Replacement of the Bartonsville Covered Bridge

design/construction solutions

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Outline of presentation

I don’t like outlines, but…

- Background
- Early efforts
- Historic preservation issues (yes, this is a replacement, but…)
- Details
- Brief comments on design
- Construction – yeah – pictures – more, more!

Background

- Located in the Town of Rockingham, along the east edge of Vermont about 30 minutes north of Brattleboro
- Original bridge built 1870–one of the longest single-span CBs in the USA
- Supported by Town lattice trusses

Background

- August 28, 2011

- Who remembers what was going on?

(for those of you NOT from the Northeast, it was a little thing called Hurricane Irene)

Perhaps one of the more "popular" YouTube videos of that event (taken by Susan Hammond)

CHA Becomes Involved

- Following the destruction of the bridge, the Town promptly hired a local consulting firm (Eckman Engineering) to commence the geotech investigation and design of the replacement abutments

- Shortly thereafter, the Town invited CHA to perform design services for the replacement

First Phase

- First effort involved identification of alternative structures
- Close proximity of RR at one end prevented change of roadway profile –hence required limited structure depth
- Steel pony truss was practical, hence steel through truss was not required
- A timber covered bridge was obviously possible, but would cost more. It was desired by the community and the Town quickly approved a timber replacement

Historic Preservation Issues

- Although there was much initial conversation about potential reuse of material from the destroyed bridge, it turned out to be impractical for a number of reasons
- Use same truss configuration of Town lattice with trunnel connections
- Use solid-sawn timber as much as possible
- Use same horizontal inside roadway opening

Historic Preservation Issues

- Retain same entry portal shape (semi-elliptical)
- Retain windows (although the number of them was an issue)
- Retain metal roof
- Use same unusual double-intersection overhead lateral bracing system

Historic Preservation Details

Unusual double intersection upper laterals to "mimic" the original detail

Configuration and Sizing

- The overall length of the superstructure was increased by 17 ft to 168 ft at the deck level (to provide my capacity for floods)

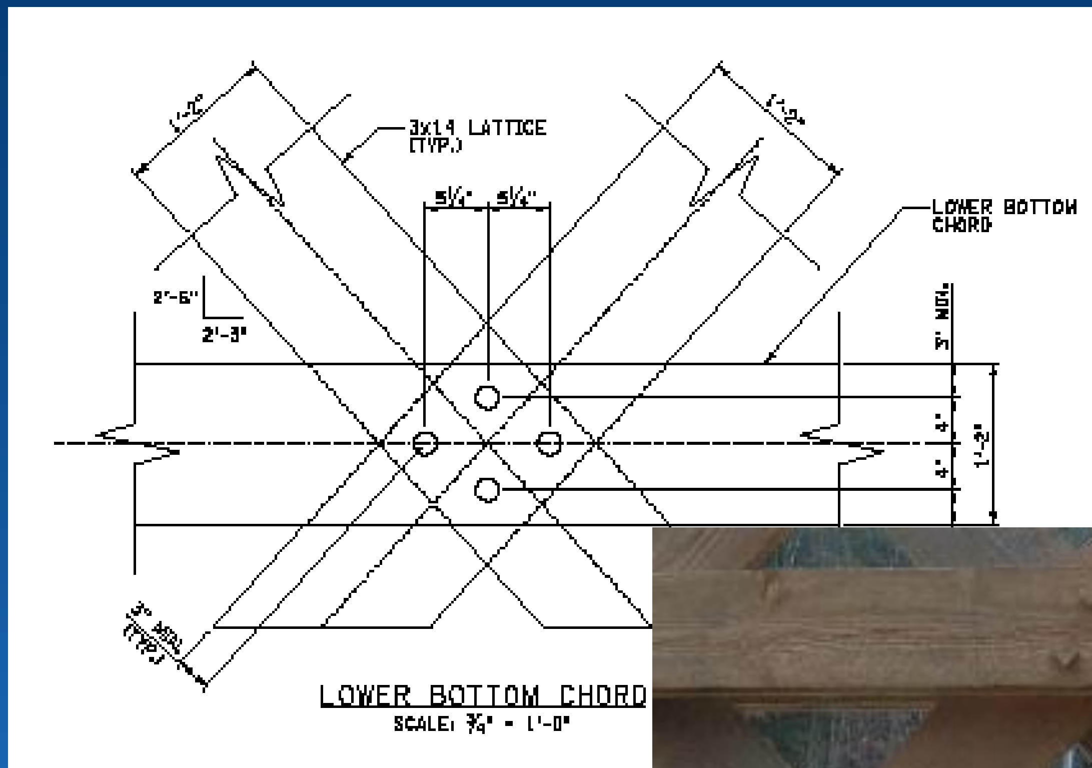
- The vertical height of the trusses was increased by two feet to provide more strength for the longer span and the desire for ample reserve capacity for vehicles – the extra height is “hidden” above the portal – most people wouldn’t notice

Configuration and Sizing

- Truss elements were increased in size (e.g. 3x12 bottom chords => 4x14s) and were made much longer (up to 40’-6”)

- Larger elements led to increasing the spacing of the lattice from 4’-0” to 4’-6”

Configuration and Sizing



Traditional hardwood pegs were used, 2-inch diameter, - two, three or four per connection

