OREGON DEPARTMENT OF TRANSPORTATION
REGION 4 BRIDGE ENGINEERING
63055 N. Highway 97, Building M
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GOOD BRIDGES, BAD DETAILS, AND UGLY CRACKS

A STUDY IN TITANIUM ALTERNATIVES TO FIBER REINFORCED POLYMERS

By Paul Strauser, PE

Overview

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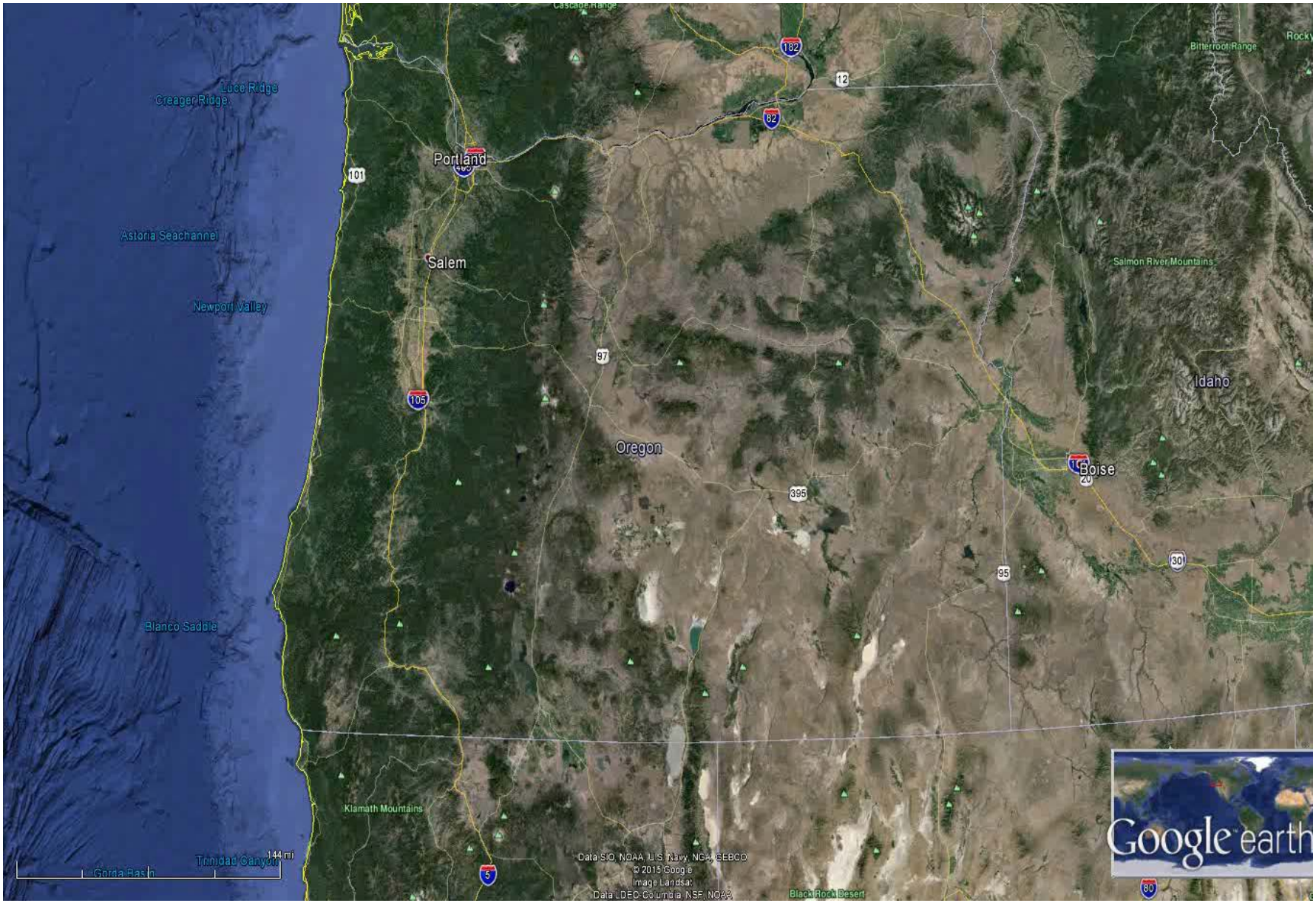
- Str. No. 07626A Mosier WB Conn over Hwy 002
- Titanium Strengthening Technology
- Discovery (Cracking) → Design → Construction

Site Location



Vicinity Map

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Structure No. 07626A
Mosier WB Conn over Hwy 002

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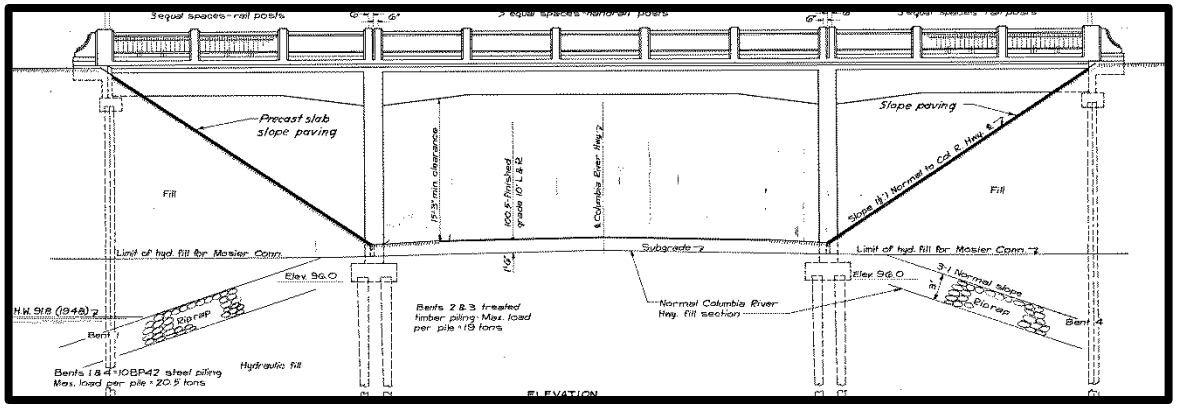
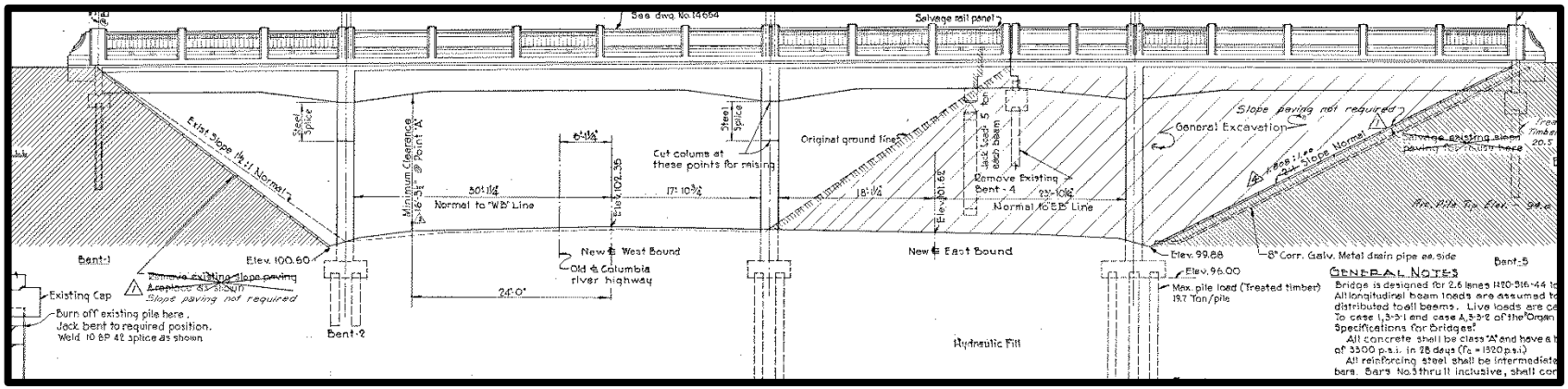
Bridge Original Construction

1952



Bridge Lengthened

1960



June 4th, 2013

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- John Adkins, PE – R4 Bridge Inspector
  - Span 1 – Interior Girders
  - "These cracks seem different from any other cracks I've seen on RCDG structures."
- ODOT Brainstorm
  - Load Rating, HQ, Inspectors
  - Region Notified Salem
    - Updated Load Rating
      - John Milcarek, PE

June 19, 2013

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- ODOT Load Rating Unit
  - Update from 1995 Rating
  - Low RFs
    - Crossbeams Bents 2 & 3
      - Shear
      - Moment
    - Int. Girders Spans 2 &4
      - Shear
      - Moment
      - Longitudinal Reinforcement
    - Legal and Permit Vehicles
- Load Posting Recommendation

