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BRB (Residuary) Ltd
Major Works Programme 2009/2012

VAR9/2602 ASSESSMENT PROGRAMME

BD21/01 ASSESSMENT

Port Hill, Hertford
Hertfordshire

BRIDGE REF: WHE/17

March 2010

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Document control sheet BPP 04 F8

Client:	BRB (Residuary) Ltd		
Project:	Major Works Programme 2009/2012	Job No:	B12360AH – WHE/17
Document Title:	VAR9/2602 Assessment Programme BD21/01 Assessment WHE/17		

	Originator	Checked by	Reviewed by	Approved by
ORIGINAL **Form BA**	NAME [redacted]	NAME	NAME	NAME
DATE **30 March 2010**				
Document Status: Form BA				

REVISION	NAME	NAME	NAME	NAME
DATE	SIGNATURE	SIGNATURE	SIGNATURE	SIGNATURE
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1 BD21 Assessment

This report presents the BD21 assessment for structure WHE/17.

1.1 Location of Structure

Structure WHE/17 carries the B158 (Port Hill Rd, Hertford) over the disused railway line from Welwyn Garden City to Hertford. The structure is located near the centre of Hertford at OS ref. TL 323129.

1.2 Construction Type

Reconstructed in 1954, the single span overbridge comprises eighteen precast pre-stressed high alumina concrete internal beams and two cast iron edge girders, with brick abutments and wingwalls. The parapets are constructed from brickwork with brick copings. The bridge prior to 1954 was a 5-span bridge, having 2-double arches adjoining the middle section consisting of 5 cast iron girders and jack arches. According to historic drawings, the arches have been partly demolished and infilled. The arch faces have been closed by brick retaining walls.

The structure has a square span of 6.63m (distance between the abutments). Road width is approximately 5.05m and both verges are approximately 1.35m wide.

1.3 Information used to form the Assessment

Section sizes used to calculate dead loads were obtained from site measurements. (See Jacobs report "05/06 BE4 Assessment Programme – Assessment and Inspection Report – Structure WHE/17 August 2005") and archive data including drawings.

Assessment live loading were obtained from and applied in accordance with BD21/01, assuming "Medium" HGV flow and "Poor" road condition. "Poor" road condition was selected on account of undulations and cracking of the road surface.

Road surface condition at bridge

1.4 Methodology

The load effects from BD21 UDL and KEL loading on the deck were analysed by simple dispersion at 45° of the 2.5m wide lane loading strips into the deck. It is noted that there is little transverse reinforcement in the deck therefore capacity for lateral distribution will be limited. Accidental vehicle loading on the footways was also be analysed initially by simple dispersal.

The beams were analysed making an allowance for conversion of the high alumina concrete. Testing of the in-situ concrete has indicated a degree of conversion of 83% and compressive strength of about 17 N/mm^2, which compares with 5000 lbs/in^2 (34.5 N/mm^2) specified on the drawing as a 48 hour strength. With this degree of conversion the concrete might be considered to be close to its residual strength. It was not possible to take cores from the pre-stressed beams. It was assumed that conversion and loss of strength in the beams is similar to the in-situ concrete. Initial specified strength at 72 hours was 7500 lbs/in^2 (51.7 N/mm^2); therefore a residual strength of 25 N/mm^2 was used in assessment.

Stressing wire properties are shown on the drawing, namely 105 $tons/in^2$ UTS, 80 $tons/in^2$ 0.1% proof stress. Characteristic strength of the wire was taken as 90% of UTS, i.e. 1470 N/mm^2.

In calculating the shear capacity of the pre-stressed beams it was assumed that the pre-stressing force related to 50% of the UTS of the wires.

The in-situ concrete was considered as acting compositely with the beams as ample binders (links) have been provided.

The cast iron edge girders will be checked for dead loads and accidental vehicle effects, using the permissible stresses in BD21/01.

1.5 Results of BD21 Assessment

Element: **Concrete beams below carriageway**

Span = 6.75m

26 tonne loading K factors for various road surface and HGV flow combinations:

	HGV Flow		
Road Surface	High (H)	Med. (M)	Low (L)
Good (g)	0.79	0.77	0.75
Poor (p)	0.89	**0.87**	0.85

18 tonne loading K factors for various road surface and HGV flow combinations:

	HGV Flow		
Road Surface	High (H)	Med. (M)	Low (L)
Good (g)	0.63	0.60	0.57
Poor (p)	0.70	**0.68**	0.65

Group 1FE : K factor for all conditions is **0.50**

C = Available live load capacity / Live load capacity required for Adjusted HA loading and relates directly to the K factors in Figures 5.2 to 5.7 of BD21/01.

Action	Location	Dead load effect	HA adjusted LL effect	Assessed live load resistance	C factor	Live load rating
Bending	Mid-span	47.3 kN.m	139.2 kN.m	119.9 kN.m	0.86	18 tonnes
Shear	Support	28.0 kN	82.5 kN.m	43.67 kN	0.53	**7.5 tonne Group 1 FE**

Element: **Cast iron edge girders (Accidental Vehicle Loading)**

Checked for accidental vehicle loading in accordance with Annex D of BD21/01.

Capacity factor = Available live load capacity / assessed live load effects (selected accidental vehicle)

Vehicle gross weight (tonnes)	**Axle weights W (tonnes) and spacings A (m)**								
Full Assessment Live Loading	W1	A1	W2	A2	W3	A3	W4	A4	W5
44[6]	**7.0**	2.8	**11.5**	1.3	**7.5**	7.6	9.0	1.35	9.0
40[5]	5.0	2.8	10.5	1.3	4.5	4.8	10.0	1.8	10.0
26 tonne RC	**7.0**	3.42	**11.5**	1.3	**7.5**				
18 tonne RE	**6.5**	3.0	**11.5**						
7.5 tonne RF	**1.5**	2.0	**6.0**						

Single 11.5 tonne axle is critical load on span; therefore 44, 40, 26 and 18 tonne vehicles have same effect.

Action	Location	Dead load effect	Accidental vehicle loading	Assessed live load resistance	Capacity factor	Live load capacity
Bending 40/44T AVL	Mid-span	129.3 kN.m	67.9 kN.m	84.3 kN.m	1.24	40/44t AVL
Shear 40T AVL	Support	74.8 kN	40.0 kN	348 kN	8.7	40t AVL

Element: **Substructure**

The supports show no signs of structural distress. By qualitative assessment, they appear to be satisfactory for current loading.

1.6 Load Rating

Based on the assessment assumptions, the pre-stressed concrete beams are marginally deficient in bending for 40 tonne loading. With "good" road surface conditions the beams would pass for 40 tonnes, but there are distinct undulations in the road which indicates the capacity should be based on a "poor" rating.

The shear capacity of the bridge presents some problems in the BD21/BD44 assessment. The permissible shear stress in BD44 is considerably lower than that given in CP116; 0.29 N/mm^2 as opposed to 0.413 N/mm^2 (60 lbs/in^2). The formulae in BD44 clause 7.4.2.2 for combined shear capacity between the beams and infill concrete give a lower value in this case than on the beam alone. The shear capacity of the beam alone is also restricted as the web width is only 51mm (2 inches) and single links only 8mm diameter. The shear capacity of the beams corresponds to 7.5 tonnes and Group 1 Fire Engines. Improving the road surface condition would not help the rating in this instance.

There is also residual doubt about the concrete compressive strength of the high alumina cement beams. Extracting cores for testing has never been attempted because the beams are stressed and relatively small. The concrete strength has been based on code requirements for high alumina beams with a conversion decrease related to the degree of conversion found by testing in the in-situ concrete.

The cast iron edge girders take only a small proportion of the load from accidental vehicle loading on the footways and appear to be satisfactory for full loading. Although not specifically assessed, it is expected that the concrete beams under the footway will be deficient for accidental vehicle loading as they are the same as under the carriageway.

Prospects for strengthening a deck of this type are limited. Individual beams would have to be propped along their length as the pre-stressing arrangements may not cope with stress reversals imposed by discrete supports. In-filling would be a more economic solution.

