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CASE STUDY: SUBSTITUTION OF EXODERMIC DECK FOR CONCRETE FILLED GRID ON A VERTICAL LIFT HIGHWAY BRIDGE

by

Neal H. Bettigole, P.E.

Exodermic Bridge Deck Institute, Inc.

Westwood, New Jersey 07675

Case Study: Substitution of Exodermic Deck For Concrete Filled Grid on a Vertical Lift Highway Bridge

Neal H. Bettigole, P.E.

Abstract: Almost ten years ago a new vertical lift bridge was designed to connect Troy and Green Island, New York following the collapse of an old structure over the Hudson River. The design incorporated the use of four separate counterweights, which produce the lowest possible profile for the towers, as well as the design of rigid towers without vibration problems. The lift span is a multiple stringer deck structure 200 feet long and 66 feet wide. The deck consists of a 5 inch concrete filled weathering steel grid, with a 2 inch thick high-density concrete overlay.

The paper presents the effect which would have occurred on the design, if the choice had been an exodermic deck instead of the concrete filled and overlayed grid deck, the State-of-the-art for grid decks at the time.

Exodermic deck, developed after the design and construction of the bridge had been completed, would have effected significant cost savings for foundation, structural steel in towers and lift span, as well as counterwright, rope and operating machinery fabrication and construction.

* *

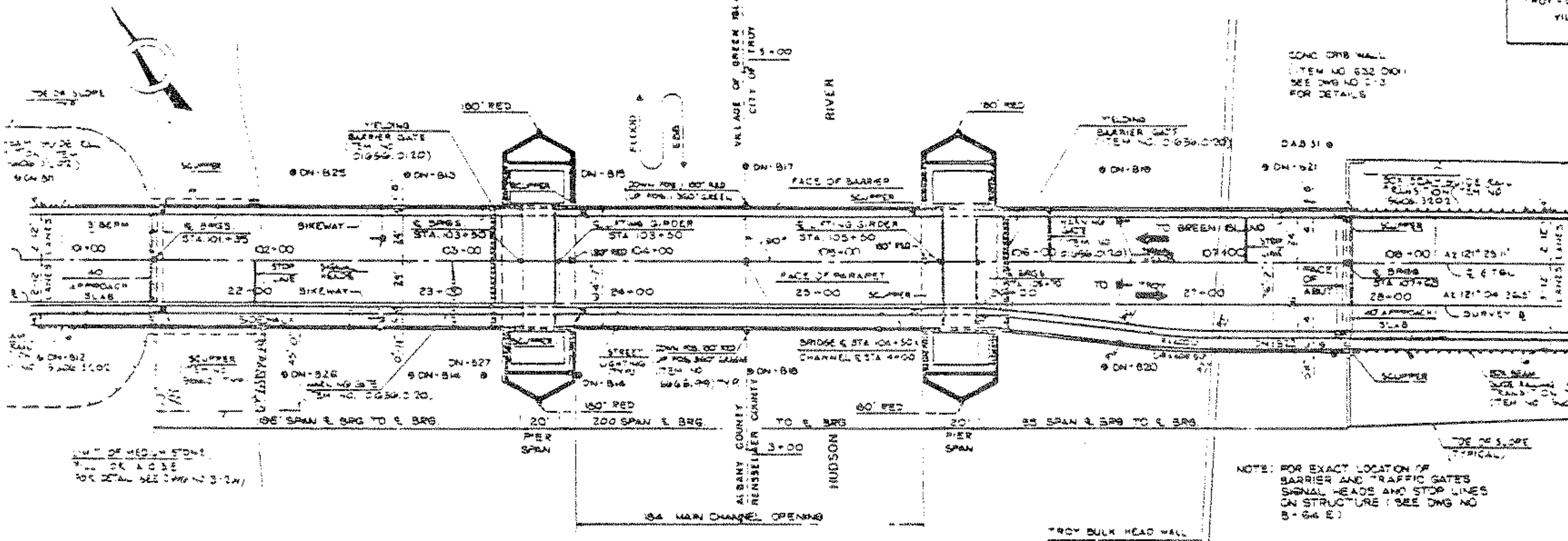
General:

The design of a movable bridge, or for that matter any other bridge, requires that the structural engineer have an early description concerning all of the elements in order to compute dead load, live load, and impact which the structure shall sustain.

