Handbook for Conventional Maintenance Practices for Railroad Bridges

@Seismicisolation

Handbook for Conventional Maintenance Practices for Railroad Bridges Was Developed In Response to Student Requests Received During the Railway Bridge Inspection Seminar Series Presented by Committee 10

The three main building materials for railway bridges require inspection and maintenance to continue to provide valuable services.

@Seismicisolation

THIS CAN BE PREVENTED

TIMBER

This. . .

CONCRETE

This. . .

STEEL

And this. . .

Have gotten this way mainly due to neglect through lack of maintenance and if let continued to fester, could result in this. . . .

@Seismicisolation

With the right tools. . .

THIS . . . .

CAN BE THIS!

@Seismicisolation

With the right tools. . .

THIS . . . .

CAN BE THIS!

@Seismicisolation

With the right tools. . .

And THIS . . .

CAN BE THIS!

@Seismicisolation

Handbook for Conventional Maintenance Practices for Railroad Bridges
The Main Reason Why…

- Passing on Knowledge
  - Timber
  - Concrete
  - Steel

@Seismicisolation

Handbook for Conventional Maintenance Practices for Railroad Bridges
The Right Tool…

Timber Chapter

1.1 Introduction
1.2 Structural Properties of Wood
1.3 Common Causes of Degradation in Wood
1.4 Timber Bridge Investigation
1.5 Wood Deterioration
1.6 Substructure Restoration
1.7 Substructure Installation
1.8 Superstructure Restoration
1.9 Deck Restoration
1.10 High Speed Replacement Methods
1.11 Ask John – Assessing a Timber Bridge
1.12 Ask John – Posting a Timber Pile
1.13 Ask John – Adding a Helper Stringer
1.14 Article – Timber Connections in Railway Bridges

@Seismicisolation

TIMBER

@Seismicisolation

1.1 Introduction

@Seismicisolation

1.1 Introduction

@Seismicisolation

1.1 Introduction

@Seismicisolation

1.1 Introduction

@Seismicisolation

1.1 Introduction

@Seismicisolation

@Seismicisolation

@Seismicisolation

@Seismicisolation

@Seismicisolation

@Seismicisolation

@Seismicisolation
shop-vac
12 GALLONS
45.5

@Seismicisolation

1.1 Introduction

@Seismicisolation

1.2 Structural Properties of Wood

Anisotropic

Means different properties in different directions

Hygroscopic

Means wood shrinks and expands with moisture content

@Seismicisolation

1.3 Common Causes of Degradation in Wood

"It's not wood's fault – it's what we do to it" - Tingley

@Seismicisolation

1.3 Common Causes of Degradation in Wood

"It's not wood's fault – it's what we do to it" - Tingley

@Seismicisolation

1.3 Common Causes of Degradation in Wood

"It's not wood's fault – it's what we do to it" - Tingley

@Seismicisolation

1.3 Common Causes of Degradation in Wood

"It's not wood's fault – it's what we do to it" - Tingley

@Seismicisolation

1.4 Ask John – Assessing a Timber Bridge

Stringers *– The stringers have two bearing areas; under the ties and over the caps. Their top surfaces between the ties (open deck structures) are subject to weather deterioration and they typically have vertical holes over the caps for drift pins, vertical holes for line bolts (securing the ties), and usually have horizontal holes for the chord bolts. These vertical holes allow moisture to gain access to the bright wood center of the timber where it can lead to accelerated decay*

Caps *– The caps also have two bearing areas; under the stringers and over the piles. The caps have vertical holes for the drift pins and possibly line bolts for the ties. If the bents have cross bracing, the caps will have horizontal holes secure the bracing*

Piles *– The piles will have vertical holes under the cap for the drift pin and horizontal holes for any cross bracing. Each pile is especially subject to decay at the ground line or at the waterline, especially if the waterline fluctuates. In addition to the drift pins at the top of the piles lead to moisture access into the brightwood at the top of the pile and accelerated decay degradation, this also negatively affected the bearing area under the cap.*

@Seismicisolation

1.4 Ask John – Assessing a Timber Bridge

@Seismicisolation

1.7.8 Caps

@Seismicisolation

1.4 Ask John – Assessing a Timber Bridge

@Seismicisolation

1.5 Timber Bridge Investigation

@Seismicisolation

1.5.1 Bore Sounding

@Seismicisolation

1.5.1 Bore Sounding

@Seismicisolation

1.5.1 Bore Sounding

@Seismicisolation

1.5.1 Bore Sounding

@Seismicisolation

1.5.1 Bore Sounding

@Seismicisolation

1.5.2 Global Stiffness Methods

@Seismicisolation

1.5.2 Global Stiffness Methods

@Seismicisolation

1.5.2 Global Stiffness Methods

BENDING MOMENT

Nearly all bridge spans other than trusses carry loads over an opening using a bending moment. As a load is applied down on the span, a tension force develops in the lower section of the beam. An equal and opposite compression force develops in the upper section of the beam and together these two forces form the Moment Couple that carries the load across the opening.

