RICHARDS

MOOREHEAD & LAING LTD

TAWD VALLEY NORTHERN

Main beams, Cross beams & Sway bracing Design

for

WEST LANCASHIRE BOROUGH COUNCIL

February 2019

3110/11

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QUALITY ASSURANCE PROCEDURES: QP4, QP7.3Doc6

Prepared by:	Gordon Roe	Date:	22/02/2019
Checked by:	Robert Jones	Date:	22/02/2019
Approved by:	David Richards	Date:	25/02/2019

ISSUE RECORD

Rev:	Date:	Description	Prepared by:	Checked by:
01	25/02/19	Issued to client	G.Roe	R.Jones

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Registered in England No. 1848683 VAT Reg. No. 401 4243 13

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INTRODUCTION

This report is supplementary to the previously submitted analysis and recommendations given in Richards Moorehead and Laing's (RML) report issued 18th February 2019.

In that report, recommendations were made concerning the parapets and deck, together with an investigation into the performance of the main beams of all five bridges.

The investigation concluded that the main beams were overstressed and had no cross beams to aid their stability. In addition, there was an absence of any cross bracing to resist lateral forces.

This report addresses these shortcomings and gives recommendations and construction details of the remedial works necessary to render all five footbridges serviceable in terms of the works required to install cross beams and bracing. It also gives further advice on the main beams.

Summary of existing conditions

All bridges have a similar span of approximately 10 metres. They consist of two main beams constructed from steel channels and have a timber deck 70mm thick attached directly to the top flange of the main beams. The deck provides some lateral stability to the main beams. The exception is bridge number 5 in which the deck is not attached directly to the beams due to the presence of a timber sole plate. This results in this bridge suffering from excessive sway under lateral load which is quite striking to experience.

There is no cross bracing beneath any of the bridges and a complete absence of sway bracing as the photographs below indicate.

	
No cross beams or bracing	Bridge number 5 showing timber sole plate over main beams

CROSS BEAMS AND SWAY BRACING DESIGN

The cross bracing and sway bracing proposals have been calculated and designed and these are suitable for all five bridges.

The main beams have been examined on site and found to be in a reasonable structural condition. Some minor rusting is evident, but no deep flaking or laminations of the steel flanges has been observed. The minor rusting observed will not interfere or affect the structural integrity of the main beams.

In addition, the performance of the main beams has been investigated by calculation.

All the calculations relating to all these items are given in Appendix A at the rear of this report.

The drawing (numbered 3110/002) which summarises these designs is given in Appendix B

The main elements of the designs are summarised as follows:

Cross Bracing

This consists of five cross beams, each 203 x 102 steel joists in section. They are to be positioned at 2.1 metre centres along the length of the bridge.

At the end of each cross beam a 10mm thick steel plate is welded which takes 4 number 14mm diameter black bolts (grade 4.6) to connect each end of the cross beams to the main beams.

To assist in placing the cross beams between the main beams, the ends of the steel plate have been rounded as the cross beams will require the main girders to flex very slightly laterally. The cross beams will need to be carefully measured and hammered into location.

Sway bracing

This bracing consists of two steel angles each 45 mm by 45mm by 6.1mm thick, placed diagonally in the space between the cross beams.

The angles are attached to the top flange of the cross beams using a 14mm diameter bolt.

At the central cross over point, a single 10mm diameter bolt is used to connect the two bracing diagonals, to stop the diagonals rattling in windy conditions.

Main Beams

The calculations (given in the RML report issued 18th February 2019) indicate that the existing main beams are badly overstressed. This is caused by the lack of lateral support (cross beams and sway bracing) yielding a very high slenderness ratio of the existing beams which in turn severely limits the allowable bending stresses to the main beams.

In addition, the calculations concerning the deflection characteristics of the main beams indicate that a deflection of 46mm under live load condition exceeds the recommended limit of 26mm.

The introduction of the cross beams and the sway bracing will improve the stress related situation of the main beams to acceptable limits.

It does not address the deflection difficulties.

