Field Observation of Steel Pier Caps

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INTRODUCTION

When faced with designing a complex interchange, problems with vertical and horizontal clearances between roadways and overhead bridges often occur. The steel pier cap has been a frequently used solution to this problem. It is not uncommon to find one or more steel caps supporting a bridge superstructure at an interchange. However, due to the difficulty of traffic control and access, hands-on inspection of these pier caps are performed infrequently.

The Ohio Department of Transportation realized this problem and in 1989 authorized Burgess & Niple, Limited (B&N) to inspect 24 bridges with steel pier caps. The bridges are located in Cincinnati, Columbus, and Dayton, as well as other small municipalities and rural locations within Ohio. A total of 58 caps were inspected that have dimensions up to 14 feet deep and 110 feet long. Forty-four of these caps are boxes and 14 are girders.

Figure 1. Elevation View of Typical Pier Cap

INSPECTION

B&N was responsible for coordinating traffic control with city and state traffic officials, railroads, and contractors for paving projects. The project consisted of a hands-on inspection of each cap. For box members, this included an interior inspection. Fatigue prone details were nondestructively tested (magnetic particle) at random locations.

Burgess & Niple, Limited, Engineers and Architects, 5085 Reed Road, Columbus, OH 43220.

Access to the caps was provided by using a manlift or ladder where a cap is over roadways. An underbridge inspection crane was used where a cap spanned railroads and waterways. Traffic control, also provided by B&N, typically consisted of closing a single lane, either above or below the bridge depending upon the means of access. Traffic control consisted of an arrow board, warning signs, and safety cones. A majority of the bridge sites involved multi-lane divided highways, however, several of the sites involved two-lane roadways which required flaggers. Off duty police or highway patrol officers were also employed to assist with the set up and tear down of the traffic control. Bridges over railroads required the use of railroad flaggers.

A subcontractor was used to remove and replace the access hatches. Many of the bolts were frozen or broke during removal. Also the access hatch covers typically do not have lifting rings making the covers difficult to handle when removing and replacing.

The exterior of the caps were inspected from a manlift, underbridge inspection crane, ladder, or by using rock climbing techniques. The interior of the box caps were inspected by climbing through the cap. In caps where the depth measured 10 to 14 feet deep, rope ladders and rock climbing techniques were necessary to inspect the inside. Only one hatch was opened on each cap due to the difficulty of traffic control and removing the cover. A portable gas monitor capable of detecting oxygen content and toxic gases was used to assure air quality. Although the air quality was always within the acceptable range, the trapped paint fumes from construction typically were uncomfortable. To provide adequate ventilation, a fresh air blower was used. The blower pumped air into the cap by means of a 2 inch diameter hose pulled along by the inspectors.

Other equipment used included a generator to run the magnetic particle yolk, an air compressor and small sand blasting unit, and helmet-mounted light similar to those used by miners. Two way radios were also used as echos inside the cap made it difficult to communicate.

OBSERVATIONS

Deficiencies observed during the inspection are separated into the following categories:

- Welded Details
- Cracks and Distortions of the Cap
- Miscellaneous Deficiencies

Figure 2. Cap Web Seal Weld Around Girder Lower Flange.

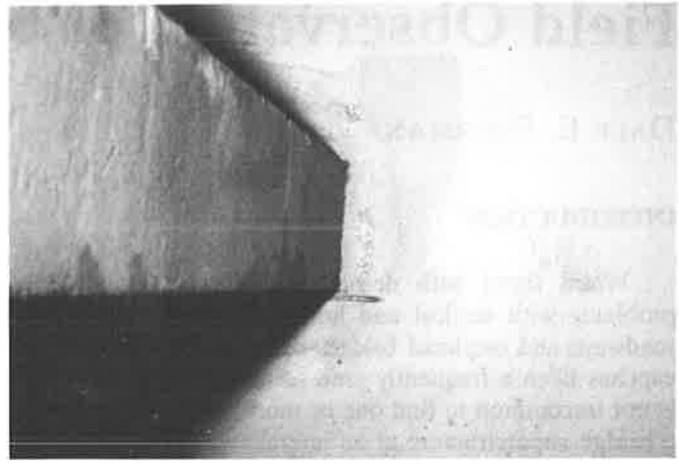

Figure 3. Opening in Cap Web for Girder Lower Flange Inside Box Cap Member

Welded Details

Seal Weld Between the Girder Lower Flange and the Tension Region of the Cap Web.

