


SANDWICH PLATE SYSTEM USE IN TEXAS

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TxDOT Bridge Division

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What is an SPS Bridge Deck?

Photo courtesy of Intelligent Engineering

The Sandwich Plate System - SPS

Structural Composite

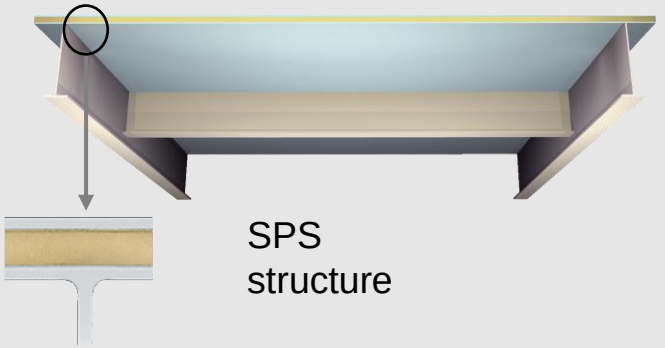
- Alternative to reinforced concrete and stiffened steel in construction, civil engineering and maritime structures

Key Benefits for Construction

- Lightweight
- Capable of fast erection
- Prefabricated

History

- Developed in 1993
- Used in ships, bridges, stadium and buildings



SPS structure

Conventional stiffened steel structure

Conventional concrete-steel composite structure

Images courtesy of Intelligent Engineering

How Does SPS Fit In With Bridge Deck Construction?

SPS has these characteristics:

- Light weight relative to concrete deck construction
- Compatible with existing bridge components, construction details and wearing surfaces
- Adaptable to multiple configurations (plan dimensions, support structure conditions)
- Prefabricated
- Readily maintained or replaceable in case of extreme events (fire, collisions, floods)

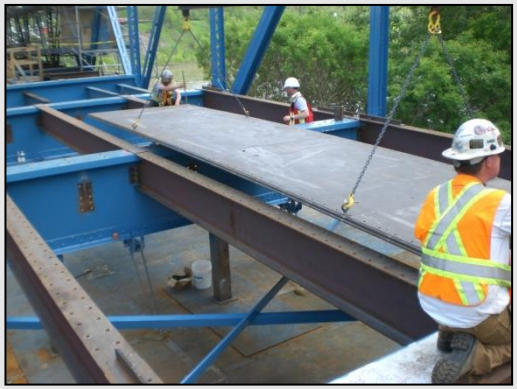
SPS Bridge Deck Plates

Light weight relative to existing deck construction

- Up to 70% lighter than concrete decks
- Lighter equipment for deck installation

Compatible with existing bridge components, construction details and wearing surfaces

- Bolted to supporting girders and stringers
- Works compositely with superstructure
- Works with standard details (deck-girder connections, drains, guardrails, abutments, curbs)
- Option for light weight or asphalt wearing surfaces



Photos courtesy Intelligent Engineering

SPS Bridge Deck Plates, Simple Design

Can be designed in accordance with AASHTO LRFD

Ultimate Limit State

- Flexural resistance
- Shear resistance
- Bond strength

Serviceability Limit State

- Deflections
- Vibrations (if applicable)

Fatigue Limit State

- Welded connections

Bolted Connections

- Shear resistance
- Bearing resistance
- Sealing requirements for bolts (watertightness)

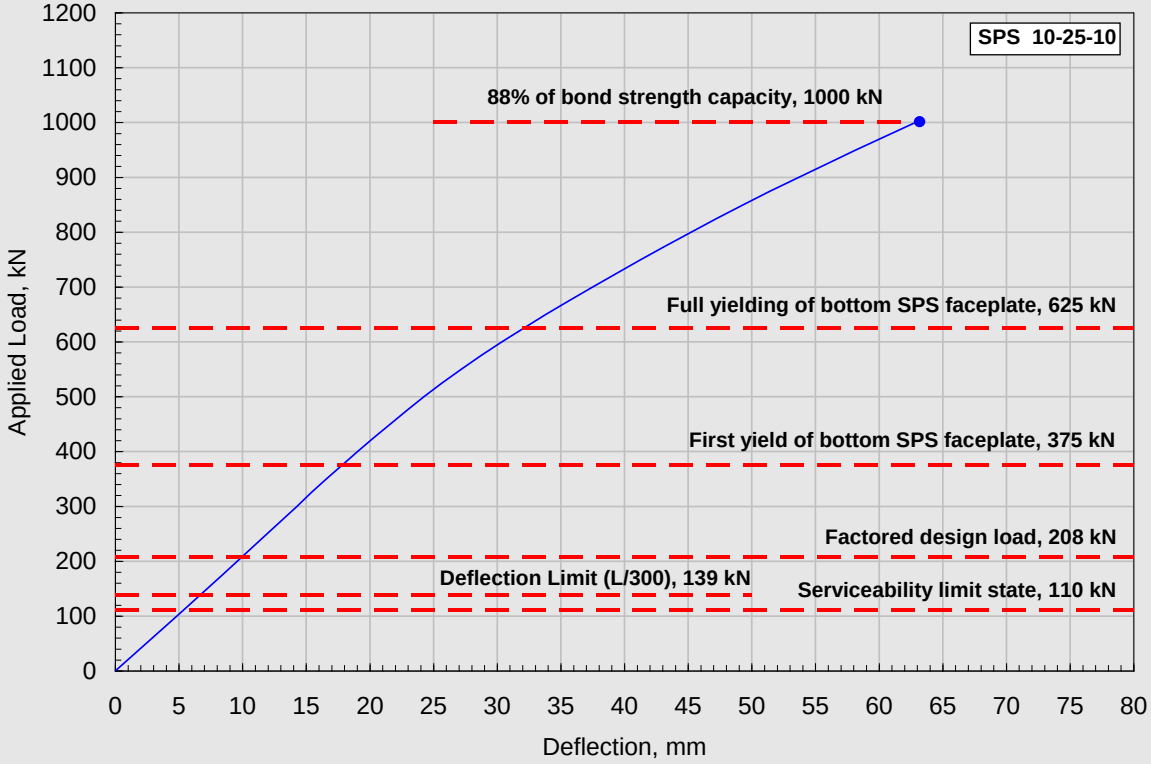
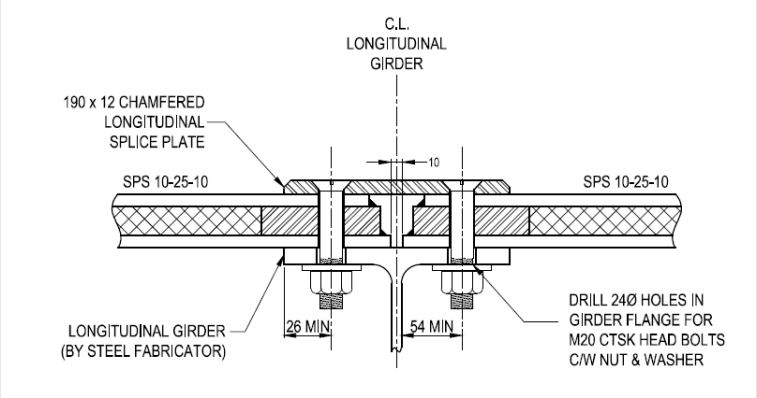


Chart courtesy of Intelligent Engineering

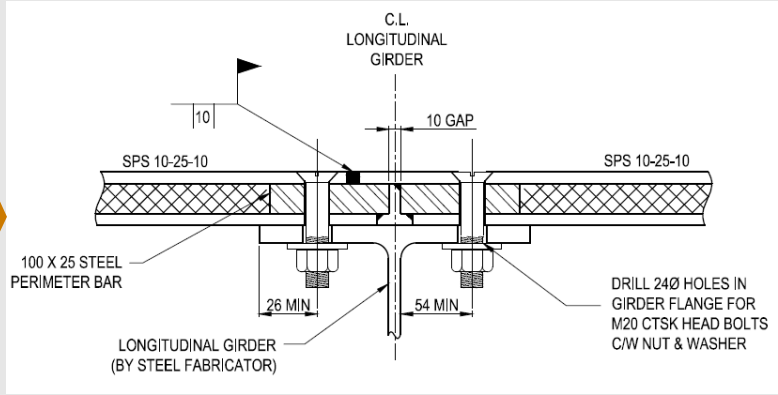
Sample Connection Details

Deck-to-Girder Connections

- SPS bridge decks bolted to top flange of girders (composite action)
- Top splice plate provides continuity between adjacent SPS deck plates



- Field weld provides a sealed joint and flush surface suitable for lightweight wearing surfaces



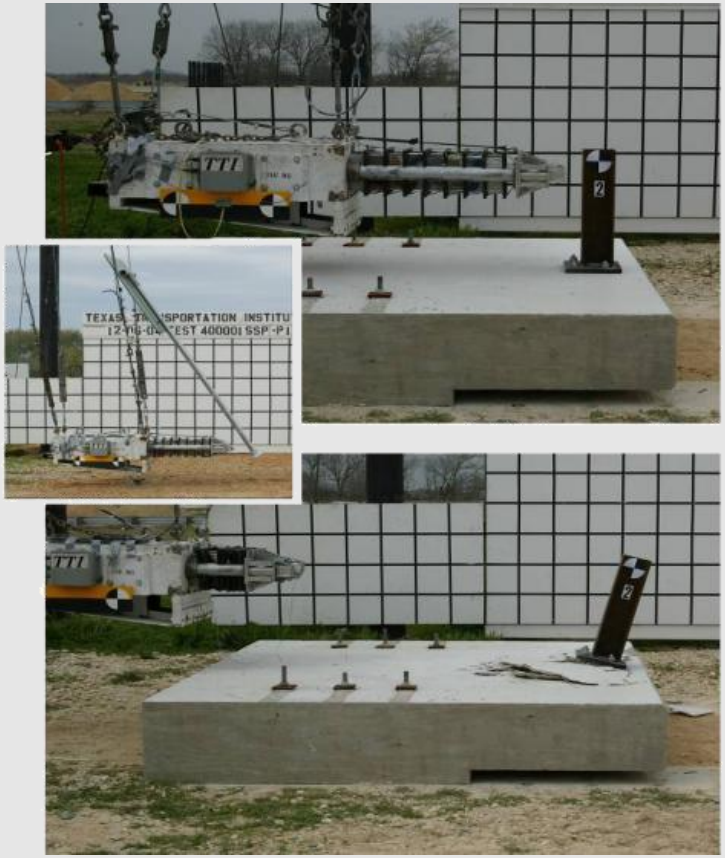
Details courtesy Intelligent Engineering

What About Strength for Railing Impact?