With regard to the deflection of the main beams, there are three options:

1. <u>Impose a weight limit</u>
   The deflection of 43mm is caused by a live load of 5Kn per square meter over the whole of the bridge. This is a full loading criteria for a bridge in the busiest location in any part of the country and would appear to be excessive for the location in Tawd Valley and the amount of use the bridge is likely to experience.
   To reduce the applied deflection to acceptable limits (26mm) it would appear possible to impose a weight limit on the bridge of 3Kn per square meter without causing any loss of practical use.
   Even at 3Kn per square meter, the total weight the bridge will acceptably support is 54Kn which is over 5 Tons and is more than adequate for practical purposes, in our opinion.
2. <u>Do nothing</u>
   The deflection of 43mm under full load at 5Kn per square meter does not overstress the beams but it possibly makes the bridge a little "uncomfortable" to experience walking over.
   It is very unlikely that the bridge will experience the 5Kn per square meter load, hence it is felt that this discomfort is likely to be very short lived, if ever experienced.
   In practical terms the bridge may be left and the "Do nothing" option regarded as sensible and practical knowing the bridges location and intended use.
3. <u>New main beams</u>
   If neither of the two options mentioned above are acceptable, then the main beams will require replacement with a 381 x 102 x 55.1 Kg per metre channel sections. The calculations to justify this size are again given in Appendix A at the rear of the report.

RECOMMENDATIONS AND CONCLUSIONS

It is necessary to install the cross beams and sway bracing as identified on drawing number 3110/002 to all five bridges. This will require very careful measurement by the contractor at each location as the distances and lengths are likely to vary per bridge. This will add to the overall lateral stability of the bridge and reduce the slenderness ration of the main beams to acceptable levels

It is recommended that there is a weight limit of 3Kn per square metre place on all bridges. This equates to a total load of 5Tons per bridge which appears more than adequate for the bridges intended use. This will reduce the deflection characteristics of the bridge to acceptable levels.

APPENDIX A

Design of Structure

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Tawd Footbridges Skelmersdale		
Job No.	3110	
Designed	GMR	21/02/2019
Checked	RSLJ	25/02/2019

Description — Steel footbridge,with timber superstructure10.0m span, 1800mm wide in Tawd valley near Skemersdale

Design new steel handrails and verticals and bolts
Check deck timber and main beams

Introduction:-

The following programme designs steel footbridges with a timber deck to support footway loading only in accordance with "The Design Manual for Roads and Bridges as issued by The Stationary Office

The bridges are **not** designed to support vehicle loads.

Design references:-

B.S. 5268 Part 2 - The Structural use of Timber

B.S 5400 Steel, concrete and composite bridges

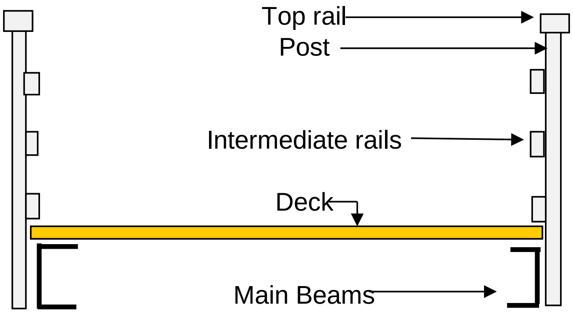
BD 52/93 - The Design of Highway Bridge Parapets

BD 37/01 - Loads for Highway Bridges

B.S. 449 The use of Structural Steel

Steelwork designers Manual (SDM)

Typical details:-



Design of top rail

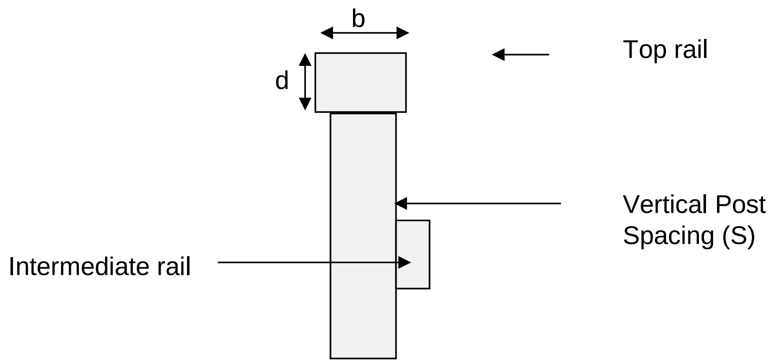
Top rail to be designed in steel hollow sections to resist vandalism

The rail has to be designed to take a horizontal force of 1.4Kn/m in accordance withTable 7 of BD52/93
Group P4 Pedestrian Parapets

The rail is supported by the vertical posts which are in turn bolted to the main beams.

