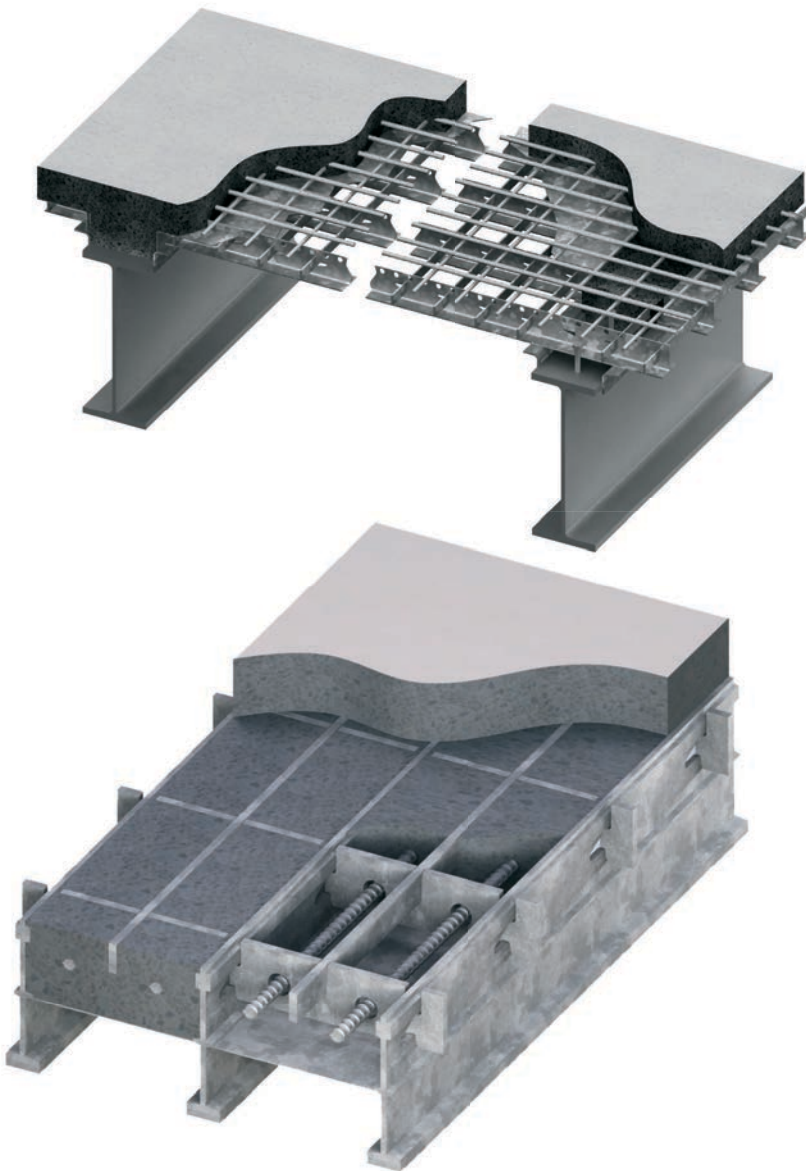


Grid Reinforced Concrete and Exodermic® Bridge Decks

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Design Properties and Product Information

February 2017

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About BGFMA

The **Bridge Grid Flooring Manufacturers Association** industry group is comprised of companies who fabricate steel grid deck systems for bridges and other companies with an interest in this market. Building on the 80-year service history of filled grid systems, this expanded professional organization is focused on the reliable development and application of open grid, grid reinforced concrete, and Exodermic® bridge decks to meet the demands of the engineering community and traveling public.

Advantages of Grid Decks:

Direct impact of heavier than anticipated truck loads, increased traffic volumes and extended service lives have taken their toll on America's traditional reinforced concrete bridge decks. These factors are the leading cause of structurally deficient ratings on the national bridge inventory.

Replacing a standard concrete deck with one that is **lighter in weight** but still strong enough to handle today's wheel loads is a smart, **cost-effective** solution to increasing the live load rating and service life of a bridge while minimizing structural repair costs. Grid reinforced concrete and Exodermic® deck systems provide superb strength and durability performance and can weigh 30-50% less than a conventional reinforced deck slab. On new construction projects this weight savings can lead to significant size reductions and cost savings in

the substructure and superstructure elements. On moveable bridges, additional cost savings can be expected in the counterweight, trunnion and drive machinery. Grid decks can be made fully composite with superstructure elements for additional strength and stiffness.

Using prefabricated bridge deck systems also **accelerates construction** to help reduce the traveling public's frustration with lengthy and inconvenient traffic disruptions. This innovative construction technique is currently receiving considerable attention by many state DOT's and the FHWA. Grid reinforced concrete and Exodermic® bridge decks can be installed as either cast-in-place (CIP) or precast sections for very rapid installation. With CIP construction, the steel grid panels act as "stay-in-place" forms, with little or no additional formwork required in the field. Utilizing precast panels it is possible to replace bridge decks during weekend, or even nighttime closure periods with only minimal construction time needed to place the panels and complete the closure pours. Installation rates up to 1,000 square feet per day have been observed with CIP construction techniques, and more than 2,000 square feet per day/night can be achieved utilizing precast methods. Actual rates will vary from project to project, and on deck replacements the rate will heavily depend on whether the existing deck is composite or non-composite.



South 10th Street, sometimes referred to as the Philip Murray Bridge in Pittsburgh, PA was built in 1932 with a grid reinforced concrete deck that is still in service today!



17th Street Causeway Bridge In Fort Lauderdale, FL. Exodermic® deck panels span floorbeams spaced at over 14 feet - composite with floorbeams and main girders.



Grid deck panels for cast-in-place construction.



Precast grid deck panels.

Why Specify BGFMA Member Fabricators?

Quality — BGFMA policies require that fabrication be performed in the member's AISC certified manufacturing facility. In addition to the stringent AISC certification requirements, members are also subject to internal audits conducted by appointed BGFMA representatives.