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Appendix A - Form AA

FORM 'AA' (BRIDGES)

GC/TP0356
Appendix: 4
Issue: 1
Revision: B (Nov 2000)

ELR/ Bridge No WHE/17

APPROVAL IN PRINCIPLE FOR ASSESSMENT (BD21)

Senior Civil Engineer's Comments

.....None.....

.....

.....

.....

Proposed Category for Independent Check .....1.....

Superstructure .....1.....

Substructure .....1.....

Name Of Checker Suggested If Cat 2 Or 3 .....

Category 1

The above assessment, with amendments shown, is approved in principle:

Signed [redacted]

Title

Date .....30/3/2000.....

Category 2 and 3

The above assessment, with amendments shown, is approved in principle:

Signed .....

Title .....

Date .....

Signed .....

Title .....

Date .....

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Appendix B - Form BA

FORM 'BA' (BRIDGES)

ELR/ Bridge No WHE/17

CERTIFICATION FOR ASSESSMENT CHECK

Assessment Group: **Jacobs Engineering UK Ltd**

Bridge/Line Name: **B158 Port Hill / Welwyn Garden City to Hertford**

Category of Check: **1**

ELR/ Bridge No: **WHE/17**

We certify that reasonable professional skill and care have been used in the assessment of the above structure with a view to securing that:

(1) It has been assessed in accordance with the Approval in Principle as recorded on Form AA approved on 30 March 2010.

(2) It has been checked for compliance with the following principal British Standards, Codes of Practice, BRB (Residuary) Limited technical notes and Assessment standards:

BD 21/01 - "The Assessment of Highway Bridges and Structures"

BD 44/95 - "The Assessment of Concrete Highway Bridges and Structures"

List any departures from the above and additional methods or criteria adopted, with reference and justification for their acceptance.

None

Category 1

Name	Signature	Date	
[redacted]		31/3/10	Assessor
		31/3/10	Assessment Checker
		16-4-10	Authorised signatory of the firm of Consulting Engineers to whom Assessor/Checker is responsible.

FORM 'BA' (BRIDGES)

GC/TP0356
Appendix: 4
Issue: 1
Revision: A (Dec 2005)

ELR/ Bridge No WHE/17

CERTIFICATION FOR ASSESSMENT CHECK

Category 2 and 3 (Note: Category 1 check must also be signed)

(a) Assessment

Name	Signature	Date	
			Assessor
			Assessment Checker
			Authorised signatory of the firm of Consulting Engineers to whom Assessor/Checker is responsible.

(b) Check

Name	Signature	Date	
			Assessor
			Assessment Checker
			Authorised signatory of the firm of consulting engineers to whom Assessor/Checker is responsible.

This Certificate is accepted by [redacted] (14/5/10)

FORM 'BAA' (BRIDGES)

GC/TP0356
Appendix: 4
Issue: 1
Revision: A (Dec 2005)

ELR/ Bridge No WHE/17

CERTIFICATION FOR ASSESSMENT CHECK

Notification of Assessment Check

Assessment Group	Jacobs Engineering UK Ltd
Bridge Name/Road No.	Port Hill / B158
Line Name	Welwyn Garden City to Hertford
ELR Code/Structure No.	WHE/17

The above bridge has been assessed and checked in accordance with Standards which are listed on the appended Form BA. A summary of the results of the assessment in terms of capacity and restrictions is as follows:-

STATEMENT OF CAPACITY

Carriageway beams	7.5 tonnes Group 1 FE
Cast iron edge girder	40/44 tonne accidental vehicle
Abutments (qualitative assessment)	Satisfactory for current loading

Recommended Loading Restrictions

7.5 tonnes Group 1 FE

Description of Structural Deficiencies and Recommended Strengthening

The high alumina concrete beams are deficient in shear capacity when assessed to BD44. The provisions for shear in BD44 are more onerous than for permissible stress analysis based on CP116, hence the difference in rating between the BD21 and BE4 (BS153 Pt 3A) assessments.

The beam capacity has been based on estimates of concrete strength and degree of conversion (high alumina cement) based on testing on the infill concrete.

The bridge is otherwise in satisfactory condition. The road surface condition at the time of inspection was rated as "poor". Improving the road condition would not enable the shear rating of the beams to reach the next loading level.

Strengthening is likely to be uneconomical. Infilling would be the preferred option.

FORM 'BAA' (BRIDGES)

GC/TP0356
Appendix: 4
Issue: 1
Revision: A (Dec 2005)

ELR/ Bridge No WHE/17

CERTIFICATION FOR ASSESSMENT CHECK

Name	Signature	Date	
[redacted]			Assessor
			Assessment Checker
			Authorised signatory of the firm of Consulting Engineers to whom Assessor/Checker is responsible.

This Certificate is accepted by [redacted] 14/5/10

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Appendix C - Calculations

CALCULATION COVER SHEET

Jacobs
Reading

Project Title:	BRB (Residuary) Ltd - Major Works 2009/2012		Calc. No.: 192.1
Job No: B12360AH			File: R16
Project Manager	[redacted]	Subject:	**WHE/17**
Designer			Port Hill Road Bridge, Hertford
Project Group	31400		BD21 Assessments - Loading

	Total Sheets	Made by	Date	Checked by	Date	Reviewed by	Date		
Original	6	[redacted]	Mar-10	[redacted]	Mar-10				
Rev									
Rev									
Rev									
Rev									
Rev									

Superseded by Calculation No. Date

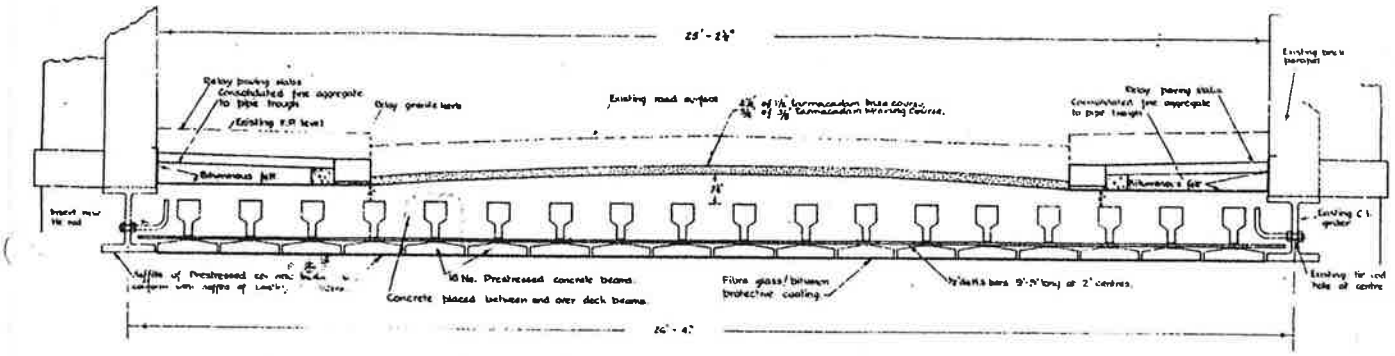
For design criteria, refer to Approval in Principle (Form AA) document