For the top rail to be designed the following data must be provided:-

			Typical
Spacing of verticals (S) =	1.25	(in m.)	*1.1m*
Width of top rail (b) =	80	(in mm.)	*80mm*
Depth of top rail (d) =	40	(in mm.)	*40mm*



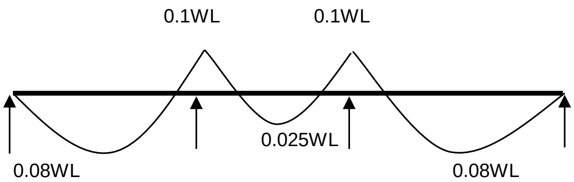
Design loads

Top rail must be capeable of supporting a horizontal load of 1.4Kn per metre. *Design ref: BD52/93 Table 7*

Rails are usually made from one piece of steel 4.0 m long i.e. rails will be continuous over 3 spans (4 verticals).

They will therefore be designed as a continuous beam acting horizontally. The vertical posts will be regarded as supports.

The maximum bending moment diagram for the top rail will be as follows:-



Where L is one span and W is u.d.l. on one span only

Design ref:- S.D.M. page 57

Design Stresses

Max. B.M. = $0.1*1.4*S^2$

M = 0.219 Knm

Section Modulus of top rail

Try 80 x 40 x 4mm thick

z = 17,400 mm^3

Bending Stress = M/z

Typical section moduli for top rail

Size	thickness mm	Mass/m Kg/m	Z cm3
80 x 40	4mm	6.97	17.4
	5mm	8.54	20.6
60 X 40	4mm	5.72	11.2

Applied bending stress = 12.57 N/mm^2

Allowable stresses (bending) *BS 449*

Max. allowable stress **180.00** N/mm^2

Top Rail Design Summary

Use 80 X 40 x 4mm thick Top rail		
Max. Allowable bending stress	180.00	N/mm^2
Applied Bending stress =	12.57	N/mm^2

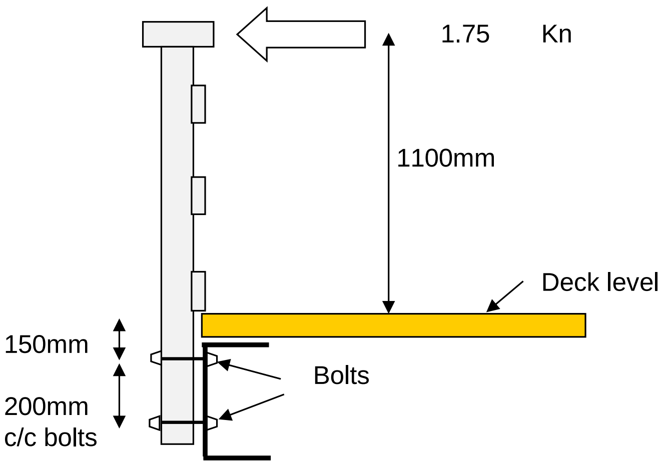
Top Rails O.K

Design of Vertical Posts

The verticals are spaced at 1.25 m centres

The design load of 1.4Kn/m (*see clause 7.1.3 of BD 37/01*) is considered to act 1100mm above deck level

Horizontal load per post = 1.75 Kn



Max. Bending Moment in vertical post is at top bolt level. Allowing 150mm from deck to bolt

M = 2.1875 Knm

Typical section moduli for vertical post

Size mm x mm	thickness mm	Mass Kg/m	Z cm3
70 x70	5	10.1	25.7
	3.6	7.62	19.9
60 X 60	4	6.97	15.4

Enter section chosen

70 x70 x 5

z = 25,700 mm^3

Applied Bending stress = M\z

Applied Bending = 85.12 N/mm^2

Allowable bending stress = 180.00 N/mm^2

Design summary for vertical post 70 x70 x 5 RHS

Use	**70 x70 x 5**	**RHS vertical posts at 1.0m c/c**	
Applied Bending =	85.12	N/mm^2	
Allowable bending stress =	180.00	N/mm^2	