D98121

FED. RD. REG. NO.	STATE	FEDERAL AID PROJECT NO.	SHEET NO.	TOTAL SHEETS
M-BRM-T497(4) ER-132(C)	NEW YORK		89	221

TROY-GREEN ISLAND BRIDGE AND APPROACHES
VILLAGE OF GREEN ISLAND, ALBANY CO.
CITY OF TROY, RENSSELAER CO.



NOTE: FOR EXACT LOCATION OF BARRIER AND TRAFFIC GATES SIGNAL HEADS AND STOP LINES ON STRUCTURE (SEE DWG NO B-64 E)

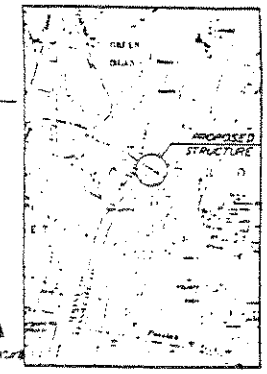
PLAN

SCALE: 1" = 30'-0

BORING KEY

DN-826

LOCATION — BORING No.



LOCATION PLAN

1" = 2000'

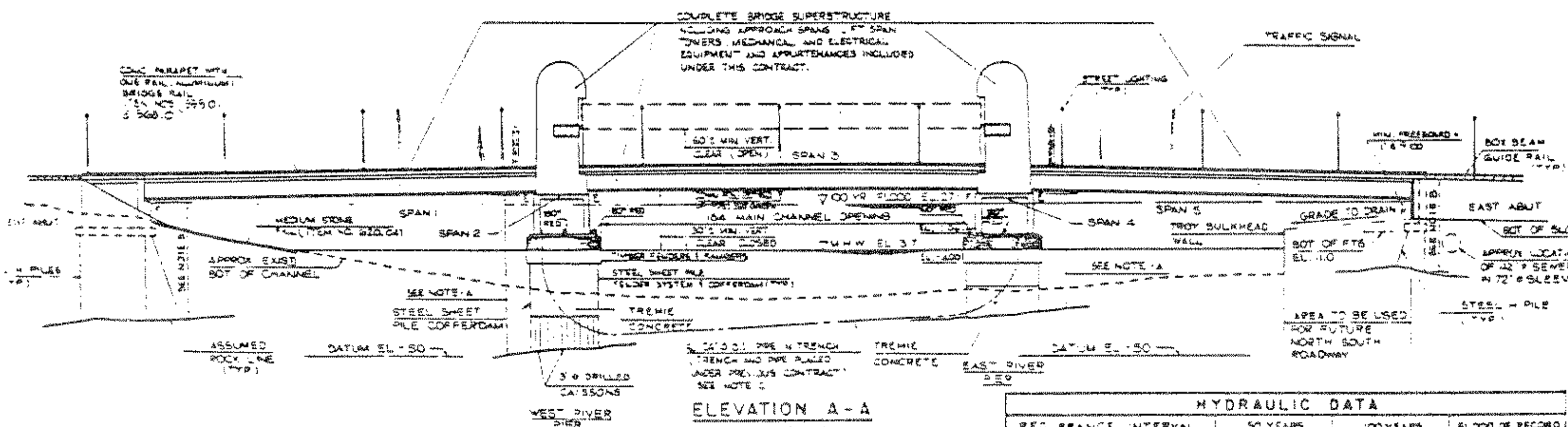
FROM N.Y.S. D.O.T. PLANIMETRIC 7.5 MINUTE SERIES TROY SOUTH QUADRANGLE

NOTE 1. RIVER PIERS CONSTRUCTED TO EL. 30.00 BY OTHERS UNDER A PREVIOUS CONTRACT (D 96103) TOWERS ABOVE EL. 30.00 AND APPURTENANCES INCLUDED IN THIS CONTRACT.

NOTE 2. ABUTMENTS, PEDESTALS AND WINGWALLS CONSTRUCTED UNDER A PREVIOUS CONTRACT (D95976)

NOTE 3. CONTRACTOR SHALL PLACE REQUIRED SUBMARINE CABLE IN THE PREVIOUSLY CONSTRUCTED 24" O.I. PIPE CROSSING.