Configuration and Sizing

- The transverse floorbeams were made stronger to accommodate vehicle axle loads up to 24 tons (the design vehicle was selected as a two-axle 30 ton vehicle to provide ample reserve capacity)

- This desired capacity led to the use of glue-laminated floorbeams –often used in rehabilitation projects of historic covered bridges

CBs are about the details…

Glulam floorbeams supported by bottom chord

Lower “X” lateral system – transverse steel tie rods with turnbuckles not yet installed

Details, details, details…

- The longitudinal decking was selected to be 4x12 timbers with staggered butt joints –these could be replaced easier than other types of decking when needed in the future

- Sacrificial 3 inch oak longitudinal running planks were installed atop the primary deck timbers

Details, details, details…

- The overhead kneebraces were increased in size - bolted to the sides of the lattice intersections and notched into the overhead transverse tie beams

Details, details, details…

Large glue-laminated bolster beams were installed beneath the trusses at each corner – they function as “diving boards” spreading support of the truss over a longer distance – partially in front of the concrete of the abutment.

Truss "Design"

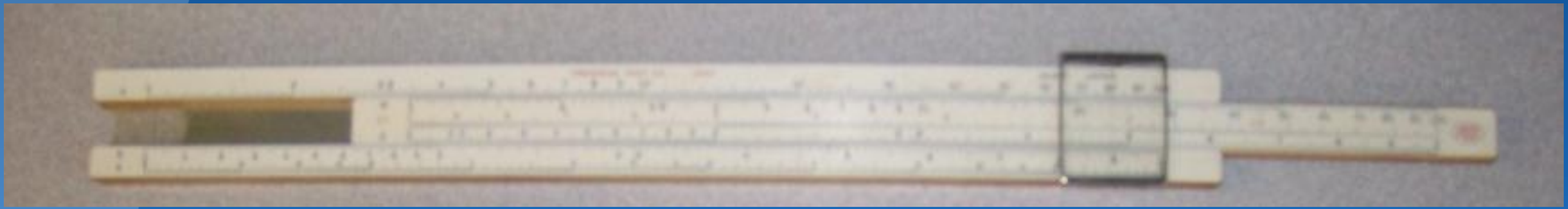
Town lattice trusses are highly indeterminate–in addition to the closely spaced components, there are six vertical planes of elements–2 layers of outer chords, 2 layers of lattice in opposite directions, and 2 layers of inner chords held together by the hardwood trunnels.

Truss "Design"

- While some of us old time bridge engineers wish that our profession did not rely so heavily on computers…

POP QUIZ -

Who knows what this is?

