

Best Practices to Evaluate, Rehabilitate, and Replace Local Road Bridges

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SOUTH DAKOTA STATE UNIVERSITY

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Three Research Projects: \$0.5 million

1. What are the common bridge types on South Dakota local roads?
2. How to “Load Rating” damaged bridges?
3. How to rehabilitate longitudinal joints?
4. Best alternatives to replace local road bridges?

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Funding Agencies & Collaborators


Connecting South Dakota and the Nation

























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Background

Common SD Local Road
Bridges & their Damages

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Local Road Bridges

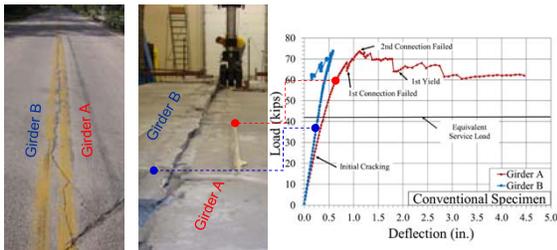
- Double-tee is the most common type of bridge on SD local roads.
- More than 700 DT bridges are in-service in SD.
- More than 75% of DT bridges are 20 years or older.
- Structural detailing, aging, environmental conditions, and damages are affecting the performance and load-carrying capacity of DT bridges.



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Current DT Long. Joint Detailing



In-Service **Laboratory**

(Wehbe et al., 2016)

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Damage of DT Girders



What is the **safe live load capacity** of distressed double-tee bridges?

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Evaluation of Damaged Bridges

How to Load Rate Damaged Double-Tee Bridges?

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What Was Done?

- Field tested two DT bridges.
- Performed strength testing of two 45-yr DT girders.
- Carried out an extensive analytical study to relate damage to capacity.
- Proposed a methodology for load-rating DT bridges.

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Evaluation of Damaged Bridges

Field Testing of Two Double-Tee Bridges

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Description of Field Test Bridges

Bridge ID	County	Span, ft. (m)	Damage Type and Condition State	Age, Yr.
42165153	Lincoln, SD	42 (12.8) (Seven 30-in. (762-mm) Deep Girders)	Non-skewed, Spalling of stem concrete cover (with a condition state of Fair), and leakage of girder-to-girder joints (with a condition state of Poor).	34
51090012	Moody, SD	50 (15.24) (Eight 23-in. (584-mm) Deep Girders)	Non-skewed, Water leakage between all deck units, stains from minor corrosion of steel plates in longitudinal joints (with a condition state of Poor), concrete spalling (with a condition state of Fair).	38



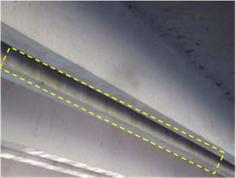

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Damage of Bridge 51-090-012



Stains from Minor Corrosion of Steel Plates



Sign of Water Leak b/w Deck Units



Concrete Spalling at Railing

23-in Deep Double-Tee Girder Bridge

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Field Testing Loading Protocols

Load Types:

- Static Tests (5 mph)
- Dynamic Tests

For Dynamic Tests:

Lincoln County

- Shear Response = 55 mph
- Flexural Response = 35 mph

Moody County

- Flexural Response = 35 mph

Test Truck used for Field Testing (Similar to SD Legal Truck Type 3)



Truck Total Weight was 49.98 kips



Truck Axle Weight Distribution

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Sample Video of Dynamic Field Testing

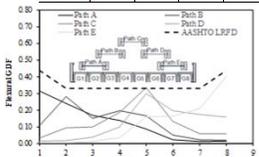


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Field Test Results: Flexural GDF

Flexural GDF of 23-in. Deep Double-Tee Girder Bridge

	G1	G2	G3	G4	G5	G6	G7	G8
Path A	0.32	0.24	0.17	0.14	0.09	0.02	0.01	0.01
Path B	0.11	0.28	0.15	0.20	0.17	0.05	0.02	0.02
Path C	0.03	0.09	0.10	0.19	0.34	0.11	0.06	0.06
Path D	0.01	0.02	0.04	0.10	0.30	0.20	0.17	0.16
Path E	0.01	0.01	0.01	0.04	0.16	0.16	0.21	0.40
Maximum GDF of each Girder	0.32	0.28	0.17	0.20	0.34	0.20	0.21	0.40
AASHTO GDF of each Girder	0.438	0.33	0.33	0.33	0.33	0.33	0.33	0.438



The measured flexural GDFs for each girder were equal to or less than those from the AASHTO LRFD.