A seal weld is commonly made around the girder lower flange where the flange frames through the cap web (see Figure 2). The seal welds produce an abrupt change in the cap cross section as the girder lower flange becomes part of the cap. This change in cross section creates a fatigue prone detail in the cap. Triaxial welds also are common at the girder lower flange connection to the cap.

The seal welds typically were made around the girder lower flange on both sides of the cap web. However, on box cap members the seal weld was often omitted where the girder flange is not easily accessible inside the cap. At these locations, the weld material from the exterior seal weld has run through to the inside of the cap. The openings cut in the cap web for the girder lower flange typically has square corners and overcuts at the corners (see Figure 3). Backing bars tack-welded to the cap web were also used to back up the exterior seal weld at some locations. These uneven weld contours, sharp corners, and the tack welds all create fatigue prone details in the cap.

Retrofit details were suggested where the girder bottom flange frames into the tension zone of the cap. The detail typically consisted of making sawcuts through the web around the sides of the girder flange. Holes are drilled at the end of the cuts.[1] Bolts are placed through the holes and the sawcuts are caulked to seal the cap.

Girder Lower Flange Splice Plate or Fill Plate is Stitch-Welded to the Bottom of the Cap Lower Flange.

At locations where the girder lower flange splice plate exists below the cap lower flange, the splice plate or a fill plate has been stitch welded to the cap lower flange to aid erection (see Figure 4). Typically, the stitch welds were used to hold the plates in place until bolts could be installed. The stitch welded plates produce a fatigue prone detail in the cap lower flange similar to a partial length cover plate.

The stitch welds were recommended to be removed and ground flush with the cap lower flange. Carefully grind away fill or splice plate until all fused area with the cap is removed.

Girder Web is Welded to the Top and Edge of the Cap Upper Flange.

The girder web is welded to the cap upper flange where the girders are continuous through the cap (see Figure 5). This abrupt change in cross section of the girder web at the edge of the cap flange produces a fatigue prone detail in the girder.

The girder web welded to the top flange and web of the cap is retrofitted by making vertical saw cuts in the girder web. The cuts are adjacent to the cap flange and terminate in holes, drilled above and below the cap flange.[1]

Figure 4. Fill Plate Between Cap and Girder Lower Flange is Stitch Welded to the Cap Lower Flange

Figure 5. Girder Upper Flange and Web are Continuous Over the Cap Upper Flange.

Lateral Bracing Gusset Plate is Welded to the Cap Web in the Tension Zone of the Cap.

The abrupt change in cross section of the cap produces a fatigue prone detail. Backing bars tack welded to the cap web were commonly used (see Figure 6). The gusset plates were attached at the girder web connection to the cap on several bridges. At these locations, the gusset plates are welded to the cap and girder web forming a triaxial weld. The gusset plates typically are located just above the girder lower flange making inspection of the seal weld difficult.

The lower lateral bracing welded to the cap web in the tension zone is recommended to be removed from the cap and the weld material ground flush. The bracing is reattached using bolts. Where the bracing is welded to the cap in the compression zone and to the cap web, a triaxial weld exists. The triaxial weld is cored from the opposite face of the girder to remove a portion of the gusset plate to girder web weld.

