The Use of a Straddle Bent Pier with a High Performance Steel Integral Cap Innovative Design Solutions for Complex Geometry I-235 Braided Ramps

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BIOGRAPHY

Ahmad Abu-Hawash is the Chief Structural Engineer with the Iowa Department of Transportation. Mr. Abu-Hawash received his BS degree in Civil Engineering from the University of Iowa and his MS degree in Structural Engineering from Iowa State University. He has over twenty years with the Iowa Department of Transportation in construction and bridge design.

Louie Caparelli is a Senior Bridge Engineer and Professional Associate with HDR Engineering in Omaha, Nebraska. Mr. Caparelli graduated from Iowa State University with BSCE and MSSE degrees and has twenty-two years of professional experience.

Patricia Schwarz is a Transportation Engineer with the Iowa Department of Transportation. She has 8 years of preliminary bridge design experience. She received a BS degree in Civil Engineering and a MS degree in Environmental Engineering from the University of Iowa.

Norm McDonald is the Bridge Engineer for the Iowa Department of Transportation. He graduated from Iowa State University with a BS in Construction Engineering. Mr. McDonald is a member of AASHTO Sub-committees on Bridges and Structures and serves on technical committees T-9, T-14, and T-17.

SUMMARY

Functional and economical constraints steered the Iowa Department of Transportation into utilizing a non-traditional steel bridge type for the design of several braided ramps on I-235 in Des Moines. The innovative solution featured straddle bent piers with HPS integral caps. The integral steel pier caps are designed as redundant structural systems composed of twin I-girders. The use of this structural system allowed Iowa DOT to meet its budgetary constraints.

THE USE OF A STRADDLE BENT PIER WITH A HIGH PERFORMANCE STEEL INTEGRAL CAP
INNOVATIVE DESIGN SOLUTIONS FOR COMPLEX GEOMETRY
I-235 BRAIDED RAMPS

INTRODUCTION

The reconstruction of the I-235 corridor in Des Moines, Iowa, required the use of innovative and non-traditional bridge types to overcome economical, functional, and environmental constraints. The I-235 reconstruction project in Des Moines is a six-year project that was started in 2002 and is expected to be completed in 2007. In addition to widening the existing facility to six continuous lanes, adding auxiliary lanes and upgrading all the interchanges, all structures located within the I-235 corridor are to be replaced or rehabilitated. The 426 million dollar project includes 39 new or replacement steel bridges and 26 concrete bridges.

Similar to other state Departments of Transportation (DOT's), Iowa DOT was dealing with limited transportation infrastructure budget due to a nation-wide economic slow down and lower revenues. The limited funding available made it imperative that the bridge replacement structures be economically sound and cost effective over the expected life span. Therefore, the economic analysis considered not only the initial construction cost, but also the long-term maintenance cost.

As in any other freeway rehabilitation effort in metropolitan downtown areas, transportation agencies are faced with functional and environmental constraints in addition to the economic factors. Constraints include limited right-of-way (ROW), complex geometry, existing bridges and structures with historical significance, traffic congestion, and other environmental issues. Given the issues, Iowa DOT engineers were assigned the task of developing conceptual designs for structures that provide grade separation between intersecting freeway/local road ramps, commonly known as braided ramps. The use of a braided ramp concept was deemed necessary at several interchange locations in the downtown area.

Initially, cast-in-place reinforced concrete tunnel structures were identified as potential solutions at these locations. After further evaluation, the Iowa DOT concluded that the use of tunnels at these locations would be cost prohibitive. A combination of limited vertical clearance and excessive span length eliminated the single span steel bridge option from consideration, and the horizontal alignment of the ramp below the bridge excluded the use of a conventional pier. Thus, other solutions were investigated.

With some fine-tuning of the roadway alignments, steel bridges featuring straddle bent piers with High Performance Steel (HPS) integral caps were chosen as the solutions for two of the braided ramps and steel bridges with standard piers were utilized at the other two braided ramps after reworking the braided alignment geometrics. The integral steel pier caps are designed as redundant structural systems composed of twin HPS I-girders. With design near completion, two of these structures will be let by the end of 2005 and constructed in 2006 and 2007.

Most often, there is some of degree of risk associated with the use of non-traditional bridge types due to the limited construction experience available locally, unproven details, and the potential for high future maintenance. But with the recent advancements in steel design, fabrication, and construction in the form of HPS, many of the risk factors can be reduced or eliminated thus increasing the owner’s comfort level. A properly designed and detailed steel section utilizing HPS exhibits characteristics such as increased toughness, improved weldability, and better corrosion resistance. These characteristics can increase the owner's confidence when using a non-traditional bridge type.

The use of an innovative structural system provided a unique solution to the complex, braided ramp problem and allowed the Iowa DOT to meet its budgetary constraints. It is expected that the bid cost for these structures will be very competitive. Furthermore, these bridges will incur lower future maintenance cost.

PRELIMINARY BRIDGE TYPE SELECTION PROCESS

In this section, the authors will attempt to summarize the structure type selection process for the braided ramp separation structures at the following locations in downtown Des Moines:

1. Ramp University C: Entrance ramp from University Avenue to WB I-235
2. Ramp E15D: Entrance ramp from East 15th Street to EB I-235
3. Ramp 7B: Exit ramp from EB I-235 to 7th Street
4. Ramp 5D: Entrance ramp from 5th Street to EB I-235

The braided ramp locations are shown below in Figure 1.

