<table>
<thead>
<tr>
<th></th>
<th>NAME (PRINT)</th>
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<td>Originator(s)</td>
<td>Reid Coughlin</td>
<td>08/15/2011</td>
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<tr>
<td>Checker</td>
<td>Ken P. Rebel</td>
<td>08/15/2011</td>
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<tr>
<td>Reviewer</td>
<td>Joost Meyboom</td>
<td>08/15/2011</td>
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</table>
STANDARD LIMITATIONS

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APPENDICES

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EXECUTIVE SUMMARY

The City of Victoria has decided to replace the existing Johnson Street Bridge with the Wilkinson Eyre Architects (WEA) concept shown in Figure 1.1. The main span of the replacement bridge will be a rolling bascule type which requires a lightweight deck system. This report summarizes our investigation into feasible options for the bridge deck for the new Johnson Street Bridge.

Figure 1.1: WEA Concept for the Johnson Street Bridge Replacement

The six (6) roadway bridge deck systems considered and compared against each other are as follows:

Option 1: Both conventional steel orthotropic deck and proprietary steel orthotropic systems were considered in the analysis. Orthotropic decks are comprised of a series of panels utilizing thin steel plates acting as the top flange stiffened by a series of steel ribs below. A thin lightweight wearing surface is typically applied to the riding surface of the steel deck in the fabrication shop.

Option 2: An open grid steel deck system with panelized steel grating which supported by a framing system of beams and stringers. No wearing surface is usually provided as the top surface of the steel grating is serrated to provide additional friction for vehicular traffic.

Option 3: The Half-filled Grid Deck with Concrete Overfill is comprised of a grid steel deck with lightweight concrete partially filling the grid and extending approximately 30 mm to 50 mm
above the grid. The grid and concrete deck can be constructed cast-in-place or with precast sections. Cast-in-place decks typically use the top surface as a wearing surface, with precast decks requiring a concrete overlay.

**Option 4:** An Exodermic™ deck is a proprietary system comprised of steel grid cast compositely with a lightweight reinforced concrete deck. The reinforced concrete deck can be constructed cast-in-place or with precast sections. Cast-in-place decks typically use the top surface as a wearing surface, with precast decks requiring a concrete overlay.

**Option 5:** A fibre reinforced polymer (FRP) deck is a proprietary system using pultruded panel sections which are mechanically fastened together and supported by a framing system of beams and stringers. The system uses a polymer concrete wearing surface bonded to the deck.

**Option 6:** A steel sandwich panel system (SPS) is a proprietary product consisting of two steel plates sandwiched with an elastomer core. SPS panels are bolted to the supporting floor beams and include a bolted splice plate over the panel joints. A thin wearing surface is typically applied to the prepared top surface of the deck panels.

**Summary of Findings**

The two steel orthotropic deck systems described in Option 1 are relatively lightweight and are durable proven alternatives that have good long term performance and require very little maintenance to their lightweight wearing surfaces.

The open grid steel deck system described in Options 2 has been used extensively in the past for movable bridges, is lightweight, but has a number of inherent drawbacks, including poor durability, high maintenance, noise, and poor skid resistance. Open deck systems are currently not recommended to be used for bridges in the CSA-S6 Canadian Highway Bridge Design Code.

The Half-filled Grid Deck with Concrete Overfill described in Option 3 and Exodermic™ deck system describes as Option 4 both provide low cost and low maintenance durable deck solutions but are significantly heavier than the other decks. With the corresponding increases to the weight of the counterweight, the increased support rollers and mechanical equipment sizes and pier foundations the cost savings are more than offset as compared to other options.
The FRP deck system described in Option 5 provides the lightest weight option but is a relatively new product that has only been in service for approximately 10 years and has been limited to around 100 bridges to date. The FRP deck has typically been used to replace open steel grid decks with varying success as some decks have had to be removed and replaced within a short time due to problems with connection details. The epoxy concrete wearing surface on FRP decks is high maintenance and needs be replaced every 10 years or so.

The SPS deck system described in Option 6 is a moderately lightweight option that has to date only been used on a small number of bridges (less than 10 bridge decks currently in service), and has not been used on any moveable bridges and the long-term performance of the system is unknown. This is an expensive alternate that is also considered to be high risk with regards to understanding long term performance.

**Recommendation**

Of the deck options considered two deck systems are proposed to be further investigated during preliminary design: the proprietary steel orthotropic deck by Structal and the Half-Filled Grid Deck with concrete overfill.

Steel orthotropic deck systems have been used extensively in the past on moveable and long-span bridges. The structural performance of orthotropic decks is very good and the total deck system weight of 285 kg/m² is relatively low compared to the other lightweight decks. The deck system has high fabrication and installation costs but utilizing the recommended Structal system provides a benefit over custom fabricated orthotropic deck systems. The deck system requires a light surface coating such as Bimagrip which requires low levels of maintenance and has been found to provide good results, especially when it is applied in the shop.

Half-filled grid deck systems with concrete overfill is another proven deck system that has been used since the 1960’s. The structural performance of half-filled grid decks is typically very good, especially with regards to maintenance requirements. The deck requires no wearing surface other than the concrete to grade slab itself and is typically very durable and low maintenance. However, even when lightweight concrete is utilized the half-filled concrete deck system is relatively heavy compared to the other decks at 400 kg/m². As lightweight concrete is not a standard product on Vancouver Island, a concrete test mix program would need to be undertaken to develop a durable concrete mix for this bridge deck.
1. OBJECTIVES AND DESIGN CONSIDERATIONS

1.1 Objectives

This report compares feasible options for the roadway deck system for the new Johnson Street Bridge. The need for an options analysis stems from the need to provide a cost-effective and lightweight deck for the bascule span of the new structure. The preferred deck option must provide the best balance of durability and low weight with reasonable initial costs and minimal future maintenance costs. Six (6) lightweight deck options currently available in the marketplace were investigated and compared.

1.2 Structure Overview

The new Johnson Street Bridge provides access across Victoria’s inner harbor. The bascule span accommodates marine traffic that travels between the inner and outer harbor. The replacement structure, to be constructed immediately north of the existing bridges, will accommodate pedestrian and bicycle traffic and three lanes of vehicular traffic (two westbound lanes and one eastbound lane). The new structure does not make provisions for rail traffic. The structure will have two approach spans and one main bascule span. The main bascule span accommodates a navigational channel of 41m and has an average deck width of approximately 15m. Renderings of the new Johnson Street Bridge are included in Appendix A.

1.3 Ranking Criteria

The four main criteria for comparing and ranking the six deck system options are: 1) the initial deck system cost; 2) the weight of the deck system and additional costs associated with the increased deck weight (additional counterweight, mechanical equipment and foundation costs), 3) deck system and wearing surface maintenance schedule and costs; 4) the risk relative to constructability and expected long term performance of each deck option (based on contractor experience and past deck performance). The ranking criteria were used to provide a comprehensive comparison of the six deck systems in Section 5 of the report.
2. DISCUSSION OF DECK OPTIONS

A lightweight bridge deck is required for the new Johnson Street Bridge to minimize the overall weight of the bridge structure and associated counterweight in order to achieve the desired efficiency. Options considered prior to the preparation of this report, included steel and aluminum orthotropic deck, open grid steel deck, Exodermic™ deck, fibre reinforced polymer deck, and sandwich plate systems. After a preliminary review of the deck options, the aluminum deck option was excluded from the analysis due to its limited use in roadway bridge construction, and uncertainty of its application for a moveable bridge. Thus six feasible deck system options were selected for further investigation. These options include:

- Option 1: Steel Orthotropic Deck,
- Option 2: Open Grid Steel Deck,
- Option 3: Half-filled Grid Deck with Concrete Overfill
- Option 4: Exodermic™ Deck,
- Option 5: Fibre Reinforced Polymer (FRP) Deck, and
- Option 6: Sandwich Plate System (SPS) Deck.

Each option is described in detail in the following sections. For all deck options, it is assumed that the deck will be supported by floor beams spaced at between 2.5m and 5.0m spanning between the bottom chords of the main trusses. For the steel grid deck, FRP deck and SPS deck additional longitudinal stringers are required to support the deck panels.

2.1 Option 1: Steel Orthotropic Deck

Two types of steel orthotropic deck are discussed: conventional and proprietary systems. A traditional steel orthotropic bridge deck consists of a steel plate for the top flange which is stiffened and supported by steel ribs. This arrangement provides excellent resistance to torsional deformation and is lightweight. Numerous variations of the stiffening ribs are available and, for this investigation closed trough sections were assumed as shown in Figure 2.1. This arrangement is similar to that used on the Lions Gate Bridge in Vancouver, BC.
The steel orthotropic deck for this study assumes 14mm thick deck plate and 8mm thick plate for the ribs with the arrangement and spacing shown in Figure 2.1 with a thin 10mm wearing course. Additional stringers are not required between the floor beams. The steel orthotropic deck panels can be either welded or bolted in-place and designed to be integral or non-integral with the floor beams. Including a thin 10mm wearing surface (see Section 3) the weight of the steel orthotropic deck system, excluding the floor beams, is approximately 255 kg/m².

A proprietary steel orthotropic deck system, designed and manufactured by Structal similarly uses steel plate for the top flange which is stiffened and supported by steel ribs orientated in the longitudinal direction. Inverted T-sections are placed in the transverse direction, which accommodate connection to the supporting superstructure (see Figure 2.2). The Structal system is fabricated in panels that span between the floor beams. Multiple panels spanning longitudinally are attached to the floor beams in the field as compared to traditional steel orthotropic deck panels which are typically fabricated from curb-to-curb incorporating the floor beams. The Structal panels are bolted to the top flange of the supporting floor beams, which increases the overall depth of the superstructure as compared to traditional steel orthotropic deck. Thus, this system is slightly heavier than traditional steel orthotropic deck systems with a unit weight (including a thin 10mm wearing surface) of 285 kg/m². Because of the Structal decks ease of installation this system has a lower overall cost than traditional steel orthotropic decks. Thus both orthotropic deck options are included in this analysis: traditional steel orthotropic deck (Option 1a) and the Structal steel orthotropic deck system (Option 1b).
Steel orthotropic decks have been used for a wide range of bridge structures, including movable bridges and long span bridges where a lightweight bridge deck is critical. Several examples of bridges using steel orthotropic deck are listed in Table 2.1.

Table 2.1: Examples of Existing Bridge Structures using Steel Orthotropic Decks

<table>
<thead>
<tr>
<th>Bridge</th>
<th>Constructed</th>
<th>Main Span [m]</th>
<th>Width [m]</th>
<th>Bascule Span [Single/Double]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Congress Pkwy Bridge</td>
<td>1956 (2011)*</td>
<td>67.5</td>
<td>25.5</td>
<td>Double</td>
</tr>
<tr>
<td>Chicago, IL</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lions Gate Bridge</td>
<td>1938 (2001)*</td>
<td>472</td>
<td>16.8</td>
<td>n/a</td>
</tr>
<tr>
<td>Vancouver, BC</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>La Porta d’Europe, Barcelona, Spain</td>
<td>2000</td>
<td>108</td>
<td>-</td>
<td>Double</td>
</tr>
<tr>
<td>Erasmus Bridge, Rotterdam, Netherlands</td>
<td>1999</td>
<td>52.4</td>
<td>35.7</td>
<td>Single</td>
</tr>
<tr>
<td>Breydon Bridge, Breydon, UK</td>
<td>1985</td>
<td>30.5</td>
<td>-</td>
<td>Single</td>
</tr>
<tr>
<td>Indian River Bridge, Port Carling, ON</td>
<td>1975</td>
<td>17.1</td>
<td>12.8</td>
<td>Single</td>
</tr>
<tr>
<td>Miller-Sweeney Bridge, Oakland, CA</td>
<td>1973</td>
<td>38.7</td>
<td>18.6</td>
<td>Single</td>
</tr>
</tbody>
</table>
| *Date of deck replacement with a steel orthotropic deck

Figure 2.2: Structal Steel Orthotropic Deck Panel
Use of this system on larger single-leaf bascule spans, such as the Erasmus Bridge in Rotterdam, Netherlands, supports its use for the new Johnson Street Bridge. Anticipated replacement of the Congress Parkway Bridge with a steel orthotropic deck indicates it is a viable deck option for bascule bridges. For the Congress Parkway Bridge the proprietary steel orthotropic deck manufactured by Structal is being used.

Regular maintenance of the deck surface is essential to fully benefit from the high performance of an orthotropic deck system. The orthotropic deck surface is usually waterproofed with a spray applied polyurethane-based membrane and wearing surface system. Resurfacing of the wearing surface along the travelled wheel lines and local touch-up of the underdeck coating are anticipated to be required after the bridge has been in service approximately 25 years. The bridge deck is expected to have a service life expectancy of 100 years with ongoing maintenance to the wearing surface and underside coatings.

The two steel orthotropic deck options described above are compared with the other deck systems in Section 5.

### 2.2 Option 2: Open Grid Steel Deck

The open grid steel deck system uses a pre-fabricated steel grid consisting of specially rolled bearing bars placed transverse to traffic support a grid system as shown in Figure 2.3. The system can be galvanized to provide resistance to corrosion. The top surface of the steel bars that make up the grating are serrated to provide slip resistance. This deck system requires a series of floor beams and stringers to support the steel grid panels.

![Figure 2.3: Open Grid Steel Deck System](image)
Open grid steel deck is manufactured in a variety of 2-way and 4-way orientations with varied bar spacing. For this project a 131.8mm deep 4-way grid system, as shown in Figure 2.3, would be appropriate. Stringers spaced at 1.6m are required in the framing system in addition to the floor beams to support the deck system. Including the stringers but excluding the floor beams, the open grid deck system has a total weight of approximately 245 kg/m². A selection of recent bascule bridges using open grid steel deck systems are shown in Table 2.2.

Table 2.2: Examples of Bascule Bridges using Open Grid Steel Decks

<table>
<thead>
<tr>
<th>Bridge</th>
<th>Deck Constructed</th>
<th>Main Span [m]</th>
<th>Width [m]</th>
<th>Bascule Span [Single/Double]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Old Youngs Bay Bridge</td>
<td>2010</td>
<td>48.7</td>
<td>6.2</td>
<td>Double</td>
</tr>
<tr>
<td>Clatsop County, OR</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wisconsin Street Bridge</td>
<td>2008</td>
<td>24.1</td>
<td>9.1</td>
<td>Double</td>
</tr>
<tr>
<td>Oshkosh, WI</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Illinois Street Bridge</td>
<td>2006</td>
<td>19.8</td>
<td>7.3</td>
<td>Single</td>
</tr>
<tr>
<td>San Francisco County, CA</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6th Street Bridge</td>
<td>2002</td>
<td>40.8</td>
<td>17.7</td>
<td>Double</td>
</tr>
<tr>
<td>Milwaukee, WI</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N. Emmber Lane Bridge</td>
<td>2000</td>
<td>36.0</td>
<td>11.6</td>
<td>Double</td>
</tr>
<tr>
<td>Milwaukee, WI</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Main Street Bridge</td>
<td>1996</td>
<td>51.2</td>
<td>15.8</td>
<td>Double</td>
</tr>
<tr>
<td>Racine, WI</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Military Street Bridge</td>
<td>1991</td>
<td>16.4</td>
<td>19.8</td>
<td>Double</td>
</tr>
<tr>
<td>Port Huron, MI</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A majority of the more recent bascule bridges using open grid steel decks have been constructed in Wisconsin. The most recent use of open grating was for the deck replacement of the Old Youngs Bay Bridge, where a quick replacement was required and an open grid steel deck was the only option that met the tight replacement schedule.

Open grating type of deck system has been used on a variety of bridge structures in the United States, including many movable bridge structures in the State of Florida. From past experiences, research in Florida is being conducted to find alternative lightweight deck systems to avoid use of open grid steel deck systems in the future due to inherent problems with this system as discussed below.
The open grid steel deck system can be installed quickly and the deck panels are easily transported and stored on site. With the grid serving as the wearing surface, the supporting steel can be easily inspected in the future; however, the open grating does not provide protection to the structural and mechanical components located below the deck. Open grid bridge deck may lead to accelerated deterioration due to direct exposure to the elements. Debris deposited by vehicles on the superstructure will create maintenance issues for the structure.

The serrated surface of the steel grading typically provides poor skid resistance, especially in wet weather. The serrated surface deteriorates over time becoming more slippery, and is very noisy when traffic passes over it. The steel grading also poses a risk to cyclists and motorcyclists who can easily slip or catch tires within the grading. A steel plate overlay would be recommended for cycling/pedestrian lanes. The grating is also prone to fatigue cracks in the attachment welds and the grating material itself.

