



Penistone CC Access Bridge

Doc Ref: TR P17010

Client:

Penistone Cricket Club
Queen Street
Penistone
S36 8YL

CG SIGMA LTD
14 Prior Road
Consibrough
DN122HB

This document and its content is copyright of CG SIGMA LTD
© CG SIGMA LTD 2017. All Rights Reserved.

Author: David Sekanina PhD
Approved: Colin Goddard IEng Fellow IMechE

Document History			
Issue	Revision Details	Date	By
0	First Issue	15.09.17	CG



Services Provided By CG SIGMA LTD

The service provided by us in the context of this report is to provide a professional opinion on the condition and capacity of the access bridge at Penistone cricket club. Our opinion, which is detailed within this report is based on a basic representation of the bridge design and appraisal by numerical methods in accordance with recognised international standards. **It must be noted by the client that this report makes no recommendations for the use of the bridge** as such a recommendation can only be realised by a thorough inspection, assessment and approval undertaken in accordance with the relevant codes of practice as published by the Highways Agency and in association with the overseeing authority and technical approval authority which would presumably be the respective departments of Sheffield City Council. The service provided by us in the context of this report is subject to our standard terms and conditions “CONDITIONS FOR THE PROVISION OF PROFESSIONAL ENGINEERING SERVICES FROM CG SIGMA LTD - Issue 01” which we advise the client to make reference to.

Summary:

Eurocode standard - EN 1993-2:2006 was used for the bridge evaluation and capacity calculation. Due to the lack of information (eg. No structure records, material data, original rail profile etc.) additional safety factors have been used which are not included in the EC standard. For comparison, a calculation based on the deflection limit criteria according to the American standard for bridges AASHTO LRFD 2012, 6th Edition has also been included. Based on the calculations as detailed within this report, the bridge components assessed would appear sufficient to accommodate vehicles with a maximum weight of circa 7 tonnes (on the basis of even wheel loading) – the timber cross beams being the limiting components within the construction. However, this is based on the information that has been obtained through measurement and does not consider any of the many unknowns such as the actual member material grade, existing defects within the bridge materials i.e. cracks and discontinuities/impurities, damage or the soundness of the piers/foundation etc. **We would recommend that the local Overseeing Authority (presumable Sheffield City Council) is consulted before any further use of the bridge.**

Contents

Services Provided By CG SIGMA LTD.....	2
Summary:	2
1.0 Subject Overview	4
1.1 Introduction	4
1.2 Definitions	4
1.3 References	4
1.4 Bridge Location	5
1.5 Bridge Construction	5
2.0 Assessment Overview	9
2.1 Procedure.....	9
2.2 Assumptions.....	9
3.0 Results.....	10
3.1 Results Summary.....	10
3.2 Table of Results.....	11
4.0 Conclusion and Recommendations.....	11
4.1 Conclusions	11
4.2 Recommendations	11
4.3 Support from CG SIGMA	12
Appendices.....	13
Appendix A – Numerical Capacity Assessment.....	13

1.0 Subject Overview

1.1 Introduction

There is a proposal to build a car park in area of cricket club with the only access using the existing bridge. Currently Penistone Cricket club players and visitors are parking in front of the gate to the bridge – See Fig 3. The bridge is currently used by pedestrians and for exceptional deliveries only. This report aims to detail our professional opinion on the capacity of the bridge as reviewed in accordance with the international standards referenced within.

1.2 Definitions

Girder - A large iron or steel beam or compound structure used for building bridges and the framework of large buildings. In the context of this report Girder refers to the x2 groups of 4 rail sections that support the timber deck.

Cross Beam - a transverse beam. In the context of this report cross beam refers to the timber sleepers that are positioned on top of the girders.

Span – Distance between two supports

Pier – The masonry construction that supports the bridge at mid span.

Ultimate Limit State (ULS) – Describes the limit of the structure whilst acting within elastic limits.

Service Limit State (SLS) – Describes the limit of the structure whilst acting in imposed limits.

Overseeing Authority – In the context of this report, the overseeing authority is the authority responsible for overseeing and controlling highway constructions.

Technical Approvals Authority – In the context of this report is the authority responsible for the approval of highway constructions – new and existing.