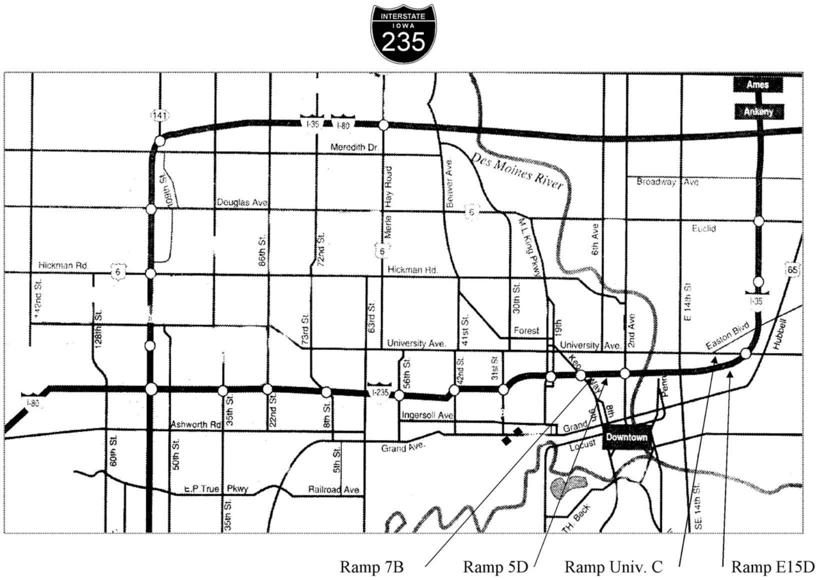


Figure 1 - Braided Ramp Location Map

Constraints

Closely spaced urban interchanges contributed to the complex geometric conditions in the ramp areas. Due to the close interchange spacing, the mainline exit and entrance ramps from adjacent interchanges were required to cross each other. The adjacent urban development in the Des Moines downtown area affected the available ROW, forcing the horizontal alignment of the braiding entrance and exit ramps into a tight area close to the mainline.

From the bridge perspective, the horizontal constraints created ramp alignments with high skews at the ramp crossings. The high skews, ranging from 71 to 81 degrees, restricted the allowable locations for placement of substructure elements. Traditional piers or abutments behind mechanically stabilized earth (MSE) walls required span lengths ranging from 260' to 330'. Steel girder depths sufficient to achieve 260'-330' span lengths would have considerable impact to the ramp vertical profiles. Furthermore, the horizontal constraints imposed by the braided ramp condition also presented many challenges to the ramp vertical profile designs. The braided ramp vertical profiles were required to meet existing and proposed roadway tie-in points while staying within the allowable Iowa DOT guidelines for geometric design criteria for maximum allowable grade, vertical curves (K), and minimum desired vertical clearance of 16'-6".

To achieve the desired minimum vertical clearance, the profiles for the lower ramps were forced into embankment cut conditions. As depth of cut increased to levels below the water table, the concern for the ability to collect and drain the groundwater had to be considered. In many areas the large cuts also required temporary or permanent soil retainment to allow for traffic staging or to stay within ROW limits.

Budget constraints also had to be considered in the bridge type selection process. In the Des Moines urban area, higher local labor costs, restrictions caused by heavy roadway traffic, and tight working conditions result in bridge costs that are higher than the state average. Using costs from I-235 bridges constructed in 2002 as a baseline, the average unit structure costs for steel bridges was estimated and incorporated into the budget. It was important to keep the proposed designs for the braided ramps in this range of estimated unit cost if possible. Estimated braided ramp bridge costs that would be significantly higher than the estimated cost budgeted, would need to be addressed with respect to the overall corridor budget.

Preliminary Structure Type Selection

In the early planning stages, steel girder bridges were planned for the I-235 braided ramp locations. During the preliminary development of the ramp profile grades and horizontal alignments, in at least one of the braided ramp locations, vertical profile grades meeting the site geometric constraints were not expected to be sufficient. The depth of steel girder superstructure required for a traditional steel bridge to achieve the horizontal clear span needs would have violated the desired 16'-6” vertical clearance.

At this point in the development, a reinforced concrete frame "tunnel" bridge was thought to be an economical solution, and preliminary tunnel bridge design was completed on the braided Ramp E15D. MSE walls were proposed to retain soil adjacent to the lower ramp at the entrance and exit of the tunnel. A consultant was contracted to determine the design and construction needs, and to complete the tunnel final design.

The consultant scope of design work and construction cost estimate for the tunnel design was much higher than expected at an estimated cost of $350-$525 per square foot of tunnel. Many factors contributed to the high cost of the tunnel solution at this site, such as a needed electrical system, lighting system, possible mechanical ventilation system, fire protection, automatic traffic warning signals, soil overburden loading, large excavation, and drainage of groundwater. Several of these elements were also complicated and expensive to design.

Due to the high cost of the tunnel solution, Iowa DOT road design engineers were asked to review all of the braided ramp alignments to see if the skew of the crossing could be improved. On two of the braided ramp sites, Ramps C and E15D, Iowa DOT road design and preliminary bridge design engineers were able to develop an alternate ramp alignment and profile that would allow the use of traditional type steel Continuous Welded Plate Girder (CWPG) bridges. Although the use of HPS was considered on these two bridges, it was determined to be unnecessary during final design. These two bridges were let in August of 2004, with the accepted bid cost at $108 and $114 per square foot of bridge.

The tight ROW constraints at the two remaining braided ramp sites, Ramps 7B and 5D, to be let in October of 2005 precluded the realignment of the ramps to the extent that would allow the use of a traditional steel bridge type. Another concept that was considered but not selected at these two sites was the use of a steel tied arch bridge. This type of bridge could have provided the needed clear span within the vertical clearance restrictions, and appeared to be considerably less expensive than the tunnel option. However, the orientation and elevation of the steel tied arch with respect to the mainline made this option less desirable aesthetically.

Although the straddle bent pier is not new to the Iowa DOT, the concept was reintroduced on the Council Bluffs Interstate System (I-29) planning document. The Iowa DOT had contracted HDR to work through similar design and construction constraint issues for the I-29 project. To address the geometric constraints, HDR had proposed braided ramp solutions using a straddle bent pier with integral pier cap. Due to the similarities between I-29 and I-235 in terms of physical constraints, Iowa DOT asked HDR to investigate the feasibility of using this concept on Ramps 7B and 5D with emphasis on addressing redundancy of the integral cap design, construction methods, long-term inspection, and maintenance.