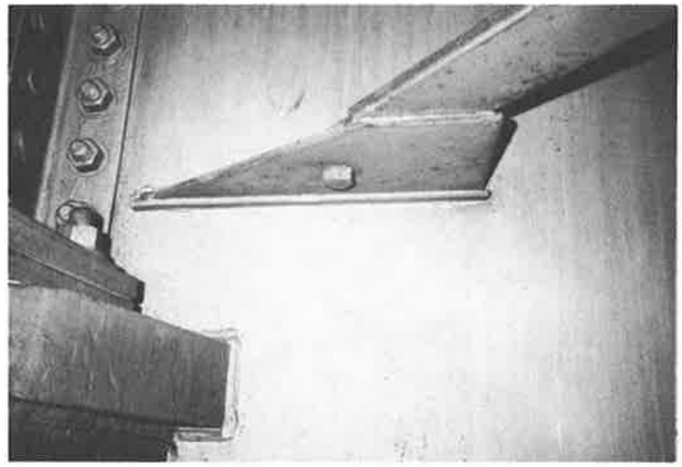

Figure 6. Lower Lateral Bracing Gussett Plate Welded to Cap Web

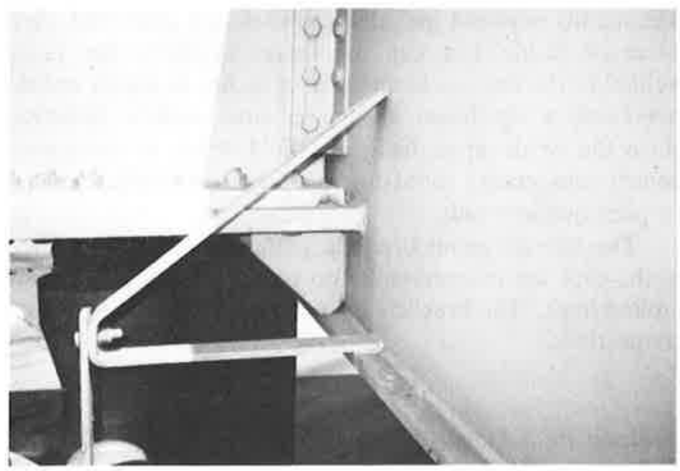

Figure 7. Roadway Drainpipe Welded to Cap Lower Flange

Roadway Drainpipe Bracket, Miscellaneous Structural Sections, Plates, Nuts, and Bolts are Welded to the Tension Zone of the Cap.

These items were welded to the cap during fabrication of the cap or erection of the bridge (see Figures 7 and 8).

Figure 8. Angle and Bolt Welded to Inside of Box Cap Member

Figure 9. Diaphragm Stiffener Inside Box Cap Member is Welded to the Cap Lower Flange

The details were not included in the design plans and often occurred inside box cap members. Typically, the items welded to the cap are less than four inches in length and do not cause a significant change in cross section. However, since the welds most likely are field welds or temporary connections, cracks could develop due to insufficient preheat or poor quality welds.

The miscellaneous brackets, plates, and sections welded to the caps are recommended to be removed and the welds ground flush. The brackets are to be reattached using bolted connections.

Welded Partial Length Cover Plates and Vertical Diaphragm Stiffeners are Welded to the Cap Flanges in the Tension Zone.

The cover plates and stiffeners cause an abrupt change in cross section of the cap and create fatigue prone details. The bottom cover plates typically are easily accessible for inspection. However, top cover plates in negative moment regions often cannot be inspected if the cap top flange is cast in the deck. Inspection of top cover plates is therefore limited to nondestructive testing or during deck replacement. The vertical diaphragm stiffeners were noted inside several of the box cap members (see Figure 9). They typically are triangular plates positioned longitudinally with the cap and are welded between the transverse diaphragms and cap flange. The stiffeners cannot be examined during routine inspections if the inspectors do not enter the box cap members.

Welded cover plates should be retrofitted with bolted splice plates across the ends of the cover plate. A horizontal saw cut also should be made in the web near the flange and centered over the cover plate termination. The saw cuts terminate in drilled holes.[1]

The diaphragm stiffeners are recommended to be removed and the weld material ground flush with the cap flange.

Backing Bars Typically are used at the Web-To-Flange Connections of Box Cap Members.