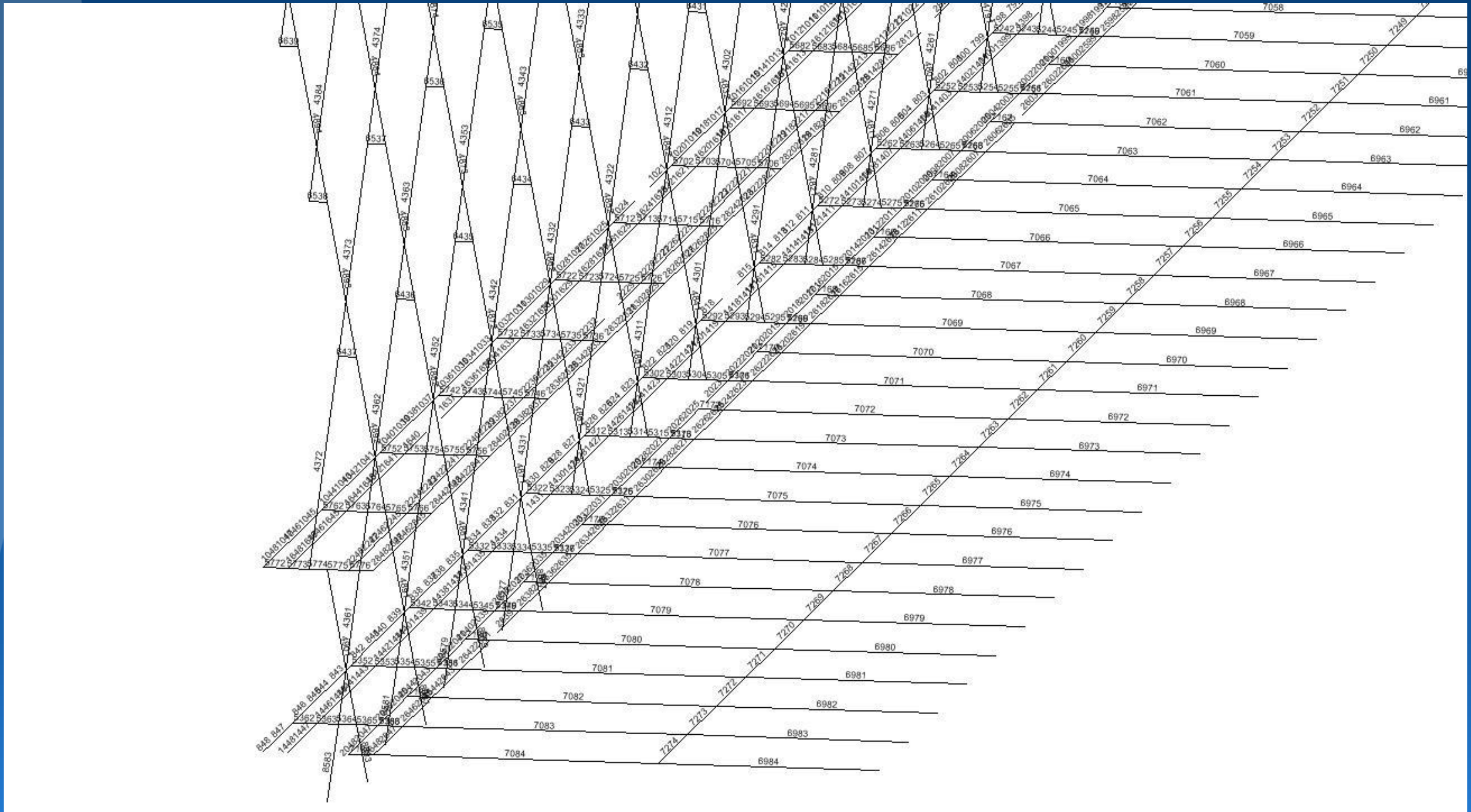


Truss "Design"

- Nonetheless….. the only way to "properly" evaluate stress and strength in such structures ***(? – long story – I will forego an explanation for your sake ☺)*** is with a first order three-dimensional finite element model of the six planes of components in each truss

- Each truss contains 84 lattice, 20 top chord, 20 upper bottom chord, and 20 lower bottom chord elements

Truss “Design”



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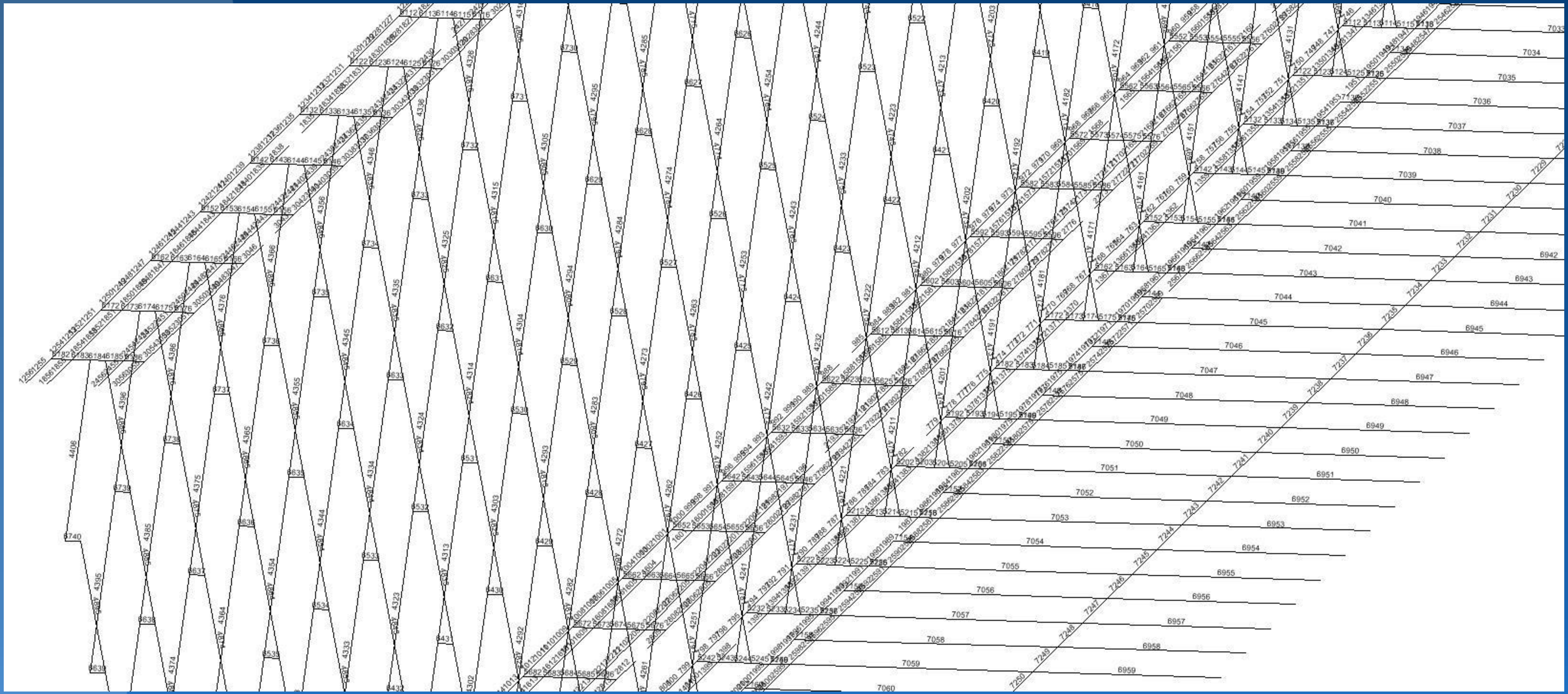

