Inspection of Luling Bridge Cable Stays: Case Study

Mary E. Elliott[1] and Ernest Heymsfield[2]

Abstract: Most cable-stayed bridges in the United States have been built in the last 30 years. As the number of existing cable-stayed bridges increase, one problem continues to arise—how to inspect the cable stays for corrosion and deterioration. An inherent difficulty in developing an inspection procedure for cable-stayed bridges is that each cable-stayed bridge is unique in its cable configuration. The Louisiana Department of Transportation and Development (LADOTD) has built two separate trolleys to aid their inspectors and maintenance crew with visual inspection and maintenance of the cable stays on the Luling Bridge over the Mississippi River in St. Charles Parish near New Orleans, Louisiana. With the use of the two trolleys, LADOTD bridge inspectors are able to inspect the cable stays at hands-on distances. The cable-stay inspection procedure adopted by the LADOTD is inexpensive and time efficient, and it minimally impacts bridge traffic. This manuscript reviews the inspection procedure adopted by the LADOTD to inspect the cable sheathing at the Luling Bridge.

DOI: 10.1061/(ASCE)0733-9364(2003)129:2(226)

CE Database subject headings: Bridges, cable-stayed; Case reports; Louisiana; Bridge inspection.

Introduction

A majority of U.S. cable-stayed bridges have been constructed in the last 30 years. As the number of cable-stayed bridges increase, a method needs to be developed to inspect the cable stays for corrosion and deterioration. However, because of the special nature and uniqueness of each cable-stayed bridge, a general inspection approach for cable corrosion problems may be difficult to develop (Stahl and Gagnon 1996). In this paper, the writers discuss the method used by the Louisiana Department of Transportation and Development (LADOTD) to inspect the Luling Cable-Stay Bridge. During the state's last cable-stay inspection of the bridge, in 1998, the writers were allowed to be involved in the inspection and to record the inspection procedure used by the LADOTD. The method used incorporates the use of two trolleys that were designed by Frank Castjohn, retired bridge maintenance superintendent for LADOTD (Soast 1986). The two trolleys allow access for the department's inspectors and maintenance crew to any location along the Luling Bridge cable stays.

Luling Bridge Description

The Luling Bridge was completed and open for traffic in 1984 (Fig. 1). The New York City firm of Franklandt and Lienhard designed the superstructure, which includes the 151 m, 372 m, and 155 m (495 ft, 1,222 ft, and 508 ft) cable-stayed spans. Seventy-two cables were installed to hold the main 372 m (1,222 ft) center span 49 m (160 ft) above the Mississippi River ("Constructing" 1981). The cables were hung from two 122 m (400 ft) steel towers. The configuration of the bridge is shown in Fig. 2. The wire used for the cables was required to be 6.35 mm (0.250 in.) diameter, cold drawn, stress-relieved prestressing wire conforming to ASTM designation A 421, Type BA, with a minimum guaranteed ultimate strength of 1,655 MPa (240,000 psi). Depending on the specific cable, either 403, 211, 271, or 307 wires were used to develop the cable. Before the cables to be used were accepted, project specifications required fatigue tests of the cable wire to confirm the fatigue life of the cable wire and anchorages. Construction of the bridge was delayed due to failure of a cable to pass the fatigue test. Wires began to break after about 500,000 cycles of the two million cycle fatigue test in the 271-wire cable. After 1.2 million cycles, approximately 70 of the wires broke and testing ceased. Holes in the surface of the 6.35 mm (0.250 in.) diameter wire were found and determined to be caused during manufacturing of the wire. Approximately one third of the wire manufactured for the bridge was rejected and had to be replaced (Thibodeaux 1982).

[1]Structural Engineer, HNTB Corporation, Baton Rouge, LA 70806.

[2]Assistant Professor, Dept. of Civil Engineering, Univ. of Arkansas, Fayetteville, AR 72701.

Note. Discussion open until September 1, 2003. Separate discussions must be submitted for individual papers. To extend the closing date by one month, a written request must be filed with the ASCE Managing Editor. The manuscript for this technical note was submitted for review and possible publication on September 28, 2001; approved on April 2, 2002. This technical note is part of the ***Journal of Construction Engineering and Management***, Vol. 129, No. 2, April 1, 2003. ©ASCE, ISSN 0733-9364/2003/2-226–230/$18.00.

