**Heavy Movable Structures, Inc.**

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Clearwater Beach, Florida

# *Exodermic Bridge Deck on Bascule Bridges*

by

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## INTRODUCTION

Because dead load has always been a primary consideration in the design of movable bridges, there has been a long history of the use of open steel grid for bridge decks on bascule bridges. Unfortunately, there have been a number of problems with this approach over the years:

- RIDING SURFACE. Most drivers are uneasy driving across an open steel grid deck. Portions of the steel grid are grabbed by modern tire tread designs, causing a sensation of loss of control; an open steel grid deck is very noisy when subjected to traffic and especially slippery when wet; and open steel grid decks can be quite hazardous when hard braking or sudden changes in direction are required in an emergency.

- LACK OF PROTECTION FOR BRIDGE AND MACHINERY. Snow and rain water to do not accumulate on an open grid deck, which can be a plus in bad weather. Unfortunately, with the tremendous increase in the use of deicing salts over the last 20 years or so, the structural steel and machinery below the deck quickly corrodes. Even in areas where road salt is not an issue, debris quickly accumulates on bridge components below the deck, trapping moisture and causing premature degradation. Good preventive maintenance (regular washing of the bridge) can help alleviate the problem, but for most jurisdictions, this is an unrealistic goal.

In addition, weight savings with open steel grid bridge decks is often not quite what it would seem at first blush: although the open grid deck itself may only weigh 16 lbs/sf to 28 lbs/sf, fatigue considerations require fairly close spacing of supporting steel beams. Superstructure framing often includes floorbeams, stringers, sub-floorbeams, purlins, etc., adding significantly to total weight of the bascule leaf.

Cost is another issue. A heavy, “5 inch - 4-way” open grid is a fairly substantial weldment, and is thus not inexpensive. The cost of the required closely spaced supports further adds to the cost.

In recent years, these problems and factors have been recognized, and owners have begun to specify closed deck systems on their new movable bridges – and also on existing bridges where feasible.

The following types of bridge deck may be used to provide a closed deck system:

•Lightweight concrete
•Orthotropic
•Filled grid (full depth)
•Half-filled grid
•Exodermic

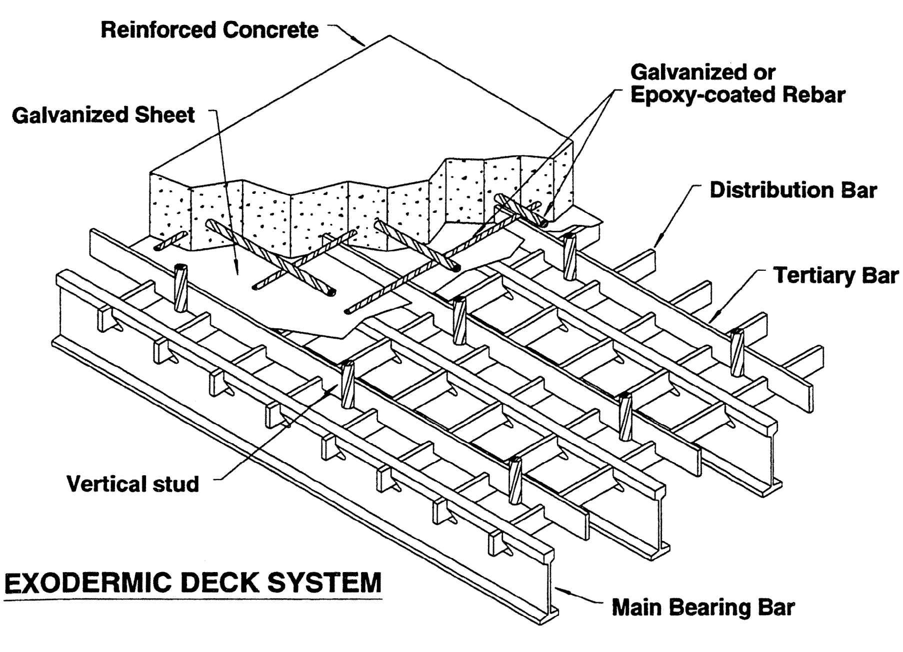
Most of these deck types will be familiar to the reader. The first exodermic deck installation on any type of structure was completed in 1984; its significant attributes may be less familiar.