CAN/CSA-S6-06 allows for a 15% reduction in wind loading when open grating is used, although the code also discourages use of open grid steel deck and recommends use of a solid deck. A typical open grid steel grating is shown in Figure 2.4.

Cost estimates and weights of the open grid steel deck option described above has been summarized Section 5.
2.3 **Option 3: Half-filled Grid Deck with Concrete Overfill**

A half-filled grid deck is an improved version of the open grid deck and variations of it have been in use since the 1960’s. The system is comprised of steel grid which is cast half filled with a lightweight concrete and overfilled with a monolithic concrete wearing surface. (Figure 2.7). There is no reinforcing above the top of the grid deck and the overall system depth varies between 160mm and 180mm depending on the thickness of the overfill. Half-filled grid decks can typically span between 2.0 metres and 3.0 metres and can utilize tightly spaced floor beams or wider spaced floor beams with longitudinal stringers.

![Figure 2.5: Half-Filled Grid Deck with Concrete Overfill](image)

Half-filled decks have been used on a number of bridges in the United States, including locally the First Avenue Southbound Bridge in Seattle, Washington which was constructed in 1995. The First Avenue Bridge is owned and maintained by the Washington State Department of Transportation and they are very pleased with the performance of the deck, especially when compared to their northbound bridge which utilizes an open grid deck. The City of Seattle has just awarded their new South Park double bascule span replacement bridge and construction is to commence in the summer of 2011. The South Park bridge was designed using a half-filled grid deck with a total concrete thickness (including overfill) of 108 mm.
In addition to weight savings, another advantage of the half-filled grid deck system is that the concrete overfill provides a wearing surface with good slip resistance without the need for an overlay. Historically, a wearing surface is not applied on top of the concrete unless the precast construction method is used. Since the total thickness of the concrete component of the deck is typically between 95 mm and 115 mm, half-filled grid systems can weigh up to 35 to 45% less than conventional reinforced concrete decks while still providing comparable strength and stiffness. Assuming that the half-filled grid deck concrete is cast-in-place and no overlay applied, the weight with 115mm thick concrete and floor beams at 2.5 metre spacings is 465 kg/m² using normal density concrete and 400 kg/m² using lightweight concrete. Although the half-filled grid deck using lightweight concrete is approximately half the weight of a traditional concrete deck, it is one of the heavier deck systems investigated.
Cost estimates and other comparisons for the half-filled grid deck option described above have been summarized in Section 5.

2.4 Option 4: Exodermic Deck

An Exodermic™ deck is a proprietary system comprised of steel grid which is compositely cast with a reinforced lightweight concrete deck and utilizes a top mat of reinforcing (Figure 2.7). The top of the main bars are embedded into the reinforced concrete slab. Depending on the support structure for the deck system the overall thickness typically varies between 150mm to 250mm. Exodermic decks can span 4.0 metres to 5.0 metres between floor beams, thus eliminating the need for stringers.

![Figure 2.7: Exodermic™ Deck System](image)

The concrete topping can be constructed in one of two ways. The first uses cast-in-place concrete where headed studs are welded to the floor beams, a single mat of steel reinforcing bar is placed, and the concrete slab is poured on the steel grid deck which acts as formwork. The second uses precast concrete where the reinforced concrete slab is connected to the steel grid panels with block outs for structural connection to the floor beams.

The Exodermic deck for this study (based on the design manual) initially assumed a 240mm deep deck system with main bearing bars spaced at 203mm and 50mm of cover over the top rebar and 25mm cover beneath the bottom rebar. The depth of the deck system includes a 115mm reinforced concrete slab which has 20M reinforcing bar spaced at 75mm. The
Exodermic deck system can span between floor beams and does not require the use of stringers. No wearing course is required if the reinforced concrete deck is cast-in-place as the concrete deck provides an adequate riding surface. A wearing surface is recommended when using precast concrete to provide a consistent finish surface at the panel joints. Assuming the reinforced concrete deck is cast-in-place and no deck overlay is applied, the weight of the Exodermic system is 395kg/m² using normal density concrete and 340kg/m² using lightweight concrete.

However when the concrete deck is constructed to match the concrete cover requirements of the Canadian Bridge Design Code (CSA S6-2010) the top cover is required to be 80 mm for a concrete to grade deck and the soffit cover required to be 50mm. This increases the concrete deck thickness to approximately 165 mm which increases the weight of the deck system to 550 kg/m² using normal density concrete and 470 kg/m² using lightweight concrete which makes it the heaviest of all of the deck systems and the maximum distance this system can span between floor beams is 4.0 metres.

Exodermic decks have been used on a number of bridges in the United States, including many bascule bridges in the state of Florida (see Table 2.4). The first use of an Exodermic deck was in 1984 on the Driscoll Bridge for the Garden State Parkway in the state of New Jersey, which remains in good condition today.

**Table 2.4: Examples of Bascule Bridges using Exodermic Decks**

<table>
<thead>
<tr>
<th>Bridge</th>
<th>Constructed</th>
<th>Main Span [m]</th>
<th>Width [m]</th>
<th>Bascule Span [Single/Double]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Johns Pass Bridge</td>
<td>2010</td>
<td>30.5</td>
<td>28.9*</td>
<td>Double</td>
</tr>
<tr>
<td>Treasure Island, FL</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NW 12th Ave Bridge</td>
<td>2009</td>
<td>45.7</td>
<td>33.5*</td>
<td>Double</td>
</tr>
<tr>
<td>Miami-Dade, FL</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Woodrow Wilson Bridge</td>
<td>2008</td>
<td>82.3</td>
<td>70.0*</td>
<td>Double</td>
</tr>
<tr>
<td>Alexandria, Virginia</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17th Street Bridge</td>
<td>2000</td>
<td>64.0</td>
<td>32.6*</td>
<td>Double</td>
</tr>
<tr>
<td>Ft Lauderdale, FL</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Main Street Bridge</td>
<td>1998</td>
<td>38.1</td>
<td>16.6</td>
<td>Double</td>
</tr>
<tr>
<td>Green Bay, WI</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Twin bascule bridge (total width for both structures)*

n/a – not available
A number of bascule bridges have been built within the past decade using the Exodermic deck system. The first time an Exodermic deck was used for a bascule bridge was for the Main Street Bridge in Wisconsin in 1998. The Wisconsin Department of Transportation chose to use an Exodermic deck, after comparison with steel open grid and half-filled grid decks, due to its lower maintenance costs and better riding surface.

Another advantage of the Exodermic deck system is that the reinforced concrete slab provides a wearing surface with good slip resistance without an overlay. Historically, a wearing surface is not applied. Since the reinforced concrete component is only approximately half of the deck thickness, Exodermic deck systems can weigh up to 40% less than conventional reinforced concrete decks while still providing comparable strength and stiffness. Although the weight is significantly lighter than traditional reinforced concrete decks, the weight of the system is the heaviest of all of the deck options investigated.

Cost estimates and other comparisons for the Exodermic deck option described above have been summarized in Section 5.

2.5 Option 5: Fibre Reinforced Polymer Deck

Fibre reinforced polymer (FRP) deck systems are commercially available as proprietary products. Two types of FRP systems are commonly used: mechanically fastened and adhesively bonded. Two suppliers that have used their products for bascule bridges include Martin Marietta Composites (MMC) who developed DuraSpan® which is an adhesively bonded system and ZellComp Inc. who developed the mechanically fastened ZellComp® system. Other FRP systems are available for use but are not outlined in this report. For both systems the deck panels use epoxy coated fibres that are formed into sections using a process called pultrusion (Figure 2.8).
Both systems are pre-fabricated and shipped to site for installation. A series of floor beams and stringers are required to support the FRP deck systems, which can be connected to the deck framing using a variety of methods specific to the type of FRP deck used. The ZellComp® deck system acts as multiple I beams, as shown in Figure 2.8, which are laterally supported by plates on the top and bottom. These shapes are laid transverse to traffic and are mechanically fastened together and connected to the stringers and floor beams using one of two methods: shear studs and grout or bolts and neoprene pads. The DuraSpan® deck system uses a series of pultruded tubes which are adhesively bonded into panels. On-site, the panels are adhesively bonded together at pre-fabricated tongue and groove field joints and are connected to the stringers and floor beams using shear studs and grout. Both systems typically use a 10mm polymer concrete wearing surface. Details on the DuraSpan® and ZellComp® decking systems are provided in Appendix B.

The cost and weight for the FRP deck options reviewed are very similar. Both deck systems must be supported at approximately 1.2 m centres and as such would require additional longitudinal stringers connected to the floor beams. For this study a 127mm thick ZellComp® deck system was selected. Bolts and neoprene pads are typically used to connect the ZellComp® deck system to the stringers and floor beams. To minimize transverse cracking in the polymer concrete it is proposed that an additional layer of mesh and resin be added over the deck system prior to the installation of the wearing surface.
The ZellComp® decking system including the additional mesh and resin layer and polymer concrete surfacing has a total weight of approximately 130kg/m².

FRP bridge decks have been used on over 100 bridge structures in the United States, including five movable bridge structures in the state of Oregon (Table 2.5).

Table 2.5: FRP Decks in Service on Bascule Bridges

<table>
<thead>
<tr>
<th>Bridge</th>
<th>Deck Replaced</th>
<th>Main Bascule Span [m]</th>
<th>Bascule Span [Single/Double]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morrison Bridge, Portland, OR</td>
<td>2011</td>
<td>86.7</td>
<td>Double</td>
</tr>
<tr>
<td>Broadway Bridge, Portland, OR</td>
<td>2005 (2010)*</td>
<td>84.7</td>
<td>Double</td>
</tr>
<tr>
<td>Siuslaw River Bridge, Florence, OR</td>
<td>2003</td>
<td>43.0</td>
<td>Double</td>
</tr>
<tr>
<td>Old Youngs Bay Bridge, Clatsop County, OR</td>
<td>2002 (2010)†</td>
<td>48.7</td>
<td>Double</td>
</tr>
<tr>
<td>Lewis and Clark River Bridge, Clatsop County, OR</td>
<td>2001</td>
<td>34.6</td>
<td>Single</td>
</tr>
</tbody>
</table>

*Deck partially replaced with another FRP deck system to accommodate the new Portland Streetcar Loop  
†Existing FRP deck replaced with an open grid steel deck in 2010

The Oregon Department of Transportation (DOT) and Multnomah County have used FRP for deck replacements on four bascule bridges and recently tendered another FRP deck replacement for the Morrison Bridge. The replacement of the steel open grid deck on the Broadway Bridge was the most recent deck replacement using FRP on a bascule bridge. To accommodate installation of tracks for the new Portland Streetcar Loop the existing DuraSpan® deck was partially replaced in 2010 with the ZellComp® decking system (Figure 2.9).
The DuraSpan® deck on the Old Young’s Bay Bridge did not perform as expected and the deck deteriorated to a level that required replacement in 2010. The Oregon DOT considered the deck at Old Young’s Bay to be a unique case, where the rapid deterioration of the deck was due to the use of a grout pad between the stringers and the FRP as well as grouted shear studs on the stringers. The stringers and floor beams were relatively flexible as was the FRP deck. As a result the bridge did not respond well to the brittle material placed between them. These connection details have been rectified by the FRP suppliers and the Oregon DOT considers this not to be an issue with current FRP deck products discussed in this section. The Lewis and Clark Bridge had a similar system installed but the deck did not deteriorate at the same rate, likely because a tighter stringer spacing and thicker wearing surface was used providing a stiffer overall deck system.

The light weight of the FRP deck system is advantageous for movable bridges, especially in high-seismic zones, where a reduction in the dead load of the bascule span can reduce the size of counterweight and mechanical systems required. Another significant advantage of the FRP deck is that it does not corrode when exposed to the elements. ZellComp® suggests a service life of 75 to 100 years for its deck system. Although laboratory tests and current installations have shown positive results, there have been problems with some of the bridge decks using this system and the long term performance of FRP deck systems is still unknown. FRP deck systems are relatively new and as such only a limited number of contractors have experience installing these systems.

During recent discussions with Multnomah County’s on the Morrison Bridge bascule deck replacement it was determined that the DuraSpan® system is no longer in production and only
the ZellComp® system met their requirements for an open cell deck. Multnomah County in Portland and the Oregon DOT noted they would consider using FRP decks in the future since they offer an outstanding weight advantage and provide a superior riding surface when compared with the steel open gird decks. The connection details of the deck to the supporting beams appear to be the main concern with FRP decks, with the bolted connection with neoprene pads between the stringers and the FRP working better than a directly supported grouted system.

Cost estimates and other comparisons for the FRP deck option described above have been summarized in Section 5.

2.6 Option 6: Sandwich Plate System

Sandwich Plate System (SPS) deck is a proprietary system, developed by Intelligent Engineering Limited (IEL), consisting of two steel plates bonded to a compact polyurethane elastomer core to form the top plate of the panel, which is typically framed by steel plates. The elastomer core provides continuous support of the deck plates and precludes local plate buckling. The SPS panel system is shown in Figure 2.10

For this study, based on a design by IEL, 50mm deep 10-30-10 SPS deck panels (10mm top and bottom steel plates with a 30mm elastomeric core) would be appropriate. From curb to curb, the system consists of two 2.4m wide 10-30-10 SPS panels which are framed on the edges and bolted to steel floor beams, a central stringer, and edge shelf plates. Additional floor beams are required (compared to the assumed baseline of floor beams spaced at 5.0m) and are spaced at 2.5m as well as a central stringer to support the SPS panels. Including the stringers, additional floor beams and a wearing surface varying in depth between 10mm and 20mm (a minimum of 10mm of wearing surface over splice plates), the SPS deck system has a total weight of approximately 380kg/m².
Examples of bridges using the SPS deck panels are shown in Table 2.6.

Table 2.6: Bridges using Sandwich Plate System Deck

<table>
<thead>
<tr>
<th>Bridge</th>
<th>Deck Constructed</th>
<th>Main Span [m]</th>
<th>Width [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dawson Bridge</td>
<td>2010</td>
<td>76.0 (236m total)</td>
<td>12.5</td>
</tr>
<tr>
<td>Edmonton, AB</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cedar Creek Bridge</td>
<td>2008</td>
<td>15.2</td>
<td>9.1</td>
</tr>
<tr>
<td>Wise County, TX</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Highway 58</td>
<td>2006</td>
<td>19.0</td>
<td>11.6</td>
</tr>
<tr>
<td>Bristol, VA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Port Britain Bridge</td>
<td>2005</td>
<td>11.3</td>
<td>7.5</td>
</tr>
<tr>
<td>Port Britain, ON</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Massawippi River Bridge</td>
<td>2005</td>
<td>42.3</td>
<td>7.6</td>
</tr>
<tr>
<td>Lennoxville, QC</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shenley Bridge</td>
<td>2003</td>
<td>22.5</td>
<td>7.1</td>
</tr>
<tr>
<td>Saint-Martin de Beauce, QC</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The Shenley Bridge is the first bridge to use the SPS deck panels as a complete deck system. Installation of the SPS deck panels for the Shenley Bridge is shown in Figure 2.11. The most recent use of SPS deck panels was for the rehabilitation of the Dawson Bridge. The SPS deck system has never been used before on a bascule bridge. SPS has also been used in Germany, China, and United Kingdom as a bridge deck overlay to strengthen existing decks, but not as a complete deck replacement. In these cases SPS was used in conjunction with the existing deck, thus these cases are not applicable to new deck construction.
Figure 2.11: SPS Panel Installation at Shenley Bridge (left) and Dawson Bridge (right)

The SPS deck system provides a lightweight deck option that reduces the dead load of the structure and allows for reduction of other bridge components. The SPS deck system provides minimal on-site welding due to the bolted connection to the supporting deck structure, thus providing increased fatigue resistance. The SPS system also allows for quick installation of the deck panels. SPS is a relatively new product and its application to bridges is limited as compared to other deck options. Because of its limited use, custom fabrication of the SPS panels increases the cost and also creates quality control issues. There are currently no code provisions for the design, fabrication, and construction of this type of deck system which presents challenges and uncertainty in performance of the system.

The bonding of the wearing surface is a concern. After a year of service on the Massawippi River Bridge, large sections of the wearing surface de-bonded due to the bridge’s flexibility causing the bridge to be reduced to one-lane for three-months to allow for the repairs. As the SPS system has never been used for a bascule bridge there is a high degree of uncertainty of how the deck system will perform when the bridge is opened for vessel traffic, more specifically concerning the durability of the system and bonding of the wearing course to the SPS panels. The preliminary layout provided by the supplier may not provide adequate stiffness and additional stringers may be required.