Experience — BGFMA member companies employ individuals with decades of grid design, detailing, fabrication and installation experience which helps ensure the success of your project.

Capacity — BGFMA members have the means to engineer and fabricate even the largest grid deck system projects. Members are also held to the highest standards for on-time delivery to ensure that construction schedules are not compromised.



Design Notes

The following pages provide design information for common configurations of grid reinforced concrete and Exodermic® bridge decks. Please contact BGFMA for more information on alternative configurations.

CONCRETE:

f'_c = 4000 psi

Normal Weight = 145 pcf (n=8)

Top 1/2" is sacrificial

Maximum aggregate size shall not exceed 3/8" to ensure proper consolidation. Weights exclude concrete in haunch areas*, additional full depth concrete at connections between panels**, and any additional deck overlay.

* From the bottom of concrete in typical deck section to the top of supporting element.

** For partial depth and Exodermic®.

STEEL:

Rebar: ASTM A615 (Fy = 60 ksi)

Plate & Flat Bars: ASTM A709 (Fy=36 or 50 ksi)

WT Shape Main Bars: ASTM A992 (Fy = 50 ksi)

Rolled Main Bars, Cross Bars, & Supplemental Bars: ASTM A709 (Fy=50 ksi)

See design tables and details on individual product pages for more information.

- Additional weight savings can be achieved utilizing lightweight concrete.
- Weights and thicknesses include 2" of overfill (cover over rebar for Exodermic®, and cover above top of main bar for full and partial depth grid decks).
- All punched holes or slots in steel members are deducted to determine cracked section properties using the transformed area method.
- Design Specification: 2014 LRFD Bridge Design Specifications, 2016 Interims – L/800 deflection – Spans are continuous from centerline to centerline of supports and incorporate a continuity factor $C = 0.8$ for DL + LL moment.
- Steel only weights include the weight of form pans and galvanizing.
- The design tables provided in this brochure were 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 BGFMA assumes no liability for use of any information contained herein.



BGFMA design program for grid reinforced concrete and Exodermic® bridge decks. Please contact the BGFMA if you would like the most current program.

Full Depth Grid Reinforced Concrete Deck

Properties and Span Capacities

Rectangular Full Depth Grid Deck with 2" Concrete Overfill													
Main Bar Type/Size	Main Bar Spacing (in)	Cross Bar Spacing (in)	Cross Bar Size (in)	S Bars (qty)	S Bar Size (in)	Bottom Rebar Spacing** (in)	Bottom Rebar Size	Concrete Thickness (in)	Total Height (in)	Approximate Weight (psf)		Max Continuous Spans (ft)	
										Steel Only	With Concrete	Main Bars Perpendicular to Traffic	Main Bars Parallel to Traffic
3" (WT 3x4.5)	8	6	1/4 x 1-1/2	2	5/8 x 5/8	6	#5	4.95	4.95	17.2	72.5	6.9	6.1
4-1/4" Rolled Shape	6	4	1/4 x 1-1/2	0	-	8	#5	6.25	6.25	16.7	87.9	8.5	7.6
4-1/4" Rolled Shape	8	4	1/4 x 1-1/2	0	-	8	#5	6.25	6.25	14.3	86.2	6.7	5.3
5-3/16" Rolled Shape	6	4	1/4 x 2	1	5/16 x 1	8	#5	7.19	7.19	21.3	102.5	10.7	9.5
5-3/16" Rolled Shape	8	4	1/4 x 2	1	5/16 x 1	8	#5	7.19	7.19	18.1	100.2	9.8	8.7
5-3/16" Rolled Shape	10	4	1/4 x 2	2	5/16 x 1	8	#5	7.19	7.19	17.6	99.8	9.2	8.1

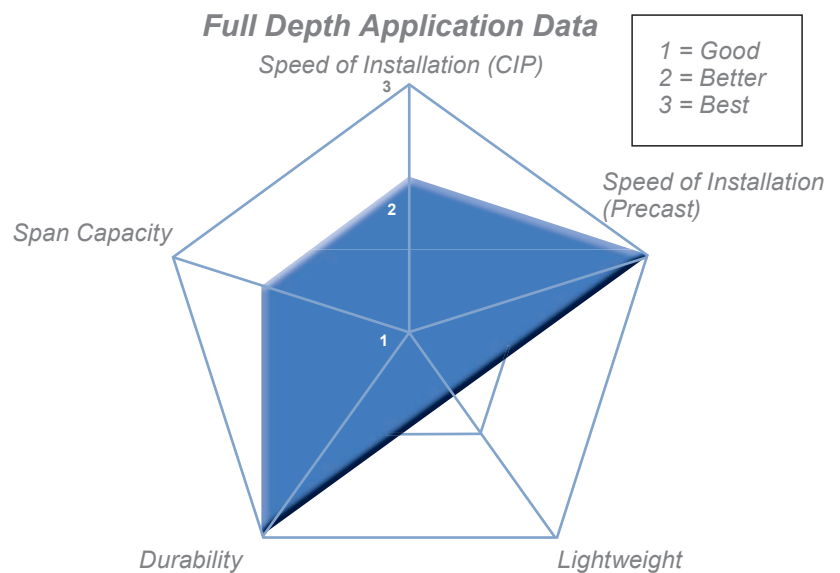
See design notes on page 3 for assumptions and additional information.

* Supplemental bars. Number of bars spaced evenly between main bars. 1/4" x 1" supplemental bars also available.

** Bottom rebar parallel with cross bars.



Contractor installing grid deck panels on the Boston Bridge carrying PA Route 48 over the Youghiogheny River just south of Pittsburgh. The deck was designed so the contractor could drive construction equipment on the steel grid panels prior to pouring concrete.