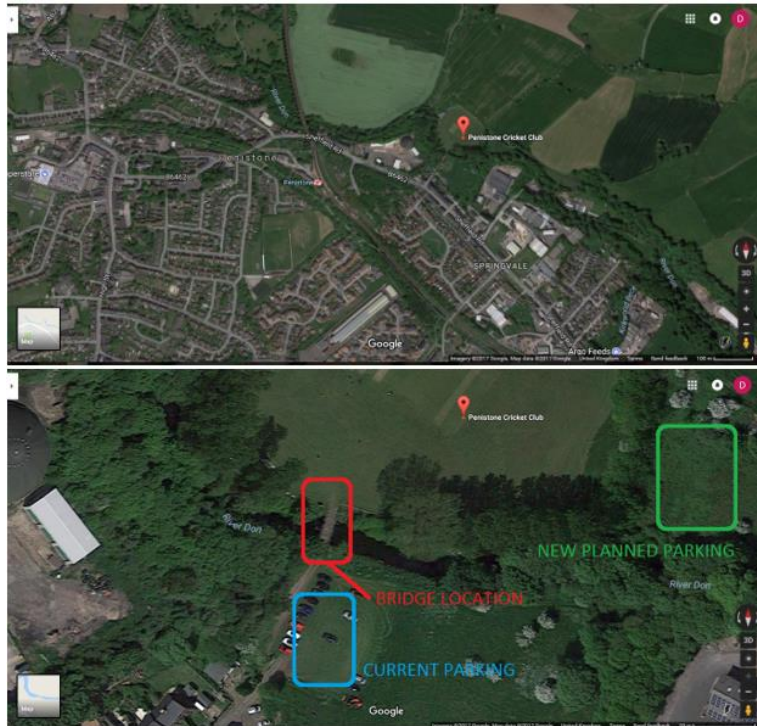
1.3 References

[1] **BS EN 1991-2:2003**. Eurocode 1. Actions on structures. Traffic loads on bridges

[2] **AASHTO LRFD 2012 6th Edition**, Bridge Design Specifications

1.4 Bridge Location

The bridge is located at the North- East part of Penistone over the river Don. Access to the cricket club is from Queen Street.



Above: Fig 1.4.1 – Bridge Location

1.5 Bridge Construction

Estimated bridge erection is between 1960-1970. Unfortunately, no structural records, documents or drawings were able to be made available to us, however the local overseeing authority may have such documents. The access bridge is continuous double span girder type bridge. Two main girders are formed from assembly of 4 steel beams which would appear to be a form of rail section. Please find more detailed information in Section 4. The bridge deck consists of lateral timber beams with a profile of 305 x 140mm. The beams are placed directly on the steel girders without any other connection. Beam lengths are variable but mostly more than 3.2m which accommodate minimum clearance 3m for the traffic plus handrail on each side.

The bridge is supported by 2 abutments and 1 middle pier. The abutments/pier are a combination of stone with concrete. Based on visual inspection only, the support structure seems to be in satisfactory condition.



Above: Fig 1.5.1 Side View



Above: Fig 1.5.2 View on underside



Above: Fig 1.5.3 View on Central Pier



Above: Fig 1.5.4 View on Timber Deck



Above: Fig 1.5.5 View with x1 No. Timber Cross Beam removed – co positive connection between steel girder and Timber Cross Members – self weight and contact only.



Above: Fig 1.5.6 View with x1 No. Timber Cross Beam removed – no positive connection between steel girder and Timber Cross Members – self weight and contact only – Note the fish plate connection

2.0 Assessment Overview

2.1 Procedure

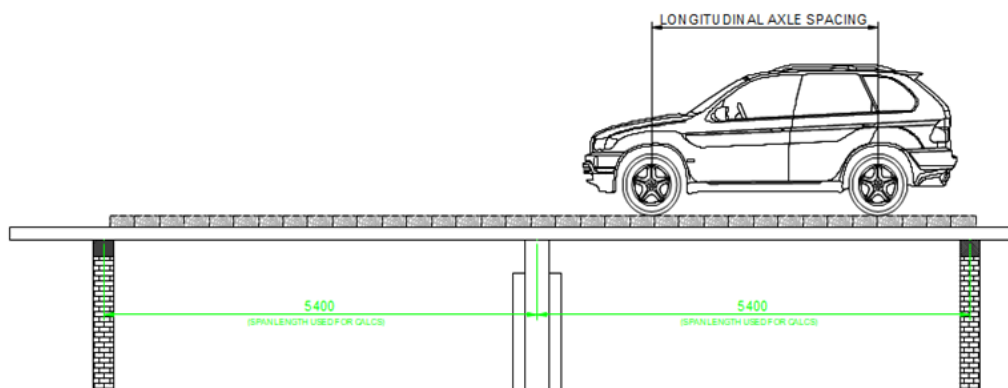
The assessment involved the following:

- Visual inspection and measurement recording of the bridge construction.
- Identification of a relevant code of practice or national standard.
- Numerical assessment/simulation to determine the bridge girder behaviour due to dead load (timber cross members) and girder self weight.
- Determination of moment and shear capacity of the girders.
- Numerical assessment/simulation to determine the bridge girder behaviour under unit loading for load centres of 1.2m apart in all possible positions.
- Ultimate Limit State capacity assessment – moment and shear force limited.
- Service Limit State capacity assessment – Deflection limited in acc with EN 1993-2:2003 and American Standard AASHTO LRFD 2012 6th Edition, Bridge Design Specifications.

