FORTH ROAD BRIDGE	Project: Cable Band Bolt Replacement			Job Ref	
	Part of structure: Main Cable			Calc sheet no	rev
	Drawing ref	Calc by: DB	Date: 12/03/2012	Check by	Date

Ref	Calculations	Output

Pannel Point 24

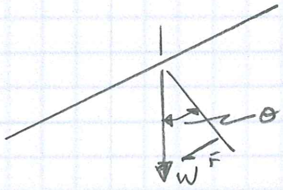
From Aecom Sheet

Hanger DL = 1540 kN, LL = 380 kN } Σ = 1920 kN

Slope = Angle θ = 16.1402°

FOS Assuming 6 Bolts Have 800 kN Tension Each & μ = 0.3 Has Been Calculated By Aecom As 2.70.

Output: μ = 0.3 (Assumed)



W = Load Due To Hangers

W_{DL} Only = 1540 kN

W_{TOTAL} = 1920 kN

$\sin\theta = \sin 16.1402° = 0.27799$

$F = W \sin\theta$

$F_{TOTAL\ LOADS} = 1920 \times 0.27799 = 533.74$ kN

F_{DL} only $= 1520 \times 0.27799 = 422.5$ kN

Two Bolts Have Cracked Nut's

Tension in Remaining Bolts Decreased Due To Relaxation. (Relaxation Unknown).

Ref: As Previous

Calculate % of Relaxation in 5 Bolts To Cause FOS ≤ 1.0

FOS = μR / F (R = Load in Bolt)

FOS = 1.0 $= 0.3 \times \frac{R}{F}$

Ref: Total Load Case

$R_T = F_T / 0.3 = \frac{533.74}{0.3} = 1779.13$ kN

Which is 355.8 kN Per Bolt

$\% \Rightarrow \left[1 - \frac{355.8}{800}\right] \times 100 = 55\%$ Reduction

Output: 5 Bolts Contributing

G:\filing\A_FILES\A64_Standard_Forms\Admin\Forth Road Bridge - Calc Sheet 2011.doc

FORTH ROAD BRIDGE

Project	Job Ref
CABLE BAND BOLT REPLACEMENT	

Part of structure	Calc sheet no	rev
MAIN CABLE		

Drawing ref	Calc by	Date	Check by	Date
	DB	12/03/2012		

Ref	Calculations	Output

PANNEL POINT 24 (CONT'D)

FOR DEAD LOAD CASE

$R_{DL} = \left(\frac{422.5}{0.3}\right)/5 = 281$ kN PER BOLT

(5 BOLTS CONTRIBUTING)

PERCENTAGE REDUCTION $= \frac{800-281}{800} \times 100 = 64\%$

ASSUME 4 BOLTS REMAINING (TOTAL LOAD)

$R_T = \frac{1779.13}{4} = 444.8$ kN (PER BOLT)

PERCENTAGE REDUCTION $= \frac{800-444.8}{800} \times 100 = 44.4\%$

ASSUME 4 BOLTS REMAINING (DEAD LOAD)

$R_{DL} = \left(\frac{422.5}{0.3}\right)/4 = 352.1$ kN (PER BOLT)

PERCENTAGE REDUCTION $= \frac{800-352.1}{800} \times 100 = 56\%$

FORTH ROAD BRIDGE	Project: **Cable Band Bolt - Factor of Safety**			File location	
				Calc sheet no	rev
	Drawing Ref: 33111/AB/20	Calc by: DB	Date: Mar2011	Chk by	Date

Ref	Calculations	Output

Determine the Slip Factor/Coefficient of Friction

Unfortunately no tests were carried out during construction to determine the friction between cable band bolts and main cables.

From the FRB ICE proceedings friction between the wires of the main cable and metal sprayed surfaces of the saddles was assumed to be equal to 15%. The Proceedings state that practical test made by the Contractor gave results of 30% however no details of these are provided.

Testing has been carried out for other suspension bridges for example for the Delaware River Bridge full size test was carried out by Lehigh University. The conclusion of these test were that bulging of the main cable contributed significantly to resisting slip.