At the two remaining braided ramp sites, Ramps 7B and 5D, a straddle bent pier with an integral pier cap was determined to be workable and economical with the given site geometric constraints and the CWPG design. Unlike a traditional pier type, the configuration of the straddle bent pier allowed the placement of a pier at approximately the mid point of the ramp crossing. For the cases of Ramp 7B and 5D, a proposed straddle bent pier allowed a reduction in the main span length and steel girder depth. Reduced girder depth in turn allowed the ramp profiles to stay within desirable geometric criteria, meet required tie-in points, and reduced the amount of cut required to obtain the minimum vertical clearance.

HDR's construction cost estimate for the design concept, based on similar completed integral pier cap designs elsewhere, indicated that the design was economical at an estimated $115/sf. For Ramps 7B and 5D, the bridge type selection was changed to CWPG bridge with straddle bent pier and possible integral pier cap. Specifics of the alternatives and integral pier cap type selection would be further investigated in final design.

In the following sections of this paper, the use of straddle pier bent on Ramps 7B and 5D will be discussed in detail.

PIER CAP SELECTION

Matrix of Pier Caps Considered

To aid in the selection of the type of straddle pier cap to carry forward into final design for these braided ramp bridges, a matrix was prepared for various types of pier caps that would be feasible. Evaluation factors considered in the matrix included: cost issues, constructability issues, structural issues, maintenance issues, and aesthetic issues. The different types of pier caps considered in this study included:

1. Welded Steel Box Cap (set below the superstructure), see Figure 2
2. Twin "I"-Girder Cap (integral with superstructure), see Figure 3
3. Welded Steel Box Girder Cap (integral with superstructure), see Figure 4
4. Reinforced Concrete Cap (integral with superstructure), see Figure 5
5. Two-Stage Concrete Cap (integral with superstructure), see Figure 6

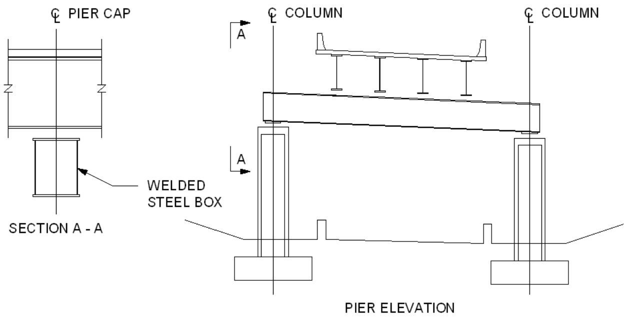
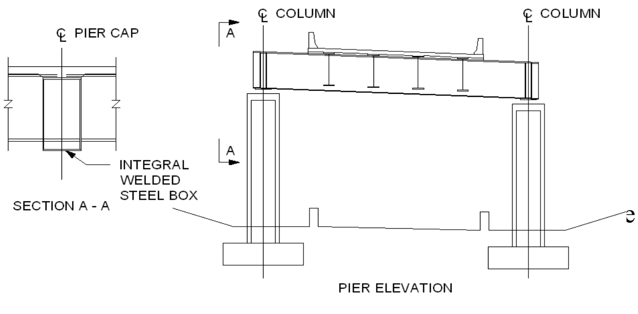


Figure 2 – Welded Steel Box Cap

The comparison matrix is shown in Table 1, and sketches of each option are presented in Figures 2 through 6. Although the Twin I-Girder Cap is not the least expensive option, the Iowa DOT selected it as the option to carry forward into final design as it fulfilled



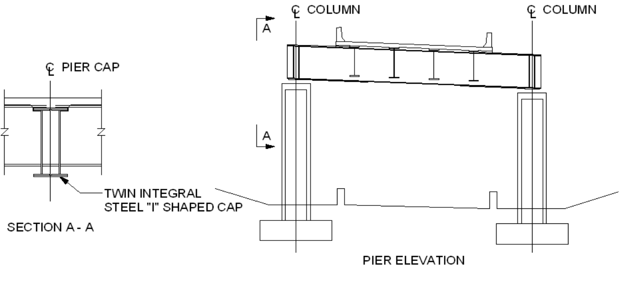


Figure 4 – Welded Steel Box Girder Cap (Integral)

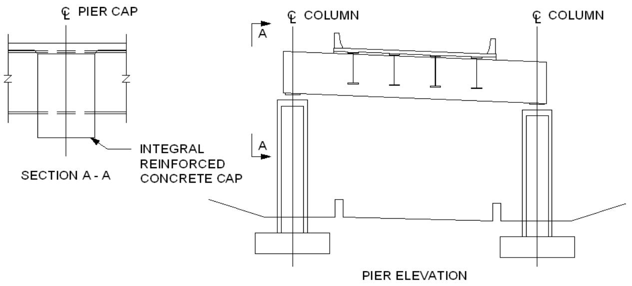


Figure 5 – Reinforced Concrete Cap (Integral)

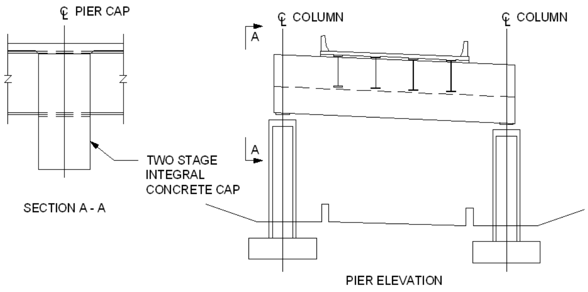


Figure 6 – Two Stage Concrete Cap (Integral)

their needs for a redundant system that would not be overly complicated to construct.

Background Of The Twin "I"-Girder Integral Steel Pier Cap

In years past, "fracture critical" elements were not as much of a concern amongst bridge designers or owners as they are today. There are numerous instances of single "I"-Girder integral steel pier caps or welded box girder integral steel pier caps (both of which are non-redundant systems) in the transportation system in this country. Some of these caps were designed prior to the presence of code requirements for fracture critical elements or were designed later and were designed for the fracture critical requirements of AASHTO. Most departments of transportation are now leaning away from designing fracture critical elements due to the extra cost of fabrication inspection, maintenance inspection, and due to the increased risk of having non-redundant systems in the transportation system.