Posts OK

Design of Bolts

Bolts are a minimum of 200mm apart

Tension in top bolt =	12.69	Kn

Alllowable tensile stress for grade 4.6 is 120 N/mm^2

Design ref
See Table 20 B.S.449

Allowable tension in bolts

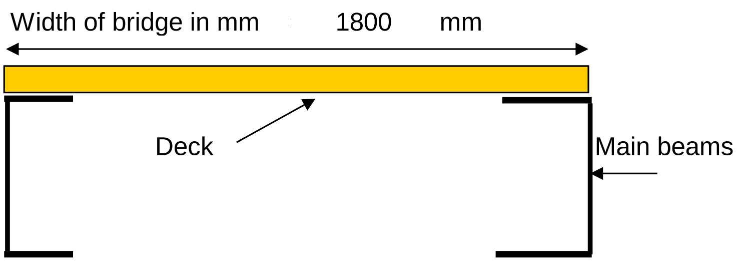
10mm diameter	9.42	Kn
12mm diameter	12.96	Kn
14mm diameter	18.47	Kn

Use 14mm diameter grade 4.6 bolts - 200mm c/c		
Applied Tension =	12.69	Kn
Allowable Tension =	18.47	Kn

Bolts OK

Design of deck planks

Deck planks span between main beams as shown below



Enter width of bridge in mm = 1800 mm

The span of a flexural member such as the deck plank is regarded as the centre to centre distance between bearings. As main beams are usually a minimum of 150mm wide, take span as width 1800-150mm.

Span of deck = 1650 mm

Design ref BS 5268
Clause 2.10.3

Design ref:-
Live Load per sq/m on deck is given in BD 37/01
(5.0Kn/m^2 for pedestrian loading)

Enter live load per sq.m on deck = 5.0 Kn/m^2

Live Load per m on plank = 0.7 Kn/m
if 140mm wide

Dead load per m on plank = 0.036 Kn/m
if 140mm wide and 70mm thick

Total dead plus live load per m on plank 0.736 Kn/m

Max. B.M on deck plank M = 0.25 Kn/m

Enter width of plank in mm. = 140 mm
Enter depth of plank in mm. = 70 mm

Section modulus z = 114,333 mm^2

Applied bending stresses to deck plank = M/z

Applied bending = 2.19 N/mm^2

Allowable bending stress is:-

Grade stress* $K_2K_3K_7$

Enter grade stress of deck plank = 5.3 N/mm^2

Modification factors

K_2 (bending) = 0.8
K_3 (duration) = 1.25 (Dead load plus temporary imposed)
K_7 (depth factor) = 1.17 $(300/d)^{0.11}$

Allowable bending stress is = 6.22 N/mm^2

Check deflection of deck

Defl. = $5WL^3/384EI$

Enter Mod. Of Elasticity

E = 5800 N/mm^2

Design ref:- BS5268 table 7

Typical values E	*N/mm^2*
Oak	*6000*
Pine	*5800*

I = $bd^3/12$

I = 4,001,667 mm^4

Applied deflection = 2.9 mm

Allowable deflection = 0.003span

Design ref:- B.S. 5268
Clause 2.10.7

Allowable defl. = 4.95 mm

Design summary deck planks

Deck planks are 140mm by 70mm			
Applied bending stress	=	2.19	N/mm^2
Allowable bending stress	=	6.22	N/mm^2
Applied deflection	=	2.9	mm
Allowable deflection	=	4.95	mm