CALCULATION SHEET

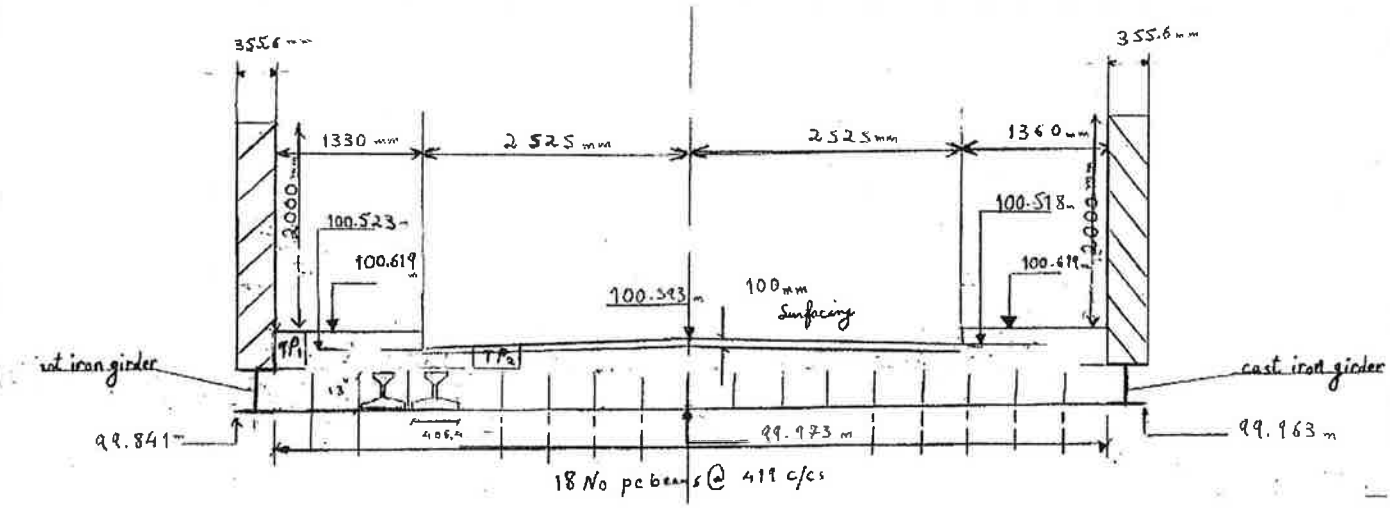
JACOBS

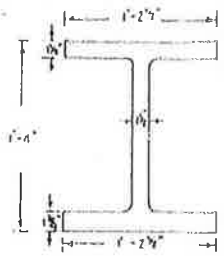
Project Title: BRB(R) Ltd - Major Works Programme 2009-2012			Sheet No: 1
Subject: WHE/17			Calc No: 192.1
Job No: B12360AH			File: R16
Made By: [redacted]	Date: 03/10	Revised By:	Date:
Checked By: [redacted]	Date: 3/10	Checked By:	Date:

BD21 assessment of WHE/17



Site survey – August 2005:



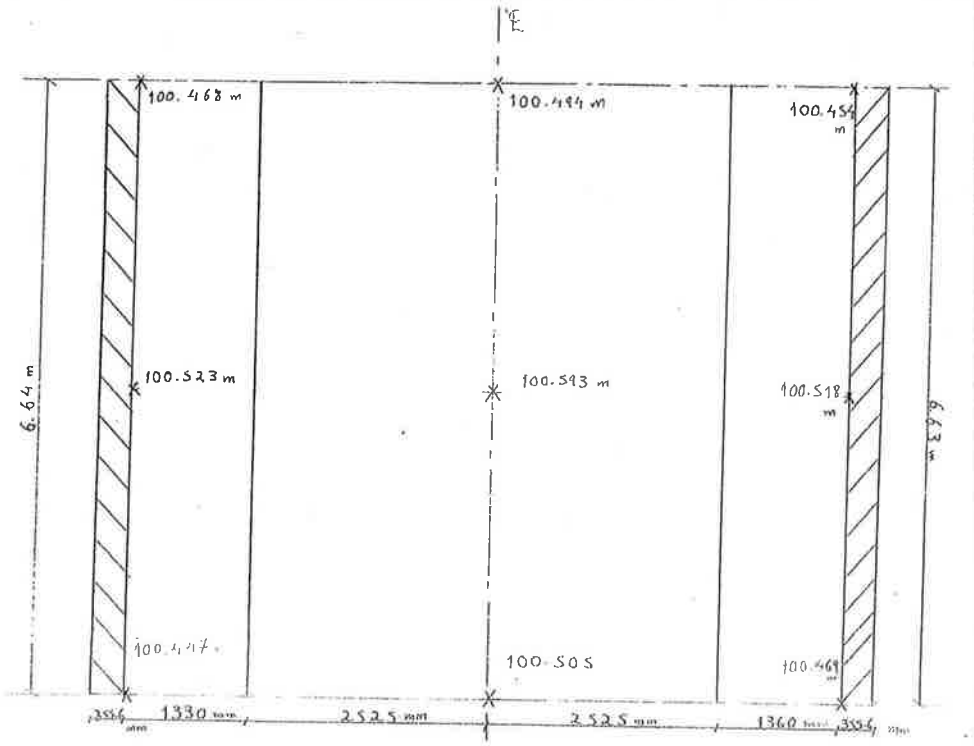


CALCULATION SHEET

JACOBS

Project Title: BRB(R) Ltd - Major Works Programme 2009-2012			Sheet No: 1A
Subject: WHE/17			Calc No: 192.1
Job No: B12360AH			File: R16
Made By: [redacted]	Date: 03/10	Revised By:	Date:
Checked By: [redacted]	Date: 3/10.	Checked By:	Date:

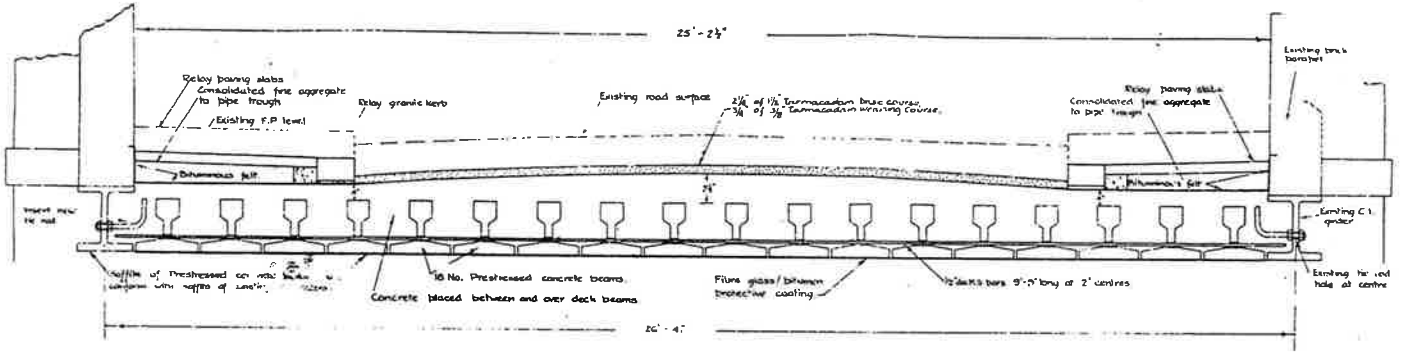
Site survey – August 2005:



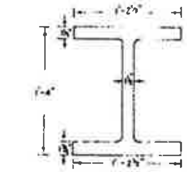
1B

HERTFORDSHIRE COUNTY COUNCIL.
HERTFORD – WADESMILL ROAD B.158.
PORT HILL RAILWAY BRIDGE.

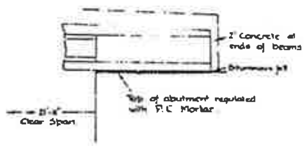
Between Hertingfordbury & Hertford Roads
Port Hill Tic No. 17 at 27m 16c



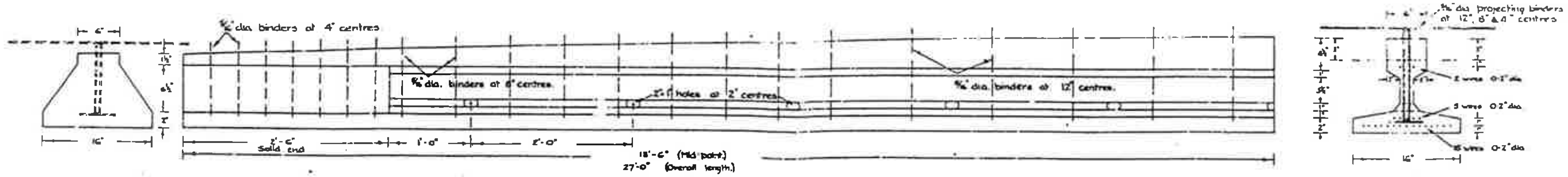
Cross Section at Centre of Bridge.
Scale ~ ¾" to 1'.