Load Rating

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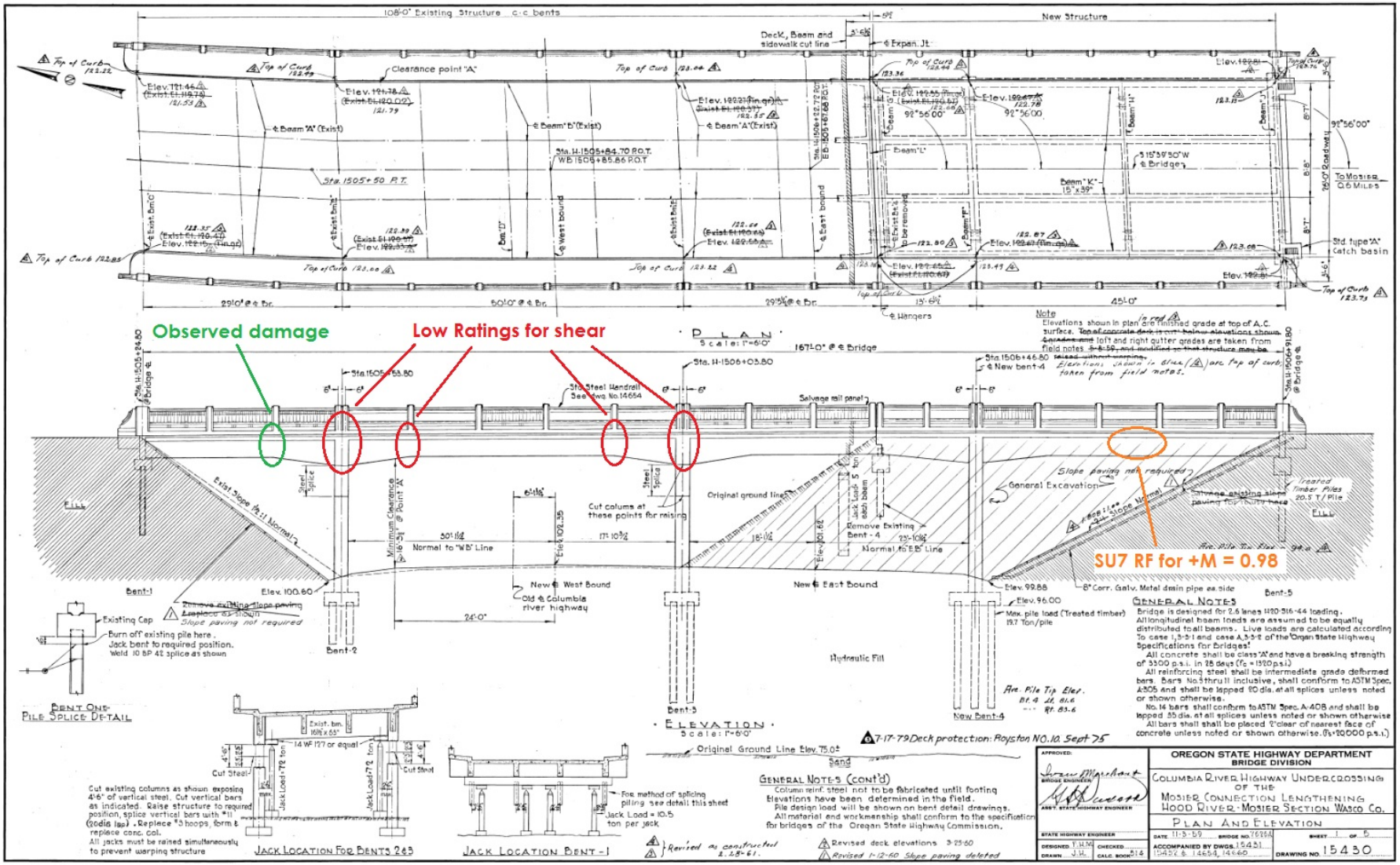

Poor Detailing

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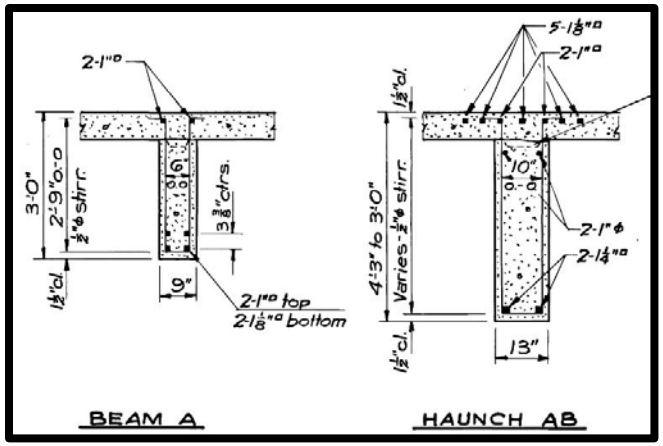
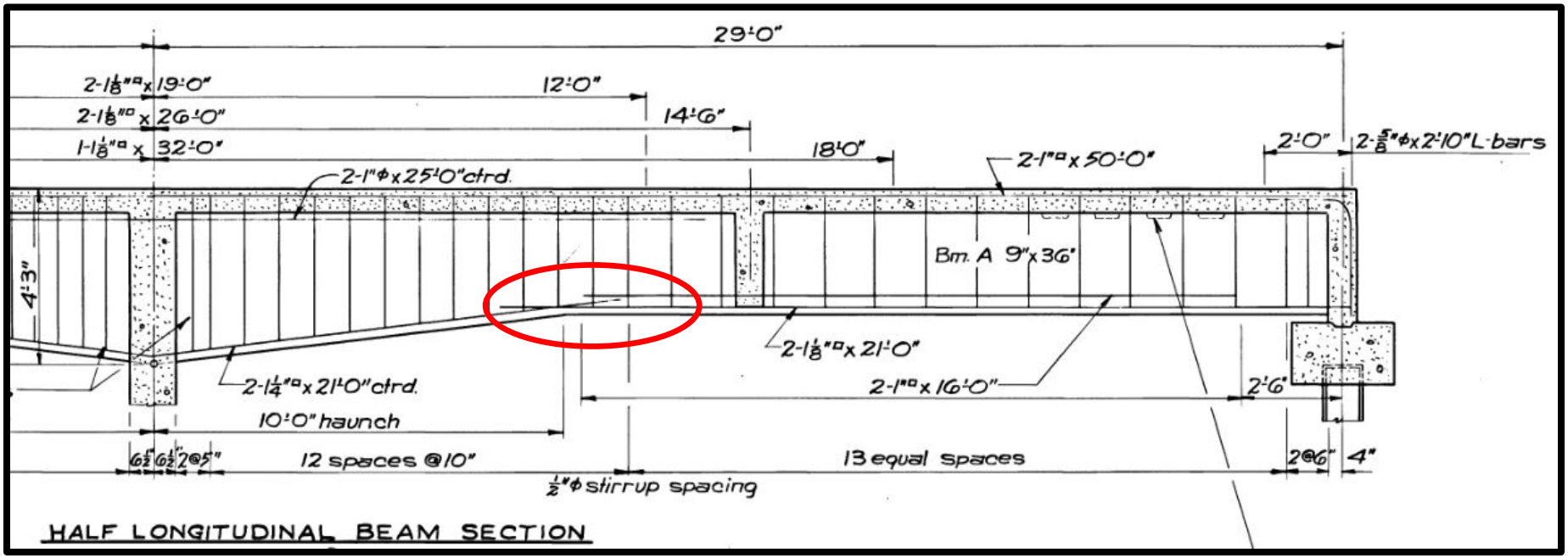


- Limited Development
  - Less than shown
- Vertical Crack Turns Horizontal
  - Anchorage Failure (Not Yield)




5/13
0.030 5/13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Elevation View
(2) No. 8 @130" o-o
(2) No. 8 @ 160" o-o
(2) No. 7 @ 212" o-o
(1) No. 8 @202" o-o
(2) No. 8 Gr 60 @136" o-o
(2) No. 8 @132" o-o
(2) No. 7 @97" o-o
2'-8"
(2) No. 9 @112" o-o
11 3/4"
8"

Temporary Support

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- Zach Beget, PE & District 9 Bridge Crew
  - Temporary Shoring Design and Installation

- Posting Improves

Load Rating

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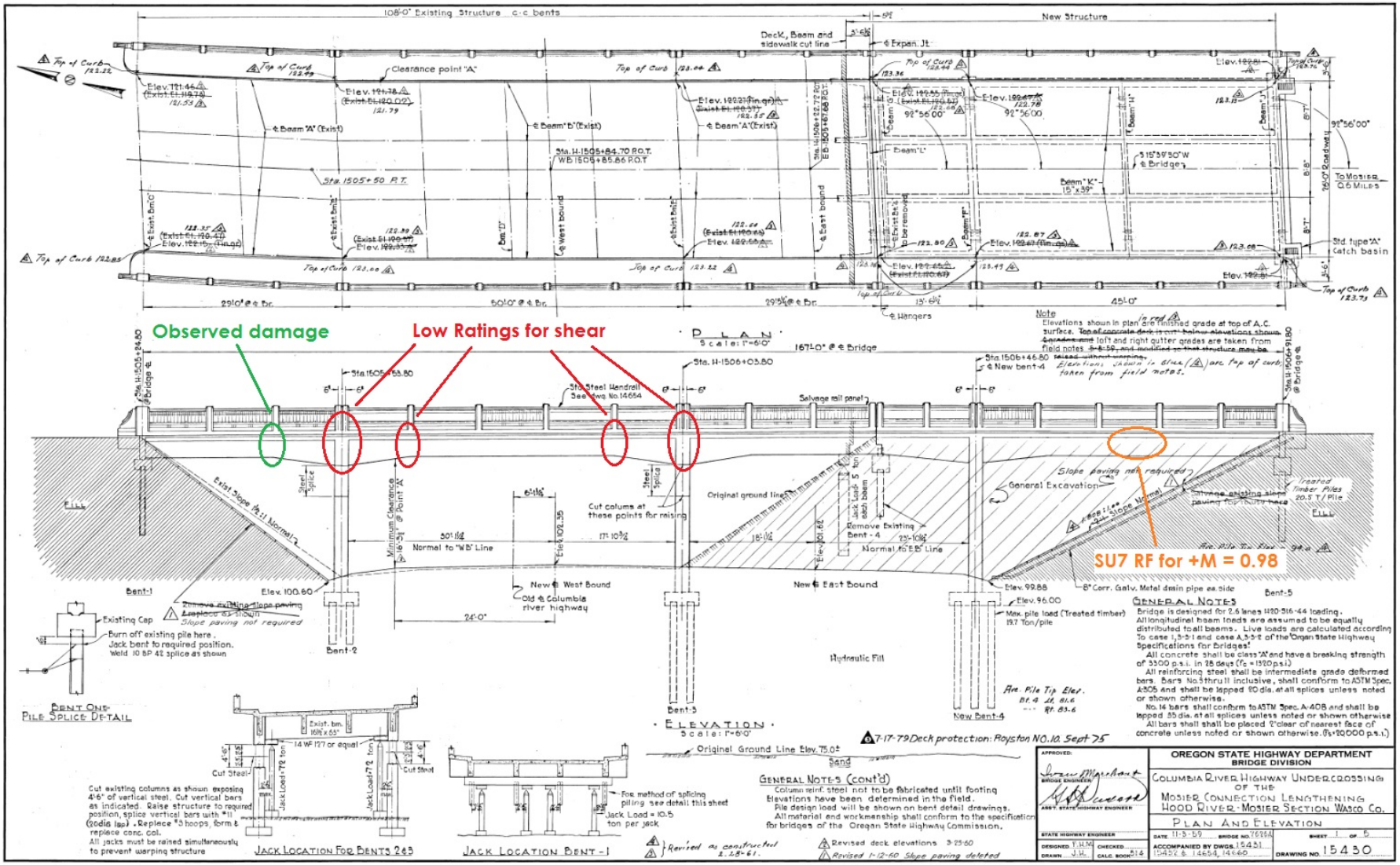