@Seismicisolation

1.5.2 Global Stiffness Methods

Elemental Cube of Wood Subjected to Applied Vertical Shear Forces Stays in Equilibrium by Resisting Cube Rotation with Vertical and Horizontal Shear Resisting Stresses. The Horizontal Shear Stresses Typically Govern Unless The Timbers are Severely Degraded.

@Seismicisolation

1.5.2 Global Stiffness Methods

@Seismicisolation

1.5.2 Global Stiffness Methods

@Seismicisolation

1.5.3 Compression Through Wave Analysis Methods

@Seismicisolation

1.5.3 Compression Through Wave Analysis Methods

Example Using the Stress Wave Velocity Timer

The modulus of elasticity of the material is theoretically related to the velocity of the stress wave and the density according to Equation 1.

$$E = \frac{c^2}{\rho} \text{ ...Equation 1}$$

Where

E=Modulus of elasticity

c=Velocity of the stress wave

ρ=Density of the material

The stress wave timer calibration curve was created by measuring stress wave times on an existing glulam and then taking an assay sample with a core drill. Specific gravity of the assay samples was measured in a laboratory to develop the curve in Figure 1.

Figure 1: Stress wave timer calibration curve.

Table 10. Shockeroo Road Bridge #1 Stringer SWT Data

Distance measurements:	Metric	Temp:	DB = 23.2°C, WB = 11.9°C
Abutment 1 Direction:	NA	RH:	23%
		Depth of SWT:	Clock Position Looking A1 to A2
		Distance Along Stringer:	From Abutment 1 Side
		Pile Direction:	Clock- 6 towards Abutment 1

SWT > 1000: Red Highlight Shows Elements requiring immediate restoration or replacement (300mm guage length)

700 < SWT < 999: Yellow Highlight Shows Elements requiring caution in use frequent inspection (300mm guage length)

Span 1

		Length: 5.78m		Diameter: Ø400mm		(assumed)	MC: 5.20%		
Stringer 1	Start	0.6m	1.2m	1.8m	2.4m	3.0m	3.6m	4.2m	4.8m
3/9 raw	2000	1142	677	667	709	625	759	1196	864
3/9 adj	1500	857	508	500	532	469	569	897	648

		Length: 5.78m		Diameter: Ø400mm		(assumed)	MC: 5.80%		
Stringer 2	Start	0.6m	1.2m	1.8m	2.4m	3.0m	3.6m	4.2m	4.8m
3/9 raw	763	585	639	762	652	615	723	701	915
3/9 adj	572	439	479	572	489	461	542	526	686

		Length: 5.78m		Diameter: Ø400mm		(assumed)	MC: NA		
Stringer 3	Start	0.6m	1.2m	1.8m	2.4m	3.0m	3.6m	4.2m	4.8m
3/9 raw	1215	647	613	708	790	594	898	767	1407
3/9 adj	911	485	460	531	593	446	674	575	1055

		Length: 5.78m		Diameter: Ø400mm		(assumed)	MC: NA		
Stringer 4	Start	0.6m	1.2m	1.8m	2.4m	3.0m	3.6m	4.2m	4.8m
3/9 raw	902	946	680	730	830	1182	1646	1610	3951
3/9 adj	677	710	510	548	623	887	1235	1208	2963

Concrete Abutments: No Readings Taken

@Seismicisolation

1.6 Wood Deterioration

@Seismicisolation

1.6.1 Wood Deterioration Due to Biotic Agents

Brown Rot – Appears darker and can crack across the grain. Brown rot fungi attack the cellulose in the wood fibers. The brown color is due to the remaining lignin (the binder which holds the cellulose structure together), which is not consumed by the fungi. The decayed wood tends to form into small cubic shaped sections, which is a sign of advanced decay.

White Rot – Appears lighter in color and does not crack across the grain until severely degraded. In contrast to brown rot, white rot fungi consume both the lignin and cellulose and leave the surface appearing generally intact, but with little or no significant mechanical strength. The surface of the decayed wood tends to have a "white" appearance. White rot impacts longitudinal shear resistance and is very common in cross heads in North America which are often governed by applied longitudinal shear. The wood often appears cubed and cracked across ray or longitudinal cell lines.