Flexural GDF of each girder in each path of 23-in. Deep Double-Tee Girder Bridge

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Evaluation of Damaged Bridges

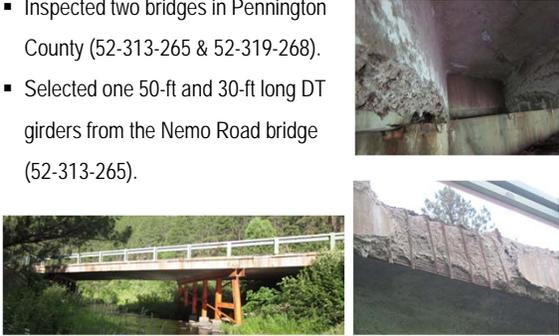
Strength Testing of Two Damaged Double-Tee Girders

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Salvaged Double-Tee Girders

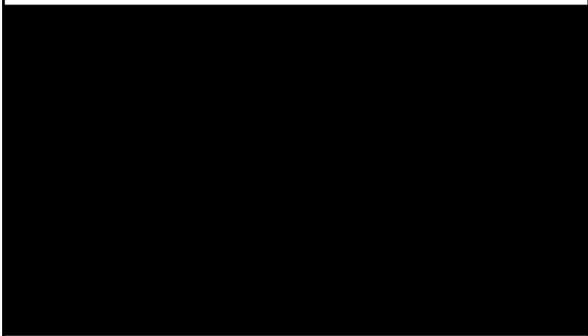
- Inspected two bridges in Pennington County (52-313-265 & 52-319-268).
- Selected one 50-ft and 30-ft long DT girders from the Nemo Road bridge (52-313-265).



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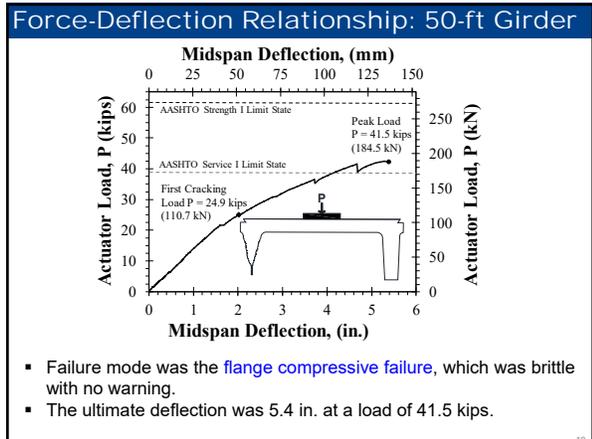
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Strength Testing of 50-ft Girder



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Evaluation of Damaged Bridges

Proposed Methodology for Double-Tee Bridges

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Methodology for Load Rating – Demand

$$RF = \frac{C - (Y_{DC})(DC) - (Y_{DW})(DW) \pm (Y_P)(P)}{(Y_{LL})(LL + IM)}$$

Live Load Components:

- To calculate GDF for a SD double-tee girder bridge with longitudinal joint damage condition state 3 or less, follow the AASHTO LRFD specifications.
- For longitudinal joint damage condition state 4, GDF is the greater of (a) the factor for the exterior girders, (b) the factor for the interior girders, and (c) 0.6.
- For Dynamic Load Allowance (IM), follow the AASHTO LRFD specifications.

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Methodology for Load Rating - Capacity

$$RF = \frac{C - (Y_{DC})(DC) - (Y_{DW})(DW) \pm (Y_P)(P)}{(Y_{LL})(LL + IM)}$$

Capacity:

$$C_{undamaged} = \phi_s \cdot \phi \cdot R_n$$

$$C_{damaged} = \phi_c \cdot C_{undamaged}$$

We need to determine moment and shear condition factors (ϕ_c) for different damage types and condition states and for different double-tee girder sections.