Load Rating

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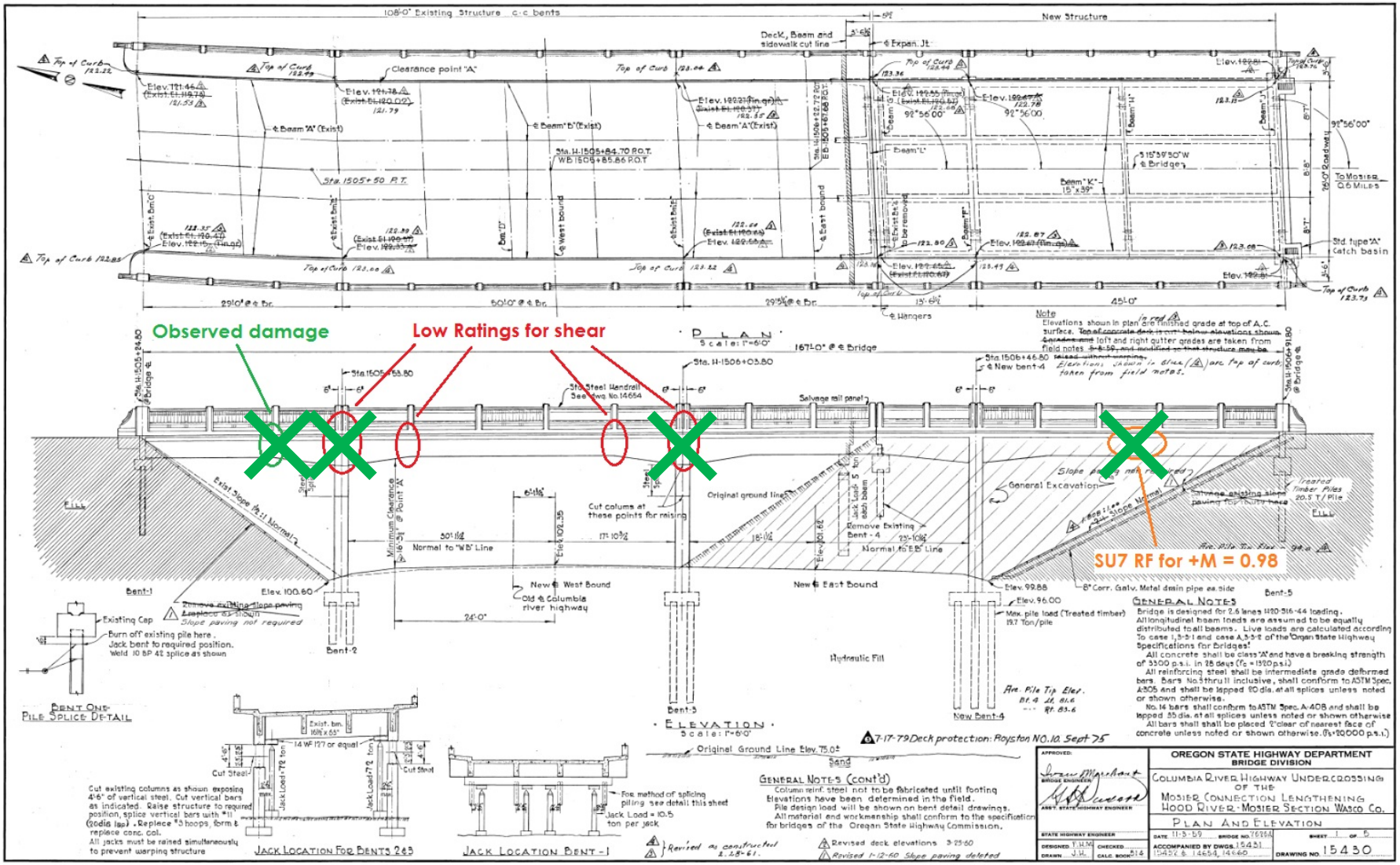
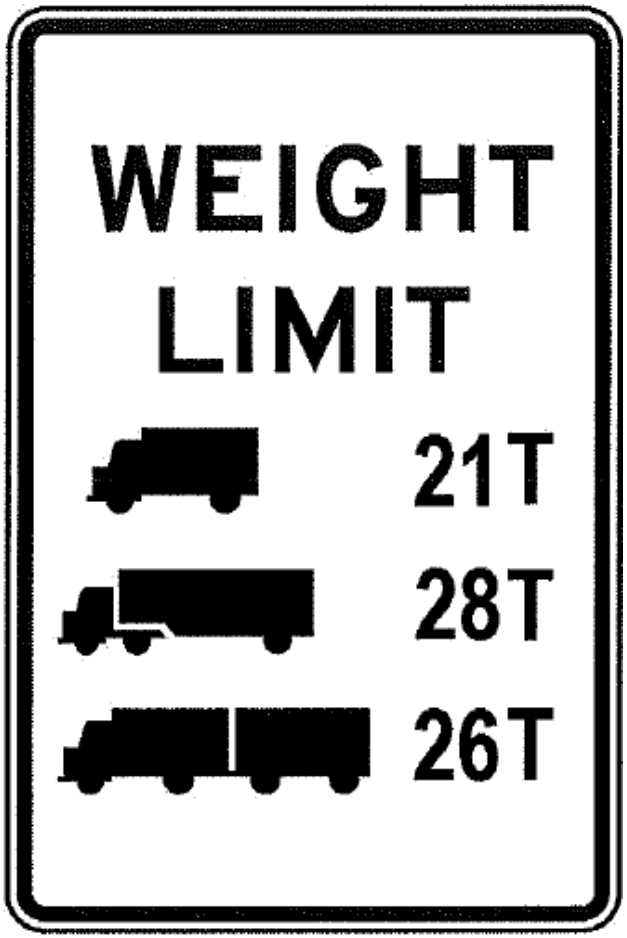


Posting Improvement

- Best we can do without substantial investment



→ → →

Community Impact

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- Local need?

- Alternative routes?

Mosier, OR

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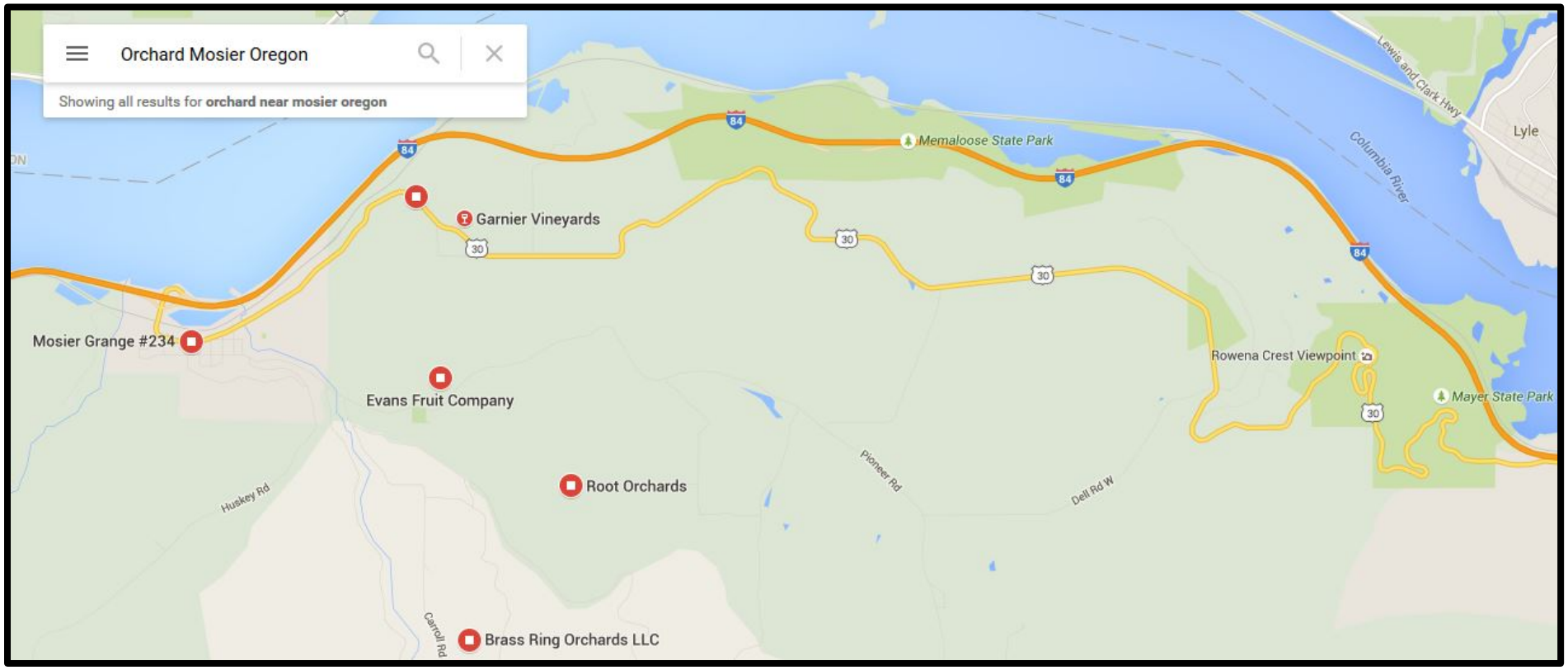
- Google Maps – "Orchard Mosier, OR"