@Seismicisolation

1.6.2 Effects of Fungal Decay on the Properties of Wood

@Seismicisolation

1.6.2 Effects of Fungal Decay on the Properties of Wood

@Seismicisolation

1.6.2 Effects of Fungal Decay on the Properties of Wood

@Seismicisolation

1.6.2 Effects of Fungal Decay on the Properties of Wood

@Seismicisolation

1.6.2 Effects of Fungal Decay on the Properties of Wood

@Seismicisolation

1.6.3 Detecting Deterioration

@Seismicisolation

1.6.3 Detecting Deterioration

@Seismicisolation

1.6.3 Detecting Deterioration

@Seismicisolation

1.6.5 Preventing Decay

@Seismicisolation

1.6.5 Preventing Decay

Decay prevention can be implemented by practicing just ten maintenance methods that will prolong the life of all types of wood structures, and facilitate continued maintenance:

@Seismicisolation

1) Replace all vertical connectors with horizontal side connectors
2) Stop the improper use of malthoid barrier
3) Ensure positive drainage away from the bridge
4) Provide for dimensional change due to change in moisture content
5) Stop the use of banding
6) Stop the use of near-end drift pinning
7) Provide proper clearance for timber elements to breathe
8) Stop the use of heavy percent solids paint on large dimension timber
9) Stop the use of heavy notching
10) Use proper sized timber in pile bents and place loads within D of pile

@Seismicisolation

1.7.1 Pile Identification

@Seismicisolation

1.7.3 Decayed and Cavitated Piles

@Seismicisolation

1.7.3 Decayed and Cavitated Piles

@Seismicisolation

1.7.3 Decayed and Cavitated Piles

@Seismicisolation

1.7.3 Decayed and Cavitated Piles

@Seismicisolation

1.7.3 Decayed and Cavitated Piles

@Seismicisolation

1.7.3 Decayed and Cavitated Piles

@Seismicisolation

1.7.3 Decayed and Cavitated Piles

Install fish plates and diffusers to finish the post.