The cap web to cap flange connections were made by external groove welds due to space and ventilation limitations inside the cap. The backing bars used inside the cap typically were tack welded to the web and flange to hold the components in place during fabrication (see Figure 10). The stitch welds are susceptible to cracking due to insufficient cross section and lack of penetration. These welds were most likely made without preheating the base metal. The welds therefore would cool very quickly due to the chilling effect of the thick flange. At several locations, the backing bars were not welded together where they are spliced (see Figure 10). The bars are butted together creating a notch or stress riser where a crack could propagate from. The backing bars are bent away from the flanges or webs at numerous locations (see Figure 11). This allowed weld material from the web-to-flange groove weld to flow between the backing bar and cap web or flange. The temperature of the molten weld material alone is insufficient to thoroughly fuse with the cap web or flange. The weld is most likely cracked due to rapid cooling. These factors combined with the nonuniform weld contour create locations where cracks can form.

The stitch welds were recommended to be removed and the base metal ground 1/16 inch deep where the weld was

Figure 10. Backing Bars Inside Box Cap Member is Tack Welded to Cap Web and not Welded Together at Splice

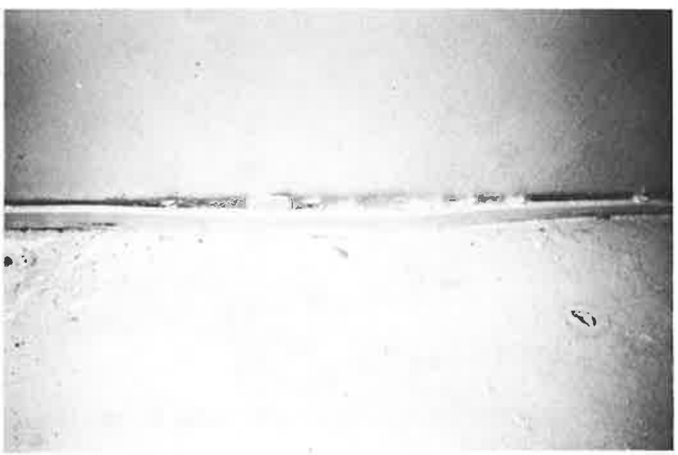

Figure 11. Backing Bar Inside Box Cap Member is Bent Away from Cap Web

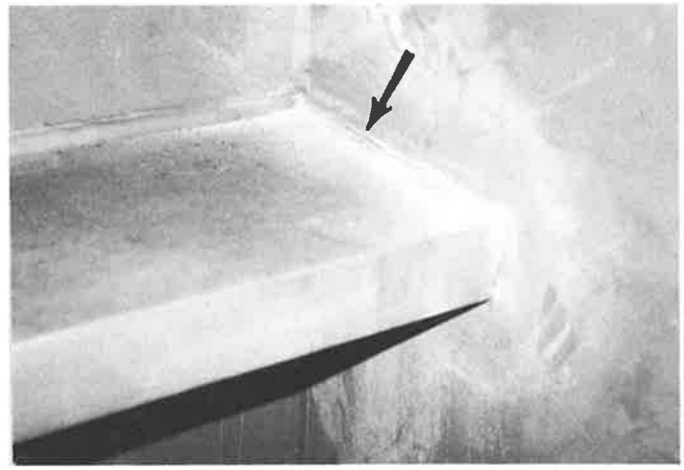

Figure 12. Crack in Seal Weld on Inside Face of Web of Box Cap Member

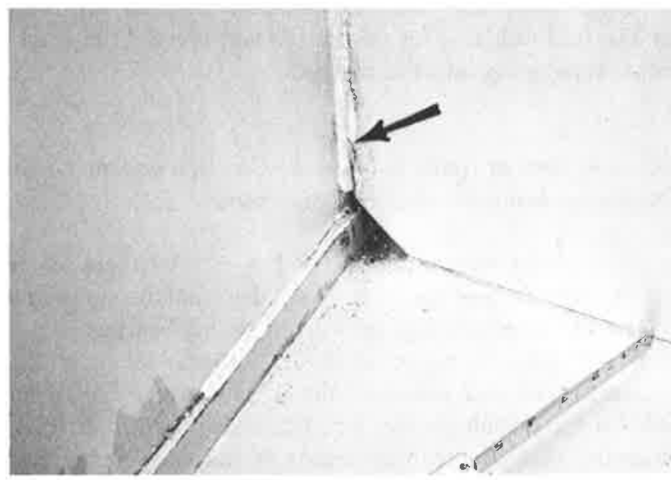

Figure 13. Crack in Vertical Weld Between Cap Web and Diaphragm Inside Box Cap Member

removed. The backing bar splices are to be beveled and groove welded together. Where the backing bars are bent, the retrofit detail consisted of removing the bent bars and tapering the ends of the remaining bars. The root of the groove weld between the cap web and flange is then gouged out and rewelded.

