Transport Scotland

APPLICATION FOR DEPARTURE FROM STANDARDS – DMRB Vol 1 Section 3 Part 14 BD 37/01

APPLICANT: Fairhurst

PROJECT TITLE: Strengthening of End Link Brackets For N.E & S.E Towers

DEPARTURE No: 004 Rev01

STRUCTURE REF: Forth Road Bridge

SUBMISSION DATE: 26/11/15

---

1. List of supporting documentation

Standards: Design Manual For Roads and Bridges (DMRB) Volume 1 Section 3 Part 14 DB 37/01

Drawings: None

Other: Dawe, Peter. *Research Perspectives: Traffic Loading On Highway Bridges.* London: Thomas Telford, 2003. Print;
Flint and Neill Partnership,. 'Interim Design Standard: Long Span Bridge Loading'. *Transport and Road Research Laboratory* Contractor Report 16 (1986): Print.
Fairhurst. '*2010 Bridge Specific Assessment Live Loading + Addendum reports*'. (2011)

---

2. Description of proposed departure
(Include details of DMRB / Eurocode Standards and Clause numbers which are being departed from)

Reduced BSALL load factor from BD37/01 Table 1.

The characteristic BSALL loading was adopted for design, this load being derived by multiplying the nominal BSALL loading by 1.2.

---

3. Designer / Assessor justification
(Include reasons why existing DMRB / Eurocode Standards are inappropriate)

The characteristic loading is the 5% probability of occurrence in a period of 10 years and was calculated from a three week sample of traffic weigh in motion data. As recommend by the TRRL contractor report 16 and BD50/92 the calculated characteristic loading is divided by 1.2 to achieve a nominal loading which can then by factored in accordance with BD37/01.

The assessment of the links was initially undertaken at the ultimate limit state in accordance with the standards. For load combinations involving dead plus BSALL this involves applying a factor of 1.5 to the nominal loading. We understand from literature that in the derivation of the full HA loading detailed in BD 37 at the ultimate limit state loading would only occur once in every 200,000 years, representing an extremely improbable occurrence. The partial factor of 1.5 was determined using engineering judgement as at the time of the code being developed no statistical data was

Forth Road Bridge
Strengthening of End Link Brackets For N.E. /
S.E. Towers
Application for Departures from Standards

FAIRHURST

available. The application of a factor of 1.5 significantly lowers the probability that the derived loading will be realised from that assumed in the original derivation based on actual traffic data on the Forth Bridge.

There is a risk that the loadings calculated from the three week sample of WIM data does not reflect all loading scenarios however the probability that these loadings occur is significantly reduced once the new Queen Ferry Crossing opens and traffic is diverted to the new bridge.

The aim of the proposed strengthening works as agreed with FETA was to reduce the level of risk associated with the assessed utilisation ratios of particular parts of the link bracket arrangement and in particular the high utilization ratios in the existing welds. For these reasons, the characteristic BSALL loading based on the WIM data was adopted for design

4. Cost Implications
(Include an estimate of cost savings to Transport Scotland as well as the effect on future maintenance costs)

4.1. Construction costs
Adopting standard loading and load factors for the assessment of the bridge and design of strengthening works will lead to significant works across the bridge structure to achieve code compliance. Reducing the load factor for the bridge reduces the extent of interventions required. The approach proposed by this departure is considered a pragmatic response to the assessed structural issues
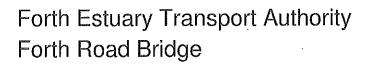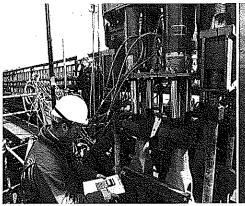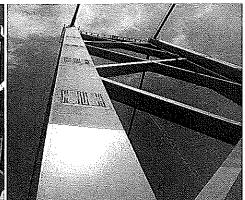
4.2. Maintenance costs
NA

5. Applicant of the Works Team Leader Declaration:

I declare that reasonable professional skill and care have been exercised in the preparation of this Departure submission.

Signed:

Name: C. A. CLARK

Date: 26/11/15

6. Overseeing Organisation Bridges Branch Comments and Recommendation:

I recommend that the above departure should be accepted / rejected

Signed:

Name:

Date: 30 - 11 - 15 .

7. Oveerseeing Organisation Recommendation

The above Departure is approved / ~~rejected~~.