Full Depth Grid Reinforced Concrete Deck

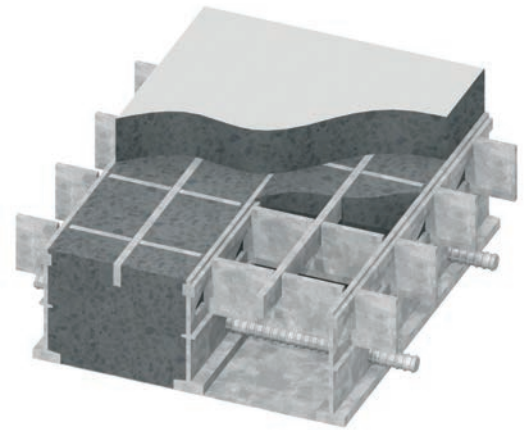
First introduced in the 1930's by engineers looking to speed construction on large projects, steel grid bridge decks with full depth concrete were originally designed as inverted WT's with flanges butted together to eliminate the need for time consuming form work. Most of today's concrete filled grid decks are fabricated with galvanized special rolled I-Beam shapes as seen in the detail to the right. Several older structures that were built in the 1930's and 40's with this type of deck system are still in service today and utilizing the original concrete filled steel grid!

Many of the older full depth grid decks were installed with the concrete flush filled, however they eventually received an overlay to help protect the steel grid from corrosion and the concrete infill from wearing and cupping. Today, the BGFMA and AASHTO recommends at least a 1-3/4" integral overpour be

specified.

Although a significant weight savings is not usually achieved by specifying a full depth grid system, the modular nature does allow for rapid installation using CIP or precast construction. If considering life-cycle costs, these durable deck systems prove to be very economical based on their strong performance history. Grid reinforced concrete bridge decks have outperformed all other deck types, lasting 2-3 times as long as conventional rebar reinforced concrete decks.

As shown in the table on the previous page, full depth grid decks have another advantage in that they can be designed much more shallow than other deck systems. Depending on the span and design requirements these systems can be as shallow as 5 inches while still maintaining the recommended cover.



Case Study: Brooklyn Bridge

The Brooklyn Bridge in New York City is one of the oldest suspension bridges in the United States, and also carried the title of longest suspension bridge in the world for nearly 20 years after it was completed. In 1953 the iconic structure received a new 3" deep steel grid deck with flush filled concrete which provided a deck system with weight savings, durability, shallow depth, and even speed of construction. After 45 years of service and over 1 billion vehicle crossings, the deck was replaced again with a new, modern 3" deep grid deck filled with lightweight concrete. At that time, the design engineer predicted that the new galvanized steel grid deck will last between 75 and 100 years. With ADT well over 130,000 vehicles at that time speed of construction was of utmost importance for this deck replacement project and the NYC DOT allowed only 150 construction days, and half-width nighttime closures (11pm-6am) of the six-lane structure to replace over 200,000 square feet of deck. To meet this aggressive construction schedule, the grid panels were precast on stringers in 7.5' x 30' sections and the contractor used two crews at different locations on the bridge to set 8 sections, or roughly 1,800 square feet of deck per night.



> Grid Deck Advantage – Reduction of Dead Load on Structure, Speed of Construction and Long Service Life

Partial Depth Grid Reinforced Concrete Deck

Properties and Span Capacities

Rectangular Partial Depth Grid Deck with 2" Concrete Overfill											
Main Bar Type/Size	Main Bar Spacing (in)	Cross Bar Spacing (in)	Cross Bar Size (in)	S Bars' (qty)	S Bar Size (in)	Concrete Thickness (in)	Total Height (in)	Approximate Weight (psf)		Max Continuous Spans (ft)	
								Steel Only	With Concrete	Main Bars Perpendicular to Traffic	Main Bars Parallel to Traffic
5-3/16" Rolled Shape	6	4	1/4 x 2	1	5/16 x 1	4.5	7.19	19.8	71.0	10.1	9.4
5-3/16" Rolled Shape	8	4	1/4 x 2	1	5/16 x 1	4.5	7.19	16.6	68.1	9.3	8.2
5-3/16" Rolled Shape	8	4	1/4 x 2	2	5/16 x 1	4.5	7.19	18.1	69.3	9.3	8.6
5-3/16" Rolled Shape	10	4	1/4 x 2	1	5/16 x 1	4.5	7.19	14.6	66.5	7.1	6.1
5-3/16" Rolled Shape	10	4	1/4 x 2	2	5/16 x 1	4.5	7.19	15.9	67.4	8.7	7.8

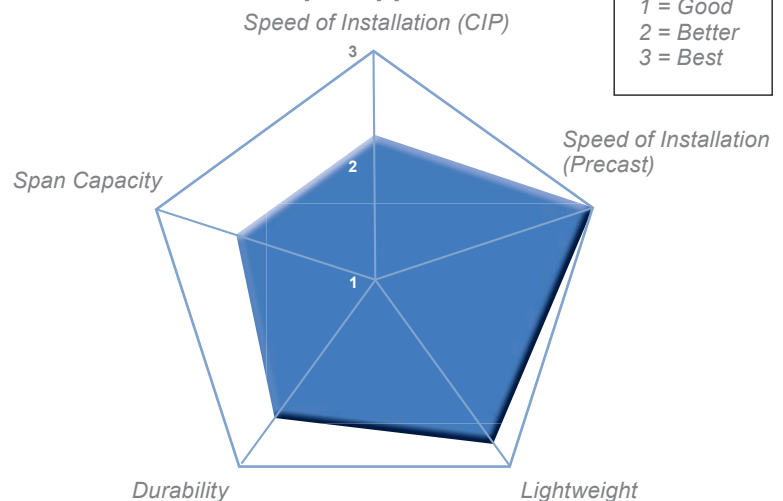
See design notes on page 3 for assumptions and additional information.

* Supplemental bars. Number of bars spaced evenly between main bars. 1/4" x 1" supplemental bars also available.



Walt Whitman Bridge deck installation in Philadelphia, PA
Partial depth grid reinforced concrete deck replaced via CIP construction.