Cracks and Distortions of the Cap

Cracks in the seal weld around the girder lower flange.

Hairline cracks were noted in the seal welds around the girder lower flange where the girders frame through the cap. The cracks were noted only in the weld and did not propagate into the web of the cap. Magnetic particle testing was used to determine the extent of cracking (see Figure 12). At several locations, the crack had followed the seal weld along the bottom or top of the flange and turned to continue along an adjacent side. The cracks were noted in either the interior seal or the exterior seal weld of a girder flange, but not in both welds. Cracks in the interior seal weld had been painted over and the paint had not cracked. From these findings, the cracks appear to have occurred during fabrication, possibly due to cooling or the making of the other seal weld on the interior or exterior of the cap web.

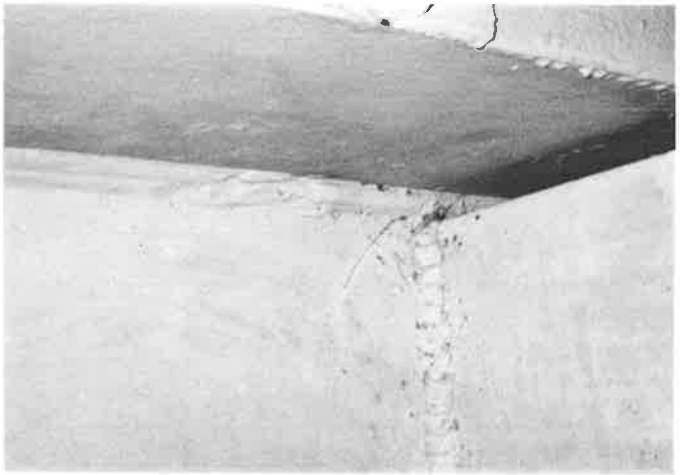

Figure 14. Crack Through Web of Girder "T" Type Pier Web Connection of the Center Beam.

Figure 15. Crack in Weld Between Vertical Stiffener and Cap Upper Flange of Girder "T" Type Pier.

Seal weld cracks are retrofitted the same as suggested for the seal welds. The saw cuts would prevent the cracks from propagating into the cap web.

Cracks in Vertical Welds Between the Cap Web and the Girder Diaphragm Inside the Box Cap Members.

The cracks were noted in two box cap members where the caps extend past the edge of the deck and are supported at its ends. The bearings are curved sliding bearings which allow the caps to rotate about its longitudinal axis. The vertical cracks were noted in the bottom of the diaphragm welds at the outside girders (see Figure 13). The cracks exist on both sides of the diaphragms at both cap webs. The cracks appear to be caused by torsion of the cap. The live load on the bridge causes the girders to deflect and rotate the cap. Friction between the curved sliding surfaces of the bearings produce torsional stresses in the cap.

The diaphragm is recommended to be welded to the cap lower flange to decrease secondary bending and improve torsional resistance. The vertical cracks are to be rewelded.

Crack in Cap Web of Girder "T" Type Pier.

The crack exists at the top of the welded beam web connection above the pier stem. The crack propagates down along both sides of the beam web and extends through the cap web (see Figure 14). Holes were drilled through the cap web at the ends of the crack to stop the crack growth.