- Harvest Season Target Start Date – June 1st

Construction Schedule

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- Goal ---------- Accommodate Local Harvest

- Schedule
  - Project Kickoff September
  - Back-out Bid Date of February 6th
  - Plans, Specifications &Estimate - Early December

Design

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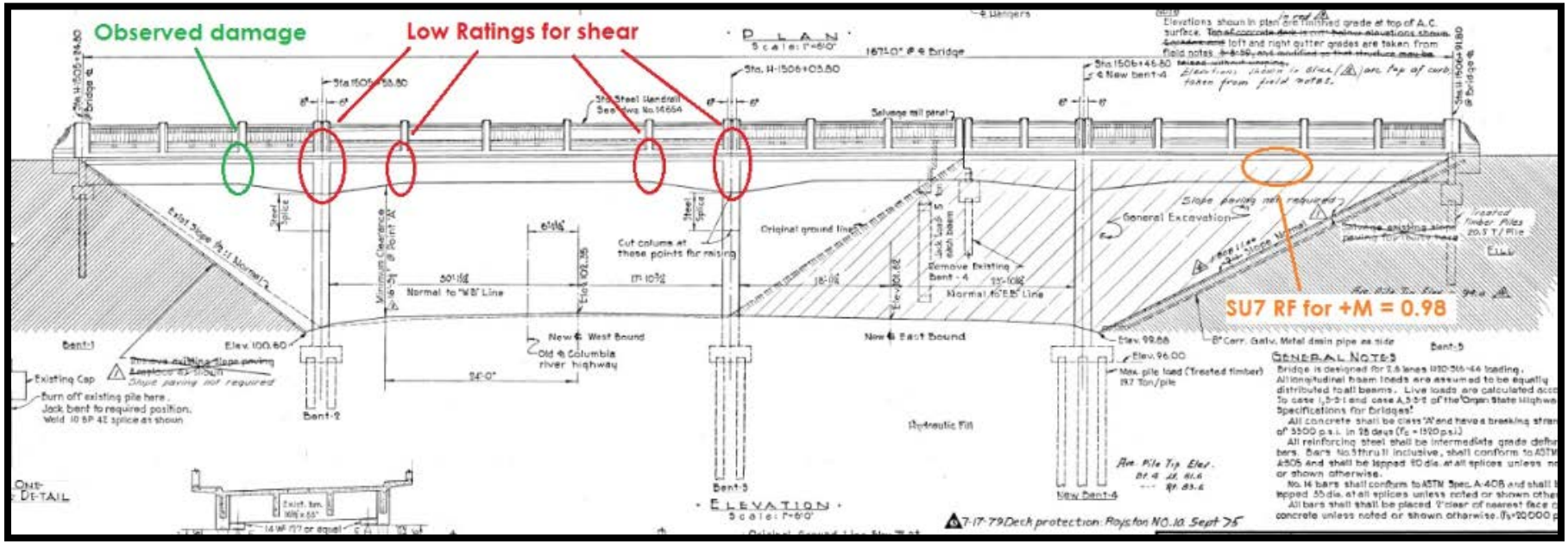
- What do we fix?
  - Strength – Standard shear and moment issues
  - Question remains
    - Longitudinal issues



Longitudinal Fix

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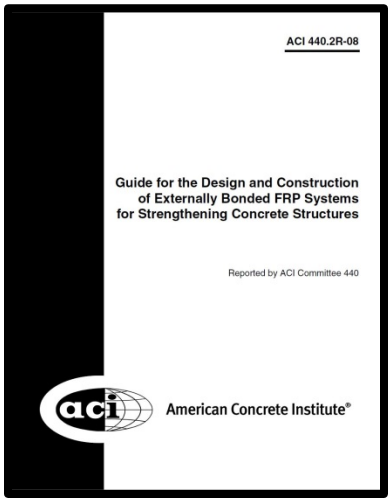
- Fiber Reinforced Polymer (FRP) Strengthening
  - Code - ACI 440 2R-08
  - 8~63NSM177 strips required
  - Narrow beams → Limited real estate
  - Existing strength requirements

$$(\phi R_n)_{existing} \geq (1.1S_{DL} + 0.75S_{LL})_{new} \qquad (9\text{-}1)$$

- Tanarat Potisuk, P.E., S.E., PhD
  - ODOT Research Initiative
    - OSU's Dr. Higgins
  - Beam w/ Haunch & Taper
    - NSM Titanium

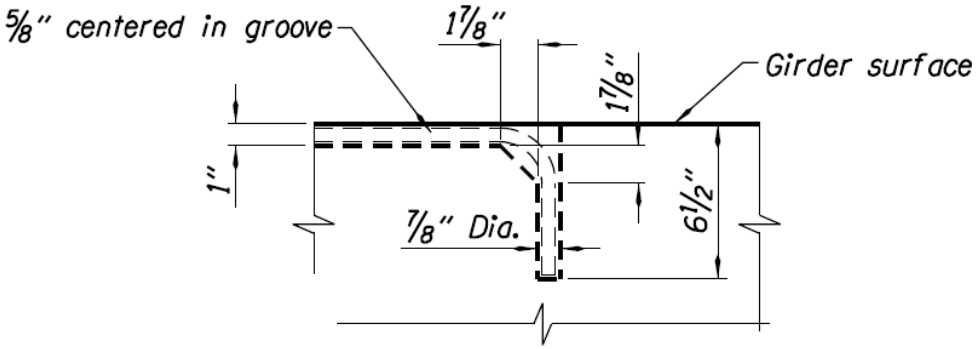


Material Properties

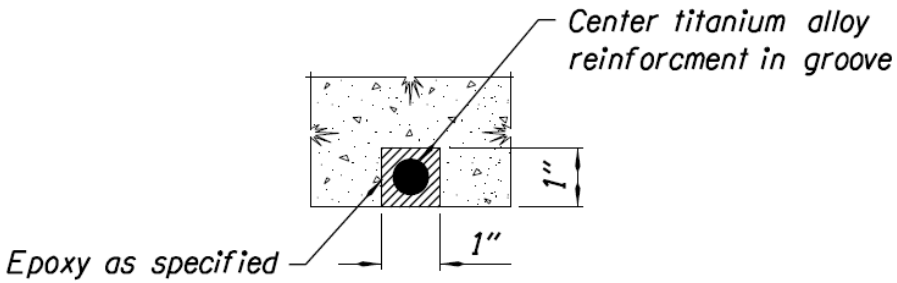
- Material Properties – From OSU Research
  - Available Bars 5/8” Diameter
  - Available Lengths 14’-0”
  - Yield Stress 140 ksi
  - Ultimate 155 ksi
  - Youngs Modulus 15,500 ksi
- ODOT Research Funding
  - Jon Rooper, PE encourages use of research resources
    - OSU Fast track production and use of Mosier Test specimens
  - Anchorage, anchorage, anchorage.

