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Stay Cable Corrosion Protection with Petroleum Wax

Protection des haubans contre la corrosion avec de la cire pétrolière

Korrosionsschutz von Schrägseilen mit Ölwachs

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SUMMARY

Stay cable technology has been extensively developed in recent years. Owners and authorities are considering lifespan of 120 years and even more. Consequently, corrosion protection materials and systems have been developed and tested. Large research programmes have been initiated all over the world. The purpose of this paper is to present the latest developments about petroleum wax used as corrosion protection for stay cables and to consider various aspects such as: fatigue resistance and fretting corrosion, individually protected galvanised and waxed strands, injection operations and connections details.

RÉSUMÉ

La technologie des haubans a fait l'objet d'un large renouvellement durant les dernières années. Les clients envisagent des durées de vie de 120 ans et plus; en conséquence, de nouveaux systèmes et matériaux de protection contre la corrosion ont été développés et testés partout dans le monde. Cet article présente les derniers progrès réalisés avec la cire pétrolière et les résultats positifs obtenus en matière de résistance à la fatigue et de protection contre la corrosion.

ZUSAMMENFASSUNG

Während den letzten Jahren wurde die Schrägseiltechnik erneuert. Die Bauherren beabsichtigten Lebensdauern von 120 Jahren und mehr; infolgedessen wurden neue Schutzvorrichtungen und Werkstoffe gegen die Korrosion weltweit entwickelt und erprobt. Dieser Artikel legt die neuesten Fortschritte über Ölwachs und die positiven Ergebnisse bezüglich der Widerstandsfähigkeit gegen die Ermüdung und den Schutz gegen die Korrosion vor.

1. INTRODUCTION

The stay cable technology has been extensively renovated during the last ten years. This development founds its origin in the owner's requests for having the longest life span as possible (120 years for instance) and in the contractor's demand for simplicity and efficiency, but also in the significant improvements recently made in the materials themselves.

How to increase the life span ? By providing a better quality product from the very beginning of the construction and by developing the surveillance concept since there are no material suppliers able to give today a 120 years guarantee ! Therefore, the service life of a stay cable is largely dependent upon the effectiveness and durability of the corrosion protection.

Cement grout was used in the early days as corrosion protection. This was the direct application of the technique used for post-tensioned cables in bridges. However, this product showed rapidly its limits :

- The cement grout is heavy ; it represents a significant part of the stay weight, which becomes a disadvantage in large bridges.
- The requirements of good quality grouting implied the use of large diameter duct, thus increasing wind effect. Grouting operations are questionable
- The cement grout in the anchorage zone has a negative influence to the fatigue resistance of the stay. It induces fretting corrosion.
- The cement grout creates a group effect which reduces the performance of the stays.

A soft material having excellent corrosion protection characteristics needed to be considered.
Also temporary corrosion protection rapidly appeared to be a necessity in the site conditions :

- harsh environment : humidity, salted atmosphere, temperature variations,
- construction requirements : storage, transport, handling.

Thus individually protected galvanized strands are commonly used today. They consist of hot dip galvanized strands coated with high density polyethylene and provided with a protective filler inside the interstices between the king wire and the outer wires and around the outer wires. This protection filler is also used as the permanent corrosion protection material in the anchorage area. It consists of a petroleum wax (INJECTELF CP or HPF type). This paper presents the latest developments and corrosion protection characteristics of this material.

2. PETROLEUM WAX FOR CORROSION PROTECTION

2.1 Definition

Several petroleum products are proposed and have been used. It is necessary to define each of these products for clarification . :

- Gatch : mix of paraffin and waxes including a high percentage of oil (up to 30 %)
- Crystalline paraffin : this product is obtained by disoiling of the gatch during crystallisation.
- Microcrystalline wax : this product is obtained from heavy components of distillation.
- Petrolatum : a mix of paraffin and oils.
- Vaseline : result of refining and dilution of petrolatum.