Railing performance established with pendulum testing

- Posts bolted to the deck
- Stiffeners below SPS for local strengthening (if not connected to beam flanges)
- Tests by Texas A&M Transportation Institute (TTI)
- TL4 resistance, NCHRP Report 350
- SPS deck undamaged

Courtesy TTI



It's a Steel Deck—It Needs a Wearing Surface

A number of options exist for steel deck wearing surfaces exist

- Thin—polymer based overlays; consistent with a light weight deck system. Proprietary products.
- Thick—asphalt based and concrete based overlays; consistent with common practice

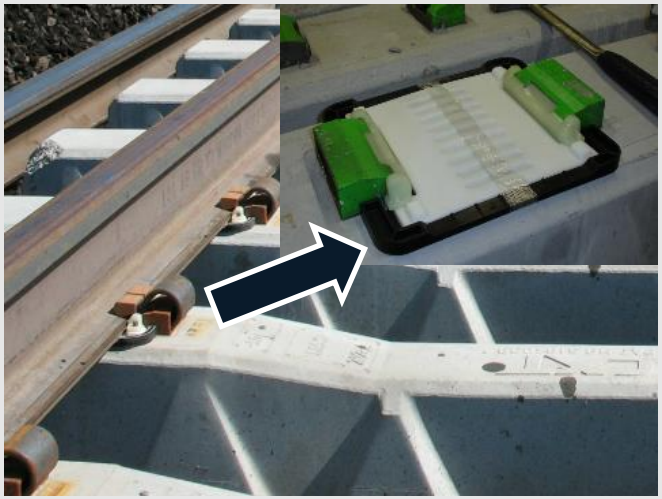
- A good resource: Manual for Design, Construction and Maintenance of Orthotropic Steel Deck Bridges, FHWA, 2012
- http://www.fhwa.dot.gov/bridge/pubs/if12027/if12027.pdf

What is the Core Material? Polyurethane

Polyurethane is a versatile and widely used material, found in the following applications:

- Construction
- Oil & Gas
- Automotive
- Footwear
- Furniture
- Textiles
- Appliances and Electronics

Extreme durability



- BASF Polyurethane is specified for the use in railroad applications (abrasion resistant pads) by the American Railway Engineering and Maintenance Association - AREMA.

- BASF Polyurethane is used on a regular basis to insulate subsea oil flowlines. The material is exposed to seawater at depths >9000 feet and temperatures >200°F on a continuous basis. Designed lifetime is > 50 years.

Info and photos courtesy BASF

Durability under extreme conditions

- Corrosion resistant
- Designed for the specific application
- Lightweight
- Impact resistant
- Excellent resistance to abrasion

Why polyurethane for bridge Decks?

Provides the needed strength over time

Fatigue tests demonstrate lifespan >75 years

Adhesion sufficient to ensure composite action

Withstands environmental conditions (cold of winter, heat of summer)

Elasticity that allows steel flex

Photo courtesy Intelligent Engineering

Bridge Projects

Images courtesy Intelligent Engineering

Bridge Projects

Dawson Bridge

Photo courtesy Intelligent Engineering

Bridge Projects

Dawson Bridge, 2010

- 5 span truss bridge (140'-140'-140'-250'-100')
- Transverse floor beams are constant depth
- Roadway profile built up from longitudinal stringers supporting a reinforced concrete deck applied over a wood base
- Deck degraded, needing replacement
- Concrete deck would be too heavy for existing truss structure
- Short summer close to complete replacement of deck and renovation of truss

Area	19,655 sq.ft
Date	Summer, 2010
Location	Edmonton, Canada
Owner	City of Edmonton
Engineer	Cohos Evamy
Contractor	Concreate

Info and photos courtesy Intelligent Engineering

Bridge Projects

Dawson Bridge, 2010

Dawson Bridge - 2” thick SPS bridge deck plate on girder

Photos courtesy Intelligent Engineering

Bridge Projects

Mettlach Bridge

Photo courtesy Intelligent Engineering

Bridge Projects

Mettlach Bridge, 2012

Background

- Suspension bridge (constructed in 1951) crossing the river Saar in Mettlach, Germany
- Double lane 355 ft span
- Original construction composed of steel-concrete composite bridge deck
- Reduction in load carrying capacity due to wear and corrosion; increased loads due to high traffic

SPS Bridge Deck

- Deck weight reduced from 500 to 200 tons using SPS bridge deck plates
- Reduction in deck weight relieves stress in suspension cables
- Accommodates increase in traffic loads and meets current standards

Accelerated Bridge Construction

- Bridge rehabilitated while one lane remained opened for traffic
- Each lane took one month to re-instate

Info and photos courtesy Intelligent Engineering

Bridge Projects

Mettlach Bridge, 2012

Mettlach Bridge - removal of existing concrete deck (500T)

Photo courtesy Intelligent Engineering

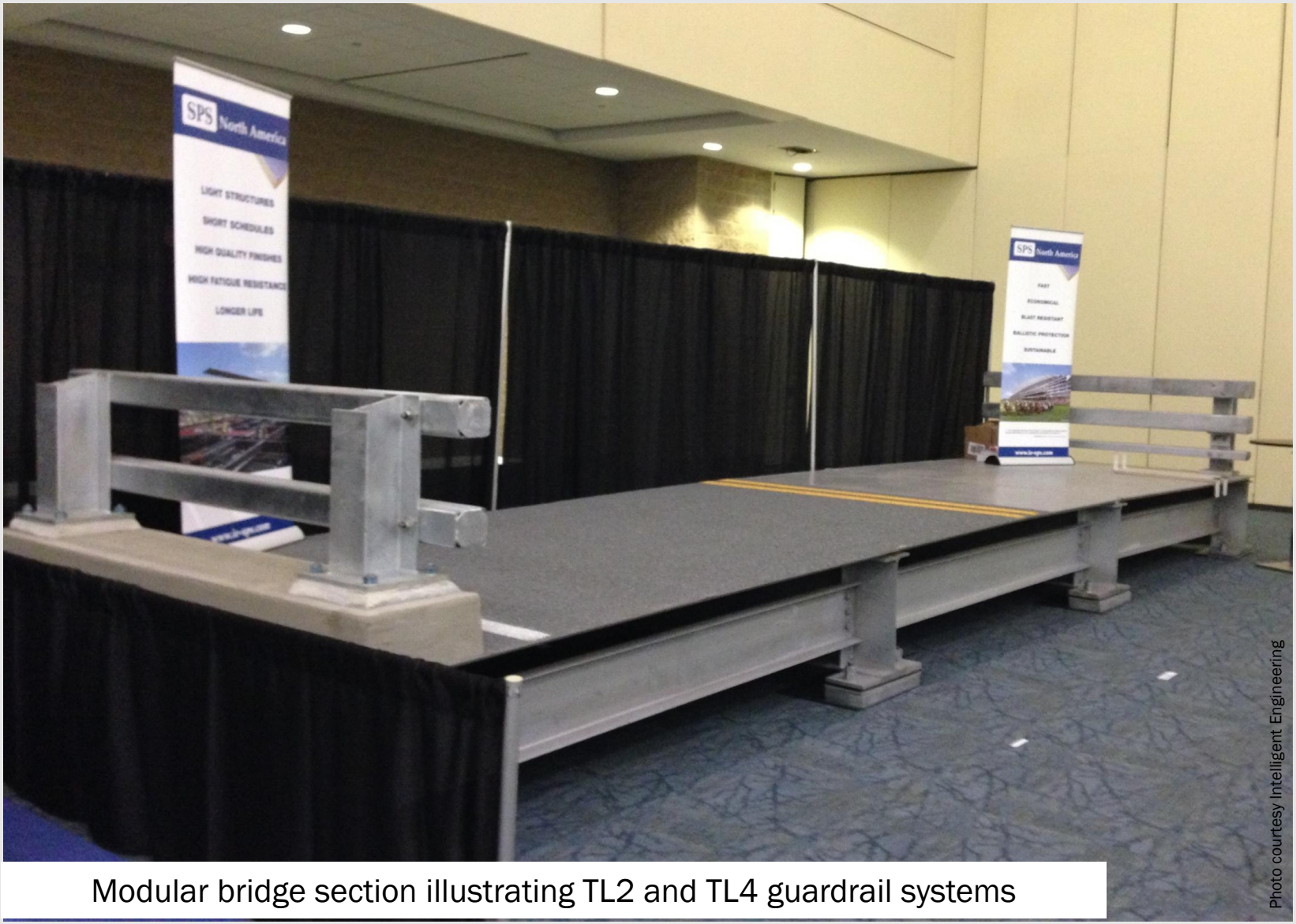
Bridge Projects

Mettlach Bridge, 2012

Lower deck dead load (SPS weighs 200T)