Deck Planks
140 x 70 are OK

Design of Main Beams

Calculate dead load per meter run on **each** beam

Enter timber density = 3.7 Kn/m^3

Design ref:- BS5268 Table 7

Typical values	Kn/m^3
Oak	6.4
Pine	3.7

Component		Kn/m
Top rail RHS 80 mm. wide 40 mm. deep		0.070
Intermediate rails 3No. RHS 25 mm. wide 50 mm. deep		0.082
Verticals RHS 70 mm. wide 70 mm deep		0.113
Deck timber 70 mm. deep 1800 mm. wide overall		0.233
Packing pieces timber 50 mm. Deep 150 mm. Wide		0.050
Cross beams (absent)		
Main beams Channels Enter mass of main beam in Kn per m	0.42	0.417
Fixings allowance		0.050
Total Dead load		1.015 Kn per m per beam
Live loads		4.5 Kn per m per beam
TOTAL LOAD PER BEAM		5.515 Kn per m

typical 50 x 25 x 2.5 thick is 2.72 Kg/m

Typical Values - Main beams		
Span	Size	Kn/m
10	305 x 89	0.417

Enter span in metres = 9.70 m

i.e. centre to centre

dist. of bearings

Pre-design check on Deflection

As a quick check on the design of the main beams, calculate the deflection under live load in acc. With B.S. 449 Clause 15

This limits the live load deflection to span/360

Beam:- 305x89@41.6Kg/m	channel

Check deflection

Deflection is = $5WL^3/384EI$

W = 43.65 Kn (live) L = 9.70 m

Enter Inertia of Main beam in cm^4 from tables

I = 5,824 cm^4

Enter Mod of Elasticity of Main beam in N/mm^2 from tables

E = 205,000 N/mm^2

Applied deflection =	43.4	mm	Under live load only
Applied deflection =	53.2		Under dead load plus live load

Allowable defl.(Live)	26.9	mm	ie. span/360

Main Beams fail deflection criteria

Pre- design check on stresses

Quick check on stresses in main beams in accordance with B.S.449

Enter sec.modulus of one main beam z = 463.3 cm^3

Max. Bending moment on one beam M = 64.86 Kn.m dead plus live

Max. bending stress = M/z =	139.99	N/mm^2

Allowable stress

Main beams are to be stabilised with cross beams, steel diagonal bracing , together with existing deck bolted to main beams and ends of main beams bolted to abutments. Hence they are restrained

Allowable bending stress =	180	N/mm^2

Check shear

Enter depth of web 245 mm

Enter thickness of web 10.2 mm

Shear force 26.75 Kn

Shear stress 10.7 N/mm^2 O.K.

Allowable shear Stress	125	N/mm^2	Table 10 BS 449

Main beam design Summary

Existing beam size selected

Beam:- 305x89@41.6Kg/m

B.S. 449 check

Main Beams Summary

Applied bending stress	=	139.99	N/mm^2
Allowable bending stress	=	180.00	N/mm^2
Applied shear Stress	=	10.70	N/mm^2
Allowable shear stress	=	125	N/mm^2
Applied deflection	=	43.4	mm - Live load only
Applied deflection	=	53.2	mm - Dead +Live load
Allowable defl.	=	26.9	mm (Span/360)

Note

The above calculations relate to the existing channel sections used on the bridges (305 by 89 at 41kg/m)

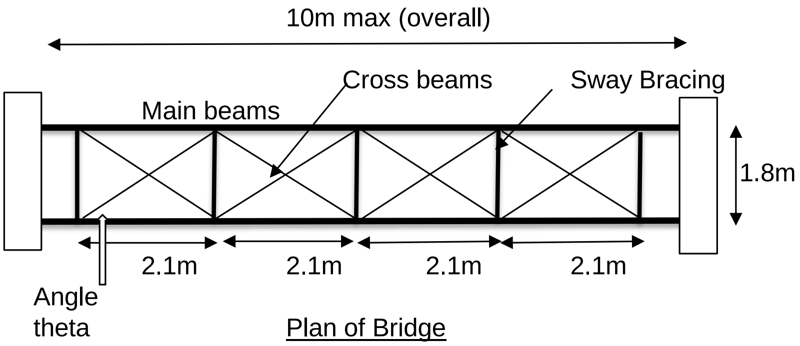
They indicate the bridges to exceed the deflection criteria under full live load of 5KN per square meter which is full footbridge loading . In our opinion this is extreemely unlikely to be experienced due to the location.

