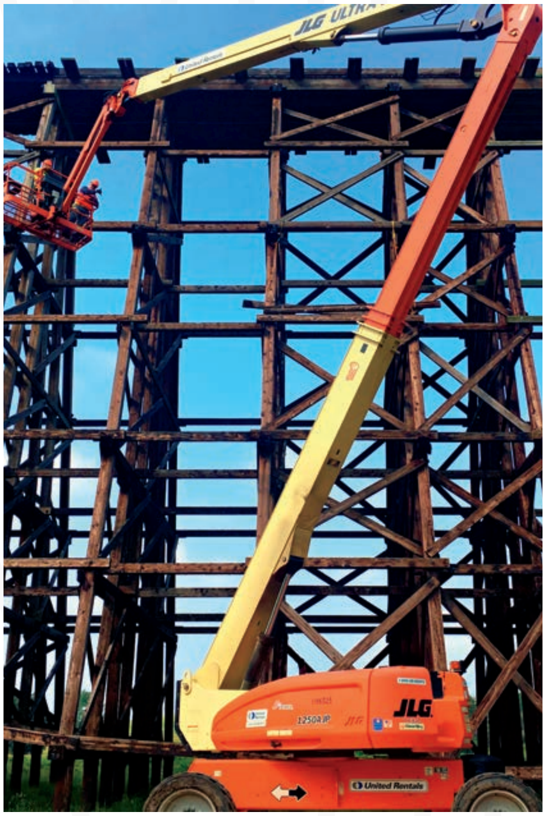
CAPABILITY PRESENTATION

INSPECTION | DESIGN | RESTORATION



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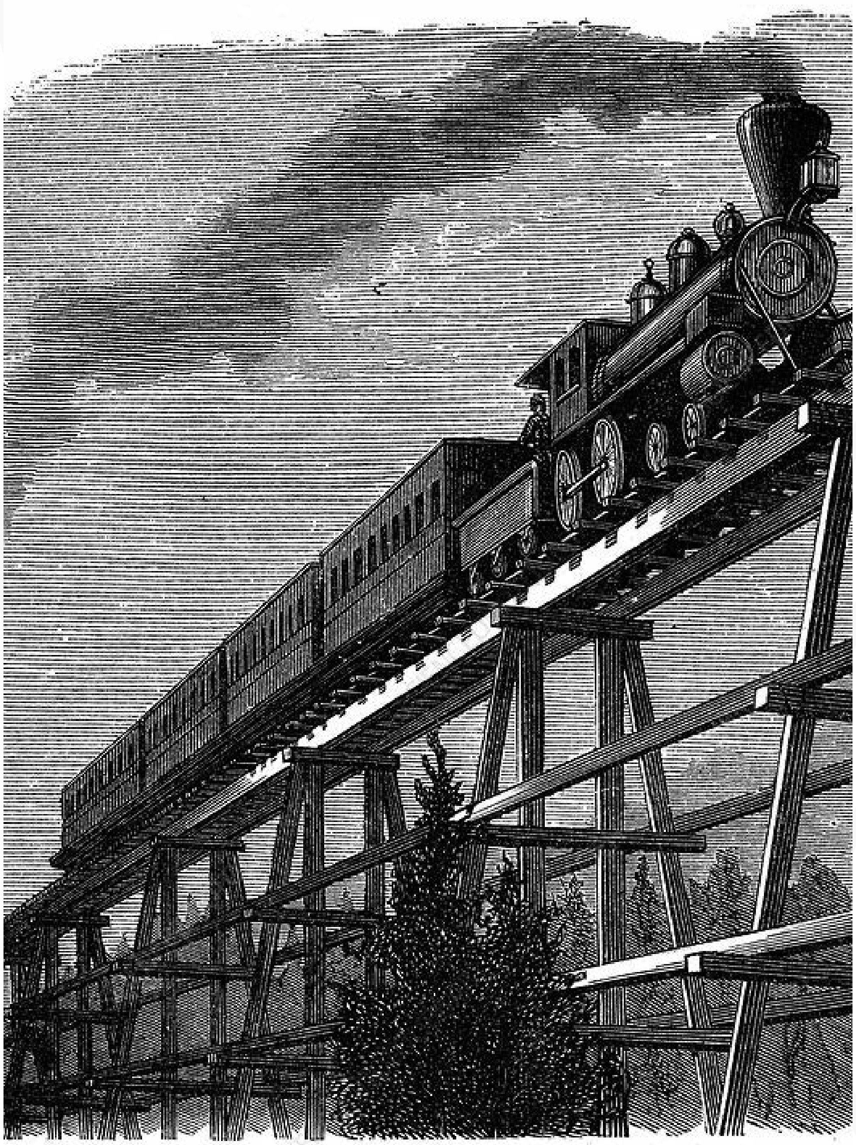
INTRODUCTION

Founded by Dr. Dan Tingley, the history of Wood Research and Development (WRD) began in 1984 as Wood Science and Technology Institute and was dedicated to the promotion and preservation of timber structures.

In 2000 Dr. Tingely reorganized Wood Science and Technology Institute into Advanced Research and Development (ARD). ARD became the parent company for Wood Research and Development (WRD) and Timber Restoration Services (TRS).

WRD would become the research, inspection, and design arm and TRS would become the construction and restoration arm of ARD.That when working together would be able to hand a structure back to it's owner stronger and renewed to it best state possible.



ABOUT US

Since the inception of Wood Research and Development (WRD), the company has become a leader in the timber structure industry by developing and implementing advanced timber inspection, repair, and replacement methods. With over 42 patents on record, Dr. Tingley and the team at WRD have designed multiple high-strength, lightweight, long-life timber restorations and new structures on almost every continent in the world.

Timber Restoration Services (TRS) specializes in the restoration and /or replacement of large timber structures, implementing the designs of Wood Research and Development (WRD). Our IAS Accredited, Certified Level II Advanced Timber Technician Crews work world-wide restoring and replacing everything from Rail, Vehicle and Pedestrian bridges to buildings and water structures. No job is too big or small.

Specializing in Both Green-field (New) and Brown-field (Existing) the two companies combined provide unmatched knowledge and experience to provide first class service to our clients.

WRD – WHAT WE OFFER

Timber Inspection | Our non-destructive inspection methods, using EPHOD™ Stress Wave Technology, offers a quick, efficient and accurate method of testing and mapping the structural condition of timber elements without damaging the element such as traditional methods: ie boring holes. To ensure accurate, high quality inspection results, WRD employs IAS Accredited, Certified Level II Advanced Timber Technicians.

Timber Design | From new construction to repairing existing structures, WRD offers unique solutions and full design services for timber structures. In Brown-Field sites, with the use of light weight high strength fibre, WRD has been able to accomplish astonishing feats, restoration in-situ, increasing element capacity, extending life of elements up to 100+ years. WRD always has the public and community in mind on brown field restorations, our non-invasive restorations focus on a reduced footprint, allowable traffic loads (often throughout the duration of the job), Aesthetically minded, reduced construction schedule.