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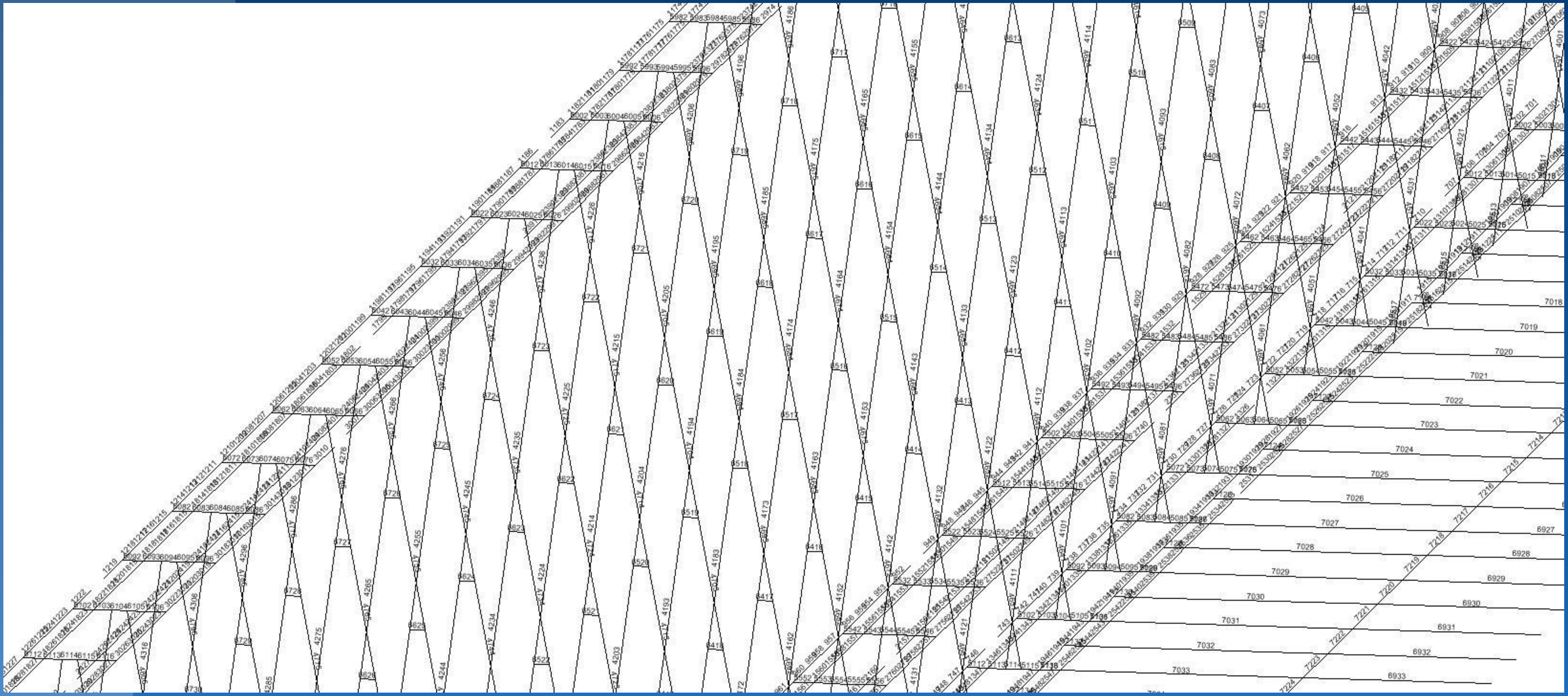

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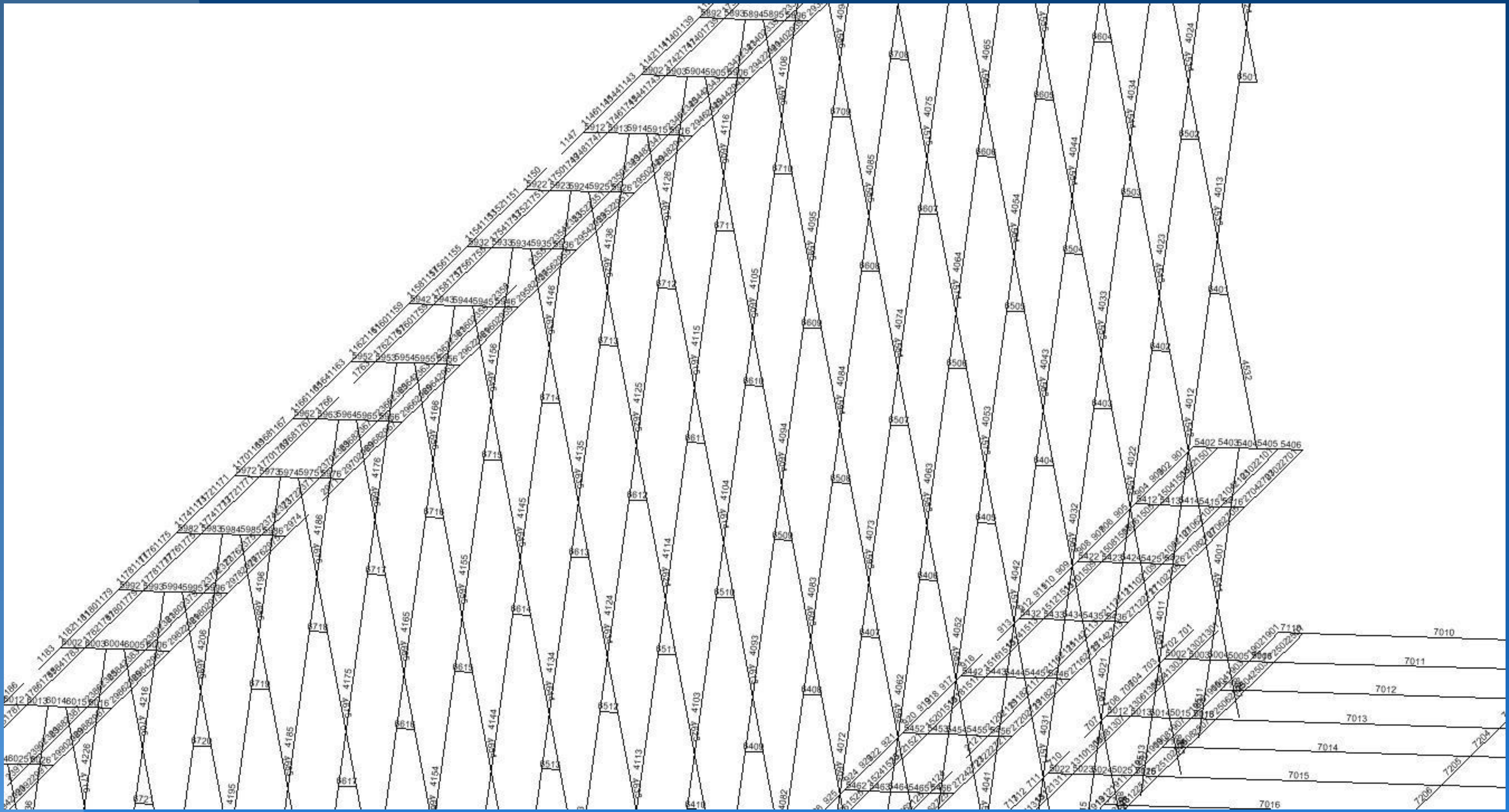