## EXODERMIC DECK

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. The design 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 two of the steel grid components: the tertiary bars and vertical studs.

Overall thickness of the system using standard components ranges from 6" to 10"; weights range from 40 to 80 pounds per square foot. Exodermic decks using standard components can span to 17' or more, depending on design loads; larger main bearing bars and thicker concrete slabs can be chosen to span considerably further.

The concrete component of an exodermic deck can be pre-cast before the modules are placed on the bridge, or cast-in-place, as they would typically be for a new bascule bridge deck. 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 DECK SYSTEM**

Exodermic decks are made composite with the steel superstructure by using headed studs welded to stringers, floor beams, and main girders as appropriate, and embedding these headed studs in a concrete haunch area. The haunch area is poured at the same time as the reinforced concrete deck where the deck is cast-in-place, or separately with a pre-cast deck. Exodermic decks require no field welding other than that required for the placement (with an automatic tool) of the headed shear studs.

### A CLOSER LOOK AT EXODERMIC DESIGN

In a standard reinforced concrete deck loaded in positive bending, the concrete at the bottom of the deck is considered 'cracked' and provides no practical benefit. Thus, the effective depth of the slab is reduced, and the entire bridge -- superstructure and substructure -- has to carry the dead load of this 'cracked' concrete. In an exodermic deck, 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 either stiffness or strength.

In negative bending, the reinforcement in the concrete handles the tensile forces, as it does for a conventional concrete deck. Rebar in the concrete component of an exodermic deck can be specified to handle the negative moment, where the deck is continuous over supporting beams, or where a cantilever is required.

Exodermic decks can be specified to accommodate the particular requirements of a specific bridge. To date, overall deck thickness on different projects has ranged from 6.75" to 10". Concrete component thickness has ranged from 3" (2" in testing) to nearly 5". Standard and light weight concrete has been used. Any overlay compatible with concrete can be specified if desired.

## ALTERNATIVE DECK SYSTEMS FOR BASCULE BRIDGES

<u>Lightweight Concrete</u>

*Advantages:*

- Lower material cost
- Reinforced concrete riding surface provides good traction and is easily maintained using standard techniques.

*Disadvantages:*

- Weight – still high relative to that possible with half-filled grid and exodermic deck. All portions of the bridge will be larger and heavier: main girders, floorbeams, stringers, machinery, substructure.
- Cost – Increased size and weight of all bridge portions will add dramatically to total cost.
- Some DOTs have had unsatisfactory experiences with lightweight concrete.

HALF-FILLED GRID

*Advantages:*

- Lighter weight than reinforced concrete slab of equal depth.
- Overfilling with concrete improves ride quality (1¾" overfill is the industry's minimum recommendation).

*Disadvantages:*

- Panels must be bolted or welded together.
- The recommended minimum 1¾" overfill is un-reinforced, and may not provide acceptable cover over embedded steel.
- Integral overpour may not hold up to future milling and resurfacing operations, requiring a more complex overlay operation in the future.

FILLED GRID

*Advantages:*

- History of long service life of basic filled grid.
- Overfilling with concrete improves ride quality (1¾" overfill is the industry's minimum recommendation).
- Some weight savings over conventional reinforced concrete deck in many applications.

*Disadvantages:*

- Still fairly heavy, given 6" of concrete and weight of steel grid.
- Panels must be bolted or welded together -- a time consuming operation.
- The recommended minimum 1¾" overfill is un-reinforced, and may not provide acceptable cover over embedded steel.
- Integral overpour may not hold up to future milling and resurfacing operations, requiring a more complex overlay operation in the future.

EXODERMIC

*Advantages:*

- Significantly lighter weight than reinforced concrete slab.
- Efficient design provides stiff deck with typically low stresses under design load.
- In cast-in-place installation, rebar is continuous. Panel connection detail does not require bolting or splicing of grid panels.
- Reinforced concrete riding surface provides good traction and is easily maintained using standard techniques, including milling, and the use of any overlays compatible with standard reinforced concrete.

*Disadvantages:*

- Contractor unfamiliarity.
- System may be labeled as proprietary despite it's availability from multiple, independent suppliers.

ORTHOTROPIC DECK

*Advantages:*

- In limited cases, structural benefits may permit savings in superstructure structural steel.