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Example of Condition Factors (ϕ_c)

Damage Type	Proposed Damage Types and Condition States for Double-Tee Girder Stem			
	CS-1 Good	CS-2 Fair	CS-3 Poor	CS-4 Severe
Cover Deterioration including Delamination/ Spall/ Patched Area	None	Loss of 1/3 of the cover without exposure or corrosion of reinforcement.	Loss of 2/3 of the cover without exposure or corrosion of reinforcement.	Exposure of reinforcement without any signs of corrosion.
Exposed Transverse Rebar	None	Minor corrosion of the reinforcement with minimal section loss.	Severe corrosion of only one leg of transverse reinforcement.	Severe corrosion of all legs of transverse reinforcement in a section.
Exposed Longitudinal Prestressing	Exposure of reinforcement without any sign of corrosion.	50% section loss due to corrosion in the extreme tendon.	100% section loss due to corrosion in the extreme tendon.	Section loss due to corrosion in the two or more tendons.
Cracking	Insignificant cracks or moderate-width cracks that have been sealed.	Unsealed moderate width cracks or unsealed moderate pattern (map) cracking. Cracks from 0.004 to 0.009 inches wide.	Wide cracks or heavy pattern (map) cracking. Cracks greater than 0.009 inches wide.	Wide cracks or heavy pattern (map) cracking that crosses multiple shear reinforcement.



$\phi_{c-M} = 1.0$
 $\phi_{c-V} = 0.75$



$\phi_{c-M} = 1.0$
 $\phi_{c-V} = 0.9$



$\phi_{c-M} = 0.90$
 $\phi_{c-V} = 0.75$

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Rehabilitation of Existing Bridges

How to Rehabilitate Double-Tee Girder-to-Girder Joints?

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What Was Done?

- 20 Rehabilitation Joint Detailing Alternatives.
- Testing of 13 Large-Scale Beams.
- Detailed Finite Element Analysis.
- Testing of 40-ft Conventional Double-Tee Bridge.
- Rehabilitation of the Conventional DT Bridge.
- Testing of Rehabilitated Bridge.
- Recommendations.

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Ultra-High Performance Concrete (UHPC)

- Fiber-reinforced cementitious concrete
- Made with very fine aggregates in size of dust
- Usually with 2% volumetric steel fibers
- Better durability than concrete

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How to Rehabilitate Long. Joints?

A Filler Material Plan
Not to Scale

- UHPC
- LMC

Pocket Detailing:
UHPC filled pockets reinforced with steel bars.

Continuous Detailing:
LMC filled joint reinforced with wire-mesh.

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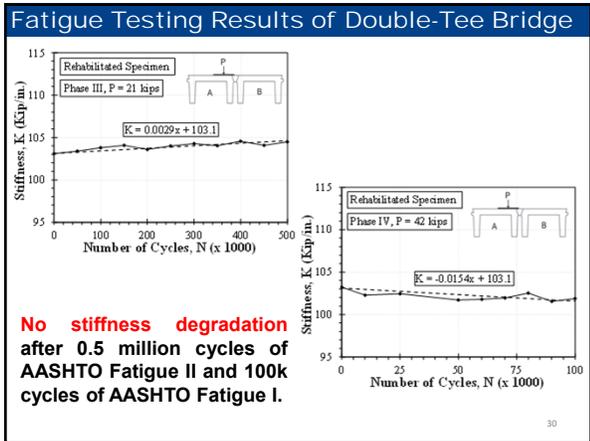
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Strength Testing of Rehabilitated Bridge

South Dakota State University

Lohr Structures Laboratory

Rehabilitation of Longitudinal Joints of Double-Tee Bridges

Project: SD2014-20

Strength Test Date: February 24, 2017

Full-Scale 40-ft Long Double-Tee Bridge

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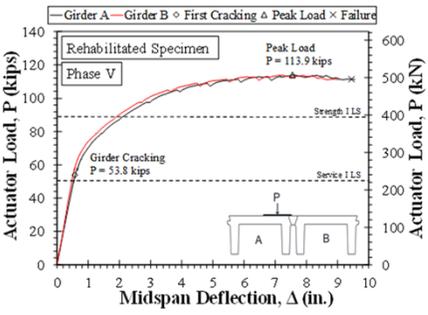
Rehabilitated Bridge Failure