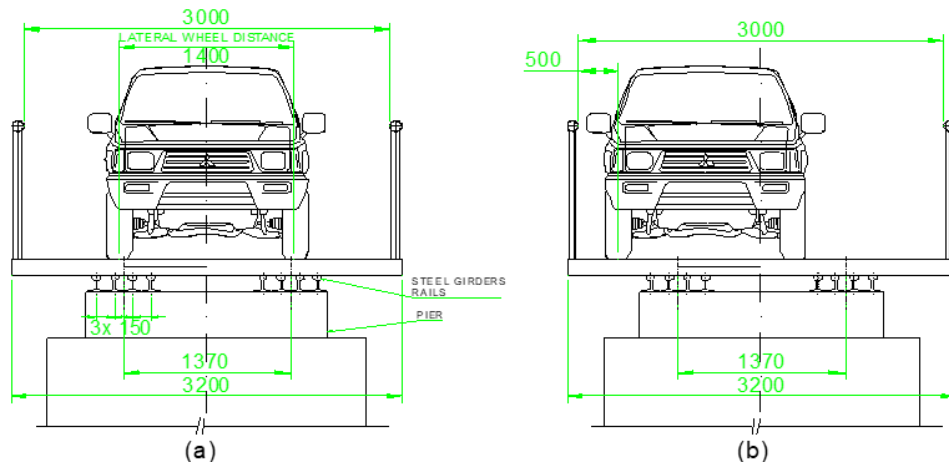
2.2 Assumptions

The following assumptions were made and considered in the assessment:

- The main steel support girders are corroded, resulting in a loss 3mm on the periphery of the rail.
- The girder material is mild steel grade S235 in accordance with BS EN 10025:2004.
- Timber cross beams are 3.4m long.
- The density of the timber used for the cross beams is 1200kg/m³ and has a yield strength of 5MPa.
- Vehicles can pass over the bridge offset from the centre and therefore the weight distribution can be biased towards one group of girders. This is portrayed in Fig 2.2.2
- The timber cross beams distribute the calculated wheel load for a group of girders evenly.
- The fish plate connections are sufficient to transfer the forces and moments.



Above: Fig 2.2.1 – Side View Schematic Showing Double Span



Above: Fig 2.2.2 - Bridge lateral section a) general dimensions; b) car position used for calculation (left girder set is overloaded)

3.0 Results

3.1 Results Summary

The bridge capacity as determined using approach outlined in section 2.1 is limited by the strength of the timber cross beams, for which a maximum vehicle weight of 9.83Tonnes has been calculated. The capacity of the steel beams is limited by deflection, for which a maximum vehicle weight of 15.6Tonnes has been calculated in accordance with EN 1993-2:2004. Considering the guidance provided by the American standard AASHTO LRFD, the bridge as a whole would be limited by the deflection of the girders, for which a maximum vehicle weight of 6.38Tonnes has been calculated. It must be noted that all calculations assume even weight distribution onto all four wheels of a potential vehicle which may not be the case, particularly considering plant and delivery vehicles. Refer to the calculations contained within Appendix A where the calculations in full are provided.

3.2 Table of Results

	Criterion	Max. live load [kN]	Max. vehicle weight [tonne]
ULS Ultimate Limit State	Max. Moment Limited	188.3	19.20
	Max. Shear force Limited	257.2	26.23
	Max stress in wood Limited	96.4	9.83
SLS Serviceability Limit state	Deflection Limited acc. Eurocode	150.3	15.6
	Deflection Limited acc. AASHTO LRFD	62.6	6.38

4.0 Conclusion and Recommendations

4.1 Conclusions

Eurocode standard - EN 1993-2:2006 was used for the bridge evaluation and capacity calculation. Due to the lack of information (eg. No structure records, material data, original rail profile etc.) additional safety factors have been used which are not included in the EC standard. For comparison, a calculation based on the deflection limit criteria according to the American standard for bridges AASHTO LRFD 2012, 6th Edition has also been included. Based on the calculations as detailed within this report, the bridge components assessed would appear sufficient to accommodate vehicles with a maximum weight of circa 7 tonnes (on the basis of even wheel loading) – the timber cross beams being the limiting components within the construction. However, this is based on the information that has been obtained through measurement and does not consider any of the many unknowns

such as the actual member material grade, existing defects within the bridge materials i.e. cracks and discontinuities/impurities, damage or the soundness of the piers/foundation etc. **We would recommend that the local Overseeing Authority (presumably Sheffield City Council) is consulted before any further use of the bridge.**