NOTE 4. FOR INDEX TO BRIDGE DRAWINGS AND QUANTITIES SEE DRAW NO B-5E



ELEVATION A-A

SCALE: 1" = 30'-0

HYDRAULIC DATA			
RECURRANCE INTERVAL	50 YEARS	100 YEARS	FLOOD OF RECORD
PEAK DISCHARGE	196,000 CFS	218,000 CFS	215,000 CFS
HIGH WATER ELEVATION	24.7	27.1	25.4

CONTRACT III

TROY-GREEN ISLAND BRIDGE AND APPROACHES

P.I.N. 1700.18

B.I.N. 1-09591-0

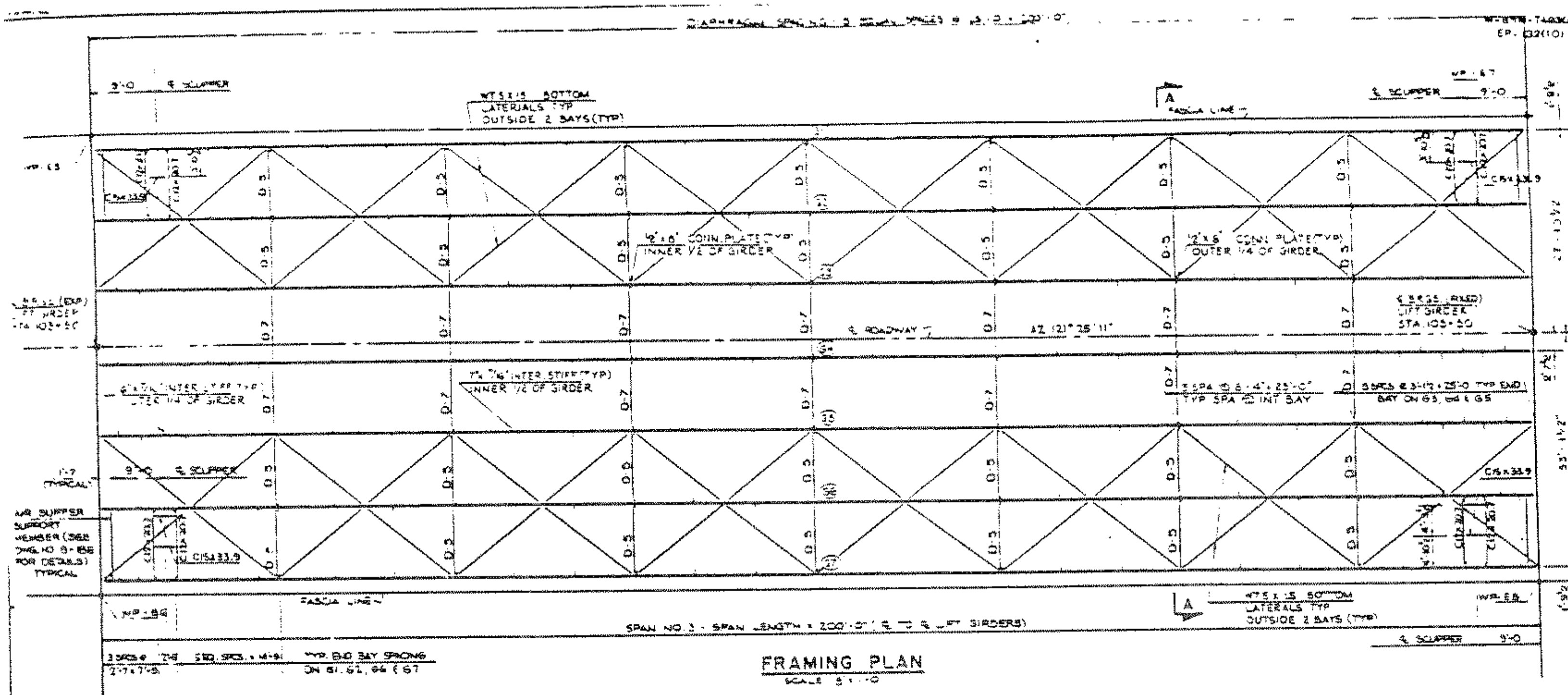
EAST CHANNEL STRUCTURE
BRIDGE PLAN & ELEVATION

