Inspection program for the Lisbon suspension bridge

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Inspection Program for the Lisbon Suspension Bridge

Programme d'inspection pour le pont suspendu de Lisbonne

Untersuchungsprogramm für die Hängebrücke in Lissabon

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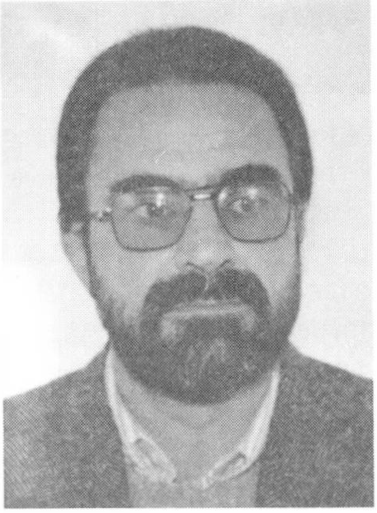

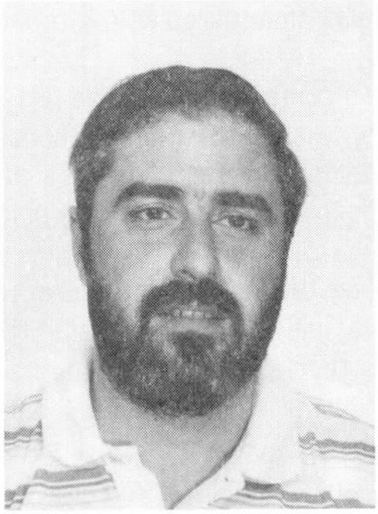

SUMMARY

The guidelines of the inspection program for the suspension bridge in Lisbon are presented. The program considered an overall inspection for corrosion and the analysis of the structural behaviour of several elements. The principal findings and the inspection techniques are presented.

RÉSUMÉ

On présente les lignes directrices d'un programme d'inspection pour le pont suspendu à Lisbonne. Ce programme consiste en une inspection générale de la corrosion et de l'étude du comportement de quelques éléments structuraux. Les résultats principaux et les techniques d'inspection sont présentés.

ZUSAMMENFASSUNG

Die Richtlinien eines Untersuchungsprogrammes für die Hängebrücke in Lissabon werden dargestellt. Dieses Programm besteht aus einer generellen Korrosionsuntersuchung und aus der Analyse des Verhaltens einiger Tragelemente. Die wichtigsten Ergebnisse und Untersuchungsverfahren werden beschrieben.

1. INTRODUCTION

The " 25th of April" bridge in Lisbon is one of the longest suspension bridges in the world with a total length of 2276m and a central span of 1013m. An observation program to study its structural behaviour was developed and implemented during its construction and carried on for several years after the bridge opening, in 1966.

Recently the Portuguese Highway Authority (J.A.E.) decided to widen the deck to carry six traffic lanes (presently it has 4 lanes). Simultaneously, studies are also being developed to introduce the railway traffic in the lower part of the deck, solution that was considered in the initial design of the bridge.

To come up with these projects, the implementation of a detailed inspection program of the structure was considered a priority task by the J.A.E. As a matter of fact during the last 23 years miner routine inspections have been undertaken, but now a deep assessment of the bridge was felt necessary.

Due to the unusual characteristics of this type of job a research was developed to define the guidelines of the inspection program. This is presented in this paper referring the main aspects to be considered in the inspection of the anchor blocks, towers, main cables, hangers, truss beam, joints and bearings. Based on the inspection, the main findings are also referred as well as some particular problems faced during the works.

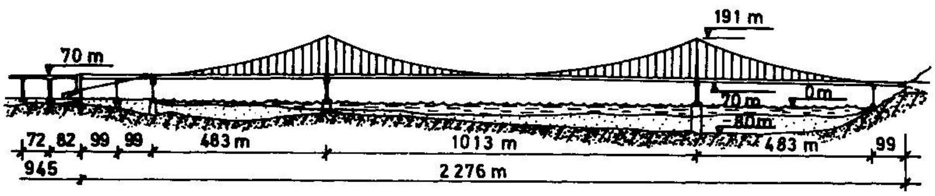

Fig. 1 - LISBON SUSPENSION BRIDGE.