Cable Protection

Cable-stayed bridges first appeared in 1955 in Germany after World War II (Billington and Nazmy 1991). Since 1955, methods to protect these cables from corrosion have evolved. There are four basic cable configurations used, which are described as follows:

- Parallel bar: Steel bars or rods located by nylon spacers placed parallel to each other. Cement grout is injected into the steel sleeve or polyethylene pipe encasing.
- Parallel wire: Groups of steel wire, typically all the same size, usually 7 mm in diameter, encased in a protective covering injected with grout.
- Stranded cable: The cables are constructed from strands that are usually composed of seven twisted wires. The entire cable

J. Constr. Eng. Manage., 2003, 129(2): 226-230

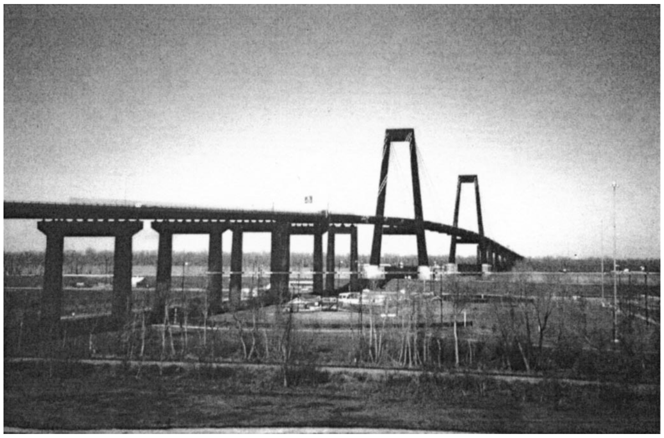

Fig. 1. Luling Bridge viewed from west bank of Mississippi River

is then encased in a polyethylene duct, which is injected with grout. The Quincy Bridge (the Bayview Bridge), built in 1987, was the first in the world to use epoxy-coated strands in the cable stays (Billington and Nazmy 1991).
- Locked-coil cable: A core of parallel wire cables is surrounded by successive layers of S-shaped locking cables, which make the cable watertight. As a result, external casing or grouting is not required; however, the outer layer is usually galvanized.

In any of these cable configurations, the consequences of any corrosion damage to the cables can be detrimental, because the cables are fracture critical (Stahl and Gagnon 1996). The following corrosion mechanisms can occur alone or act together: (1) uniform or atmospheric corrosion; (2) pitting corrosion; (3) crevice corrosion; (4) stress corrosion cracking; (5) hydrogen cracking; (6) corrosion fatigue; and (7) electrolytic corrosion. In all cases, for corrosion to take place, the cable needs to be exposed to the elements by a failure of the protective coating. In addition, pollutants in the environment can accelerate the corrosion process. Stress corrosion cracking, hydrogen cracking, and corrosion fatigue require the presence of stresses, which are present in cable stays, as well as a corrosive environment. In addition, since cables are the primary load-carrying members of a cable-stayed bridge, high forces and stress variations present in the cables may cause weakening of the cable's protecting sheathing.

The Luling Bridge has the traditional cable-stay corrosion protection system. In this type of system, the cables are encased using a high-density polyethylene sheathing and injected with a portland cement grout to fill any void space. Since construction of the Luling Bridge, new protection systems have been incorporated at other bridge sites. These systems include epoxy-coated, galvanized, greased, and sheathed cables. These newer systems typically use an improved grout with silica fuma. Except for the locked-coil cable, steel or polyethylene pipe, sheathing, filled with cement grout generally protects the cable configurations previously described. Therefore, during construction, careful attention has to be paid while injecting the grout to ensure a good protective covering. Because the cables are covered after completion of construction, access to cables to investigate corrosion or failure of the cable is limited. Therefore, the condition of the cable-stay's sheathing needs to be maintained in order to protect the cables from deterioration.

In 1985, the LADOTD noticed some cracking of the high-density polyethylene sheathing used to encase the cables. To remedy this cracking, the original black polyethylene pipes were repaired and then wrapped with white PVF tape (Tedlar tape). The new tape provided protection of the polyethylene pipes, and in addition the white color resulted in reduced temperature variation of the cable stays.