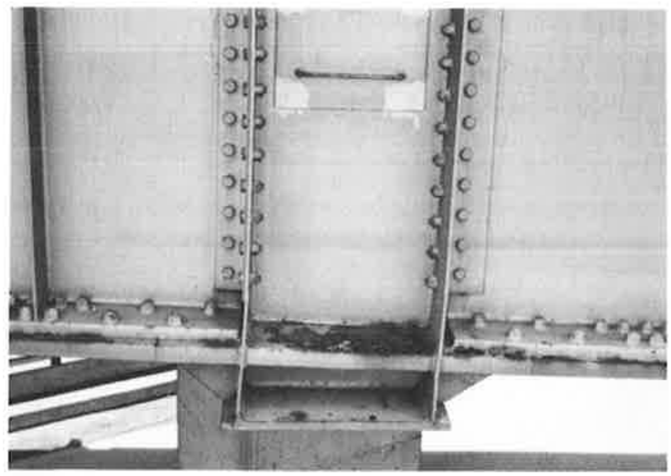

Figure 16. Cap Webs Bent at Cantilevered End of Box Cap Member

Crack in the Weld Between the Vertical Stiffener and the Upper Flange of a Girder "T" Type Pier.

The crack initiates at the girder web and propagates towards the edge of the flange (see Figure 15). The vertical stiffener appears to have been cut too short causing a gap between the top of the stiffener and the cap upper flange. As the weld between the flange and stiffener cooled and contracted, tension forces developed in the weld causing the cap flange to be bent downward. The tension force is greatest at the cap web where the flange is most difficult to deflect.

The top of the stiffener was recommended to be trimmed and the weld on the cap upper flange be ground flush.

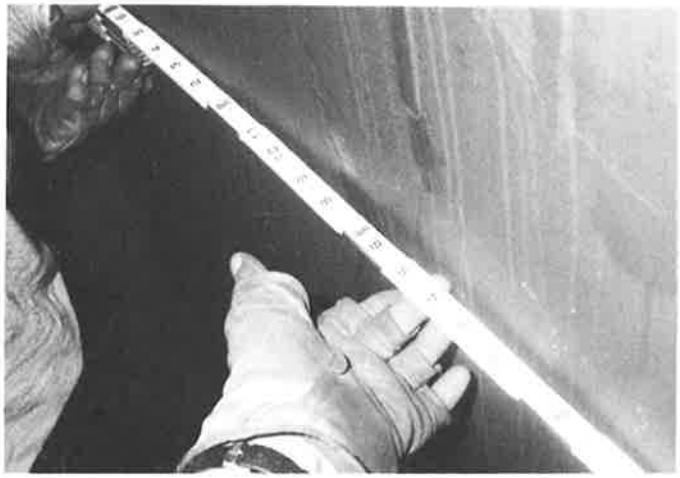

Figure 17. Cap Web Bowed at Web Splice Weld

Cap Webs are Bent Where the Outside Girder Frames into the Cantilevered End of the Box Cap Member.

This condition appears to have occurred during erection of the superstructure. The cap was not bent at the other girder connections and no signs of distress were noted in the deck, superstructure, or substructure. The cap webs appeared to be bowed approximately two inches (see Figure 16).

Cap Webs are Bowed at the Welded Web Splices.

The splices were noted to be bowed out a maximum of 5/16 inch over a 12-inch length (see Figure 17). The splices most likely were bent during fabrication and were noted in several box cap members.

Miscellaneous Deficiencies

Access Hatch Covers on Box Cap Members Leak Due to Deteriorated Gaskets and Insufficient Bolt Spacing.

The gasket materials encountered in this project consisted of asphalt impregnated felt or an elastomeric sheet. Although leaking access hatch covers were noted with both types of gaskets, the asphalt impregnated felt gaskets typically were deteriorated. Deterioration begins by the presence of a tar-like substance running down the inside of the cap from the bottom of the access hatch (see Figure 18). As the gasket continues to deteriorate, increasing amounts of water and decreasing amounts of the tar would be noted

