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# A New Life for the Main Cables of Williamsburg Bridge

## Nouvelle vie pour les câbles du pont de Williamsburg

## Neues Leben für die Hauptkabel der Williamsburg-Brücke

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**SUMMARY**

This paper describes the cable preservation system designed for the main suspension cables of the Williamsburg Bridge in New York City. A review of the studies and field tests performed prior to the preparation of the Contract Documents for the cable rehabilitation precedes the work-in-progress report. The cable preservation system consists of the application of a corrosion inhibitor inside the cable, and red lead paste in the exposed surface of the main cable, wire wrapping and a neoprene wrapping system.

**RÉSUMÉ**

Les auteurs décrivent le système de protection des câbles porteurs principaux du pont suspendu de Williamsburg, à New York. Ils passent en revue les études en laboratoire et les essais sur le site qui ont précédé la préparation des documents servant à l'appel d'offres pour la réhabilitation de ces câbles; ils indiquent ensuite l'état actuel des travaux. Le système de protection consiste à appliquer un inhibiteur de corrosion à l'intérieur des câbles porteurs, une pâte au plomb de couleur rouge sur la surface extérieure exposée aux intempéries, un enroulement de fil métallique et une enveloppe externe en néoprène.

**ZUSAMMENFASSUNG**

Der Beitrag beschreibt das Schutzsystem für die Haupttragseile der Williamsburg-Brücke in New York. Zuerst werden die Laborstudien und Feldversuche geschildert, die der Aufstellung der Ausschreibungsunterlagen für die Tragseilerneuerung vorangingen, und anschliessend der gegenwärtige Stand der Arbeiten. Das Seilschutzsystem besteht aus einem Korrosionsverhinderer im Seilinnern, rote Bleipaste auf der Witterung ausgesetzten Seiloberfläche, Drahtwicklung und einer Neoprenebandagierung.

## 1. INTRODUCTION

The Williamsburg Bridge in New York City has a 488 m suspended span, two 182 m side spans which are independently supported on intermediate towers with no attachment to the main suspension cables (Figure 1), and steel bent and girder approaches. The bridge was opened to traffic in 1903, and currently carries eight traffic lanes, two heavy rail transit tracks and a pedestrian footwalk.