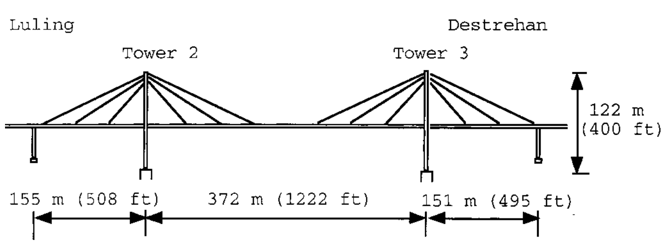

Fig. 2. Luling Bridge configuration

Inspection of Luling Bridge Cable Stays

The Luling Bridge is unique because it is the only major cable-stayed bridge in the United States without multicables and, as a result, has a vertically thick deck (Billington and Nazmy 1991). The maintenance section of the LADOTD constructed two trolleys to assist them in the visual inspection and maintenance of the cable stays of the Luling Bridge. Although trolleys have been used in Europe for cable-stay inspection, they have had limited use in the United States. The LADOTD trolleys were initially built in 1985 for a cost of $3,000.00 (Soast 1986). Because of their simple design, maintenance costs on the trolleys are minimal. An added benefit is that use of a trolley inspection system only minimally impacts traffic, because only the maintenance lane and one traffic lane is required to be closed during the inspection process. LADOTD's decision to use trolleys negated the need for inspection cranes, which would have been more costly and would have had a more detrimental effect on bridge traffic.

Trolley Description

Due to the cable-stay configuration, one trolley was built to ride along the top two horizontally parallel cables of the four-cable configuration of the side spans, and a second trolley was built to ride along the side of two vertically parallel cables of the two-cable configuration of the main span (Fig. 3). The inspection of the cable stays began on March 2, 1998, and continued intermittently throughout the months of March and April. The inspection was expected to require one week to inspect all 72 cables of the Luling Bridge using the two trolleys; however, the completion of the inspection was delayed due to required equipment modifications and other previously scheduled projects. These equipment modifications were required due to changes in the cable-stay diameter from the time of the previous inspection. Since an earlier inspection in 1985, the polyethylene pipes were wrapped with white PVF tape (Tedlar tape). This procedure was done to protect and reduce temperature variation of the stays. However, the white PVF tape added extra thickness around the stays and therefore changed the dimension between the stays as well as the surface the tires of the trolley gripped. The extra thickness resulted in the trolley ''walking'' sideways and damaging the PVF tape during the 1998 initial inspections. To correct this problem, modifications to the wheels of the original trolleys were required and were made by changing the type of wheels used and altering the width of the wheelbase.

J. Constr. Eng. Manage., 2003, 129(2): 226-230

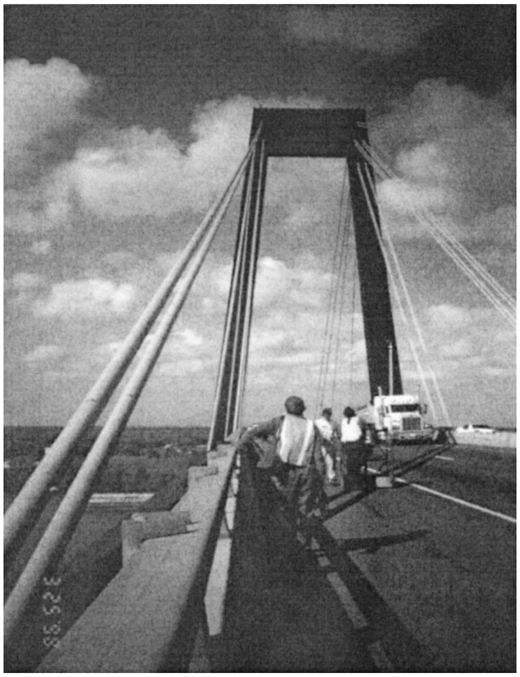

Fig. 3. Configuration of cables of Luling Bridge over main span

Four-Cable Trolley Setup

The four-cable trolley is used to inspect the side bridge spans. The trolley is a steel frame carriage with a detached basket (Fig. 4). The basket within the trolley is used to carry two inspectors and the inspection equipment, weighing approximately 1,780 N (400 lb). The total weight of the trolley and basket is approximately 2,450 N (550 lb). A steel 8 mm (5/16 in.) wire rope with a working strength of 4,890 N (1,100 lb) is used to pull the trolley up the bridge cables. With a 25° cable-stay slope, the total trolley weight of 4,230 N (950 lb) develops a 1,780 N (400 lb) static load on the wire rope. To pull the trolley up the cable stay, one end of a wire rope is attached to a removable winch at the top of the bridge tower (Fig. 5). During a previous inspection, permanent brackets had been welded to the tower platforms in order to provide a secure connection between the removable winch and the tower. In addition, pulleys were positioned and welded to the top and side of the towers to allow for proper alignment of the wire rope used to pull the trolley. To position the tower winch, a rope at the top of the tower is lowered to the bridge deck to hoist the winch and