HDR tackled the redundancy problem in integrally framed steel

OPTION	EVALUATION FACTORS				
	RELATIVE COST	CONSTRUCTABILITY	STRUCTURAL	MAINTENANCE	AESTHETICS
WELDED STEEL BOX CAP (DROPPED)	2.27	1. Simplified cap and girder handling. 2. Construction sequence closely resembles standard pier and girder construction. 3. Difficult to fabricate due to size of the box.	1. Fracture critical. (See Note 1) 2. Very good resistance to torsional forces. 3. Very good resistance to out of plane bending forces.	1. This design allows access to the interior of the box (by access hatch in box) so that the interior could be inspected. Dimensions of the box make it tight to inspect. (crawling through a confined space) 2. Weathering steel could be utilized; may be prudent to paint interior.	1. Not as aesthetically pleasing option as the integral cap options. 2. Bottom of cap will be at a lower elevation than other options. (e.g. less veritical clearance compared to the other options)
TWO I-GIRDER CAP (INTEGRAL) WITH BOLTED FLANGE COVER PLATES	1.85	1. Multiple pieces to handle and erect.	1. Redundant 2. Good resistance to torsional forces. 3. Good resistance to out of plane bending forces.	1. Can not access inside of cap to inspect (However, the hand hole cover plates could be removed for inspection, but this would only allow limited viewing). 2. If weathering steel is used, it is unknown if the inside of the cap will get wet and/or have a difficult time drying out; therefore, it may be prudent to paint the interior space.	1. Cover plate on bottom flange could be partial length or full length. Full length plate would be more acceptable from an aesthetic viewpoint. 2. Will bolted cover plate on bottom flange be objectionable?
WELDED STEEL BOX GIRDER CAP (INTEGRAL)	2.02	1. Fewer pieces to handle and erect than other options. 2. Workers will have to enter box during fabrication and construction.	1. Fracture critical. (See Note 2) 2. Very good resistance to torsional forces. 3. Very good resistance to out of plane bending forces.	1. This design allows access to the interior of the box (by means of a access hatch) so that the interior could be inspected. 2. Weathering steel could be utilized; may be prudent to paint interior.	1. No known objectionable details with respect to aesthetics.
REINFORCED CONCRETE CAP (INTEGRAL)	1.92	1. Steel girders will need to be shored while the cap reinforcing is tied and concrete for the cap is poured. 2. Construction time will be longer than the other options. 3. Different crews will need to coordinate during construction. 4. Closing the roadway below the cap would aid shoring requirements during construction.	1. Redundant 2. Good resistance to torsional forces. 3. Good resistance to out of plane bending forces.	1. Should not require any more maintenance than a typical pier cap.	1. No known objectionable details with respect to aesthetics. 2. Cap will be deeper than the other integral cap options, but there is still more than satisfactory vertical clearance available below the cap.
TWO-STAGE CONCRETE CAP (INTEGRAL)	1.00	1. Steel girders will be supported by phase 1 of the cap. 2. Difficult to handle due to the size and weight of phase 1 of the cap.	1. Redundant 2. Good resistance to torsional forces. 3. Good resistance to out of plane bending forces.	1. Should not require any more maintenance than a typical pier cap.	1. No known objectionable details with respect to aesthetics. 2. Cap will be deeper than the other integral cap options, but there is still more than satisfactory vertical clearance available below the cap.

Note 1:

A. Although this option is fracture critical, the box could be sized to minimize the fatigue stress range to an acceptable value and/or use HPS which has better toughness properties.
B. If A is not preferred, an investigation could be made into the feasibility of fabricating a fully bolted steel box or a "hybrid" where the top flange is welded to the webs and the bottom flange is bolted to the webs.
C. Both options would still be considered fracture critical though.

Note 2:

A. Although this option is fracture critical, the box could be sized to minimize the fatigue stress range to an acceptable value and/or use HPS which has better toughness properties.
B. Another option would be to bolt a cover plate to the bottom flange, if the redundancy of the bottom flange is the concern (However, webs may also be a concern).
C. If A and B are not preferred, an investigation could be made into the feasibility of fabricating a fully bolted steel box or a "hybrid" where the top flange is welded to the webs and the bottom flange is bolted to the webs.
D. All options would still be considered fracture critical though.

TABLE 1 - PIER CAP COMPARISON MATRIX

pier caps during the late 1980's by proposing to replace the conventional box-shaped or single "I"-shaped cap members with twin "I" shaped girders. The theory of the twin "I"-shaped cap is based upon the redundancy afforded by having two totally independent members to provide redundant load paths. If a fracture were to occur in one of the twin pier cap girders, the remaining twin girder is capable of supporting the entire live load and dead load prior to yielding. This twin "I"-shaped cap system provides a more robust structure with respect to redundancy compared to other single "I" shaped steel girders and welded steel boxes.

HDR has incorporated the twin steel "I" shaped integral cap system in bridges for several departments of transportation around the country, including the following:

- I-10/I-70 Interchange Mainline Viaduct in Phoenix, Arizona
  - Ten Double "I" Integral Caps
  - Opened To Traffic In 1989
- Airport Interchange in Reno, Nevada
  - One Double "I" Integral Cap
  - Opened To Traffic In Late 1980's
- I-80/I-480 Kennedy Freeway Interchange in Omaha, Nebraska
  - Six Double "I" Integral Caps
  - Opened To Traffic In 1996
- Viaduct Street Bridge, Boston, Massachusetts
  - Three Double "I" Integral Caps
  - Opened To Traffic In 2003
- US77 Over The BNSF Railroad Near Beatrice, Nebraska
  - One Double "I" Integral Cap
  - Opened To Traffic In 2000
- US281/Loop 604 Interchange, San Antonio, Texas
  - Two Double "I" Integral Caps
  - In Final Design

Additionally, there are basically two different variations of double "I" shaped integral steel pier caps that have been utilized by HDR, and these include the straddle bent type and the hammer head type. Photographs of a few of these installations are shown in Figures 7 and 8 for the straddle bent type of cap, and a drawing of the hammer head type is shown in Figure 9.

