SANDWICH PLATE SYSTEM USE IN TEXAS

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TxDOT Bridge Division
# Table of Contents

<table>
<thead>
<tr>
<th></th>
<th>What is an SPS Bridge Deck?</th>
<th>3 - 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Polyurethane</td>
<td>11 - 14</td>
</tr>
<tr>
<td>3</td>
<td>Bridge Projects</td>
<td>15 - 24</td>
</tr>
<tr>
<td>4</td>
<td>TxDOT Project: Genesis, Funding, Design, and Construction</td>
<td>25 - 46</td>
</tr>
<tr>
<td>5</td>
<td>Field Studies</td>
<td>47 - 50</td>
</tr>
<tr>
<td>6</td>
<td>Consideration of Future Use</td>
<td>51 - 66</td>
</tr>
<tr>
<td>7</td>
<td>Summary</td>
<td>67 - 68</td>
</tr>
</tbody>
</table>
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

Images courtesy of Intelligent Engineering
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
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
A number of options exist for steel deck wearing surfaces exist

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

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

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

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
Polyurethane

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
Bridge Projects

Martins Branch Bridge

Dawson Bridge

Mettlach Bridge

Grand Duchess Charlotte Bridge

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

<table>
<thead>
<tr>
<th>Area</th>
<th>19,655 sq.ft</th>
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<tbody>
<tr>
<td>Date</td>
<td>Summer, 2010</td>
</tr>
<tr>
<td>Location</td>
<td>Edmonton, Canada</td>
</tr>
<tr>
<td>Owner</td>
<td>City of Edmonton</td>
</tr>
<tr>
<td>Engineer</td>
<td>Cohos Evamy</td>
</tr>
<tr>
<td>Contractor</td>
<td>Concreate</td>
</tr>
</tbody>
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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
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 bridge section illustrating TL2 and TL4 guardrail systems

Photo courtesy Intelligent Engineering
More Information

Selected References


3. Evaluation of the Bridge Railing Post Designs (Crash Barrier Test), Letter of Approval, Texas Transportation Institute, August 2005.


5. Intelligent Engineering. SPS Diaphragms and Shear Cores, Ottawa, Canada, April 2015.
SPS in Texas, Project Location

Location: CR 4191 at Martin Branch in Wise County, near Decatur (NW of Fort Worth)

Located in Barnett Shale region, which translates into intensive oil & gas drilling
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
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.
### Off-System Bridge Replacement Project

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

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

### Elevation of Bridge

**Scale:** 1/16" = 1 FT

- **Girder Web:** 22.5" x 1/2" PL
- **Top FL:** 14" x 3/4" PL
- **Bottom FL:** 14" x 1" PL
- **SPS:** 5 1/6" - 1" - 5/16"
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

![Diagram showing section view through SPS deck field splice](image-url)

**Typical Transverse Section**
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
Each span half weighed approximately 52 kips

An equivalent portion of a prestressed concrete slab beam bridge would weigh about 215 kips
SPS Use in Texas, Project Construction
SPS Use in Texas, Project Construction
All six span halves erected within 3 days
Views from underneath spans, along bolted field splice
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
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

TxDOT Dump Truck
42.28 kips Gross

Back Tandem, 32 k
Steer axle, 10 k
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
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 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
- 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.
The crown point is to be offset from center line of Roadway by 1’-0”
**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
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.

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

<table>
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<tr>
<th>SPS Deck Size (in-in-in)</th>
<th>Girder Spacing (ft)</th>
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<tbody>
<tr>
<td>3/8-1-3/8</td>
<td>6-7</td>
</tr>
<tr>
<td>7/16-1-7/16</td>
<td>7.5-9</td>
</tr>
<tr>
<td>1/2-1-1/2</td>
<td>9.5-11</td>
</tr>
</tbody>
</table>

- Minimum Girder Depth calculated from AASHTO LRFD Table 2.5.2.6.3-1
  - Depth = 0.033 x span (simple spans)
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 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
Thank you for listening.

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