Titanium Restraints

- Max length -14ft
- 5/8" Dia.
- 1"x1" groove required
- 6" embedment hook required



CHAMFER DETAIL
Not to Scale



GROOVE DETAIL
Not to Scale

Titanium Design

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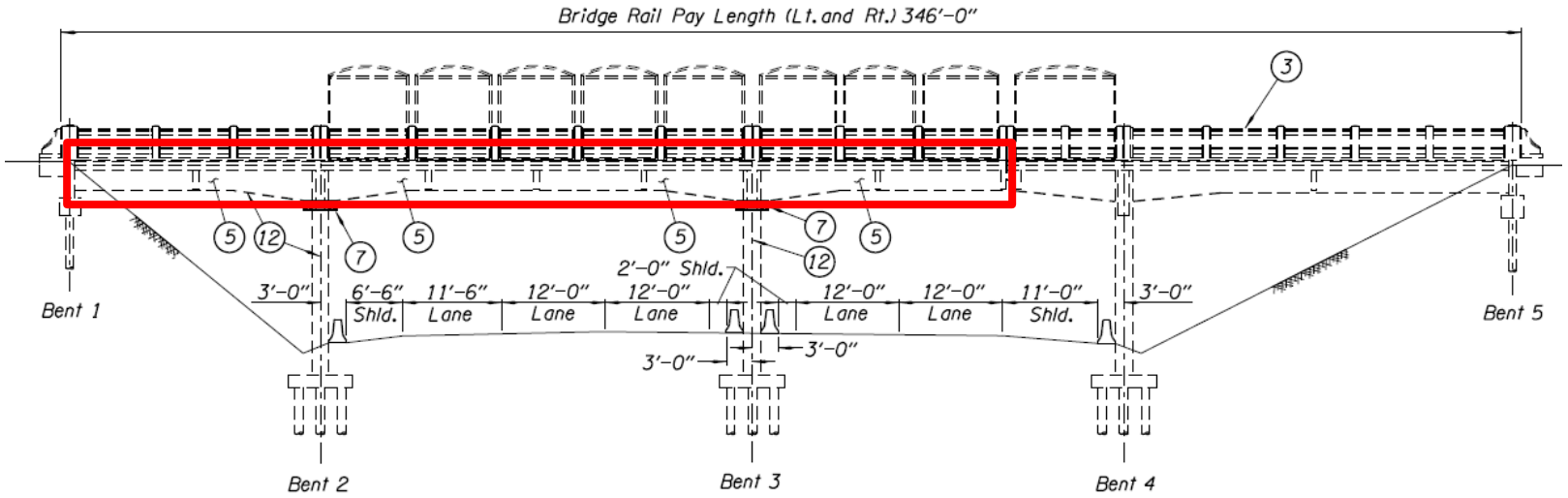
- Titanium design required 4 bars maximum
- Mid-span deficiencies cause staging issues



AASHTO LRFD Provision 5.8.3.5.1

- "The area of longitudinal reinforcement on the flexural tension side of the member need not exceed the area required to resist the maximum moment acting alone..."

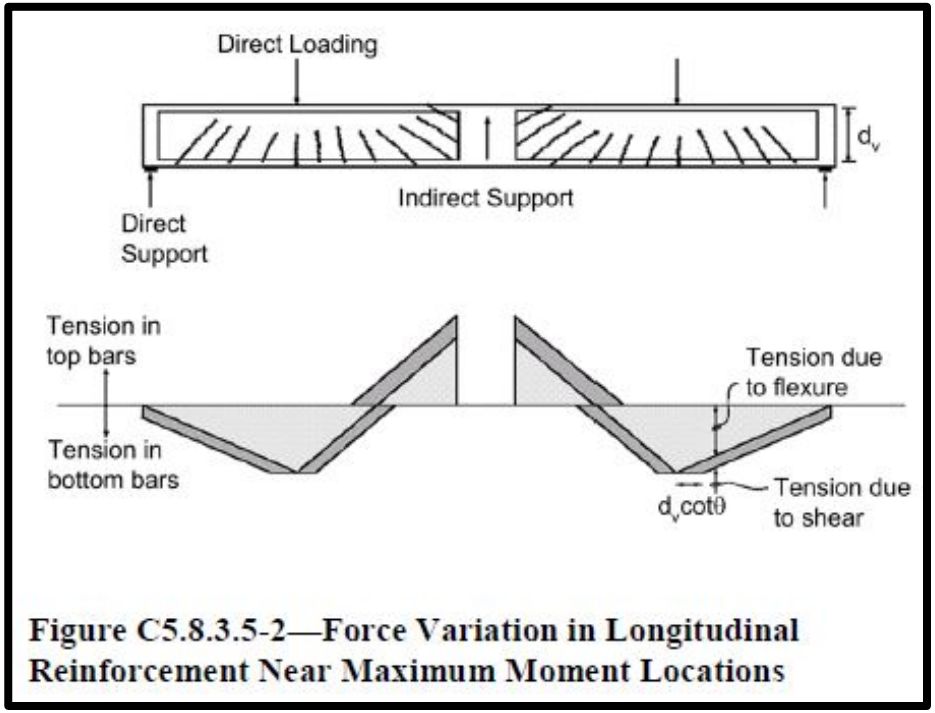


Figure C5.8.3.5-2—Force Variation in Longitudinal Reinforcement Near Maximum Moment Locations

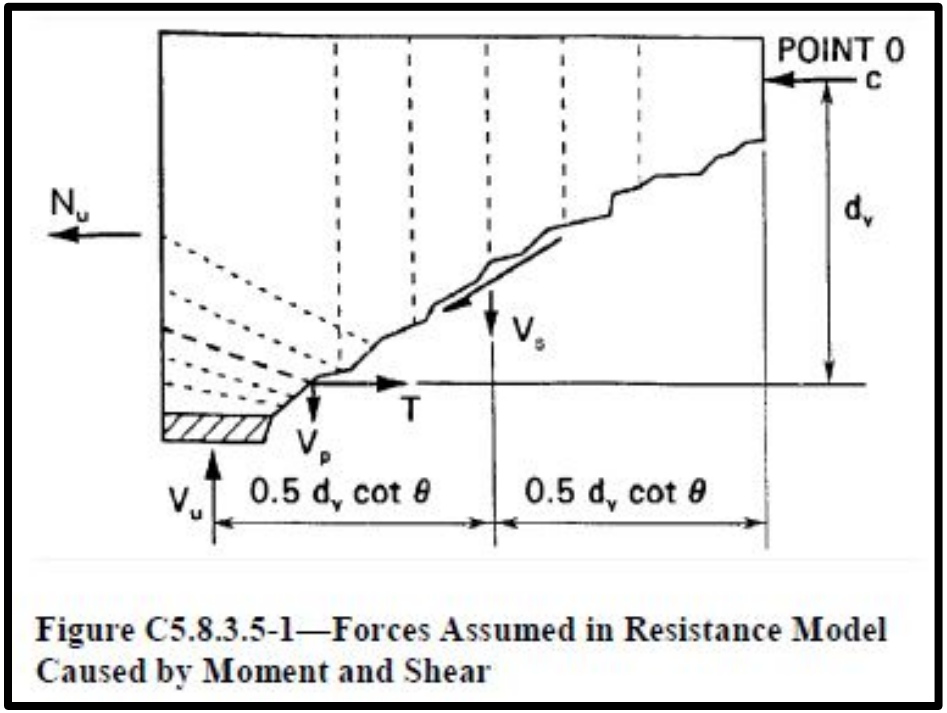


Figure C5.8.3.5-1—Forces Assumed in Resistance Model Caused by Moment and Shear

Provision 5.8.3.5.1

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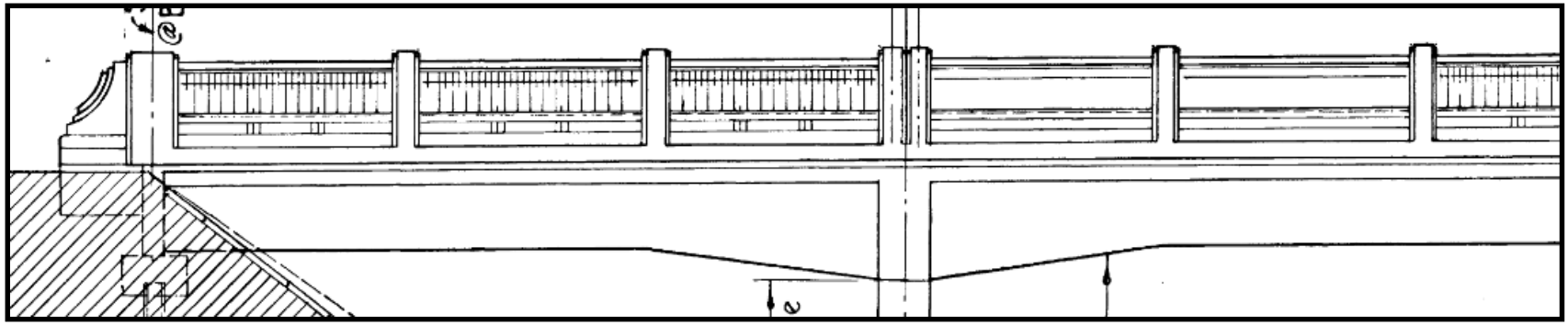
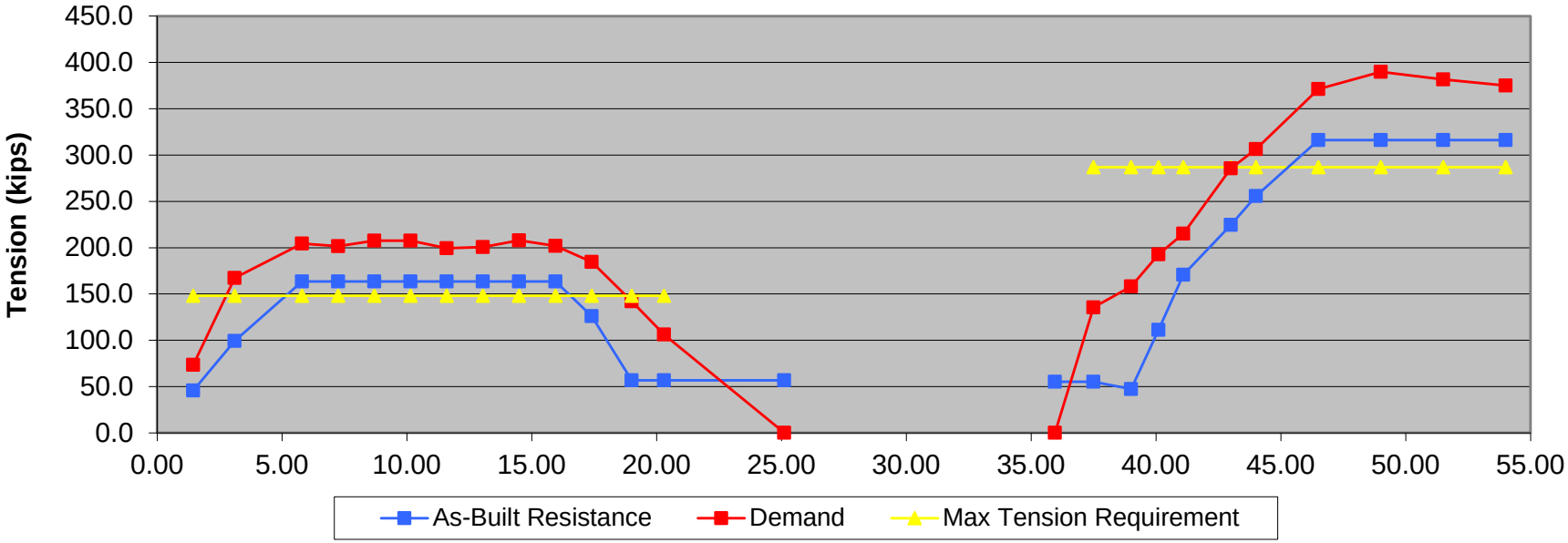
Bent 1 Span 1 Bent 2 Span 2 Mid





Access issues cont.