*Disadvantages:*

- Generally prohibitively expensive -- several times the cost of other alternatives.
- Complex design
- Overlays are expensive and overlay life is limited. Replacement disrupts traffic.

FURTHER NOTE ON LIGHTWEIGHT CONCRETE

Exodermic, filled, and half-filled grid decks can use normal or light weight concrete. This choice may be dictated by the quality of aggregate available in the area, and the experience of the bridge owner. Of the two bascule bridges described below, one will use normal weight concrete with its exodermic deck, the other will use lightweight concrete.

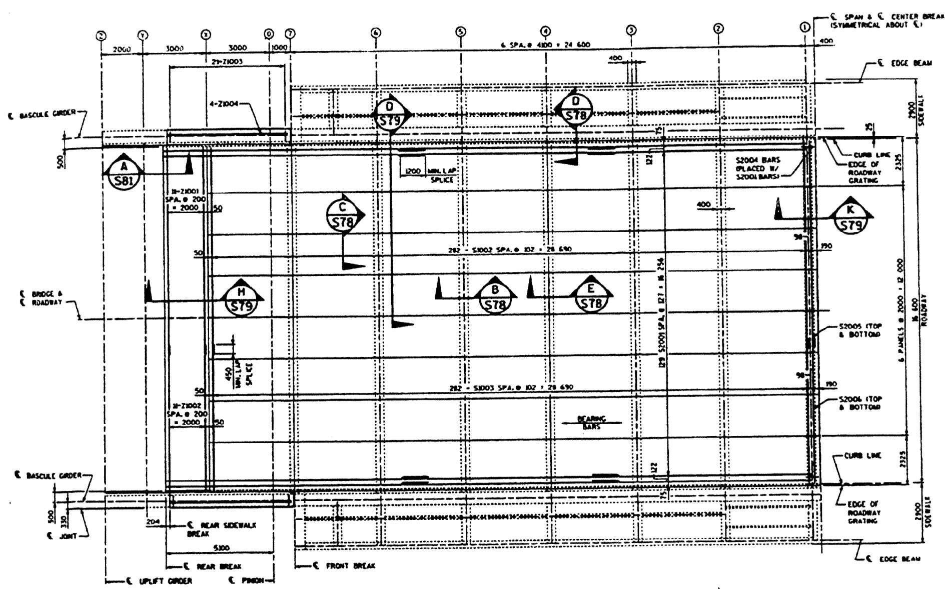
## EXODERMIC ON BASCULE BRIDGES – TWO EXAMPLES

Several bascule bridges have been (or are being) designed with exodermic decks. Two will be described below. These projects take advantage of the efficiency of the exodermic design to eliminate stringers, spanning between floorbeams without additional supports.

## MAIN STREET BRIDGE, GREEN BAY, WISCONSIN

The old Strauss Trunnion Bascule Bridge over the Fox River at Main Street in Green Bay had been slated for replacement for some time. When the piers began to exhibit some instability in 1995, the bridge was closed and demolished. At the time, the Chicago and Minneapolis offices of Parsons Brinkerhoff Quade & Douglas had already been selected to design a replacement bridge. After studies, the city chose a Scherzer rolling lift design over a more conventional trunnion-type bascule, in keeping with the predominance of the Scherzer type in the city.

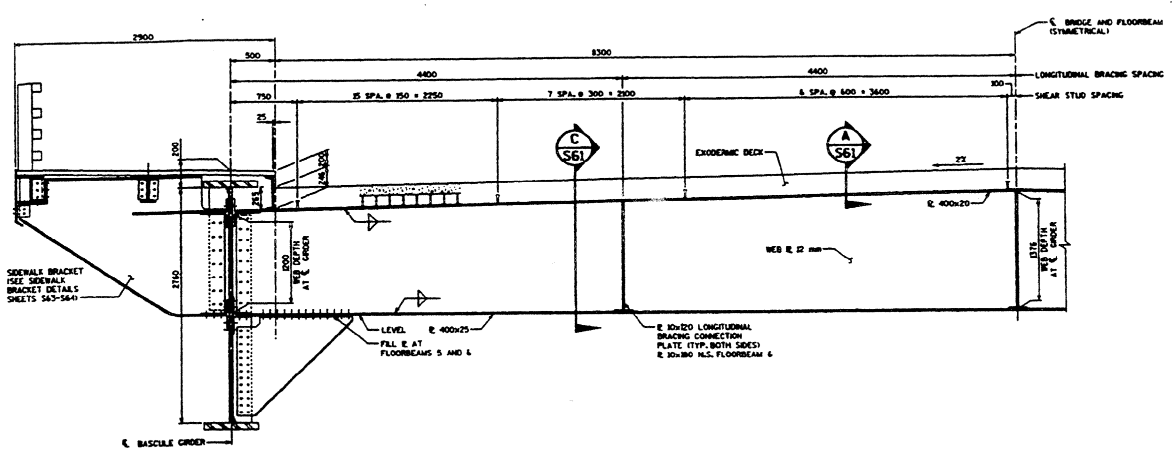
Early on in the design process, a decision was made to provide a concrete riding surface, and the different deck options were considered. The final design uses an exodermic deck.