Partial Depth Application Data



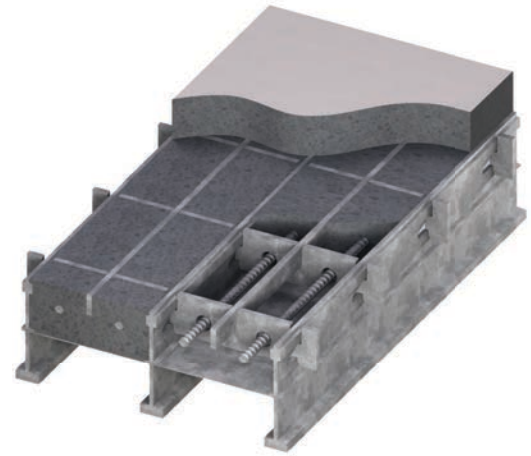
Partial Depth Grid Reinforced Concrete Deck

Partial depth grid reinforced concrete bridge decks have been successfully utilized since the early 1950's. These systems evolved from the full depth system that engineers capitalized on weight savings that could be achieved by eliminating the concrete in the bottom half of the grid. Moving the form pans up to an intermediate flange on the main bar allowed designers to reduce weight by roughly 25-30% from full depth grid reinforced concrete decks with nearly no reduction in the span capacity.

Although partial depth grid reinforced concrete bridge decks have not been around quite as long as full depth grid systems, the 60-year history of these decks has been very successful with many still in service today. The BGFMA and AASHTO also recommend at least

a 1-3/4" minimum concrete overfill to protect the steel grid on all partial depth grid deck systems.

Like other concrete filled grid decks, partial depth systems can be specified as precast or cast-in-place construction, providing options for owners, engineers and contractors looking to speed construction. Full and partial depth grid decks fabricated with rolled I-beam main bars are rigid systems even before the concrete is placed. This rigidity allows the contractor to drive equipment on the panels prior to pouring concrete which is useful when construction staging requirements or clearance issues prohibit the use of an overhead crane for setting panels in place.



Case Study: Gill-Montague Bridge

The Turner Falls-Gill Bridge, also commonly known as the Gill-Montague Bridge crosses the Connecticut River between the towns of Gill and Montague in Massachusetts. Built in the late 1930's, this fixed multi-span truss structure was in need of major rehabilitation after more than 70 years of service. The project scope included replacing the existing concrete deck with a new, roughly 20 percent lighter partial depth grid reinforced concrete deck. The weight savings achieved by using a partial depth concrete filled grid allowed the bridge owner to widen the new deck by three feet. More importantly the reduced dead load contributed to increasing the live load rating of the bridge to HS25, while limiting the amount of costly strengthening required to the truss.



> Grid Deck Advantage – Reduction of Dead Load on Structure

Exodermic® Deck

Properties and Span Capacities

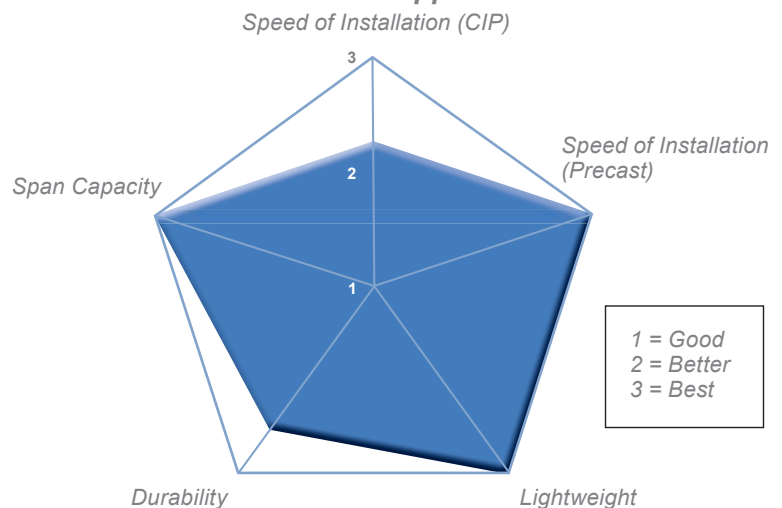
Exodermic® Deck with 2" Concrete Cover over Rebar										
Main Bar Type/Size	Main Bar Spacing (in)	Top Rebar Size and Spacing (in)	Cross Bar Size (in)	Cross Bar Spacing (in)	Concrete Thickness (in)	Total Height (in)	Approximate Weight (psf)		Max Continuous Spans (ft)	
							Steel Only	With Concrete	Main Bars Perpendicular to Traffic	Main Bars Parallel to Traffic
Shallow WT4x5	8	#5 @ 4	1/4 x 1-1/4	4	4	6.28	12.2	63.5	9.5	7.6
Shallow WT4x5	10	#5 @ 5	1/4 x 1-1/4	4	4	6.28	10.7	61.6	7.2	5.5
Shallow WT4x5	12	#5 @ 4	1/4 x 1-1/4	4	4	6.28	9.8	61.2	5.1	4.2
WT4x5	8	#5 @ 4	1/4 x 1-1/2	6	4.125	7.07	11.7	64.6	10.8	9.8
WT4x5	10	#5 @ 5	1/4 x 1-1/2	6	4.125	7.07	10.2	62.7	9.6	7.2
WT4x5	12	#5 @ 4	1/4 x 1-1/2	6	4.125	7.07	9.2	62.2	7.4	5.9
WT5x6	8	#6 @ 4	1/4 x 2	6	4.25	8.19	13.9	69.4	13.4	12.2
WT5x6	10	#6 @ 5	1/4 x 2	6	4.25	8.19	12.2	67.0	12.5	11.3
WT5x6	12	#5 @ 4	1/4 x 2	6	4.125	8.06	11.0	64.0	11.6	9.7
WT6x7	8	#6 @ 4	1/4 x 2	6	4.25	9.21	15.5	71.0	15.6	14.4
WT6x7	12	#6 @ 4	1/4 x 2	6	4.25	9.21	12.0	67.6	13.9	12.7

See design notes on page 3 for assumptions and additional information.
Bottom distribution rebar shown is #4 @ 6" for all configurations.