@Seismicisolation

1.7.3 Decayed and Cavitated Piles

@Seismicisolation

1.7.3 Decayed and Cavitated Piles

@Seismicisolation

1.7.3 Decayed and Cavitated Piles

@Seismicisolation

1.7.3 Decayed and Cavitated Piles

@Seismicisolation

1.7.3 Decayed and Cavitated Piles

@Seismicisolation

1.7.4 Segment Posting

@Seismicisolation

1.7.4 Segment Posting

@Seismicisolation

1.7.4 Segment Posting

@Seismicisolation

1.7.4 Segment Posting

@Seismicisolation

1.7.4 Segment Posting

@Seismicisolation

@Seismicisolation

1.7.5 Dutchman's Patch

@Seismicisolation

1.7.5 Dutchman's Patch

@Seismicisolation

1.7.5 Dutchman's Patch

@Seismicisolation

1.7.5 Dutchman's Patch

@Seismicisolation

1.7.5 Dutchman's Patch

@Seismicisolation

1.7.5 Dutchman's Patch

@Seismicisolation

@Seismicisolation

@Seismicisolation

@Seismicisolation

1.7.6 Framing Pile Bents | Partial & Full

@Seismicisolation

1.7.6 Framing Pile Bents | Partial & Full

@Seismicisolation

1.7.6 Framing Pile Bents | Partial & Full

@Seismicisolation

1.7.6 Framing Pile Bents | Partial & Full

@Seismicisolation

1.7.6 Framing Pile Bents | Partial & Full

@Seismicisolation

1.7.6 Framing Pile Bents | Partial & Full

@Seismicisolation

1.7.8 Caps

@Seismicisolation

1.7.8 Caps

@Seismicisolation

1.7.8 Caps

@Seismicisolation

1.7.8 Caps

@Seismicisolation

1.7.8 Caps

@Seismicisolation

1.7.8 Caps

@Seismicisolation

1.7.8 Caps

@Seismicisolation

1.7.8 Caps

@Seismicisolation

@Seismicisolation

1.7.8 Caps

@Seismicisolation

1.7.8 Caps

@Seismicisolation

@Seismicisolation

1.7.8 Caps

@Seismicisolation

1.7.8 Caps

@Seismicisolation

@Seismicisolation

1.7.8 Caps

@Seismicisolation

1.7.8 Caps

	Pile Load (kips)			P1 Right	P2 Left	P2 Right	P3 Left
Pile Restraint Condition	P1 (X)	P2 (Xb)	P3 (Xa)	3V/2A (psi)	3V/2A (psi)	3V/2A (psi)	3V/2A (psi)
AREMA Pile Calcs:	3.9	24.0	32.3	32	24	30	162
Multiframe Fixed:	6.9	23.9	29.4	57	49	54	138
Multiframe Springs P2-P5 200 K/in:	14.8	19.1	26.3	122	114	79	113
Multiframe Springs P2-P5 70 K/in:	24.3	14.8	21.1	200	192	122	70
Multiframe Springs P2-P5 50 K/in:	28.4	13.1	18.7	234	226	141	51
Multiframe Springs P2-P5 25 K/in:	37.4	9.3	13.5	308	300	185	7

@Seismicisolation

1.7.8 Caps

@Seismicisolation

1.7.8 Caps

@Seismicisolation

1.7.8 Caps

@Seismicisolation

1.9.1 Driving Piles

@Seismicisolation

1.9.1 Driving Piles

@Seismicisolation

1.9.1 Driving Piles

@Seismicisolation

1.9.1 Driving Piles

@Seismicisolation

1.9.1 Driving Piles

@Seismicisolation

1.10.1 Chords

@Seismicisolation

@Seismicisolation

1.10.1 Chords

@Seismicisolation

1.10.1 Chords

@Seismicisolation

@Seismicisolation

Handbook of Conventional Maintenance Practices

@Seismicisolation

1.10.2 Stringers

@Seismicisolation

1.10.2 Stringers

@Seismicisolation

1.10.2 Stringers

@Seismicisolation

1.10.2 Stringers

@Seismicisolation

1.10.2 Stringers

@Seismicisolation

1.10.2 Stringers

@Seismicisolation

@Seismicisolation

1.10.2 Stringers

@Seismicisolation

1.10.2 Stringers

@Seismicisolation

1.10.2 Stringers

@Seismicisolation

1.10.2 Stringers

@Seismicisolation

1.10.2 Stringers

@Seismicisolation

1.12.1 Ballast Tray Restoration

@Seismicisolation

1.12.2 Ballast Guard Restoration

@Seismicisolation

1.12.3 Bridge Tie Restoration

@Seismicisolation

1.13 High Speed Replacement Methods

@Seismicisolation

1.13.1 Piles

@Seismicisolation

1.13.2 Caps

@Seismicisolation

1.13.4 Stringers

@Seismicisolation

1.14 Article on Timber Connections

@Seismicisolation

Handbook for Conventional Maintenance Practices for Railroad Bridges
The Right Tool…

Concrete Chapter

2.1 Introduction
2.2 Structural Properties of Concrete
2.3 Common Causes of Degradation in Concrete
2.4 Basic Requirements of a Quality Repair
2.5 Diagnosis of Deterioration in Concrete Structures
2.6 Restoration Methods
2.7 Underwater Repair of Concrete
2.8 Rapid Cure Concrete
2.9 Ask John – Comparison of Concrete Repair Methods
2.10 Ask John – Quality Assurance in Concrete Construction
2.11 Ask John – Fiber Reinforcement in Concrete
2.12 Ask John – Downstream Head Cut
2.13 Article – Fire Resistance of Wood vs. Concrete Construction
2.14 Article – Is the 90 Minute Delivery Time for Concrete Still Applicable

@Seismicisolation

Handbook for Conventional Maintenance Practices for Railroad Bridges

@Seismicisolation

2.1 Introduction

- Guide from AREMA Committee 10
- Maintenance and repairs to concrete railroad bridges.
- References:
  - Portland Cement Association
  - American Concrete Institute
  - Guide to Concrete Repair, United States Department of the Interior, Bureau of Reclamation
  - AREMA Chapter 8

@Seismicisolation

2.2 Structural Properties of Concrete

- Strong in compression, weak in tension
  - Great for supports and axial loads
  - Requires steel reinforcement for bending and movement
- Weight limits length height
  - New technologies - composite beams and light weight reinforcement
- Strength determined by
  - The proportion and quality of ingredients
  - Mixing and placement
  - Curing methods used

@Seismicisolation

2.3 Common Causes of Degradation

- Excess Mix Water / Construction Defects
- Faulty Design Sulfate Deterioration
- Alkali-Aggregate Reaction
- Cyclic Freeze-Thaw
- Abrasion-Erosion Damage
- Corrosion of Reinforcing Steel
- Acid Exposure
- Over Loading
- Vehicle Impact