DATE MARCH 1979 | SCALE AS SHOWN | DWG NO B-1E

H. H. BETTIGOLE CO.
CONSULTING ENGINEERS — NEW YORK

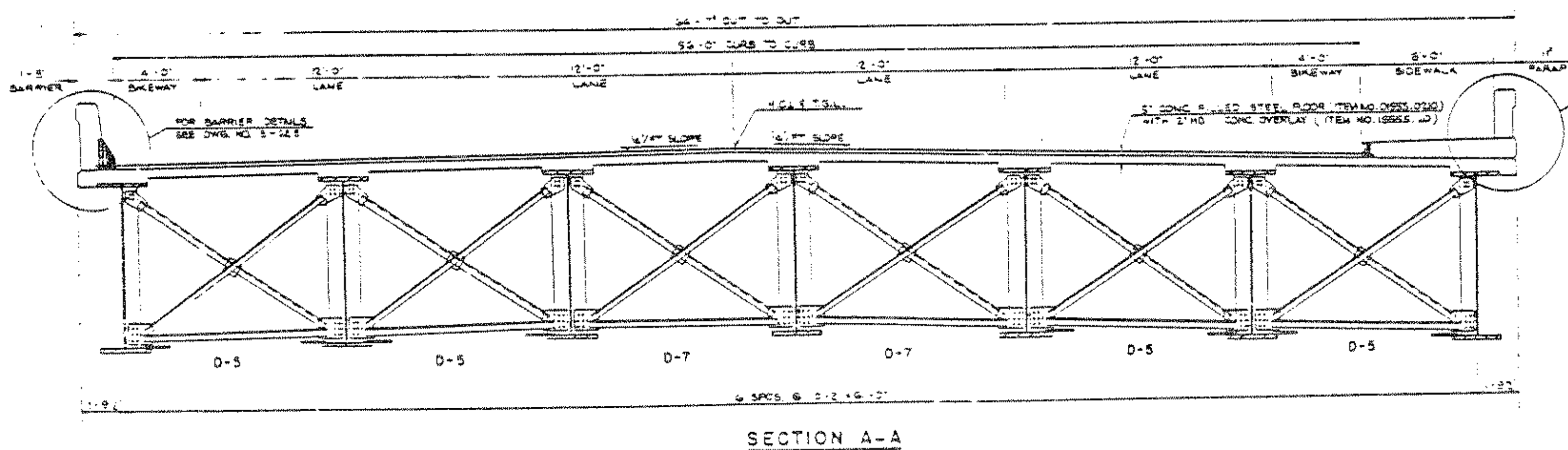
NEW YORK		99

TROY-GREEN ISLAND BRIDGE AND APPROAC
VILLAGE OF GREEN ISLAND, ALBANY CO
CITY OF TROY, RENSSELAER CO



FRAMING PLAN

SCALE 1/8" = 1'-0"



SECTION A-A

1. FOR DIAPHRAGM DETAILS SEE DWG NO 5-6E & 5-21E
2. ALL STEEL SHOWN ON THIS SHEET SHALL BE SELF WEATHERING A588 STEEL
3. FOR LOCATION OF WORK POINTS SEE DWG NO A4
4. FOR DETAILS OF STRINGERS SEE DWG NO 5-4E
5. FOR DETAILS OF LIFT GIRDER SEE DWG NO 5-6E & 5-17E
6. FOR STEEL FLOOR DETAILS SEE DWG NO 5-6E & 5-6E
7. FOR ADDITIONAL SCUPPER DETAILS AND SUPPORT DETAILS SEE DWG. NO. 5

CONTRACT III

TROY-GREEN ISLAND BRIDGE AND APPROACHES

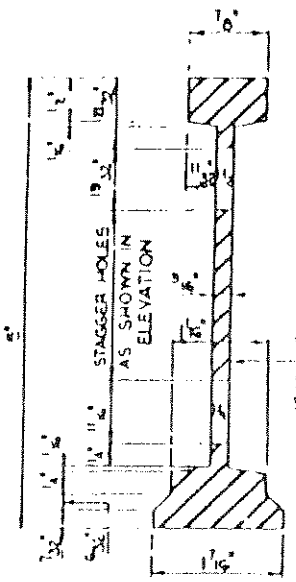
P.I.N. 170018

B.I.N. 1-09591-0

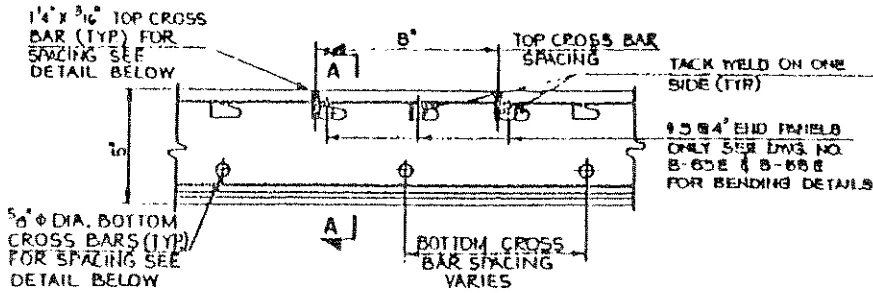
EAST CHANNEL STRUCTURE
FRAMING PLAN & DECK SECT
SPAN 3