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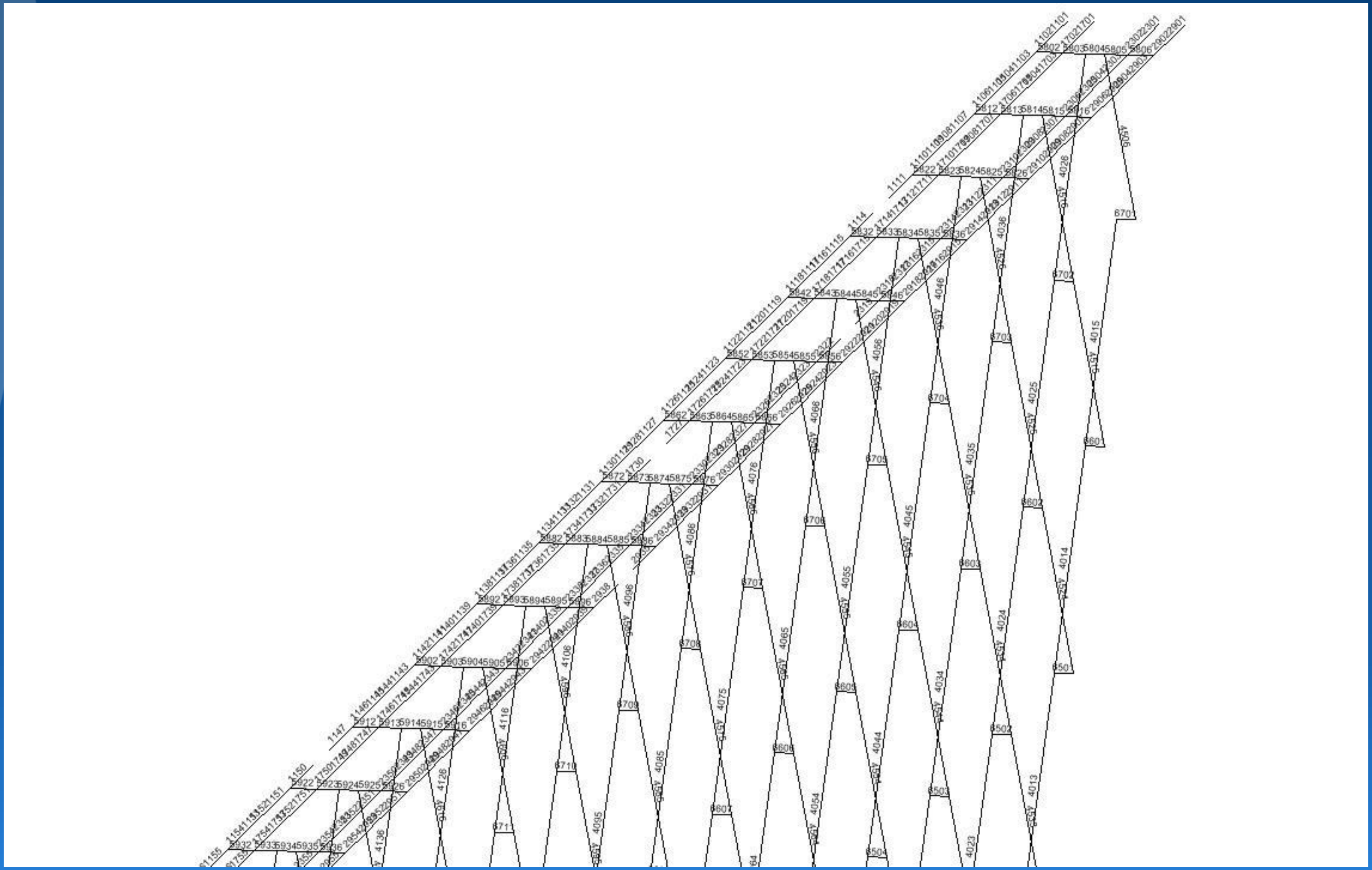