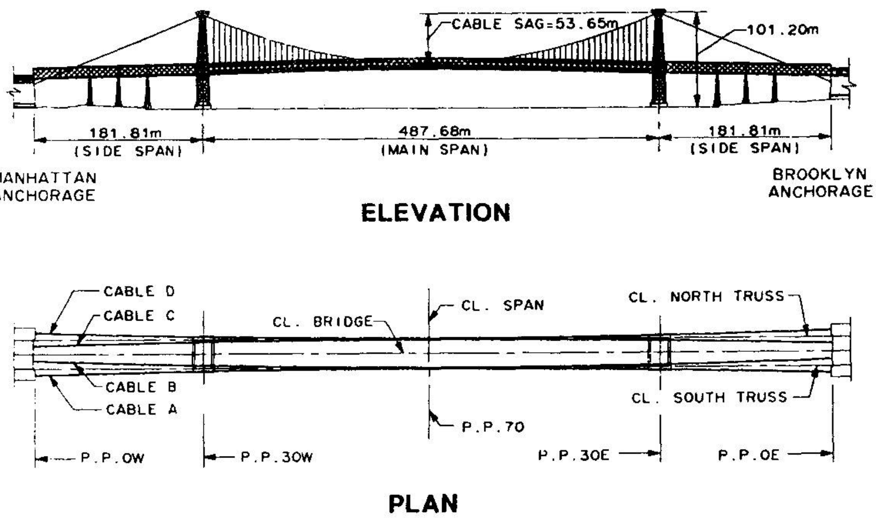


Figure 1
Plan and Elevation of Williamsburg Bridge

The main span is suspended from four cables of 476 mm diameter, each made of 7696 non-galvanized parallel steel wires 4.9 mm in diameter. The corrosion protection originally specified for the main cable wires included a shop coat of boiled linseed oil, and a shop coat and two field coats of slushing oil and graphite. The cables were compacted after spinning, and then wrapped with cotton duck impregnated with an asphaltic compound, and covered with a sheet metal sheath. By 1921 the sheath had badly corroded. The sheath was then removed, the cable was wedged and raw linseed oil was applied along its full length. After re-compaction the cable was wrapped with galvanized wire. In 1944 raw linseed oil was poured into the cables at their saddles on the tower tops, and in 1963 a similar operation was performed using fish oil and mineral spirits.

## 2. THE MAIN CABLE INVESTIGATION

A cable investigation conducted in the early 1980's projected that, by 1992, the cables would be unsafe to support the bridge and its traffic, and that cable rehabilitation would not be cost effective. The recommendation was to replace the cables. The Federal Highway Administration hesitated to participate in a cable replacement project on a substandard bridge with narrow roadway lanes and low clearances, and suggested a complete bridge replacement. In 1987 New York City and New York State Department of Transportation formed the Technical Advisory Committee (TAC) to evaluate the alternatives. It was recognized that the earlier studies were not supported by enough hard data, and Steinman was directed by the TAC to perform an in-depth cable investigation.

As the first steps in this investigation, a geometric survey of the cable sag and a photogrammetric survey of the deflection under controlled live load suggested that no significant loss of cable cross-section had occurred. Following this, the visual inspection, selection, sampling, metallurgical examination, testing and analysis of wire samples showed that significant corrosion had only occurred on a small number of wires, mainly those located in the bottom of the cable cross-section. Samples removed from the interior of the cables indicated that in some areas the oils used over the years to protect the cables had oxidized and dried [Ref. 1, 2, 3]. The worst condition was found at the Manhattan anchorage on Cable D. Hundreds of wires were broken between the splay casting and the strand shoes. The conclusion of the cable investigation was that the calculated factor of safety of the existing cables was at least 3.0, and that it could be increased to nearly the original 4.0 with minimal expenditure.

At the same time, the data gathered during the Biennial Inspection (1988) revealed that the most severe deterioration occurred at the approaches, while the trusses and towers of the main bridge were in relatively good condition.

In light of these conclusions, after extensive evaluation of replacement and rehabilitation alternatives, the Technical Advisory Committee decided that the rehabilitation of the suspension bridge and the complete replacement of the approaches was most viable from the economic point of view. The work was sequenced into several contracts, with the first one comprising the rehabilitation of the suspension system, which includes the cable preservation work described in this paper, plus the replacement of all suspenders, suspender connections to the truss, and cable bands. The reconstruction of the cable enclosures at the tower tops and anchorages, including replacement of the anchorage roofs, are essential part of this contract. The replacement of the approach structures and rehabilitation of the main bridge was staged into three contracts, with the first starting in 1995.

## 3. PRESERVATION SYSTEM FOR THE WRAPPED PORTIONS OF THE CABLE

After an evaluation of different cable preservation systems currently in use, which took into account the specific type of cable and its condition, the decision was made to use a penetrating liquid corrosion inhibitor, a red lead paste coating, non-galvanized wire wrapping, and a neoprene outer wrapping system.

### 3.1 The corrosion inhibitor selection

Several commercially available corrosion inhibitors were evaluated, and seven were selected for laboratory testing. Although some of these materials were found very good in resisting corrosion, most of them had very poor penetrating ability. Two non-proprietary materials were further selected for testing on the actual bridge cable. Pure raw linseed oil was finally selected, since it penetrated very well between the wires, including laterally and throughout the cable cross-section. This oil has been used successfully to treat suspension bridge cables for over one hundred years.

### 3.2 Cable oiling

A procedure for oiling and compacting the main cable was developed and tested in the field before being included in the Plans and Specifications for the Cable Rehabilitation.