DATE MARCH 1979	SCALE AS SHOWN	DWG NO 8

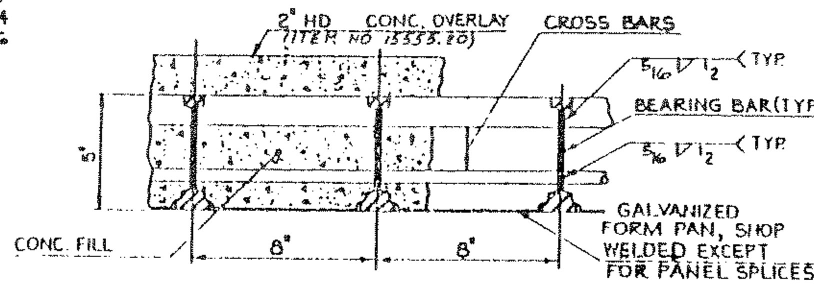
H. H. BETTIGOLE CO.
CONSULTING ENGINEERS



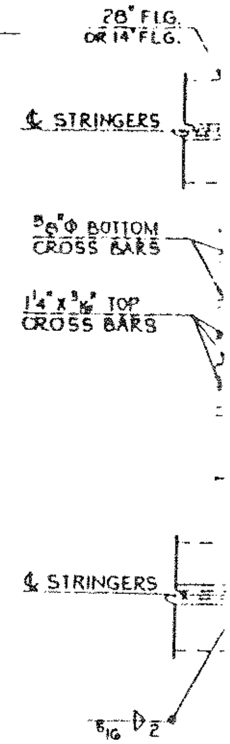
BEARING BAR DETAIL
FULL SCALE



ELEVATION
SCALE: 3" = 1'-0

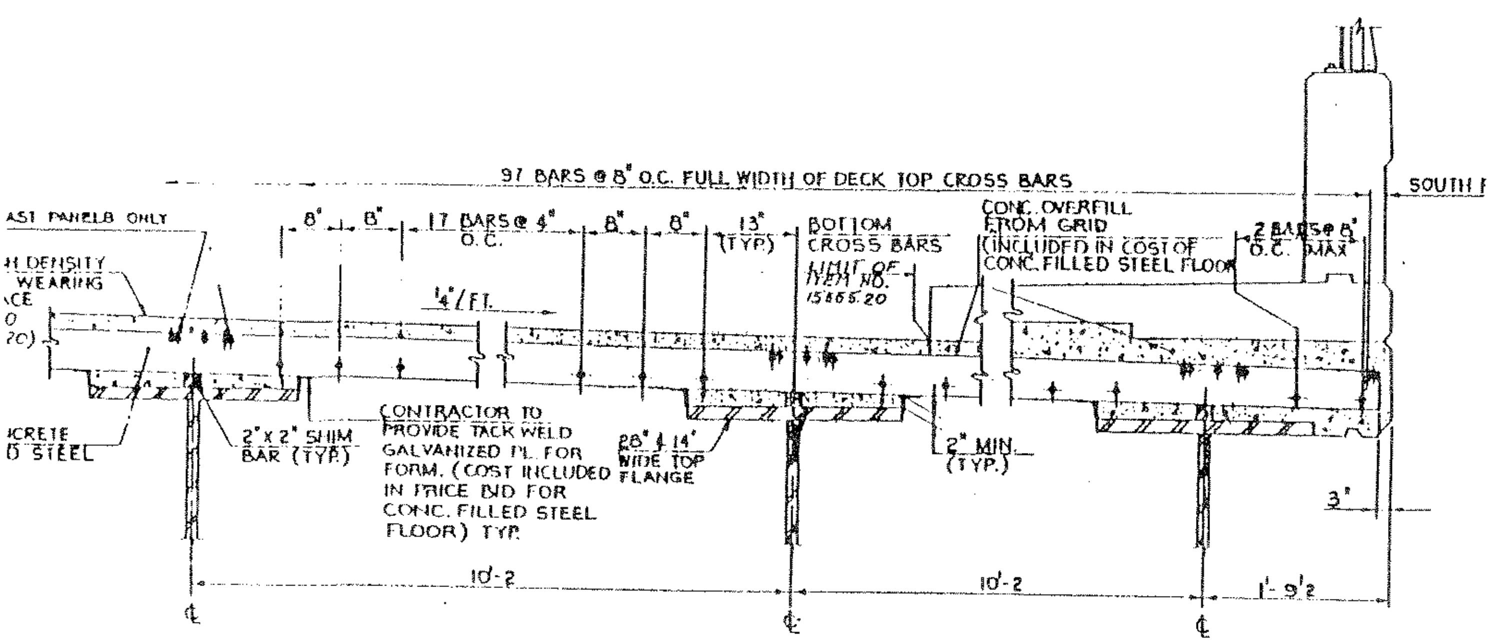


SECTION A-A
SCALE: 3" = 1'-0



5" I-BEAM INTERLOCK SYSTEM DETAILS
AS SHOWN

TY



SECTION C-C
LONGITUDINAL CROSS BAR SPACING

The purpose of any bridge is to carry live load. The definition of live load might be expanded to include utility installations of all kinds, as well as vehicular and pedestrian traffic. The dead load which a structure carries is, in most cases, simply a necessary burden. Even