Section of existing C.I. girder.
Scale ~ 1½" to 1'.



Detail of beam on abutment.



Solid End Section.

Detail of half beam.
Scale ~ 1½" to 1'.

Mid beam Section.

404054

Notes –

Test Loads for Beams.

(i) 2 No. 1.12 ton point loads at 5'-0" centres at midspan to produce a deflection of 0.403" with at least 90% recovery.

(ii) Load to be applied in increments of ½ ton and deflection measured at both increase and decrease of load.

Prestressed Beams.

High Alumina cement to comply with B.S. 915.
Max. size of aggregate ½".
Proportions and water cement ratio to give 6,600 lbs/sq.in. at 24 hrs. and 7,500 lbs/sq.in. at 72 hrs. — see specification for details of cube and load tests.
Wire — 105 tons/sq.in. ultimate stress with 0.1% proof stress 80 tons/sq.in.
Initial stress 140,000 lbs/sq.in. for 3 minutes released to 135,000 lbs/sq.in.

In-situ Concrete.

High Alumina cement to comply with B.S. 915.
Max. size of aggregate 1½".
Mix
Test cubes to give 5000 lbs./sq.in. at 48 hrs.

COUNTY REF. B.1335
RECD. WITH LETTER FROM Hertford Eng. C.E.
d. 31/8/54 ref. T/S/CW 30721

404054

C.H. ffolliott, B.A., M.Inst.C.E.,
Chartered Civil Engineer.
County Surveyor,
County Hall,
Hertford.
Drg. No. A6377. Date. H.G. 29.vi.53.

5A/29/17/1

RAILTRACK
UNSUITABLE FOR MICROFILMING

CALCULATION SHEET

JACOBS

Project Title: BRB(R) Ltd - Major Works Programme 2009-2012			Sheet No: 2
Subject: WHE/17			Calc No: 192.1
Job No: B12360AH			File:
Made By: [redacted]	Date: 03-10	Revised By:	Date:
Checked By: [redacted]	Date: 3/10	Checked By:	Date:

Edge girder properties:

Element	Dimension b(cm)	Dimension d(cm)	Area	y from top	Ay	A(y-y1)^2	I=bd^3/12
Top flange	**36.8**	**3.8**	139.8	**1.900**	265.70	51622.78	168.27
Web	**3.8**	**32.35**	122.9	**19.975**	2455.53	159.32	10720.75
Bottom flange	**36.8**	**4.45**	163.8	**38.375**	6284.29	48794.20	270.24
NET AREA			426.5		9005.51		
GROSS AREA			426.5				
Depth to Neutral Axis y1		21.11					
					Sum	100576.30	11159.26

Ixx= 111735.57
Ztop= 5292.16
Zbot= 5733.98

CALCULATION SHEET

JACOBS

Project Title: BRB(R) Ltd - Major Works Programme 2009-2012			Sheet No: 3
Subject: WHE/17			Calc No: 192.1
Job No: B12360AH			File: R16
Made By: [redacted]	Date: 03/10	Revised By:	Date:
Checked By: [redacted]	Date: 3/10	Checked By:	Date:

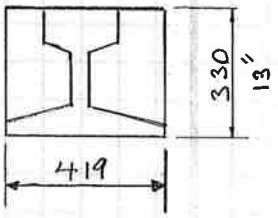
Dead load (Precast centre beam)

Beam + surrounding concrete:

BD 21/01 Table 4.1

Take concrete density = 2400 kg/m³

wt. = 2400 x 0.33 x 0.419 = 331.8 kg/m



Road level at Road centre line (centre beam) = 100.593

∴ concrete overlay depth = (100.593 − 99.973) − 0.33 − 0.1

= 0.19 m

wt. = 2400 x 0.19 x 0.419 = 191.1 kg/m

surfacing density = 2300 kg/m³

wt. = 2300 x 0.1 x 0.419 = 96.4 kg/m

Table 3.1 Total factored dead load = 331.8 x 1.15 x 1.1
+ 191.1 x 1.15 x 1.1
+ 96.4 x 1.75 x 1.1

= 847.03 kg/m = 8.31 kN/m ✓

CALCULATION SHEET

JACOBS

Project Title: BRB(R) Ltd - Major Works Programme 2009-2012			Sheet No: 4
Subject: WHE/17			Calc No: 192.1
Job No: B12360AH			File: R16
Made By: [redacted]	Date: 03/10	Revised By:	Date:
Checked By: [redacted]	Date: 3/10	Checked By:	Date:

Dead load (cast Iron edge girders):

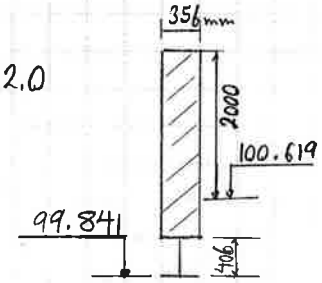
BD21/01 Table 4.1

cast iron area = 426.5 cm^2

cast iron density = 7200 kg/m

wt. = $7200 \times 426.5 \times 10^{-4}$ = 307.1 kg/m

The edge girders carry only the parapet dead load.



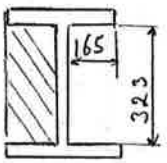
Parapet height = (100.619 - 99.841 - 0.406) + 2.0

= 2.372 m

Table 4.1 Parapet density = 2100 kg/m^3

Wt. = 2100 x 2.372 x 0.356 = 1773.3 kg/m

concrete fill:



wt. = 2400 x (165 x 323) x 10^{-6} = 127.9 kg/m

Table 3.1 Total factored dead load = 307.1 x 1.0

+ 1773.3 x 1.0

+ 127.9 x 1.0

2208.3 kg/m = 21.66 kN/m

CALCULATION SHEET

JACOBS

Project Title: BRB(R) Ltd - Major Works Programme 2009-2012			Sheet No: 5
Subject: WHE/17			Calc No: 192.1
Job No: B12360AH			File: R16
Made By [redacted]	Date: 03/10	Revised By:	Date:
Checked By: [redacted]	Date: 3/10	Checked By:	Date:

Effective span:

P. 1A — clear span = 6.64 m

BD 44/95 cl. 5.3.1.1 — Beams are supported on concrete slabs; except edge beams that are supported on the soft bricks.

Effective span = $6.64\text{m} + 2 \times (0.5 \times 0.330)/3 = 6.75\text{m}$ (Precast beams)

Effective span = $6.64\text{m} + 2 \times (1.0 \times 0.406)/3 = 6.91\text{m}$ (Cast iron edge girders)

Dead load effects (centre beam):

P. 3 — Max. Moment = $8.31\ \text{kN/m} \times 6.75^2/8 = 47.33\ \text{kN.m}$

Max. shear = $8.31\ \text{kN/m} \times 6.75/2 = 28.05\ \text{kN}$

Dead load effects (cast iron edge girders):

P. 4 — Max. Moment = $21.66\ \text{kN/m} \times 6.91^2/8 = 129.3\ \text{kN.m}$

Max. shear = $21.66\ \text{kN/m} \times 6.91/2 = 74.8\ \text{kN}$

CALCULATION SHEET

JACOBS

Project Title: BRB(R) Ltd - Major Works Programme 2009-2012			Sheet No: 6
Subject: WHE/17			Calc No: 192.1
Job No: B12360AH			File: R16
Made By: [redacted]	Date: 03/10	Revised By:	Date:
Checked By: [redacted]	Date: 3/10	Checked By:	Date:

Live load (centre beam):

Raad width = 2 x 2.525m = 5.05 m > 5.0m

BD 21/01 Table 5.1 — No. of national lane = 2

Effective span = 6.75m

5.18 — $HA = 336 \times (\frac{1}{L})^{0.67} = 93.48$ kN/m/lane

5.23 — AF = 3.65/2.5 = 1.46 — $\gamma_m = 1.5$

5.18 — KEL = 120 kN/Lane — $\gamma_{f_3} = 1.1$

Beam width = 0.419m

lane width = 2.5m

∴ Max moment at mid span (live load)