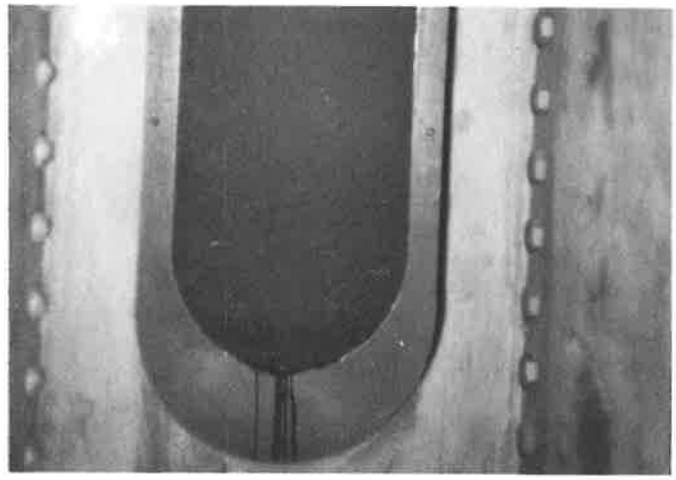

Figure 18. Access Hatch Gasket Inside Box Cap Member Beginning to Deteriorate

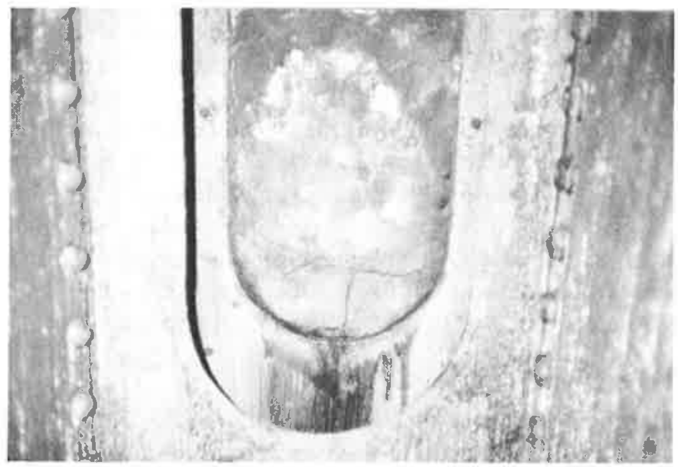

Figure 19. Access Hatch Gasket Inside Box Cap Member in Advanced Deterioration Stage

running from the hatch. The gasket would begin to tear, crack and wrinkle, exposing the corroded surface of the access cover (see Figure 19). It is uncertain whether the deterioration of the gasket caused the hatch to leak or if the leaking hatch caused the gasket to deteriorate. However, a significant amount of the hatches using asphalt impregnated gaskets allowed water to enter the cap. The hatches using elastomeric gaskets also had cases of leakage; the leakage is due to lack of a proper seal, and not from deterioration.

The leaking gaskets allow water and roadway drainage to pass into the cap. This condition also promotes corrosion between the hatch cover and the cap. The corrosion causes the hatch cover to bow and further funnel more water into the cap (see Figure 20). Once inside the cap, the moisture

Figure 20. Access Hatch Cover Bowing Due to Corrosion

Figure 21. Condensation on Inside of Box Cap Member

causes high humidity, condensation, ponding water, corrosion and peeling paint (see Figure 21). Ponding water in one cap measured a maximum of 1/2-inch deep (see Figure 22).

Temporary utility lines at a construction site were attached to the handles of the access hatch cover. The tension in the utility lines has bowed the access cover away from the cap allowing moisture to enter the cap.

The access hatches were repaired by adding additional bolts to decrease bolt spacing. Elastomeric gaskets and caulking were also used to seal the caps. The utility lines were recommended to be removed from the hatch cover.

Openings for Utilities and Retrofit Details in Webs of Box Cap Members Allows Birds, Moisture, and Debris to Enter the Cap.

Holes and sawcuts made through the cap webs to prevent crack growth at fatigue prone details and openings cut in the webs for a water main were observed (see Figure 23). The openings allow birds, debris, and moisture to enter the cap. These conditions have caused peeling paint and corrosion of the cap. The bird droppings and nesting material deteriorates the paint and holds moisture.

Nesting material inside one cap measured 18 inches deep (see Figure 24). This debris inhibits inspection inside the cap.

The Interior of the Box Caps Typically Have Only a Primer Coat of Paint.