4.2 Recommendations

We recommend that before any further use or work is undertaken on the bridge, that the local Overseeing Authority is consulted to obtain the facts about the bridge – i.e. status, recorded capacity etc. In the instance that there is limited information available for the bridge it may be necessary to inspect and assess the bridge in accordance with the codes of practice as published by the Highways Agency. This would likely involve the following activities:

- Principal Inspection undertaken in accordance with the requirements as detailed within the Highways Agency document BD 63/07 “Inspection of Highway Structures”
- Inspection for Assessment undertaken in accordance with the requirements as detailed within the Highways Agency document BD 21/01 “The Assessment of Highway Bridges and Structures”
-

4.3 Support from CG SIGMA

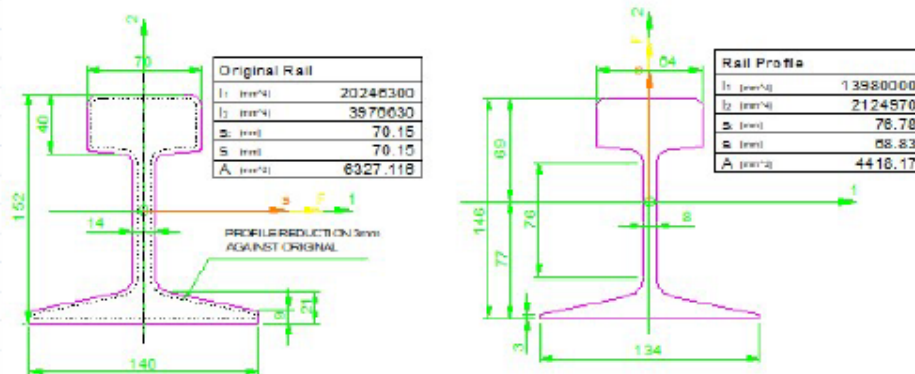
Should you decide to act on the recommendations provided, we are able to act as agents on your behalf, to undertake and manage any further investigation and/or works pertaining to the bridge. Having considerable experience and knowledge of technical construction contracts, we are well positioned to provide an effective professional service which will expedite the bridge assessment process. Should it be determined that the bridge requires further work or replacement we can offer the services required to complete a feasibility study which could appraise both the possibility of replacing the bridge or undertaking any necessary further works with full cost appraisal for both schemes.

Appendices

Appendix A – Numerical Capacity Assessment

STEEL GIRDER MATERIAL AND CROSS SECTION PROPERTIES

$t_{wREDUCED} := 8 \text{ mm}$	(Reduced, considering that the beam is corroded and 3mm layer is excluded in calcs.)
$h_w := 76 \text{ mm}$	(rail web height)
$I_{yORIGINAL} := 20246300 \text{ mm}^4$	(Original rail profile second moment of area.)
$I_{yREDUCED} := 13980000 \text{ mm}^4$	(Reduced section second moment of area, considering that the beam is corroded and 3mm layer is excluded in calcs.)
$A_w := t_{wREDUCED} \cdot h_w = 608 \text{ mm}^2$	(web cross sectional area)
$z_{CG} := 77 \text{ mm}$	(distance from section centroid to extreme fibres)
$f_y := 235 \text{ N} \cdot \text{mm}^{-2}$	(material yield - considering the rail to be grade S235 in acc with BS EN 10025)
$\gamma_{MAT} := 0.8$	(Material reduction factor. Unknown material, expected S235.)



MOMENT AND SHEAR RESISTANCE OF THE REDUCED CROSS SECTION

$$M_{max} := f_y \cdot \frac{I_{yREDUCED}}{h_w} \rightarrow \frac{821325000 \cdot \text{N} \cdot \text{mm}}{19} = 43.228 \text{ kN} \cdot \text{m} \quad (\text{moment resistance})$$

$$Q_{max} := 0.6 \cdot A_w \cdot f_y \cdot \gamma_{MAT} = 68.582 \text{ kN} \quad (\text{Shear resistance})$$

SELF WEIGHT AND DEAD LOAD

$$L := 5.4 \text{ m} \quad (\text{Max span})$$

(3.2m is average wooden beams to accommodate handrail. Some members are longer. From that point is calculated with length 3.4m)

$$b_{deck} := 3.4 \text{ m}$$

$$h_{beam} := 140 \text{ mm} \quad (\text{section height of the timber cross member})$$

$$\gamma_{wood} := 1200 \text{ kg} \cdot \text{m}^{-3} \quad (\text{density of cross member})$$

$$g = 9.807 \frac{\text{m}}{\text{s}^2} \quad (\text{gravitational acceleration})$$