Figure 7 - Straddle Bent With Integral Steel Pier

Figure 8 - Straddle Bent With Integral Steel Pier

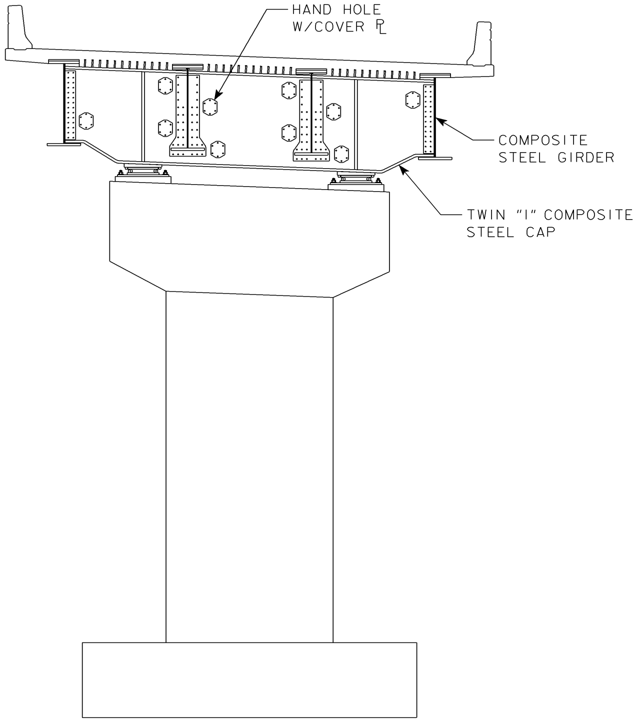


Figure 9 – Hammer Head Pier With Integral Steel Pier Cap

Special Considerations

To avoid framing congestion, bearings preferably should be located between the girders if the supports are located within the plan area of the superstructure. For this situation, torsional effects can usually be handled by treating the longitudinal loads as lateral loads being resisted by the bottom flanges of the pier cap girders. Torsional effects on the twin "I"-shaped girder pier caps due to differential rotations of the adjacent longitudinal girders have been found to be relatively insignificant.

Most of the pier caps on past projects have been supported by expansion bearings. At extreme temperatures, the centerline of the bearing will be eccentric with respect to the centerline of the twin pier cap system. Since the pier cap members are usually spaced approximately 12” to 18” apart, this minor eccentricity simply creates a vertical load differential between the twin cap members.

To maintain a redundant load path to the substructure, it is necessary for the multi-rotational bearings to lock-up after a predetermined amount of rotation occurs if fracture of one pier cap girder were to occur, to maintain a stable system. Lock-up has been easily achieved by the multi-rotational bearing manufacturers on past projects.

The connection between the superstructure girders and the web of the pier cap girder is provided by means of an end plate welded to the end of the superstructure girder and bolted to the web of the pier cap girder. Due to the prying action present on the end plate, some bolts are removed from the bolt pattern in the end plate near the top of the connection and near the web of the superstructure girders to reduce the bending stress and fatigue stress on this end plate. The decision on the number of bolts to remove is based on an analytical approach using hand calculations which has been verified by means of a finite element investigation.

Erection of the twin caps is obviously more complicated than erection of a single “I” shaped cap or a box girder. Hand holes with bolted cover plates are located to provide access where the end plates are bolted to the pier cap girder webs. On several past projects, full sized cardboard mock-ups have been constructed by the design engineers to ensure that the proposed hand hole locations provide access to the critical bolted connections. Neither the fabricators nor the erectors have had problems assembling the pier caps and girder splices to date.

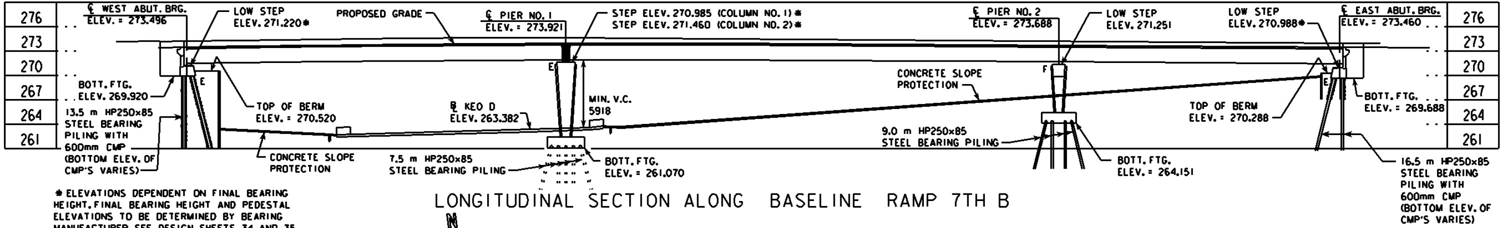
Selected Solution

The selected integral pier cap solution for the two braided ramp bridges consists of twin "I"-girders consisting of welded steel plates. To create an even more robust integral pier cap system, the pier caps were detailed utilizing HPS Grade 70W steel, but were designed limiting the yield stress to that allowed for Grade 50W steel. The robustness of the system is due to the fact that the HPS steel has enhanced fracture toughness and yield strength as compared to Grade 50W steel. Because the integral pier caps are important members in the structure, this extra measure adds to the safety of the system at very little cost with respect to the total cost of the bridge.

Figures 10 and 11 show the situation plans of the two braided ramp structures that will utilize the straddle bent piers with integral steel pier caps, and Figure 12 illustrates details of the integral pier cap.