Photo courtesy Intelligent Engineering

Modular

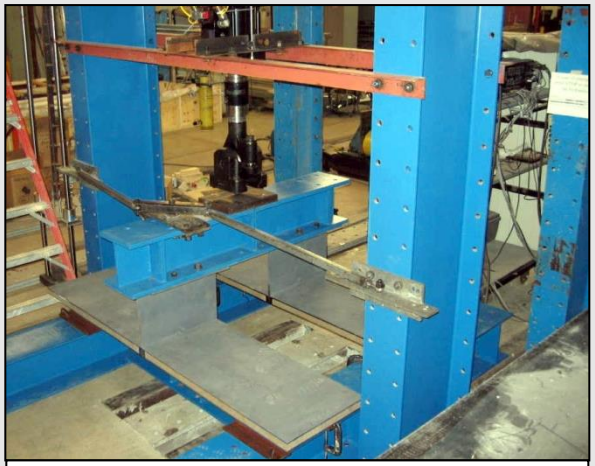


Modular bridge section illustrating TL2 and TL4 guardrail systems

More Information

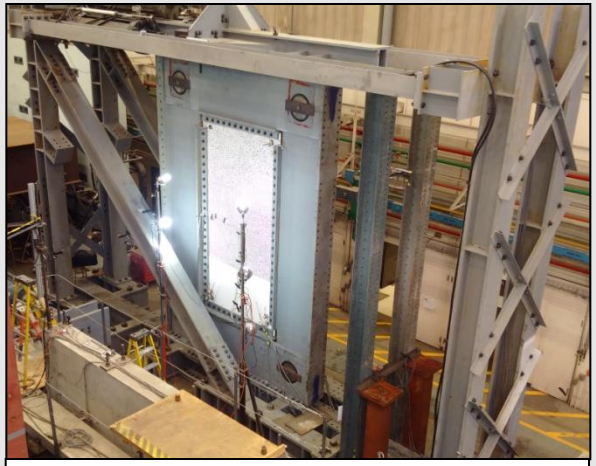
Selected References

1. Martin J. D., Murray, T. M. Sandwich Plate System Bridge Deck Tests, Report No. CEE/VPI-ST04/07. Virginia Polytechnic Institute and State University, Blacksburg, VA, April 2005.
2. Accelerated Construction of Bridges with Decks of Prefabricated Sandwich Plate System Panels Acting Compositely with the Girders". Kennedy, D.J.L., Ferro A., Dorton, R.A., Vincent, R.B., Cousins, T., and Murray, T.M., 2005 FHWA Accelerated Bridge Construction Conference, San Diego, California, December 15-18, 6pp.
3. Evaluation of the Bridge Railing Post Designs (Crash Barrier Test), Letter of Approval, Texas Transportation Institute, August 2005.
4. Intelligent Engineering. IE Technical Note 006 – Fatigue Resistance at Steel-Elastomer Interface. Ottawa, Canada, April 2012.
5. Intelligent Engineering. SPS Diaphragms and Shear Cores, Ottawa, Canada, April 2015.



Fatigue Test
Virginia Polytechnic Institute and State University

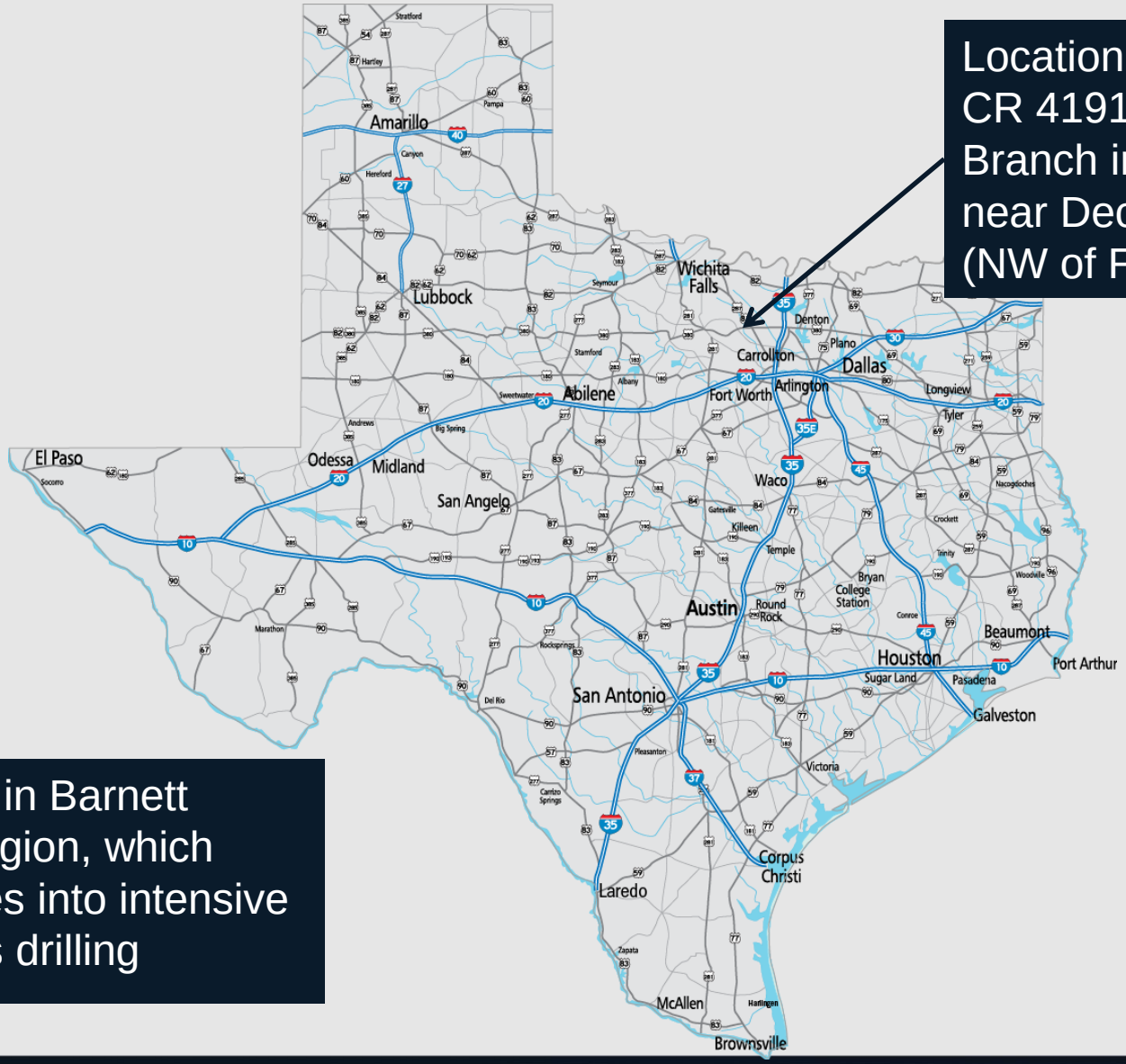
Crash Barrier Test
Texas Transportation Institute



Full Scale In-Plane Shear Test
Lehigh University

Info and photos courtesy Intelligent Engineering

SPS in Texas, Project Location



SPS Use in Texas, Project Genesis

2000

TxDOT begins implementation of Accelerated Bridge Construction (ABC) projects

2004

TxDOT is approached by Solicor and Intelligent Engineering to introduce Sandwich Plate System (SPS) technology and its applications.

- Shenley Bridge, Quebec: SPS deck on steel girders

SPS appeared attractive to TxDOT to meet ABC needs—rapid deck or superstructure installation

TxDOT elected to find a project to implement SPS to determine its viability for ABC

SPS Use in Texas, Project Funding

2004

FHWA IBRC (Innovative Bridge Research and Construction) funds are sought

TxDOT uses internal research funds to investigate bridge railing anchorage to SPS deck

- TxDOT contracted with Texas A&M Transportation Institute as an Implementation Project

$400,000 received

SPS Use in Texas, Project Design

Off-System Bridge Replacement Project

One lane, county road bridge over Martin Branch aka Center Creek

New Structure
150’ Overall bridge length (3 – 50’ Spans)
Two lanes, 30’ roadway width, 32.35’ overall width
W27 x 114 Steel beams, 6 beams spaced at 6.27’
Railing, TxDOT Type T6 (low-speed, energy absorbing railing)
SPS Deck
Thin polymer overlay
DL of deck and overlay used in design, 40 psf

SPS Use in Texas, Project Design

Steel Selection

- Beams, A709 Gr 50W (TxDOT uses weathering steel to the extent recommended)
- Deck Plates
  - Investigated use of ASTM A1010 steel, to extend scope of innovation
  - Used A709 Gr 50W, based on cost considerations