Dead load & Self Weight - calculation per 1 beam girder

$$g_{SW} := 0.42 \text{ kN} \cdot \text{m}^{-1}$$

(force per meter from rail self weight)

$$g_{deck} := \frac{(b_{deck} \cdot h_{beam} \cdot \gamma_{wood}) \cdot g}{8} = 0.7 \text{ kN} \cdot \text{m}^{-1}$$

(force from deck weight - dead load)

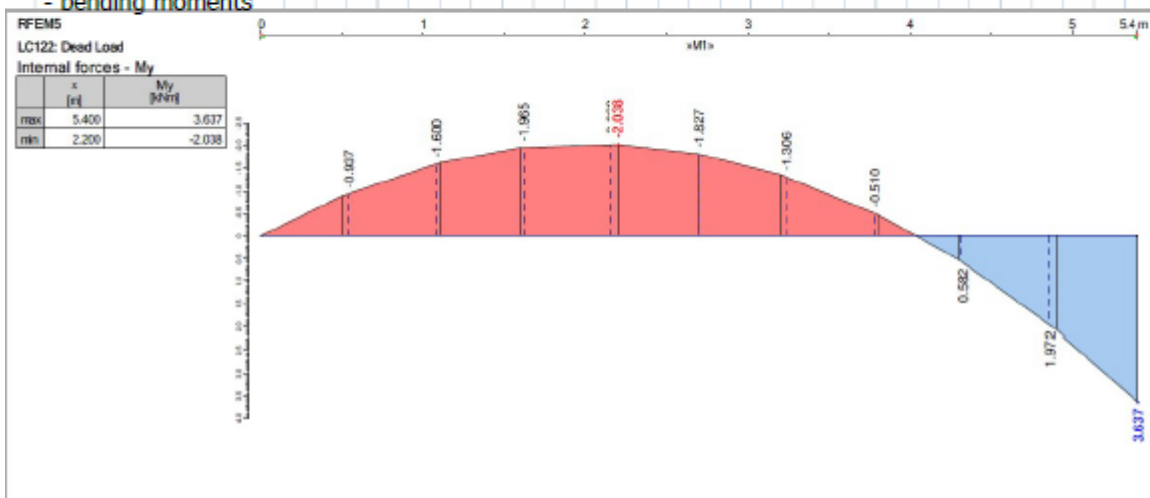
$$g_{TOT} := g_{SW} + g_{deck} = 1.12 \text{ kN} \cdot \text{m}^{-1}$$

(total dead+self weight force)