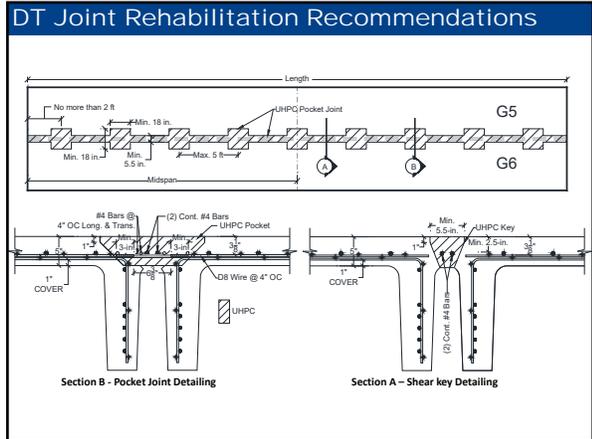

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Rehabilitated Bridge Strength Test Results and Costs



- Pocket joint rehabilitation cost is **28%** of that of replacement.
- Continuous joint rehabilitation cost is **57%** of that of replacement.

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Bridge Replacement Alternatives

Best Alternatives to Replace Local Road Bridges?

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What was Done?

- Literature Review on 10 Alternatives.
- Testing of one 50-ft Long Fully-Precast Bridge.
- Testing of one 50-ft Long Girder Timber Bridge.
- Testing of one 16.5-ft Long Slab Timber Bridge.
- Evaluation and comparison with Double-Tee.
- Recommendations.

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Bridge Replacement Alternatives

Construction of Precast, Glulam Girder, and Glulam Slab Bridges

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Fully-Precast Bridge - Test Model

50 ft

9.5 ft

Panel-to-Panel Joint

Full-Depth Deck Panel

Precast/Pre-stressed Inverted Bulb-Tee Girder

Panel-to-Panel Joint

Hidden Pocket, Headed Studs

Full-Depth Pocket, Inverted U-Shape Bars

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Glulam Bridges - Prototype

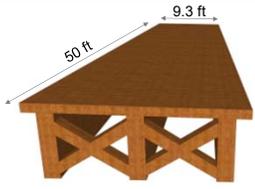
50-ft long, 34.5-ft Wide Girder Bridge

30-ft long, 34.5-ft Wide Slab Bridge

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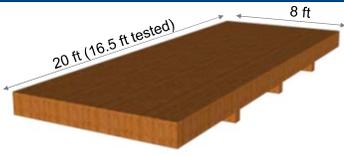
Glulam Girder Bridge - Test Model



- Bridge was designed based on 26F-1.9E Southern Yellow Pine Glulam.
- Bridge was made of 24F-2.0E Southern Yellow Pine Glulam – **Construction Error.**
- Deck was made up of 11 interior 48 x 5.5 x 110.75-in. panels and 2 exterior panels with a dimension of 36 x 5.5 x 110.75 in.
- Bridge consisted of 3 girders with a dimension of 8.5 in. x 30.25 in. x 50 ft.

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Glulam Slab Bridge - Test Model



- Bridge was designed based on 24F-2.0E Southern Yellow Pine Glulam.
- Deck consisted of 2 interior panels with a dimension of 48 in. x 10.75 in. x 16.5 ft.
- Also consisted of 3 stiffeners with a dimension of 5.5 in. x 5 in. x 7.5 ft.
- Deck panels were connected to the stiffeners by 12 in. x 3/4 in. dia. lag bolts.

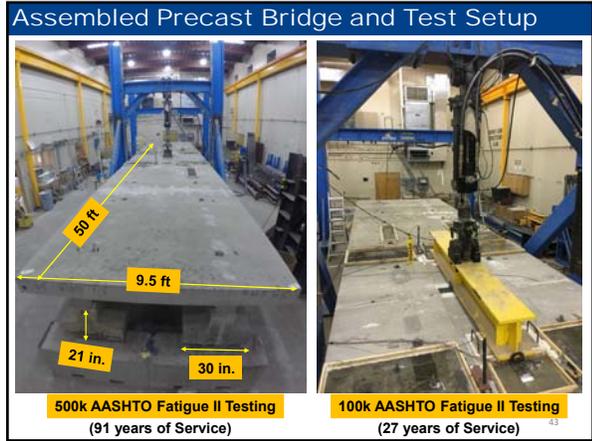
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Assembly of Test Specimen