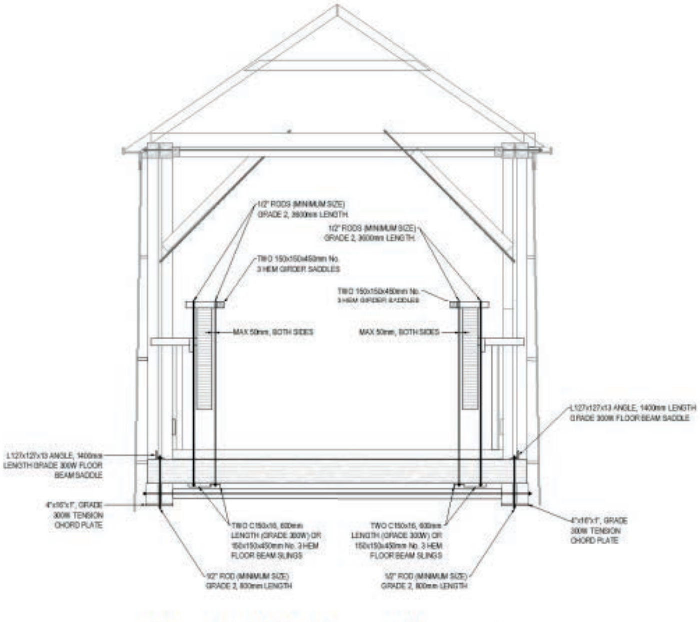


Figure 3-1 Lifting beam and lift apparatus

Lift Aparatis Design for Bayswater Covered Bridge Restoration

WRD – WHAT WE OFFER

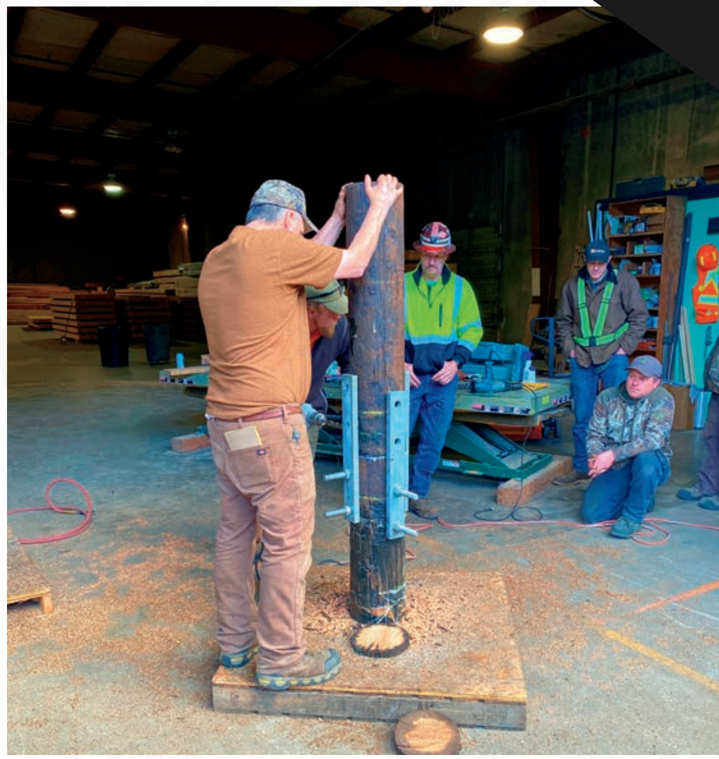
Timber Design | The design work WRD has been able to accomplish on Green-Field sites has been nothing short of astonishing. An example of this is the Roger Bacon Bridge in Amherst, NS, it is a 4-time award winning timber bridge and the longest clear span 3 lane timber bridge in Canada. Similar to Brown-Field sites these light weight structures are non- invasive and leave a minimal construction footprint during install.

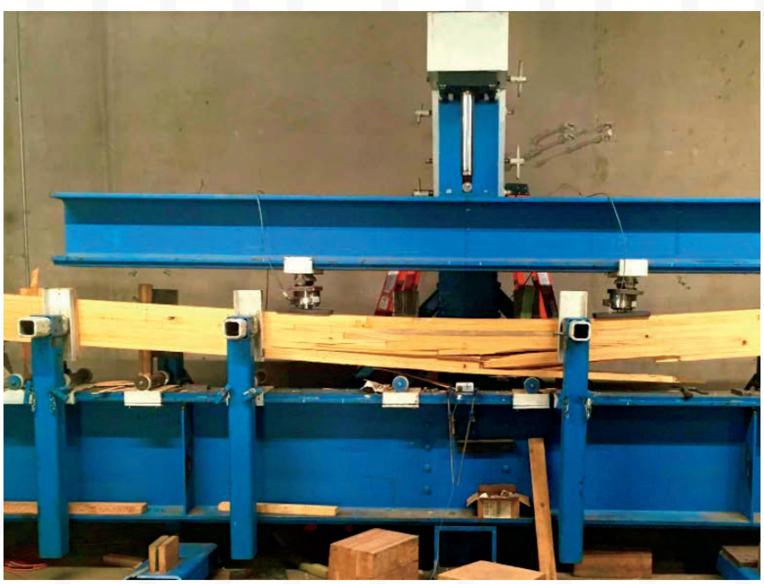
Photo to the right shows 80 year old piles being prepared for the installation of the new bridge

4-time award winning Roger Bacon Bridge, Amherst, Nova Scotia

WRD – WHAT WE OFFER

Training | WRD offers 16 different courses to train individuals in timber bridge inspection, design, maintenance, and retrofit. The various courses are custom tailored for bridge maintenance workers, inspectors, engineers, owners, consultants and asset managers. In the various classes, the students are taught how to perform and analyze non-destructive testing, beam performance with and without High strength reinforcement, inspect bridges, install high strength reinforcement, Maintenance techniques, calculations and much more!





Big Blue Beam Tester

Timber Testing | WRD is an IAS certified test laboratory, third part quality assurance agency, and American Lumber Standards Committee approved test laboratory specializing in advanced wood testing and forensic analysis as well as new product testing and development. These services allow WRD to help clients better understand the condition of their timber structure and develop a practical repair solution.

TRS – WHAT WE OFFER

Timber Bridge Restoration| Timber Restoration Services (TRS) uses unique, patented methods to get the job done. Methods such as pile posting, pile wrapping, dutchman's patches, epoxy injection, diffusing, High strength reinforcement to elements such as piles, girders, caps, decks, guardrails, beams, columns, etc. This method of restoration is extremely efficient and cost effective, at roughly 15% the cost of a new concrete structure it also allows the asset managers to extend the life of their asset without having to replace it or close it down for an extended period of time.

Patented Products | Patented material products used in TRS restoration include, but not limited to:

- **FiRP®** -Fiber reinforced polymer technology. FiRP® Fiber reinforced polymer Panels are thin laminates (0.07 -0.05 in) composed of high strength fibers oriented parallel to the strength axis.
- (0.07 in) composed of high strength fibers oriented parallel to the strength axis.
- **Retroten®** -Reinforced Polymer (RP) laminated to Lamstock. Used to restore or increase/reinforce the tension face of an element, it consists of 1 single layer of RP up to 500' long and 12 inches wide.
- **Retroshear®**- High Strength Fiber Panels laminated between plywood - ½", 1", 2". Used to restore or increase the shear capacity in elements
- **Retrocom® Reinforcement** - There are many different forms of Retrocom® Reinforcement, It is used to reinforce or restore the compression face of an element
- **Structurfill®** Epoxy2 part slow cure epoxy with a strength of 90MPA. There are two different versions of this, Both High viscosity (HV) and Low viscosity (LV).
- **Decaystop®**- is used to Neutralize the acidic PH wave in a timber fungal colony. Essentially, the rod is drilled into the timber element, once the element reaches a moisture content of 18%-19% the rod will start to deplete allowing the brine to leech into the wood, this will prevent the wood from decay caused by fungus.

TRS - WHAT WE OFFER

Manufacturing | Timber Restoration Services (TRS) strives to provide clients with the high level of workmanship and quality possibly. Holding an ISO 9001 certification, TRS Operates within an extensive Quality assurance and Quality Control program. Whenever possible the structure is manufactured and assembled in raw stock, the structure is then dismantled, the wood is sent for treatment and the steel sent for galvanizing. This method ensures an expedited installation on site as well as dramatically increasing the longevity of the structure. Once the components are shipped to the project site, our crews go to work quickly installing the lightweight timber structures.

Lantz Bridge - Manufacturing

Accelerated Installation | For new bridges, Timber Restoration Services starts the process in our manufacturing plant. Here the bridge is manufactured and assembled. This helps ensure a quick and efficient installation on site. Treated wood stays treated by not exposing bright wood and everything is quickly bolted together. TRS Crews specialize in accelerated installation due to the unique method used to manufacture the structure, this allows preassembly of components and quick installation on site, designed to minimize down time for clients.

Lantz Bridge - Installation

PROJECT OVERVIEW

Wood Research and Development and Timber Restoration Services have worked on multiple projects for Canadian National Railroad.

Following is a list of the CNR projects:

- **Rochfort Bridge Retrofit**
- **Dawson Creek Bridge**
- **Val d'or Sub MP 41.4 Inspection**
- **Sorel Sub MP 22.6 Inspection**
- **Brazeau Sub MP 74.1 Retrofit**
- **Brazeau Sub MP 62.2 Retrofit**

CNR PROJECT SAMPLES

ROCHFORD BRIDGE

The Rochfort Bridge, built in 1914, is the largest rail bridge in North America. at 736 meters long and 33.5 meters high.

The original plan for the Rochfort Bridge was to replace 4 caps and 30 intermediate sills, kind for kind with a timeframe of 3 months. WRD designed a restoration using our unique, patented methods, cutting the timeframe to 3 weeks. This resulted in huge savings for the Rail Line and gave the restored components a new lifespan of almost double of traditional methods.