Starting at the lowest point on the cable, a suspender and its cable band and the existing wire wrapping were removed, then 6 m long grooves were opened in the cable, using hardwood and plastic wedges (Figure 2). All the exposed wires were then inspected, and broken wires were spliced using a specially developed technique. Both ends of the broken wire were cut to allow for the splicing of a new piece of wire at each end, using press-on ferrules. A threaded ferrule connects the two ends of new wire, allowing it to be tensioned.

The uphill side of the wedges was then covered with petroleum jelly, to retard the flow of oil downhill in the groove and to obtain a better transverse distribution of the oil, and oil was applied inside the grooves (Figure 3). Based on the field test results, an amount equivalent to 25 liters of oil per linear meter of cable was specified in the Contract Plans; however, this application rate was somewhat modified during construction in response to varying conditions at different locations along the cable. After completion of oiling in one panel, the wedges were removed and the cable re-compacted. The procedure was repeated in each adjacent uphill segment of cable until reaching the cable saddles at the tower tops.

### 3.3 Cable Compaction

During the wedging and oiling operations the position of the main cable wires is disturbed, resulting in an increased diameter of the cable after wedges are removed. Cable compaction is then necessary to restore the original dimension and shape of the cable, essential for the correct installation of the cable bands and the proper functioning of the wire wrapping machine. Hydraulic compactors equipped with four 1000 kN capacity jacks were used for the cable compaction.

The main objective of the cable compaction is to minimize the voids between main cable wires, thereby reducing the opportunity for water and oxygen to enter and remain inside the cable, and for moisture condensation to occur. In addition, the clamping effect of the compacted cable allows for recovery of the full tension in an individual broken wire over a shorter length.

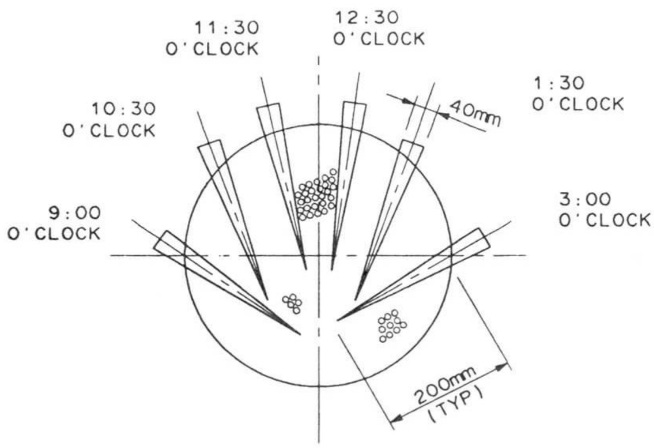


Figure 2
Cross-Section of Wedged Cable

Figure 3
Applying Oil into the Grooves

### 3.4 Cable Wrapping

The new wrapping system consists of a coat of red lead paste applied directly on the main cable wires, wire wrapping, and a neoprene outer wrapping system.

Red lead paste is used to coat the exposed surface of the main cable wires and to fill the voids between wires, in order to completely seal the main cable from moisture. Red lead paste was selected because it is the most effective corrosion inhibitor for the main cable wire surfaces.

The wire wrapping provides an armored protection for the main cable wires, and holds the compaction of the main cable wires between the cable bands. Non-galvanized wrapping wire is used on these cables (Figure 4) to avoid galvanic action which could lead to hydrogen embrittlement of the non-galvanized main cable wires.

The neoprene wrapping system provides a watertight protection against atmospheric attacks. The system consists of a liquid air-curing neoprene applied to the surface of the wire wrapped cable. Then 152 mm wide uncured neoprene sheetstock is spirally wrapped around the main cable starting at the "downhill" end of the panel. Thinner, which welds neoprene sheets on contact, is applied on the overlapping portion of neoprene sheets. Successive turns are installed with 50% overlap to create a "shingle" effect that prevents the entry of water through the joint between them. The cable band edges are caulked using a polyurethane sealant. An air curing coating is then applied on the neoprene wrapped surface. Ground walnut shells are sprinkled over the top surface of the cable, prior to the final coating, to provide an antislip surface (Figure 5).