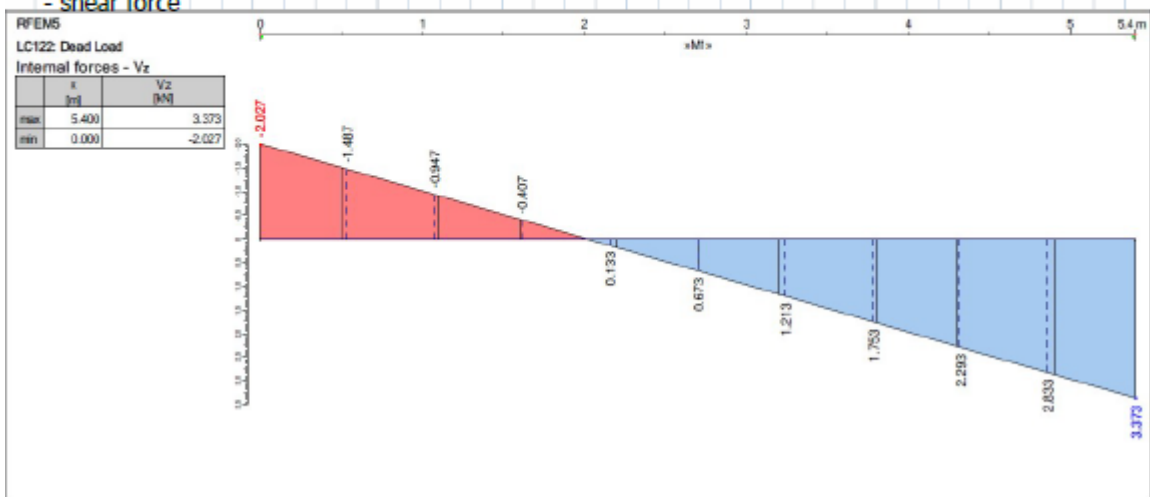
Internal forces due to the Dead Load

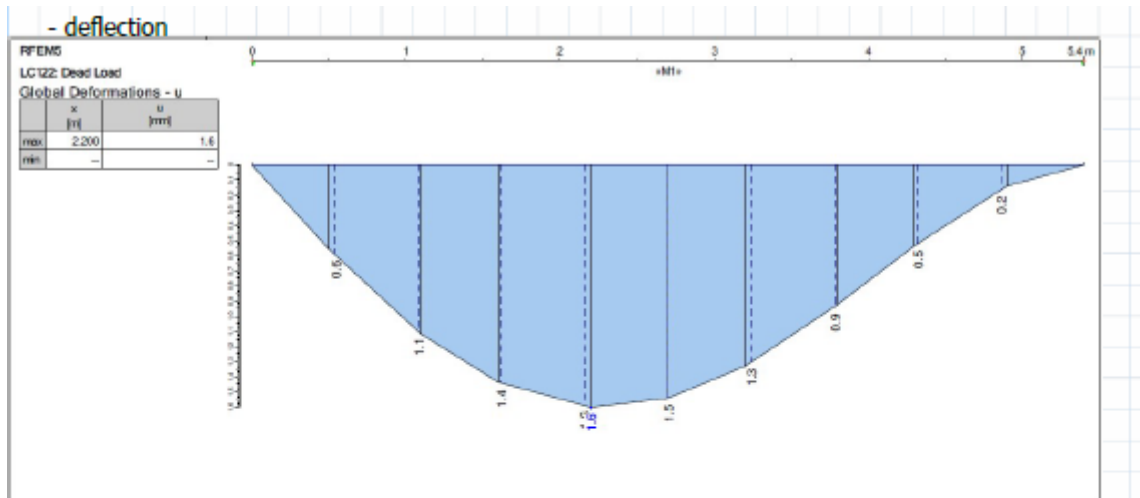
Figure below shows determination of factors for linear uniform load 1kN/m'.

- bending moments



- shear force





$$factM_{pos} := 2.038 \text{ m}^2 \quad (\text{Max positive moment factor})$$

$$factM_{neg} := 3.637 \text{ m}^2 \quad (\text{Max negative moment factor})$$

$$factQ := 3.373 \text{ m} \quad (\text{Max shear force factor})$$

$$M_{DLPOS} := factM_{pos} \cdot g_{TOT} = 2.283 \text{ kN} \cdot \text{m} \quad (\text{Max moment in span due to the DL})$$

$$M_{DLNEG} := factM_{neg} \cdot g_{TOT} = 4.074 \text{ kN} \cdot \text{m} \quad (\text{Max moment at the middle support due to the DL})$$

$$Q_{DLmax} := factQ \cdot g_{TOT} = 3.778 \text{ kN} \quad (\text{Max Shear Force due to the DL})$$

Remaining Girder Capacity

$$M_{EdLL1} := M_{max} - M_{DLPOS} = 40.945 \text{ kN} \cdot \text{m} \quad (\text{remaining capacity limited by max positive moment})$$

$$M_{EdLL2} := M_{max} - M_{DLNEG} = 39.153 \text{ kN} \cdot \text{m} \quad (\text{remaining capacity limited by max negative moment})$$

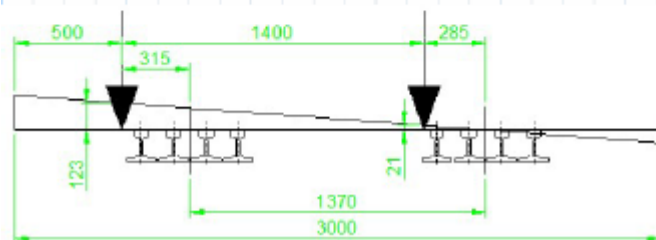
$$Q_{Edmax} := Q_{max} - Q_{DLmax} = 64.804 \text{ kN} \quad (\text{remaining capacity limited by shearforce})$$

DETERMINATION OF MAXIMUM VEHICLE WEIGHT

Beam lateral distribution factor

It is considered that car on the bridge is not at the center but on side (eg. overpassing pedestrians etc.) Factor is calculated from the principle of lateral bridge geometry. It calculated with wheel distance 1.4m.

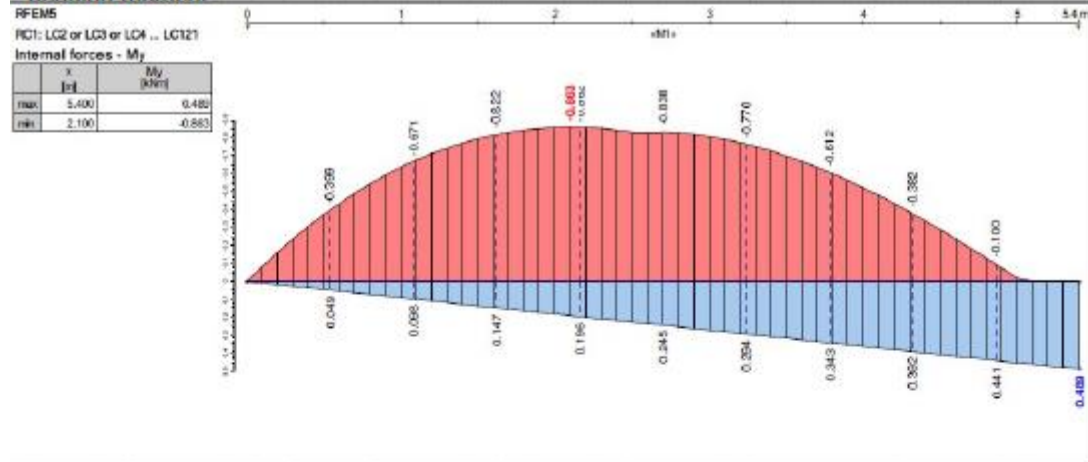
$$factor_{lateral} := \frac{315 + 1370}{1370} + \frac{285}{1370} = 1.438$$



