Cotton Duck Bearing Pad Design Criteria

Keywords
Precast, Bearing Pad, Cotton Duck, AASHTO, LRFD, PCI

Introduction

This text was created to educate the design engineer on the design methodologies applicable for evaluating cotton duck bearing pads. Three references and their guidelines are presented. The references are listed in table 1. State and project specific requirements should also be considered as well as engineering judgment and local practice when designing cotton duck bearing connections.

Reference Number	Reference Citation	Reference Abbreviation
1	**LRFD design criteria for cotton duck pad bridge bearing**, by C W Roeder; National Cooperative Highway Research Program.; American Association of State Highway and Transportation Officials.; National Research Council (U.S.). Transportation Research Board. http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_w24.pdf	LRFD-2000
2	**AASHTO LRFD Bridge Design Specification, 6th Edition (US)** by American Association of State Highway and Transportation Officials, Washington, DC (See footnote 1)	LRFD-2012
3	**PCI Design Handbook 7th Edition**, by Precast Concrete Handbook Committee, Precast Concrete Institute, Chicago Illinois.	PCI

Table 1: Reference Guidelines

Material Properties

Cotton Duck Pads (CDP) are preformed elastomeric pads consisting of thin layers of elastomer interlayed with layers of cotton duck fabric. CDP has a large compressive load capacity and is stiff. The impact of the pad stiffness is that translational movement and rotational capacity of CDP is limited. CDP is manufactured per the *Standard Specification for Bridges and Military Specification*, MIL-C-882E. The design criteria presented are not specific to any manufacturer. The recommendations found within this text should not be considered practical unless the supplied pads are tested and verified to meet the test requirements of MIL-C-882E.

[1] AASHTO LRFD Bridge Design Specifications, 6th Edition are based on research done by Lehman, D. E, Cotton duck bearing pads : engineering evaluation and design recommendations Washington (State). Department of Transportation. Washington State Transportation Commission. http://www.wsdot.wa.gov/research/reports/fullreports/569.1.pdf

Supplemental Engineering Text-1.1

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Service Limit State Average Uniform Compressive Stress (English Units)

Reference Abbreviation	Maximum Allowable Uniform Compressive Stress	Reference Eq. #
LRFD-2000	$\sigma_s \leq 1500\ psi$	Appendix B (14.7.6.3.2-3)
LRFD-2012	$\sigma_s \leq 3000\ psi$ $\sigma_L \leq 2000\ psi$	(14.7.6.3.2-5) (14.7.6.3.2-6)
PCI	$\sigma_s \leq 2500\ psi\ (uniform)$	Figure 6.10.3
Where:	$\sigma_s =$ Average Compressive Stress Due to Total Service Load $\sigma_L =$ Average Compressive Stress Due to Service Live Load	

Service Limit State Compression with Rotation

Reference Abbreviation	Maximum Allowable Stress with Rotation	Reference Eq. #
LRFD-2000	$\sigma_s \leq 1500 - 500\dfrac{\theta_s}{\frac{t_p}{L \cdot 12}}$	Appendix B (14.7.6.3.5.2-2)
LRFD-2012	$\varepsilon_t = \varepsilon_c + \dfrac{\theta_s \cdot L}{2 \cdot t_p} < 0.20$ $\varepsilon_c = \dfrac{\sigma_s}{E_C}$ This equation can be rearranged to solve for a pad thickness ()as: $t_p = \dfrac{\theta_s \cdot L}{2 \cdot \left(0.20 - \frac{\sigma_s}{E_C}\right)}$ Additionally for direct comparison to previous LRFD requirements, solving for σ_s $\sigma_s = \left(0.2 - \dfrac{\theta_s \cdot L}{2 \cdot t_p}\right) E_c$	(14.7.6.3.5b-1) (14.7.6.3.5b-2)
PCI	$\theta_{max} \leq 4000\ psi\ (non-uniform)$ For non-uniform loading the maximum stress experienced at a single edge of the pad is allowed to increase to 4000 psi. If the maximum recommended rotation limits in Figure 6.10.3 are satisfied, the pad will experience the maximum stress at one end and zero stress at the other. This creates a condition where the average stress is: $\theta_{avg} \leq \dfrac{4000\ psi}{2} = 2000\ psi$ θ_{avg} is then comparable to the stress limits with consideration of rotation, σ_s , for the other references.	Figure 6.10.3
Where:	$E_c =$ uniaxial compressive stiffness. Taken as 30 ksi in lieu of specific test data $L =$ Length of CDP in plane of rotation $t_p =$ Pad Thickness $\varepsilon_c =$ uniaxial strain due to compression under total load	

$\varepsilon_t =$ uniaxial strain due to combined compression & rotation from total service load
$\sigma_s =$ average Compressive Stress Due to Total Service Load
$\theta_s =$ rotation due to total service load
$\theta_L =$ rotation due to service live load

Maximum Rotation Limit

Reference Abbreviation	Maximum Allowable Rotation	Reference Eq. #
LRFD-2000	$\theta_s \leq \frac{t_p \cdot \sigma_s}{L \cdot 10000}$	Appendix B (14.7.6.3.5.2-1)
LRFD-2012	$\theta_s \leq 0.80 \frac{2 \cdot t_p \varepsilon_c}{L}$	(14.7.6.3.5b-3)
	$\theta_L \leq 0.20 \frac{2 \cdot t_p \varepsilon_c}{L}$	(14.7.6.3.5b-4)
	$\varepsilon_c = \frac{\sigma_s}{E_C}$	(14.7.6.3.5b-2)
PCI	$\theta_s \leq \frac{0.12 \cdot t_p}{L}$	Figure 6.10.3

Where:

$E_C =$ uniaxial compressive stiffness. Taken as 30 ksi in lieu of specific test data
$L =$ Length of CDP in plane of rotation
$t_p =$ Pad Thickness
$\varepsilon_c =$ uniaxial strain due to compression under total load.
$\sigma_s =$ average Compressive Stress Due to Total Service Load
$\theta_L =$ rotation due to service live load

Maximum Horizontal Displacement

The allowed horizontal deformation for CDP pads is significantly smaller than other elastomeric bearing pads. This is due experiments demonstrating cracking at large shear strains and the fact that CDP has a much larger shear stiffness than other elastomeric bearings. Limiting the horizontal deformation can limit the tensile forces transferred through the bearing connection. CDP pads are suitable for the addition of PTFE sliding surfaces should larger horizontal deformation need to be accommodated.

Reference Abbreviation	Minimum Pad Thickness	Reference Eq. #
LRFD-2000	$t_p \geq 10\Delta_s$	Appendix B (14.7.6.3.4-2)
LRFD-2012	$t_p \geq 10\Delta_s$	(14.7.6.3.4-2)
PCI	$t_p \geq 2\Delta_s$	Figure 6.10.3

Where: $\Delta_s =$ Design Horizontal Movement at the end of a component.

Stability Check

To ensure stability, the total thickness of the pad shall not exceed the least of L/3 or W/3.

References

LRFD design criteria for cotton duck pad bridge bearing, by C W Roeder; National Cooperative Highway Research Program.; American Association of State Highway and Transportation Officials.; National Research Council (U.S.). Transportation Research Board. http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_w24.pdf

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PCI Design Handbook 7th Edition, by Precast Concrete Handbook Committee, Precast Concrete Institute, Chicago Illinois.

Cotton duck bearing pads : engineering evaluation and design recommendations by D. E Lehman, Washington (State). Department of Transportation. Washington State Transportation Commission. http://www.wsdot.wa.gov/research/reports/fullreports/569.1.pdf

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