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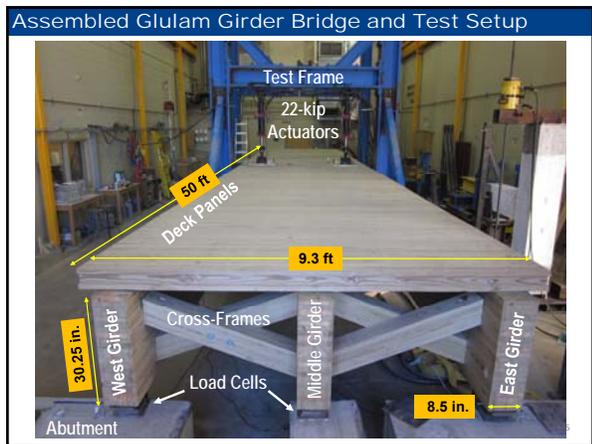
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Test Procedure

Each bridge was tested under:

- At least 0.5 million cycles of AASHTO Fatigue II loads.
- Intermediate stiffness loading.
- Strength (ultimate) loading.

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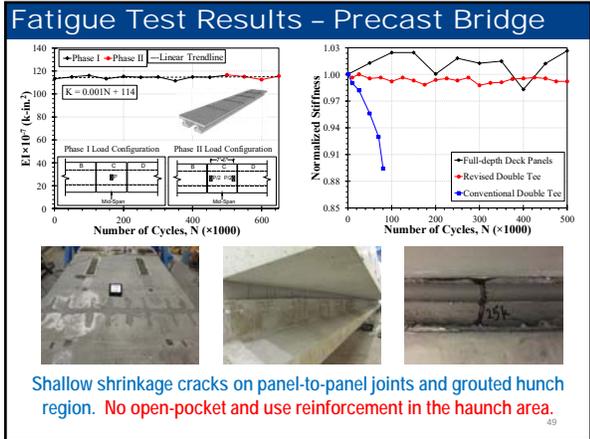
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Bridge Replacement Alternatives

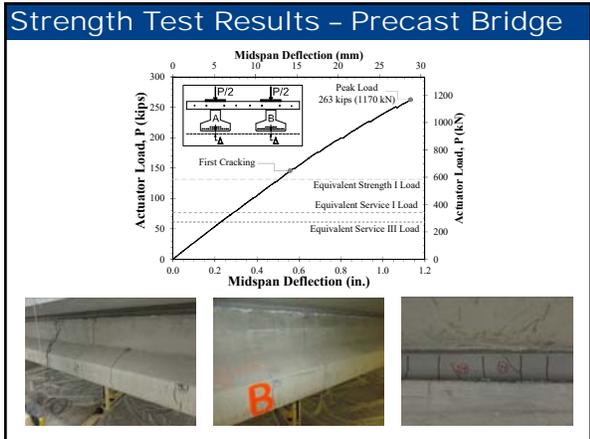
Testing of Precast, Glulam Girder, and Glulam Slab Bridges

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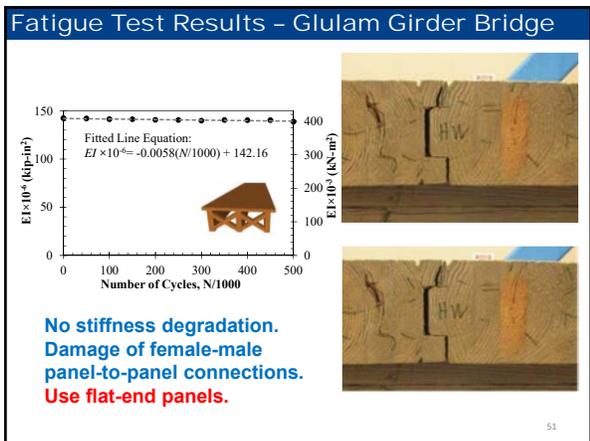
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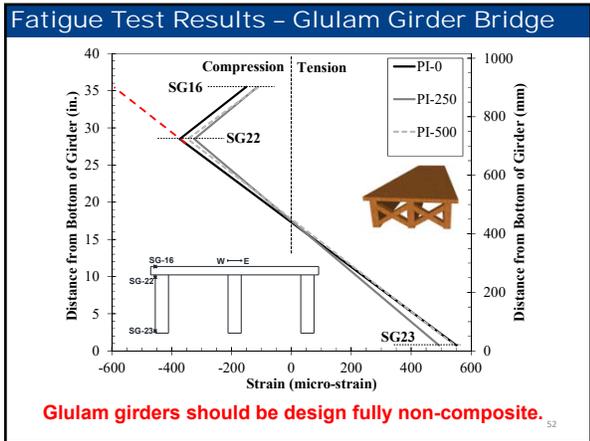