Bearings

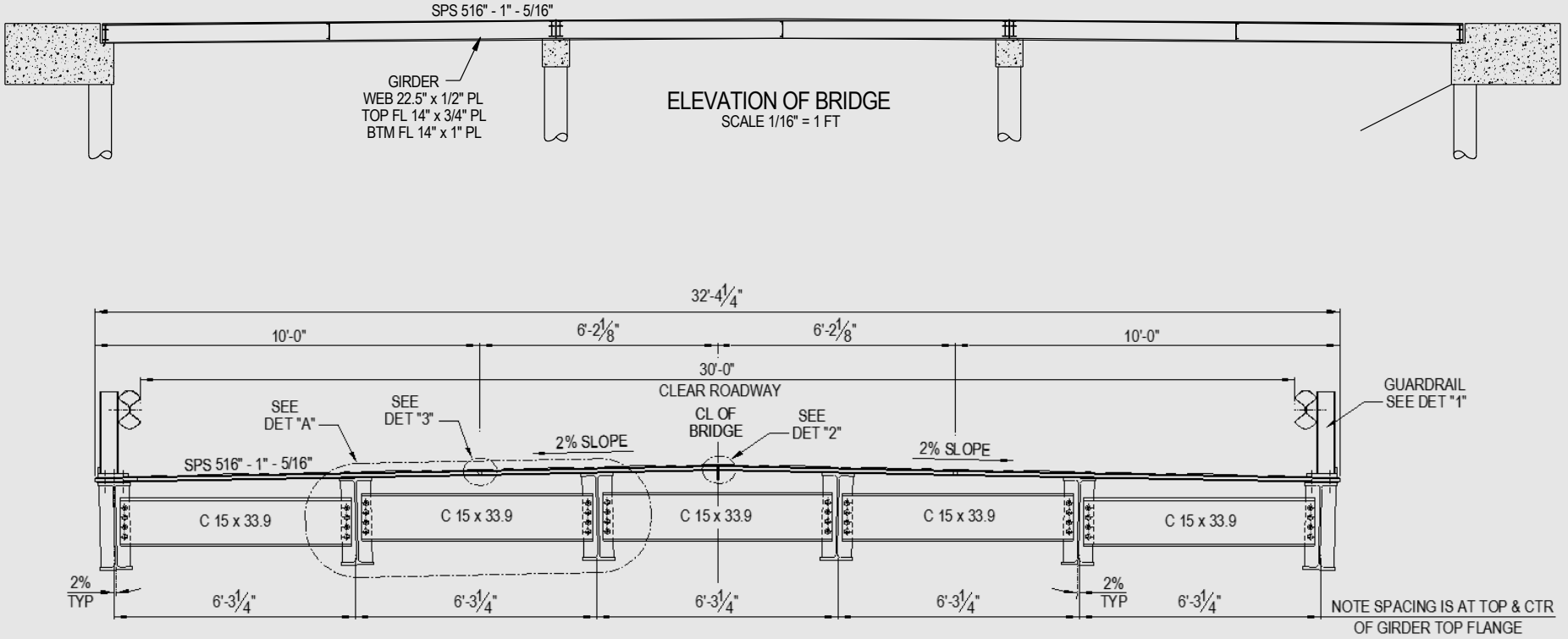
- Reinforced elastomeric with sole plates
- Not ideal for light dead load, but better than alternatives

SPS Use in Texas, Project Design

How to connect the SPS deck to the beams?

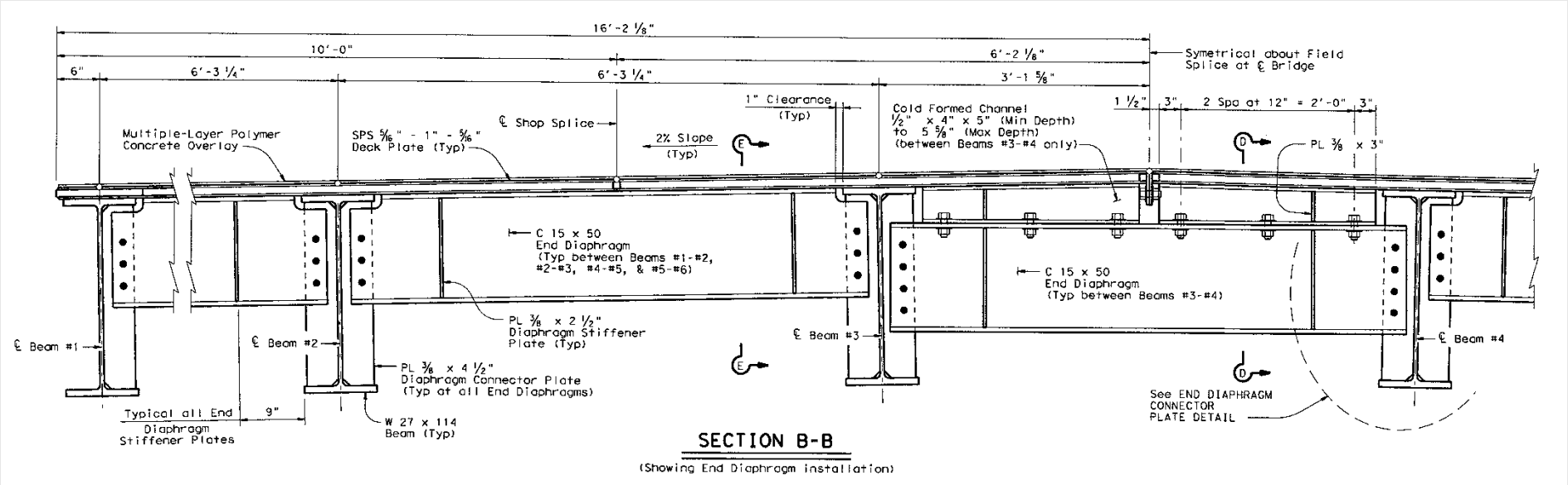
- Fabricator outreach by Intelligent Engineering led to proposal to fabricate spans in two equal span halves with the SPS deck welded to 3 girders
- Resulted in what is now called Prefabricated Bridge Elements and Systems (PBES)
- The field connection between the two span halves involved:
  - Steel channel diaphragms between the beams (bolted)
  - Welding of top deck plate
  - Bolted connection of bottom deck plate

SPS Use in Texas, Project Design



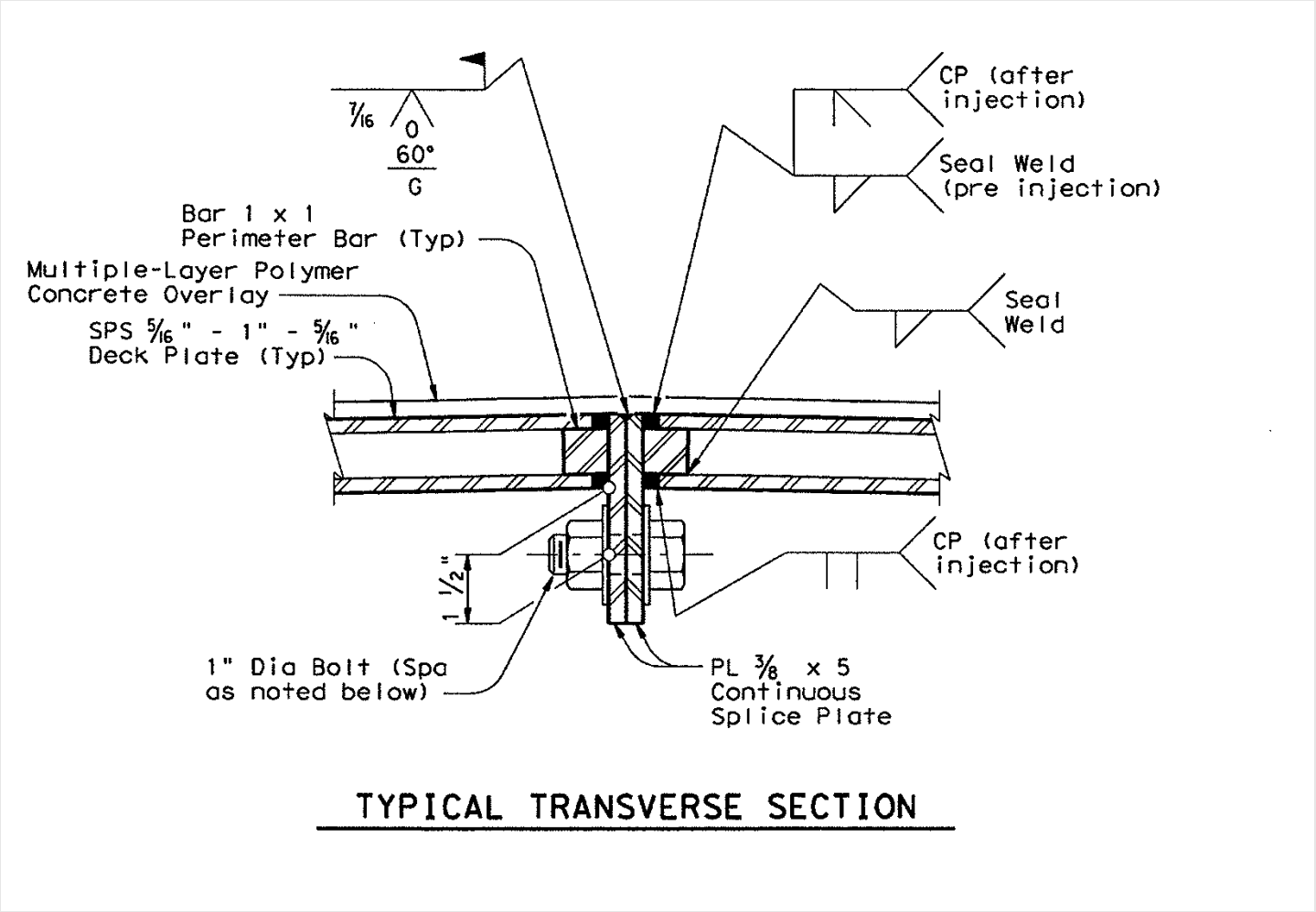
SPS Use in Texas, Project Design

- Span Typical Section
- Note the beams are not plumb; they are perpendicular to the 2% cross slope



SPS Use in Texas, Project Design

- Section View Thru SPS Deck Field Splice



SPS Use in Texas, Project Design

Other aspects of the design

- SPS Deck Design by Intelligent Engineering, used 5/16 – 1 – 5/16 arrangement (1.625” deck thickness); companion design by TxDOT Bridge Division
- Beams designed by Intelligent Engineering; companion design by TxDOT Bridge Division
- Live Load Distribution, used the approximate AASHTO LRFD distribution equations for flexure and shear
- Substructure designed by TxDOT
  - 30” Dia drilled shafts supporting round, RC columns
  - Substructure caps not precast

SPS Use in Texas, Project Construction

- Prior to letting, Intelligent Engineering engaged in outreach with potential bidders and fabricators
- Project let in January 2007
  - 10 bidders, project awarded to American Civil Constructors, Inc., for low bid of $970,116.50
  - Highest bid, $1.3M. Very little spread in bids
  - Bids for SPS deck item ranged from $67.33/SF to $91.00/SF; very little spread in bids with a completely new deck system.
  - Steel fabricator, North Texas Steel, Inc.
- 70 Working Day contract; no incentives/disincentives
- Lack of immediate availability of specified beam sections caused an immediate delay in work