Timber Restoration Services (TRS) Certified Technicians installed shear panels and injected Sturcturfill® into the areas that were determined to have voids in the inspection. Once the injection is completed the drill holes are plugged with plastic plugs. Finally, salt rods were installed to help control control the acidic PH wave in the timber elements due to high moisture in the components. Piles showing signs of decay were wrapped using a fiber wrap and then injected with Structurfill® Epoxy and diffused as well.

CNR PROJECT SAMPLES

ROCHFORD BRIDGE

The immense size of this rail bridge meant that both scaffolding and snorkel lifts were used by the crew to access the areas they were working on. Many portions required work from the platform of the snorkel lift.

Rail services were never halted during the duration of the restoration. The rail line was able to operate without any delays or any stoppages and were able to cross regularly on their intended schedule.

CNR PROJECT SAMPLES

ROCHFORD BRIDGE

Tier 3 Sill, Pile Bent 93, Pile 1

This photo shows the nomenclature used during inspection to label all elements using a systematic method to inspect the entire structure. This method is used for all structure inspections to provide information for processing the data collected. This will allow the engineering team to pinpoint the location of the element and develop bulleted design repairs for the elements that require it. Once the repair design is completed the restoration crew will use the labelling system to identify the elements requiring repair.

CNR PROJECT SAMPLES

ROCHFORD BRIDGE

Readings are taken with the use of EPHOD® Stress Wave Technology (SWT) to determine areas of degradation in the structure With this information a report is produced in which engineers make recommendations and provide a detailed design for the areas requiring attention.

Bent 93

3		Length :							Type :	Square	
Location :	14 in	36 in	80 in	116 in	139 in	167 in	194 in	224 in	240 in	263 in	285 in
Width :	11.75	11.75	11.75	11.75	11.75	11.75	11.75	11.75	11.75	11.75	11.75
? Raw - Top Sill L/R	595	277	373	263	270	298	1302	699	456	332	0
? Adj - Top Sill L/R	608	283	381	269	276	304	1330	714	466	339	0
Raw - Top Sill L/R	314	292	283	310	279	333	1047	763	298	352	275
Adj - Top Sill L/R	321	298	289	317	285	340	1069	779	304	359	281
	P1			P2			P3			P4	
Note :											

3														
Location :	300 in	336 in	349 in	370 in	390 in	412 in	444 in	470 in	495 in	520 in	550 in	595 in	615 in
Width :	11.75	11.75	11.75	11.75	11.75	11.75	11.75	11.75	11.75	11.75	11.75	11.75	11.75
? Raw - Top Sill L/R	0	0	0	304	431	633	408	316	377	490	516	581	369
? Adj - Top Sill L/R	0	0	0	310	440	646	417	323	385	500	527	593	377
Raw - Top Sill L/R	314	397	397	274	660	926	590	346	392	381	301	382	384
Adj - Top Sill L/R	321	405	405	280	674	946	603	353	400	389	307	390	392
	Lap Joint		P5			P6			P7			P8	

Tier 3 Sill Left		Length :					
Location :	Bottom	12 in	24 in	36 in	48 in	60 in	72 in
Width :	11.75	11.75	11.75	11.75	11.75	11.75	11.75
? Raw	1177	1730	2028	561	709	416	646
? Adj	1202	1767	2071	573	724	425	660
Raw	5809	6042	5821	1202	1046	811	1010
Adj	5933	6171	5945	1228	1068	828	1031
Note :	CN Approved Added to Scope.						

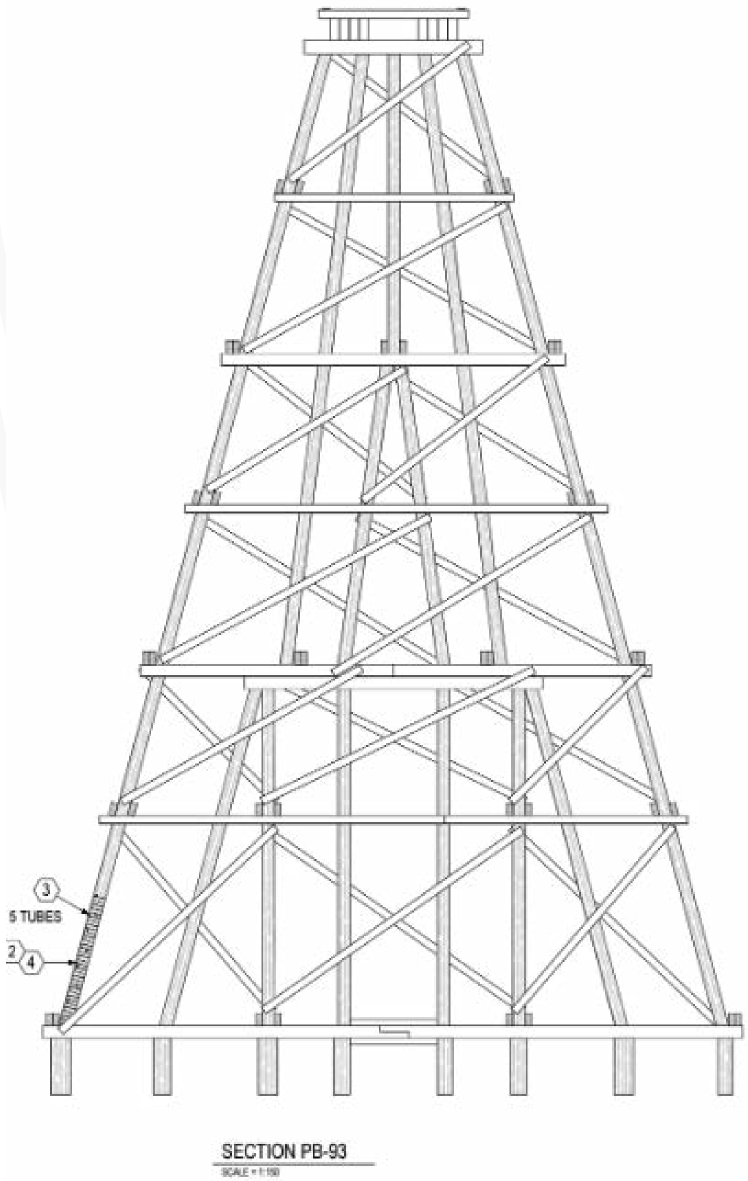
Type : Square

Above is the EPHOD® Stress Wave Technology reading for Tier 3 Sill, Pile Bent 93, Pile 1 . The numbers in white show good portions, the numbers in yellow are areas of some concern and the numbers in red are areas of extreme concern. Yellow indicates an approximate loss of 25% in structural capacity, red indicates an approximate loss of 50% or greater respectively.

CNR PROJECT SAMPLES

ROCHFORD BRIDGE

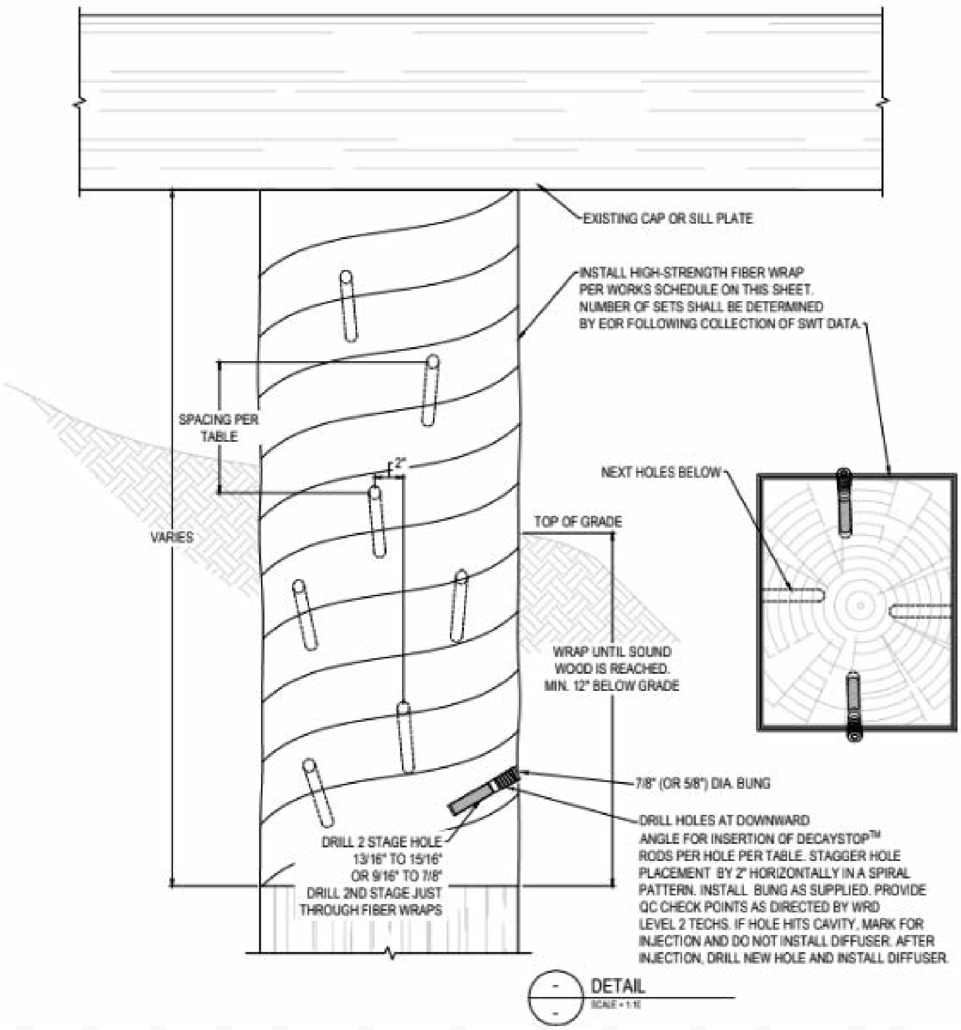
Readings are taken with the use of EPHOD® Stress Wave Technology (SWT) to determine areas of degradation in the structure With this information a report is produced in which engineers make recommendations and provide a detailed design for the areas requiring attention.