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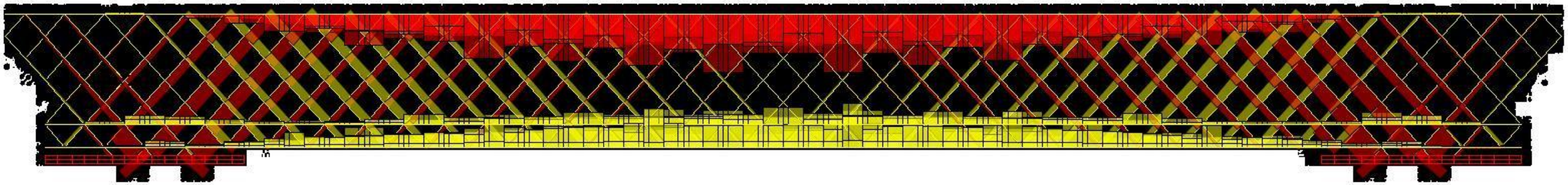
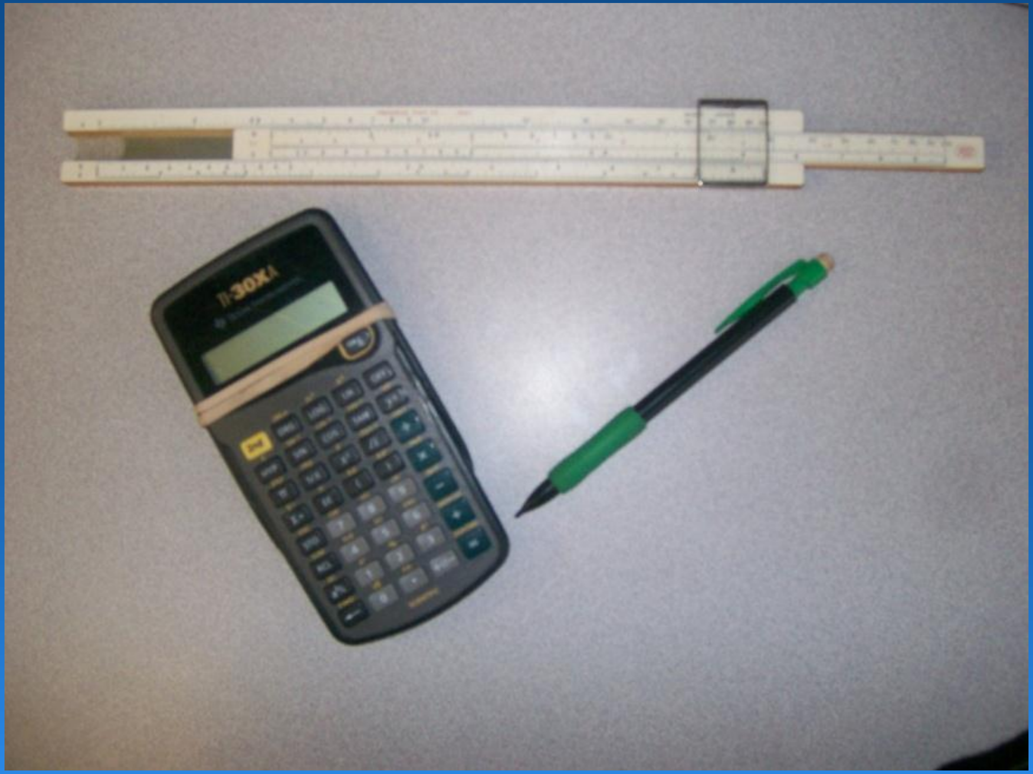


Truss "Design"

- ENOUGH!!!!!



Truss “Design”

- Okay – we have a model – now to the force analysis for “dead” and “live” loads
- And then there is the issue of combined vehicular (i.e. “live”) and snow load! Remember – we’re talking about Vermont
- And then there is design methodology – old school Allowable Stress versus the “new and improved” Load and Resistance Factor Design ?!?

Truss "Design"

- One of the more important aspects is evaluation of the actual stress around the trunnels and corresponding allowable stress (they don't list that allowable in the National Design Specifications!!)
- And another important issue is the combination of axial and bending stresses in the lower bottom chord which supports the floorbeams
- I'll stop here – it can become boring/tedious

Truss “Design”

- And then there is the issue of combined vehicular and snow load! For open bridges this combination is not considered since the snow may exist, but is assumed to be plowed off the bridge – design for snow OR vehicles (and vehicles are heavier). But the combination must be considered for work on CBs.

Wood Preservative Treatment?