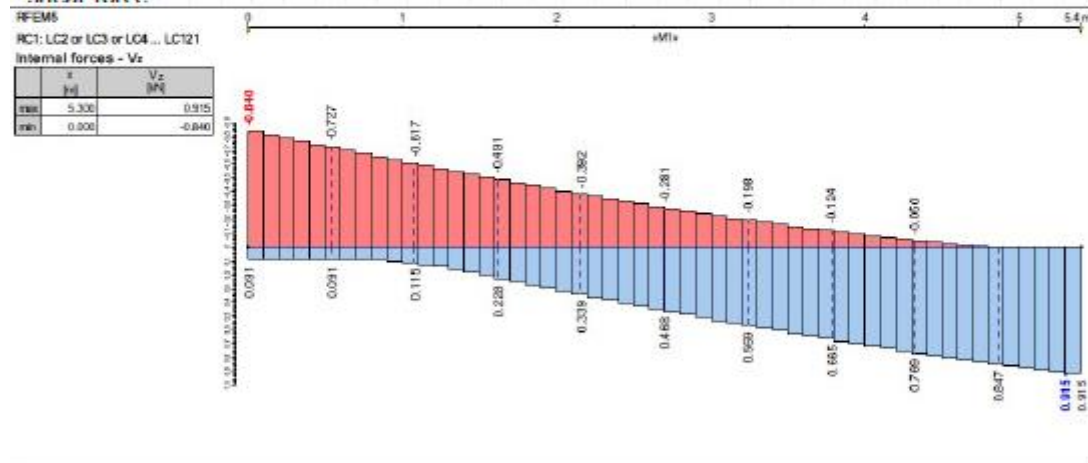
ULS (Ultimate Limit State) - Moment criterium

The load capacity factor is calculated from the diagram. Diagram covers all positions of double force in total action of 1kN (2x 0.5kN, 1.2m apart) vertical load.

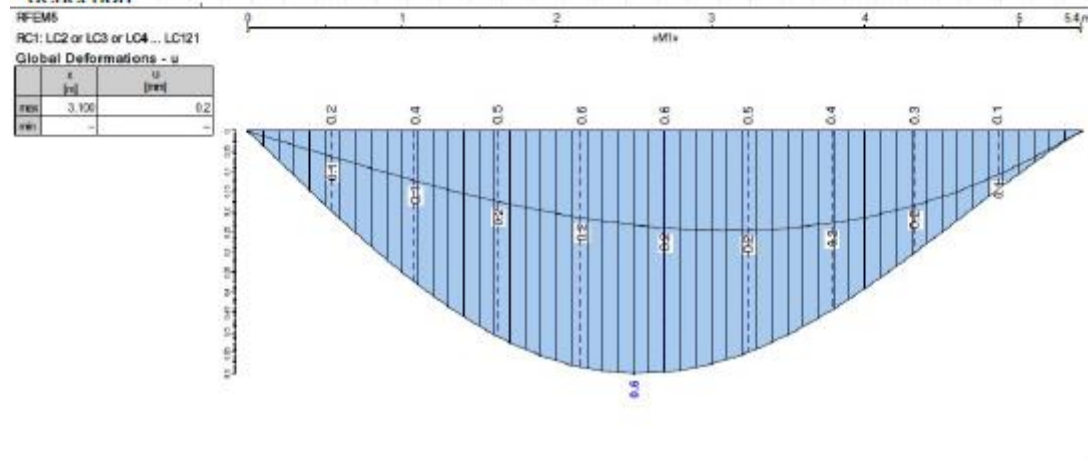
- bending moment



- shear force



- deflection



$$factor_{GM_{pos}} := 0.863 \text{ m}$$

(Max positive moment factor)

$$factor_{GM_{neg}} := 0.489 \text{ m}$$

(Max negative moment factor)

$$n_{girder} := 4$$

$$G_{Mlimited1} := \frac{M_{EdLL1}}{factor_{GM_{pos}}} = 47.445 \text{ kN}$$

(ULS capacity limited by max positive moment - unfactored)

$$G_{Mlimited2} := \frac{M_{EdLL2}}{factor_{GM_{neg}}} = 80.068 \text{ kN}$$

(ULS capacity limited by max negative moment - unfactored)

$$sf_{LL} := 1.4 \quad (\text{Safety Factor for Live Load according EC})$$

$$G_{Mvehicle} := G_{Mlimited1} \cdot \frac{2}{1.44 \cdot sf_{LL}} \cdot n_{girder} = 188.272 \text{ kN}$$