Cost estimates and other comparisons for the SPS panel deck option described above have been summarized in Section 5.
3. DECK WEARING SURFACE

Selection of the most appropriate bridge deck wearing surface is critical to the overall durability of the bridge deck. Wearing surface options typically used for lightweight bridge decks have been identified and evaluated below.

3.1 Wearing Surface Types

3.1.1 Traditional Hot Mix Asphalt

Traditional hot mix asphalt will require a modified binder to be used with a steel orthotropic, FRP, or SPS deck. Without a modified binder the flexible nature of the deck system will cause the hot mix asphalt to crack and the required durability would not be achieved. Traditional hot mix asphalt is typically placed and compacted in 40mm to 50mm thick lifts. However, on bascule bridges, debonding and sliding failures of hot mix asphalt has occurred in the past and this system is not recommended.

3.1.2 Mastic Asphalt

Mastic asphalt is a mixture of asphalt and aggregate containing higher levels of binder and it is typically poured into place. Higher levels of binder in mastic asphalts allow for good bonding and improve impermeability. Use of mastic asphalts is limited in North America but is commonly used in Europe. Mastic asphalts have an expected service life of approximately 50 years. Commonly mentioned disadvantages include poor skid resistance as compared to traditional hot mix asphalts and a difficult application process. Mastic asphalt is typically placed in 30mm to 50mm thick lifts.

3.1.3 Epoxy Asphalt

Epoxy asphalt is a mixture of traditional hot mix asphalt and epoxy resin. The wearing surface provides better skid resistance as compared to mastic asphalts, and similarly provides good bonding to steel and other substrate materials. Epoxy asphalt has an expected service life of 30 years as compared to traditional hot mix asphalt which has an expected service life of 10 to 15 years. Epoxy asphalt has a good track record in North America and is placed using conventional paving equipment in 40mm to 50mm lifts. Curing of the asphalt is dependent on temperature and can take significant time in cold temperatures.
3.1.4 Polymer Concrete

A polymer concrete wearing system consists of a polymer based binder mixed with fine aggregate and is in thicknesses up to 10mm. Three different types of polymer based binders are typically used for bridge deck overlays, including methyl methacrylate, polyester, and epoxy. The Oregon DOT (has recent experience with polymer concrete on a number of bridges) and suppliers suggest that a polyester binder be used. Specialized paving equipment is required for polymer concrete overlays and proper curing is dependent on climatic conditions. A higher cost is also associated with the use of polymer concretes. Figure 3.1 shows an example of the finished wearing surface for the FRP deck replacement at Broadway Bridge in Portland, OR.

![Figure 3.1: Polymer Concrete Wearing Course at the Broadway Bridge in Portland, OR](image)

3.1.5 Proprietary Lightweight Wearing Surfaces

Two proprietary lightweight wearing course systems are available for use on bridge decks. The BimaGrip and Bridgemaster products are typically used with steel plate substrates and are compatible with flexible deck systems.

The BimaGrip LS system is manufactured by R.S. Clare & Co. Ltd. for vehicular bridges with high traffic volumes. The system uses a polyurethane primer topped with a mixture of polyurethane adhesive and aggregate. The BimaGrip system has been used on a number of
bridge structures providing good durability and is currently being used for the new Congress Parkway bascule bridge in Chicago, IL in conjunction with the *Structal* steel orthotropic deck system. The BimaGrip system was also used on the sidewalks of the Lion’s gate bridge in Vancouver, BC in 2001.

The Bridgemaster system manufactured by Sterling Lloyd uses a methyl methacrylate resin for a primer followed by a coating of methyl methacrylate binder resin mixed with siliceous fillers and hardener powder. The system uses an acrylic sealer clear coat which is rolled onto the binder/aggregate surface.

Both of these systems are very sensitive to moisture and temperature during the application process, which may cause delays in placement if ambient conditions are not acceptable. In some cases with prefabricated panels, deck overlays can be applied during fabrication. Use of a proprietary lightweight wearing surface is advantageous for moveable bridges as it decreases the weight of the deck system as compared to use of traditional or modified asphalt surfaces.

### 3.2 Wearing Surface Recommendations

#### 3.2.1 Steel Orthotropic Deck

It has been observed from steel orthotropic deck applications that debonding of the wearing surface from the plate deck is an issue. Improvements in mastic and epoxy asphalts have been made to mitigate this problem, although this has increased the complexity of the application process. Ambient conditions have a significant effect on the quality of the bond of the wearing surface and steel plate. If moisture and temperature requirements are not strictly met, the bonding of the wearing surface will be inadequate leading to maintenance and durability issues. If a steel orthotropic deck is used for the new Johnson Street Bridge one of the proprietary lightweight wearing surfaces discussed in Section 3.1.5 is recommended based on their light weight and past performance. Applying the lightweight wearing surface to the steel deck in the controlled environment of a fabrication shop would result in the best final product.

#### 3.2.2 Half-filled Grid Deck and Exodermic Deck

Both of these grid deck options utilize an at grade concrete riding surface that is cast monolithically with the deck pour. As such no separate wearing surface is required for either of these bridge deck options. The final concrete surface can be provide with a variety of finishes from a rough brushed to a tined surface for improved traction.
3.2.3 Fibre Reinforced Polymer Deck

Polymer concrete is typically used as the wearing surface on FRP decks. The Oregon DOT has used both polymer concrete wearing surfaces and urethane wearing surface for three bascule bridges in Oregon and through experience with these wearing courses, the Oregon DOT recommends the use of a polyester polymer concrete overlay. The Washington DOT has used 10mm thick polymer concrete (methyl methacrylate) systems on FRP decks and initially experienced poor performance of the wearing surface. After identification of earlier issues relating to temperature and moisture and lack of experience, polymer concrete surfaces have been improved and they are being used more frequently by the Washington DOT with success. There is limited experience with the use of mastic and epoxy asphalt on FRP bridge decks. It is recommended that a polyester polymer concrete be used for the wearing surface on FRP deck systems.

3.2.4 Sandwich Plate System Deck

SPS deck systems have never been used for bascule bridges and, similar to steel orthotropic deck, debonding of the wearing surface when in the open position is a concern. Bonding of the wearing surface to the steel top plate remains similar to steel orthotropic steel decks, and similar challenges for placement of the wearing course as stated above for the orthotropic deck will also apply. Similar to the steel orthotropic deck, a proprietary lightweight wearing surface is recommended if a SPS deck system is used.
4. BRIDGE PARAPETS / BARRIERS

It is a requirement of the Canadian Highway Bridge Design Code CAN/CSA-S6-06 (CHBDC) that bridge barriers meet a specified barrier performance level, including crash test requirements. Using the barrier classification to be included in the 2010 version of the CHBDC, the required barrier performance level is a TL–3.

Many of the crash-tested TL–3 barriers are not compatible with some of the deck options reviewed in this report. The lightweight decks reviewed in this report also may have anchorage challenges to meet the standard connection details for a TL–3 barrier. A steel post and railing barrier, as shown in Figure 4.1, is a type of barrier that could be considered.

Alternatively, since the design speed on the Johnson Street Bridge is significantly slower than that of a major highway and it is on a straight alignment, consideration could be given to designing a more aesthetically pleasing barrier to resist the barrier design forces without undertaking expensive crash testing. The barrier would need to be designed such that if it was impacted the connection would fail at the design impact load and not damage the main structural components of the bridge.

Figure 4.1: Example of Steel Post and Railing Barrier (TAC Manual 2010)
5. BRIDGE DECK SYSTEM COMPARISONS

The bridge deck system options have been evaluated based on the following criteria.

1) Cost of deck systems, including supply, installation, surfacing and floor beams;
2) Weight of deck systems and additional costs associated with the increased deck weight (additional counterweight, mechanical equipment and foundation costs);
3) Maintenance frequency and cost for wearing surface of each deck system;
4) Evaluation of risk relative to constructability and expected long term performance of each deck option (based on local contractor experience and past deck performance).

Write-ups on how each deck system performs with regards to the criteria have been summarized below with an overall weighted score provided in section 5.5.

5.1 Bridge Deck System Costs

Cost estimates have been calculated for the six roadway bridge deck options. These cost estimates have been assembled based on unit price budget estimates received from the deck suppliers and recent projects. The unit prices estimates have been broken down to include deck fabrication, deck shipping and installation, lightweight deck concrete (if required), wearing surface or polymer concrete (if required) and floor beams and stringers (if required).

Unit price costs and total costs for each roadway deck option have been provided below.

Table 5.1: Comparative Cost Estimates of Deck Alternatives

<table>
<thead>
<tr>
<th>Deck System</th>
<th>Deck Fabrication</th>
<th>Deck Shipping and Installation</th>
<th>Floor Beams at 5.0m centres*</th>
<th>Proprietary Lightweight Wearing Surface**</th>
<th>Sub-Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Option 1a: Traditional Steel Orthotropic Deck</td>
<td>$1,550 / m²</td>
<td>$450 / m²</td>
<td>$200 / m²</td>
<td>$150 / m²</td>
<td>$2,350 / m²</td>
</tr>
<tr>
<td>Option 1b: Proprietary Steel Orthotropic Deck</td>
<td>$1,200 / m²</td>
<td>$450 / m²</td>
<td>$200 / m²</td>
<td>$150 / m²</td>
<td>$2,000 / m²</td>
</tr>
<tr>
<td>Option 2: Open Grid Steel Deck</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-------------------------------</td>
<td>-------------------</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Steel Grid Fabrication</td>
<td>$400 / m²</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deck Shipping and Installation</td>
<td>$400 / m²</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Floor Beams at 5.0m centres c/w Stringers*</td>
<td>$300 / m²</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Sub-Total Cost</strong></td>
<td><strong>= $0.9 Million</strong>†</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>$1,100 / m²</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Option 3: Half-Filled Grid Deck with Overfill</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel Grid Fabrication</td>
<td>$400 / m²</td>
</tr>
<tr>
<td>Deck Shipping and Installation</td>
<td>$400 / m²</td>
</tr>
<tr>
<td>Floor Beams at 2.5m centres*</td>
<td>$400 / m²</td>
</tr>
<tr>
<td>Lightweight Concrete Infill</td>
<td>$250 / m²</td>
</tr>
<tr>
<td><strong>Sub-Total Cost</strong></td>
<td><strong>= $1.2 Million</strong>†</td>
</tr>
<tr>
<td></td>
<td><strong>$1,450 / m²</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Option 4: Exodermic™ Deck</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel Grid Fabrication</td>
<td>$400 / m²</td>
</tr>
<tr>
<td>Deck Shipping and Installation</td>
<td>$400 / m²</td>
</tr>
<tr>
<td>Floor Beams at 4.0m centres*</td>
<td>$350 / m²</td>
</tr>
<tr>
<td>Reinforced Lightweight Concrete</td>
<td>$400 / m²</td>
</tr>
<tr>
<td><strong>Sub-Total Cost</strong></td>
<td><strong>= $1.25 Million</strong>†</td>
</tr>
<tr>
<td></td>
<td><strong>$1,550 / m²</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Option 5: Fibre Reinforced Polymer Deck</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>FRP Deck Materials</td>
<td>$850 / m²</td>
</tr>
<tr>
<td>Deck Shipping and Installation</td>
<td>$300 / m²</td>
</tr>
<tr>
<td>Floor Beams at 5.0m centres c/w Stringers*</td>
<td>$300 / m²</td>
</tr>
<tr>
<td>Polymer Concrete Wearing Surface***</td>
<td>$200 / m²</td>
</tr>
<tr>
<td><strong>Sub-Total Cost</strong></td>
<td><strong>= $1.4 Million</strong>†</td>
</tr>
<tr>
<td></td>
<td><strong>$1,650 / m²</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Option 6: Sandwich Plate System</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Deck Fabrication</td>
<td>$1,250 / m²</td>
</tr>
<tr>
<td>Deck Shipping and Installation</td>
<td>$400 / m²</td>
</tr>
<tr>
<td>Floor Beams at 5.0m centres c/w Stringers*</td>
<td>$300 / m²</td>
</tr>
<tr>
<td>Proprietary Lightweight Wearing Surface ***</td>
<td>$150 / m²</td>
</tr>
<tr>
<td><strong>Sub-Total Cost</strong></td>
<td><strong>= $1.7 Million</strong>†</td>
</tr>
<tr>
<td></td>
<td><strong>$2,100 / m²</strong></td>
</tr>
</tbody>
</table>

† Total cost based on a main deck area of 810 m²
*Estimated based on a current steel cost (May 2011) of $ 4.00 / kg
**Includes cost of field touch-up application of surfacing at deck joints
***Includes cost premium to apply specialty deck surfacing to small deck area
Estimated budget bridge deck system costs with wearing surfaces ranged from $1,100 per m² to $2,350 per m². The most cost effective orthotropic plate deck system is Option 1b, the *Structal* prefabricated system with an estimated supplied and installed price including surfacing of $2,000 per m². The Option 2 open grid steel deck had the lowest estimated cost of the steel grid systems at $1,100 per m² with the half-filled steel grid deck at $1,450 per m² and the Exodermic deck at $1,550 per m². The Option 5 FRP deck system supply and installed price with a polymer concrete surfacing was estimated at $1,700 per m² and the Option 6 SPS deck system supplied and installed with a wearing surface was estimated at $2,100 per m².

### 5.2 Bridge Deck System Weights and Additional Costs

A comparison of the bridge deck option weights is presented below. The calculated bridge deck system unit weights include the bridge deck, floor beams and stringers and wearing surfaces. The main span bridge deck system total weight has been determined based on a deck area of 810 square metres. Preliminary calculations have also determined that the weight of the main span bridge trusses, support ring, sidewalk structure and multimodal structure will be approximately 1000 tonnes (without counterweight material) and it has been assumed that this weight is constant for all of the deck options. When the bridge deck system weights are added to the truss and sidewalk weights the total main span superstructure weights can be calculated and overall comparisons made.

**Table 5.2: Bridge Deck System Weight Comparisons**

<table>
<thead>
<tr>
<th>Deck Option</th>
<th>Bridge Deck System Weight (\text{[kg/m}^2\text{]/tonnes})</th>
<th>Truss, Support Ring, Sidewalk Weights [tonnes]</th>
<th>Total Estimated Superstructure Weight [tonnes]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a – Traditional Orthotropic</td>
<td>255 / 210t</td>
<td>1000t</td>
<td>1210t</td>
</tr>
<tr>
<td>1b – Proprietary Orthotropic</td>
<td>285 / 230t</td>
<td>1000t</td>
<td>1230t</td>
</tr>
<tr>
<td>2 – Open Grid Steel Deck</td>
<td>245 / 200t</td>
<td>1000t</td>
<td>1200t</td>
</tr>
<tr>
<td>3 – Half-filled Grid Deck</td>
<td>400 / 325t</td>
<td>1000t</td>
<td>1325t</td>
</tr>
<tr>
<td>4 – Exodermic™ Deck</td>
<td>470 / 380t</td>
<td>1000t</td>
<td>1380t</td>
</tr>
<tr>
<td>5 – FRP Deck</td>
<td>220 / 180t</td>
<td>1000t</td>
<td>1180t</td>
</tr>
<tr>
<td>6 – SPS Deck</td>
<td>380 / 310t</td>
<td>1000t</td>
<td>1310t</td>
</tr>
</tbody>
</table>
Based on the bridge deck system weight comparisons in Table 5.2, the FRP deck system provides the lightest deck system at 180 tonnes which results in the lightest superstructure weight of 1180 tonnes. The Exodermic deck is the heaviest deck system at 380 tonnes which results in the heaviest superstructure weight of 1380 tonnes. Note that these superstructure weights do NOT include the counterweight or counterweight materials.

The bridge deck system weights have additional cost implications over and above the initial capital costs provided in section 5.1. The bridge deck weights affect the size and cost of the superstructure counterweight, the capacity and cost of the mechanical roller supports / drive gear and the cost of the main pier foundation.

Estimated additional costs for each of these items over and above the lightest FRP deck system have been provided below in Table 5.3. The additional counterweight costs have been calculated based on steel priced $2.00 per kilogram. Additional mechanical costs have also been pro-rated based on the total superstructure weight for each deck option over and above the base FRP option. Additional pier foundation costs have been based on using 1.5m diameter concrete filled pipe piles approximately 20m long with a service capacity of 500 tonne and a cost per pile of $150k with the additional pier loads requiring additional length of piling.