@Seismicisolation

2.5.4 Determine the Cause for Damage or Deterioration

@Seismicisolation

2.5.5 Evaluate the Extent of Damage or Deterioration

@Seismicisolation

2.5.6 Evaluate the Need for Repair

- Not all damage or deterioration requires immediate repair.
  - Cosmetic cracking/shrinkage cracking
- Structural cracking usually warrants immediate attention.
- Any damage or deterioration that exposes the reinforcement steel to corrosion, or loosens the concrete support, should be investigated further and restored

@Seismicisolation

2.5.7 Select the Repair Method

- Surface Grinding
- Portland Cement Mortar
- Dry Pack and Epoxy-Bonded Dry Pack
- Preplaced Aggregate Concrete
- Shotcrete
- Polyurea Aggregate Mixtures
- Replacement Concrete
- Epoxy-Bonded Epoxy Mortar
- Epoxy-Bonded Replacement Concrete
- Polymer Concrete
- Thin Polymer Overlays
- Resin Injection
  i. Epoxy resins
  ii. Polyurethane resins
- Polymer Surface Impregnation
- Silica Fume Concrete
- Alkyl-Alkoxy Siloxane Sealing Compound

@Seismicisolation

2.5.8 Prepare the Existing Concrete

- Typically, all unsound concrete should be removed remaining concrete cleaned.
  - Hydroblasting, bush-hammering, scrabbling, jack-hammering and sand-blasting.
- Saw cutting cut the perimeter and avoid feather edges or sharp corners.
- Reinforcement steel should be carefully cleaned or replaced to remove all rust, scale, corrosion and bonded concrete.
- Always avoid free water on the prepared surface.

@Seismicisolation

2.5.9 Apply the Repair Method and Cure

- Apply chosen repair method as per design
- Follow all the appropriate procedures.
- Ensure proper mixing of components and temperatures
- Monitor formwork during material placement
- Follow recommended curing procedures and times

@Seismicisolation

2.6 Article on Concrete Delivery Times

The first documented use of ready-mix concrete occurred in 1913, the first modern concrete truck was developed in 1916, and the popularity of ready-mixed concrete as a building material greatly accelerated in the 1920s. The popularity of ready-mixed concrete increased, but the low power output of early motorized mixers prolonged delivery times, and in 1935 the American Society for Testing and Materials (ASTM) wrote the C94 standard. Part of the C94 standard required concrete be discharged within 90 minutes.

Many railroads began using ready-mixed concrete in the 1930s and quickly adopted the ASTM C94 standard once it came out in 1935. Since then, AREMA and most railroads have adopted some version of the ASTM C94 standard. Neither modern mixing trucks nor chemical admixtures were in use when the 90-minute time limit was established in 1935. Have these developments reduced the need for the strict 90-minute time limit?

@Seismicisolation

2.6.1 Concrete Strength

- Concrete
  - Aggregate - crushed rock (filler)
  - Cement paste - cement and water (glue)
- Hydration - concrete cement powder reacts with water to form a gel that hardens as it dries
  - Water that is not absorbed by the cement
    - absorbed by the aggregate OR evaporates and leaves microscopic holes
- Low cement-to-water ratio
  - fewer microscopic holes
  - stronger concrete
  - loses flowability
  - incomplete compaction -> reduction in final compressive strength

@Seismicisolation

2.6.1 Concrete Strength

- Admixtures
  - allow for lower water-to-cement ratios
  - aids in complete compaction of the concrete
  - fly ash
  - chemical admixtures
- Water Reducing admixtures
  - will increase the slump with less water
- Retarding admixtures
  - slow the hardening of placed concrete.

@Seismicisolation

2.6.2 Overview of Maximum Travel Time Requirement

- ASTM C 94
  - limitations on 'travel plus wait time'
  - Based on field observations
  - maximum mixer revolutions
  - written in the 1930s has not changed
  - Discharge within 1.5 hours
  - Discharge before 300 revolutions
  - can be waived if slump is achieved without additional water
  - free water is reduced during transportation and mixing
    - decreases slump and workability
    - Low slump -> low compaction
    - adding water -> High w/c ratio

@Seismicisolation

2.6.3 Modern Water Reducing and Retarding Admixtures

- Water reducing and retarding admixtures - delay the stiffening of concrete/improve flowability
  - for high mix times and low RPM
- mechanism behind the delay is not fully understood
- The effectiveness of water reducing and retarding admixtures should not be relied upon to allow extended transportation times