Above is an as-built drawing showing the area on PB-93 that will require repairs to the pile with the recommended amount of high strength pile wrap, diffusers and Structurefill® Epoxy to be used.

CNR PROJECT SAMPLES

ROCHFORD BRIDGE



Above is a detailed design with instructions for the diffusers to be used in the PB 93 pile restoration.

CNR PROJECT SAMPLES

ROCHFORD BRIDGE

Using patented technology the TRS Technicians wrapped the piles, filled the voids in the piles with Structurefill® Epoxy(a slow cure, 2 part, 90 mpa epoxy mixture) and diffusers to control decay within the element

PB-93 Triple Wrap For 7'-0" at pile 1 from tier 3 up, injected 5 tubes Structurefill® Epoxy (slow cure, 2 part, 90 mpa epoxy mixture and diffused.

CNR PROJECT SAMPLES

ROCHFORD BRIDGE

Top Sill, Pile Bent 79, Pile 2

This photo shows the nomenclature used during inspection to label all elements using a systematic method to inspect the entire structure. This method is used for all structure inspections to provide information for processing the data collected. This will allow the engineering team to pinpoint the location of the element and develop bulleted design repairs for the elements that require it. Once the repair design is completed the restoration crew will use the labelling system to identify the elements requiring repair.

CNR PROJECT SAMPLES

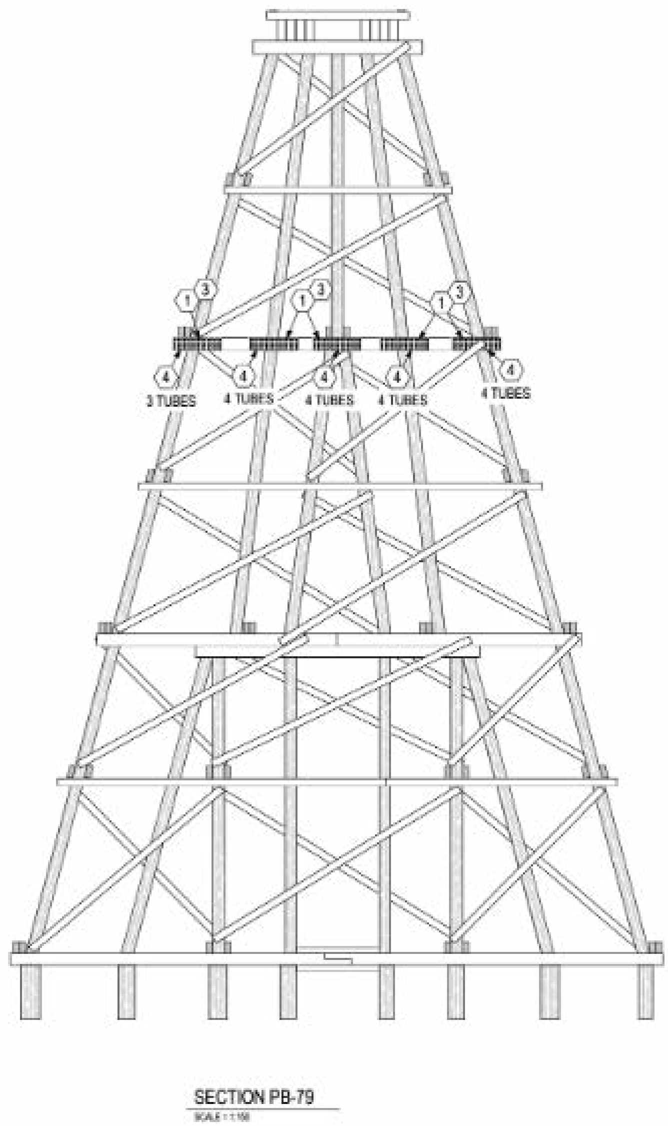
ROCHFORD BRIDGE

Bent 79

Tier 1 - Top Sill		Length :							Type :	Square				
Location :	22 in	40 in	60 in	88 in	108 in	132 in	156 in	186 in	210 in	235 in	255 in	275 in	300 in	318 in
Width :	11.75	11.75	11.75	11.75	11.75	11.75	11.75	11.75	11.75	11.75	11.75	11.75	11.75	11.75
6/12 Raw	679	835	1012	857	882	957	1179	1178	1125	847	999	1538	1080	870
6/12 Adj	693	853	1034	875	901	977	1204	1203	1149	865	1020	1571	1103	889
3/9 Raw	688	2625	6000	10000	3400	5000	4400	5700	4781	10000	10000	4460	2230	951
3/9 Adj	703	2681	6128	10213	3472	5106	4494	5821	4883	10213	10213	4555	2277	971
	P1			P2			P3 / P4			P5			P6	
Note :	Vertical Split through cap.													

Above is the EPHOD®Stress Wave Technology reading for Top Sill, Pile Bent 79, Pile 2 . The numbers in white show good portions, the numbers in yellow areas of some concern and the areas in read areas of extreme concern.

This as-built drawing showing the areas on PB-79 that will require repairs using shear panels with the recommended amount of Structurefill™ to be used in each area.



CNR PROJECT SAMPLES

ROCHFORD BRIDGE

Pile Bent 79
1 Inch Shear Panels at piles 1 and 2 in top 2 sill, installed on both sides. Injected with 7 tubes of Structurefill® Epoxy and diffused.

Pile Bent 79
1 Inch Shear Panel at pile 3 and 4 in top sill. Installed on both sides. Injected with 4 tubes of Structurefill® Epoxy and diffused with Decaystop™

Pile Bent 79
1 Inch Shear Panel at piles 5 and 6 in top sill. Installed on both sides. Injected with 8 tubes of Structurefill® Epoxy and diffused.

CNR PROJECT SAMPLES

KISKATINAW BRIDGE

The inspection of Kiskatinaw River Bridge was completed by Wood Research and Development (WRD) Level II Certified Inspection Technicians on July 21, 2017. The objective of the investigation was to establish the general condition of the primary structural elements of the Howe truss, and to assess what techniques could be implemented to restore the bridge to an E55, or upgrade to an E65 Cooper load rating, should it be found to not meet this capacity. Visual inspection and non-destructive testing were conducted using an assortment of instruments including; EPHOD™ Stress Wave Technology, distameter, psychrometer, moisture meter and digital camera.