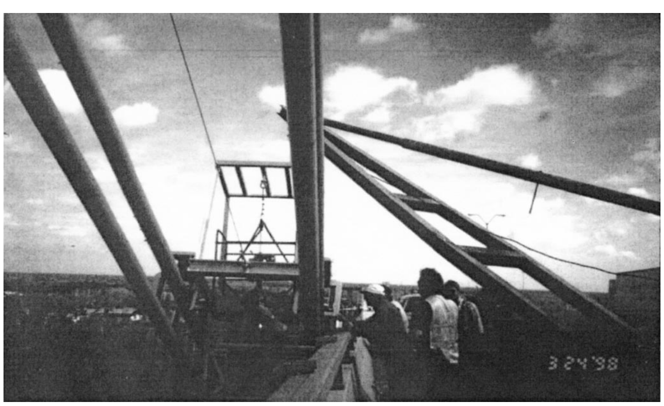

Fig. 4. Lowering four-cable trolley onto cables

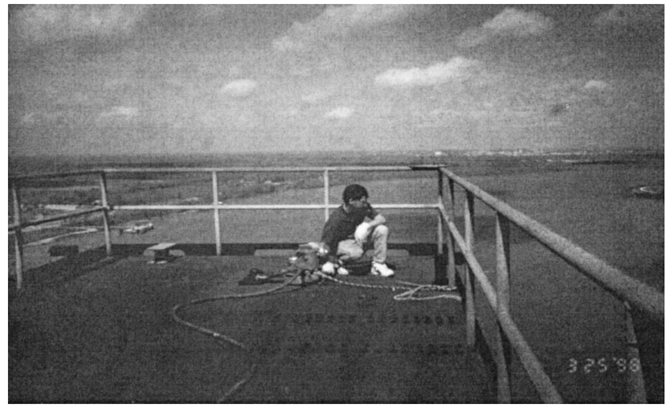

Fig. 5. Winch on top of tower, which is used to pull trolley up cables

wire rope to the tower platform level. Using a crane, the four-cable trolley is lowered and set onto the top two horizontally parallel cables of the four-cable group. The tower winch is secured to the tower brackets, and the wire rope is threaded through the pulleys at the top of the tower and attached to the trolley located initially at the cable-stay base. A second wire rope is used with one end attached to the roof of the trolley and the other end to a winch in the trolley basket. The installed basket winch allows the basket to be lowered to inspect cables below the cables that the trolley is riding on. To connect the basket to the trolley carriage, the trolley is pulled up the cable stays by the tower winch to slightly above the bridge deck. At this level, the basket winch is used to position the basket within the trolley. The tower winch is controlled by an operator on the tower platform, while the basket winch is controlled by an inspector in the trolley basket.

Since the basket within the trolley can be lowered to any height, the four-cable trolley can be used to inspect all eight cables of the bridge side spans; however, this warrants calm wind conditions (Fig. 6). Therefore, in other than calm wind conditions, inspection needs either to be limited to the cable stays the trolley

Fig. 6. Lowering basket to inspect lower cable stays

J. Constr. Eng. Manage., 2003, 129(2): 226-230

Fig. 7. Repairing cable stays with PVF tape

is riding on or to be postponed. When cracking in the sheathing is detected during the inspection process, repair work can easily be made from the trolley by retaping the crack area with PVF tape (Fig. 7).

Two-Cable Trolley Setup

While the four-cable trolley is appropriate for the side spans, the main span has a different cable configuration and thus required the development of a second inspection trolley. Because of the cable configuration in this area, the trolley is unsymmetric and rides on two parallel cables aligned vertically. The two-cable trolley is lowered into place using a crane (Fig. 8). The removable winch at the top of the tower is relocated to the main span side of the tower platform. Similar to the four-cable trolley, an 8 mm (5/16 in.) wire rope is used to pull the two-cable trolley up the top two vertically aligned cables over the main span. The trolley is pulled up the cable to the bridge deck level with the tower winch,