@Seismicisolation

2.6.4 Is the Current 90 Min Requirement Relevant Today

- YES
- Admixtures *may* add 30 minutes of transit time
- Not worth cost of installing substandard batch

@Seismicisolation

2.8.1 Types of Cracking

@Seismicisolation

2.8.1 Types of Cracking

@Seismicisolation

2.8.1 Types of Cracking

@Seismicisolation

2.8.1 Types of Cracking

@Seismicisolation

2.8.1 Types of Cracking

@Seismicisolation

2.8.1.4 Low Strength Concrete

- Concrete variable throughout depth
- Low compression concrete may be in place
- Concrete cores can be analyzed
- Check with an Engineer for sizing and placement of holes
- Document sample locations

@Seismicisolation

2.8.1.4 Low Strength Concrete

@Seismicisolation

2.8.1.4 Low Strength Concrete

@Seismicisolation

2.8.2 Spalling and Delamination

@Seismicisolation

2.8.2 Spalling and Delamination

@Seismicisolation

2.8.2 Spalling and Delamination

@Seismicisolation

2.8.3 Reactivity and Corrosion

Alkali-Aggregate reaction (AAR) is a chemical reaction between ions associated with alkalis (sodium and potassium) present in Portland cement and certain mineral phases present in some coarse and fine aggregates.

Alkali-Silica Reaction (ASR) –

Reaction between the alkalis and certain siliceous rocks or minerals

chert, strained quartz, and acidic volcanic glass.

May cause abnormal expansion due to the production of an alkali-silica solution or gel

absorbs water from the cement paste and external moisture

Requires reactive silica, alkali, and moisture.

Alkali-Carbonate Reaction (ACR) –

Defined as the reaction between the alkalis and certain carbonate rocks

calcitic dolomite and dolomitic limestones such as Calcite Dolomite and Magnesite.

Reaction can causes abnormal expansion and cracking of the concrete in service due to production of hydroxides and converting dolomite into Burcite and Calcite and swelling under the accretion of moisture.

@Seismicisolation

2.8.3 Reactivity and Corrosion

- Condition survey - ACI 201.1R
  - medium to wide linear cracks
  - Delamination detected by sounding
  - high severity spalling
  - pattern cracking
  - efflorescence
- Cores obtained from testing
  - Characterization of concrete
    - Petrographic analysis
    - Scanning Electron Microscopy (SEM)
  - expansion potential of the aggregates
    - Humidity response
    - Chloride content
    - Alkali compounds
- The lab confirmed AAR (ACR)

@Seismicisolation

2.9.2 Guniting or Shotcrete

@Seismicisolation

2.9.2 Guniting or Shotcrete

@Seismicisolation

2.9.2 Guniting or Shotcrete

@Seismicisolation

2.9.2 Guniting or Shotcrete

@Seismicisolation

2.9.2 Guniting or Shotcrete

@Seismicisolation

2.9.2 Guniting or Shotcrete

@Seismicisolation

2.9.3 Epoxy Injection

@Seismicisolation

2.9.3 Epoxy Injection

@Seismicisolation

2.9.3 Epoxy Injection

@Seismicisolation

2.9.5 Structural Concrete Repair

@Seismicisolation

2.9.5 Structural Concrete Repair

@Seismicisolation

2.9.5 Structural Concrete Repair

@Seismicisolation

2.9.6 High Strength Fiber Wrapping

@Seismicisolation

2.9.6 High Strength Fiber Wrapping

@Seismicisolation

2.9.6 High Strength Fiber Wrapping

@Seismicisolation

2.9.6 High Strength Fiber Wrapping

@Seismicisolation

2.9.6 High Strength Fiber Wrapping

@Seismicisolation

2.9.6 High Strength Fiber Wrapping

@Seismicisolation

2.9.6 High Strength Fiber Wrapping

@Seismicisolation

2.10.2 Large Scale Repair of Structural Concrete

@Seismicisolation

2.10.2 Large Scale Repair of Structural Concrete

@Seismicisolation

2.10.2 Large Scale Repair of Structural Concrete

@Seismicisolation

2.10.5 Steel Sleeve Repairs

- Permanent formwork
- Filled with concrete from the bottom-up
- The sleeve must be design to withstand the forces exerted on the pile
- The interior steel reinforcement may no longer be capable of carrying the required load