in cases in which the contribution which dead load makes to vibration dampening is a consideration, there may be methods of accomplishing this result by other than maximizing dead load.

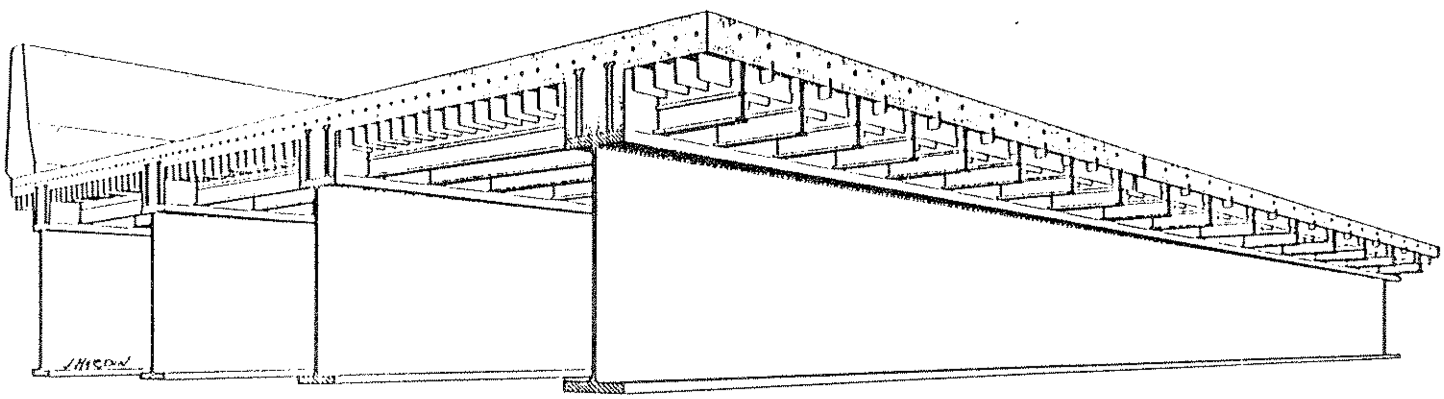
In a vertical lift bridge every pound of dead load in the moving span requires the addition of another pound in the counterweights. In addition to the counterweights, of course, additional dead load adds more friction force to be overcome by the machinery. The machinery design itself sustains the loads imposed by the lift span and counterweights, and is therefore quite cost-sensitive to the dead load of the lift span.

Exodermic Bridge Deck:

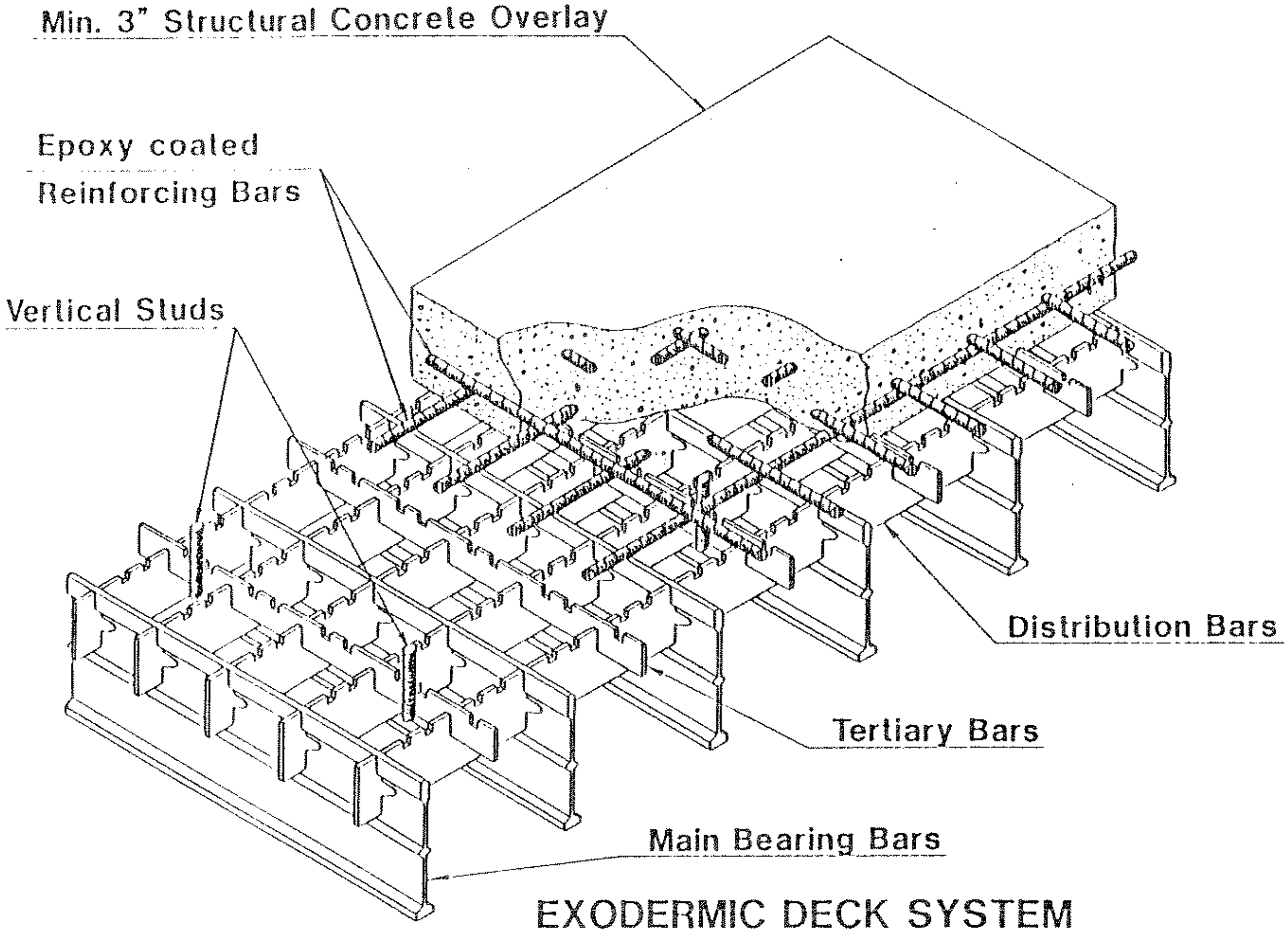
Exodermic bridge deck is a design concept that combines steel grid and reinforced concrete in a unique way. It maximizes the use of the compressive strength of concrete and the tensile strength of steel. Based on working stress principles, the design positions stress raisers in the steel grid at or close to the neutral axis of the composite deck.

The deck comprises a reinforced concrete component on top of, and bonded to, a welded steel grid component. The dimensions and properties of each component of the deck are selected for the specific bridge by the design engineer.

The design is composite within itself and can be made composite with most types of existing or new bridge framing systems. The concrete component embeds a two-way web of epoxy-coated reinforcing bars and between 1/2 and 3/4 inches of the tertiary bars of the coated steel grid. Vertical studs



EXODERMIC DECK SYSTEM



EXODERMIC DECK SYSTEM

M.R., J.R.H

welded to the tertiary bars of the steel grid are also embedded in the concrete component of the deck.

Horizontal shear transfer is developed through the partial embedment of the tertiary bars, in conjunction with the vertical studs.

All steel used in the design may be protected from corrosion to extend the useful life of the individual components to match the extended fatigue life afforded by the design. Embedded bar reinforcement must be fusion bonded epoxy coated to provide such protection.

Many distinct advantages stem from the design concept of exodermic bridge deck. Among them:

1. Lightweight - Primary factor in new design, as well as rehabilitation. In rehabilitation projects, this translates into higher live load capacity where existing superstructure requires only normal maintenance, or permits maintenance of original design live load on degraded superstructures without need for extensive reinforcement or replacement.
2. Prefabrication - Exodermic modules can be made indoors or out, all year-round, on- or off-site. Prefabrication permits building the entire deck in suitable sections in advance of or in conjunction with preparatory work on old bridge rehabilitation. For new bridge projects, modules can be fabricated while substructure and framing construction are completed.