SPS Use in Texas, Project Construction

SPS Use in Texas, Project Construction

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SPS Use in Texas, Project Construction

SPS Use in Texas, Project Construction

Views from underneath spans, along bolted field splice

SPS Use in Texas, Project Construction

SPS Use in Texas, Project Construction

SPS Use in Texas, Project Construction

- Lessons learned
  - Pre-letting outreach efforts paid off
  - TxDOT required full shop assembly of span halves; importance of this effort apparently not communicated between fabricator and contractor as full bearing contact did not occur. Shims between sole plates and beams needed to be fabricated
  - No thin polymer overlay product met the specifications, specifications which were generated largely by input from producers. Result of delay in bridge opening
  - Bottom line, SPS can be used to install bridge remarkably fast

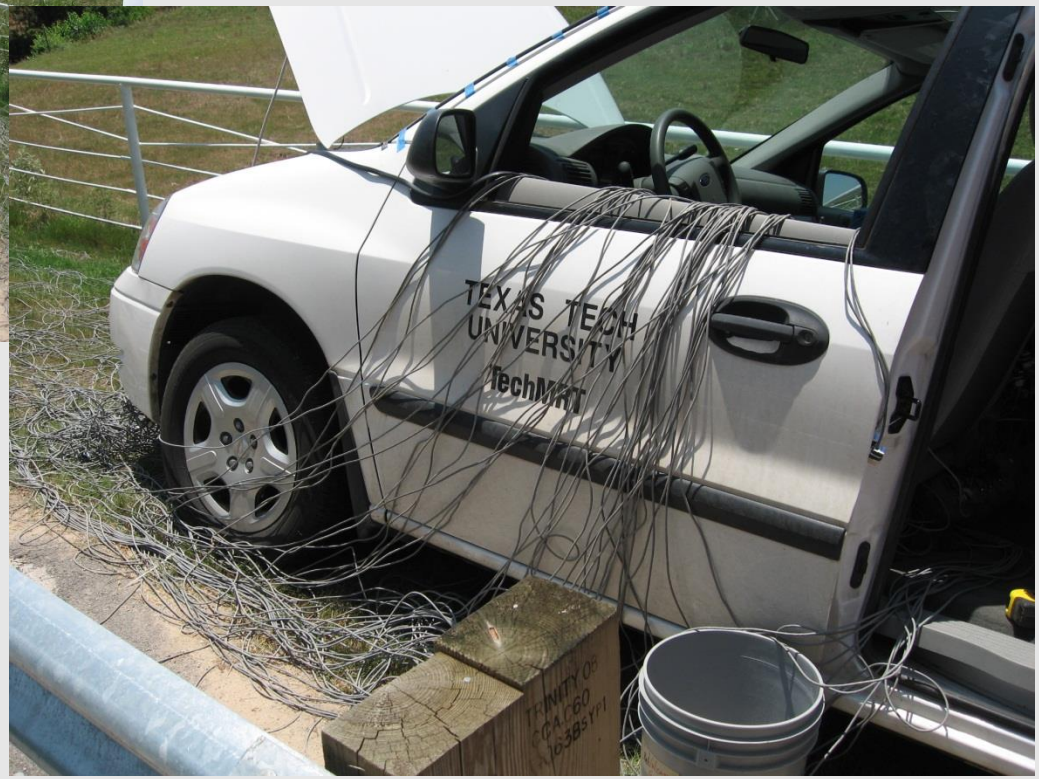
SPS Use in Texas, Research Field Study

- After bridge completion, TxDOT contracted with Texas Tech University to study:
  - Live load distribution to the beams (primary focus)
  - Behavior of the longitudinal deck field splice
  - Dynamic load allowance (impact)
  - Noise of truck passage on deck/overlay system
- Research/field study led by Dr. Charles Newhouse, P.E.
- Report “Live Load Testing of Sandwich Plate System (SPS) Bridge in Wise County, Texas” available from TxDOT

SPS Use in Texas, Research Field Study

SPS Use in Texas, Research Field Study

TxDOT Dump Truck
42.28 kips Gross



Back Tandem, 32 k
Steer axle, 10 k

SPS Use in Texas, Research Field Study

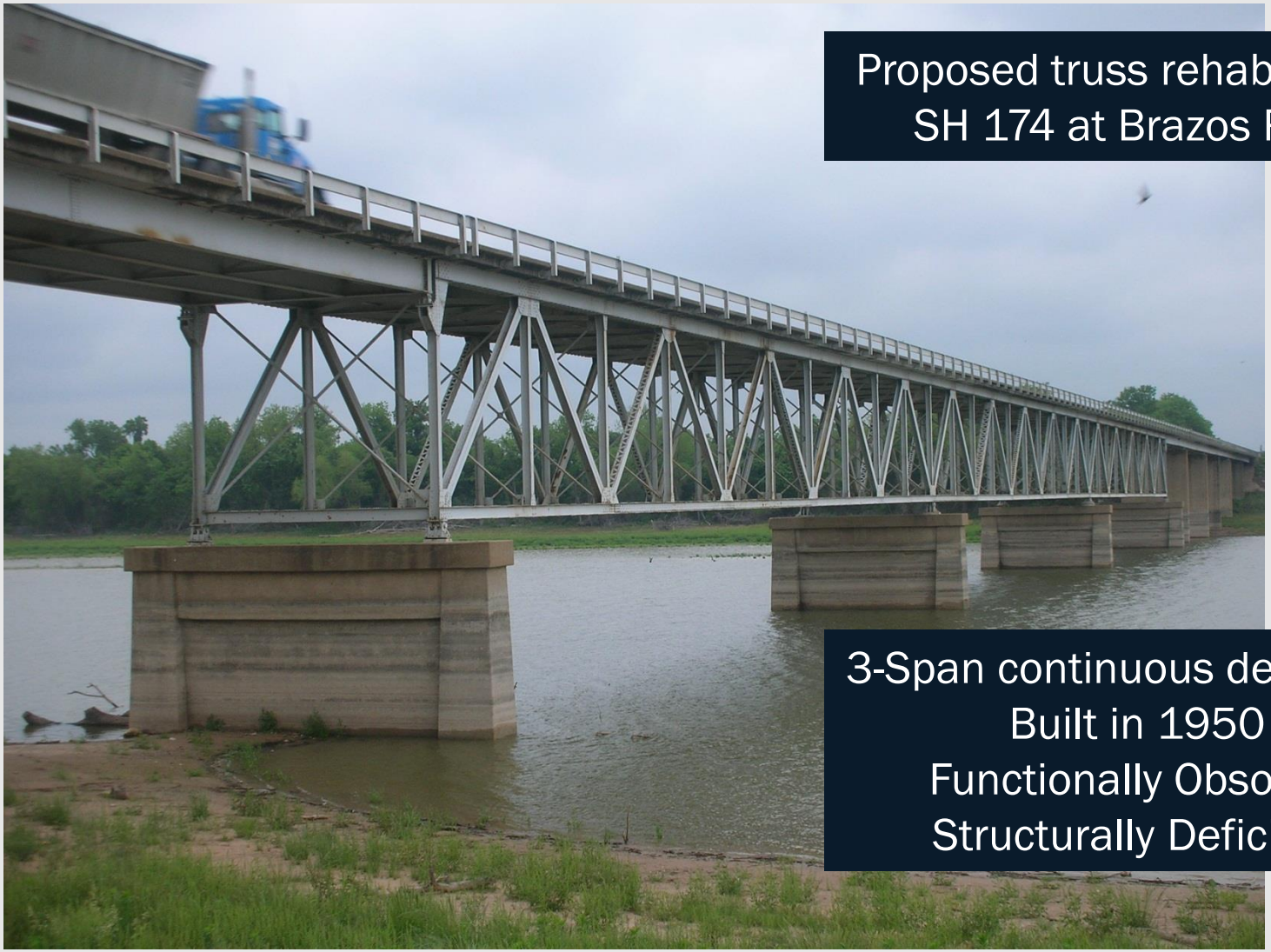
Brief summary of results

- Field-measured live load distribution factor, 0.37 (one lane loaded)
- AASHTO LRFD (1998), steel bridge concrete deck, 0.51 (one lane loaded)
- AASHTO Std Spec (1992), 0.48 (one lane loaded)
- Deflection from test truck, L/1850
- IM from LRFD appropriate for SPS
- Field splice data inconclusive (noise in data)
- Sound generated on SPS/polymer overlay not significantly different from concrete deck/steel beams

SPS Use in Texas, Consideration of Future Use

- SPS is being considered for
  - Trusses needing rehabilitation
  - Moveable spans needing rehabilitation
- Low DL deck very helpful to minimize gusset plate strengthening or replacement and rivet replacement
- Low DL may allow wider roadway maintain weight advantage over concrete deck
- It is still faster than pouring and curing a concrete deck