$= \left(93.48 \times 6.75^2/8 + 120 \times 6.75/4 \right) \times \frac{1}{1.46} \times \frac{0.419}{2.5} = 84.36$

BD21/01 Table 3.1 — ∴ Max factored live load moment = 84.36 x 1.5 x 1.1 = 139.2kN.m

Max shear at supports (live load)

$= (93.48 \times 6.75/2 + 120) \times \frac{1}{1.46} \times \frac{0.419}{2.5} = 50$ kN

∴ Max factored live load shear = 50 x 1.5 x 1.1 = 82.5 kN.m

P.5 — ∴ Total Moment (DL+LL) = 47.33 + 139.2 = 186.53 kN.m

P.5 — Total shear (DL+LL) = 28.05 + 82.5 = 110.55 kN

CALCULATION COVER SHEET

Jacobs
Reading

Project Title:	BRB (Residuary) Ltd - Major Works 2009/2012	Calc. No.:	192.2
Job No: B12360AH		File:	R16
Project Manager	[redacted]	Subject:	**WHE/17**
Designer			Port Hill Road Bridge, Hertford
Project Group	31400		BD21 Assessments - Section Capacity

	Total Sheets	Made by	Date	Checked by	Date	Reviewed by	Date		
Original	8	[redacted]	Mar-10	[redacted]	Mar-10				
Rev									
Rev									
Rev									
Rev									
Rev									

Superseded by Calculation No. Date

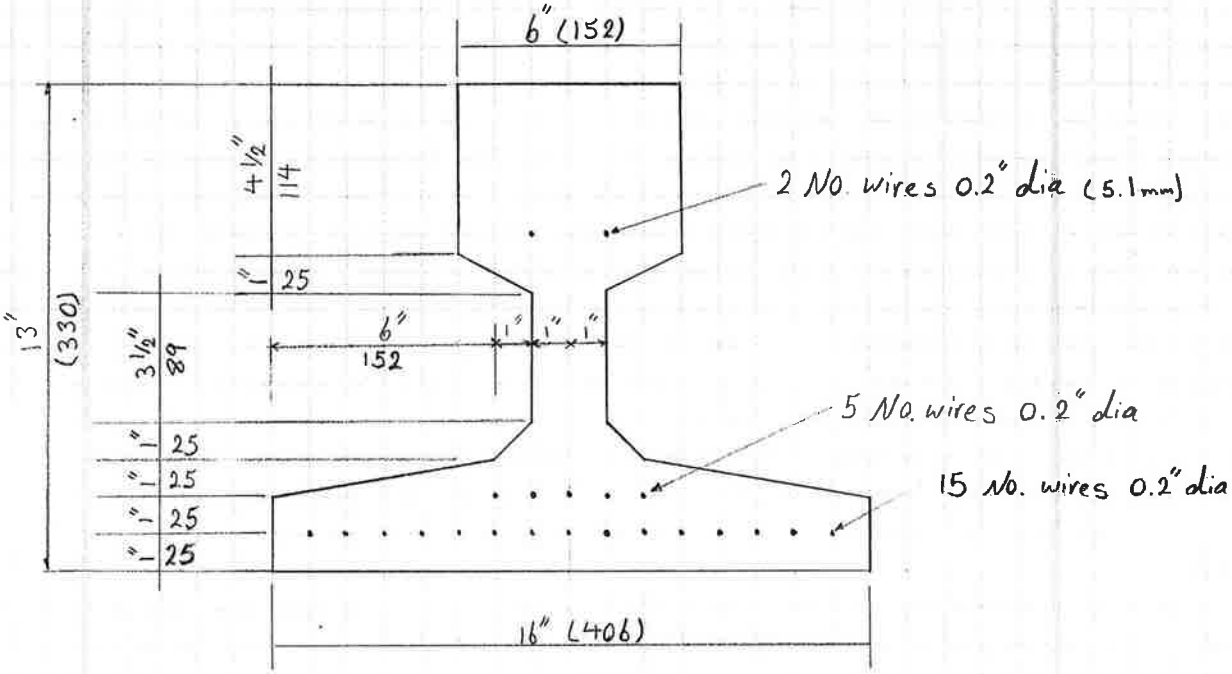
For design criteria, refer to Approval in Principle (Form AA) document

CALCULATION SHEET

JACOBS

Project Title: BRB(R) Ltd - Major Works Programme 2009-2012			Sheet No: 1
Subject: WHE/17			Calc No: 192.2
Job No: B12360AH			File: R16
Made By: [redacted]	Date: 03/10	Revised By:	Date:
Checked By: [redacted]	Date: 3/10	Checked By:	Date:

Precast beams capacity:



X-sec area of beam:

$(6 \times 4\frac{1}{2}) + (2 \times 1) + (2 \times \frac{1}{2} \times 2 \times 1) + (3\frac{1}{2} \times 2) + (2 \times \frac{1}{2} \times 1 \times 1) + (2 \times 1) + (2 \times \frac{1}{2} \times 1 \times 6) + (16 \times 2)$

$= 79\ in^2\ (50967.6\ mm^2)$

Centroid of pre-stressing force (from top)

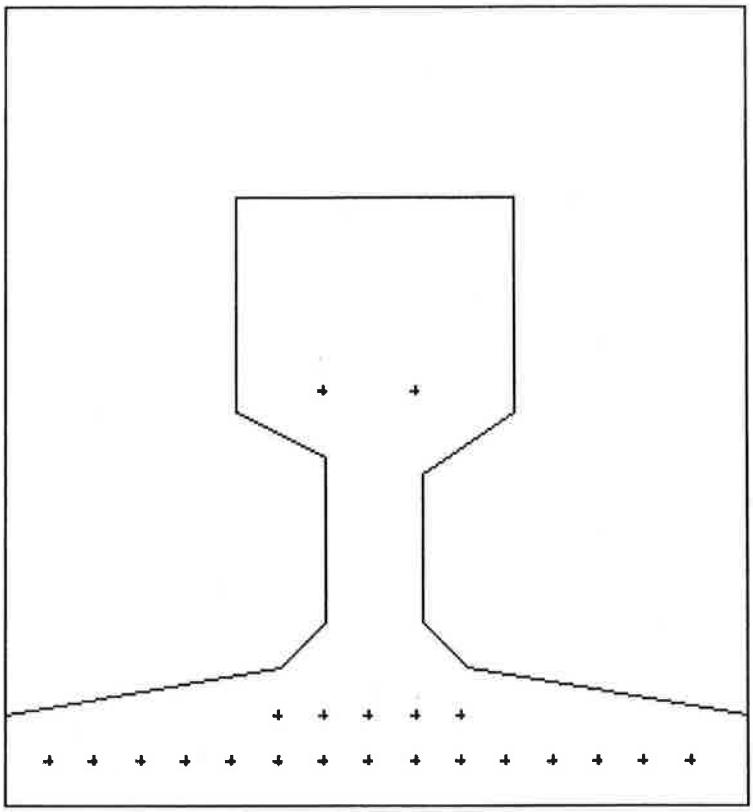
$\frac{(15 \times 12) + (5 \times 11) + (2 \times 4)}{22} = 11.04"$

Centroid of area = Approx: $9\frac{3}{4}"$ from top.

