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.

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**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 $\frac{3}{8}$” 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 $\frac{3}{8}$” 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.
**Exodermic Design**

**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.
## Deck Properties & Spans

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<th>Main Bar Spacing (in.)</th>
<th>Top Rebar</th>
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### 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) ($F_p = 20$ 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.

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: 5,509,243; 5,664,378; and 7,197,856) (Canadian: 2,181,554; 2,239,727; and 2,489,170) its availability from multiple, independent, licensed suppliers allows it to be considered ‘generic’ in most jurisdictions.
Typical Details

**Plan View – Precast Panels Shown (Cast-in-Place Similar)**

**Section A-A**

**Cast-in-Place Details**

- All concrete cast-in-place
- Shear stud
- Existing stringer

**Section B-B**

- All concrete cast-in-place
- Shear stud
- Existing stringer

**Section C-C**

- All concrete cast-in-place (other haunch forming options possible)
- 20 gauge galvanized sheet metal – field placed

**Precast Details**

- Precast concrete
- Field placed concrete
- Field placed rebar

**Section B-B**

- Precast concrete
- Field placed concrete
- 20 gauge galvanized sheet metal – field placed

- Field placed concrete
- Field placed rebar

**Section C-C**

- Field placed concrete
- 20 gauge galvanized sheet metal – field placed

- Field placed concrete
- 20 gauge galvanized sheet metal – field placed
**Typical Details**

**TYPICAL LONGITUDINAL PANEL SPLICE**

- 2" x 1/4" trim bars shop welded to main bars
- Existing stringer

**SECTION D1-D1**

(OTHER HANLIN FORMING OPTIONS POSSIBLE)

**LONGITUDINAL PANEL SPLICE FOR STAGED CONSTRUCTION**

- Limit of stage 1 deck removal
- Existing deck
- Existing stringer

**SECTION D2-D2**

(STAGE 1)

**HEIGHT ADJUSTMENT DETAILS**

**PREFERRED DETAIL**

- Nut welded to flange

**ALTERNATE DETAILS**

**OPTION #1**

- Nut welded to plate

**OPTION #2**

- Drilled plate

**TYPICAL JOINT DETAIL**

- Joint may be welded to distribution bars prior to placing concrete
- Field installed continuous strip seal, gland
- Existing end diaphragm

**FIELD FIBER**

(ADDITIONAL DETAILS AVAILABLE)

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