BS 5400 part 3 clause 14.5.4.4 gives slip factors at friction surfaces for HSFG bolts:

For weathered surfaces clear of rust and mill scale	μ =	0.45
For surfaces with sprayed zinc	μ =	0.4
For surfaces blasted with shot or grit	μ =	0.5
For surfaces with sprayed aluminium	μ =	0.4
For surfaces treated with zinc silicate paint	μ =	0.35
For surfaces treated with etch Primer	μ =	0.25

Neither BS 5400 or the Eurocodes provide a slip factor for galvanised surfaces. Various tests have been carried out for galvanised surface and results range significantly. The Galvanisers Association specifies the following slip factors are achieved depending on the preparation of the surface:

Preparation Technique		
As galvanised	μ =	0.14
Weathered galvanised	μ =	0.20
Galvanised-wire brush	μ =	0.31
Galvanised-grit blasted	μ =	0.31
Bare steel, as-rolled	μ =	0.35

Some time after the connection is made the Galvanisers Association states that galvanised joints will develop a characteristic known as 'lock-up' The 'lock-up' is a result of friction between the two galvanized surfaces during dynamic movements. After 'lock up' a friction coefficient equal to that of bare steel can be achieved as above (35%).

Cable Band Bolts Surfaces

The surface of the cable band is assumed to be bare steel.
The surface the main cable wire is galvanised steel.

The minimum sip value should therefore be used - 0.20 for weathered steel.

FORTH ROAD BRIDGE

Project	Job Ref
CABLE BAND BOLT	

Part of structure	Calc sheet no	rev
BOLT ELONGATION		

Drawing ref	Calc by	Date	Check by	Date
	DB	05/03/2012		

Ref	Calculations	Output
	CABLE BAND BOLT	
	DETERMINE MAXIMUM ELONGATION PRIOR TO FAILURE.	
	REFERENCE: AECOM "REPORT ON FAILED CABLE BAND BOLT NUTS, MAY 2011"	
	BOLTS WERE REPLACED IN 1998 - 1999	
	BOLTS TESTED TO FAILURE:	
P46	10 NO. BOLTS, WERE TESTED TO FAILURE, FAILURE LOADS VARIED FROM 1009 kN TO 1182 kN EQUIVALENT STRESSES OF 1064 N/mm^2 to 1247 N/mm^2 ON THE SHANK AREA.	
P46, TS.12	TENSILE STRENGTH = 1240 N/mm	(ORIGINAL SPEC 826M40X to BS 970)
	MAXIMUM ELONGATION > 10% OF (GL $5.65\sqrt{S_0}$ %)	
	$S_0 = 948mm^2$ GL = 173.9mm	
	ELONGATION = 17.4mm	
P55	MEASURED EXTENSION = 3.11mm	
	POSSIBLE INCREASE BEFORE FRACTURE = 14.29mm	
	ELASTIC BOLTS ARE CURRENTLY WITHIN THE ELASTIC ZONE:	
	CALCULATE EXTENSION USING, E = 217 kN/mm^2 AT LIMIT OF ELASTIC DEFORMATION = $\frac{1009}{217}$ = 4.65MM	
	OVERALL ELONGATION OF 665MM (17.4mm) WOULD BE 2.6%.	

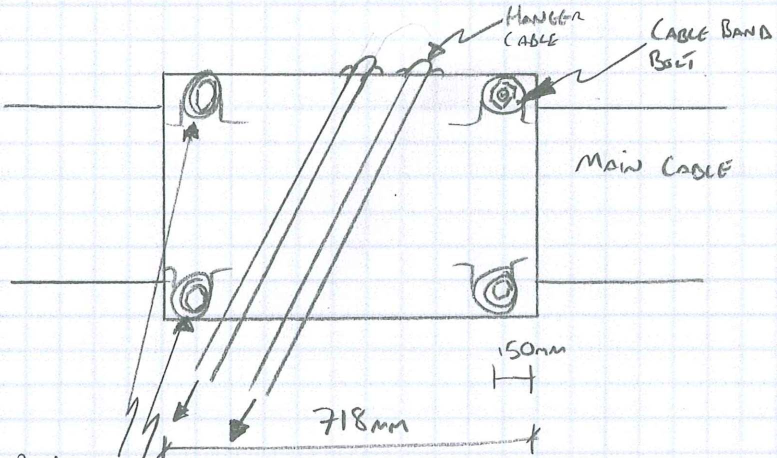
G:\filing\A_FILES\A64_Standard_Forms\Admin\Forth Road Bridge - Calc Sheet 2011.doc

Project			Job Ref
Cable Band Bolts			
Part of structure			Calc sheet no / rev
Bolt Elongation			
Drawing ref	Calc by: DB	Date: 05/03/2012	Check by / Date

FORTH ROAD BRIDGE

Ref	Calculations	Output

Cable Band Idealised



If damaged nuts are ineffective and begin to splay what movement would cause failure (fracture) of higher bolts.

Visable movement of 14mm prior to bolt failure, therefore fracture unlikely prior to band slippage/nut failure.