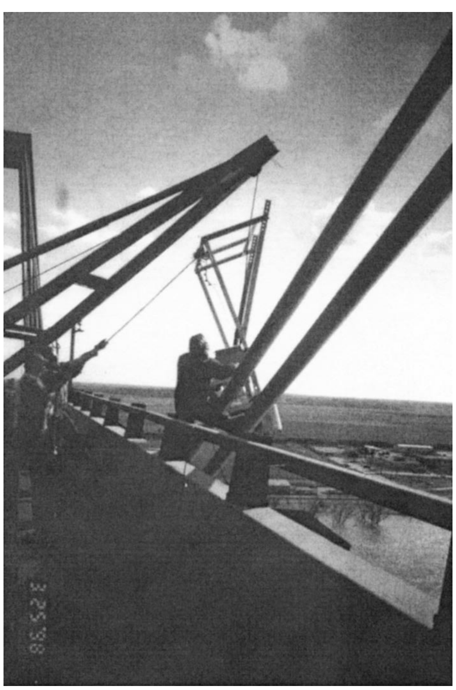

Fig. 8. Lowering two-cable trolley onto cable stays

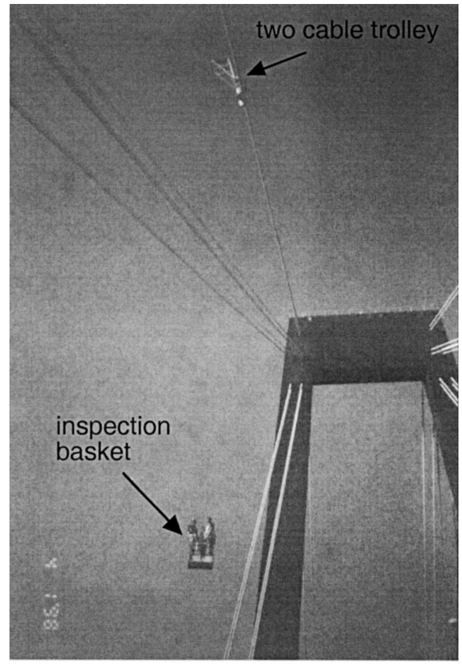

Fig. 9. Lowering basket to inspect lower cable stays

and the basket, where the inspectors ride, is attached and pulled into place with the second winch attached to the riding basket. As with the four-cable trolley, the basket can be lowered to inspect the bottom two sets of four cables below (Fig. 9). The two-cable trolley is slightly heavier than the four-cable trolley, where the two-cable trolley and basket weighs approximately 2,670 N (600 lb).

Inspection Procedure

Initially, a visual inspection using binoculars from the bridge deck was conducted in order to determine cable-stay sections that would require further in-depth inspection using the trolleys. The cable-stay layout is symmetrical about the centerline of the Luling Bridge, and inspection began on the west side of the bridge on the north tower cables attached to the side span. With the use of the trolleys, inspectors are able to get within hands' reach along any section of the cable stays at the Luling Bridge. The trolley is slowly pulled up from the base of the top cable stays to the tower top using the top cable stays as a track. The lower cable stays are inspected by lowering the basket to the lower cable-stay height. After the trolley reaches the tower, the wire rope used to pull the trolley is slackened and the trolley slowly descends back to the base of the bridge cable stay.

Bridge traffic was impacted minimally during the inspection procedure. The inspection procedure required use of the bridge maintenance lane and closure of a single traffic lane on the inspection side of the bridge. On the opposite side of the bridge, no traffic modifications were needed and, throughout the inspection, no traffic shut downs were required.

Conclusion

As cable-stay bridges age, there is a need to develop a feasible inspection procedure to inspect cable stays that highway departments can easily implement. This paper has discussed the proce-

J. Constr. Eng. Manage., 2003, 129(2): 226-230

dure used by the LADOTD to inspect the cable-stay sheathing at the Luling Bridge. Even with the many complications associated with inspecting the cable stays of a cable-stayed bridge, the procedure developed by the LADOTD has been found to be adequate and inexpensive. Although the LADOTD has addressed the problem of access to the cable stays and visual inspection of the sheathing, a procedure to internally inspect the steel cables within the cable stays has not been implemented as yet by the LADOTD.

Acknowledgments

The field information was gathered when the writers were allowed by the LADOTD to participate in the inspection of the cable stays of the Luling Bridge in March–May 1998. The writers would like to thank the LADOTD, the HNTB Corporation, and Louisiana State University for the opportunity to participate in the inspection. The writers also wish to thank the following members of the inspection and maintenance crew for sharing their knowledge and experience: Russel Hargrave, Vince Varisco, Bobby Ambrose, Robert Kerry, Bruce Brown, Dan Daniels, Johnny Spillman, and Eric Spillman.

References

Billington, D. P., and Nazmy, A. (1991). ''History and aesthetics of cable-stayed bridges.'' *J. Struct. Eng.*, 117(10), 3103–3134.

''Constructing cable-stayed orthotropic bridge.'' (1981). *Construction News*, Apr. 17, 22–25.

Soast, A. (1986). ''Trolleys cut cost of inspecting bridge cables.'' *Engineering News Record*, May 15, 58.

Stahl, F. L., and Gagnon, C. P. (1996). *Cable corrosion in bridges and other structures*, ASCE, New York.

Thibodeaux, R. (1982). ''Luling Bridge support cables finally installed.'' *The Times-Picayune/The States Item*, June 11, 1:17.

J. Constr. Eng. Manage., 2003, 129(2): 226-230