- This topic could take up an entire presentation by itself, but….
- Truss elements were not treated–cost, delay, and significant loss of strength (of Douglas Fir from incising)
- Deck planks and curb timbers were treated
- Floorbeams and bolster beams were specified so that the fabrication process must start with pretreated wood

Construction Bids and Winning Team

- The bids for the timber superstructure:
  - Low bidder – $1.2m
  - #2 behind by <$10,000 (that's 0.8%!!)
  - 9 bidders – 4 lowest within 6.5%
  - Engineer's Estimate – oops - $1.65m (timber portion was very close, but I blew it on the other costs)

Construction and Erection

<= Piles driven to rock – these abutments are going to stay!

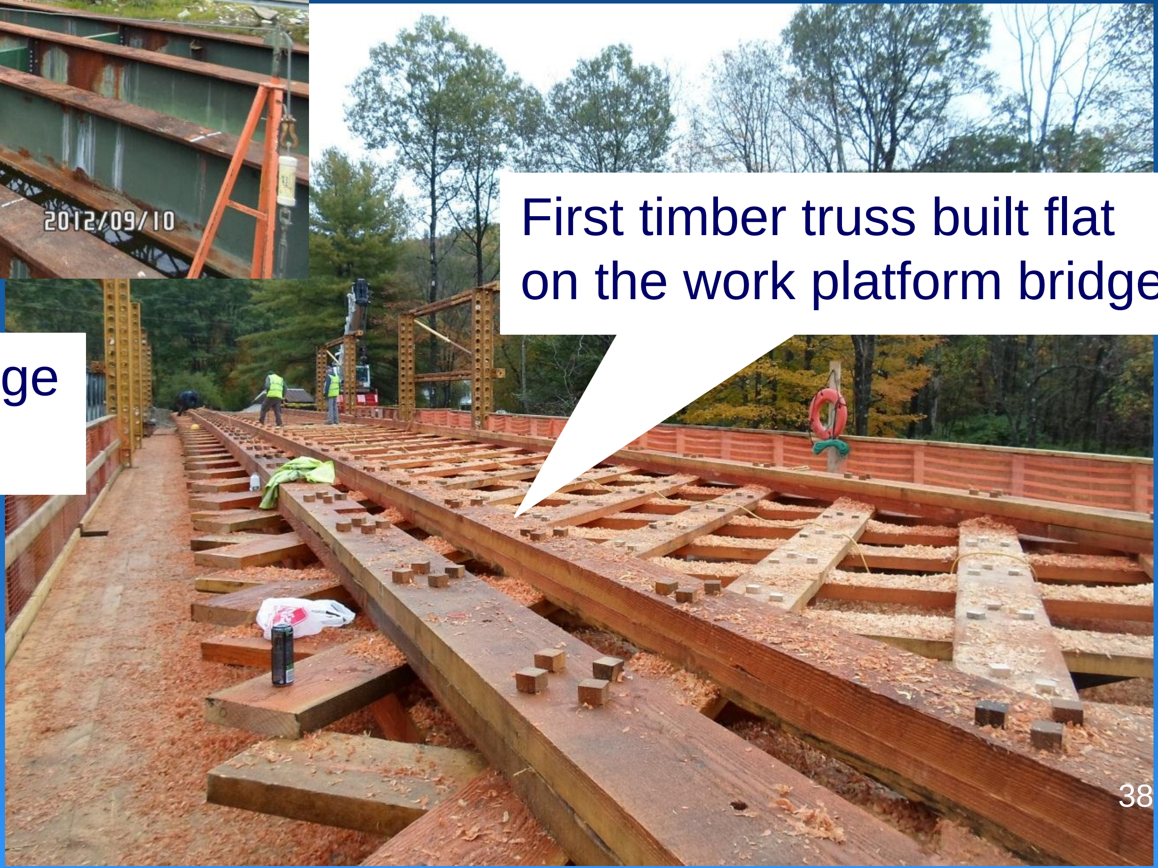
A shelf extension to help a bit with waterway opening =>

<= Getting ready to install the temporary bridge for traffic during construction

Construction and Erection

Temporary Mabey Bridge for traffic maintenance

Work platform bridge being erected

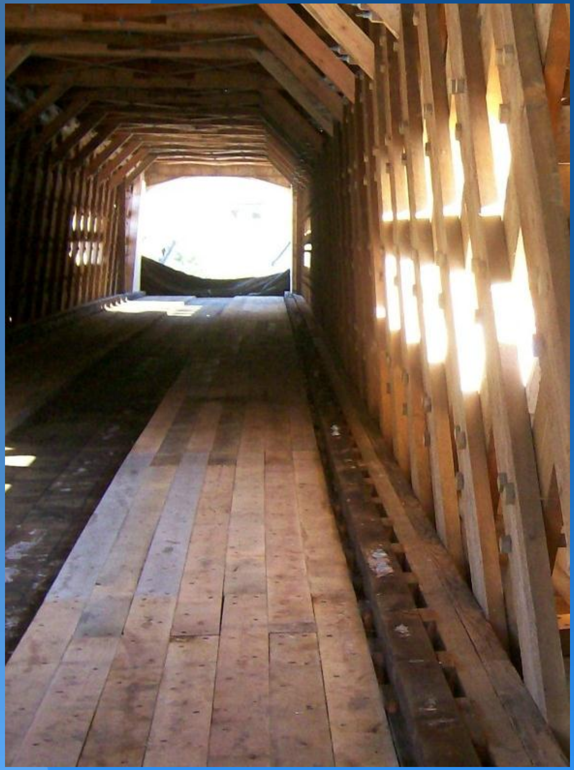


First timber truss built flat on the work platform bridge

Construction and Erection

More details, details, details…

- "Drainage and ventilation slots" –were provided along the curb, but wood fills were installed over the floorbeams and bottom lateral system elements to prevent dripping onto the elements below