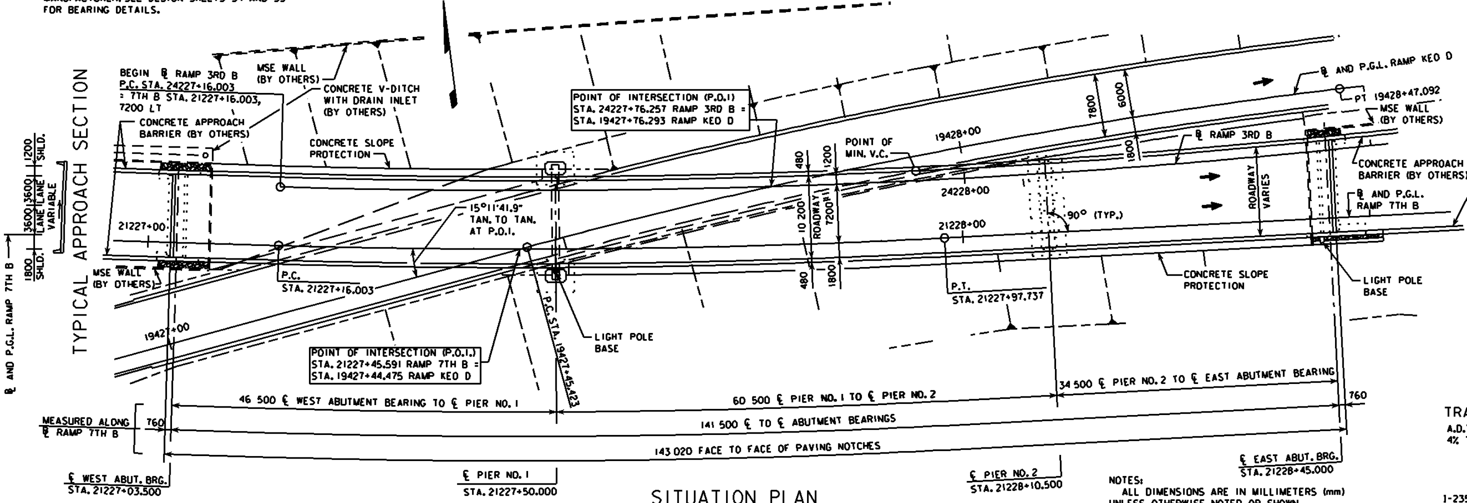
The top and bottom flanges of the pier cap girder have cover plates bolted to them on the cantilever portion that is outside the limits of the deck. The top cover plate is to prevent water from entering the system, and the bottom flange is cover plated to enable the system to act more like a closed box to aid in transferring longitudinal loads to the bearings.

BENCH MARK NO. 548, STA. 526+31.190, 43.37 RT. ℄ I-235 SURVEY, (X) ON CONC. SIGN BASE RT. S. LEG OF OVERHEAD SIGN EASTBOUND LANE FREEWAY EAST OF KEO WAY. ELEV. 271.185



LONGITUDINAL SECTION ALONG BASELINE RAMP 7TH B

* ELEVATIONS DEPENDENT ON FINAL BEARING HEIGHT. FINAL BEARING HEIGHT AND PEDESTAL ELEVATIONS TO BE DETERMINED BY BEARING MANUFACTURER. SEE DESIGN SHEETS 34 AND 35 FOR BEARING DETAILS.



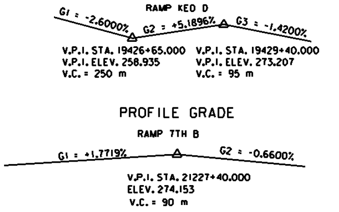
SITUATION PLAN

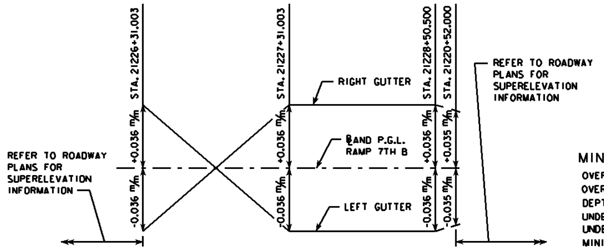
PROFILE GRADE

RAMP KEO D

PROFILE GRADE

RAMP 7TH B





SUPERELEVATION DIAGRAM FOR RAMP 7TH B

NOTES:

ALL DIMENSIONS ARE IN MILLIMETERS (mm) UNLESS OTHERWISE NOTED OR SHOWN.

ALL ELEVATIONS AND STATIONS ARE IN METERS (m).

ADD 200 TO ALL SPOT ELEVATIONS.

STORM SEWER TO BE RELOCATED BY OTHERS.

SEE DESIGN SHEETS 41-43 FOR LIGHTING DETAILS.

FOR DETAILS OF TYPICAL GRAVEL TOP DRESSING BEHIND MSE WALL, SEE DESIGN SHEET 4.

MINIMUM VERTICAL CLEARANCE

OVERHEAD STATION=21227+94.638, 8400 LT
OVERHEAD ELEVATION=273.490
DEPTH OF SUPERSTRUCTURE=2.01 m
UNDERPASS STATION=19427+94.070, 1800 RT
UNDERPASS ELEVATION=265.562
MINIMUM VERTICAL CLEARANCE=5.918 m

CURVE DATA

RAMP KEO D

P.I. STA. = 19427+96.347
Δ = 8°19'18.14" (RT)
T = 50.924 m
L = 101.669 m
E = 1.850 m
R = 700.000 m

CURVE DATA

RAMP 7TH B

P.I. STA. = 21227+56.893
Δ = 4°40'58.86" (LT)
T = 40.890 m
L = 81.734 m
E = 0.836 m
R = 1000.000 m

CURVE DATA

RAMP 3RD B

P.I. STA. = 24227+87.280
Δ = 8°12'46.22" (LT)
T = 71.277 m
L = 142.309 m
E = 2.555 m
R = 992.800 m

TRAFFIC ESTIMATE

A.D.T. = 22,500 VPD (2025)
4% TRUCKS

LOCATION

I-235 EAST BOUND EXIT RAMP TO 7TH, 6TH, 5TH, 3RD & 2ND (RAMP 7TH B) OVER KEO WAY ENTRANCE RAMP TO EAST BOUND I-235 (RAMP KEO D)
T-78N R-24W
SECTION 4
DES MOINES TOWNSHIP
POLK COUNTY
FHWA NO.