Job: WHE/17 Clac No: 192.2
Section: Inverted T-beams and concrete infill

Job No.: B12360AH
Calc. By:
Checked:

Data File: P:\B1236000 BRB(Residuary) 2009-12\2010 Assessments\WHE-17\SAM\Combined section.sam 22/03/2010 16:54:26



ANALYSIS TYPE: BS 5400 Ultimate Limit State

SECTION DETAILS

Number of elements: 2
Number of reinforcing bars: 0
Number of tendons: 22

Elements

Ref	Library	Section	Property: name	ref
1	Define shape	inverted T-beam	C25 Es 26.0 fcc 0.5	1
2	Define shape	infill concret	C17 Es 25.0 fcc 0.5	2

Element coordinates for element 1

Node	X-Y coords mm		Node	X-Y coords mm		Node	X-Y coords mm	
1	0.0	0.0	6	229.0	180.0	11	177.0	189.0
2	406.0	0.0	7	280.0	214.0	12	177.0	100.0
3	406.0	50.0	8	280.0	330.0	13	152.0	75.0
4	254.0	75.0	9	127.0	330.0	14	0.0	50.0
5	229.0	100.0	10	127.0	214.0			

Element coordinates for element 2

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Node	X-Y coords mm		Node	X-Y coords mm		Node	X-Y coords mm	
1	406.0	432.0	6	177.0	189.0	11	229.0	180.0
2	0.0	432.0	7	127.0	214.0	12	229.0	100.0
3	0.0	50.0	8	127.0	330.0	13	254.0	75.0
4	152.0	75.0	9	280.0	330.0	14	406.0	50.0
5	177.0	100.0	10	280.0	214.0			

$432 = 17'' = 13''(\text{Beam}) + 4''(\text{cover})$

No Reinforcing bars

Tendons

Ref	X-Y coords mm		area mm²	initial force kN	Property: name	ref
1	25.0	25.0	20.3	25.8622	Grade 1470 E 200.0	3
2	50.0	25.0	20.3	25.8622	Grade 1470 E 200.0	3
3	75.0	25.0	20.3	25.8622	Grade 1470 E 200.0	3
4	100.0	25.0	20.3	25.8622	Grade 1470 E 200.0	3
5	125.0	25.0	20.3	25.8622	Grade 1470 E 200.0	3
6	150.0	25.0	20.3	25.8622	Grade 1470 E 200.0	3
7	175.0	25.0	20.3	25.8622	Grade 1470 E 200.0	3
8	200.0	25.0	20.3	25.8622	Grade 1470 E 200.0	3
9	225.0	25.0	20.3	25.8622	Grade 1470 E 200.0	3
10	250.0	25.0	20.3	25.8622	Grade 1470 E 200.0	3
11	275.0	25.0	20.3	25.8622	Grade 1470 E 200.0	3
12	300.0	25.0	20.3	25.8622	Grade 1470 E 200.0	3
13	325.0	25.0	20.3	25.8622	Grade 1470 E 200.0	3
14	350.0	25.0	20.3	25.8622	Grade 1470 E 200.0	3
15	375.0	25.0	20.3	25.8622	Grade 1470 E 200.0	3
16	150.0	50.0	20.3	25.8622	Grade 1470 E 200.0	3
17	175.0	50.0	20.3	25.8622	Grade 1470 E 200.0	3
18	200.0	50.0	20.3	25.8622	Grade 1470 E 200.0	3
19	225.0	50.0	20.3	25.8622	Grade 1470 E 200.0	3
20	250.0	50.0	20.3	25.8622	Grade 1470 E 200.0	3
21	175.0	225.0	20.3	25.8622	Grade 1470 E 200.0	3
22	225.0	225.0	20.3	25.8622	Grade 1470 E 200.0	3

PROPERTIES DETAILS

ref: 1 Type: Concrete - BS 5400
Name: C25 Es 26.0 fcc 0.5

Characteristic strength fcu:	25.0 N/mm²
Material partial factor γ_m :	1.5
Elastic modulus - short term:	26.0 kN/mm²
Elastic modulus - long term:	13.0 kN/mm²
Compressive Stress limit factor:	0.5 x f_{cu}
Limiting minimum stress:	0.0 N/mm²
Coefficient of thermal expansion:	0.000012 /°C
Density:	23.6 kN/m³

ref: 2 Type: Concrete - BS 5400
Name: C17 Es 25.0 fcc 0.5

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Characteristic strength fcu:	17.0 N/mm²
Material partial factor γ_m :	1.5
Elastic modulus - short term:	25.0 kN/mm²
Elastic modulus - long term:	12.5 kN/mm²
Compressive Stress limit factor:	0.5 x f_{cu}
Limiting minimum stress:	0.0 N/mm²
Coefficient of thermal expansion:	0.000012 /°C
Density:	23.6 kN/m³

ref: 3 Type: Prestress Strand BD 44/95 Figure 4
Name: Grade 1470 E 200.0

Characteristic strength f_{pu} :	1470.0 N/mm²
Material partial factor γ_m :	1.15
Elastic modulus:	200.0 kN/mm²
Initial Prestress force:	60.0 % of f_{pu}
Max. relaxation after 1000 hours:	5.0 %
Relaxation at transfer:	50.0 % of total

ANALYSIS TO BS 5400 ULTIMATE LIMIT STATE

Neutral axis free to rotate
Neutral axis angle (applied loads) = 0.0° (clockwise from xx)

depth in compression = 0.1888018 m
Strain at centroid of outer 25% of tendons = -0.004045
(excludes initial strains)
-0.005 - fpu/Es*gamma_m) - clause 6.3.3.1 = -0.011391
(includes initial strains)

MAXIMUM Strains:

Material Property	Strain	Stress N/mm²	location x	y
C25 Es 26.0 fcc 0.5	0.0016091	11.166667	280.0	330.0
C17 Es 25.0 fcc 0.5	0.0035	7.5933333	406.0	432.0
Grade 1470 E 200.0	-0.011666	-1278.261	175.0	225.0

MINIMUM Strains:

Material Property	Strain	Stress N/mm²	location x	y
C25 Es 26.0 fcc 0.5	-0.004508	0.0	0.0	0.0
C17 Es 25.0 fcc 0.5	-0.003581	0.0	406.0	50.0
Grade 1470 E 200.0	-0.015373	-1278.261	25.0	25.0

LOADING relative to centroidal axes:

Applied Loads	Applied Strains	Tendon Forces	Spare Resistance	(Internal Forces)

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Mx kN.m	0.0	none	94.5195	167.219	167.219
My kN.m	0.0	none	1.7094	n/a	1.72955
Ax kN	0.0	none	-568.968	n/a	0.136749

Spare resistance for X Moment - Positive = 167.21901 kN.m

Summary of Internal Forces

	Force kN	Acting Height mm
compression force, F_{cd}		
- concrete	571.00805	341.752
- reinforcement	(no compression reinforcement)	
- combined	571.00805	341.752
tension force, F_{td}		
- reinforcement	-570.8713	48.8636

inner lever arm, z = 341.752 - 48.8636 = 292.88856 mm

Note: Moments arising from eccentricity of axial loads are relative to the centroidal axis of the section.
The transformed section centroid is used.

No initial strains defined.

End

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CALCULATION SHEET

JACOBS

Project Title: BRB(R) Ltd - Major Works Programme 2009-2012			Sheet No: 6
Subject: WHE/17			Calc No: 192.2
Job No: B12360AH			File: R16
Made By: [redacted]	Date: 03/10	Revised By:	Date:
Checked [redacted]	Date: 3/10	Checked By:	Date:

P. 5 Precast beam bending capacity (live load) = 167.2 − 47.33 = 119.87 kN.m

calc 192.1 P. 6 Max applied moment = 139.2 kN.m

$\therefore C = 119.87 / 139.2 = 0.861$

BD21/01 Fig 5.3 K (Medium traffic, Poor road condition) $\begin{cases} 26^t = 0.87 \\ 18^t = 0.68 \end{cases}$

∴ Centre precast beam is adequate for 18^t loading in bending.