2. THE SUSPENSION BRIDGE

The "25th of April" bridge is a steel structure with a total length of 2276m connected with a concrete approach viaduct (north side) with 945m. The steel structure includes the suspended structure with a 1013m central span and two 483m lateral spans, and a supported continuous stiffened truss with a south end span (99m) and two north end spans (2x99m) (Fig. 1).

There are seven supports along the bridge: the two abutments (P_1, P_7), the two main towers (P_3 , P_4), an intermediate column in the south side (P_2) and two other in the north side (P_5, P_6). The suspension structure is defined by supports P2 and P5 at which the main cable passes below the deck level. These columns are fixed at the base and slip free for the deck, at the top. The main towers are 191m high and are fixed at the base in concrete caissons which found 80m below water level.

The truss beam is, 10,6m high and 21m wide, suspended from the hangers (23m apart) about 70m above water level. Fig. 2 shows the actual cross section and the future situation with the train. The actual widening design considers the space between the border of the upper deck and the hangers.

The main cables have a diameter of Ø = 0,586 m and are made of 11 248 steel wire (Ø = 5mm - f_{yu}= 1560 N/mm^2). During construction the wires were tied in groups of 304 units, then compacted and tied with helicoidal wire and finally painted with anticorrosive paint. The hangers are connected to the main cables with two shell clamps tied with high strength bolts.

The structure was built with several types of steel. The connections between steel members were mainly done with high strength bolts.

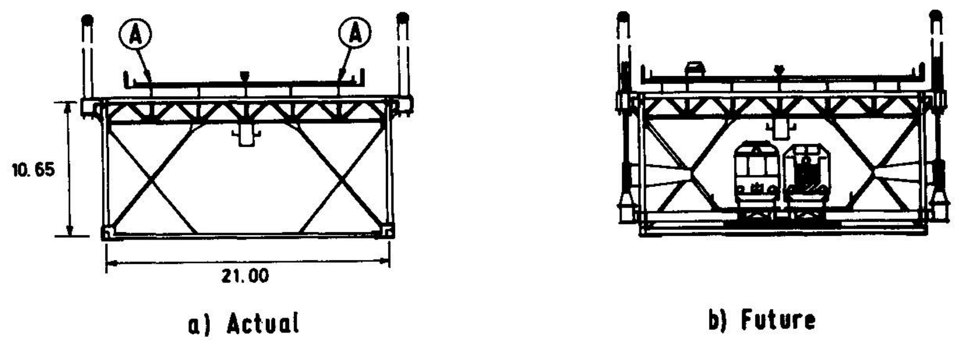

Fig. 2 - DECK CROSS SECTION.

3. THE INSPECTION PROGRAM GUIDELINES

The two main objectives of this program are:

- To perform an overall inspection for corrosion problems;
- To check the structural behaviour of the bridge elements.

The study began with a preliminary research about suspension bridge inspection techniques [1,2]. Next the program was developed considering the guidelines for the inspection of each main structural element. These are briefly referred.

3.1 Anchor Blocks

Inside the concrete cameras, where the cable anchors are placed, usually high humidity may occur. This may be associated to corrosion problems what leads to a careful inspection of cables and anchorage. The main structural problem associated with these elements is its movement along the time, what may lead to the collapse of the bridge. Topographic periodical inspections are highly recommended.

3.2 Columns

The steel bridge columns and the towers need a general inspection for corrosion. Special attention should be paid to:

- The base of the columns where the highest forces usually occur;
- The transverse cross beam in the top of the towers where unusual forces may occur due to asymmetrical loading;
- The connections of the cables to the top of the columns, to check for eventual slips.

3.3 Main Cables

The problems that may occur in the cables are the corrosion and cracking of the wires. A visual external inspection should be done along the cable with particular attention to the anchor zones and the lower part of the parabola where the water from rain converges and accumulates.

For the internal inspection of the cables there are presently two electromagnetic techniques, available [4]: The Foucault Current Method and the Induced Current Method. The first one measures the oscillations in the magnetic field of a solenoid placed around the cable, which is proportional to the oxidation of the wires. In the second method one measures the induced current that arises in an alternative magnetic field placed around the cable, due to its imperfection. This technique was developed to find cracked wires which are shown by tension peaks in the induced tensions.