Signed:

Name: S. W. HINDSHAW

Date: 30 November 2015 .

Forth Estuary Transport Authority
Forth Road Bridge

2010 Bridge Specific
Assessment Live Loading

Return Periods Addendum Report

February 2011

FAIRHURST

engineering solutions, delivering results

CONTROL SHEET   **FAIRHURST**

CLIENT: **Forth Estuary Transport Authority**

PROJECT TITLE: **Forth Road Bridge 2010 BSALL**

REPORT TITLE: **2010 Bridge Specific Assessment Live Loading**
                                   Return Periods Addendum Report

PROJECT REFERENCE: **81189**

Issue and Approval Schedule:

ISSUE 1 <Final>	Name	Signature	Date
Prepared by	Scott Allan	▮	09 Feb. 11
Reviewed by	Colin Clark	▮	09 Feb 2011
Approved by	Colin Clark	▮	09 Feb 2011

Revision Record:

Issue	Date	Status	Description	By	Chk	App
2						
3						
4						
5						
6						
7						
8						

This report has been prepared in accordance with procedure OP/P03 of W A Fairhurst & Partners' Quality Assurance System.

FAIRHURST

CONTENTS

Page No.

FAIRHURST

1   INTRODUCTION

The Forth Road Bridge currently adopt a Bridge Specific Assessment Live Loading (BSALL) for the assessment of the suspended structure to carry day to day loading which may occur on the bridge. The BSALL is derived from traffic data recorded at the bridge with the calculated loading having a 5% probability of occurrence in 120 years. However in order to prioritise remedial and upgrading works FETA commissioned W.A. Fairhurst & Partners to derive BSALL loading curves with shorter return periods.

This report provides BSALL loading curves for return periods of 10, 50 and 120 year periods. The 120 year period loading is the recommended BSALL for the bridge and is provided for comparison. Full details of the recommended BSALL including the principles of which have been used to derive the BSALL, are provided in our report "2010 Bridge Specific Assessment Live Loading" dated February 2011.

2   CALCULATION FOR SHORTER RETURN PERIODS

The calculation of the BSALL for reduced return periods has been undertaken in a similar manner to that to derive the recommended 2010 BSALL.

The effect of reducing the return period is taken into account in the calculation of the tail probability. This is then used to determine the number of standard deviations from the mean for a variable of a specific probability of occurrence. As the calculated probability reduces with reducing the return period the number of standard deviations from the mean (r) for the variable also reduces. This effect is shown in the tables in Appendix B with r reducing from approximately 5.5 to 5.0 between 120 years and 10 years respectively

3   COMPARISON OF CALCULATED BSALL FOR REDUCED RETURN PERIODS

A BSALL has been derived for reduced return periods of 50 years and 10 years. The total bridge loading and lane 1 loadings for these return periods are plotted in Figures 1 and 2 respectively of Appendix A along with the 2010 recommended loading for comparison. The bridge total loading has been calculated using the same lane factors adopted for the recommended loading. The lane factors are 1.0, 0.67, 0.33 and 0.33 for lanes 1 to 4 respectively.

The reduction in return period results in the following reduction in the calculated critical lane 1 loading;

*   For a 50 year return period the loading reduces by an average of 3%.

*   For a 10 year return period the loading reduces by an average of 8%.

Lane factors for the nominal BSALL (120 year return period) are derived as follows.

*   .   Lane 1 is derived on the basis of a 5% probability of occurrence in 120 years,

*   Lane 2 is derived in a similar manner to Lane 1,

*   Lanes 3 and 4 are based on the mean queue weights which are assumed to be co-existent with lanes 1 and 2 loading.

In considering the above we considered that retaining the lane factors from the standard BSALL derivation would remain appropriate.

FAIRHURST

4 REFERENCES

1. Research Perspectives: Traffic loading on highway bridges, Peter Dawe TRRL. Thomas Telford Publishing 2003.

2. 2010 Bridge Specific Assessment Live Loading Report by W.A. Fairhurst & Partners dated January 2011.

FAIRHURST

APPENDIX A – FIGURES

Figure 1 :   BSALL for Return Periods of 120 years, 50 years and 10 years – Bridge Total

Figure 2 :   BSALL for Return Periods of 120 years, 50 years and 10 years – Lane 1 Loading.