Robert C. Beach Memorial, or West Buckeye Bridge near Morgantown, WV. Precast Exodermic® deck panels prior to closure pour.

Exodermic® Deck Application Data



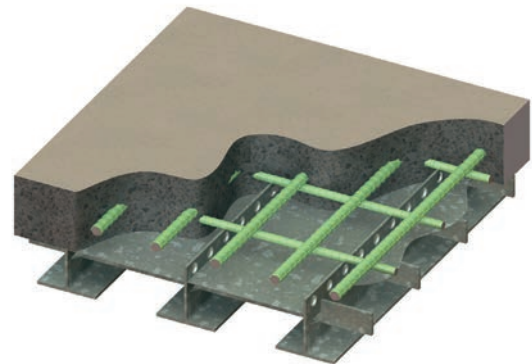
Exodermic® Deck

An Exodermic® bridge deck is comprised of a reinforced concrete slab on top of, and composite with an unfilled steel grid. This hybrid system was developed in the mid-1980's to maximize the compressive strength of the concrete and tensile strength of the steel. Horizontal shear transfer between the reinforced slab and WT members is developed through the partial embedment in the concrete of the top portion of the main bars, which are punched with 3/4" diameter holes to provide the composite action.

Under negative moment, the rebar in the reinforced concrete slab takes the tensile forces just as it would in a conventional deck, and the WT main bars handle the compressive forces. In positive moment regions the WT main bars are in tension, while the concrete is in compression.

Assuming 2" of cover over the rebar, the overall thickness of the system using standard components ranges from 6-1/4" to 9-1/4". Total deck weights range from 61-71 pounds per square foot (assuming normal weight concrete). Exodermic® decks have the best strength to weight ratio of the grid deck systems making it the most structurally efficient grid, which in return yields one of the most cost efficient lightweight deck systems available.

When required, a larger WT section can be used to achieve span capacities greater than what is shown in the design tables.



Case Study: Grand Island Bridge

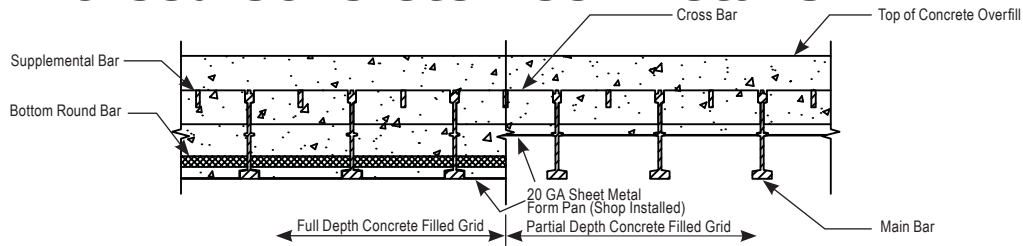
The Grand Island Bridges on Interstate 190 over the Niagara River between Tonawanda, Grand Island and Niagara Falls are a great example how grid deck systems help bridge owners follow through on FHWA's initiative to use prefabricated bridge technology to accelerate construction. The contractor on the northbound, South Grand Island Bridge replaced nearly 2,000 square feet of deteriorated bridge deck with new precast Exodermic® deck panels during every 7-8 hour nighttime closure.

This construction schedule allowed the New York State Thruway Authority (NYSTA) to have all lanes open for morning and afternoon rush hour traffic and facilitated the early completion of this roughly 90,000 square foot redecking project.

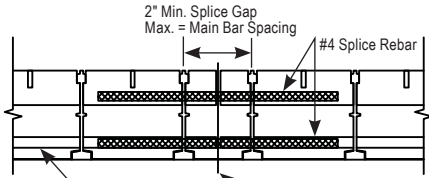
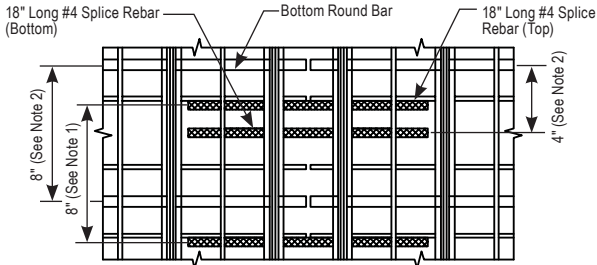
> Grid Deck Advantage – Speed of Construction



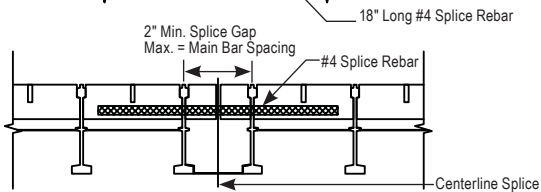
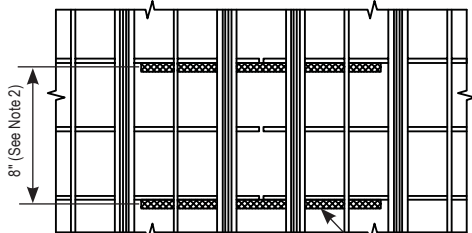
Grid Reinforced Concrete Deck Details



Typical Section Through Concrete Filled Grid Deck

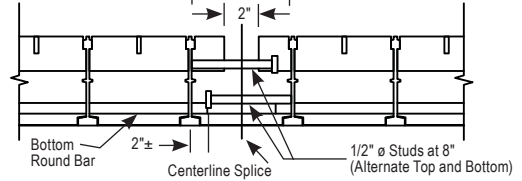
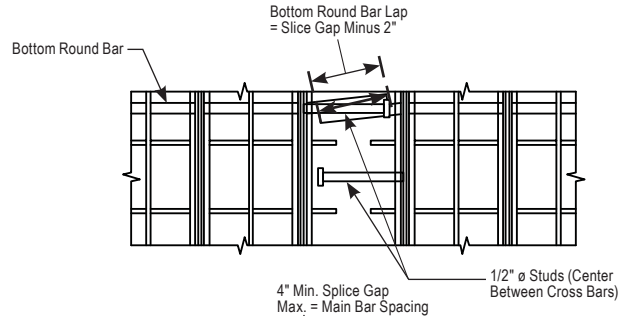