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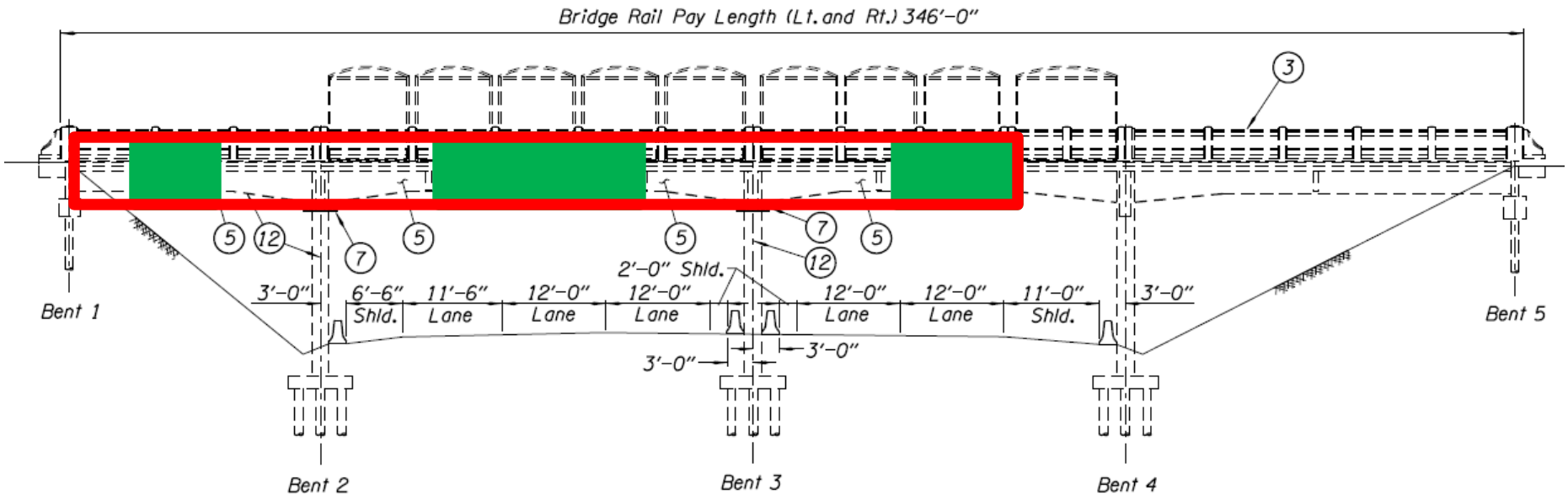
- Alleviates strengthening in most difficult location



Titanium Design

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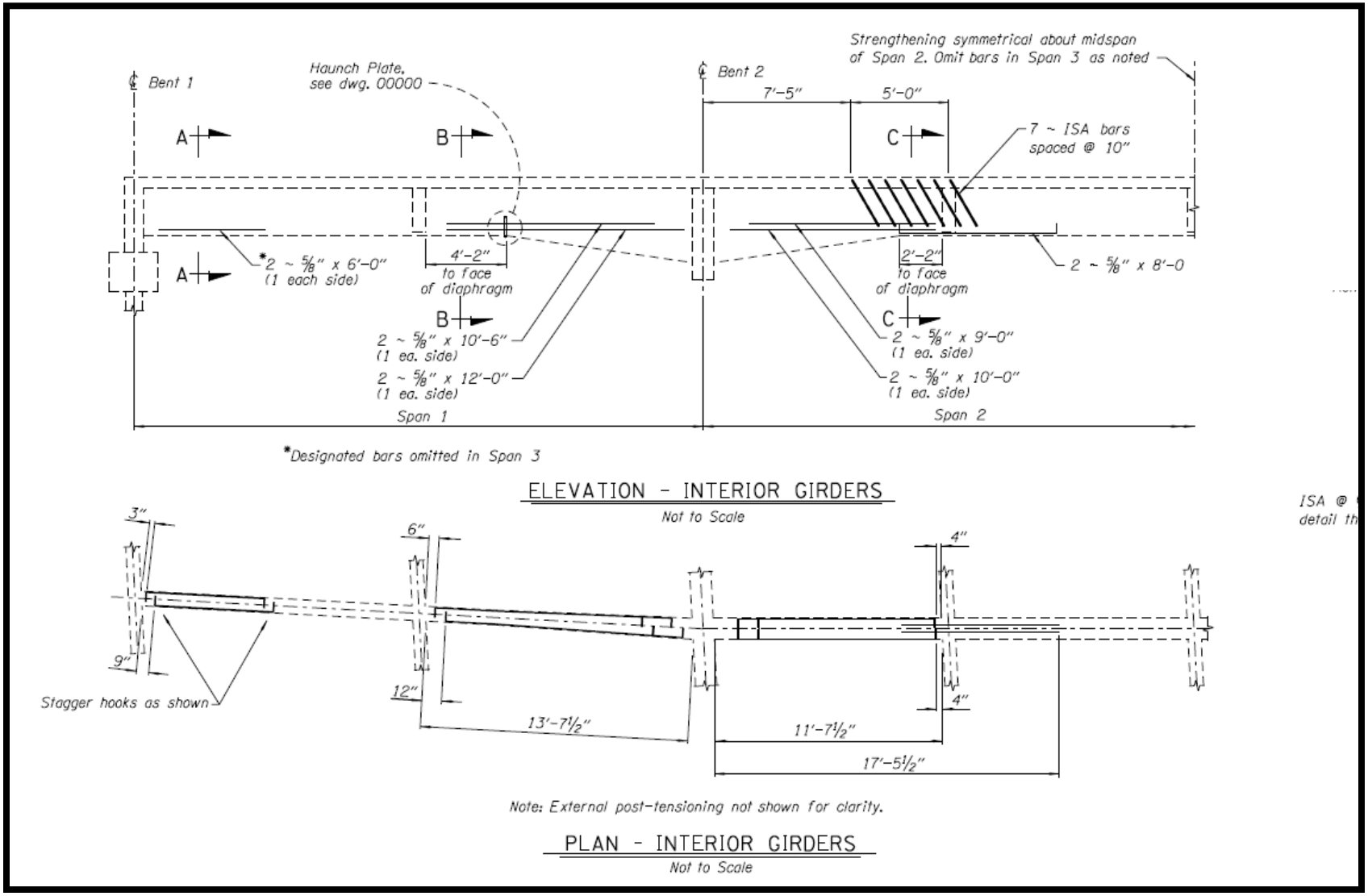