Table 5.3: Additional Costs Related to Bridge Deck System Weights

<table>
<thead>
<tr>
<th>Deck Option</th>
<th>Additional Counterweight Costs</th>
<th>Additional Mechanical Costs</th>
<th>Additional Pier Foundation Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a – Traditional Orthotropic</td>
<td>$46,000</td>
<td>$20,000</td>
<td>$7,000</td>
</tr>
<tr>
<td>1b – Proprietary Orthotropic</td>
<td>$128,000</td>
<td>$54,000</td>
<td>$19,000</td>
</tr>
<tr>
<td>2 – Open Grid Steel Deck</td>
<td>$68,000</td>
<td>$29,000</td>
<td>$10,000</td>
</tr>
<tr>
<td>3 – Half-filled Grid Deck</td>
<td>$546,000</td>
<td>$232,000</td>
<td>$82,000</td>
</tr>
<tr>
<td>4 – Exodermic™ Deck</td>
<td>$760,000</td>
<td>$322,000</td>
<td>$114,000</td>
</tr>
<tr>
<td>5 – FRP Deck</td>
<td>$0</td>
<td>$0</td>
<td>$0</td>
</tr>
<tr>
<td>6 – SPS Deck</td>
<td>$485,000</td>
<td>$206,000</td>
<td>$73,000</td>
</tr>
</tbody>
</table>
5.3 Wearing Surface Maintenance Frequency and Repair Costs

A summary of the anticipated maintenance requirements and the estimated repair costs and timelines for the bridge deck systems wearing surfaces has been provided below based on a bridge design life of 100 years. Cost estimates for the major wearing surface maintenance work activities are based on 2011 prices.

**Steel Orthotropic Plate Deck System and SPS Deck System** – The steel orthotropic deck systems and SPS deck system both consist of fabricated steel components that are typically painted on the underside and utilize a proprietary lightweight wearing surface such as Bimagrip for the driving surface. In discussions with the Bimagrip supplier it is anticipated that the majority of the surfacing should last +/- 25 years with only local repairs required up until that time. At approximately 25 years it is highly likely that the wheel-line strips in each of the driving lanes will have worn down and these longitudinal strips will need to be removed and replaced. As such we estimate that 50% of the deck wearing surface needs to be replaced at year 25 and year 75 and 100% of the surface needs to be replaced at year 50. Three (3) major deck wearing surface repairs are anticipated where traffic will be affected for approximately a two week period each time. The anticipated cost for the removal and replacement of the wearing surface is $200 per square meter resulting in a cost of $80,000 for the 50% deck repair and $160,000 for the complete replacement.

**Open Grid Deck System** – The open grid steel deck system does not require a deck wearing surface, although the serrated wearing surface is very noisy and provides poor slip resistance for wheeled traffic. It is anticipated that the open grid system will last 40 years and as such would need to be replaced twice at a cost of $650,000 for each replacement. Traffic would be affected during the deck replacement for approximately four weeks.

**Half-filled Grid Deck System and Exodermic Deck System** – The half-filled grid deck system and Exodermic deck system do not require a wearing surface as the concrete deck above the top of the steel grid acts as the roadway riding surface. The concrete deck surface will initially be brushed or tined to provide a roughened surface for improved traction. It is anticipated that roughening the deck to restore the surface back to original levels by shallow transverse sawcutting of the concrete surface would be required at year 25 and year 75 with the original concrete surface required to be milled down 40 mm and a new 40 mm thick concrete overlay placed at year 50.
Roughening of the existing concrete deck could be undertaken at night to minimize traffic disruption while the milling and concrete overlay work would affect traffic for at approximately a four week period. Roughening of the deck is relatively inexpensive at approximately $25,000 per occurrence with the concrete overlay is estimated at $200,000.

**FRP Deck System** – The FRP deck system utilizes a polymer concrete wearing surface bonded to the FRP deck panels. In discussion with Owners of bridges with this deck system they anticipate that the polymer overlay will need to be replaced every 10 years. This would result in approximately nine (9) replacement overlays being required over the bridge design life and with a two to three week interruption to traffic during each replacement. The cost of a polymer concrete overlay replacement is estimated at $200,000.

Based on our evaluation of the wearing surface maintenance of each bridge deck system, the concrete to grade decks perform the best with the least amount of major maintenance (major repair every 50 years and minor repairs every 25 years) followed by the steel deck systems (major repair every 25 years) and lastly the FRP deck system which required significant maintenance every 10 years. Between the proposed major maintenance activities the concrete deck may require a few local surface repairs while the Bimagrip surface and polymer concrete surface will require local repairs to cracks and spalls on an ongoing basis. Open grid decks are known to require significant on-going maintenance as the welds holding the deck in place to the stringers frequently break and require re-welding to the supporting stringers.

### 5.4 Bridge Deck System Risks

Another criterion considered for selection of the best deck system for the main span bridge is the risk associated with long term performance and general constructability.

The FRP and SPS deck systems are relatively new designs with a limited number of decks in service which poses an increased risk as the long term performance of these deck systems is unknown. The Exodermic deck system has been in use since the 1980’s and the half-filled grid decks since the 1950’s and both incorporate conventional bridge construction materials. However, to save weight both of these deck systems are proposed to utilize lightweight concrete which adds some risk as this type of concrete is not typically used on Vancouver Island. Both of the concrete filled grid decks systems are considered to have a lower risk than the FRP and SPS systems but a concrete testing program would have to be developed for the lightweight concrete to minimize the concrete performance risks.
The steel orthotropic, open grid steel deck and half-filled grid deck systems have all been in service for more than fifty years and performance is well understood. With the open grid deck system the steel grids are welded to the supporting stringers and this connection has been found to fatigue and break, requiring ongoing weld maintenance. This is an ongoing issue with the open grid deck and is very problematic resulting in poor long term performance. Orthotropic decks systems has proven themselves to be very low risk if the steel deck to longitudinal stiffener welds and other details have designed to account for fatigue. In our opinion the orthotropic deck provides the least amount of long term risk of all of the deck systems considered.

The Exodermic, FRP, SPS and Structal orthotropic deck are all proprietary systems. Use of these systems can be a disadvantage for tendering as the products are mostly sole-sourced with no competitive bids provided by competing suppliers. The FRP and SPS deck systems are relatively new and contractors are typically not familiar with or have experience installing these products. The lightweight surfacing systems such as BimaGrip and the polymer concrete products are specialized products that require specialty Contractors to prepare the substrate and apply the surfacing as per the manufacturer’s specifications. If the products can be applied in the fabricators shop under controlled environments the risks are considered minimal, with risks increasing if the products are applied in the field.

5.5 Bridge Deck System Ranking Evaluation

The proposed bridge deck system options have been evaluated and ranked based on the information summarized in Sections 5.1 to 5.4. These findings have been presented as evaluation matrix in Table 5.4 – Bridge Deck System Ranking Evaluation on the following page. Each deck system was ranked against the four (4) evaluation criteria with a value between 1 and 5, with a ranking of 1 representing a deck system that best meets the criteria and 5 representing a deck system that poorly meets the criteria.

Each of the evaluation criteria were given a weighting which when multiplied by the ranking number and added up to determine the final ranking for the each deck system. The first and second criteria are related to costs (initial deck costs and additional costs due to deck weight) and weighted at 20% and 25% resulting in a total weighting for cost comparisons of 45%. Deck and wearing surface maintenance was weighted at 25% and long term performance risk was given a weighting of 30%. The bridge deck systems with the lowest final ranking numbers provide the best solutions for the Johnson Street Bridge roadway deck.
Based on the previously described weightings the final rankings for the bridge decks have been summarized below:

Orthotropic steel deck – *Structal* proprietary deck Final Ranking: 2.1
Steel grid deck - Half-filled grid deck with concrete Final Ranking: 2.25
FRP deck – ZellComp® proprietary deck Final Ranking: 3.3
SPS deck – Intelligent Engineering proprietary deck Final Ranking: 3.8

The two deck systems with the highest rankings are the *Structal* Orthotropic Deck System and the Half-filled Grid Deck System with Lightweight Concrete.
### Table 5.4: Bridge Deck System Ranking Evaluation

<table>
<thead>
<tr>
<th>Ranking Criteria</th>
<th>Weight</th>
<th>1b Orthotropic</th>
<th>2 Open Grid</th>
<th>3 Half-filled Grid</th>
<th>4 Exodermic™</th>
<th>5 FRP</th>
<th>6 SPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deck Initial Cost</td>
<td>20%</td>
<td>$1.6M</td>
<td>$0.9M</td>
<td>$1.20M</td>
<td>$1.25M</td>
<td>$1.4M</td>
<td>$1.7M</td>
</tr>
<tr>
<td>Deck Weight &amp; Additional Costs</td>
<td>25%</td>
<td>285 kg/m²</td>
<td>245 kg/m²</td>
<td>400 kg/m²</td>
<td>470 kg/m²</td>
<td>220 kg/m²</td>
<td>380 kg/m²</td>
</tr>
<tr>
<td>Relative to FRP Deck Weight</td>
<td></td>
<td>$0.20M</td>
<td>$0.11M</td>
<td>$0.86M</td>
<td>$1.2M</td>
<td>$0</td>
<td>$0.76M</td>
</tr>
<tr>
<td>Deck &amp; Wearing Surface Maint.</td>
<td>25%</td>
<td>Good</td>
<td>Very Poor</td>
<td>Very Good</td>
<td>Very Good</td>
<td>Very Poor</td>
<td>Good</td>
</tr>
<tr>
<td>Risk (Long-term Performance)</td>
<td>30%</td>
<td>Low</td>
<td>Moderate</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
<td>Very High</td>
</tr>
<tr>
<td>100% Weighted Score (Lowest Best Meets Criteria)</td>
<td></td>
<td>2.1 2.6 2.25 2.5 3.3 3.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Final Ranking</td>
<td></td>
<td>1     4     2   3   5   6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
6. RECOMMENDATIONS

Of the deck systems considered, the two types of decks with the best final rating results that warrant further consideration during the preliminary design of the Johnson Street Bridge replacement are the half-filled grid deck with concrete infill and the *Structal* steel orthotropic deck systems.

The half-filled grid system with concrete overfill is a proven deck system that has been used since the 1960's. The structural performance of half-filled grid decks is typically very good, especially with regards to maintenance requirements. The deck requires no wearing surface other than the concrete to grade slab itself and is typically very durable and low maintenance. However, even when lightweight concrete is utilized the half-filled concrete deck system is relatively heavy compared to the other decks at 400 kg/m². (465 kg/m² with conventional concrete) Lightweight concrete has generally performed well on other moveable bridges in North America but as it is not a standard product on Vancouver Island due to the lack of lightweight aggregate, consideration should be given to developing a concrete test program to develop mix designs that provide a durable concrete mix for the bridge deck should this deck system be chosen.

The steel orthotropic deck system is another proven deck system that has been used extensively in the past on moveable and long-span bridges. The structural performance of orthotropic decks is typically found to be very good and the deck system weight of 285 kg/m² is relatively low compared to the other lightweight decks. The deck system has high fabrication and installation costs but utilizing the recommended *Structal* system provides a benefit over custom fabricated orthotropic deck systems. The deck system requires a light surface coating such as BimaGrip which has been found to provide good performance, especially when it is applied in a controlled environment in a fabrication shop. These light coatings typically require only small amounts of maintenance between reapplication periods and the riding surface provides a high traction surface.
7. REFERENCES


Richards, Dan (ZellComp Inc.). “FRP Deck for Movable Bridge.” February 7, 2011. Email.


ZellComp Inc. “August 2010 Installation: Historic Broadway Bridge in Portland, Oregon”. 2010
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Option 1
Proprietary Orthotropic
Orthotropic decks for multiple longitudinal girder bridges

Important technical aspects

- The transverse members form an integral part of the orthotropic deck.

- They are generally spaced at 3-metre centers and in continuous spans over the width of the bridge, as determined by the spacing between the main girders. The transverse members are T-shaped and installed under the deck so that the deck plate acts as the top flange.

- Flexural bending of the deck plate is greatly reduced compared to the bending that occurs in the plate of a conventional orthotropic deck due to the small spacing between the transverse members as well as to the longitudinal Ts, which are supported by the main girders over their entire length.

- The longitudinal Ts and transverse members support the deck plate along both orthogonal axes. This allows for the use of a thinner deck plate, thus reducing the weight and cost of the deck.

- As the new type of deck is significantly lighter than a concrete slab, it is ideal for increasing the capacity of existing bridges and raising payload limitations without having to replace or modify the main girders, piers or abutments.

- To further reduce the weight on the bridge, it is possible to use a thin-coat wearing surface that is much lighter than the regular asphalt surface normally used. This system consists of a primer coat of an aluminum-pigmented polyurethane primer. It serves both as the membrane for the steel surface and as the primer for the thin-coat wearing surface that consists of an aggregate-impregnated polyurethane coating. The thin-coat wearing surface, subjected to accelerated wearing surface tests, demonstrated greater durability as well as a substantially higher friction coefficient over conventional asphalts used on roads and highways.

- The new deck can be manufactured using atmospheric corrosion-resistant steel (also known as weathering steel), thus avoiding the need to paint or apply any other surface coating. When used for architectural reasons or under conditions that are incompatible with weathering steel, the deck can be painted to protect it against corrosion. The top of the deck plate is protected against corrosion by a protective membrane.

- Edge stiffeners reinforce the deck plate along the longitudinal axis of the bridge and are designed to support connectors for fastening "Jersey" type, cast-in-place or precast concrete barriers. For steel or aluminum barriers, posts are fastened directly onto the ends of the transverse members.

- The transverse member spacing was selected to adapt to the majority of approved impact-tested safety barrier systems. For the deck plate, this characteristic offers the best protection against damage caused by vehicle impact.

Information
For further information, contact Dominique Blouin:

Telephone: 418-683-2561 / Toll-free: 1-800-304-2561
Online: www.structalbridges.ws/contactus
Option 2
Open Grid Steel Deck
L. B. Foster’s 5-Inch 4-Way HD Modified is the highest evolution in open grid design. It is engineered to provide the highest level of reliability for the heaviest and most intense loading conditions, even on longer spans.

HD Modified combines the best design features of all other 4-Way designs including diagonal bars, deeper/stiffer cross bars and closely spaced main beams. These features all work together in the HD Modified to provide the top-of-the-line open grid on the market today.

No other open grid can deliver the longitudinal, transverse and torsional stiffness of the HD Modified deck. The high deck stiffness results in improved load and stress distribution throughout the grid network reducing localized stresses.

The grid is available with the 5 3/16" x 5.3# main beam spaced on 3 3/4" centers. Material is either 50 ksi or 50 ksi weathering steel.

### APPLICATION GUIDELINES

- **Decking Weight**: Lighter
- **Decking Cost**: Less expensive
- **Ride Quality**: Better ride
- **Decking Strength**: Stronger
- **Speed of Installation**: Faster installation
- **Durability**: Longer lasting

<table>
<thead>
<tr>
<th>Style / Main Beam Size &amp; Spacing</th>
<th>50 ksi Steel Max Continuous Clear Span HS25 Wheel Load</th>
<th>Approximate** Weight (lbs/SF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 way / 5.3# @ 3.75&quot;</td>
<td>Top: 5.588 Bottom: 8.100 L/800 Deflect: 5.45 ft. 27 ksi Stress: 7.41 ft.</td>
<td>25.8</td>
</tr>
</tbody>
</table>

* Section modulus based on 50% of the diagonal bars active.
** The deck weight psf is based on an uncoated standard panel width of 7'-8", actual weights may vary due to panel widths used, coating weight and deck attachments.

NOTE: The information contained herein has been prepared in accordance with generally accepted engineering principles. However, L.B. Foster Company is not responsible for any errors that may be contained herein. The user of the information provided herein should check the information supplied and make an independent determination as to its applicability to any particular project or application.
Typical Specification

The welded open steel grid bridge flooring shall be 5-Inch 4-Way HD Modified as manufactured by the L.B. Foster Company, 1016 Greentree Road, Pittsburgh, Pennsylvania 15220 – Phone (412) 928-3452 & Fax (412) 928-3514. The deck shall be manufactured from the following steel elements:

<table>
<thead>
<tr>
<th>Main Beam (MB) @ 3.75&quot; c/c</th>
<th>Cross Bar (C/Bar) @ 4&quot; c/c</th>
<th>Diagonal Bar (1 between each main bar)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 3/16&quot; deep special rolled beam x 5.3#/LF</td>
<td>2 1/2&quot; x 1/4&quot; flat bar</td>
<td>1&quot; x 1/4&quot; (minimum) flat bar</td>
</tr>
</tbody>
</table>

Steel Specification

All steel shall be 50 ksi (A709 Gr. 50 / A-572) or 50 ksi weathering (A709 Gr. 50W / A588)

Typical Details: 5-Inch 4-Way HD Modified

All elements shall be serrated on their top surfaces. Serration pattern shall be @ 1" c/c (max.), where possible. The new uncoated deck shall provide a skid resistance number (SN) of 53 @ 40mph-when tested in accordance with ASTM E274.