If it is an issue, then two options are open:

Reduce the load carrying capability to 3.1Kn per square meter (5 x 27/43) or

Replace the main beams with a section which increases the moment of intertia from 5842 to 5842 x 43/27 =9303 cm4 which is a 381 by 102 by 55.1Kg/m

Design Sway Bracing



Plan of Bridge

Design Sway bracing as ties (in tension only)

Tan Theta is 1.8/2.1 = 0.857

Theta is 40.5 degrees

Horizonatal load per m on handrail is 1.4m

Total length is 10m

Therefore total load is 14 Kn

i.e 7Kn each end

Resolving forces, tension in sway bracing at end (maximum)

is = $\frac{7}{\text{Sin } 40.5}$ = 10.77 KN

Use 45 by 45 by 6.1mm thick angle

Area of Section is 5.12cm2

Tensile stress is = $\frac{10.77 \times 100}{5.12 \times 100}$ = 21.0 N/mm^2

Allowable tension stress is 180N/mm^2

Use 45mm x 45mm x 6.1mm thick angle sway bracing

Check end bolts

Applied Shear 10.77 Kn

Single shear capacity for 14mm diameter bolt grade 4.6

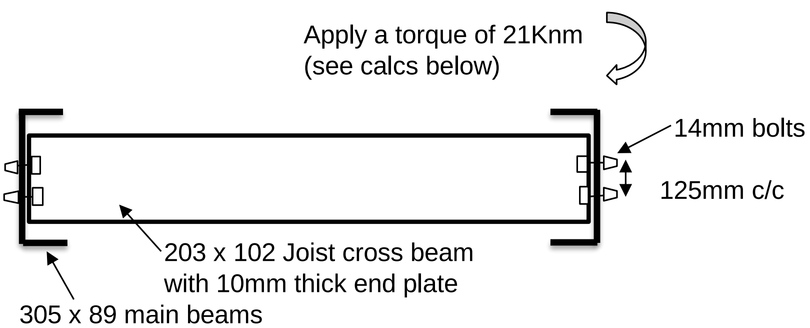
is 14.6 Kn (single shear)

Use 14mm dieameter bolt grade 4.6 at end of bracing

Also

Use 14mm dieameter bolt grade 4.6 at centre cross over

Cross beams



Main beams are subject to torque (or twist) by the horizontal forces on the handrails of 1.4Kn per meter

For a 10m span bridge the total horizontal force is 14Kn acting approximately 1.5 m above bottom bolt

Therefore total torque is 14.0 x 1.5 = 21Knm on whole main beam

Bolts

If bolts are at 125mm c/c the 21Knm torque is resisted by 10 bolts in tension (5 beams two top bolts in each)

Tension per bolt is 21/10 x 0.125 = 16.8Kn per bolt

Allowable tension for 14mm dia bolt 18.47Kn

Use 14mm diameter grade 4.6 bolts 4 per each end of cross beam

Cross beams

A total of 5 cross beams take a Bending moment of 21Knm

4.2 Knm each cross beam

Section modulus is 225 cm^3

Stress is = 18.67 N/mm2 O.K

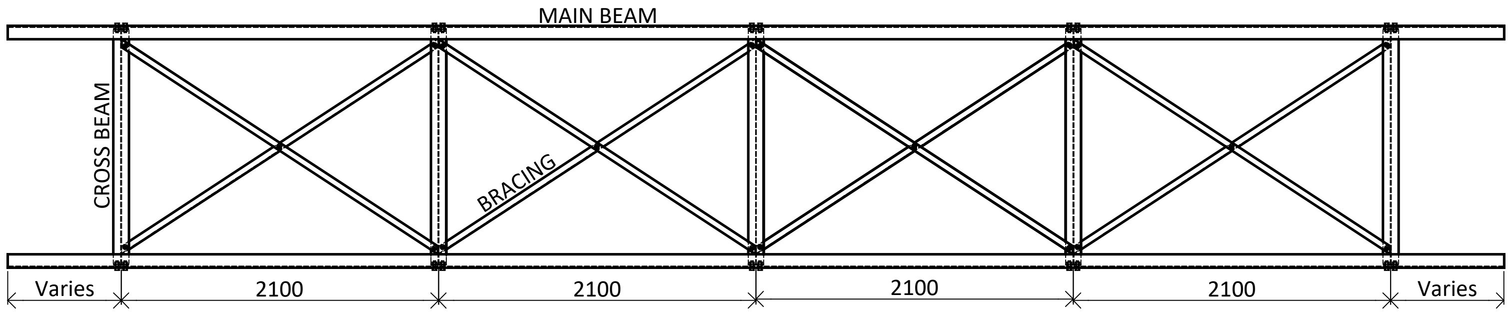
Use 203 x 102 steel joists for cross beams with 10mm thick end plate