Shear Strengthening

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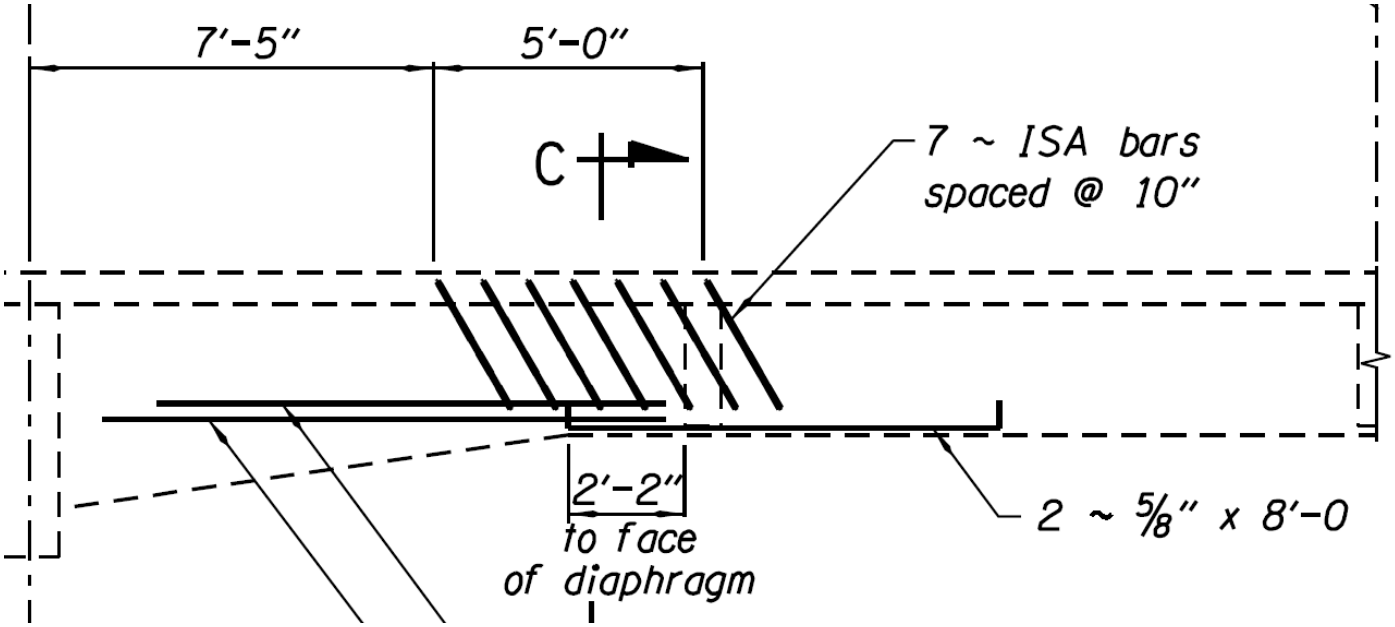
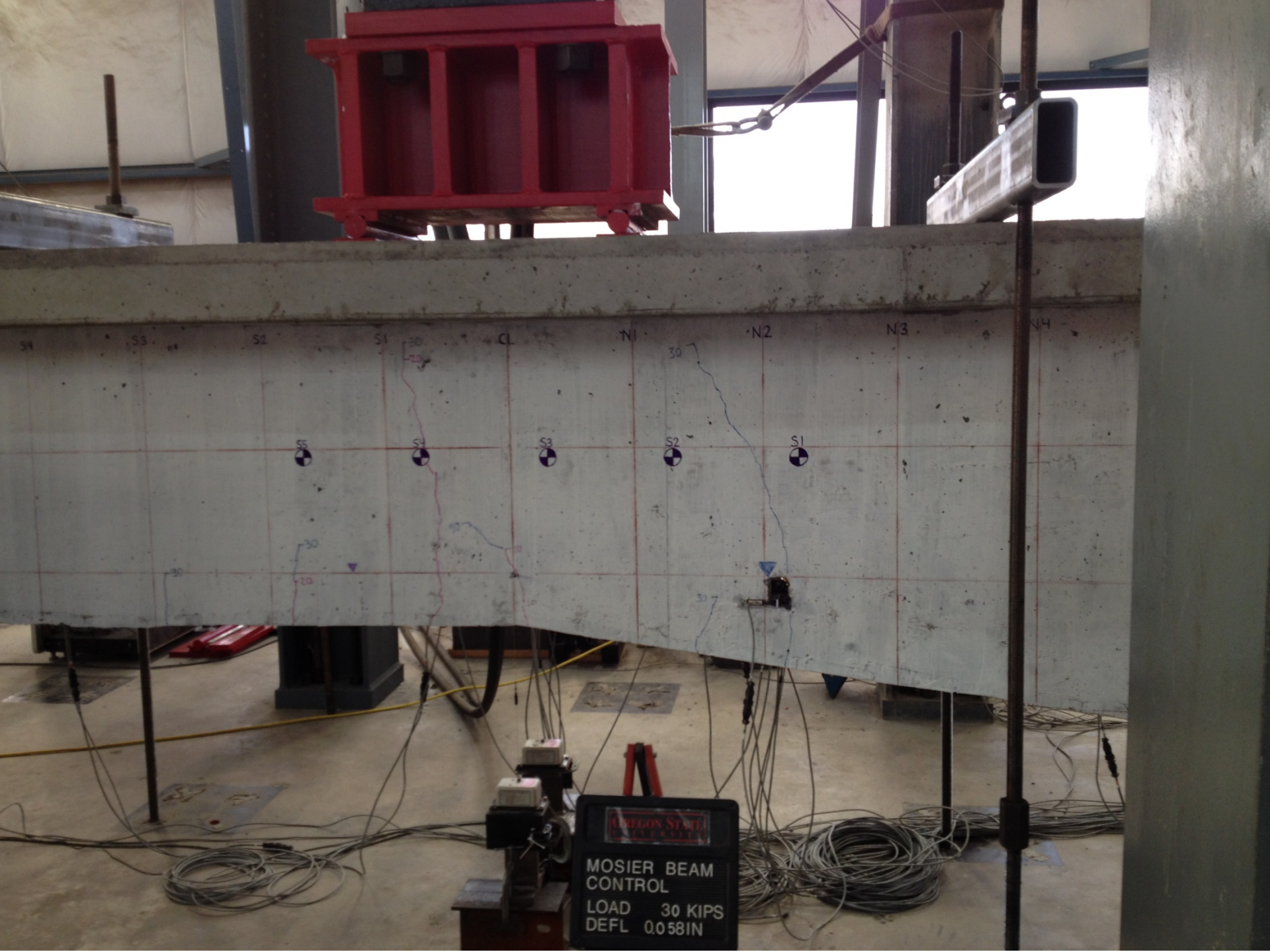
- Shear Strengthening via Internal shear anchors (ISA)
- Utilize the additional long. capacity of the titanium to decrease the number of ISA bars required

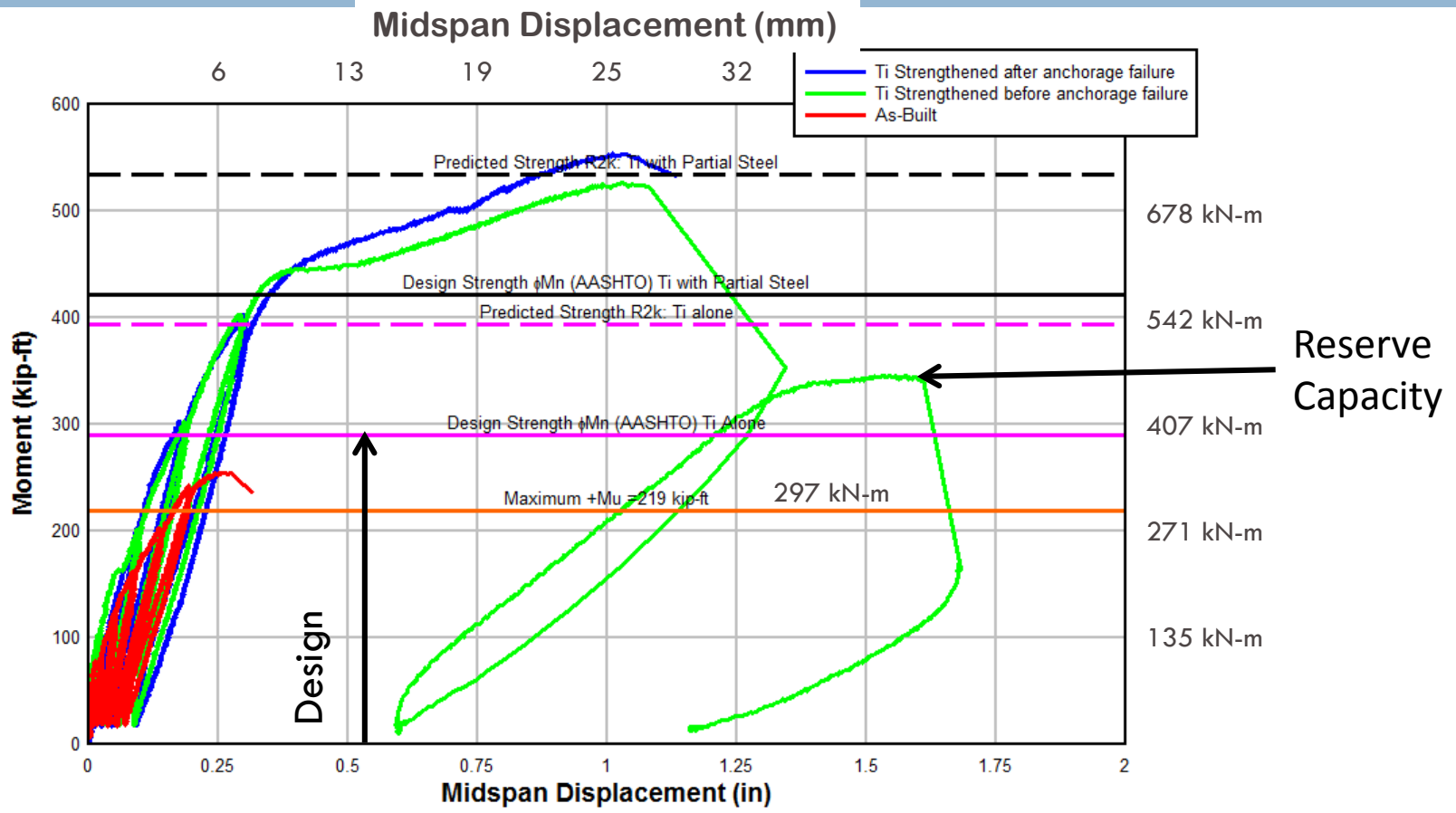



S4
S3
S2
S1
CL
N1
N2
N3
N4
S5
S4
S3
S2
S1
30
20
OREGON STATE
MOSIER BEAM
CONTROL
LOAD 30 KIPS
DEFL 0.058IN


S3
S2
S1
CL
N1
N2
N3
N4
S5
S4
S3
S2
S1
MOSIER BEAM
CONTROL
LOAD 60 KIPS
DEFL 0.215 IN

Analysis

- Reserve strength of Ti girder substantially exceeds factored demands
- Failed anchorage provided similar response as intact



- Design strength of Ti girder exceeds factored demands even with conservative assumptions

