Introduction

Design of new pedestrian footbridge at Ponsonby Tarn. Bridge span 2.4m and is support on concrete base on each bank.

Design Codes

Building Regulations Part A: 2010
BS EN 1990: 2002 Basis of structural design
BS EN 1991-1: Actions on structures
NA to BS EN 1991-1-1: 2005 Part 1-1
BS EN 1995-1-1:2004 + A1:2008 Design of timber structures

General Loading Conditions

From BS EN 1991-1: Actions on structures
National Annex to BS EN 1991-1-1: 2005 Part 1-1

Material Data

Timber Characteristic Values - C16

Bending	$f_{m,k}$	= 16 N/mm^2
Compression Parallel	$f_{c,0,k}$	= 17 N/mm^2
Compression Perpendicular	$f_{c,90,k}$	= 2.2 N/mm^2
Shear	$f_{v,k}$	= 3.2 N/mm^2
Mean modulus of elasticity parallel to grain	$E_{0,mean}$	= 8 kN/mm^2
5% modulus of elasticity parallel to grain	$E_{0,05}$	= 5.4 kN/mm^2
Mean modulus of elasticity perpen to grain	$E_{90,mean}$	= 0.27 kN/mm^2
Mean shear modulus	G_{mean}	= 0.5 kN/mm^2
Density	ρ_k	= 310 kg/mm^3

For solid timber γ_m = 1.3

k_{mod} Values

Service Class 1, solid timber

Permanent Action: 0.60 Medium term Action: 0.80

Use k_{mod} corresponding to action with shortest duration.

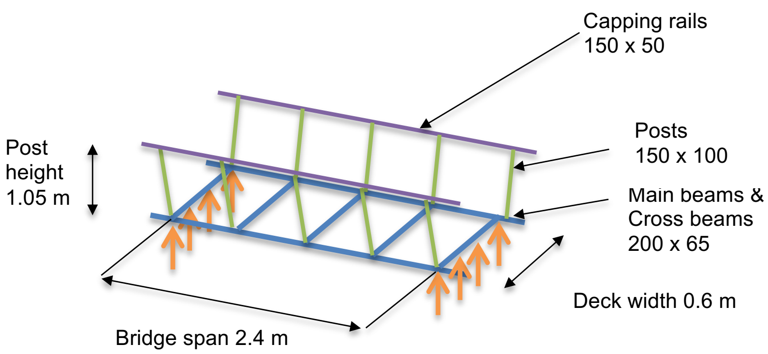
$\therefore$ k_{mod} = 0.8

Redstone Consulting Engineers	Project: Ponsonby Tarn Footbridge	Ref: 96.01 rev -
		Date: 15/07/2022
	Section: Timber Footbridge	By: PLC

	Design Loadings	
	Permanent Actions	
	1. Timber elements	
	1.1 Decking - 125 x 32 at 200 c/cs = 0.08 kN/m^2	
	1.2 Main beams & Cross beams– 200 x 65 = 0.05 kN/m	
	1.3 Capping Rails – 150 x 50 = 0.03 kN/m	
	1.4 Intermediate Rails – 100 x 50 = 0.02 kN/m	
	1.5 Posts – 150 x 100 = 0.06 kN/m	
	Variable Actions	
	1. Decking (vertical)	
	q_k = 4.0 kN/m^2, Q_k = 2.0 kN	
	2. Handrail (horizontal)	
	q_k = 0.74 kN/m Q_k = 1.8 kN	

1.0

Structure Layout



1.1

Top Rail

Design Span = 0.6 m

Check for horizontal parapet load,

Loading

Imposed Horizontal q_k = 0.74 kN/m

Design

Beam analysed using CADS SMART engineer (output at appendix App A 1.1)

Use min **47 x 150 grade C16.**

1.2 **Posts**

Post length = 1.05 m

Cantilever supports loading from Top rail (1.1)