Grid Deck with Full Depth Concrete



Grid Deck with Partial Depth Concrete

Cast-In-Place Transverse Panel Connection



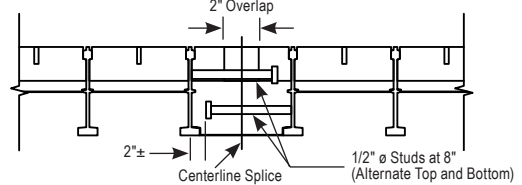
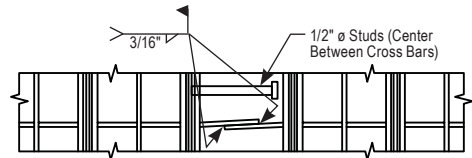
Note 1: Splice Rebar may be inserted either through slot for cross bar in grid main bar or through separate punched slot.

Note 2: Bottom round bar punch at 4" O.C.
Alternate #4 bottom splice rebar with
bottom round bar.

Concrete not shown for clarity.

Sheet metal form pans between main bars in panel splice regions are shipped loose and field installed.

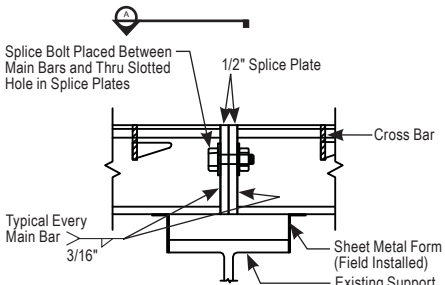
Typical cross bar spacing is 4".



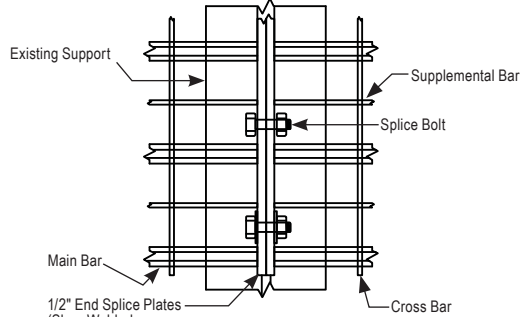
Grid Deck with Partial Depth Concrete

Precast Transverse Panel Connection

Longitudinal Panel Splice

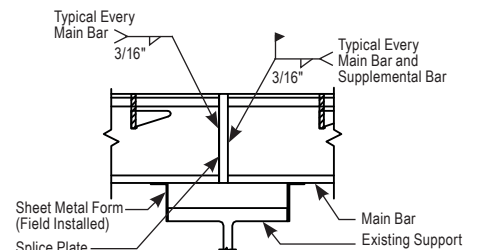


Bolted Main Bar Splice



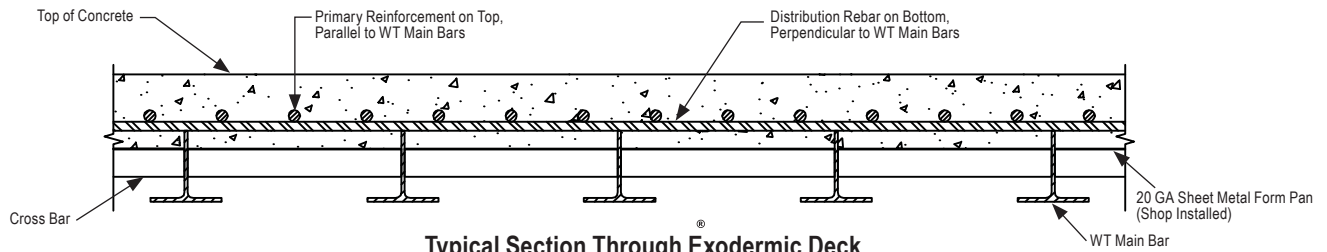
View 'A'