Oregon State University

Construction

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PM12:22 APR/ 7/2014


PM12:09 APR/ 7/2014


AM 7:54 MAY/ 6/2014


AM 8:32 MAY/ 6/2014


PM12:37 MAY/ 6/2014


AM10:23 SEP/10/2014

Project Schedule

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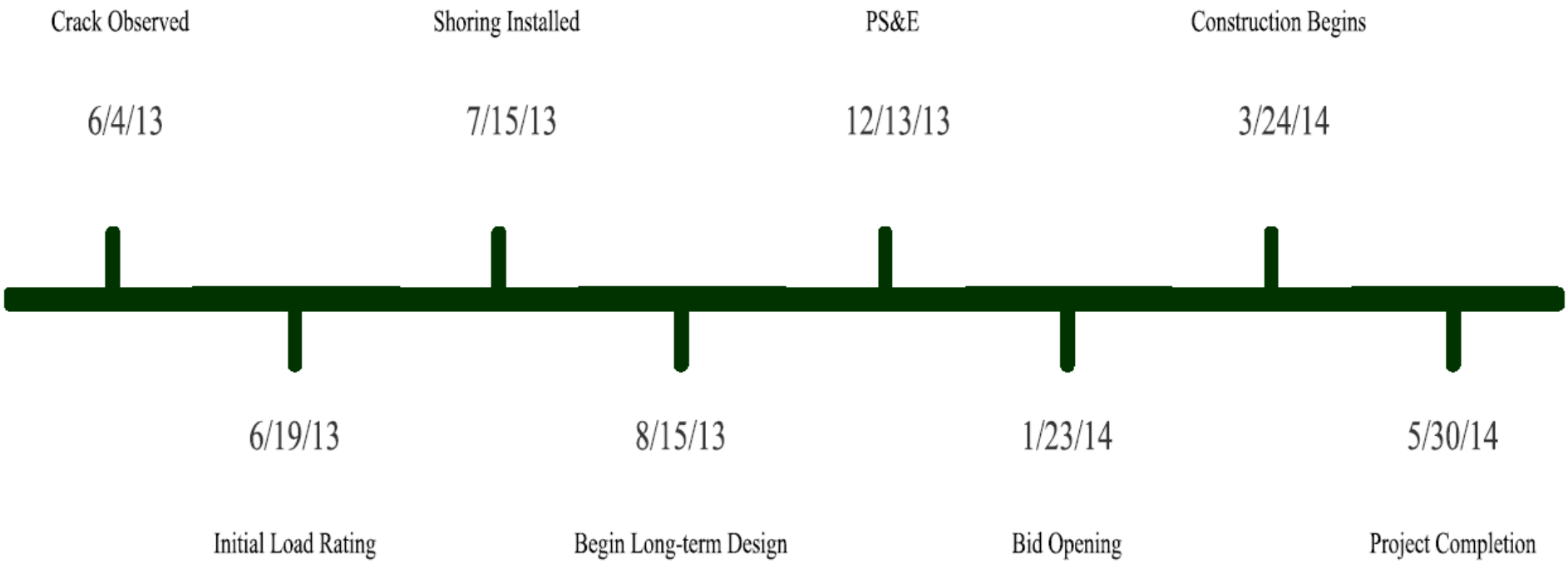
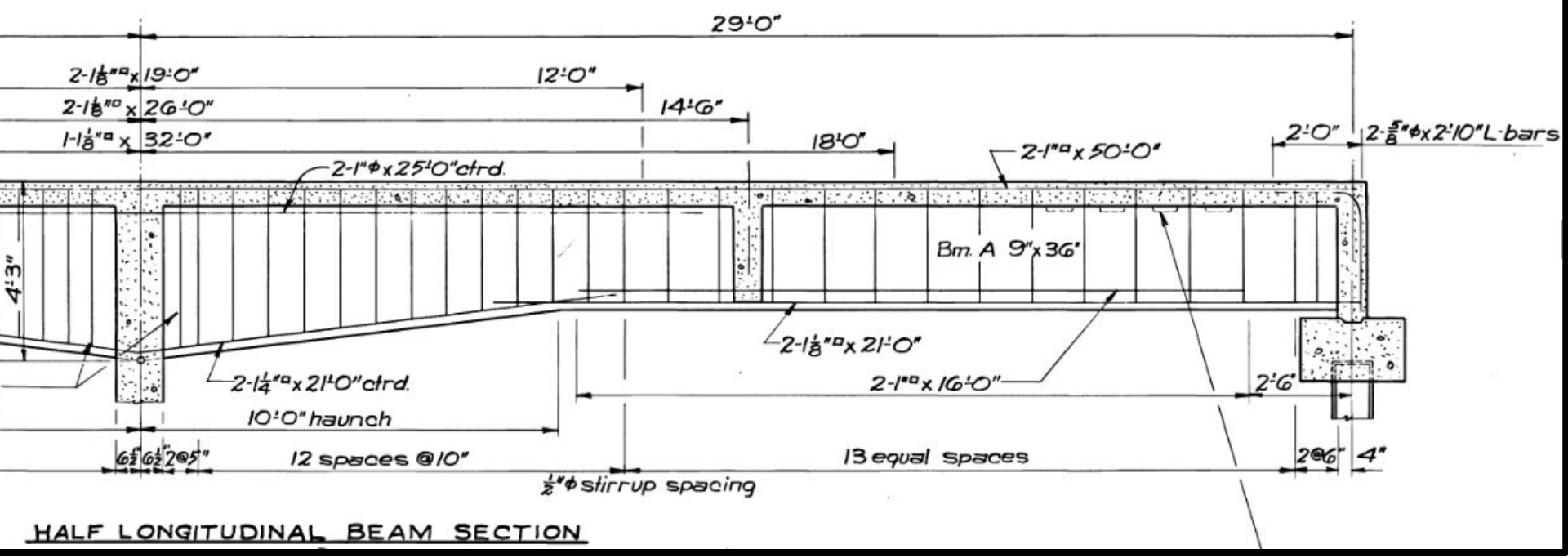
- Project June Completion Date → Success!

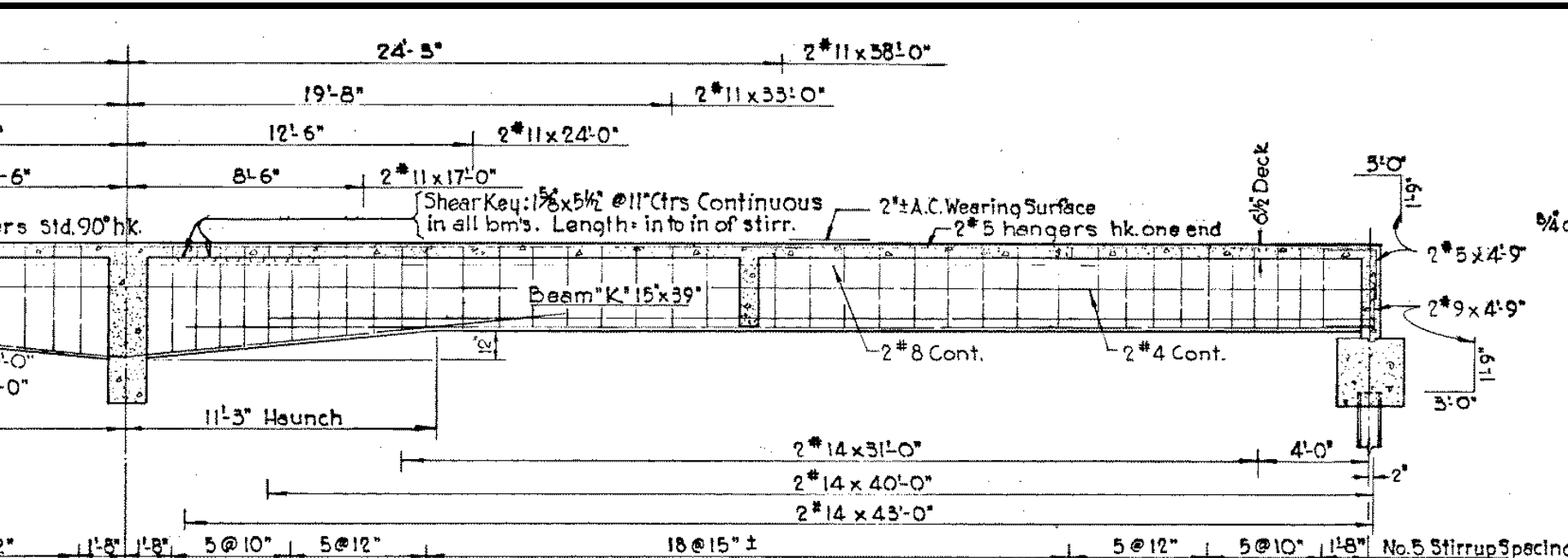


Final Thoughts

- Total project cost $800,000
  - Bridge strengthening cost $350,000
- Titanium extends the range of strengthening capabilities moving forward
- Things to keep in mind
  - Shallow stirrups….
  - Working with untrained manufacturer/supplier
  - Field bend versus shop bent hooks
  - Hooks, haunch, web taper, anchorage!
  - $110 per foot with good access



HALF LONGITUDINAL BEAM SECTION



Questions

- Paul Strauser, P.E.
  - Paul.J.Strauser@odot.state.or.us
  - 541-388-6210
- OSU Research by Dr. Christopher Higgins
  - "METHODS FOR STRENGTHENING REINFORCED CONCRETE BRIDGE GIRDERS CONTAINING POORLY DETAILED FLEXURAL STEEL USING NEAR-SURFACE MOUNTED METALICS"
- GIANT THANK YOU TO PERRYMAN COMPANY