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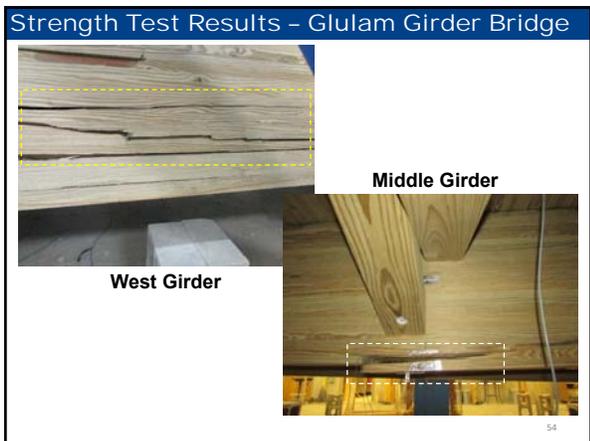




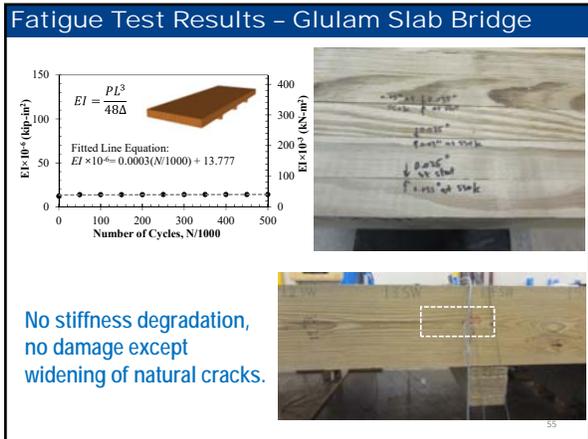
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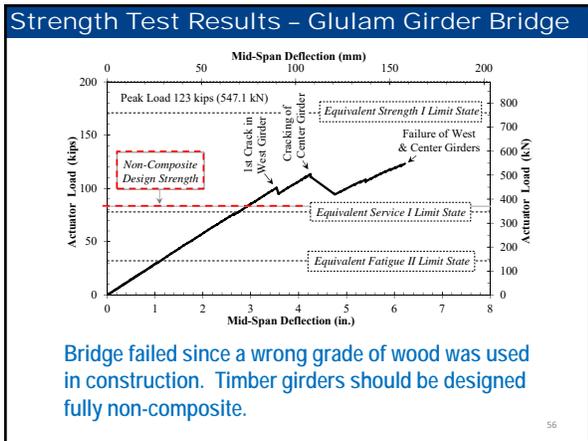
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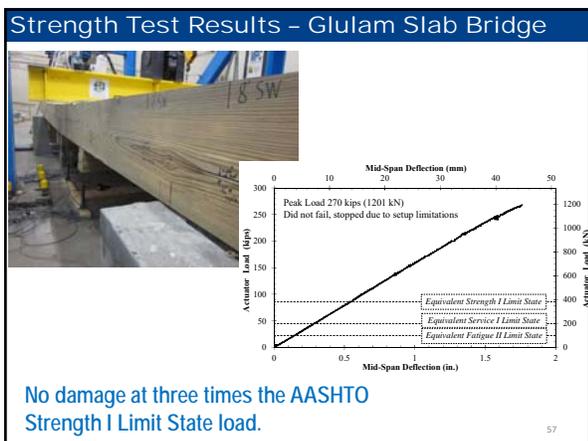
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Bridge Replacement Alternatives

Overall Evaluation of Precast, Glulam Girder, and Glulam Slab Bridges

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Evaluation of Three Alternatives

Bridge System	Superstructure Cost
Glulam Slab Bridge	50% Less than Double-Tee
Glulam Girder Bridge	15-20% Less than Double-Tee
Precast FDDP Bridge	11% higher than Double-Tee

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Summary of Three Studies

Answers to Four Questions
and Research Reports

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Summary of Three Studies

- Double-Tee (DT) Bridges are common in SD.
- Load-rating should be performed on damaged DT bridges.
- UHPC-filled pocket or continuous detailing can be used to rehabilitate DT joints.
- Three new bridge alternatives can be used in new/replacement projects.

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Research Reports



Go to MPC website & search for "Tazarv"
<https://www.mountain-plains.org/>

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Questions?

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