FAIRHURST

Figure 1 : BSALL for Return Periods of 120 years, 50 years and 10 years (Nominal) - Bridge Total
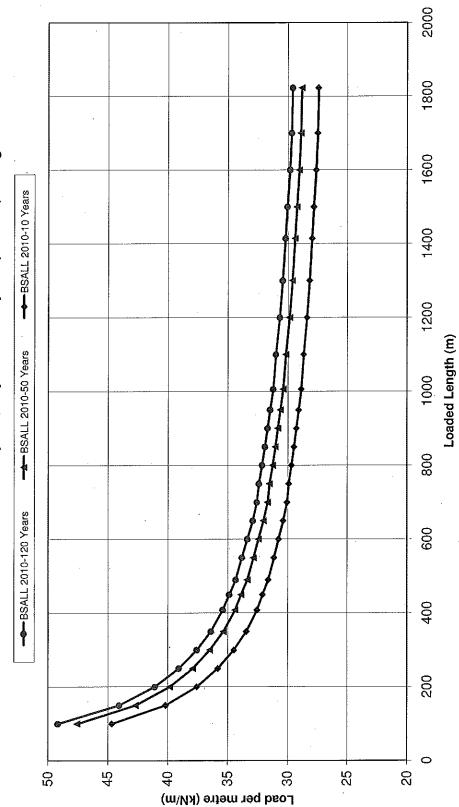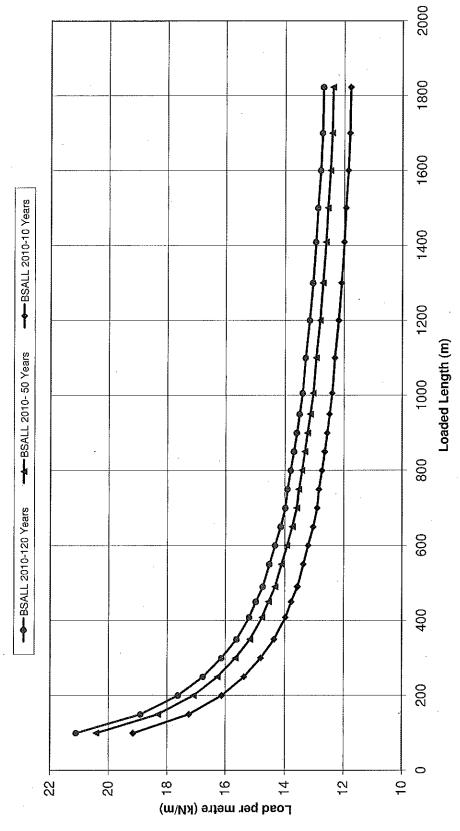
Legend: BSALL 2010-120 Years · BSALL 2010-50 Years · BSALL 2010-10 Years

Load per metre (kN/m) vs Loaded Length (m)

FAIRHURST

Figure 2 : BSALL for Return Periods of 120 years, 50 years and 10 years (Nominal) - Lane 1

Legend: BSALL 2010-120 Years   BSALL 2010- 50 Years   BSALL 2010-10 Years

FAIRHURST

APPENDIX B – TABLES

Table 1 :   Calculation of the 2010 assessment loading for the northbound slow lane based on a return period of 120 years.

Table 2 :   Calculation of the 2010 assessment loading for the northbound slow lane based on a return period of 50 years.

Table 3 :   Calculation of the 2010 assessment loading for the northbound slow lane based on a return period of 10 years.

LEGEND

P (tail probability) and 'r' :

The calculation of P (tail probability) takes account of the probability that the derived loading has a 5% chance of being exceeded in the assumed return period. The factor 'r' is the number of standard deviations from the mean corresponding to the tail probability.

Mean and 's' :

The mean of the square root of each of the individual queue weights obtained from the analysed traffic data. 's' is the standard deviation of the mean.

FAIRHURST

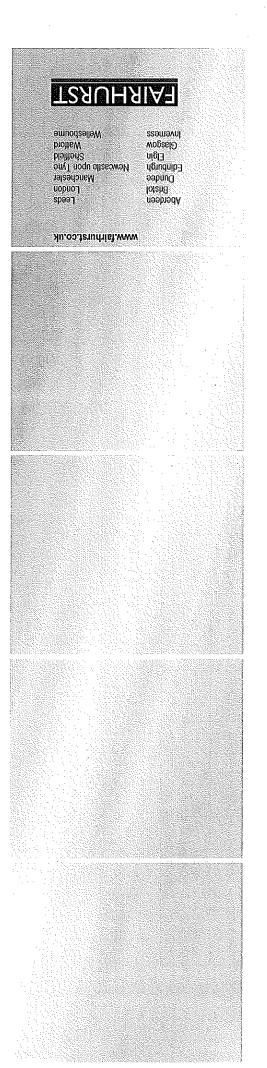## Table 1   Calculation for Northbound slow lane for a return period 120 years