(ULS capacity limited by max positive moment - factored)

$$G_{Mvehicle2} := G_{Mlimited2} \cdot \frac{2}{1.44 \cdot sf_{LL}} \cdot n_{girder} = 317.732 \text{ kN}$$

(ULS capacity limited by max negative moment - factored)

ULS - Shear criterium

To simplify shear resistance of the girders we can declare on safety side the factor is 1.

$$G_{Qvehicle} := Q_{Edmax} \cdot \frac{2}{1.44 \cdot sf_{LL}} \cdot n_{girder} = 257.159 \text{ kN}$$

(ULS capacity limited by shearforce - factored)

SLS (Serviceability Limit State) - Deflection criterium

Deflection criterium is 2 is L/300 according Eurocode EN1993. Limited deflection is calculated as a superposition of Live load deformation + dead load deformation.

Deflection criterium according AASHTO LRFD (US bridge standard is more strict) and allows maximal deflection L/800.

$$defl_{limTOT} := \frac{L}{300} = 18 \text{ mm}$$

(Allowable deflection - EC)

$$factor_{defIDL} := 1.6 \frac{\text{mm}}{\frac{\text{kN}}{\text{m}}}$$

(deflection facotor - dead load)

$$factor_{defULL} := 0.6 \frac{\text{mm}}{\text{kN}}$$

(deflection facotor - live load)

$$defl_{DL} := factor_{defIDL} \cdot g_{TOT} = 1.792 \text{ mm}$$

(dead load deflection limit EC)

$$defl_{limLL} := defl_{limTOT} - defl_{DL} = 16.208 \text{ mm}$$

(live load deflection limit EC)

$$G_{defULL} := \frac{defl_{limLL}}{factor_{defULL}} = 27.013 \text{ kN}$$

(live load deflection limit EC)

$$G_{defVEHICLE} := \frac{G_{defULL} \cdot n_{girder} \cdot 2}{factor_{lateral}} = 150.284 \text{ kN}$$

(maximum vehicle load - deflection limited - EC)

Deflection according AASHTO LRFD 2012 6th Edition.

$$defl_{limAASHTO} := \frac{L}{800} = 6.75 \text{ mm} \quad (\text{Allowable deflection- AASHTO LRFD})$$

$$G_{deflAASHTO} := \frac{defl_{limAASHTO}}{factor_{defLL}} = 11.25 \text{ kN}$$

$$G_{deflVEHICLE} := \frac{G_{deflAASHTO} \cdot n_{girder} \cdot 2}{factor_{lateral}} = 62.589 \text{ kN} \quad (\text{maximum vehicle load - deflection limited - AASHTO LRFD})$$

DETERMINATION OF MAXIMUM VEHICLE WEIGHT ON TIMBER CROSSBEAMS

$$b_{beam} := 310 \text{ mm} \quad (\text{timber cross member width})$$

$$h_{beam} := 140 \text{ mm} \quad (\text{timber cross member depth})$$

$$Wy_{beam} := \frac{b_{beam} \cdot h_{beam}^2}{6} \rightarrow \frac{3038000 \cdot \text{mm}^3}{3} = (1.013 \cdot 10^6) \text{ mm}^3 \quad (\text{timber cross member cross sectional area})$$

$$\sigma_{wood} := 5 \frac{\text{N}}{\text{mm}^2} \quad (\text{Maximum allowable stress in wood members is usually double. 5MPa was used as a very safe value})$$

$$M_{woodMax} := \sigma_{wood} \cdot Wy_{beam} = 5.063 \text{ kN} \cdot \text{m}$$

$$e_{axle} := 150 \text{ mm} \quad (\text{Distance between girder centers})$$

$$G_{WHEELmax} := \frac{M_{woodMax}}{e_{axle} \cdot sf_{LL}} = 24.111 \text{ kN} \quad (\text{maximum allowable wheel load})$$

$$Gw_{vehicle} := G_{WHEELmax} \cdot 4 = 96.444 \text{ kN} \quad (\text{maximum allowable vehicle load assuming even wheel load and 4No. wheels})$$