CNR PROJECT SAMPLES

KISKATINAW BRIDGE

Scaffolding was erected for both the inspection and restoration phases to ensure safe access to the bridge components

This photo shows rail traffic while the restoration crew is working on the bridge below

CNR PROJECT SAMPLES

KISKATINAW BRIDGE

Component :	Lower Chord | Left Truss							
Component Number :	1			2	3	4		
Type :	Glulam			Glulam	Glulam	Glulam		
Component Width :	*9.0 in*	*9.0 in*	*9.0 in*	*9.0 in*	*9.0 in*	*9.0 in*	*9.0 in*	*9.0 in*
Component Heigth :	*18.0 in*	*18.0 in*	*18.0 in*	*18.0 in*	*18.0 in*	*18.0 in*	*18.0 in*	*18.0 in*
Gauge Length :	9.0 in	9.0 in	9.0 in	16.6 in	16.6 in	9.0 in	9.0 in	9.0 in
Correction Factor(s) :	200 ms	200 ms	200 ms	200 ms	200 ms	200 ms	200 ms	200 ms
Reading Location :	Top	Mid	Bottom	Diag	Diag	Top	Mid	Bottom
	Ply 2	Ply 6	Ply 10	None	None	Ply 2	Ply 6	Ply 10
Distance / Node								
1 FT	x	x	x	x	x	x	x	x
Node - L0								
5 FT	564	2332	x	x	x	803	1135	x
11 FT	619	971	1267	x	x	521	973	1188
Node - L1								
15 FT	Splice	Splice	Splice	x	x	535	791	1655
21 FT	Splice	Splice	Splice	x	x	197	371	712
Node - L2								
25 FT	327	467	716	x	x	Splice	Splice	Splice
31 FT	496	611	937	x	x	Splice	Splice	Splice
Node - L3								
35 FT	441	1003	1104	x	x	281	344	915
41 FT	512	599	936	x	x	321	1011	1101
Node - L4								
45 FT	415	751	1257	x	x	333	640	1533
51 FT	1907	1921	2747	x	x	975	1233	1012
Node - L5								
55 FT	Splice	Splice	Splice	x	x	200	771	1668
61 FT	Splice	Splice	Splice	x	x	668	817	1188
Node - L6								
65 FT	508	859	885	x	x	440	800	1133
71 FT	392	745	1485	x	x	479	465	672
Node - L7								
75 FT	877	1300	953	x	x	352	597	444
81 FT	557	899	1267	x	x	205	1001	1375
Node - L8								
85 FT	377	1680	2733	x	x	299	1115	1965
91 FT	401	333	1179	x	x	476	1189	2004
Node - L9								
95 FT	377	843	867	x	x	Splice	Splice	Splice
101 FT	333	1464	1587	x	x	Splice	Splice	Splice
Node - L10								
105 FT	193	339	747	x	x	327	773	1160
111 FT	953	1035	1280	x	x	415	1209	1133
Node - L11								
115 FT	1391	1551	735	x	x	1469	1764	2099
121 FT	573	456	1927	x	x	392	1529	804
Node - L12								
125 FT	Splice	Splice	Splice	x	x	383	1823	1797
131 FT	Splice	Splice	Splice	x	x	364	601	867
Node - L13								
135 FT	548	880	2488	x	x	Splice	Splice	Splice
141 FT	689	657	1119	x	x	Splice	Splice	Splice
Node - L14								
145 FT	365	800	2473	x	x	875	940	1804
151 FT	1119	x	x	x	x	376	285	x
Node - L15								
155 FT	x	x	x	x	x	x	x	x

Adjusted SWT Values

Component :	Lower Chord | Right Truss							
mponent Number :	5			6	7	8		
Type :	Glulam			Glulam	Glulam	Glulam		
omponent Width :	*9.0 in*	*9.0 in*	*9.0 in*	*9.0 in*	*9.0 in*	*9.0 in*	*9.0 in*	*9.0 in*
omponent Heigth :	*18.0 in*	*18.0 in*	*18.0 in*	*18.0 in*	*18.0 in*	*18.0 in*	*18.0 in*	*18.0 in*
Gauge Length :	9.0 in	9.0 in	9.0 in	16.6 in	16.6 in	9.0 in	9.0 in	9.0 in
rrection Factor(s) :	200 ms	200 ms	200 ms	200 ms	200 ms	200 ms	200 ms	200 ms
Reading Location :	Top	Mid	Bottom	Diag	Diag	Top	Mid	Bottom
	Ply 2	Ply 6	Ply 10	None	None	Ply 2	Ply 6	Ply 10
nce / Node								
1 FT	x	x	x	x	x	x	x	x
ode - L0								
5 FT	2321	1633	x	x	x	[illegible]	x	x
11 FT	[illegible]	[illegible]	[illegible]	x	x	[illegible]	[illegible]	[illegible]
ode - L1								
15 FT	Splice	Splice	Splice	x	x	435	19	656
21 FT	Splice	Splice	Splice	x	x	213	[illegible]	511
ode - L2								
25 FT	504	291	2277	x	x	Splice	Splice	Splice
31 FT	[illegible]	[illegible]	[illegible]	x	x	Splice	Splice	Splice
ode - L3								
35 FT	[illegible]	[illegible]	[illegible]	x	x	[illegible]	[illegible]	[illegible]
41 FT	[illegible]	[illegible]	556	x	x	[illegible]	719	644
ode - L4								
45 FT	737	384	1854	x	x	1348	983	[illegible]
51 FT	380	1821	[illegible]	x	x	[illegible]	[illegible]	[illegible]
ode - L5								
55 FT	Splice	Splice	Splice	x	x	217	603	[illegible]
61 FT	Splice	Splice	Splice	x	x	455	[illegible]	665
ode - L6								
65 FT	488	[illegible]	687	x	x	496	355	[illegible]
71 FT	451	[illegible]	[illegible]	x	x	401	[illegible]	727
ode - L7								
75 FT	[illegible]	[illegible]	[illegible]	x	x	491	[illegible]	[illegible]
81 FT	[illegible]	[illegible]	[illegible]	x	x	348	[illegible]	[illegible]
ode - L8								
85 FT	401	979	[illegible]	x	x	404	[illegible]	[illegible]
91 FT	631	[illegible]	[illegible]	x	x	511	[illegible]	[illegible]
ode - L9								
95 FT	293	[illegible]	[illegible]	x	x	Splice	Splice	Splice
101 FT	277	[illegible]	[illegible]	x	x	Splice	Splice	Splice
ode - L10								
105 FT	[illegible]	[illegible]	[illegible]	x	x	244	728	711
111 FT	387	[illegible]	[illegible]	x	x	376	[illegible]	[illegible]
ode - L11								
115 FT	561	[illegible]	[illegible]	x	x	396	672	[illegible]
121 FT	480	209	527	x	x	337	844	851
ode - L12								
125 FT	Splice	Splice	Splice	x	x	360	[illegible]	[illegible]
131 FT	Splice	Splice	Splice	x	x	607	619	[illegible]
ode - L13								
135 FT	509	[illegible]	[illegible]	x	x	Splice	Splice	Splice
141 FT	333	[illegible]	[illegible]	x	x	Splice	Splice	Splice
ode - L14								
145 FT	467	975	[illegible]	x	x	304	867	[illegible]
151 FT	796	615	x	x	x	363	244	x
ode - L15								
155 FT	x	x	x	x	x	x	x	x

Readings and data taken from the non-destructive stress wave technology show areas of concern in the structure.
Red Highlighted shows Elements requiring immediate restoration or replacement. Yellow highlighted shows elements requiring potential restoration and frequent inspection.

Typical average global reduction values:

Yellow: 26%

Red: 56%

Zero capacity is assumed for an element that has a Red SWT Value of 2,200 or greater