Shear capacity:

BD 44/95 6.3.4.2 $V_{co} = 0.67\ b\ h\ \sqrt{(f_t^2 + f_{cp} f_t)}$ (Pre-cast units acting alone)

calc 192.2 P. 1 $b = 2'' = 50.1$ mm (The effect of concrete fill ignored)

$h = 330$

$A_{tendons} = 20.3\ mm^2$

$f_t = 0.32 \sqrt{\frac{f_{cu}}{\gamma_{mc}}} = 0.32 \sqrt{\frac{25}{1.5}} = 1.31\ N/mm^2$

calc 192.1 P. 5 clear span = 6.64 m

Beam length = 27'-0" = 8.230 m

BD 44/95 CL. 6.7.4 Transmission length:

$l_t = k_t \phi / \sqrt{f_{ci}}$

$k_t = 600$

$\phi = 5$ mm

$f_{ci} = 0.75 f_{cu} = 0.75 \times 25 = 18.75\ N/mm^2$

$l_t = 600 \times 5 / \sqrt{18.75} = 693$ mm

CALCULATION SHEET

JACOBS

Project Title: BRB(R) Ltd - Major Works Programme 2009-2012			Sheet No: 7
Subject: WHE/17			Calc No: 192.2
Job No: B12360AH			File: R16
Made By: [redacted]	Date: 03/10	Revised By:	Date:
Checked By:	Date:	Checked By:	Date:

Supported length of beam = $(8.230 - 6.64)/2$

$= 0.795\text{m} > 0.693$ (transmission length)

∴ Capacity can be based on full tendom stress.

Prestressing force will be 70% of ultimate tensile stress, less losses:

Take tendons stress = $1470 \times 50\% = 735\ N/mm^2$

No of tendons = $15+5+2 = 22$

$f_{cp} = (735 \times 22 \times 20.3)/(50967.6) = 6.44\ N/mm^2$

$V_{Co} = 0.67 \times 50.1 \times 330 \times \sqrt{(1.31^2 + 6.44 \times 1.31)} \times 10^{-3}$

$= 35.3\ kN$

Capacity of links:

BS 8110 cl. 6.3.4.4 $V_s = A_{sv}(f_{yv}/\gamma_{ms})\frac{d_t}{s_v}$

$A_{sv} = 2 \times \left(\pi \times (5/16)^2/4\right) \times 25.4^2 = 98.97\ mm^2$

Table 4A $\gamma_m = 1.15$ $s_v = 6''$

P. 1B $d_t = (12'' \times 15 + 11'' \times 5 + 4'' \times 2)/22 = 11.04''$

$V_s = 98.97\ (230/1.15)\ 11.04''/6 \times 10^{-3} = 36.42\ kN$

∴ Total shear capacity = $35.3 + 36.42 = 71.72\ kN$

calc 1921 P.5 live load shear capacity = $71.72 - 28.05 = 43.67\ kN$

Applied live load shear = $82.5\ kN$

∴ $C = 43.67/82.5 = 0.53$

CALCULATION SHEET

JACOBS

Project Title: BRB(R) Ltd - Major Works Programme 2009-2012			Sheet No: 8
Subject: WHE/17			Calc No: 192.2
Job No: B12360AH			File: R16
Made By: [redacted]	Date: 03/10	Revised By:	Date:
Checked By:	Date:	Checked By:	Date:

BD 21/01
Fig. 5.3

Medium traffic, poor road condition:

18^t loading : $K = 0.68$

Group 1 FE : $k = 0.49$

$C = 0.53$

∴ Centre precast beam is adequate for 7.5^t and Group 1 FE in shear

CALCULATION COVER SHEET

Jacobs
Reading

Project Title:	BRB (Residuary) Ltd - Major Works 2009/2012	Calc. No.:	192.3
Job No:	B12360AH	File:	R16
Project Manager	[redacted]	Subject:	**WHE/17**
Designer	[redacted]		Port Hill Road Bridge, Hertford
Project Group	31400		BD21 Assessments - Edge Girder

	Total Sheets	Made by	Date	Checked by	Date	Reviewed by	Date		
Original	9	[redacted]	Mar-10	[redacted]	Mar-10				
Rev									
Rev									
Rev									
Rev									
Rev									

Superseded by Calculation No. Date

For design criteria, refer to Approval in Principle (Form AA) document

CALCULATION SHEET

JACOBS

Project Title: BRB(R) Ltd - Major Works Programme 2009-2012			Sheet No: 1
Subject: WHE/17			Calc No: 192.3
Job No: B12360AH			File: R16
Made By: [redacted]	Date: 03/10	Revised By:	Date:
Checked [redacted]	Date: 3/10	Checked By:	Date:

Edge girder :

P.2 $Z_{top} = 5292.16\ cm^3$

$Z_{bat} = 5733.98\ cm^3$

Dead laad stress (bending):

Calc. 192.1 P. 5 $\sigma_t = \frac{M}{Z_{bat}} = \frac{129.3 \times 10^6}{5733.98 \times 10^3} = 22.55$ (tensile)

$\sigma_c = \frac{M}{Z_{top}} = \frac{129.3 \times 10^6}{5292.16 \times 10^3} = 24.43$ (compression)

Dead load stress (shear):

calc 192.1 P1. P.5 Web area at supports = $1\frac{1}{2}" \times 16" \approx 25.4^2 = 15483\ mm^2$

$\sigma = \frac{74.8 \times 10^3}{15483} = 4.83\ N/mm^2$

Dead load effect:

BD 21/81 cl. 4.10 ∴ Total tensile bending stress = $22.55 < 46\ N/mm^2$ ∴ OK

Total compressive " " = $24.43 < 154\ N/mm^2$ OK

Total shear stress = $4.83 < 46\ N/mm^2$ ∴ OK

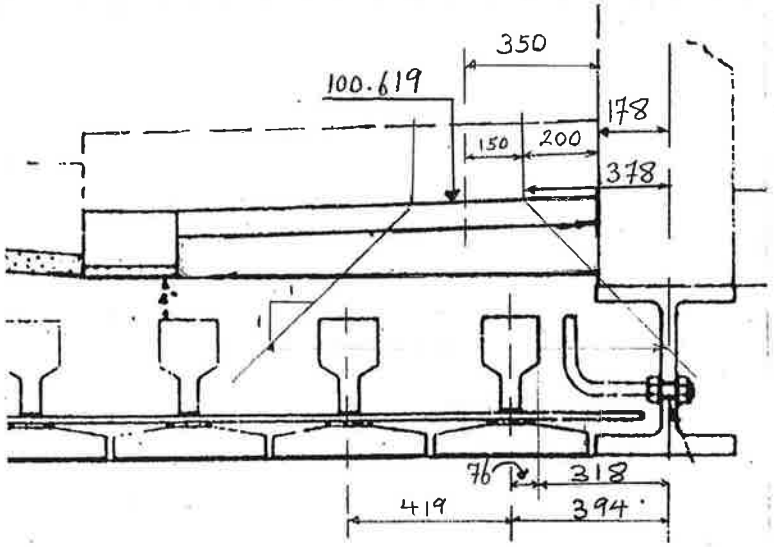
∴ Edge girders are adequate for dead load.

CALCULATION SHEET

JACOBS

Project Title: BRB(R) Ltd - Major Works Programme 2009-2012			Sheet No: 2
Subject: WHE/17			Calc No: 192.3
Job No: B12360AH			File: R16
Made By: [redacted]	Date: 03/10	Revised By:	Date:
Checked [redacted]	Date: 3/10	Checked By:	Date:

Accidental Vehicles loads (Edge girder):



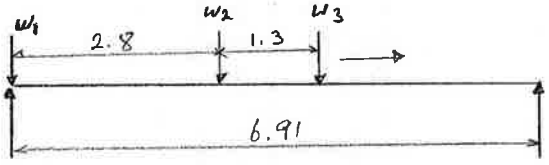
Effective span = 6.91m

Dispersal length = 2 x 378 + 300 = 1056mm

Proportion factor for edge beam = $(318/1056)/2 = 0.15$

Most critical AVL; 448 VGW (Max bending and shear load effect):

Table D1:
448 VGW.