Loaded Length (m)	Survey No. of events	Average No. of vehicles in queue	No. of events per year	No. of events in 120 years	No. of vehicles involved in Queues (1.93%)	P Probability	r	mean	s	Characteristic Loading kN/m	Nominal Loading kN/m
100	72406	15	1258485	151018229	2914652	1.72E-08	5.518	20.31	5.53	25.33	21.11
200	72249	28	1255756	150690771	2908332	1.72E-08	5.518	20.54	4.70	21.16	17.63
300	71759	42	1247240	149668771	2888607	1.73E-08	5.517	20.60	4.32	19.36	16.13
408	71156	58	1236759	148411086	2864334	1.75E-08	5.515	20.62	4.08	18.24	15.20
1006	68634	142	1192924	143150914	2762813	1.81E-08	5.509	20.67	3.60	16.09	13.41
1414	66385	199	1153835	138460143	2672281	1.87E-08	5.503	20.73	3.47	15.55	12.96
1823	63930	256	1111164	133339714	2573456	1.94E-08	5.496	20.80	3.39	15.25	12.71

Table 2   Calculation for Northbound slow lane for a return period 50 years

Loaded Length (m)	Survey No. of events	Average No. of vehicles in queue	No. of events per year	No. of events in 50 years	No. of vehicles involved in Queues (1.93%)	P Probability	r	mean	s	Characteristic Loading kN/m	Nominal Loading kN/m
100	72406	15	1258485	62924262	1214438	4.12E-08	5.366	20.31	5.53	24.50	20.42
200	72249	28	1255756	62787821	1211805	4.13E-08	5.37	20.54	4.70	20.51	17.10
300	71759	42	1247240	62361988	1203586	4.15E-08	5.36	20.60	4.32	18.79	15.66
408	71156	58	1236759	61837952	1193472	4.19E-08	5.363	20.62	4.08	17.71	14.76
1006	68634	142	1192924	59646214	1151172	4.34E-08	5.356	20.67	3.60	15.65	13.05
1414	66385	199	1153835	57691726	1113450	4.49E-08	5.351	20.73	3.47	15.14	12.62
1823	63930	256	1111164	55558214	1072274	4.66E-08	5.344	20.80	3.39	14.85	12.38

FAIRHURST

Table 3 Calculation for Northbound slow lane for a return period 10 years

Loaded Length (m)	Survey No. of events	Average No. of vehicles in queue	No. of events per year	No. of events in 10 years	No. of vehicles involved in Queues (1.93%)	P Probability	r	mean	s	Characteristic Loading kN/m	Nominal Loading kN/m
100	72406	15	1258485	12584852	242888	2.06E-07	5.086	20.31	5.53	23.01	19.17
200	72249	28	1255756	12557564	242361	2.06E-07	5.085	20.54	4.70	19.35	16.13
300	71759	42	1247240	12472398	240717	2.08E-07	5.084	20.60	4.32	17.77	14.81
408	71156	58	1236759	12367590	238694	2.09E-07	5.083	20.62	4.08	16.77	13.98
1006	68634	142	1192924	11929243	230234	2.17E-07	5.076	20.67	3.60	14.87	12.40
1414	66385	199	1153835	11538345	222690	2.25E-07	5.071	20.73	3.47	14.40	12.00
1823	63930	256	1111164	11111643	214455	2.33E-07	5.064	20.80	3.39	14.14	11.78

FAIRHURST

Inverness	Wellesbourne
Glasgow	Watford
Elgin	Sheffield
Edinburgh	Newcastle upon Tyne
Dundee	Manchester
Bristol	London
Aberdeen	Leeds

www.fairhurst.co.uk

CIVIL ENGINEERING · STRUCTURAL ENGINEERING · TRANSPORTATION · ROADS & BRIDGES
PORTS & HARBOURS · GEOTECHNICAL & ENVIRONMENTAL ENGINEERING · PLANNING &
DEVELOPMENT · WATER SERVICES · CDM COORDINATOR SERVICES