@Seismicisolation

The right tool

A HANDBOOK

On Conventional Maintenance Practices

Three chapters treating Timber, Concrete & Steel

Steel Chapter

3.1	Introduction
3.2	Structural Properties of Steel
3.3	Common Causes of Degradation in Steel
3.4	Welding Practices and Procedures
3.5	Rivet Removal and Bolting
3.6	Installation of High Strength Bolts
3.7	Top & Bottom Flange Angle Repair
3.8	Stiffener Repair
3.9	Web Corrosion Repair
3.10	Connector Repair
3.11	Bearing Maintenance and Repair
3.12	Crack Repair
3.13	*Ask John – Replacing Rivets*
3.14	*Ask John – Rivet Strength vs. Bolt Strength*
3.15	*Ask John – Fire Damaged Steel Deck*
3.16	*Ask John – Inspection of High-Strength Bolts*
3.17	*Ask John – Underwater Repair of Steel Piles*
3.18	Article on Tension Indicators for High-Strength Bolting

@Seismicisolation

SAFETY

Safety is much more than having a safety meeting before each days work each day. Safety begins with the mindset of each individual but must be cultivated and required by the supervision all the way up to the ownership of the company. Working at heights and on railroads is recognized as a hazardous environment. Some studies have indicate one of biggest causes of accidents is complacency.

Safety is ALWAYS the first consideration when planning any work.

@Seismicisolation

STEEL

@Seismicisolation

3.1 Introduction

Steel bridges are, perhaps, the best candidates for life extending maintenance. Steel bridges older than 120 years are still being strengthened to extend the useful life for many years to come.

@Seismicisolation

3.2 Structural Properties of Steel

It is essential that properties of the steel in an existing structure be determined before permanent repairs are begun. Since existing railroad bridge have such a long life the steel can easily vary from Cast Iron to 50KSI weathering steel. Consideration must be given to interactions between different types of steel and the surrounding environment when selecting not only the steel from the repair but also the type of fastening material to insure compatibility.

@Seismicisolation

3.3 Common Causes of Deterioration in Steel

@Seismicisolation

3.3 Common Causes of Deterioration in Steel

@Seismicisolation

3.4 Welding Procedures

All welding must be accomplished by a certified
structural welder. Weld verification should be
Accomplished using an approved NDT method.
Random testing on rotating days and times of the
Day is recommended for testing.

@Seismicisolation

Identification of Deterioration in Steel Structures

@Seismicisolation

Identification of Deterioration in Steel Structures

@Seismicisolation

Identification of Deterioration in Steel Structures

Lines of red on the surface indicate movement of
the connection parts and or working and loosening
of the rivets

@Seismicisolation

Identification of Deterioration in Steel Structures

@Seismicisolation

3.5 Bolts to Replace Rivets

When burning rivet heads off with a torch, great care must be maintained to prevent damaging the structural components.

@Seismicisolation

Torch Cutting Rivet Heads

@Seismicisolation

Bolts to Replace Rivets

Rivets were installed hot and malleable to facilitate the process of producing the rivet head. The holes in the components did not (and usually were not) have to be perfectly aligned. This mis-alignment makes reaming of the hole required to fit a perfectly round bolt. Holes must NEVER be torch but to facilitate bolt installation.

@Seismicisolation

Bolts to Replace Rivets

@Seismicisolation

Bolts to Replace Rivets

@Seismicisolation

3.6 Installation of High Strength Bolts

Table 15-3-2. Minimum Tension of Installed Bolts		
Nominal Bolt Size–Inches	Minimum Tension in Kips	
	A325 Bolts	A490 Bolts
1/2	12	15
5/8	19	24
3/4	28	35
7/8	39	49
1	51	64
1-1/8	56	80
1-1/4	71	102
1-3/8	85	121
1-1/2	103	148

TENSION TESTER MODEL	BOLT ASSEMBLY PART NO.	TEST BOLT SIZE	HEX SOCKET (IN)	MAXIMUM "NORM" (LBF)	TORQUE "FACTOR"	MAX. TORQUE (FT*LB)	MAX. TORQUE (NM)
S	S-105	5/16	3/8	5,000	250	20	27
J	J-110	5/8	9/16	20,000	150	130	176
J	J-114	7/8	7/8	30,000	105	300	407
M, ML, RL	R-112	3/4	1-1/4	40,000	120	350	475
M, ML, RL	R-116	1	1-1/2	70,000	90	800	1,085
M, ML, RL	R-120	1-1/4	2	110,000	70	1,500	2,034
H	H-112	3/4	1-1/4	40,000	120	350	475
H	H-116	1	1-1/2	70,000	90	800	1,085
H	H-120	1-1/4	2	110,000	70	1,500	2,034
H	H-124	1-1/2	2-3/8	170,000	60	2,800	3,797
K	K-120	1-1/4	2	110,000	70	1,500	2,034
K	K-124	1-1/2	2-3/8	170,000	60	2,800	3,797
K	K-128	1-3/4	2-3/4	225,000	50	4,500	6,102
K	K-132	2	3-1/8	225,000	45	5,000	6,780
K	K-140	2-1/2	3-7/8	225,000	35	6,400	8,678