The primer coat does not adequately protect the steel if moisture enters the cap. Mill scale on the interior face of the steel is typical. The paint is peeling or easily removed at

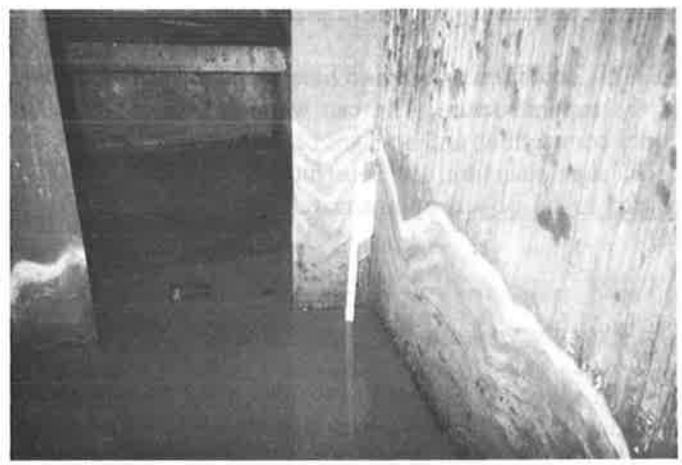

Figure 22. Water Accumulated Inside Box Cap Member Due to Leakage of Access Hatch Cover.

these locations. The primer paint also does not reflect light well, making inspection inside the cap more difficult. Areas of burned and blistered paint are typical on the inside of the cap where welds were made to the cap exterior.

Cap Bearings are Not as Shown on the Design Plans.

A multi-span bridge composed of continuous steel girders is supported over several piers using steel box pier caps. The girders frame through the pier caps. The center pier has fixed bearings between the cap and concrete columns, while the remaining caps were designed to have sliding bearings. During our inspection, it was discovered

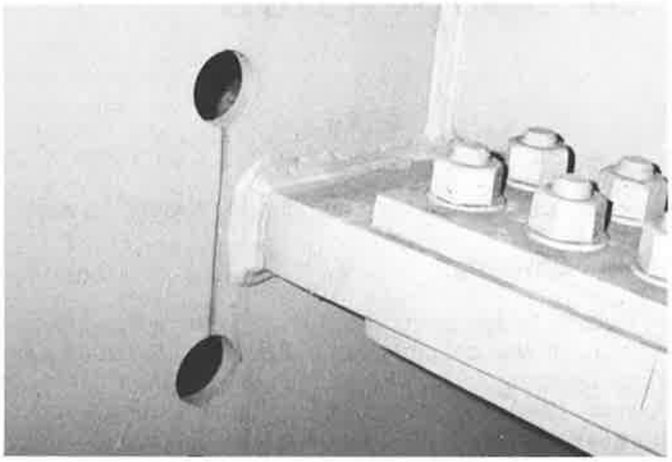

Figure 23. Retrofit Detail Cut in Cap Webs of Box Cap Member

Figure 24. Nesting Material Inside Box Cap Member

that two caps actually had fixed bearings. The expansion of the bridge between the fixed bearings has caused the bearings to slide on top of the concrete columns. Movement of the base plate is evident by the unpainted and corroded areas adjacent to the anchor bolts. These unpainted areas at one time were under the anchor nuts.

A similar condition was noted on another bridge. The pier cap was designed to have the only fixed bearing of a series of continuous spans. However, during the inspection it was discovered that a sliding bearing had been installed at the cap and no fixed bearings existed between expansion joints.

SUMMARY

This project has shown some of the defects and problems encountered with steel pier caps. The clearance restrictions imposed on these members have caused the caps to be compacted within the bridge superstructure. For this reason, the caps typically contain many fatigue prone details. Although some details were included by design, some additional details and poor workmanship were a result of space and ventilation restrictions during fabrications. These details typically exist inside box cap members and cannot be inspected from the outside of the cap. Inspection of the cap interior is also impared by the same space limitation making a close visual examination difficult but necessary.

REFERENCE

1. *Fatigue and Fracture in Steel Bridges: Case Study.* John W. Fisher, 1984.