The deck shall be assembled such that the tops of all elements are in the same plane and notching (other than serration) of the main bar top flange shall not be permitted. One tertiary diagonal bar shall be provided between each grid main beam to provide a diagonal style riding surface. Notching the bottom of the cross bar or substitution of a rectangular patterned grid is not permitted.

The grid shall be welded at all intersections using the manufacturers standard welding process. The grid shall be manufactured and designed to provide the properties indicated in the 5-Inch 4-Way HD Modified Properties Table 5.4-HM.

Finish: Most types of coatings can be provided; common finishes are mill finish (for 50 ksi weathering steel) and hot dipped galvanized for 50 ksi steel — note that distortion from galvanizing will occur, request manufacturer’s tolerances.

WARNING: Uncoated-weathering steel provides the best skid resistant open grid surface. Galvanized or painted coatings can reduce the skid resistance. Vertical and/or horizontal curves on the bridge decking can increase lateral forces on vehicles, further reducing skid resistance efficiency. It is recommended that lane changes be prohibited and appropriate speed limits be strictly enforced to promote safety. Various studies are available upon request.

Telephone: 412.928.3452 • Fax: 412.928.3514 • www.lbfoster.com
Option 3
Half-Filled Grid Deck
## Grid Deck Properties - Design and Specification Data

### Rectangular Half Filled Grid Deck with 2” Overfill

- Cast-in-Place or Precast
- Light Weight
- High Strength to Weight Ratio
- Proven Performance since 1960’s
- Rapid Construction

<table>
<thead>
<tr>
<th>Main Bars</th>
<th>Supplemental Bars</th>
<th>Top Rebar</th>
<th>Positive Moment Region</th>
<th>Negative Moment Region</th>
<th>Approximate Weight (psf)</th>
<th>* Maximum Spans (LRFD 4.6.2.1.8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spacing (in.)</td>
<td>Number of bars evenly spaced between Main Bars</td>
<td>Number of bars spaced between Main Bars</td>
<td>Top of Concrete (compression)</td>
<td>Bottom of Steel (tension)</td>
<td>Total Height (in.)</td>
<td>Steel Only</td>
</tr>
<tr>
<td>One Supplemental Bar</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>0</td>
<td>108.7</td>
<td>11.0</td>
<td>6.4</td>
<td>7.7</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>0</td>
<td>91.7</td>
<td>7.8</td>
<td>4.3</td>
<td>5.1</td>
</tr>
<tr>
<td>8</td>
<td>1</td>
<td>0</td>
<td>81.6</td>
<td>6.0</td>
<td>3.2</td>
<td>3.8</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>0</td>
<td>74.7</td>
<td>5.0</td>
<td>2.5</td>
<td>3.1</td>
</tr>
</tbody>
</table>

| Multiple Supplemental Bars | | | | | |
| 6 | 2 | 0 | 94.0 | 7.7 | 5.7 | 5.5 | 7.188 | 20.6 | 71.3 | 10.0 | 9.3 |
| 8 | 2 | 0 | 82.9 | 6.0 | 4.3 | 4.1 | 7.188 | 17.1 | 68.3 | 9.2 | 8.5 |
| 8 | 3 | 0 | 84.2 | 6.0 | 5.3 | 4.2 | 7.188 | 18.3 | 69.2 | 9.2 | 8.5 |
| 10 | 2 | 0 | 75.5 | 5.0 | 3.4 | 3.3 | 7.188 | 15.0 | 66.5 | 8.6 | 7.4 |
| 10 | 4 | 0 | 76.8 | 4.9 | 5.1 | 3.5 | 7.188 | 17.0 | 68.0 | 8.6 | 7.9 |

| 1 Supplemental Bar & 2 Rebar | | | | | |
| 6 | 1 | 2 | 91.5 | 7.8 | 4.9 | 5.1 | 7.188 | 20.4 | 71.1 | 9.5 | 9.0 |
| 8 | 1 | 2 | 81.2 | 6.1 | 3.7 | 3.8 | 7.188 | 16.9 | 68.2 | 8.8 | 7.9 |
| 10 | 1 | 2 | 74.3 | 5.0 | 2.9 | 3.1 | 7.188 | 14.9 | 66.5 | 5.9 | 5.7 |

| 2 Supplemental Bars & 1 Rebar | | | | | |
| 6 | 2 | 1 | 93.9 | 7.8 | 6.0 | 5.4 | 7.188 | 21.3 | 71.8 | 9.6 | 9.1 |
| 8 | 2 | 1 | 82.7 | 6.0 | 4.5 | 4.1 | 7.188 | 17.6 | 68.7 | 8.8 | 8.3 |
| 10 | 2 | 1 | 75.2 | 5.0 | 3.6 | 3.2 | 7.188 | 15.4 | 66.9 | 7.2 | 6.6 |

**Design Notes:**
- **Main Bars:** 5.188” rolled shape; 5.6 pounds per lineal foot.
- **Cross Bars:** 1/4” x 2” @ 4” spacing.
- **Steel:** ASTM A709 GR 50. **Rebar:** ASTM A615 (Fy=60 ksi).
- **Concrete:** f’c=4000 psi, n=8, (n=24 for sustained dead load). Top 0.5” of concrete is sacrificial. Concrete is not considered in tension regions.
- Total weights shown are with normal weight concrete and exclusive of “haunch” concrete (between top of beams and intermediate flange), additional full depth concrete at connections between panels, and any additional deck overlay. Further weight reduction is possible by using lightweight concrete.

**Cross Bars:** 1/4” x 2” @ 4” spacing.

**Supplemental Bars:** 1/4” x 1” (5/16” x 1” Supplemental Bars are also available).

**Top Rebar:** #3 rebar.

**Concrete:** f’c=4000 psi, n=8, (n=24 for sustained dead load). Top 0.5” of concrete is sacrificial. Concrete is not considered in tension regions.

*Design in accordance with current 2010 AASHTO LRFD Bridge Design Specifications and BGFMA proposed code revisions. Meets deflection criteria of L/800. All punched holes or slots in steel members are deducted when computing section properties. Sectional properties and weights are within 5% (+/-) of an individual fabricator’s calculated values. Consult with fabricators for actual values. Other configurations are available. Contact individual BGFMA fabricators for more information.*
Design Considerations
A Grid Reinforced Concrete Bridge Deck with a monolithic (integral) overfill is significantly stiffer than a comparable flush filled grid. When designing a Grid Reinforced Deck using the orthotropic plate model described in the AASHTO LRFD Bridge Code, this enhanced stiffness is taken into account through the use of plate constants, which vary depending on the presence of an overfill. Those plate constants, for both fully or partially filled grids, are given in AASHTO Article 4.6.2.1.8.

Construction Considerations
An overfilled grid installation allows a contractor to use conventional finishing equipment, and enables the deck to be completed in a single pouring operation. Finishing equipment used on an overfilled grid installation can handle cross-slopes, super-elevations, etc. in a conventional manner, and the equipment is familiar to all contractors. This technique has a very positive impact on installed costs.

Performance
In addition to structural advantages, an integral overfill creates a smooth, non-skid riding surface suitable for any structure and provides protection to the steel grid. This protection assures that the grid, and the depth of concrete within the grid, will be structurally sound when the original overfill needs to be replaced. This scenario is illustrated quite well by the following case study of the Verrazano Narrows Bridge.
Integral Overfill Case Study: The Verrazano Narrows Bridge

The Verrazano Narrows Bridge consists of an upper deck placed into service in 1964, and a lower deck in 1968. A grid reinforced concrete bridge deck was chosen for use in order to reduce dead load on the 7200 long suspension bridge. A 4-1/4”-beam design was specified, and an integral overfill of 1-3/4” was used to achieve an overall deck thickness of six inches. All components of the steel grid were uncoated; therefore, the overfill was the only means of protection afforded the steel grid.

Through the mid 1980s, a minimal amount of patching to the overfill was required. As the amount of patching increased, a decision to investigate overlay options was considered. In 1997, after 30 years of service, approximately 100 deck cores were taken, extending to within 2” of the bottom of the deck. The cores revealed high chloride ion concentrations, but very little corrosion activity. (The ability of a grid to resist chloride has been previously documented. See reference to Angeloff report, listed below.)

At some sections of the deck, all of the concrete was removed and it was noted that the steel grid was in very good condition. Based upon that investigation, it was determined that the grid and concrete within the steel grid were in excellent structural condition, and that only a new overlay was necessary.

In 1999, an area of the lower deck, approximately 50’x 40’, representing two floor beam bays, was used to demonstrate the suitability of an overlay replacement method. Approximately 3/4” of the original integral overfill was removed. The exposed concrete surface was then cleaned, and 1-1/2” of New York State DOT HP (high performance) concrete was placed on the cleaned surface. It is anticipated that the overfill of the entire deck will be replaced in this fashion.

For thirty years the original overfill provided a good riding surface and protected the lower portion of the deck (steel grid and contained concrete), while requiring minimal maintenance. The application of a dense concrete overlay will further serve to protect the integrity of the original steel grid. There is reason to believe that at the end of the useful life of the new overlay, the original deck will still be sound, and the deck would simply require an overlay replacement.

Summary

An integral overfill enhances the structural capacity of a Grid Reinforced Concrete Deck. It provides a high quality ride surface, protects the integrity of the grid and the concrete within the grid, is economical to install and easy to maintain. The cost implications of this scenario through a 60-70 year life of a major structure with extremely high traffic volumes, is significant.

References

“An Evaluation of the Comparative Effects of Chlorides on the Deterioration of Reinforced Concrete Slab and Concrete Filled Grid Bridge Decks” Angeloff, Carl (1977)


NOTE:
The information contained herein has been prepared in accordance with generally accepted engineering principles. However, L. B. Foster Company is not responsible for any errors that may be contained herein. The user of the information provided herein should check the information supplied and make an independent determination as to its applicability to any particular project or application.
Option 4
Exodermic Deck
An Introduction to: Exodermic™ Bridge Decks
An Exodermic™ (or “composite, unfilled steel grid”) deck is comprised of a reinforced concrete slab on top of, and composite with, an unfilled steel grid. This maximizes the use of the compressive strength of concrete and the tensile strength of steel. Horizontal shear transfer is developed through the partial embedment in the concrete of the top portion of the main bars which are punched with ¾” diameter holes.

Assuming 2” cover over rebar, overall thickness of the system using standard components ranges from 6¼” to 9¼” and total deck weights range from 58 to 70 pounds per square foot. Exodermic™ decks using standard components can span over 17’ however larger main bearing bars and/or thicker concrete slabs can be chosen to span considerably further.

The concrete component of an Exodermic™ deck can be precast before the panels are placed on the bridge, or cast-in-place. Where the concrete is cast-in-place, the steel grid component acts as a form, the strength of which permits elimination of the bottom half of a standard reinforced concrete slab.

Exodermic™ decks are made composite with the steel superstructure by welding headed studs to stringers, floor beams, and main girders as appropriate, and embedding these headed studs in full depth concrete. This area is poured at the same time as the reinforced concrete deck when the deck is cast-in-place, or separately when the deck is precast.

Exodermic™ decks require no field welding other than that required for the placement (with an automatic tool) of the headed shear studs.

Why Use An Exodermic™ Bridge Deck?

**LIGHT WEIGHT**

An Exodermic™ deck can weigh up to 50% less than a reinforced concrete® deck that would be specified for the same span. Reducing the dead-load on a structure can often mean increasing the live-load rating. The efficient use of materials in an Exodermic™ deck means the deck can be much lighter without sacrificing strength, stiffness, ride quality, or expected life.

**ACCELERATED CONSTRUCTION**

Precast Exodermic™ decks can be erected during a short, nighttime work window, allowing a bridge to be kept fully open to traffic during the busy daytime hours.

Cast-in-place Exodermic™ decks also permit considerable savings in construction time – the steel grid panels come to the site essentially ready for concrete. The steel grid component of an Exodermic™ deck acts as a pre-cut, pre-formed, stay-in-place form. Panels are quickly placed, and layout of the single mat of rebar is simple and straightforward, without the need for chairs or other aids in most cases. Typical cantilevered overhangs can be formed without temporary supports.

**EASE OF MAINTENANCE**

An Exodermic™ deck is easily maintained with standard materials and techniques, since the top portion of an Exodermic™ deck is essentially the same as the top half of a standard reinforced concrete deck. If desired, any overlay compatible with concrete can be used, including latex modified concrete, polymer concrete, microsilica concrete, or a membrane with asphaltic concrete overlay.

For more information on the Exodermic™ Bridge Deck System:

Phone: 419.257.3561  Web: www.exodermic.com
Exodermic Overview

Exodermic™ Design
How it Works

In Positive Bending

Standard Reinforced Concrete Deck
In a standard reinforced concrete deck, in positive bending, the concrete at the bottom of the deck is considered ‘cracked’ and provides no structural benefit. Thus, the effective depth and (stiffness) of the slab is reduced, and the entire bridge – superstructure and substructure – has to carry the dead load of this ‘cracked’ concrete.

Exodermic™ Deck
In an Exodermic™ deck in positive bending, essentially all of the concrete is in compression and contributes fully to the section. The main bearing bars of the grid handle the tensile forces at the bottom of deck. Because the materials (steel and concrete) in an Exodermic™ deck are used more efficiently than in a reinforced concrete slab, an Exodermic™ design can be substantially lighter without sacrificing stiffness or strength.

In Negative Bending

Standard Reinforced Concrete Deck
In negative bending, a standard reinforced concrete deck handles tensile forces with the top rebar; concrete handles the compressive force at the bottom of the deck.

Exodermic™ Design
Similarly, in an Exodermic™ design, the rebar in the top portion of the deck handles the tensile forces, while the compressive force is borne by the grid main bearing bars and the full depth concrete placed over all stringers and floorbeams. Rebar can be selected to provide significant negative moment capacity for longer continuous spans and sizable overhangs.
Cast-in-Place Exodermic™ Decks

Cast-in-place Exodermic™ decks are simple and straightforward to erect.

Haunches may be formed before placing deck panels on the bridge, using self-adhesive foam strips, galvanized sheet steel or structural angles (connected with straps or welded to the supporting beam), or timber.

Exodermic™ steel grid panels are placed and set to the required elevation using built-in leveling bolts.

Headed studs are welded or bolted through the grid to the superstructure, rebar is placed, and concrete is poured.

In effect, the steel grid panels act as super 'stay-in-place' forms, and little or no additional formwork is required in the field. Rebar layout is straightforward. Bottom rebar (typically #4 bars) sit directly on the main bars. Concrete fills the 'haunch' areas, capturing the headed shear studs at the same time the finished riding surface is poured. The use of ⅜” maximum coarse aggregate and a 'pencil' type vibrator are recommended.

The concrete can be finished with a textured surface for skid resistance, or any overlay compatible with standard reinforced concrete decks.

Precast Exodermic™ Decks

Pre-cast Exodermic™ decks are an excellent choice where the roadway must be returned to active service as soon as possible. Precasting allows rapid deck replacement during a short, nighttime or weekend work window, with roadways fully open to traffic during the day or on Monday morning.

During precasting, blockouts or slotted forms exclude concrete from deck panel areas that will be directly over the top flanges of stringers, girders, or floorbeams.

Haunches are generally formed before placing deck panels on the bridge. Self-adhesive foam strips, galvanized sheet steel or structural angles (connected with straps or welded to the supporting beam), and timber have all been used successfully.

Once positioned, panel elevation is set by built-in leveling bolts; headed shear connectors are welded to the superstructure through blockouts in the precast concrete and this area is filled full depth with rapid setting concrete. The use of ⅜” maximum coarse aggregate is recommended.

It is recommended to apply an overlay after all closure pours are complete. Latex modified concrete, polymer concrete, microsilica concrete, or a membrane and asphaltic concrete may be specified.

Typical transverse connections between panels are double female shear keys or an open transverse joint with bent rebar extending into the opening (see details). Field-placed closure pour concrete should be properly consolidated into the haunch and transverse panel connection with a 'pencil' type vibrator.

Where desirable (such as in areas over supports where negative moments are high), rebar can be spliced between panels by several common methods.
### Design History

Historically, the Exodermic™ deck evolved from traditional concrete-filled grids. The innovation was to move the concrete from within the grid to the top of the grid in order to make more efficient use of the two components. Putting the concrete on top also allowed the use of reinforcing steel in the slab to significantly increase the negative moment capacity of the design, and moved the neutral axis of the section close to the fabrication welds of the grid. A shear connecting mechanism was required between the grid and the slab to make the two composite. This was originally provided by the addition of "tertiary bars" to which were welded short, ½" diameter studs.