CNR PROJECT SAMPLES

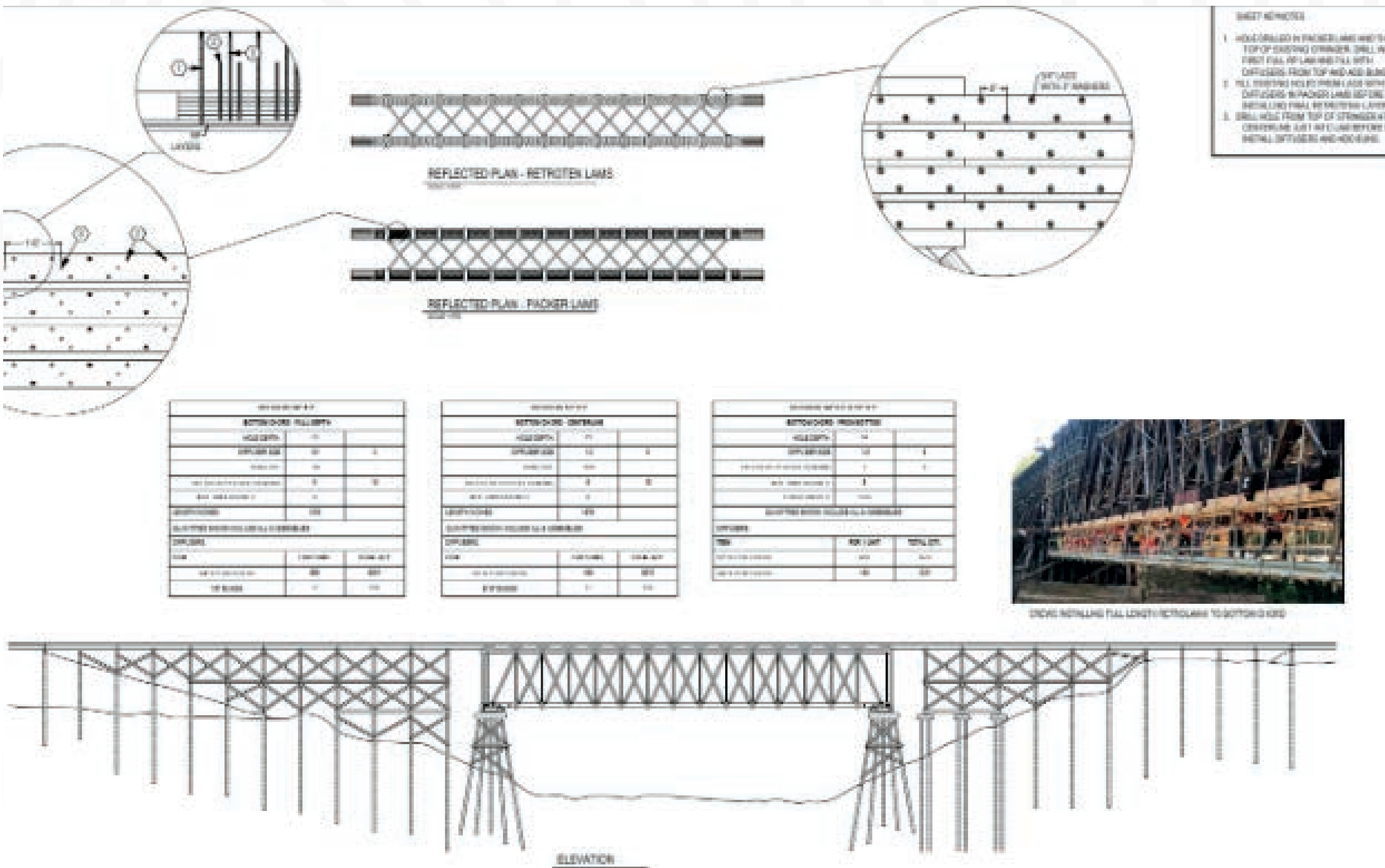
KISKATINAW BRIDGE

Bottom Chord prior to installation of packer blocks and Retroten® Reinforced Polymer

Preparing to install packer blocks between the steel node connections

CNR PROJECT SAMPLES

KISKATINAW BRIDGE



As-built drawings showing engineering requirements for installing Retroten® Reinforced Polymer lams to restore to the bottom chord

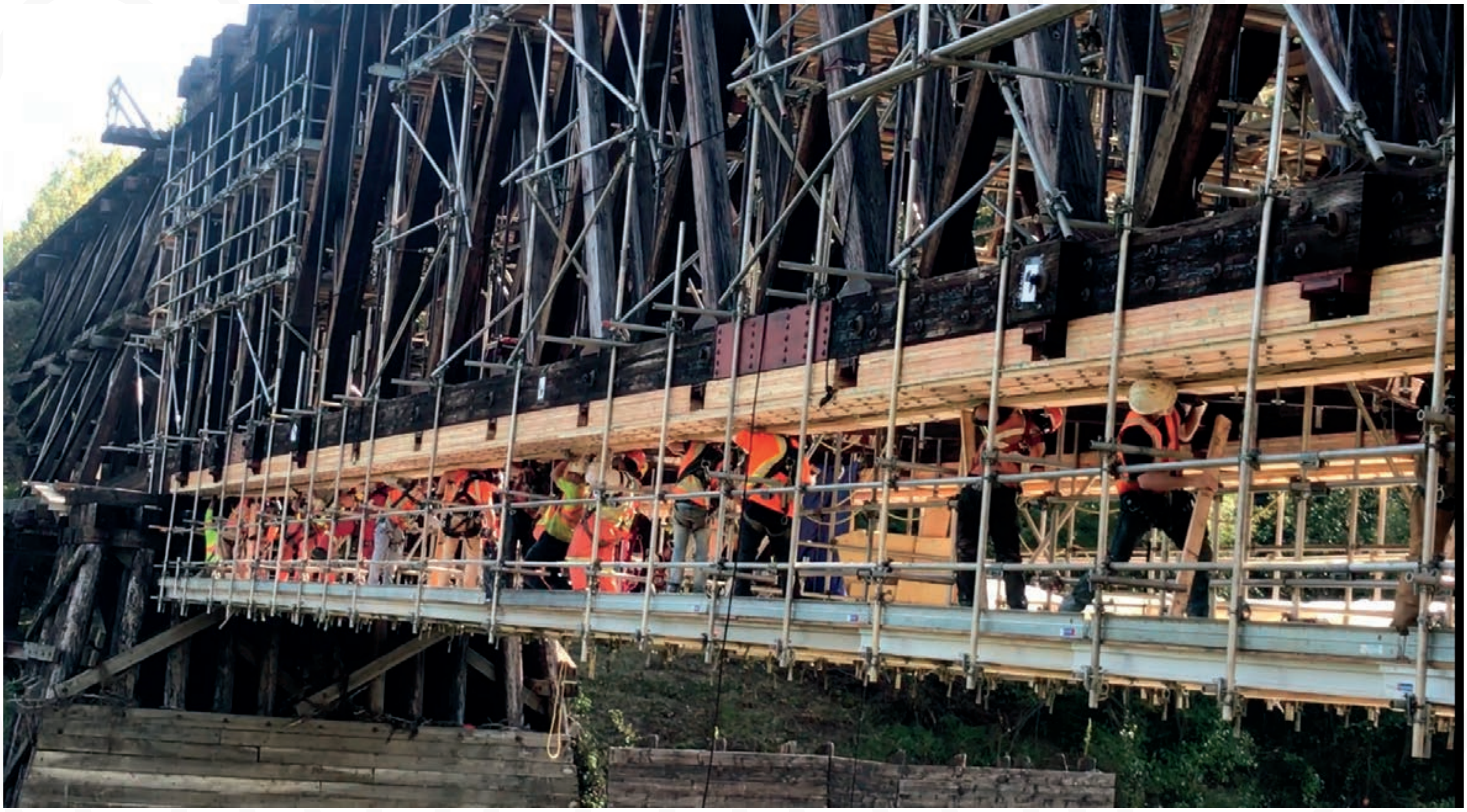
CNR PROJECT SAMPLES

KISKATINAW BRIDGE

Reinforced Polymer (RP) being prepared and added to Retroten® Reinforced Polymer boards prior to installation

CNR PROJECT SAMPLES

KISKATINAW BRIDGE



RP is sandwiched between the two tension lams and the lams are glued together. Six layers of packer blocks were required between the steel connections to provide clearance for the continuous layer of Retroten® Reinforced polymer.

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KISKATINAW BRIDGE

The final pieces of Retroten® Reinforced Polymer were installed

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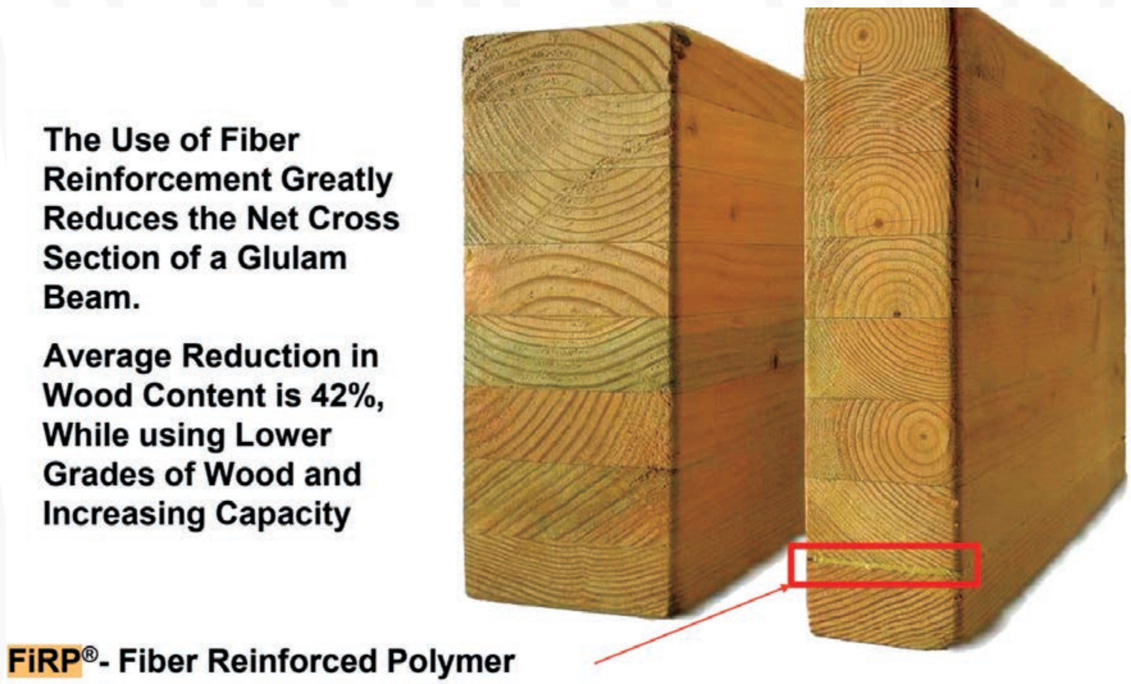
KISKATINAW BRIDGE

Retrocom® Reinforcement added to vertical supports at each end of the truss section

Retrocom® Reinforcement installed on bracing.
The green boards show that Copper Naphthenate (CN) was added for protection.