DESIGN FOR 0° SKEW ON HORIZONTAL CURVE

141.5 m X VAR. CONTINUOUS WELDED GIRDER BRIDGE

46.500 m AND 34.500 m END SPANS 60.500 m CENTER SPAN

SITUATION PLAN

STATION: 21227+74.250 ℄ RAMP 7TH B JUNE 2005

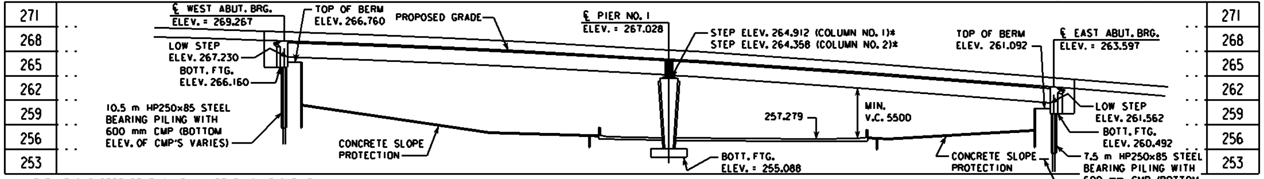
POLK COUNTY

IOWA DEPARTMENT OF TRANSPORTATION - HIGHWAY DIVISION

DESIGN SHEET NO. 3 OF 51 FILE NO. 29552 DESIGN NO. 806

DESIGNED BY IADOT
DETAILED BY IADOT
CHECKED BY HDR
CADD FILE H770806.S03
POLK COUNTY
PROJECT NUMBER IM-235-2(386)8--13-77
SHEET NUMBER 4

BENCH MARK NO. 660, STA. 534+04.265, 274.40 RT, CUT (X) TOP BOLT F-HYDRANT SE QUAD 5TH AVE AND CROCKER. ELEV. 265.534



* ELEVATIONS DEPENDENT ON FINAL BEARING HEIGHT. FINAL BEARING HEIGHT AND PEDESTAL ELEVATIONS TO BE DETERMINED BY BEARING MANUFACTURER. SEE DESIGN SHEET 25 FOR BEARING DETAILS.

LONGITUDINAL SECTION ALONG ℄ RAMP 5TH D

NOTES:

ALL DIMENSIONS ARE IN MILLIMETERS (mm) UNLESS OTHERWISE NOTED OR SHOWN.

ALL STATIONS ARE IN METERS (m).

ADD 200 TO ALL SPOT ELEVATIONS.

SEE DESIGN SHEETS 29 AND 30 FOR LIGHTING DETAILS.

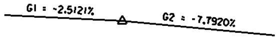
FOR DETAILS OF TYPICAL GRAVEL TOP DRESSING BEHIND MSE WALL, SEE DESIGN SHEET 4.

△ FOR DETAILS, SEE PILING DETAILS, DESIGN SHEET 27.

MSE WALLS BY OTHERS.

PROFILE GRADE

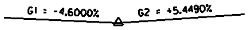
RAMP 5TH D



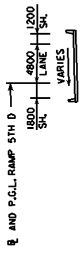
V.P.I STA. 23434+40.000
ELEV. 268.576
V.C. = 90 m

PROFILE GRADE

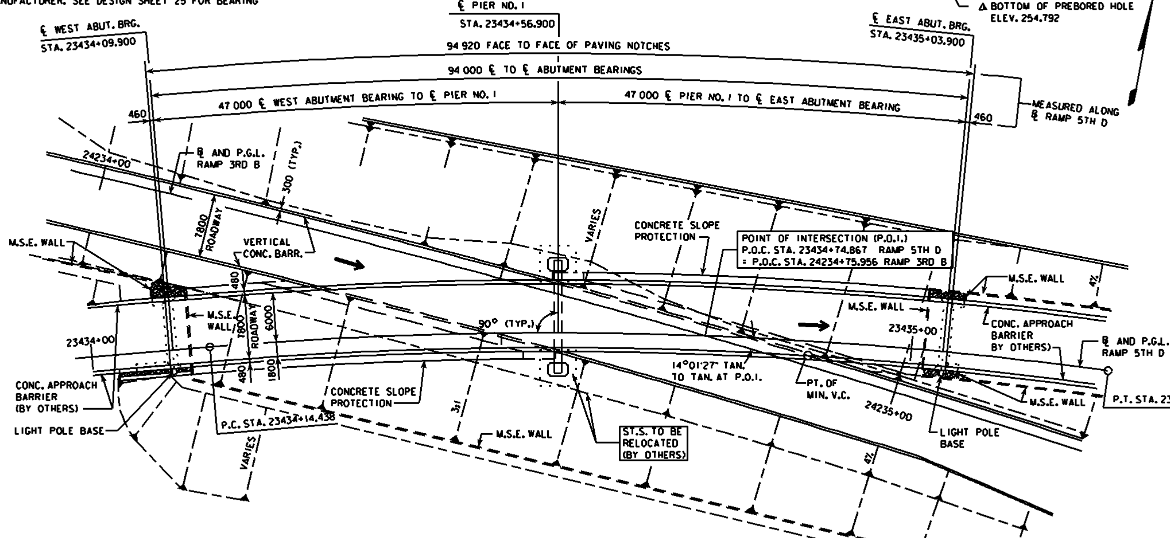
RAMP 3RD B



V.P.I. STA. 24234+80.000
ELEV. 256.281
V.C. = 80 m



TYPICAL APPROACH SECTION



SITUATION PLAN

CURVE DATA

RAMP 5TH D

P.I. STA. = 23434+69.504
Δ = 12°34'10.14" (RT)
T = 55.066 m
L = 109.689 m
E = 3.023 m
R = 500.000 m

CURVE DATA

RAMP 3RD B

P.I. STA. = 24234+53.365
Δ = 8°33'22.03" (RT)
T = 112.208 m
L = 223.999 m
E = 4.191 m
R = 1500.000 m