### Second Generation Design

In the 2nd generation design described in this publication, the tertiary bars have been eliminated, and their function taken over by the extension of the main bars of the grid 1" into the slab. ¾” diameter holes are punched in the top 1” of the structural tee main bars, to aid in the engagement of the bars with the concrete. Static and fatigue testing of the revised design was conducted at Clarkson University, and is in accordance with ASTM specification D6275-98, "Standard Practice for Laboratory Testing of Bridge Decks." The fatigue test consisted of two million load cycles delivered to a two span continuous panel through two loading shoes simulating a full HS-20 truck axle (with impact). No significant difference in behavior of the panel was observed from start to finish of the test.

### Design Flexibility

The designer has a number of choices to make in choosing an Exodermic™ deck configuration: main bar size and spacing, rebar size and spacing, and concrete thickness. A number of Exodermic™ decks have used a 4½” or 4⅝” concrete component in order to provide a standard 2½” of cover over rebar, and 1” of bottom cover. Achieving desired deck thickness and weight may require reducing the concrete thickness. Exodermic™ decks have been constructed with concrete component thicknesses of 3” to 5”. Service history dates to 1984, when an Exodermic™ deck was used on the longest bridge on the Garden State Parkway (NJ). Lightweight concrete can be specified where weight is particularly critical.

While several structural tees can be used to construct an Exodermic™ grid panel, use of industry standard grid configurations is advised where possible to avoid costs associated with new tooling. The standard types are referred to by the size of structural tee employed as the main bearing bar: WT4x5, WT5x6 or WT6x7. Please check with D.S. Brown for availability of alternate main bar sizes. Section moduli and other properties of standard and non-standard Exodermic™ deck configurations are available from D.S. Brown.

Choice of main bearing bar type is generally determined by desired deck thickness and span. Depending on span, the WT4x5 grid should provide the lightest option, minimizing the amount of full depth concrete over supports and the full depth transverse connection between panels.

### For Further Information

The D.S. Brown Company is an information source for Exodermic™ design and construction details. We can also provide printed and computer-based design aids, suggested specifications, and informational materials to bridge engineers, owners, and contractors. Sample designs to meet project specific requirements are also available upon request.

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### Exodermic Case Studies

The use of cast-in-place and precast Exodermic™ Deck panels for bridge rehabilitation projects can considerably reduce lane closures and motorist frustration. Two examples of projects that embody FHWA’s focus on prefabricated bridge technology are summarized below.

#### Case Study 1 – Mill Creek Bridge, Oregon

Highway 26 on the Warm Springs Reservation is a busy weekend route for tourists and therefore ODOT limited work periods for redecking the structure from midnight Sunday to midnight Thursday. Specification of an Exodermic™ deck allowed intermittent construction and the 9,360 square feet of deck was replaced in four weeks (585 square feet per day). Traditional deck replacement would have taken approximately three to four months with a continuous detour.

#### Case Study 2 – Tappan Zee Bridge, New York

Speed of construction was a critical element in deck selection for this project where the owner (NYSTA) imposed penalties up to $1300 per minute if all seven lanes were not opened to traffic by 6 a.m. every day. Working within a 10 hour overnight work window (7 hr for closure of 3 lanes), the contractor was able to achieve deck replacement rates of 3000 to 3400 square feet per night using two crews.
### Assumptions and Notes:

- WT Shape main bars are ASTM A992 ($f_y = 50$ ksi). Plate and flat bars are ASTM A709 Grade 36 or Grade 50.
- Rebar is ASTM A615 ($f_y = 60$ ksi) ($f_t = 20$ ksi).
- 4000 psi concrete, $n = 8$, ($n = 24$ for sustained dead load). Top 0.5" of concrete is sacrificial. Concrete not considered in tension regions.
- Spans are continuous from centerline support to centerline support, with 7" flange width assumed, and incorporate a continuity factor = 0.8 for DL & LL moment.
- Meets deflection criteria of $L/800$.
- Total weights shown are with normal concrete and exclusive of “haunch” concrete (between top of beams and top of distribution bars), additional full depth concrete at connections between panels, and any additional deck overlay. Further weight reduction is possible by using lightweight concrete.
- Cover over rebar (2") meets AASHTO requirements. More or less cover is possible to meet site requirements.
- For other deck configurations, or for other information, please contact The D.S. Brown Company.

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### MAXIMUM SPANS (ft.)

<table>
<thead>
<tr>
<th>Deck Properties &amp; Spans</th>
<th>Main Bars Transverse</th>
<th>Main Bars Parallel</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cast-in-Place</td>
<td>Precast</td>
</tr>
<tr>
<td><strong>Cast-in-Place</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Precast</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>LRFD</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table Contents:****

- **Main Bar Spacing (in.)**
- **Top Rebar (in.)**
- **Concrete Thickness (in.)**
- **Deck Thickness (in.)**
- **Weight of Grid with Pans (psf)**
- **Total Weight (psf)**

**Table Data:**

1. **Shallow WT4x5, 2" cover over rebar**
   - 12 #4 @ 4" 3 7/8 6.2 9.7 68.1
   - 12 #5 @ 4" 4 6.3 9.7 60.5
   - 12 #6 @ 4" 4 1/8 6.4 9.7 62.9
   - 10 #5 @ 5" 4 6.3 10.7 61.0
   - 8 #4 @ 4" 3 7/8 6.2 12.2 60.5
   - 8 #5 @ 4" 4 6.3 12.2 62.9
   - 8 #6 @ 4" 4 1/8 6.4 12.2 65.3

2. **Standard WT4x5, 2" cover over rebar**
   - 12 #4 @ 4" 4 6.9 9.0 59.1
   - 12 #5 @ 4" 4 1/8 7.1 9.0 61.4
   - 12 #6 @ 4" 4 1/8 7.2 9.0 63.9
   - 10 #5 @ 5" 4 1/8 7.1 10.0 61.9
   - 10 #6 @ 5" 4 1/8 7.2 10.0 64.2
   - 8 #5 @ 4" 4 1/8 7.1 11.5 63.8
   - 8 #6 @ 4" 4 1/8 7.2 11.5 66.8

3. **Standard WT5x6, 2" cover over rebar**
   - 12 #4 @ 4" 4 1/8 8.1 10.9 63.3
   - 12 #5 @ 4" 4 1/8 8.2 10.9 65.7
   - 10 #5 @ 5" 4 1/8 8.1 11.2 64.0
   - 10 #6 @ 5" 4 1/8 8.2 11.2 66.3
   - 8 #6 @ 4" 4 1/8 8.2 13.9 68.6

4. **Standard WT6x7, 2" cover over rebar**
   - 12 #4 @ 4" 4 1/8 9.1 11.9 64.3
   - 12 #5 @ 4" 4 1/8 9.2 11.9 66.7
   - 10 #5 @ 5" 4 1/8 9.1 13.3 65.2
   - 10 #6 @ 5" 4 1/8 9.2 13.3 67.5
   - 8 #6 @ 4" 4 1/8 9.2 15.4 70.1

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**The information provided herein was prepared with reference to generally accepted engineering practices. It is the responsibility of the user of this information to independently verify such information and determine its applicability to any particular project or application. The D.S. Brown Company assumes no liability for use of any information contained herein. While Exodermic™ design is covered by US and Canadian patents (US: 5,903,242; 5,904,378; and 7,197,856) (Canadian: 2,197,554; 2,239,727; and 2,448,170) its availability from multiple, independent, licensed suppliers allows it to be considered ‘generic’ in most jurisdictions.**
**Typical Details**

<table>
<thead>
<tr>
<th>Grid with Pans</th>
<th>HS20</th>
<th>HS25</th>
<th>HS20</th>
<th>HS25</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight (psf)</td>
<td>58.1</td>
<td>4.9</td>
<td>58.1</td>
<td>4.9</td>
</tr>
<tr>
<td>Top Rebar</td>
<td>3 7/8</td>
<td>6.2</td>
<td>3 7/8</td>
<td>6.2</td>
</tr>
<tr>
<td>Concrete</td>
<td>6.4</td>
<td>8.4</td>
<td>6.4</td>
<td>8.4</td>
</tr>
<tr>
<td>Deck Thickness</td>
<td>4.1</td>
<td>5.4</td>
<td>4.1</td>
<td>5.4</td>
</tr>
<tr>
<td>Weight of Grid</td>
<td>58.1</td>
<td>4.9</td>
<td>58.1</td>
<td>4.9</td>
</tr>
</tbody>
</table>

**Main Bar Spacing**

- **Top Rebar**
  - 12 #4 @ 4"
  - 12 #5 @ 4"
  - 12 #6 @ 4"
  - 10 #5 @ 5"
  - 10 #6 @ 5"
  - 8 #4 @ 4"
  - 8 #5 @ 4"
  - 12 #5 @ 4"
  - 12 #6 @ 4"
  - 10 #5 @ 5"
  - 10 #6 @ 5"

**Concrete Thickness**

- 4 1/4" in. for HS20 and HS25.

**Total Weight (psf)**

- 58.1 for HS20.
- 4.9 for HS25.

**Assumptions and Notes**

- WT Shape main bars are ASTM A992 (f_y = 50 ksi). Plate and flat bars are ASTM A709 Grade 36 or Grade 50.
- Rebar is ASTM A615 (f_y = 60 ksi) (Ft = 20 ksi).
- 4000 psi concrete, n = 8, (n = 24 for sustained dead load). Top 0.5" of concrete is sacrificial. Concrete not considered in tension regions.
- Spans are continuous from centerline support to centerline support, with 7" flange width assumed, and incorporate a continuity factor = 0.8 for DL & LL moment.
- Meets deflection criteria of L/800.
- Total weights shown are with normal concrete and exclusive of "haunch" concrete (between top of beams and top of distribution bars), additional full depth concrete at connections between panels, and any additional deck overlay. Further weight reduction is possible by using lightweight concrete.
- Cover over rebar (2") meets AASHTO requirements. More or less cover is possible to meet site requirements.
- For other deck configurations, or for other information, please contact The D.S. Brown Company.

**Plan View**

- Precast panels shown (cast-in-place similar).

**Section A-A**

**Cast-in-Place Details**

- All concrete cast-in-place.
- Sheet metal bulhead.
- Shear stud.
- Existing stringer.

**Precast Details**

- Precast concrete.
- Field placed concrete.
- Adhesive backed film.

**Shear Stud**

- Existing stringer.
- Adhesive backed film.

**Field Plugs or Tape Fabrication**

- Holes in main bars before placing concrete.
- Holes in main bars before placing concrete.

**Section C-C**

- 20 gauge galvanized sheet metal - field placed.
- 8" mix.

**Section C-C**

- Field placed concrete - 1" min.
- Field placed concrete - 1" min.
- 20 gauge galvanized sheet metal - field placed.
- 8" mix.

**Exodermic**

- Design is covered by US and Canadian patents (US: 5,509,243; 5,664,378; 5,952,691; 6,129,883; 6,364,003; 6,564,136; 6,646,335; 7,385,808; 7,647,332) and is available from multiple, independent, licensed suppliers. It is covered by a broad range of international patents.

**Availability**

- Availability from multiple, independent, licensed suppliers allows it to be considered 'generic' in most jurisdictions.
Option 5
FRP Deck
ZellComp™ Decking System

Fiber-Reinforced Composite
High-Load Structural Decking System

Tangier Island, Virginia

November 2006 – First commercial installation of ZellComp™ Decking System (a patented prefabricated decking system manufactured from FRP composites)
Introduction

ZellComp, Inc. (the “Company”), a Delaware corporation, is a North Carolina based woman-owned small business founded in 2002. ZellComp’s primary focus to date has been on its patented composite structural decking system. Following over four years of development and testing, the high-load ZellComp decking system (“ZellComp™ Decking System”) (Patent No. 6,912,821) is now being commercialized. ZellComp’s first bridge deck was successfully installed in Virginia in November 2006, and ZellComp has bridge deck installations planned in at least three other states, all currently scheduled to be completed in 2007 or early 2008.

In addition to designing and marketing its decking system for highway bridging, ZellComp is actively exploring programs for utilization of its product in parking garages, offshore drilling platforms, Army temporary bridging needs, Navy vessels, and other military applications. ZellComp has participated in the Navy Small Business Technology Transfer (STTR) Program (developing low-shrink, fire-retardant epoxy resin formulations for use in large composite structures) and has recently submitted a proposal to the U.S. Army regarding a multipurpose bridge decking system.

The ZellComp Decking System

The ZellComp Decking System, made from fiber-reinforced composite materials, is a two-part design. The system utilizes mechanical fasteners and is an “open” system unlike any other on the market. The proprietary decking system offers onsite flexibility, and the bottom section can be manufactured in a variety of depths.

ZellComp’s prefabricated composite deck is lightweight and corrosion resistant and offers superior strength. The system is very low maintenance and offers a long life cycle. The proprietary two-part system and ability to be manufactured in several depths make it readily adaptable to a number of uses. A key feature is that the system utilizes mechanical fasteners. Most composite decking systems are “glued” together onsite. The mixing and
application of these adhesives are hazardous and impose moisture and temperature restrictions.

The ZellComp Decking System can be manufactured in a variety of depths. Based on our tests and installations to date, for highway bridge decks, we currently recommend the following maximum stringer spacing for 3 different depths of the ZellComp Decking System:

- 5-inch system – 4.5 feet
- 7-inch system – 6.5 feet
- 9-inch system – 8.5 feet

See Figure 1, a cross-sectional drawing for the 5-inch profile. The other depths utilize the same material and geometry design as the 5-inch, with additional height to the bottom section.

![Figure 1: Cross Sectional Drawing for the 5 inch profile system.](image)

ZellComp’s deck is manufactured via the pultrusion process by Creative Pultrusions, a leading manufacturer in the fiber reinforced composites industry.

**Test Results**

This decking system has been tested at over 8 million cycles of American Association of State Highway and Transportation Officials (AASHTO) loading and subjected to 7 “strength to failure loadings” at four major labs over the past two years. The test results, as summarized below, have been extremely positive and reflect the superior strength of the
Extensive testing has been performed on three sizes – the 5-, 7-, and 9-inch systems. The 5 and 7 inch systems are in commercial production and the 9-inch system (and other sizes) can be quickly manufactured as soon as an order is placed and the production mold is built.

5 inch Deck

The 5-inch ZellComp deck was tested in the Florida DOT lab in Tallahassee, Florida during 2006. The test set up, designed by the Florida DOT and the University of Central Florida, follows the same structural set up as the bridge structure that will be replaced. The beams were spaced at 4 feet (on center) for a 2 span test. The test was done for fatigue and static loading conditions. The fatigue was done with dual loading to simulate the largest truck loads possible on the bridge. The load pads were spaced at 4 feet apart and loaded to 18 kips per pad (or 36 kips total) for 2,000,000 cycles. After the fatigue loading, the deck was loaded in a static test up to 90 kips on one load pad in one span before failure.

This fatigue loading was repeated at the Florida DOT lab with different boundary conditions for another 2 million cycles, and no failure occurred in the composite deck or the wear surface material until the loads exceeded the truck requirements for greater than a factor of safety of at least 3 in all tests. These are extremely favorable test results, and the ZellComp Decking System has been approved by the Florida DOT for installation. The 5-inch deck was also successfully tested at Virginia Tech during 2006 in advance of the Tangier Island installation. A 5-inch deck is also currently scheduled to be installed in Vermont.
7-inch Deck

In advance of an upcoming installation in Indiana, the 7-inch ZellComp deck was tested in a static test at Purdue University on June 8, 2007. This test was again set up to duplicate the bridge structure that will be replaced. The bridge required a 2% slope in the middle of the bridge, i.e. a crown. As shown in the following picture, the test at Purdue was set up with the 2% crown and the support beams spaced at 6’ 3” on center. The static test was set up with a dual loading pad system, but for this test the load pads were spaced at 6 feet, which is the standard for a single truck on a bridge. The ZellComp deck was tested to 150 kips (75 kips per load pad), and there was no failure in the composite deck system or the crown designed in the deck. Purdue intended to test to failure, but the test reached the limits of the load actuator before failure was reached. Again, these were extremely positive test results, and the deck has been approved for installation in the state of Indiana.