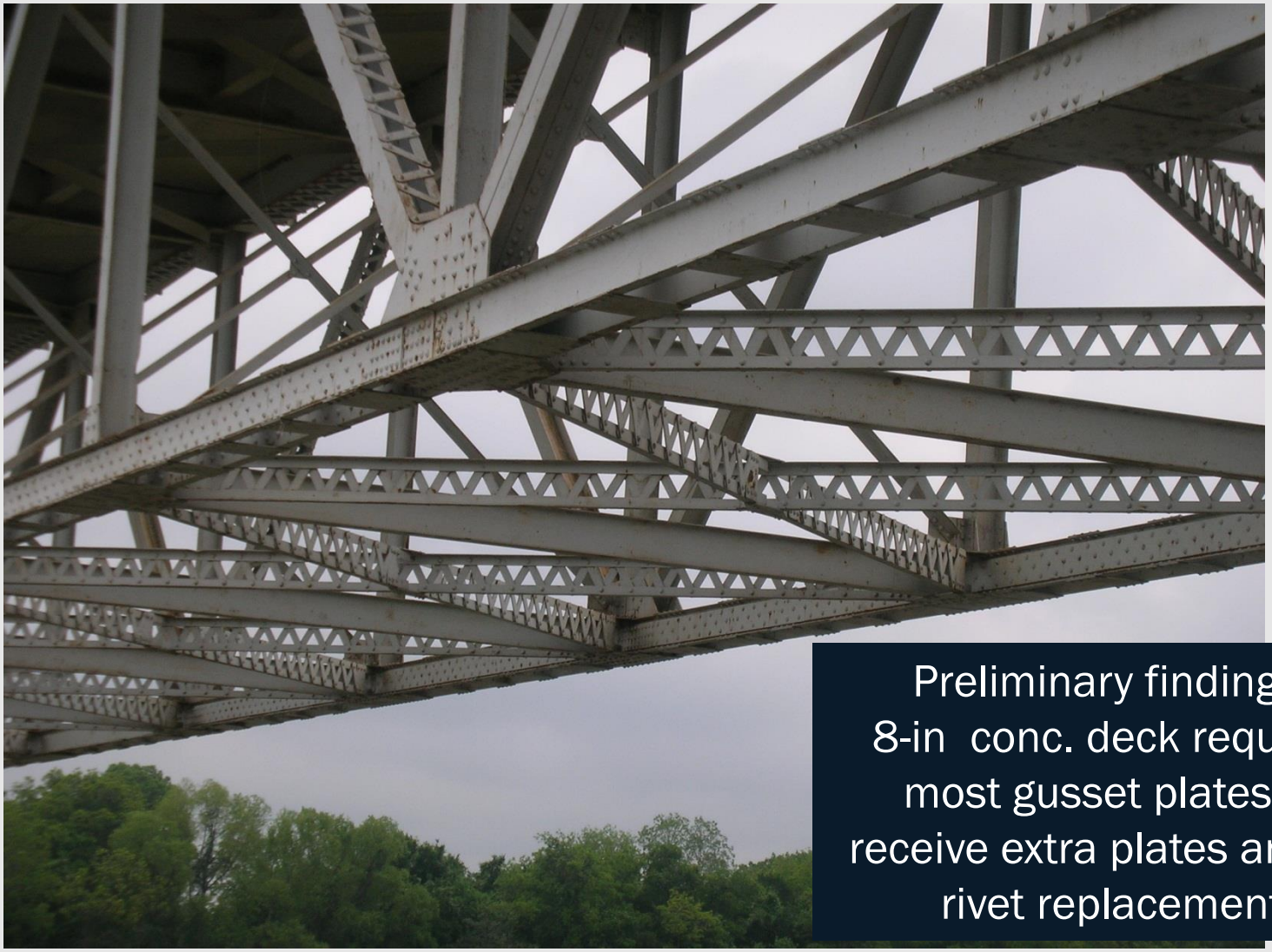
SPS Use in Texas, Consideration of Future Use



Proposed truss rehabilitation
SH 174 at Brazos River

3-Span continuous deck truss
Built in 1950
Functionally Obsolete
Structurally Deficient

SPS Use in Texas, Consideration of Future Use



Preliminary findings:
8-in conc. deck requires most gusset plates to receive extra plates and/or rivet replacement

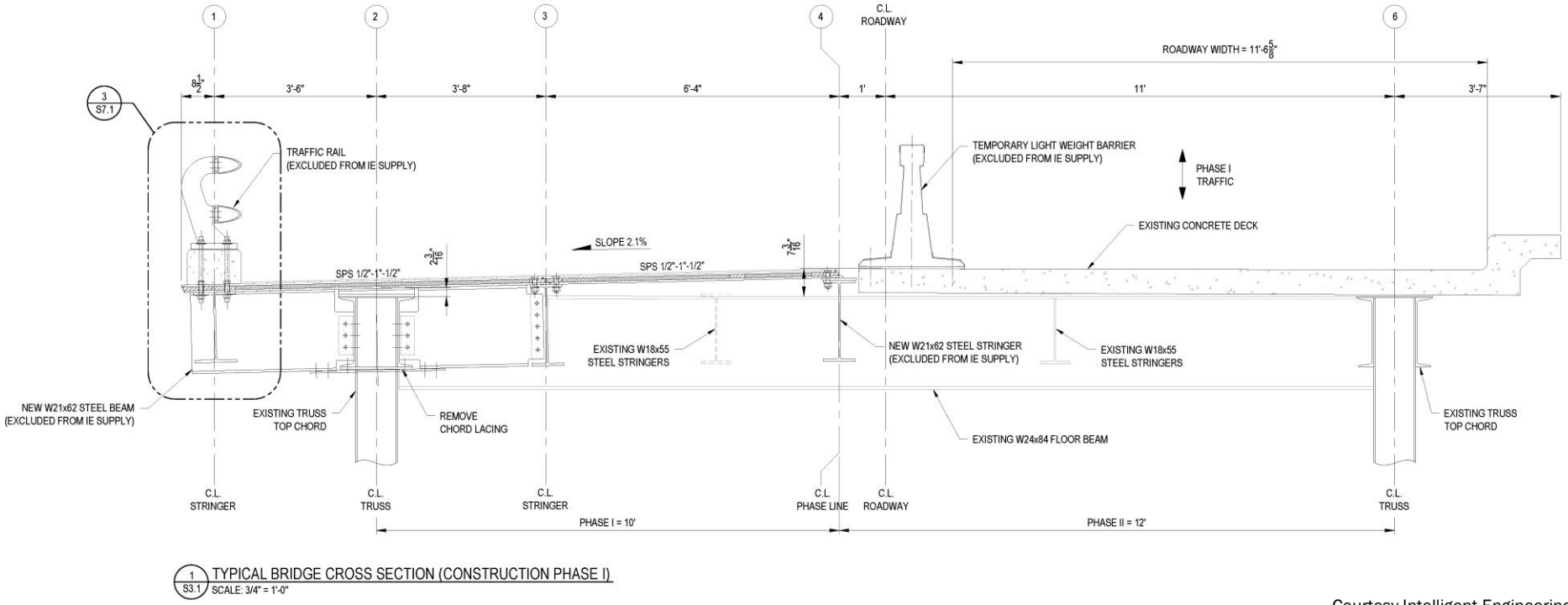
SPS Use in Texas, Consideration of Future Use

Future work:
Investigate effects of low DL, SPS deck with thin polymer overlay

SPS Use in Texas, Consideration of Future Use

SPS reduces the deck dead load by over 50% from 100 lbs/ft (8” concrete deck) to 45 lbs/ft (SPS)
Deck Area is approximately 18,000 SF ft

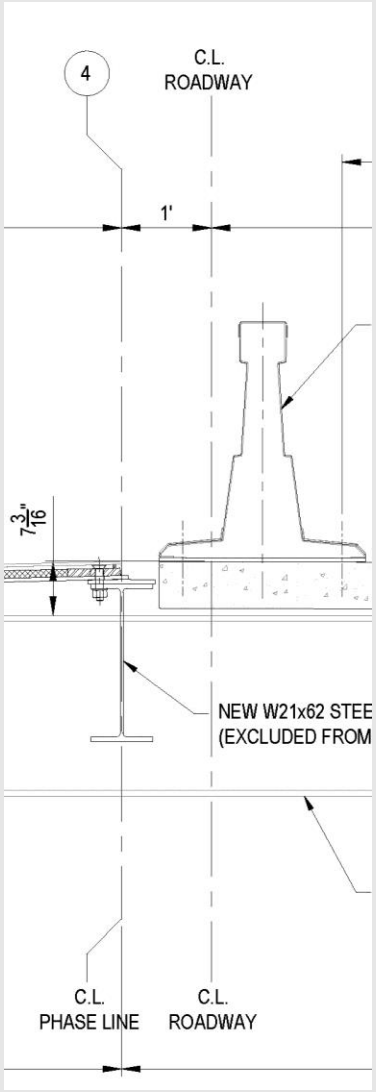
SPS Use in Texas, Consideration of Future Use

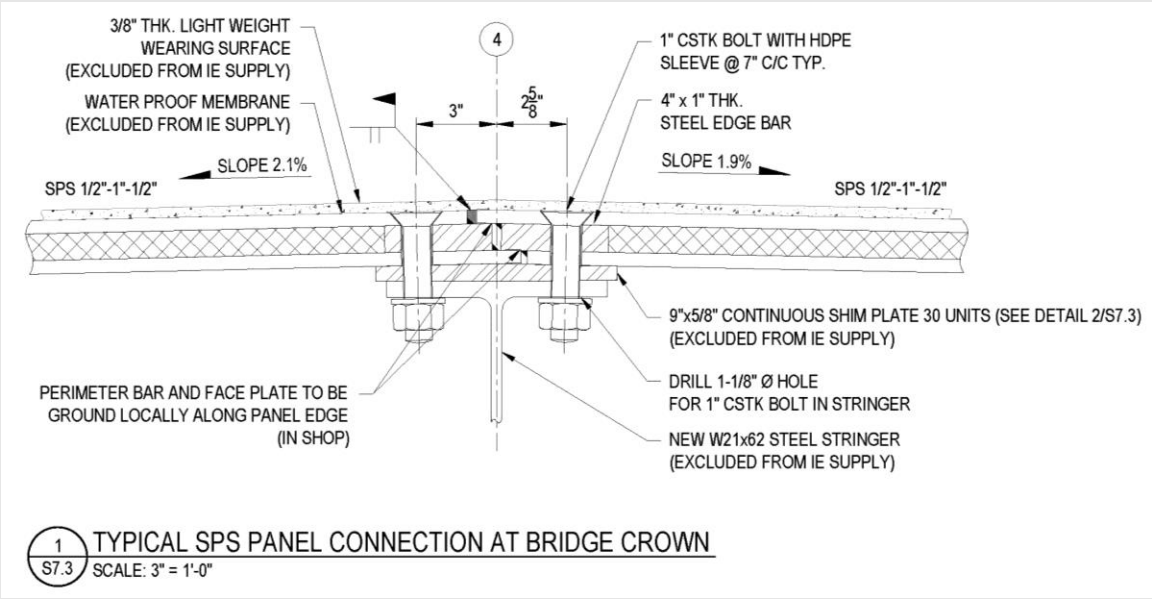


Courtesy Intelligent Engineering

- Bridge Deck will be replaced with phased construction
- It will take approximately 1.9 man hours per square foot to install the SPS deck where as it would take approximately 3.9 man hours per square foot to install 8” concrete deck
  - Assuming 15 man crew for each deck type.