APPENDIX B

Drawing 3110/002

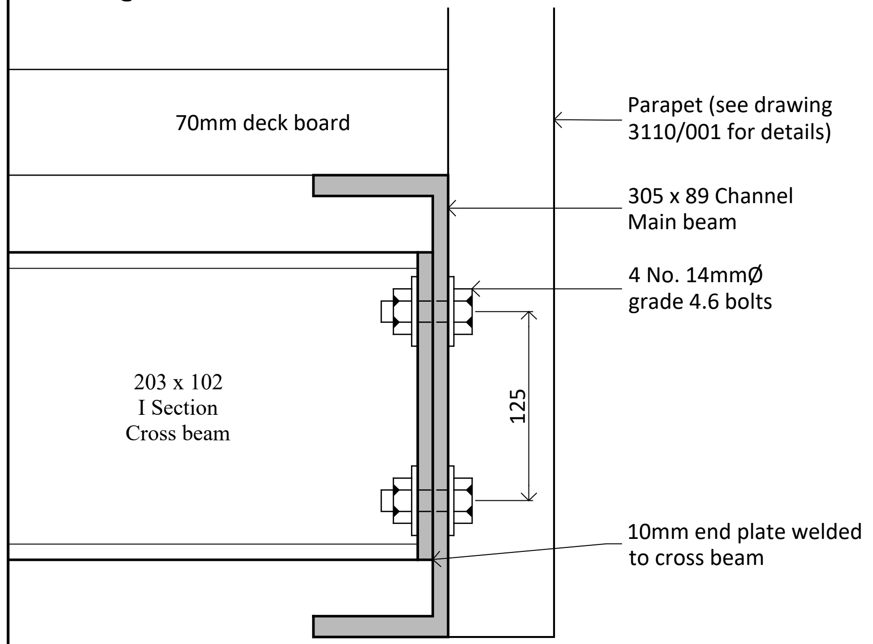
Plan of Bracing

Scale 1:50 @ A3



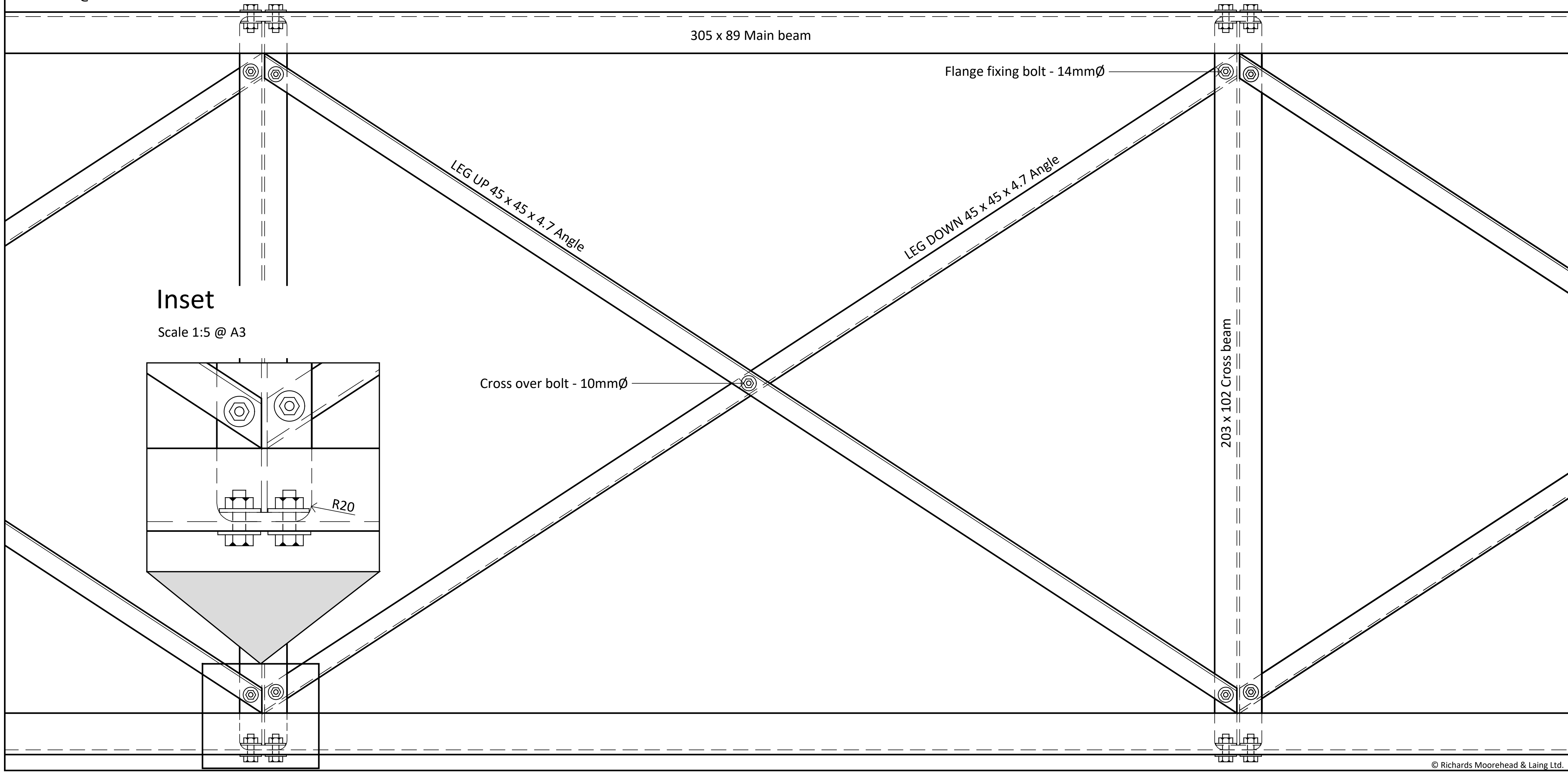
Cross Beam Fixing to 305 x 89 channel

Scale 1:5 @ A3



Cross Beam & Bracing Detail

Scale 1:10 @ A3



Notes:

1. The contractor is to visit the site and view all bridges to check access and conditions.
2. It is the intention to leave the main beams in position and fit the cross beams, bracing and parapets to the existing main beams in situ.
3. The length of each cross beam is to be carefully measured by the contractor before fabrication.
4. The ends of the cross beams and end plates to be rounded to 20mm to aid installation between the existing main beams.
5. All cross beam, bracing and parapet steelwork is to be hot dipped galvanised after holes are drilled.
6. The length of all five bridges varies slightly. To avoid a clash between cross beam locations and vertical parapet post locations, the cross-beam positions are to take precedent and the vertical parapet post locations varied slightly to suit.
7. The existing main beams are to be wire brushed and all rust removed and treated with a proprietary product to inhibit the return of rust. The product is to be approved by West Lancashire Borough Council and should comply with the relevant standards.
8. At the time of writing, the Client is considering the removal of the timber deck and its replacement with 70mm thick CTS Hi Grip hardwood deck boards , pre-treated with an anti-slip surface.

PRELIMINARY

Cywi. Rev.	Dyddiad Date	Disgrifiad Description	Gan By	Gwiriwyd Checked	Cymer. Appro.
01	25/02/2019	Issued with site visit report	RSLJ	GMR	DGR

Cleient / Client:

PARKS & COUNTRYSIDE RANGER SERVICE West Lancs BC

Enw project / Project name:

TAWD VALLEY NORTHERN Bridge surveys

Teitl lluniad / Drawing title:

Cross Bracing Design

Darparwyd gan / Prepared by:

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Graddfa / Scale (A3):	Dyddiad / Date:	Darlunwyd gan: Drawn by: RSLJ
As shown @ A3	Feb 2019	Gwiriwyd gan: Checked by: GMR
Rhif lluniad / Drawing number: 3110 / 002		Cywiriad: Revision: 01