3.4 Hangers and Cable Bands

The hangers corrosion is also an important problem, especially in the lower connection, but a visual inspection is usually sufficient. The structural problems associated with the hangers are the following:

- Inclination - inclined cables are associated with slips in the clamps;
- Hangers Tension - when connection problems occur, the tension may decrease. This can be checked measuring its vibrations frequency which is proportional to the tension [3];
- Longitudinal Profile of the Deck - irregular profiles of the deck are usually associated with suspension problems;
- Cable Bands - should be visually checked to detect slips. To check the clamping forces two methods are now under research: the ultrasonic measurement and the use of a hydraulic "bell" system that tensions the bolt from the nut side [1].

3.5 Deck Truss Beam

In this element the inspection should consider the corrosion and the local problems. Regarding corrosion, attention should be paid to water retaining details, zones near water gutters and closed sections where the internal inspection is also necessary. The local problems are associated with car damages in the structure, fatigue problems in welded connections (especially at midspan and support sections), and cracked or loose bolts in the connections.

3.6 Supports and Joints

The inspection of these elements should consider essentially their cleaning to guarantee a good behaviour. This can be observed during a day, checking the temperature movements. Eventual cracks in the supports may be detected by unusual noises under traffic.

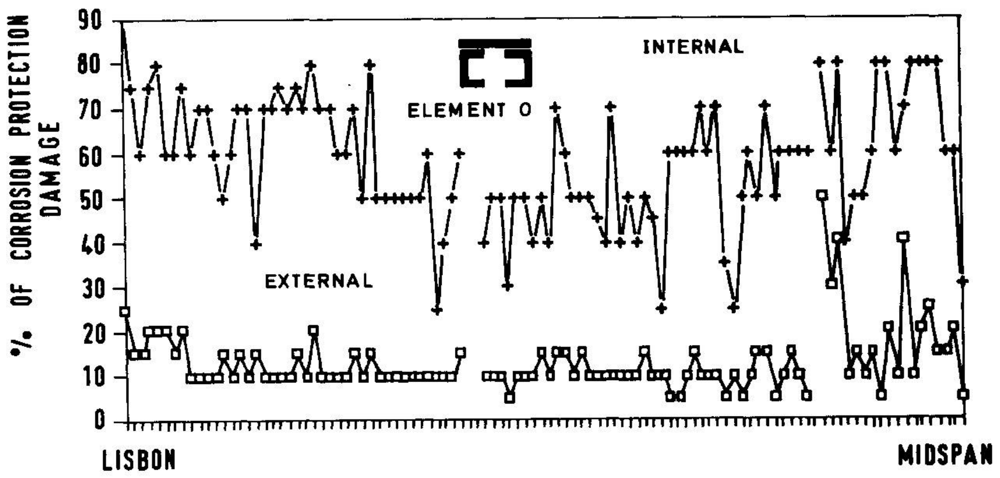

Fig. 3 - ANTICORROSION PROTECTION DAMAGE AT ELEMENT O, ALONG THE SPAN.

4. THE INSPECTION RESULTS

At the first stage of the program, the corrosion inspection was implemented. At the columns only superficial corrosion was found, mostly at the interior of the base section. The concrete caissons were also observed and filmed under water to check for concrete degradation, but no relevant findings were obtained. At the cables hangers and cable bands, and with an external observation, only small spots of superficial corrosion were found. Due to the good external condition, an internal observation with electromagnetic techniques was not considered necessary at this stage. All the bars of the deck truss were also inspected and plots of the superficial corrosion along the bridge were drawn for each element (Fig. 3). Structural damage by corrosion was found only in a few nuts of the bolted connections which presented section reductions of more then 20% . It is estimated that about 2% of the deck bolts will need to be replaced shortly. During deck inspection some transversal bars located over the longitudinal girders (shown in Fig. 2 by A). It is estimated that 13% of the total number present this problems.

The second phase of the program considering the inspection of structural behaviour of several elements is now under development. The first problem is the rechecking of the tension on the cable bands bolts. The results from the ultrasonic measurement and the hydraulic bell system are being checked with those from a prototype to come up with an easy and reliable technique. To obtain the hangers tension, a cable prototype is also under research to calibrate the vibration method, considering different lengths of cables. Also checked were the hand rails cables, over the main cables. Their forces were measured to analyse their capacity to carry the loads of the future inspection system.

4. ACKNOWLEDGEMENTS

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