SPS Use in Texas, Consideration of Future Use

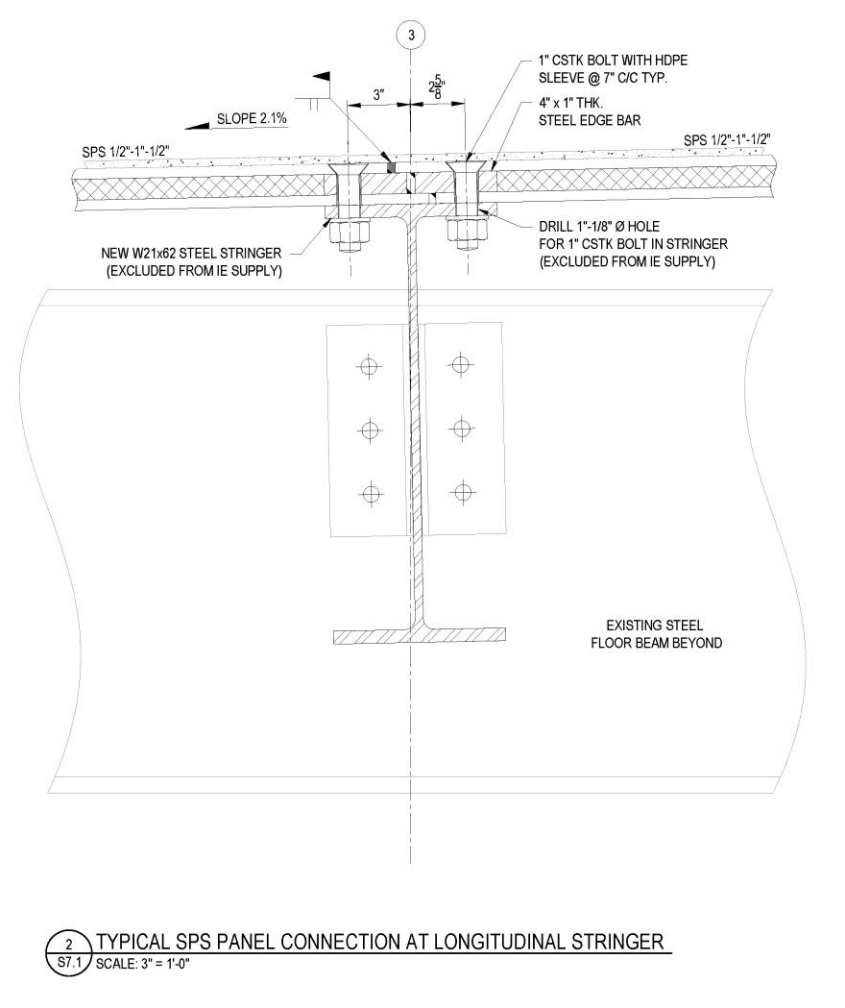


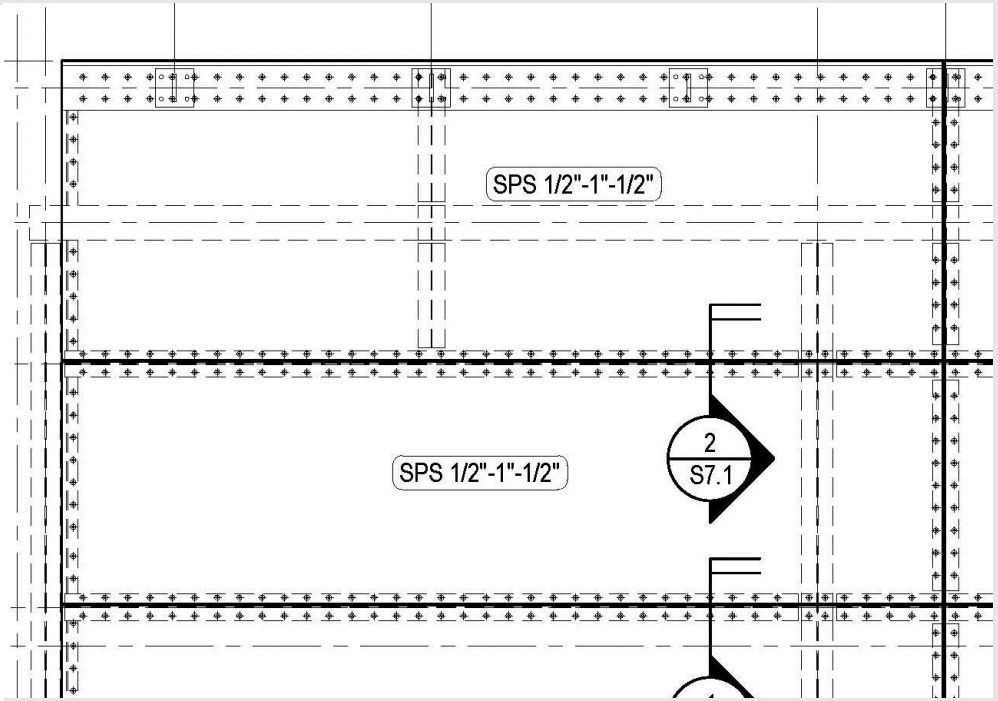


- The crown point is to be offset from center line of Roadway by 1’-0”

Courtesy Intelligent Engineering

SPS Use in Texas, Consideration of Future Use



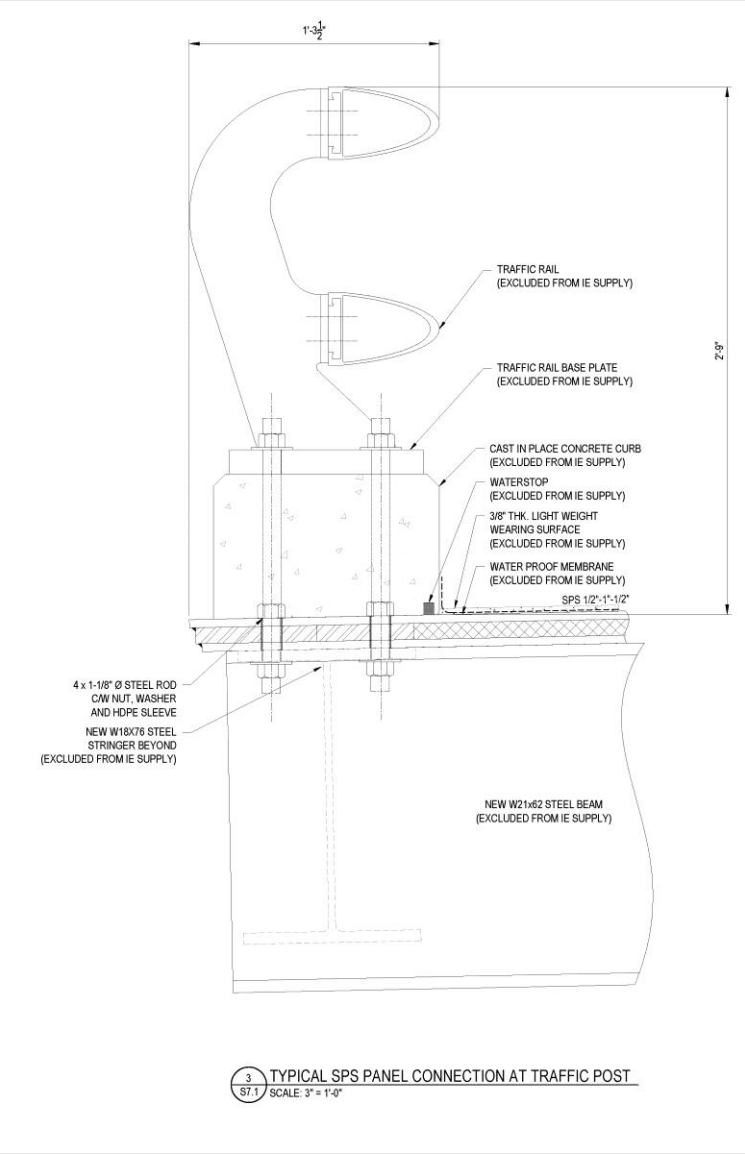


- Panel Connection Details

Images courtesy Intelligent Engineering

SPS Use in Texas, Consideration of Future Use

- Curb Connection Details
  - Thru-bolted
  - Welded DBRs or headed studs
- Types of Rails used
  - Steel post and beam
  - Concrete