More details, details, details…

- Shiplap siding was used rather than vertical without battens which was on the bridge at the time of its destruction

- The siding was attached to spacer wood strips to avoid direct contact with the truss chords – face-to-face contact promotes rot

Moving into position

<= nearing completion of the new bridge atop the work platform bridge, while traffic still on the Mabey Bridge

Mabey Bridge out, making ready to shift the new one sideways onto the abutments =>

Moving into position

Underside at end – lifted the timber bridge (with the bolster beams strapped in place) – then installed metal frame with rollers =>

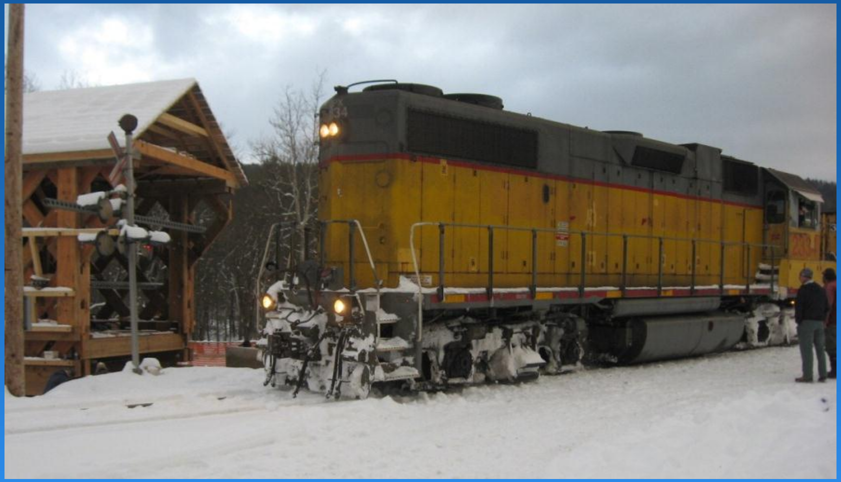
<= “Hilman rollers” inside belly-up channel

Moving into position

TIME OUT!!!!

<= Here he comes – watch out!

I’m baaaccckkkk! =>



Moving into position

<= 10-ton come-along to pull the bridge sideways – none of us dreamed it would be this hard, but they got a "cheater bar" shortly after I gave up

The contractor owner (Jim Hollar of Cold River Bridges) tried to push it in place, but not quite enough oomph! =>

Moving into position

<= as it turns out, the channel web was so thin that it “curled” a bit, causing an interference with the base of the roller unit so that it had to be skidded, rather than rolling

“X” marks the spot=>

Lessons Learned This Project

- I wanted to specify Southern Pine for the truss elements, but suppliers balked due to the sizes (4x14x40’-6” !!) – would have distorted and checked a lot while drying – I finally backed off and accepted Douglas Fir (slightly less bending strength)

- Rough-cut timber is not of a fixed size and minor sawing differences can accumulate (e.g. top lateral system) – *beware of CADD implications of accuracy when working with rough-cut wood precut in the shop before delivery*

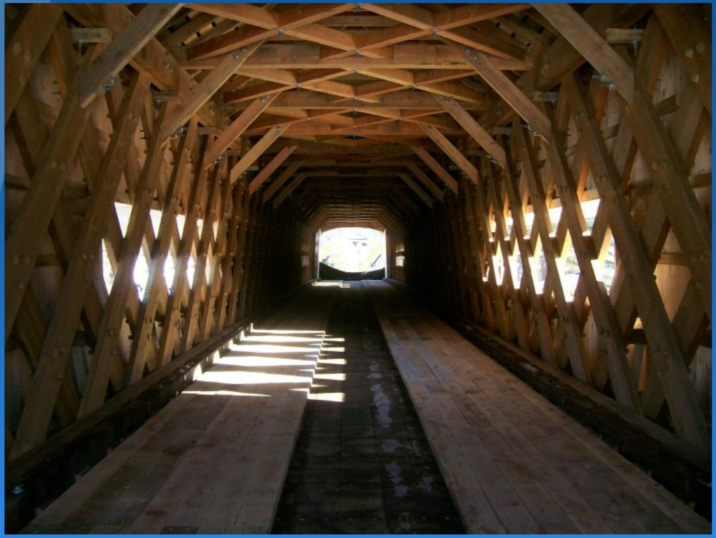
Lessons Learned This Project

End tie beam cut more narrow and STILL overhung

Minutiae

- The new bridge is the longest single-span covered bridge in the United States (and as far as I can find out–in the world too) supported by Town lattice trusses
- The bridge weighs about 130 tons
- The bridge deflected about 3 inches from the 10 inch initial cambered position as built flat

Ribbon Cutting – January 26, 2013



Ribbon Cutting – January 26, 2013

Acknowledgements

- The Town of Rockingham – what a wonderful client
- Eckman Engineering – a cooperative effort between two engineering firms with no contractual relationship
- Cold River – a contractor who put their heart and soul into this bridge
- The community of Lower Bartonsville – we would not have had a project without them

Questions ?

Thank you

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