@Seismicisolation

Bolting

Table 15-3-3. Nut Rotation from Snug Tight Condition			
Bolt Length (as measured from underside of head to extreme end of point)	Condition of Outer Faces of Bolted Parts		
	Both faces normal to bolt axis.	One face normal to bolt axis and other sloped not more than 1:20 (bevel washer not used)	
Up to and including 4 diameters	1/3 turn	1/2 turn	
Over 4 diameters but not exceeding 8 diameters	1/2 turn	2/3 turn	
Over 8 diameters but not exceeding 12 diameters (Note 2)	2/3 turn	5/6 turn	

Note 1: Nut rotation is relative to bolt regardless of the element (nut or bolt) being turned. For bolts tightened by one-half turn or less, the tolerance is ± 30 degrees; for bolts tightened by two-thirds turn or more, the tolerance is ± 45 degrees.
Note 2: Where the bolt length exceeds 12 diameters, the required rotation shall be determined by actual tests in a suitable tension device simulating actual conditions.

@Seismicisolation

Bolts to Replace Rivets

If H.S. bolts are to be tightened with an impact tool, the impact wrench must be calibrated each day and checked with a torque wrench. A random number of bolts in random locations should be double checked with a torque wrench each day.

@Seismicisolation

Tension Calibration

@Seismicisolation

Twist Off Type Tension Control Bolt Tensioning

- Twist-off-type tension-control bolt assemblies that meet the requirements of ASTM F1852 shall be used.
- An installation verification test specified in Section 3.3.4 shall be performed prior to bolt installation.
- All fastener assemblies shall be installed in accordance with the requirements of Section 3.2 without severing the splined end and with washers positioned as required in Section 3.3. If a splined end is severed during snugging, the fastener assembly shall be removed and replaced. Subsequently, all the bolts in the joint shall be tensioned with the twist-off-type tension-control bolt installation wrench, progressing systematically from the most rigid part of the joint in a manner that will minimize relaxation of the previously tensioned bolts.

Twist-off Bolts

@Seismicisolation

Direct Tension Indicators

All bolts shall be installed with the washers positioned as follows:

- When the nut is turned and the direct-tension-indicator is located under the bolt head, an ASTM F436 washer shall be used under the nut;
- When the nut is turned and the direct-tension-indicator is located under the nut, an ASTM F436 washer shall be used between the nut and the direct-tension-indicator;
- When the bolt head is turned and the direct-tension-indicator is located under the nut, an ASTM F436 washer shall be used under the bolt head;
- When the bolt head is turned and the direct-tension indicator is located under the bolt head, an ASTM F436 washer shall be used between the bolt head and the direct tension indicator.

@Seismicisolation

Tension Indicator Bolt Heads

@Seismicisolation

Restoration Procedure

@Seismicisolation

Additional Information

For much more information, please consult AREMA chapter 15 sections 3 and 4 regarding steel fabrication and erection, and the Research Council on Structural Connections "Specifications for Structural Joints Using High-Strength Bolts".

@Seismicisolation

3.12 Crack Repair

@Seismicisolation

IDENTIFYING THE EXTENT OF A CRACK

@Seismicisolation

Crack Repair

@Seismicisolation

3.11 Bearing Repair

@Seismicisolation

Jacking Frames

@Seismicisolation

Jacking Operations

@Seismicisolation

Engineering Considerations

Budget and cost considerations are part of any project. To the extent possible engineering considerations should always be high on the priority list. Some of these considerations are:

1. Current requirements to bring the structure in to a safe mode for current speed and loading.
2. Expected life cycle of the structure.
3. Anticipated future speed and loading requirements.

North American Bridges in the early to middle of the of last century were designed for 263k axle loadings with steam impact. As steam engines were phased out loading was increased to 286k with diesel impact. With the proliferation of double stack, articulated, unit trains now the norm is for 315k loadings. I could spend the rest of my allotted time with a discussion between Coopers ratings and design and actual railroad consists.

@Seismicisolation

Safe Access

@Seismicisolation