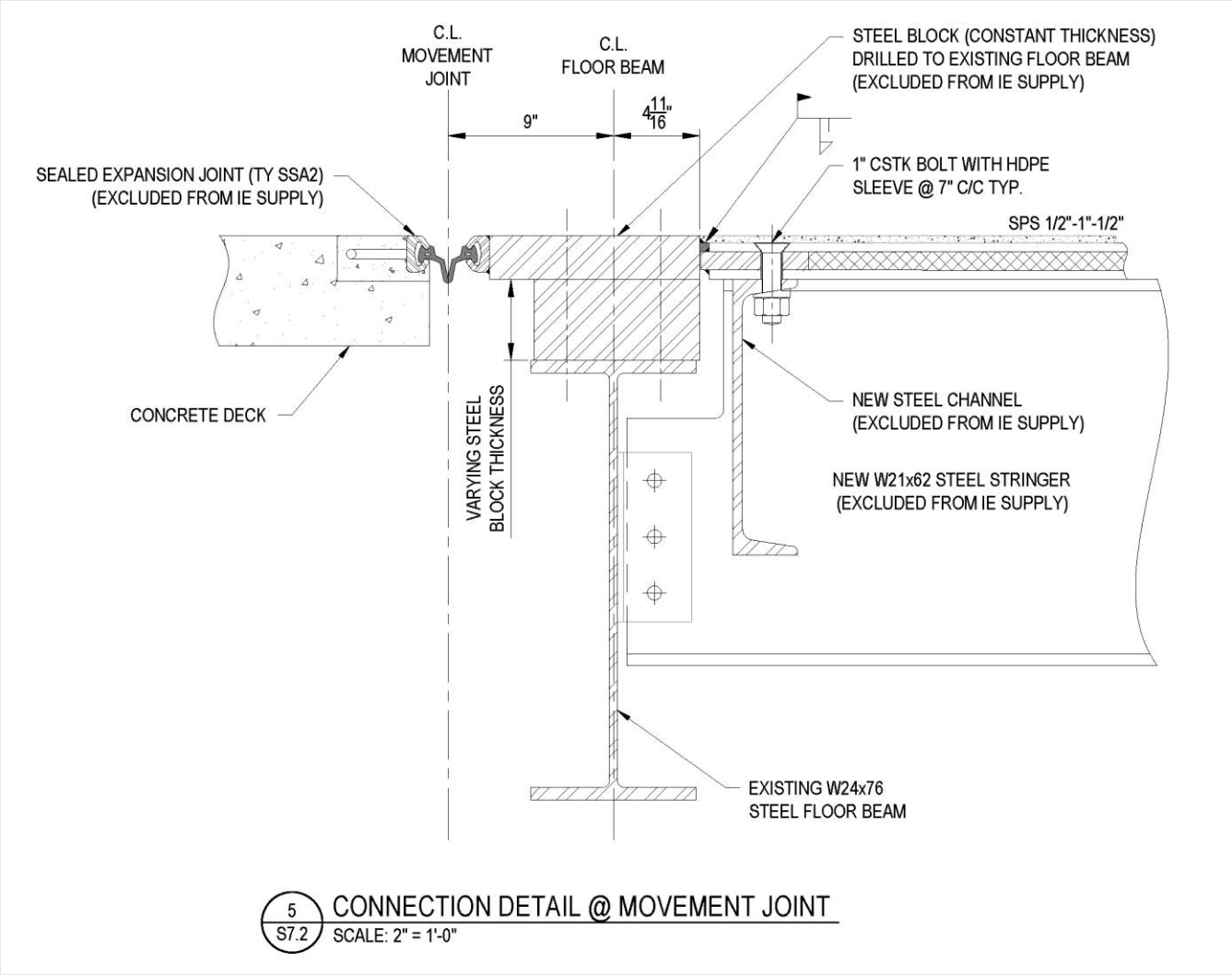


- TxDOT Type T1F shown

Courtesy Intelligent Engineering

SPS Use in Texas, Consideration of Future Use

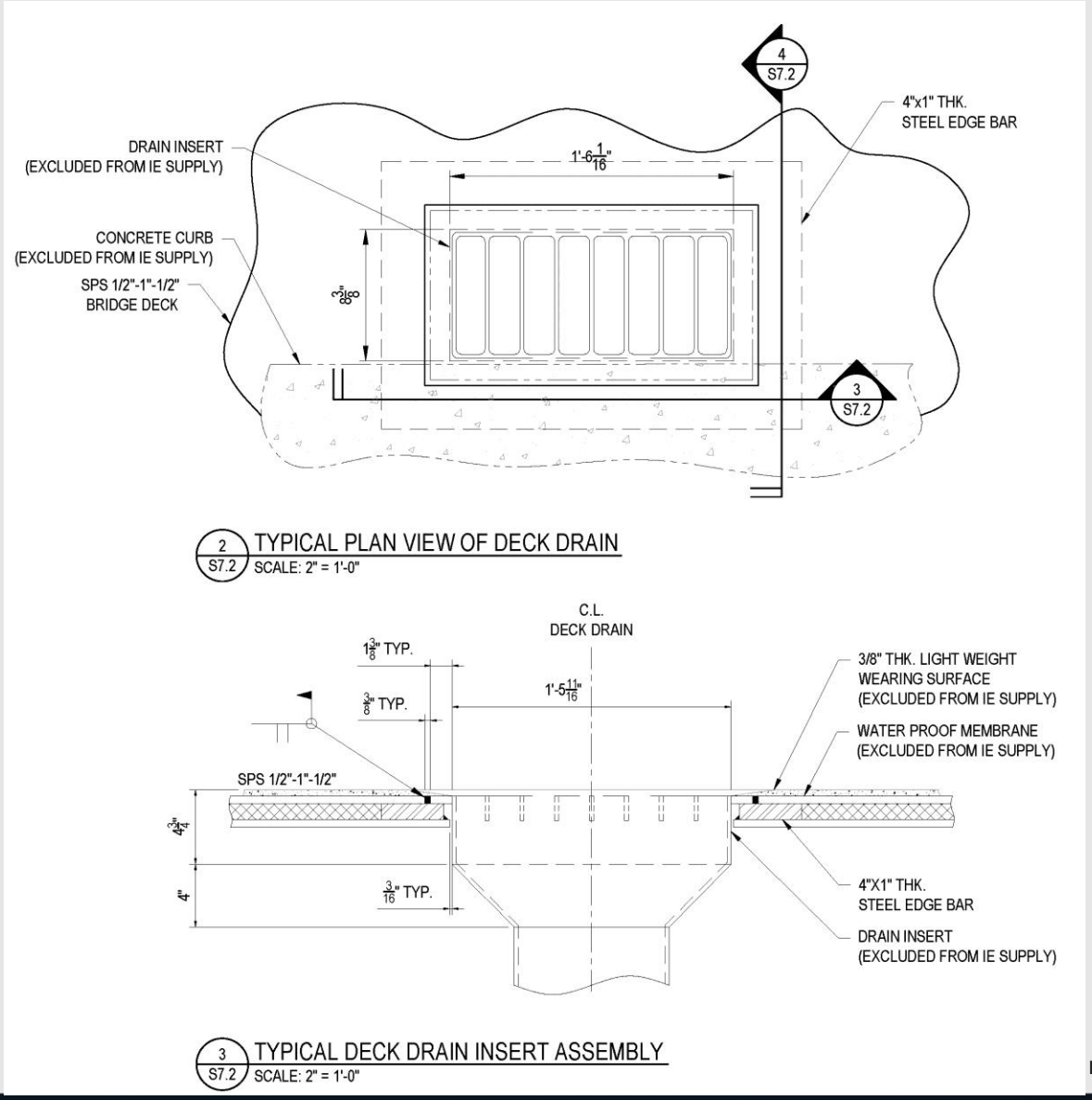
- Expansion Joint Connection Details



Courtesy Intelligent Engineering

SPS Use in Texas, Consideration of Future Use

- Drain Details



Images courtesy Intelligent Engineering

SPS Use in Texas, Consideration of Future Use

- Wearing Surface—Multi Layer Polymer Overlay (MLPO) per TxDOT Standard Specification Item 439, “Bridge Deck Overlays”
  - Epoxy with aggregate “overlay”
  - Thickness is generally 3/8”
  - Replacement cycle between five to 10 years (depending on product)
  - Ease of application
    - Temperature range 32°F to 104°F
    - Clean surface to product specifications
    - Apply primer
    - Apply resin (pot life of 15 to 20 minutes)
    - Broadcast Aggregate
    - Apply Sealant (depends on product)

http://www.concretebridgeviews.com/i75/Article2.php

SPS Use in Texas, Consideration of Future Use

Fire

- The SPS deck plates are non-combustible, hermetically sealed steel boxes
- If an extreme fire event occurred, the plates could be easily and quickly replaced.

http://www.dnainfo.com/new-york/20130816/new-york-city/huge-smoke-cloud-hovers-over-queensborough-bridge-after-truck-catches-fire

Fatigue

- Can be designed for infinite life in accordance with AASHTO LRFD 2012 Bridge Specifications 6th Edition.

SPS Use in Texas, Consideration of Future Use

Sizing

- One way span to depth ratio for SPS

SPS Deck Size (in-in-in)	Girder Spacing (ft)
3/8-1-3/8	6-7
7/16-1-7/16	7.5-9
1/2-1-1/2	9.5-11

- Minimum Girder Depth calculated from AASHTO LRFD Table 2.5.2.6.3-1
  - Depth = 0.033 x span (simple spans)

SPS Use in Texas, Consideration of Future Use

Grading

- SPS adaptable to any cross slope or superelevation; transitions handled panel to panel, with discrepancies taken up in wearing surface

SPS Use in Texas, Availability

Distributors

- Currently one distributor in the US located in Ohio
- At least one more added to the US by the end of 2015

- Likely approach:
  - Design with both concrete deck and SPS as an alternate
  - Compared to SPS, concrete deck will
    - require gusset plate strengthening or replacement
    - rivet or bolt replacement
    - longer construction duration
    - ready-mix concrete availability could be a hindrance

SPS Use in Texas, Summary

- SPS is an effective tool tool for ABC (Martin Branch Bridge project clearly demonstrated this)
- SPS is a Prefabricated Bridge Element and System (PBES) and can be integrated with other superstructure components
  - Railings
  - Expansion joints
  - Deck drains
  - Wearing surfaces
- Designers can use the AASHTO LRFD live load distribution factors and impact factor with confidence for conventional steel beam bridges
- SPS can also be a tool for deck replacements on DL-sensitive bridges, such as very long spans and older bridges

Contact Information for Questions

Thank you for listening.

- TxDOT:
  - John Holt, john.holt@txdot.gov or 512-416-2212
  - Patrick Bachman, patrick.bachman@txdot.gov or 512-416-2228
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