Loading

Imposed q_k = 0.6 x 0.74 = 0.44 kN

Ultimate Limit State Design

ULS Actions - Persistent/transient design situation

$F_d = \gamma_G G_k + \gamma_Q Q_k$

where $\gamma_G = 1.35$, $\gamma_Q = 1.50$

$\therefore F_d = 1.50 \times 0.44 = 0.66$ kN

Bending

$M_{y,d} = FL$

$M_{y,d} = 0.66 \times 1.05 = 0.69$ kNM

For bending about the y-y axis only the following expression shall be satisfied:

$\sigma_{m,y,d} \leq f_{m,y,d}$

$$\sigma_{m,y,d} = \frac{M_{y,d}}{W_y}$$

Using 150 x 100 C16 timber

$W_y = 375{,}000 \text{ mm}^3$

$$\sigma_{m,y,d} = \frac{0.69 \times 10^6}{375{,}000} = 1.85 \text{ N/mm}^2$$

Design bending strength $f_{m,y,d} = (f_{m,y,k} \times k_{mod} \times k_h \times k_{sys}) / \gamma_m$

$f_{m,y,k} = 16$

$k_{mod} = 0.8$

$k_h = 1.0$

$k_{sys} = 1.0$

$f_{m,y,d} = (16.0 \times 0.8 \times 1.0 \times 1.0) / 1.3 = 9.8 \text{ N/mm}^2$

$\therefore$ section satisfactory for bending

Shear

$F_{v,d} = 0.66$ kN

For stress components the following expression shall be satisfied: $f_{v,d} \geq \tau_d$

For Shear Stress at end (assume no notch)

$$\tau_d = \frac{1.5 \times F_{v,d}}{bh_{ef}}$$

$$\tau_d = \frac{1.5 \times 0.66 \times 10^3}{150 \times 100} = 0.07 \text{ N/mm}^2$$

Design shear strength $f_{v,d} = (f_{v,k} \times k_{mod} \times k_v \times k_{sys}) / \gamma_m$

$v_{v,k} = 3.2$

$k_{mod} = 0.8$

$k_v = 1.0$

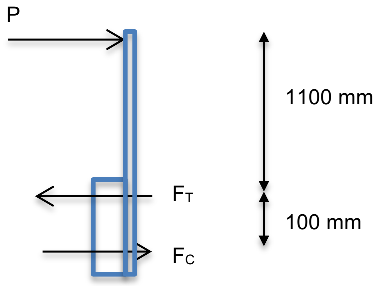
$k_{sys} = 1.0$

$f_{v,d} = (3.2 \times 0.8 \times 1.0 \times 1.0) / 1.3 = 1.97 \text{ N/mm}^2$

∴ section satisfactory for shear.

Connection to beam

Bolted connection to beam. Bolts acting in tension and compression to resist moment in post



Taking moments about C

$F_T = 0.66 \times 1.2 / 0.1 = 7.9$ kN

For Axial loaded bolts the capacity is taken as the lower of:

- The bolt tensile capacity
- The load bearing capacity of the washer

Bolt Tensile capacity

Using M8 grade 8.8 bolts

Tensile strength $F_{t,Rd} = 21$ kN

Washer Bearing capacity

$\sigma_{c,90,d} \leq f_{c,90,d}$

$f_{c,90,d} = 3.0 f_{c,90,k} = 3.0 \times 2.2 = 6.6 \text{ N/mm}^2$

Area required $= 1.3 \times 7.9 \times 10^3 / 6.6 = 1{,}556 \text{ mm}^2$

Use M8 bolts with 50 x 50 x 3 square plate washer

1.3

Decking Boards

Design Span = 0.6 m

Loading

Permanent g_k = 0.08 x 0.2 = 0.016 kN/m
Imposed q_k = 4.0 x 0.2 = 0.8 kN/m

Ultimate Limit State Design

ULS Actions - Persistent/transient design situation

$F_d = \gamma_G G_k + \gamma_Q Q_k$
where $\gamma_G = 1.35$, $\gamma_Q = 1.50$

$\therefore F_d = 1.35 \times 0.016 + 1.50 \times 0.8 = 1.22$ kN/m

Bending

$M_{y,d} = FL^2/8$

$M_{y,d} = 1.22 \times 0.6^2/8 = 0.05$ kNM

For bending about the y-y axis only the following expression shall be satisfied:

$\sigma_{m,y,d} \leq f_{m,y,d}$

$\sigma_{m,y,d} = \dfrac{M_{y,d}}{W_y}$

Using 125w x 32 dp C16 timber

$W_y = 21{,}333\ mm^3$

$\sigma_{m,y,d} = \dfrac{0.05 \times 10^6}{21{,}333} = 2.58\ N/mm^2$

Design bending strength $f_{m,y,d} = (f_{m,y,k} \times k_{mod} \times k_h \times k_{sys}) / \gamma_m$

$f_{m,y,k}$ = 16
k_{mod} = 0.8
k_h = 1.0
k_{sys} = 1.0

$f_{m,y,d} = (16.0 \times 0.8 \times 1.0 \times 1.0) / 1.3 = 9.8\ N/mm^2$

$\therefore$ section satisfactory for bending

Shear

$F_{v,d} = 1.22 \times 0.6/2 = 0.37$ kN

For stress components the following expression shall be satisfied: $f_{v,d} \geq \tau_d$

For Shear Stress at end (assume no notch)

$\tau_d = \dfrac{1.5 \times F_{v,d}}{bh_{ef}}$

$\tau_d = \dfrac{1.5 \times 0.37 \times 10^3}{125 \times 32} = 0.14\ N/mm^2$

Design shear strength $f_{v,d} = (f_{v,k} \times k_{mod} \times k_v \times k_{sys}) / \gamma_m$

$v_{v,k} = 3.2$

$k_{mod} = 0.8$

$k_v = 1.0$

$k_{sys} = 1.0$

$f_{v,d} = (3.2 \times 0.8 \times 1.0 \times 1.0) / 1.3 \quad = 1.97\ N/mm^2$

∴ section satisfactory for shear.

1.4 Main Beams

Design Span = 2.4 m

Loading

Permanent g_k = 0.6/2 x 0.08 + 0.05 + 0.03 + 2 x 0.02
+ 5/2.4 x (0.3x0.05 + 1.1x0.06) = 0.31 kN/m

Imposed q_k = 0.6/2 x 4.0 = 1.2 kN/m

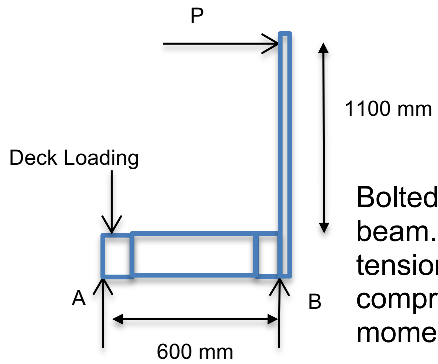
Design

Beam analysed using CADS SMART engineer (output at appendix App A 1.1)

Use min **65 x 200 grade C16.**

1.5 Stability

Examine overall stability with full parapet loading (P) and minimum deck loading (permanent only)



Bolted connection to beam. Bolts acting in tension and compression to resist moment in post

Taking moments about B.

R_A = 1.1 x (1.5 x 0.74)/0.6 – 0.31 = 1.73 kN/m uplift (ULS)

Note: less than ULS design loads on beam at 1.4 but foundations will need to take account of uplift.

Anchor load at Support = 2.4/2 x 1.73 = 2.1 kN

Use M8 Anchors into foundations

1.6

Foundations

Design strip footings to walls for allowable Bearing Pressure of 50 kN/m^2
Loading from full bridge (3.0m length)

Loading

Permanent g_k = 3.0/2 x 0.31 x 2 = 0.93 kN
Imposed q_k = 3.0/2 x 0.6 x 4.0 = 3.6 kN

Strip footing Self Weight gk = 0.4 x 0.6 x 0.8 x 25 = 4.8 kN kN/m

Ultimate Limit State Design

At ULS, $F_d = \gamma_G G_k + \gamma_Q Q_k$ where $\gamma_G = 1.0$, $\gamma_Q = 1.3$

F_d = 1.0 x (0.93+4.8) + 1.3 x 3.6 = 10.41 kN

Area = 0.6 x 0.8 = 0.48 m

BP = 10.41/0.482 = 21.7 kN/m^2