9-inch Deck

The 9-inch ZellComp Deck has been tested extensively, but not in production widths. The effective width of the 9 inch test specimens was 18 inches and 2 webs. The test shown in the picture below took place at North Carolina State University and was done in static loading (one load pad) in 3-Point Bending. The test specimen was supported at 8 feet clear spacing and failed at 100 kips. Comparing these results to the tests of the commercially pultruded 5- and 7-inch systems, ZellComp believes the prototype test results from its 9-inch system should be equaled or improved upon by the commercially pultruded product.
Tangier Island Installation

Attach Bottom Sections

The following pictures show the installation of the bottom sections on Tangier Island, Virginia.
Connect Top Sections

Mechanical fasteners are used at the site of installation to attach the top section to the bottom section and to join adjacent bottom sections. Fasteners are drilled through the top sheet and into the flanges of the T-Section in the bottom sections. The average number of fasteners is 3 to 4 per square foot.

Installation of Top Sections completed – Tangier Island, Virginia

Representatives from the Federal Highway Administration and the Virginia DOT visited the Tangier Island construction site during installation of the ZellComp Decking System
A Composite Deck that is Prefabricated, Lightweight and Corrosion Resistant

Advantages to Prefabricated Decks

- On-site construction time is reduced (less time in traffic, increased safety, minimized environmental impact).
- The difficulty of building bridges on more challenging sites is reduced.
- Offsite manufacturing lends itself to improved quality controls and more consistent final product.
- Life cycle costs are lowered due to better quality and reduced construction time (which reduces indirect costs caused by traffic delays).

The vast majority of prefabricated bridge projects to date involve either composite materials or pre-stressed concrete. Why use composites? Why does ZellComp offer the best solution?

ZellComp Decks are Lightweight and Corrosion Resistant

The unique two-part “open” system makes it:

- **Less expensive** to manufacture.
- Even more **lightweight** than other composite decks, (a plus on the construction site).
- **Easier to inspect and repair** onsite (the top panel can be removed if necessary).
- More readily **adaptable** to a variety of bridge types and
  Functional with shear studs – a major advantage over other FRP decks.

Additional Advantages:

- ZellComp’s Decking System **utilizes mechanical fasteners**.
- This means **no structural bonding onsite**. (Most composite systems are “glued” together onsite. The mixing and application of these adhesives are hazardous and impose moisture and temperature restrictions.)
- Potential to add utilities, lighting, and security devices with the two-part system.
ZellComp’s Commitment

ZellComp stands behind its product, working hand in hand with transportation officials, contractors, and engineering firms and offering detailed installation instructions as well as onsite installation advice and technical assistance by Dan Richards. ZellComp will be there for each step of the installation process.

ZellComp Management

Dr. Richards has over 25 years’ experience in composites design and engineering analysis, including finite element analysis, and is well known in the composites community, having authored and participated in numerous papers and/or presentations regarding composite bridge decks. With undergraduate degrees in math and engineering, a M.E. in Civil Engineering from Mississippi State, and a Ph.D. in Mechanical Engineering from North Carolina State University, Dr. Richards has the unique combination of excellent academic and research credentials in the composites arena (for example, his 1995 dissertation is entitled *Woven Hybrid Fiber-Reinforced/MultiPhase-Matrix Composites for Low Thermal Expansion Applications*, with a section focusing on the application of these materials to highway bridges), as well as many years of practical experience in the composites industry. In his work experience, he has specialized in the composite bridge deck and aerospace markets, having worked with E-Systems, Inc., Lockheed Martin, LTV Aero-Products, and Martin Marietta Composites, among others.

While at Martin Marietta Composites, in addition to participating in making changes to the initial bridge deck design, running the testing program, and participating in the selection of the manufacturer, Dr. Richards also provided onsite management and oversight for the installation of approximately 10 composite bridge decks. During this process, Dr. Richards gained the respect of DOT representatives, bridge owners, and contractors, by being onsite, working with the construction crews, and ensuring that onsite issues were addressed in a timely, responsive manner.

Having been involved in composite deck installations across the United States, Dr. Richards has insights into problems that can arise on a construction site when joints must be bonded in a field environment. Moisture, temperature, and the mixing of adhesives create difficult situations. Avoiding these difficulties is a major reason ZellComp’s unique system is superior to systems relying on bonded joints. Other key advantages are the high factors of safety offered by the ZellComp Decking System and the ability to easily install, inspect, and repair the ZellComp Decking System onsite.

Meg Goodman Richards, Chief Operating Officer, Chairman of the Board, and majority owner of ZellComp, provides business and financial planning and communications skills and expertise to ZellComp. With degrees from Millsaps College and Southern Methodist University, Ms. Richards has been a practicing attorney for 22 years, has an accounting background, and is the co-author of two design and planning books for Meredith Books (The Home Depot brand). She has excellent academic credentials and business experience, having worked in large law firm and corporate settings. She has over 20 years’ experience in business transactions and has worked as a team leader on multi-national projects and
transactions, many of which included manufacturing, distribution, and quality control components.

**Sean Walsh**, currently working with ZellComp on a consulting basis, has extensive international experience in FRP composite materials engineering and processing and brings knowledge of material behavior that is necessary to succeed in a material-substitution effort, such as converting concrete and steel structures to FRP composites. Prior to joining ZellComp, Mr. Walsh had a successful 18-year career with Reichhold Chemicals, where his accomplishments included developing a patented design and manufacturing process for FRP composite rebar that does not corrode like steel, yet is cost-competitive. Mr. Walsh has a B.S. in Chemical Engineering from Virginia Tech and work towards a Master of Mechanical Engineering, North Carolina State University.

**Barbara E. Bumgarner** serves as Director of Operations for ZellComp, providing operations and administrative assistance. Ms. Bumgarner has a B.S. from Meredith College in Raleigh, North Carolina.

**Board of Advisors**

ZellComp is extremely fortunate to have the following three highly qualified consultants serving, by invitation, as members of its Board of Advisors.

**Karen C. Appleby**, Wilmette, Illinois: Ms. Appleby is a senior financial professional with over 20 years of experience (including 13 at Amoco Corporation) in financial forecasting, strategic planning, cost management systems, and other key financial functions. She is currently a consultant with DLC, Inc. in Chicago, Illinois.

**William F. Goodman, Jr.**, Jackson, Mississippi: Mr. Goodman has been a practicing attorney with Watkins & Eager in Jackson, Mississippi, for over 50 years. In addition to having received numerous awards and recognitions, Mr. Goodman is one of only three Mississippi lawyers who are members of both the American College of Trial Lawyers and the American Academy of Appellate Lawyers. Mr. Goodman practices in the following areas: Appellate Practice, Banking and Consumer Finance, Class Action and other Complex Litigation, Commercial and Business Litigation, and Oil and Gas. Mr. Goodman also has 18 years experience as a director and executive committee member of one of Mississippi’s major financial institutions.

**Eric Klang, Ph.D.**, Raleigh, North Carolina: Dr. Klang is Associate Professor and Director of Undergraduate Programs, Department of Mechanical & Aerospace Engineering, at North Carolina State University in Raleigh, North Carolina. Dr. Klang has degrees from the University of Missouri and Virginia Polytechnic Institute and did post doctoral work at the Delft University of Technology in The Netherlands and at the University of Illinois. Dr. Klang has been teaching at North Carolina State for almost 20 years, with a focus on composite materials.
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Production run of ZellComp Decking System at Creative Pultrusions

© 2007 by ZellComp, Inc.
With over two dozen installations in the U.S. and abroad, Martin Marietta Composites has faced a wide variety of applications. Composite materials have significant advantages over conventional materials (steel, wood and concrete) in those cases where light weight, corrosion resistance and rapid installation are important. As such, DuraSpan finds great applications in historic bridges, movable bridges and urban environments. In many cases, FRP decks are the only means of preserving a historic or movable bridge while updating it to modern standards. DuraSpan can reduce dead load on the structure, possibly increasing its live load capacity. Like steel grating, DuraSpan has low weight and can be installed in modules. However, DuraSpan is a solid surface, corrosion resistant deck that offers improved skid resistance and is capable of developing composite action with the bridge’s longitudinal beams.

Facing increasing pressure from the public to keep roads and bridges operational, bridge owners are seeking innovative materials and methods of construction. DuraSpan offers an excellent solution, particularly for time-critical, urban projects. It can often be installed in less time than conventional materials, reducing overall construction time and minimizing public impact.

Introducing

What Are the Benefits of DuraSpan®?

Bridge owners and engineers have discovered the advantages DuraSpan® decks offer over bridge decks made of conventional materials. When compared to typically used materials, these FRP (fiber – reinforced polymer) bridge decks are:

- **Lower weight** — one-fifth the weight of a comparable concrete deck.
- **Resistant to corrosion and freeze/thaw cycles**, resulting in longer life expectancy and lower maintenance costs.

**Continuous fiber reinforcement** in the DuraSpan deck homogenizes the stress distribution, significantly reducing the amount of shrinkage and deflection. These decks are made from a 90% matrix of low modulus polyester resin, giving them outstanding fatigue strength and durability. The interlaminar adhesives used are rigid, making it nearly impossible to peel or delaminate. The polymer encapsulated reinforcement ensures that the decks resist sudden applications of high stress.

**What Are the Benefits of DuraSpan®?**

<table>
<thead>
<tr>
<th>Depth</th>
<th>Weight</th>
<th>Typical Allowable Beam Spacing</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.00” (127mm)</td>
<td>13 p.s.f. (.62 kN/m²)</td>
<td>5’-0” (1.52m)</td>
</tr>
<tr>
<td>7.66” (195mm)</td>
<td>19 p.s.f. (.91 kN/m²)</td>
<td>10’-0” (3.05m)</td>
</tr>
</tbody>
</table>

Both decks support AASHTO HS25 live loadings (plus impact). Extensive laboratory and field load tests indicate that the ultimate capacities of both decks far exceed requirements.

**Which Bridges Are Ideal for FRP?**

With over two dozen installations in the U.S. and abroad, Martin Marietta Composites has faced a wide variety of applications. Composite materials have significant advantages over conventional materials (steel, wood and concrete) in those cases where light weight, corrosion resistance and rapid installation are important. As such, DuraSpan finds great applications in historic bridges, movable bridges and urban environments.

In many cases, FRP decks are the only means of preserving a historic or movable bridge while updating it to modern standards. DuraSpan can reduce dead load on the structure, possibly increasing its live load capacity. Like steel grating, DuraSpan has low weight and can be installed in modules. However, DuraSpan is a solid surface, corrosion resistant deck that offers improved skid resistance and is capable of developing composite action with the bridge’s longitudinal beams.

Facing increasing pressure from the public to keep roads and bridges operational, bridge owners are seeking innovative materials and methods of construction. DuraSpan offers an excellent solution, particularly for time-critical, urban projects. It can often be installed in less time than conventional materials, reducing overall construction time and minimizing public impact.
FRP composite material is a combination of a polymer matrix (resin, fillers and additives) and a reinforcing agent (glass or carbon fabrics). These constituent elements retain their identities — that is, they do not dissolve or merge completely into one another — yet function like a single element.

What Are FRP Composites?

FRP composites are anisotropic — meaning that the mechanical properties vary with the volume and orientation of the fiber reinforcement. Just as reinforcing steel can be placed in concrete for specific loads, the fiber components of composites can be oriented to meet specific design loads and performance requirements.

Design of FRP structures is typically driven by deflection requirements. With polymer composites in general, use of innovative geometry and optimal fiber orientations can enhance the stiffness. Martin Marietta Composites utilizes its patented deck tube design and fiber lay-ups to achieve optimal stiffness and cost effectiveness. Our well-balanced, quasi-isotropic fabrics yield a highly durable product.

Using a rule of thumb from the aerospace industry, Martin Marietta Composites typically limits design strains to 20% of ultimate capacity. Conservative deflection criteria often drive the design strains even lower than this 20% criterion. The end result is a product that possesses an extremely high safety factor for strength and sees negligible effects from fatigue and creep.

What Are its Structural Characteristics?

DuraSpan products are manufactured through a strategic alliance with Creative Pultrusions, Inc., a world leader in structural composites. Martin Marietta Composites chose pultrusion as its manufacturing process because of its proven 30-year history. Pultrusion’s automation and quality control make it the most cost-effective process in the business today.

The pultrusion process begins when continuous fibers and stitched engineered fabrics are drawn from creels and formed to the desired shape via a series of complex forming tools. The fabrics are then drawn through liquid polymer resin and a heated die at a specific speed and temperature to form the solid composite tube. A computerized translating saw then cuts the cured tubes to the desired lengths.

Individual pultruded tubes are sent to a fabrication facility, where they are assembled into panels using adhesive. Workers perform secondary processes such as hole cutting and sealing, installation of edge closeouts and surface finishing. The prefabricated panels are finally shipped to the job site for installation. The panel length equals the bridge deck width or staging width. Panel width typically equals 8’ - 10’ due to shipping constraints.

How is it Made?

MD 24 over Deer Creek
Harford County, Maryland
- Length: 125.21 feet
- Width: 31.5 feet
- Area: 3844 square feet
- Year Installed: 2001

This historic bridge demonstrates the feasibility of staged construction with Martin Marietta Composites’ FRP decks. This bridge has 4'-1" longitudinal stringer spacing, 24'-6" transverse floorbeam spacing and a severe skew of 146 degrees. The deck was overlaid with asphalt.

Monitoring and load testing was conducted by the University of Maryland.
DuraSpan decks have been installed on steel, concrete, timber and FRP girders. The majority of DuraSpan decks achieve composite bending action with the girders via conventional shear studs/stirrups and grouted deck cavities. These connections have a proven history with broad acceptance by bridge engineers and contractors. In addition, all work is performed from above. These deck-to-girder connections have endured rigorous static and fatigue tests in both horizontal shear and transverse bending.

Depending on site conditions, other methods of attachment are available, including mechanical fasteners. However, as with most concrete decks, variable haunches (build-ups) are usually required to adjust for cross-slopes on the roadway, camber in the beams or variations in the top of beam elevations. As such, the shear stud/stirrup connection described above is most common.

**Concrete Girders**

Concrete girders utilize conventional shear stirrups to achieve composite bending action with FRP decks.

**Steel Girders**

Steel beams utilize conventional shear studs to achieve composite bending action with beams.
Details

Railing Details

A variety of railings have been utilized with DuraSpan decks. Owners may choose from their own list of pre-approved concrete, steel, or timber designs. Martin Marietta Composites can accommodate many railing configurations.

A concrete barrier or curb can be connected to DuraSpan decks by embedding reinforcing steel into the deck’s grouted cavities. If steel guardrails are desired, the base plates for the posts can be bolted directly to the deck, or anchor bolts can be embedded into a closed cavity in the deck and filled with non-shrink grout. Steel railings may also cantilever from the bridge’s exterior beams.

Schuyler Heim Lift Bridge

Long Beach, California

- Length: 45 feet
- Width: 35 feet
- Area: 1575 square feet
- Year Installed: 2003

Martin Marietta Composites was selected for this project over four international firms to design FRP test panels. This bridge has a custom 5-inch thick deck and is arranged in 8 panels measuring 6' by 36'. It has 4' longitudinal stringer spacing and 24' transverse floorbeam spacing. 3/4" diameter threaded shear studs were used for the deck-to-stringer connections. The overlay is 3/8" polymer concrete. Adjacent to Long Beach’s port, an extensive testing program is planned to monitor this heavily traveled bridge.

Abutments and Expansion Joints

Like railings and overlays, abutment and expansion joint designs are chosen by the engineer and owner to best suit the project requirements. Integral and semi-integral abutments are preferable and can be integrated with the FRP deck via U-shaped reinforcing bars. Where expansion allowance is required, compressible foam joints have performed quite well.
Testing and

Testing

Martin Marietta Composites’ FRP bridge decks have been thoroughly tested in both laboratory and field settings. Labs across the United States have rigorously tested the static and fatigue performance of the panel and its connections. Static tests typically indicate an extremely high factor of safety for strength, while fatigue tests show little to no degradation after millions of load cycles. Field load tests commonly verify in-place performance and validate the initial design assumptions. From coupon tests through full-scale multi-beam assemblies, results consistently reflect DuraSpan’s high strength, durability and its tendency to meet or exceed project requirements.

Broadway Bridge
Portland, Oregon
- Length: 258.35 feet
- Width: 46.33 feet
- Area: 11970 square feet
- Year Installed: 2004

The Broadway Bridge over the Willamette River is in the heart of the Portland harbor and is a vital structure to the surrounding areas. The historic bridge carries four lanes of traffic with an average daily volume of 30,000 vehicles. Originally constructed in 1913, the bridge is the largest of only three Rall bascule bridges remaining in the United States. According to the bridge’s owner, the Broadway Bridge is the seventh longest bascule bridge in the world. Due to safety and maintenance issues, the worn steel grid deck on the bascule spans was replaced with the DuraSpan 500 FRP deck as a part of an overall $26.2 million rehabilitation project. A solid-surface, lightweight deck that could be rapidly installed made DuraSpan the preferred decking material. The Broadway Bridge is one of the largest and most frequently traveled FRP vehicular bridge decks in the world.