FiRP® Fiber Reinforced Polymer

The policy of TRS is to manufacture structures and FiRP® Fiber reinforced polymer wood products that meet or exceed the minimum requirements.
Timber Restoration Services maintains a complete and thorough quality control system to achieve their goal of uniform and high product quality. For this goal, TRS has retained WRD (International Accreditation Service Certified AA-644) as its third-party Quality Assurance Agency (QAA). In addition, WRD (International Accreditation Service Certified TL-193) is the subcontractor for quality control testing.



The Quasar structure built in Fort St. John, B.C. is the first commercial structure build in Canada to use FiRP® Reinforced glulam beams.

Retroten® Reinforced Polymer

Retroten® -Reinforced Polymer (RP) laminated to Lamstock. Used to restore or increase/reinforce the tension face of an element, it consists of one single layer of RP up to 1,000 feet long and 12 inches wide.

Retroten® Reinforced Polymer (RP)is made from dimension lumber that has a layer of high strength fiber attached to one side with high strength epoxy. Retroten® Reinforced Polymer can be made in different widths and lengths depending on the size of the girder that it will be attached to. Where Retroten® Reinforced Polymer is high in tensile strength they are added to the bottom of a girder to increase strength and stiffness to the girders.

Top Right Photo: Retroten® Reinforced Polymer being prepared and added to the Retroten® Reinforced Polymer board prior to installation

Photo Above: Close up view of Retroten® Reinforced Polymer (RP) added to the Retroten® board prior to installation

Photo Above:: Retroten® Reinforced Polymer board being installed to underside of girder. Photo Below: Retroten® Reinforced Polymer added to the bottom of a roof beam in an aquatic centre.

Retroten® Reinforced Polymer (RP) Widths

2 x 4
2 x 6
2 x 8
2 x 10
2 x 12

Tensile design stress is 215,000 psi

Retroshear® High Strength Fiber Panels

Retroshear® - High Strength Fiber Panels laminated between plywood - ½", 1", 2".

The Retroshear® High strength fiber shear panels are designed to reinforce beams against vertical and horizontal shear stresses, which are typically highest near the ends of the beams. They are made of FiRP® Fiber reinforced polymer panels fixed to plywood sheets. The panels are then mounted to the beam using Retrobond® Epoxy adhesive.

Retroshear® High Strength Fiber Panels

1 foot x 4 foot panels in the following thicknesses and design shear resistance stress:
1/2 inch = 1,000 psi
1 inch = 2,000 psi
2 inch = 2,000 psi

Above Shear panels installed in an Aquatic Center in Camrose, Alberta.

To the Right, tension Chord (Bottom Chord) Repairs. Retroshear® High strength fiber panels were installed to both sides of the tension chords.

Heavily loaded, short-span elements are often controlled by shear capacity. Additionally, timber decay is often focused around connectors and bearing supports; these areas typically experience the highest shear stresses.
The shear reinforcements used typically by WRD consist of FRP fabrics sandwiched between layers of plywood to create prefabricated shear panels. These panels are then bonded to the existing beams in the field using structural epoxy adhesive. The shear reinforcements are typically attached to the vertical faces of the beams, near the supports where shear stresses are highest. Shear panels can also be used to repair longitudinal cracks.

The member of the structure requiring shear panels must first be planed to open the fibers. In areas that can't be planed the portion is leveled with a flapper disk, then scraped to open the fibers. Next the shear panels are planed, and a thin layer of epoxy is spread on one side. Screws are then installed via the predrilled holes in the shear panels to hold the panels in place until the epoxy sets. The holes are in a pattern to create equal pressure on the panel. Panels used for restoration work inside are not treated while panels used outside on structures such as bridges are treated with copper naphthenate. If needed, epoxy is injected into the timber afterwards fill any voids.

Shear panels can be made to accommodate any size area.

Retrocom® Reinforcement

Retrocom® Reinforcement - There are many different forms of Retrocom® Reinforcement, some with reinforcement and some without. It is used to reinforce or restore the compression face of an element

Retrocom® Reinforcement compression panels were applied to the trusses and beams. Manufactured and installed by TRS, Retrocom® Reinforcement compression panels are frequently used for compression retrofits to upgrade girders and truss members. Compression reinforcing panels consists of longitudinal glass, aramid, and/or carbon fibres. These panels are bonded to the compression face of the truss or beam. Retrocom® Reinforcement is made from dimension lumber that has a layer of high strength fiber attached to one side with high strength epoxy. Retrocom® Reinforcement can be made in different widths and lengths depending on the size of the element that it will be attached to. Elements requiring compression panels are frequently injected with with a 90 mpa, two part slow cure epoxy and diffused to prevent crushing an further degradation of the element

Photos above and to the right shows Retrocom® Reinforcement installed onto trusses

Retrocom® Reinforcement installed on two sides of the trusses and onto the beams above

Retrocom® Reinforcement widths vary in sizes from 2 x 4 up to 6 x 14

Structurfill® Epoxy

Structurfill® Epoxy is a two part epoxy system that when mixed together forms a single compound that dries to 90 mpa. Structurfill® Epoxy is used to fill in cavities that are found in timber members to prevent internal collapse.

Injecting a pile cavity with Structurfill® Epoxy once wrap is in place and cured

Injecting Structurfill® Epoxy into the chord piles from the top of the bridge

The technician injects Structurfill® Epoxy under water into a pile that has been posted complete with rotation spline and steel side plate.

Cross section view of structurfilled pile

Diffuser Rods

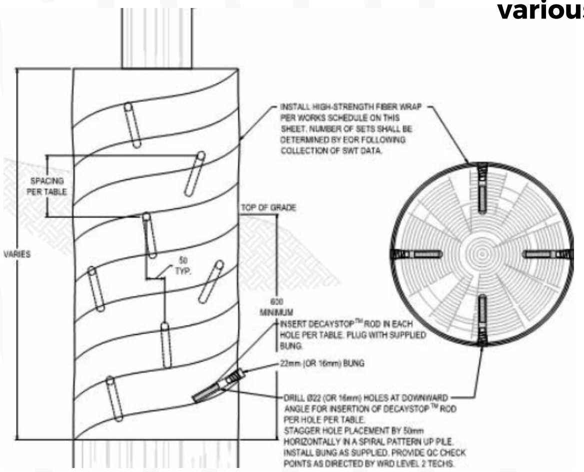
Diffuser Rods - a highly concentrated, solid-formed, water-diffusable boron rod derived from a naturally occurring preservative element

Diffusers act similarly to fumigants except they begin to deplete and brine solution (diffuse) through the wood when moisture contents exceed approximately 20%. This means diffusers travel more effectively and are utilized only when the wood reaches decay causing levels of moisture. This MC triggered dissipation reduces the maintenance cost for diffusers. Fumigants deplete and vaporize through the wood at all moisture contents. Diffusers are typically made from naturally occurring, non-toxic, basalts which neutralize the PH wave that is created by fungi hyphae secreting acidic enzymes that break down the wood. Typical diffuser rod. The rods are between ½” to ¾” in diameter and 3” to 5” long. Areas susceptible to high moisture conditions or have illustrated the initial signs of decay (yellow SWT zone), should have diffusers installed as a preventative maintenance strategy.

Sample of Diffuser Rods showing different sizes.

Sample of Plugs of various sizes

The piles in this photo show yellow plugs used to keep diffuser rods in place. The plugs can be removed to check and or replace diffusers.