PLAN OF BASCULE DECK
(WEST SPAN SHOWN)
(EAST SPAN SYMMETRICAL ABOUT ℄ BREAK)

Overall dimensions of the bridge are:

- Centerline pinion to centerline center break: 26 meters
- Overall girder length: 34 meters
- Centerline girder to centerline girder:  17.6 meters
- Roadway width: 16.6 meters
- Sidewalk width (both sides): 2.9 meters
- Total width: 19.5 meters




FLOORBEAM 6
(LOOKING TOWARD CENTER BREAK)
(FLOORBEAMS 2-5 SIMILAR UNLESS NOTED)

Framing consists of floorbeams at 4.1 meter spacing, with longitudinal and bottom lateral bracing.  In the absence of stringers, the exodermic deck spans floorbeam to floorbeam. The exodermic deck will be composite with the floorbeams through the use of standard welded headed shear studs.

EXODERMIC DECK CONFIGURATION:  In order to span the 4.1 meters between floorbeams, a fairly substantial exodermic design was selected.  On this project, grid dimensions were soft converted to metric in order to avoid expensive retooling.  The exodermic deck will have 5.1875" grid main bearing bars oriented in the direction of traffic and spaced on 152 mm (6") centers.  Top (main) rebar is to be #20 @ 127 mm (approximately equivalent to #6 bars @ 5" centers); bottom (distribution) rebar is #10 @ 102 mm ((approximately equivalent to #3 bars @ 4" centers).

Normal weight concrete was specified by Wisconsin DOT due to prior negative experience with lightweight concrete.  The concrete component of the exodermic deck will be 114 mm (4.5"), providing nearly 2½" of cover over the embedded epoxy coated reinforcing bars.

Deck weight will be approximately 35 kgs/sq. meter (78 lbs/sf), which is fairly light for a deck spanning 4.1 meters (13½ ft) using normal weight concrete.

It is anticipated that the bascule leaves will be erected in the open position.  Once the steel grid panels, headed shear studs, and rebar are all in position, a leaf will be closed for the concrete pour, minimizing interruption of river traffic.

Work on this project will commence early in 1997, and is to be complete by July, 1998.