Sheet Metal Forms Not Shown for Clarity



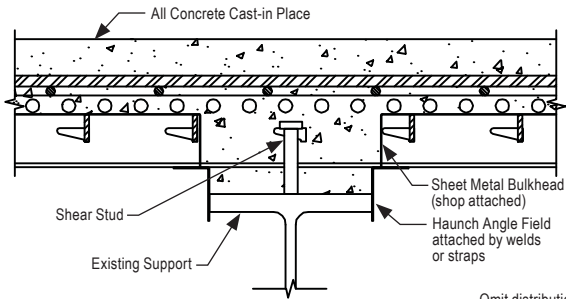
Welded Main Bar Splice

Exodermic® Deck Details

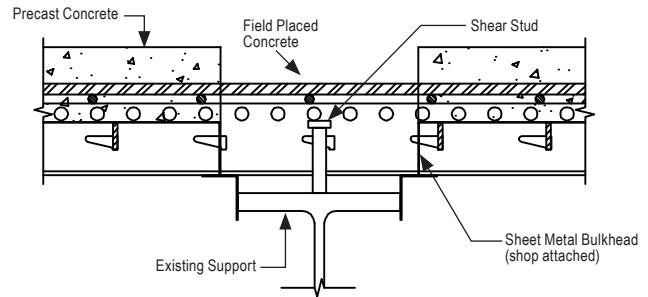


Typical Section Through Exodermic Deck

Cast-In-Place Details

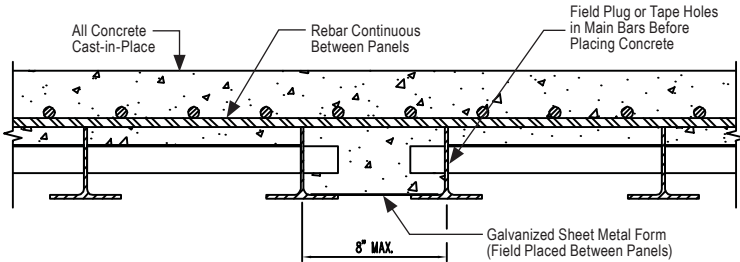


Precast Details



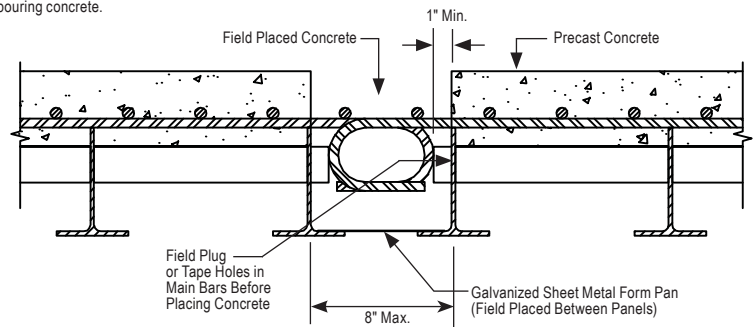
Haunch Detail

(Other haunch forming options possible)



Haunch Detail

(Other haunch forming options possible)



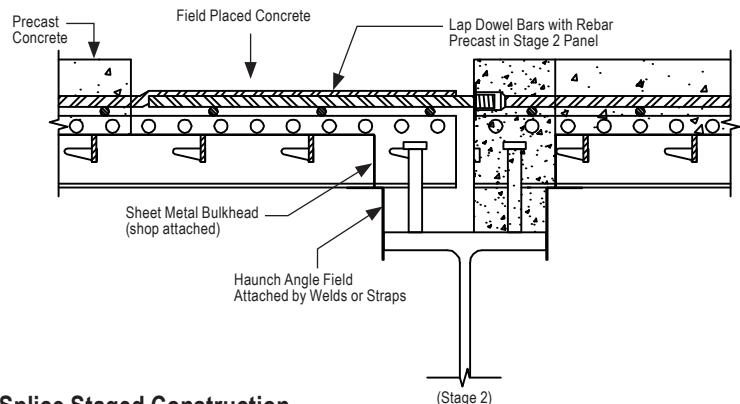
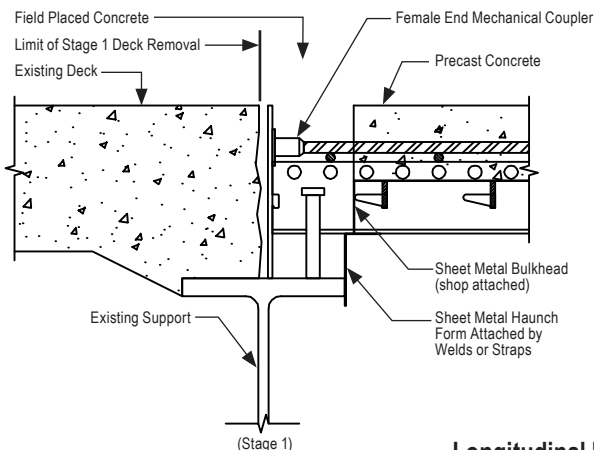
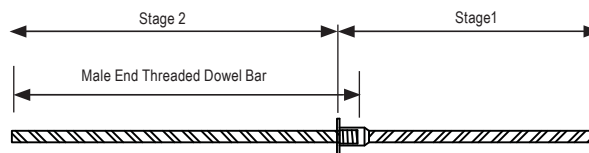
Omit distribution bars over stringers as necessary to provide clearance for shear studs and leveling devices. Leveling devices not show for clarity.

For haunch heights less than 1.5 inches, place high strength pourable grout up to the bottom of the WT Main Bar prior to pouring concrete.

Typical Connection Between Panels

Typical Connection Between Panels

(Rebar bent 180 degrees as shown for 5 inch and taller WT Main Bars. Bend 90 degrees for 4 inch tall WT Main Bars)

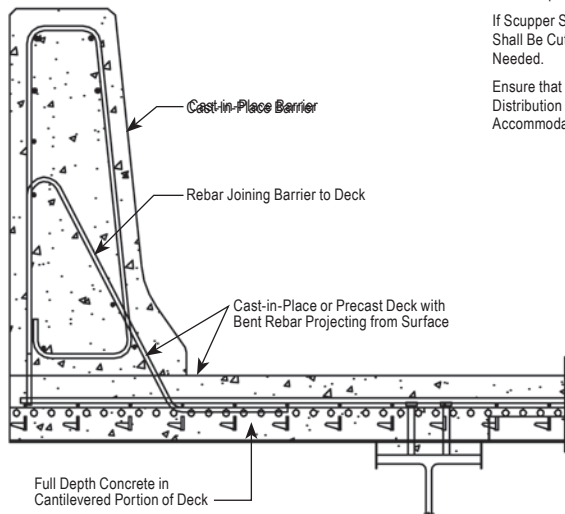


Longitudinal Panel Splice Staged Construction

Miscellaneous Details

Other Barrier Details Available Upon Request.

Details for Barriers Used with Full and Partial Depth Grid Systems Similar



Concrete Barrier

Example Shown with Exodermic® Deck

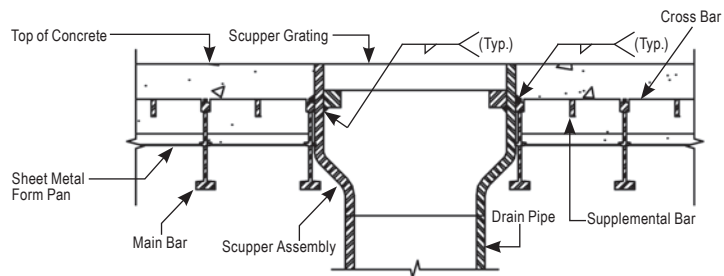
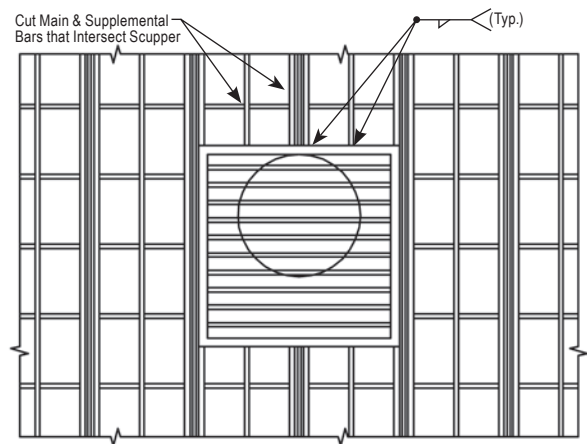
Other Scupper Details Available Upon Request.