DuraSpan transverse bending test — North Carolina State University
Two million cycle fatigue and static test — University of California at San Diego
Effective width/composite action test — University of Pittsburgh
DuraSpan flexural response and damage tolerance — Lehigh University
Field load testing — Union County, North Carolina
Field load testing — Greene County, Ohio
Installation

DuraSpan’s light weight and design flexibility allow panels to be delivered to the jobsite in large, pre-fabricated modules. Once they arrive, the panels are ready to be installed by maintenance forces or licensed contractors. Martin Marietta Composites typically works closely with construction crews, providing detailed installation manuals to help transition the installation team to this new material.

The installation process:
• Apply adhesive to panel’s tongue and groove field joints.
• Set panel on beam haunches with crane or forklift.
• Jack panels together with light duty jacks.
• Once several panels have been installed and bond lines have cured, workers install a field splice strip over each field joint.

After FRP deck installation is complete, shear connections are attached to beams and certain deck cavities are filled with grout. Finally, the overlay is placed.

DuraSpan’s pre-fabricated design speeds up construction and decreases its impact on the traveling public.

Chief Joseph Dam Bridge
Douglas County, Washington
- Length: 309.6 feet
- Width: 32 feet
- Area: 9907 square feet
- Year Installed: 2003

The Chief Joseph Dam Bridge utilizes glulam beams in its approach spans and a historic timber truss in its main span. A new FRP deck was installed in late 2003 and was Martin Marietta Composites’ first bridge to utilize timber beams. DuraSpan allowed preservation of this historic truss, of which only a few of its type still exist. The FRP deck also widened the bridge by six feet to accommodate modern traffic lanes. The DuraSpan deck was pigmented to match the existing timber truss and the deck was covered with an asphalt overlay.

Overlay

A variety of overlays have been utilized on DuraSpan bridge decks. Owners select these overlays based upon their project’s requirements. Previous selections include polymer concrete, conventional asphalt, polymer-modified asphalt and micro silica-modified concrete. On weight-critical structures (like movable and historic bridges), owners often select polymer concrete for its thin lift capabilities.
Martin Marietta Composites is a subsidiary of Martin Marietta Materials, Incorporated (NYSE:MLM), the nation’s second largest producer of construction aggregates. Development of the DuraSpan deck system began in late 1992 at the Lockheed Martin Missile and Space Division’s Palo Alto Research and Development Laboratory, where composite technology was applied to aerospace and transportation industries.

In 1995, Martin Marietta Materials acquired the technology and established Martin Marietta Composites. Headquartered in Raleigh, North Carolina, Martin Marietta Composites develops and markets composite products to the construction, infrastructure and transportation industries.

At Martin Marietta Composites, we understand introducing a new material requires support and teamwork. We are committed to providing support and expertise to assist our customers’ transition from traditional materials to composites. Our services include finite element modeling (where needed), a technical staff with both FRP and bridge expertise, extensive FRP resources, and on-site field personnel to assist during installation. Numerous DOTs, engineering consulting firms and contractors substantiate Martin Marietta Composites’ reputation for high quality products and services.

**Martin Marietta Composites**

For more information, please contact us at:

**Martin Marietta Composites**
Raleigh, North Carolina
Toll free: 1-866-864-6548
www.martinmariettacomposites.com

*It’s not just what we make, it’s what we make possible®*
Option 6
SPS Deck
SPS Bridge Decks

a better way to build
SPS technology

SPS is a composite material comprising two metal plates bonded with a polyurethane elastomer core. SPS delivers a high strength to weight ratio making it an excellent alternative to both reinforced concrete and stiffened steel.

SPS technology was developed by Intelligent Engineering (IE) and used in its first commercial project in 1999. Over 200 projects have been completed in ships, bridges, buildings, and stadia.

contents

- SPS Bridge Decks
- SPS Overlay for Bridges
- Development & Testing
- Details
- Production
- Modification & Repair
- Global Network Support
- Typical Projects
bridge decks for the 21st century

- 70% lighter than concrete decks
- Erect 600m² of deck per day
- Simple erection, factory finished quality
- Avoid cast-in-place curing delays
- Avoid the complexity and fatigue problems inherent in orthotropic decks
- Increase architectural elegance with lighter, thinner decks
- Over a 120 year service life
- Lighter beams, lighter piers, fewer piles per pier
- Replace existing concrete decks, increase load capacity, add lanes and avoid superstructure reinforcement
- Avoid weather risk
- Reinstate bridge decks in days not weeks
lighter new bridges

SPS Bridge Decks enable lighter bridges with lighter girders, longer spans, fewer piers and reduced piling.

SPS Bridge Deck panels are delivered to site virtually complete. Erection uses light equipment and is mostly limited to bolting plates together. 3000m² of deck can be installed each week (working from both ends of the bridge).

All bridge geometries such as vertical and horizontal curves, deck camber, super-elevations and skew can be accommodated.

SPS Bridge Decks reduce total project costs and substantially reduce project schedules.

faster deck replacement

Increasingly countries face the problem of an ageing bridge inventory, with increasing traffic volumes and heavier truck loads. Many bridges throughout North America and Europe are in need of major repair or total replacement.

Reducing the deck dead load by up to 70% allows the bridge to carry significantly greater live load without needing girder or pier strengthening. Load restrictions on bridges can be removed and extra lanes added to increase traffic capacity. Deck replacement can be completed leaving the steel or concrete girders in place or, if speed is critical, by replacing the deck and girders with pre-assembled longitudinal deck-girder units.

The replacement of these old decks takes days rather than weeks and in some projects, can be completed without closing the bridge.
Dawson Bridge, Edmonton, Canada

lighter structures

SPS Bridge Decks are up to 70% lighter than equivalent reinforced concrete decks and create fully composite decks with either steel or concrete girders.

faster erection

SPS Bridge Deck erection is fast, uses a single trade, light equipment and standard industry practices. Once the girders are in place, SPS Bridge Decks are bolted directly to their top flanges, crash barriers are erected and asphalt laid.

high quality

SPS Bridge Decks are simple to produce. They are produced by welding two steel faceplates and four perimeter bars together to form a cavity into which an elastomer core is injected. Deck flatness is below L/1500. Panels are made to a +0mm -3mm tolerance, preventing oversize decks during erection.

typical savings

- 30% lighter girders
- 30% fewer piers
- 30% lighter piers
- 3000m² installed each week
- Two fewer deck replacements over the bridge’s life

longer life

SPS Bridge Decks offer over 120 years of service life, significantly reducing the deck replacement costs associated with the short 30 year service life of concrete. Typically, SPS Bridge Decks are made from weathering steel although other metals can also be used.

The wearing surface can be conventional asphalt with a membrane protection for the steel, or wearing surfaces. These thinner surfaces are particularly valuable for weight constrained movable bridges.
orthotropic bridge deck strengthening

With traffic loads and frequency increasing, made worse by ever decreasing wheel contact areas, much of the existing orthotropic steel bridge deck inventory needs to be replaced or strengthened. SPS Overlay is a fast, cost effective answer to deck strengthening, which can be completed without closing the bridge and with little disruption to traffic flow.

Initially developed to reinstate strength and stiffness of vehicle decks on ships without the intrusive complexity of steel replacement, SPS Overlay is an in-situ process, which uses the existing steel deck as one plate of a new composite to stiffen the deck and reduce fatigue stresses without deck removal.

proven deck stiffening and fatigue reduction

A deck renewed with SPS Overlay improves the distribution of wheel loads across the troughs decreasing critical stresses at fatigue prone details to enhance fatigue resistance and extend service life. Additionally the thicker stiffer deck plate reduces deck plate curvatures which increases the durability and life of the wearing surface.
simple fast process

SPS Overlay is a 4-stage process that combines conventional in-situ steel work with computer controlled elastomer injection in a predictable and repetitive procedure that can strengthen over 200m² per day per crew without closing the bridge. Since 2000, SPS Overlay has been used in more than 190 projects worldwide.

1 Remove existing wearing surface and grit blast steel to near white
2 Weld perimeter bars to deck and weld top plate to form airtight cavities
3 Inject elastomer into cavities and allow to cure
4 Apply new surface coating

typical benefits

- Enhance fatigue resistance
- Extend service life
- Improve load capacity
- Achieve weight neutral deck
- Minimize project schedule
- Maximize traffic flow
A coordinated test programme on SPS Bridge Decks and SPS Overlay has been conducted by industry experts at leading bridge research institutions in North America and Europe.

comprehensive testing

› SPS Bridges: in-field static and dynamic performance and FEA correlation
› Full-scale SPS Bridge Deck panels: in lab plate and panel deflection
› Half-scale SPS Bridge: composite action in positive and negative moment areas as well as tyre load distribution
› SPS Overlay Bridge Deck: in lab static and fatigue performance as well as tyre load distribution

excellent results

Statics

› Legal load limit of six axle truck applied (70 tons)
› Deflection and strains in plate and girders as predicted
› SPS Bridge Deck panel acts compositely with girders
› Ultimate capacity: Bottom flange of girder yields at 3.75 times the specified truck load (15,100 kN.m)
› Actual yield moment within 1% of the moment calculated from section properties
› Maximum shear stresses at the steel-elastomer interface at the ultimate load is less than the factored bond resistance of 4 MPa (tests show SPS typically achieves 10 MPa bond resistance)

Dynamics

› Full size SPS Bridge Deck tested for vibration
› Mode 1: Measured 5.8 Hz, Predicted: 5.7 Hz
› Mode 2: Measured 6.0 Hz, Predicted: 5.9 Hz
extensive R&D

SPS Technology is supported by over 16 years of research and development carried out in close cooperation with independent institutions and regulators.

The material characteristics of SPS are well documented and include: static and dynamic behaviour, vibration damping, fire resistance, and reaction to extreme impacts and blast. Good correlation between full-scale tests and analytical models allows engineers to design SPS structures with confidence.

Leading research institutions in North America, Europe and Asia have recently completed full-scale load and fatigue testing on SPS structures.
Once completed, SPS plates can be treated as any other steel plate and benefit from the ease of attachment of traditional steel elements. The broad range of proven wearing surfaces already available for orthotropic steel decks can also be applied to SPS Bridge Decks and last longer.

**material options**

SPS Bridge Decks can be manufactured in a wide range of steel alloys. Most SPS Bridge Decks are made from weathering steel allowing the deck plates to mirror the corrosion resistant steel work of the superstructure. Decks can also use standard structural steel; or vanadium steel for high strength to stainless steel for architectural impact.

**curbs**

All standard curb details can be integrated to SPS Bridge Decks with all attachment holes predrilled in the factory to allow for rapid fixing in the field, increased accuracy and improved QA.

**crowns**

The crown of the road can be created to match the road on both ends creating a seamless transition between existing road and new Deck with new asphalt overlaid. This allows for existing surface run off designs to be respected. Other typical bridge geometries including: skew, super-elevations, crossfall and camber can also be readily accommodated.

**wearing surfaces**

SPS Bridge Decks do not suffer from the surface cracking associated with concrete decks or the high deck curvatures experienced with orthotropic steel decks. Engineers can now save significant weight by specifying thinner asphalt or more advanced polymer wearing surfaces. Both wearing surface types use a polyurethane membrane to protect the steel deck. Properly maintained, these wearing surfaces allow the SPS Bridge Deck to achieve a working life of over 120 years.
Pre-engineered details are available to accommodate all industry standard attachments and fixings. The modular and bolted nature of the SPS Bridge Decks means that all items can be installed in the field or in the factory giving the contractor the flexibility of taking certain items like drilling or coring off site and into a more controlled environment.
panel design

SPS Bridge Deck panels are designed in 3D CAD BIM allowing for design and construction teams to integrate the deck design with the rest of the structure. This ensures accurate fit up of the bridge elements on site.

panel fabrication

The panels are made using the latest CNC cutting equipment directly off CAD drawings as well as high speed robotic welding equipment to deliver high finished accuracy. The production process allows for excellent Q&A of all panels prior to shipping allowing for significant risk reduction in quality of installed decks. The production capacity IE allows for deck production to match the procurement schedule of the bridge superstructure.

shipping

SPS Bridge Deck panels are shipped in a high density stacking arrangement of up to 125m² per load which allow for large areas to be delivered on flat bed trailers and left on site to be drawn down as required. A recent project had a 5:1 reduction in truck loads over conventional concrete deck deliveries on a highly constrained site.

installation

The speed of SPS Bridge Deck installation allows for projects to be completed in days rather than weeks. With similar skill sets, equipment and methodology to the rest of the steel structure work, and being a fully bolted solution, this process is easily integrated into existing steel work packages allowing for a smooth installation process. Allowing immediate full loading capacity, just installed plates create working platforms that the bridge deck to be assembled from both sides thereby further accelerating the deck insulation and shortening overall project schedules.
re-use

SPS Bridge panels are 100% reusable and the only determining factor is matching geometry of the new structure. However new infill panels can be created if geometry of different thereby allowing a high percentage of panels to be reused on future bridges.

re-cycling

SPS Bridge Deck panels consist of steel and PU which can both be 100% recycled into new SPS Bridge Deck panels at the end of their life.

Combining this re-use and recycling with reduced with long life reduced material in the bridge’s superstructure and foundations, SPS Bridge Decks offer substantial sustainability advantages over concrete decks.
design & regulatory support

When designing with SPS, bridge engineers are supported by an experienced team of structural engineers and material scientists at Intelligent Engineering and BASF Elastogran.

Intelligent Engineering invented SPS and leads its continuing development for a diverse range of maritime and civil engineering structures. Elastogran is part of the world’s leading chemical company, BASF, and provides the elastomer core of SPS. Our joint team includes structural engineers, material scientists, regulatory advisors and production engineers.

With over 15 years of SPS design, testing and regulatory approval, our team will help projects develop the most efficient combination of SPS and conventional structural engineering materials. We will support regulatory approval processes with detailed data and analysis based on test programmes and studies with leading research institutes.

experienced bridge fabricators

Local SPS licensees are industry leading steel structures fabricators with track records of delivering large and small high-quality, innovative solutions.

They all have significant experience in bridge fabrication and have their own design teams also able to support project designs.

SPS is an integrated part of their production and erection processes and therefore comes with all the quality and production standards you would expect of a modern fabricated steel structure.
typical projects

Dawson Bridge
This 100 year heritage 5 span through truss bridge in Edmonton required a full deck replacement and renovation of the truss to be completed within a short construction season. SPS Bridge Decks allowed the contractor to save 3 months off the expected concrete deck schedule and avoid costly strengthening of the truss.

M6 Pedestrian Bridges
SPS bridge decks were selected as the preferred replacement solution of the M6 pedestrian bridge replacements due to the rapid deck installation process which resulted in individual lane closures only for a few hours and not the entire motorway. Stainless steel faceplates make this a maintenance friendly bridge on Britain’s busiest motor way and 5 Bridges have now been installed.

Ma Fang Bridge
The orthotropic steel deck of this highly trafficked road bridge in China was suffering from fatigue. SPS Overlay was used to carry out a lane by lane strengthening allowing the bridge to remain open to traffic throughout the project.

Schönwasserpark Bridge
This main highway bridge in Germany carrying over 140,000 AADT vehicles a day over an electrified train line was strengthened using SPS Overlay in 2005 using a weight neutral solution which avoided the need for deck replacement or girder strengthening.

Cedar Creek Bridge
Texas DoT supported by the US Federal Highway Authority used SPS Bridge Decks (with their girders pre-attached in the factory) to perform the rapid replacement of this remote 3 span road bridge over just one weekend avoiding the need for any concrete work.

Huskisson Canada Passage Bridge
This business critical harbour bridge needed significant strengthening to accommodate larger and heavier industrial equipment needing to traverse it and SPS Overlay was selected for its ability to complete the project in 9 days with bridge closed for only 2 hours a day and full original load capacity at all other hours during the strengthening work.
stadia and arenas
SPS Terraces save weight, time and cost in the construction of high quality stadia and arenas.

buildings
SPS Floors enable significantly lighter structures with shorter, less risky construction programmes.

bridges
SPS Bridge Decks are much lighter and less complicated than conventional concrete and steel solutions.

ship repair
SPS Overlay is used extensively throughout the world in maritime repairs, including the refurbishment and strengthening of bulk carriers, ferries, liners, oil rigs and offshore structures.

ship building
SPS is used in components for new build vessels that improve efficiency during fabrication and performance in service.