MINIMUM VERTICAL CLEARANCE

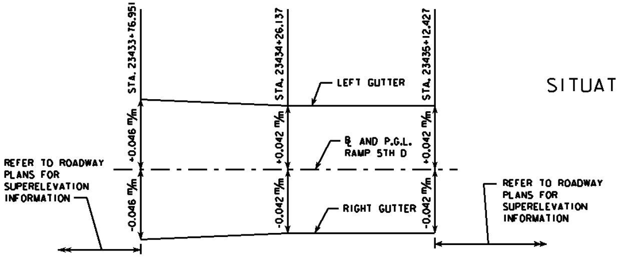
OVERHEAD STATION=23434+87.486, 1800 RT
OVERHEAD ELEVATION=264.800
DEPTH OF SUPERSTRUCTURE=1.907 m
UNDERPASS STATION=24234+88.618, 1200 LT
UNDERPASS ELEVATION=257.393
MINIMUM VERTICAL CLEARANCE=5.500 m

LOCATION

I-235 EAST BOUND
ENTRANCE RAMP FROM 5TH
AVE. (RAMP 5TH D) OVER
I-235 EAST BOUND EXIT
RAMP TO 2ND AND 3RD
(RAMP 3RD B)
T-78N R-24W
SECTION 4
DES MOINES TOWNSHIP
POLK COUNTY
FHWA NO.

TRAFFIC ESTIMATE

A.D.T. = 9,900 VPD (2025)
4% TRUCKS



SUPERELEVATION DIAGRAM FOR RAMP 5TH D

DESIGN FOR 0° SKEW ON HORIZONTAL CURVE

94.0 m X 7.8 m CONTINUOUS WELDED GIRDER BRIDGE

47.0 m AND 47.0 m SPANS

SITUATION PLAN

STATION: 23434+56.900 ℄ RAMP 5TH D   JUNE 2005

POLK COUNTY

IOWA DEPARTMENT OF TRANSPORTATION - HIGHWAY DIVISION

DESIGN SHEET NO. 3 OF 38 FILE NO. 29552 DESIGN NO. 906

DESIGNED BY IADOT CHECKED BY HDR
DETAILED BY IADOT CADD FILE H770906.S03

POLK COUNTY

PROJECT NUMBER

BRFIM-235-2(319)8--05-77

SHEET NUMBER 4

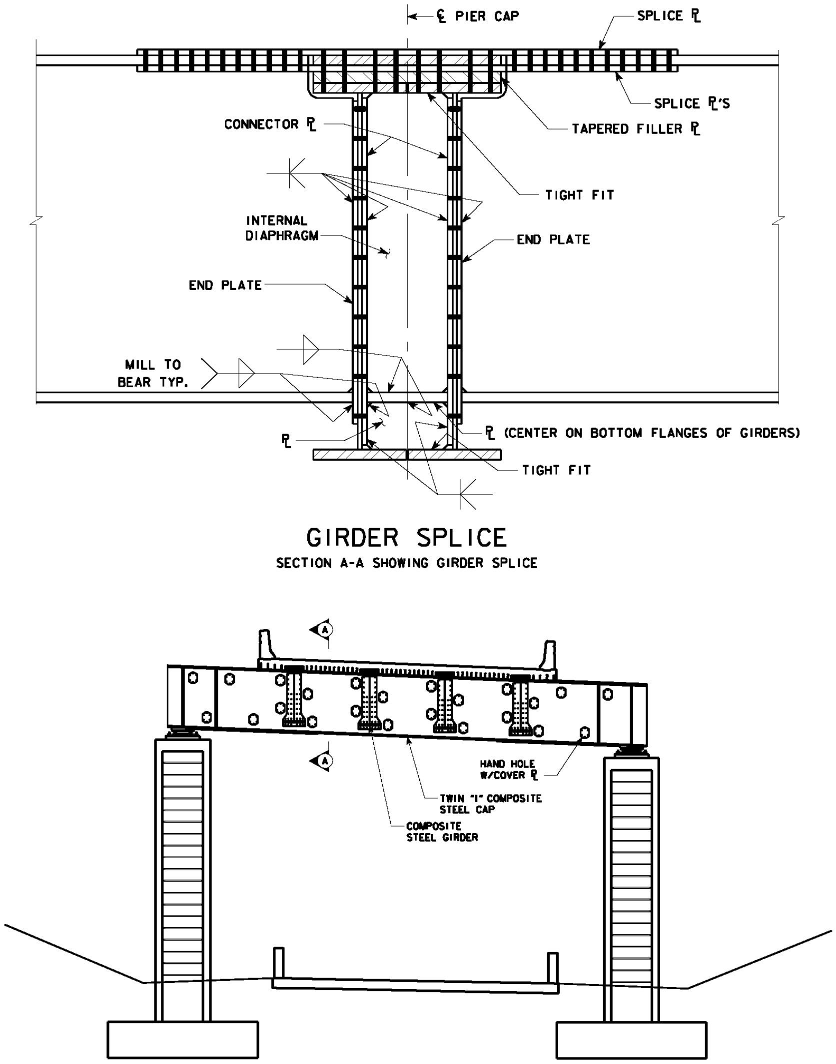


Figure 12 – Straddle Bent With Twin "I"-Shaped Integral Steel Pier Cap

CONCLUSION

Steel continues to offer economical solutions to many of the complex challenges in bridge engineering as this paper has illustrated. In addition to the traditional characteristics of steel girders such as accommodating complex geometry (including curvature and skew) and limited horizontal and vertical clearances, new traits have been made available through the introduction of HPS. Properties such as increased toughness and improved weldability have made it possible for bridge owners to accept more risk and utilize non-traditional details in bridge design.

The four braided ramp structures that were the subject of this paper have demonstrated the adaptability of steel to accommodate varying degree of complexity without incurring significant increase in cost. The steel solution ranged from a traditional steel girder bridge to a more complex system utilizing straddle pier bent with an integral cap.