   Prefabrication itself generates equally significant advantages:
3. Quality Control - The quality of prefabricated sections is assured before installation, no lost time or added expense due to faulty material or

incomplete construction. Concrete shrinkage occurs prior to placement on the bridge.

4. Reduced Construction Time - Construction time costs and its consequent liability exposure are significantly reduced.
5. Ease of Installation - The deck can be installed continuously with no waiting or delay time. Individual sections are easily replaced. No underside access to deck required during installation.
6. Improved Traffic Maintenance - An increasing concern at all public levels, traffic delay and congestion is minimized. Exodermic's speed of installation cannot be matched by any in-place construction, or other precast system.

   Integral Wearing Surface - The wearing surface is integral with the design and will accept a supplementary wearing surface or overlay if desired.
7. Cost Effective - On new bridge construction, all cost factors considered, exodermic provides a lower cost than any other accepted bridge deck design for any given live load capacity.
8. Fatigue Life - Exodermic is the only bridge deck which is not considered subject to fatigue damage.

Factors Involved in Deck Substitution:

The substitution of exodermic deck for the deck which was used on the Troy Green Island Bridge, would result in a reduction of 550,000 pounds in the weight of the lift span, or 19% of the total weight of this span. This, of course, means that the total moving load to be supported by the main trunnion bearings would be reduced by 1,100,000 pounds.

To estimate the dollar saving of such a major reduction in the moving weight of a vertical lift bridge would not be possible without a complete design. However, some examples of the effect serve to illustrate that a very significant savings of the total cost would result from the reduction of 19% in the total weight of the lift span. For instance, on the Troy-Green Island Bridge there are 48 wire ropes, 12 in each corner of the span, which pass over sheaves to lift the bridge. A reduction from 12 ropes to 10 ropes in each corner would not only reduce the dimensions of the sheaves, but would also result in a reduction in the number of rope connectors, the size of the deflector castings, the size of the main trunnion shafts and bearings. The design of the air buffers would be reduced and, of course, the entire operating machinery train would be reduced proportionately as well.

It is estimated that the additional cost of exodermic bridge deck as compared to a filled grid would be approximately 4 to 5 dollars per square foot. In the case of the Troy-Green Island Bridge this would be reduced by the cost of the 2 inch Iowa high density concrete overlay and the epoxy bonding compound which was placed in the field prior to installation of the overlay. Bids for the overlay varied from 1.50 to 7.00 per square foot, the low bidder's price was 6.50 per square foot.

<u>Deck Substitution Effect on Cost</u>:

In attempting to analyze the effect on construction cost of using exodermic deck in place of the deck which was used, there are difficulties based on the variation in bid unit prices. One illustration will serve to illustrate the point: Item 01555.0210, concrete filled grid, of which 13,000 square feet were required. The low bidder's price was $15 per square foot, however, the other seven bidder's prices were, in ascending order of total bid, $32, $30, $30, $15, $36, $30, and $45. This illustrates why using bid prices in order to compare materials or structural systems requires careful consideration and not simple arithmetic comparison. It would appear to me that the two bidders which quoted $15 per square foot for the concrete filled grid, used the price which was probably the purchase cost of the grid alone FOB the job site, and not the cost of the grid installed on the girders and filled with concrete. The epoxy bonding compound and the high density wearing surface were of course not part of this unit price, and the two $15 bidders quoted 6.50 and 1.50 per square foot for the overlay.

Conclusion:

In my opinion, the substitution of light weight exodermic deck, which would have produced a surface which was indistinguishable from that which presently exists on the bridge, would have been at a saving of approximately $1,000,000. A breakdown of this savings is estimated as follows:

Foundation Construction	$ 200,000
Structural Steel in Towers and Girders	400,000
Wire Rope and Sockets	40,000
Rope Connectors, Deflectors and Miscellaneous Castings	65,000
Cwt. Sheaves, Shafts and Bearings	140,000

Operating Machinery, Air Buffers, etc.	150,000
Counterweights	20,000
	1,500,000

Divided by the square foot area of the bridge deck, this savings is $75 per square foot, which, in the lingo of cost benefit analysis, is astronomical since, as we have already seen, there would have been at most an added cost of $2.00 per square foot, or a total added cost of $25,000 for the use of exodermic bridge deck. In addition, the benefit of more than doubling the strength of the deck is not quantified.