$w_1 = 7.0^t \times 0.15 \times 9.81 = 10.3\ kN$

$w_2 = 11.5^t \times 0.15 \times 9.81 \times 1.8 = 30.5\ kN$ (impact)

$w_3 = 7.5^t \times 0.15 \times 9.81 = 11.1\ kN$

STRAP

STRUCTURAL ANALYSIS PROGRAMS

GTS CADBUILD LIMITED
Woodbrook House
30 Bridge Street
Loughborough LE11 1NH
Tel:(0)1509 260559
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Jacobs UK Limited
Jacobs House, 427 London Road
Reading RG6 1BL

Edge Girder AVL
Edge Beam AVL
Prepared by: ME

Date: 24/03/10

NODAL COORDINATE TABLE (units - meter)

NODE	X1	X2	X3
1	0.000	0.000	0.000
2	6.910	0.000	0.000

NODAL RESTRAINED DOF TABLE

NODE	X1	X2	X3	X4	X5	X6
1	1	1	1	0	0	0
2	0	1	1	0	0	0

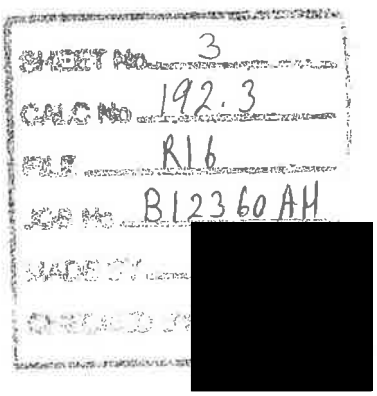
MATERIAL TABLE (units - kN meter)

NO.	Name	Modulus of Elasticity	Poisson ratio	Density	Thermal coefficient	Shear modulus
1	STEE	0.2100E+09	0.300	0.7850E+02	0.00001000	0.8077E+08

SECTION PROPERTY TABLE (units - cm.)

PROPERTY NO. 1

A=0.4265E+03 I2=0.1117E+06 I3=0.1000E+05 J=0.0000E+00 SF2=0.850
Material = 1 - STEE SF3=0.850



Edge Girder AVL
Edge Beam AVL
Prepared by: [redacted]

Page: 0
Date: 24/03/10

Load no. 1: 44 tonnes VGW (units - kN meter)
/ GLOBAL LOADS / GLOBAL LOADS / GLOBAL LOADS POINT FX2 -11.1 COOR 0. 0. BEAMS POINT FX2 -30.5 COOR -1.3 0. BEAMS
POINT FX2 -10.3 COOR -4.1 0. BEAMS / END
F O R C E S U M M A T I O N FX1=0. FX2=-11.1 FX3=0.

Load no. 2: 44 tonnes VGW #2 (units - kN meter)
* MOVE DX1 0.1 / GLOBAL LOADS / GLOBAL LOADS / GLOBAL LOADS POINT FX2 -11.1 COOR 0.1 0. BEAMS
POINT FX2 -30.5 COOR -1.2 0. BEAMS POINT FX2 -10.3 COOR -4. 0. BEAMS / END
F O R C E S U M M A T I O N FX1=0. FX2=-11.1 FX3=0.

SHEET NO. 4
CALC NO
FILE
JOB NO
MADE BY [redacted]
CHKD

Edge Girder AVL

Load 1: 44 tonnes VGW

X2
X1

SCALE = 1:77	UNITS: kN m	DATE:24/03/10

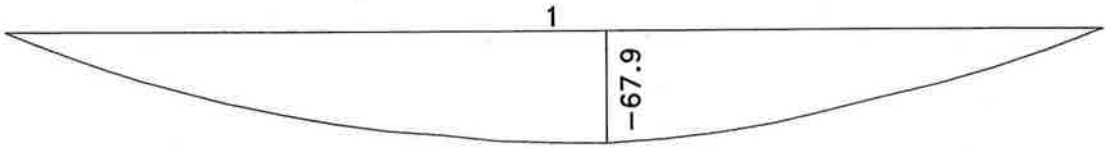
SHEET NO. 5
CALC NO
REV
JOB NO
MADE BY
CHECKED

Edge Girder AVL

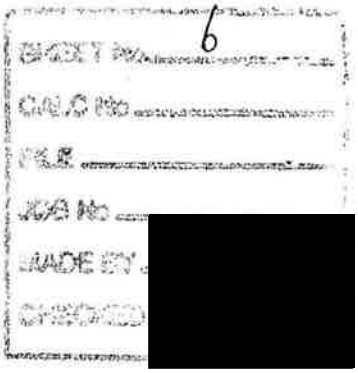
Edge beam Accidental Vehicle Loading

X2
X1

SCALE = 1:47	UNITS: kN*m	DATE:24/03/10



M3 MOMENT LOADS ENVELOPE

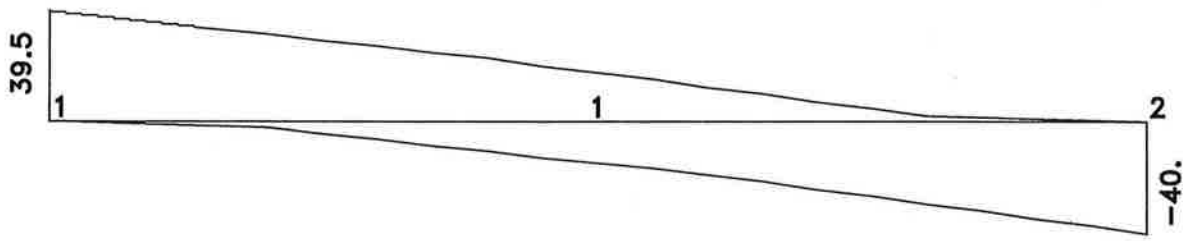


Edge Girder AVL

Edge beam Accidental Vehicle Loading

X2
X1

SCALE = 1:47	UNITS: kN	DATE:24/03/10



V2 SHEAR **LOADS ENVELOPE**

SHEET NO. 7
CALC NO
FILE
JOB NO
MADE BY [redacted]
CHECKED

CALCULATION SHEET

JACOBS

Project Title: BRB(R) Ltd - Major Works Programme 2009-2012			Sheet No: 8
Subject: WHE/17			Calc No: 192.3
Job No: B12360AH			File: R16
Made By: [redacted]	Date: 03/10	Revised By:	Date:
Checked [redacted]	Date: 3/10	Checked By:	Date:

P.6 Max bending moment = 67.9 kN.m (live load)

P.7 Max live load shear = 40.0 kN

BD 21/01 cl. 4.10

Permissible live load tensile stress:

$f_L = 24.6 - 0.44 f_d = 24.6 - 0.44 \times 22.55 = 14.7 \ N/mm^2$

Assessed live load resistance (tensile)

$= 14.7 \times 5733.98 \times 10^{-3} = 84.3 \ kN.m$

Applied live load moment = 67.9 < 84.3 kN.m

∴ Edge girder is adequate for Accidental Vehicle Loading in tensile bending

Permissible live load stress (compression)

P.1

$f_L = -43.9 + 0.79 f_d = -43.9 + 0.79 \times (-24.43) = -63.2 \ N/mm^2$

$f_L = -81.3 + 3.15 f_d = -81.3 + 3.15 \times (-24.43) = -158.2 \ N/mm^2$

$f_L + f_d < 154$

$\therefore f_L = 154 - 24.43 = 129.6 \ N/mm^2$

∴ Assessed lived load resistance (compression)

$= 129.6 \times 5292.16 \times 10^{-3} = 685.9 \ kN.m > 67.9 \ kN.m$

Edge girders are adequate for Accidental Vehicle loading in comp. bending

CALCULATION SHEET

JACOBS

Project Title: BRB(R) Ltd - Major Works Programme 2009-2012			Sheet No: 9
Subject: WHE/17			Calc No: 192.3
Job No: B12360AH			File: R16
Made By: [redacted]	Date: 03/10	Revised By:	Date:
Checked [redacted]	Date: 3/10	Checked By:	Date:

Permissible live load shear stress:

$q_L = 24.6 - 0.44\, q_d = 24.6 - 0.44 \times 4.83 = 22.5\ N/mm^2$

Assessed live load shear $= 22.5 \times 15483 \times 10^{-3} = 348\ kN$

HA adjusted live load stress $= 40.0\ kN < 348$

Edge girder are adequate for Accidental Vehicle Loading in shear