Optimal Detail When Scupper Intersects the Least Number of Main Bars Possible.

If Scupper Does Not Fit Tight with Edge of Main Bars, a Shim or Splice Bar Can Be Used to Bridge Small Gaps.

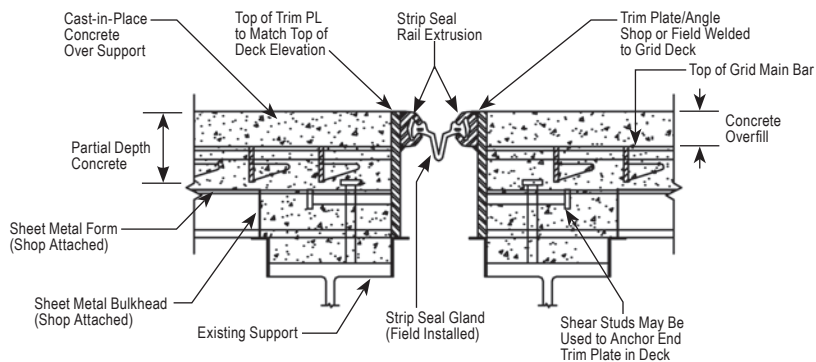
If Scupper Size or Location Requires, Cross Bars Shall Be Cut and Welded to Scupper Assembly as Needed.

Ensure that Details Provide Adequate Distribution to Supports When Cutting Bars to Accommodate Scuppers or Other Details.



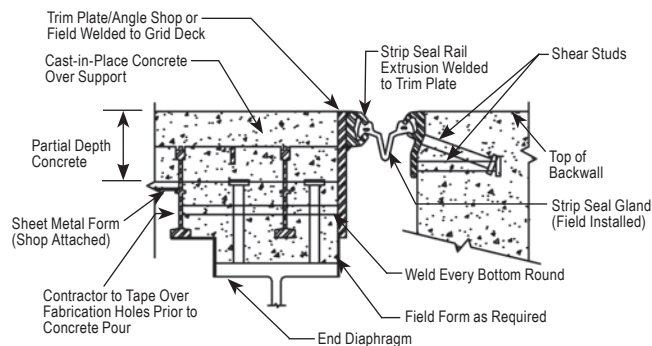
Scupper Detail

Example Shown with Partial Depth Concrete Filled Grid



Typical Mid-Span Expansion Joint

With Main Bars Parallel to Structure
Partial Depth Concrete Grid Shown. Full Depth Similar with Form Pans Placed at Bottom Flange



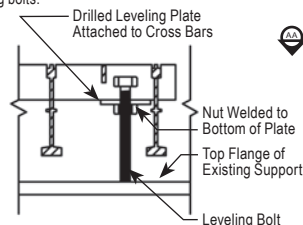
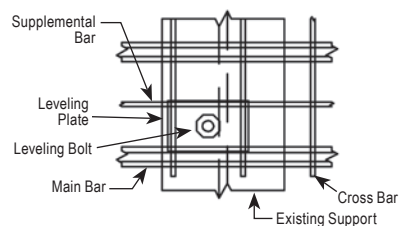
Typical End Span Expansion Joint Detail

With Main Bars Perpendicular to Structure
Partial Depth Concrete Grid Shown. Full Depth Similar with Form Pans Placed at Bottom Flange

Use two per supporting beam per panel for typical precast panels up to 9' wide. Devices to be located on first interior main bars from each panel edge.

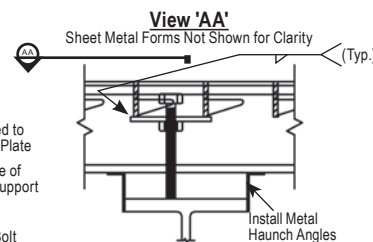
For cast-in-place applications use three per supporting beam per panel for typical panels up to 9' wide. Devices to be located on first interior main bar and on a bar at or close to the panel centerline.

When positioning the grid panel horizontally, use a crane to keep the full dead load off of the leveling bolts.



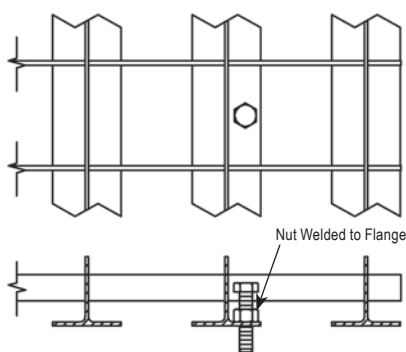
Leveling Detail

In Lieu of Welding a Nut to the Bottom of Plate, The Plate May Be Drilled and Tapped

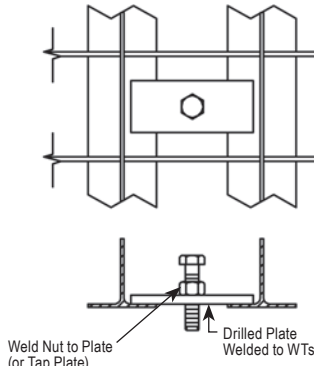


Section 'A'

Supplemental Bar Not Shown for Clarity



Preferred Detail
Bolts Can Be Located on Either Side of the Web of a Main Bar



Alternate Detail

Exodermic Height Adjustment Details

Filled Grid Height Adjustment Details



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