Engineered drawing showing areas requiring diffusers

Retromatrix® High Strength Fiber Wrap

Retromatrix® High strength fiber wrap - a combination of two types of fiberglass cloth - Biax and Uni used in combination with an epoxy/hardener mixture used to restore piles.

To repair the axial capacity of the pile, a method of wrapping is used with patented products such as epoxy, hardeners. A slow cure epoxy - Structurfill® Epoxy is used to fill the void under the wrapped portion of the pile Based on the SWT readings, the pile is wrapped 600mm past the subsequent yellow reading on either side of the cavity. The final step is to diffuse the pile under the wrappings with a diffuser rod to help reduce moisture in the pile.

Photo to Right shows Retromatrix® High strength fiber wrap extended to cover the entire pile. This will prevent shelf water from running down the pile and underneath the bottom section of fiber wrap.

Photo above and to the right shows Retromatrix® High strength fiber wrap on CPR Kootenay Landing Bridge in British Columbia

Retromatrix® High strength fiber wrap strength properties for double wrap (2 sets), 300 mm diameter pile:

Wrap Type	Average Thickness of wrap (mm)	Tensile Strength (MPa)	Tensile Strength KN/mm of width	Modulus of Elasticity (MPa)	I (m^4)	Wrap 'Stiffness' EI (kN.m2)
Double Wrap (2 Sets)*	6.60	265.25	1.75	19086.50	7.47346E-05	1426.42

* values are for 0 and 90 degree directions

Pile Posting

Pile Posting - To repair piles by removing a portion of a pile and replacing with new.

The first steps in a proper posting detail. Cut down to clean, bright wood typically found below the oxygen level. Drill a hole out of the 45 degree quadrant in the direction of traffic in the stub, 30 to 35mm (1-1/8"– 1-1/4" steel pin), inserted and if the top is available lower the top section over it. If the top is not available the section must have inletting on the side behind a tapered anti-rotation spline for the pin to slip horizontally into the top posting segment. The pin must be off center to allow the placement of the steel fish plates on four sides with horizontal galvanized steel fish plate through bolts. Piles receive pile posting.

Below shows installing new portion onto pin.

The pile shown above has been cut to good wood

The pile shown above has been Taper cut for rotation spline slots. Photo below shows the application of structural epoxy (2 part paste, odourless, 100 percent solids). to the slots.

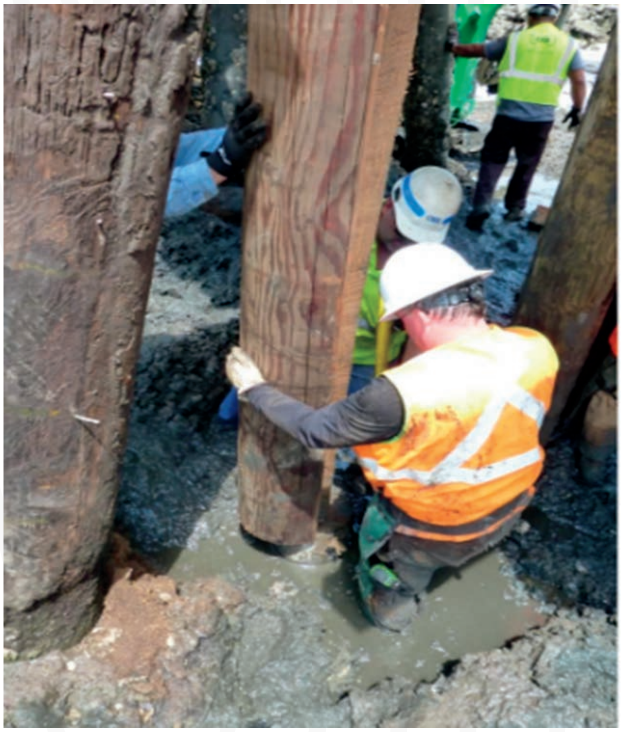
Photo to the left: Pile posting completed with rotation spline and steel side plate. Note yellow diffuser plugs indicating where the diffuser rods have been placed once the piles were posted.

Dutchmans Patch

One solution to allow the upgrading of the piles and elimination of the need for framing a pile bent is to use a Dutchman's patch on certain piles in conjunction with posting. Alternatively all the piles might be either injected if they are cavitated or Dutchman's patched if they have a suitable core without the need for framing the bent. A core segment is squared up utilizing the chainsaw and a skilled operator. The core is made with the faces of the square at 45 degrees to the longitudinal in the bridge to allow chainsaw access.

Above the technician squares up the affected pile

The pre-manufactured DF Pentachlorophenol pressure treatec Dutchman's patch is cut to length and ready for installation



The two halves are installed one at a time, then glued and screwed together. After installation is complete the the interior will receive two part, slow cure, 90 mpa Structurfill® Epoxy

DR. DAN TINGLEY

Daniel A. Tingley, Ph.D., P. Eng., MIE Aust., CPEng., RPEQ, CMEngNZ.
Photograph from Discovery Channel series "How Stuff Works"

Dan Tingley serves as Executive Director for Wood Research & Development Ltd. He is the inventor of the award-winning FiRP® Feber reinforced polymer panel reinforcement technique, which makes use of high-strength reinforced plastics to strengthen wood products. He holds a number of associated patents.

Here is a brief biography of Dr. Tingley. A complete curriculum vitae is available in PDF format with more information on his past experience.

DR. DAN TINGLEY

MEMBERSHIPS:

USA

- ALSC - American Lumber Standards Committee – Lumber Agency & WPM Agency
- AREMA – American Railway Engineering and Maintenance of Way Assoc.
- ASCE – American Society of Civil Engineers
- ASTM – American Society Testing Materials: Voting Member
- FPS – Forest Products Society
- SAF – Society of American Foresters
- SWST – Society of Wood Science and Technology
- WCLIP – West Coast Lumber Inspection Bureau

CANADA

- APEGBC - Assoc. Professional Engineers & Geoscientists of British Columbia
- APEGNB – Assoc. of Professional Engineers & Geoscientists of New Brunswick
- APEGA – Assoc. of Professional & Geoscientists of Alberta
- APEGS – Assoc. of Professional Engineers & Geoscientists of Saskatchewan
- APENS – Engineers of Nova Scotia (Life Member)
- APEY – Assoc. of Professional Engineers of Yukon
- APEGM – Engineers Manitoba
- CSCE – Canadian Society for Civil Engineering
- ICOMOS – International Council on Monuments and Sites
- PEGNL – Assoc. of Professional Engineers & Geoscientists of Newfoundland & Labrador
- PEO – Professional Engineers of Ontario
- SEA BC – Structural Engineer Association of British Columbia
- Canadian Wood Council

AUSTRALIA

- BPEQ – Board of Professional Engineers QLD
- AUS EA – Engineers Australia, National Engineering Register (NER)
- IPENZ – Engineering New Zealand
- IPWEAQ – Institute of Public Works Engineering Australia Queensland
- Engineers VIC
- myCAV – Victoria Consumer Affairs

DR. DAN TINGLEY

PUBLICATIONS:

More than 100 publications including:
• Books
• Published Research Papers
• Trade Magazine Articles
• Research Paper Reports

SPECIAL AWARDS, PRIZES, DECORATIONS:

- 2022 - WoodWorks Atlantic top award for all wooded products in Eastern Canada
- 2022 - WoodWorks Atlantic Jurors award for Roger Bacon Bridge
- 2022 - WoodWorks Atlantic Wood Champion Award
- 2021 - Albert County Chamber of Commerce Business Excellence Award – Environmental Stewardship
- 1997 - CIF “Nova” Award for Innovation (worldwide competition all construction products. Only person to win NOVA and Charles Pankow Awards back-to-back, only person to win both awards in wood and high strength fibers)
- 1996 - Applied Science Technologists & Technicians of British Columbia (ASTTBC) Award for advanced technology (worldwide competition).
- 1996 - Civil Engineering Research Foundation (CERF) Charles Pankow Innovative Applications Award (worldwide competition only structural products).
- 1993 - Association of Professional Engineers of Nova Scotia design award for designing the “Hector Heritage Quay,” an all timber connector building with adjustable base connectors creating fixed end moment connectors in a green wood situation.
- 1993 - Advanced Material Center, Oregon State University, $3,000.00 scholarship for graduate study.
- 1992-94 - Graduate Fellowship for three years to complete Ph.D. at Oregon State University
- 1988 - Nova Scotia Architects Association Innovation in Engineering Award (Timber frame distillery).
- 1982-83 - Association of Professional Engineers of New Brunswick, post graduate studies scholarship (two consecutive years).