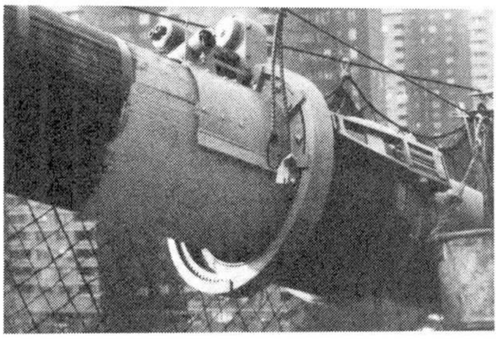

Figure 4
Wire Wrapping Machine in Place on the Main Cable

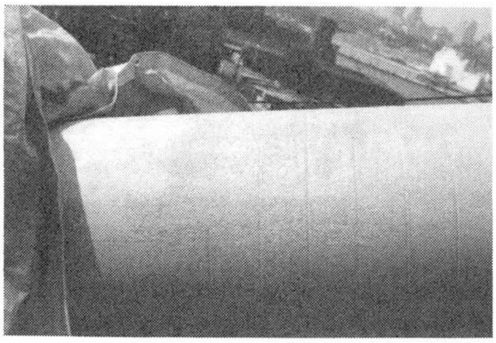

Figure 5
Finished Cable with the New Neoprene Wrapping

## 4. THE CABLE PRESERVATION SYSTEM AT THE ANCHORAGES

As part of the cable investigation, and after decision had been made to rehabilitate the main cables, Steinman replaced two strands and spliced many wires in the Manhattan anchorage of cable D [Ref. 4]. These repairs increased the calculated factor of safety from 3.0 to approximately 3.5.

The cable rehabilitation work at the anchorages includes oiling of all non-wrapped portions of the cable using a proprietary corrosion inhibitor and procedure developed by Steinman for the Brooklyn Bridge rehabilitation. Before oiling, any loose, broken, heavily corroded or galvanized wires are replaced using special splicing techniques. The corrosion inhibitor is reapplied every year as part of the routine maintenance. In addition, new watertight cable enclosures at the anchorages, a new waterproof anchorage roof and a passive ventilation system [Ref. 5], will help protect these non-wrapped portions of the cables from further corrosion.

## 5. THE CABLE REHABILITATION CONTRACT

The cable rehabilitation contract, bid at 73 million dollars, is now being completed by the joint venture NAB/KOCH under the supervision of the New York City Department of Transportation. Construction inspection is performed by Greenman Pedersen Inc. and construction support services are provided by Steinman.

Work started in September 1992 and is scheduled to be completed at the end of September 1995. The first stage was the construction of 2.4 m wide footwalks under each cable (Figure 6), except at the center of the main span, where the proximity of the cable to the roadway allowed the Contractor to work from scaffolding installed on the roadway. The work proceeded according to the Contract Plans, and as described here, except for some minor modifications. Work remaining to be done consists primarily of the cable enclosures and the remainder of the new roof at the anchorages. In addition to the work included in the Rehabilitation Contract Plans, the cable condition encountered after removal of the splay casting of Cable A at the Manhattan anchorage forced the decision to replace seven strands [Ref. 6].

Figure 6
Partial View of Williamsburg Bridge during the Cable Rehabilitation Work

## 6. CONCLUSION

The objective of the work described here was to rehabilitate the main suspension cables of the Williamsburg bridge to return them to nearly the original strength, and to provide for an additional life of at least 100 years. The protection that is being provided to the cables, together with regularly scheduled inspection, and maintenance when required, will provide for a potentially infinite life.

## 7. ACKNOWLEDGEMENTS

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