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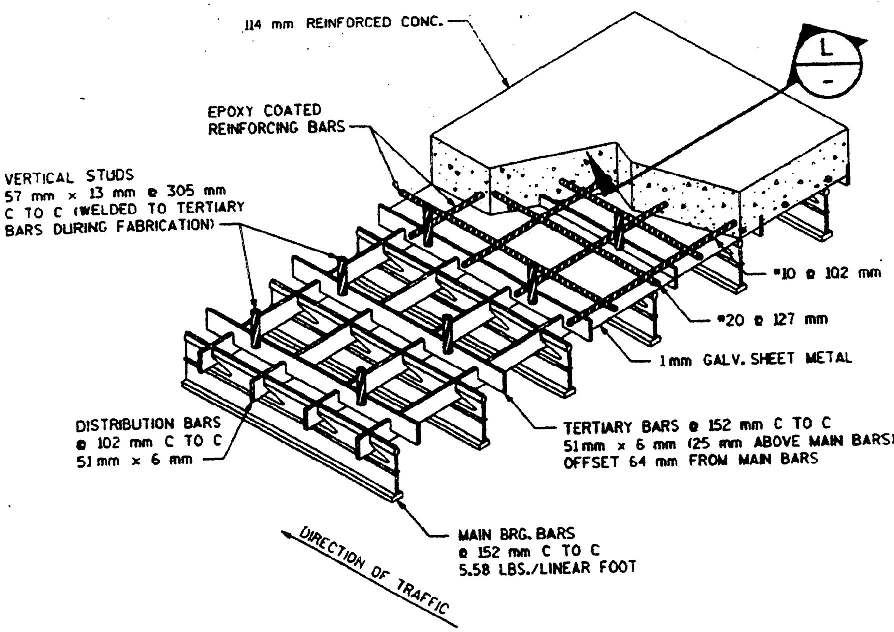
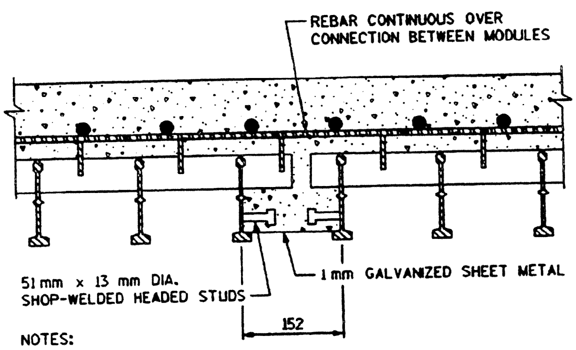


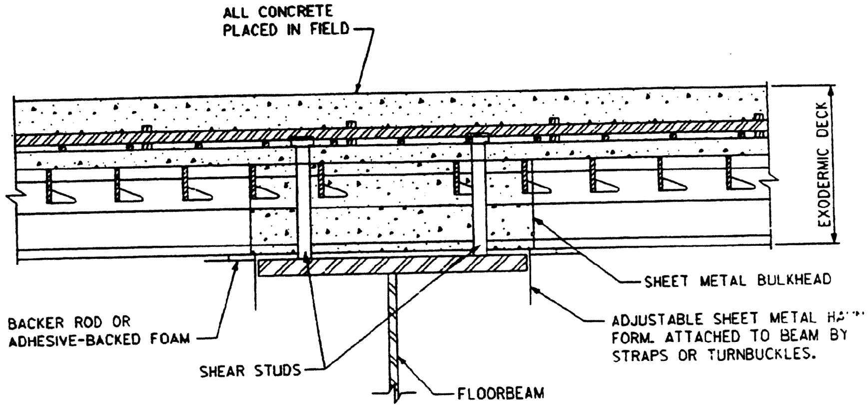

## EXODERMIC DECK SYSTEM




NOTES:

1. ALL CONCRETE POURED IN FIELD.
2. TOP REBAR OFFSET 25 mm MIN. FROM TERTIARY BARS.

## SECTION C/S77



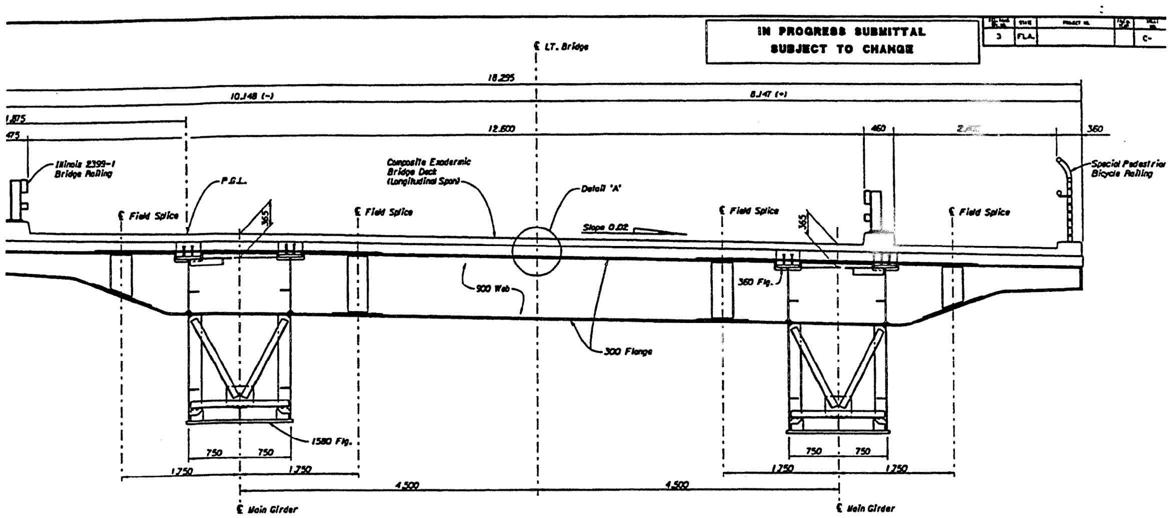

## SECTION B/S77

## 17th STREET BRIDGE, FT. LAUDERDALE, FLORIDA

The 17th Street Causeway project in Ft. Lauderdale is large and complex. Portions of this project will be discussed in other papers at this symposium. The 17th Street Causeway is a major link in the City, so its reconstruction involves major maintenance of traffic considerations. One portion of the causeway crosses an existing low level (25' clearance) double leaf bascule bridge. The reconstructed causeway will include new mid-level (50' clearance) twin bascule bridges. E.C. Driver, consultants, have designed an innovative large, double leaf bascule bridge, using an exodermic deck to provide a concrete riding surface, and to permit use of simplified and -- lighter -- structural framing.

Overall dimensions of the bridge are:

- Centerline trunnion to centerline center break: 32.15 meters
- Overall box girder length: 44 meters
- Centerline box girder to centerline box girder: 9 meters
- Roadway width: 12.6 meters
- Sidewalk width (one side): 2.4 meters
- Total width: 16.3 meters




SECTION THRU BASCULE LEAF
AT FLOORBEAM FB5
(FLOORBEAM FB3 SIMILAR)

Main girders are steel boxes. Floorbeams are at 4.4 meter spacing. Cantilevered brackets (floorbeam extensions) extend 2.875 meters beyond the outside edge of the box girders. In the absence of stringers, the exodermic deck spans floorbeam to floorbeam. The exodermic deck will be composite with both the floorbeams and the top flanges of the box girders.

EXODERMIC DECK CONFIGURATION: Again, a fairly substantial exodermic design was selected in order to span the 4.4 meters between floorbeams. As on the Main Street Bridge project, grid dimensions were soft converted to metric in order to avoid expensive retooling. The exodermic deck configuration is very close to that of the Main Street Bridge, except that top rebar will be on a slightly closer spacing to accommodate the longer span. The main bearing bars of the grid will span in the direction of traffic.

Light weight concrete is specified in order to save additional weight. The concrete component of the exodermic deck will be 114 mm (4.5"), providing nearly 2½" of cover over the embedded epoxy coated reinforcing bars.

Deck weight will be approximately 31 kgs/sq. meter (68 lbs/sf).

As on the Main Street Bridge, the bascule leaves will be erected in the open position. Because of maintenance of traffic issues, one of the twin bridges will carry four lanes of traffic during construction of the other bridge. The full width of the bridge will be used for traffic lanes (no sidewalks). Once the other bridge is in service, the first will be reconfigured with a curb and barrier in order to protect the sidewalk.

The bascule bridge portion of the new Causeway is due to bid in December, 1996. Both double leaf bascule bridges will be completed by 2000.

## REDECKING PROJECTS

Existing bascule bridge decks can sometimes be redecked with a closed system without extensive redesign, by using an exodermic or half-filled grid deck design, eliminating some of the closely spaced framing required by the existing open grid deck, and adding to the counterweight (steel or even lead can be substituted for concrete if required). Two difficulties are encountered: since the original deck is almost invariably flat (water drains straight through), provision for drainage has to be made in the redecking design. Top of elevation of the deck is likely to change due to the new cross slope, and replacement of the open deck, sub-floorbeams, etc. with a new deck. Thus adjustment to the approaches may also be required.

In some cases it may be possible to convert an existing open grid (if in good shape) to an exodermic deck by field welding tertiary bars, placing galvanized sheet steel between them, placing a single layer of welded wire fabric, and placing a thin concrete slab, which can be as little as two inches in thickness.

## CONCLUSION

Its capability of spanning over 4 meters in the direction of traffic (HS-20 loading) permits simplified bascule leaf framing with an attendant savings in weight, erection time, and total project cost, while providing a standard reinforced concrete riding surface.