2.2 Petroleum wax characteristics

The product described hereafter is a microcrystalline wax INJECTELF CP HPF which has been specially developped by the Laboratoire Central des Ponts et Chaussées at Paris with a french oil company [1].
Waxes are made of saturated hydrocarbures according to formula $C_n\ H_{2n}+2$ types with a high percentage of ramified chains and a microcrystallisation. This explains its flexibility, and its adesive properties to various supports. Somme specific additives provide excellent behaviour under extreme pressure (fretting corrosion) [2] and[3].

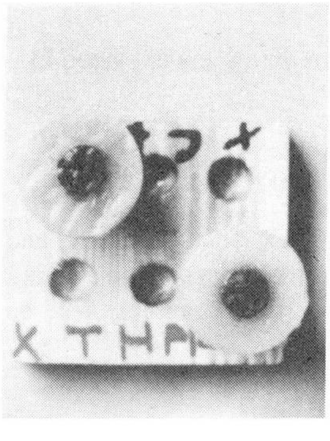
2.3 Corrosion protection properties

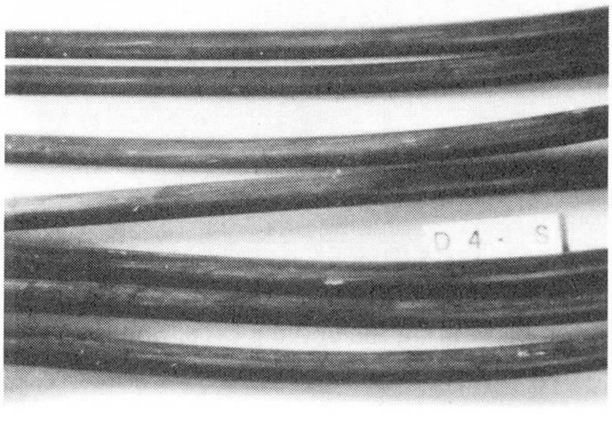
A series of comparative stress corrosion tests have been carried out [4] in distilled water at the LCPC according to the French standard NF A05-302.

The samples for tests were taken in the same coil of a strand T12,4-III-TBR.

The mechanical characteristics of these non-protected prestressing steels were determined by tensile tests before and after the stress corrosion tests and were considered as a basis for comparison. These basis corrosion tests were continued till rupture of a least one of the individual strand wires.

Before applying the protection products, the strands have been examined on a magnetoscopic device neither crack nor micro crack has been observed. Some of the protection products have been spread on the sample surface in two layers : one so called thin layer through which the steel was still visible. A so called thick layer (0.5 to 1 mm) under which the steel disappeared. The protected samples (two samples per tested product) were put in waterproof cells then installed on constant length devices. The loading was made with a jack ; once the load applied, filling the cell with water and circulating it were done as quick as possible.





Taking into account the available test devices, twelve products were being tested by the LCPC at Nantes during 270 days, the left three products by the LCPC at Paris during 6 months for the first series and 31 months for the second test series with and interruption of one month after 22 months.
For all the protection products, we observed that they bring an increase in the life time of the strands in the standardized stress-corrosion testconditions (NF A 05-302).

Results obtained after 31 months on three different samples (Complex aluminium grease,wax,calcium grease) have demonstrated the better behaviour of the petroleum wax.

- 31 months without rupture to be compared with the 4 months life time of the non-protected strands coming from the same coil.
- No pit
- No mechanical characteristic losses
- Rupture in the emerged zone. This proves that the observed dissolution spots in the immerged were zones of little importance and had no detrimental effect.

2.4 Low temperature behaviour of the wax

It has been reported [5] that wax was showing irreversible cracking at -50°C. A series of tests have been carried out at the LCPC at Paris with different waxes : one having a melting point at 70/75°C (type a) and another at 110/115°C (type b). The tests parameters were the injection temperature 95°C, 105°C, 125°C. Then, the test samples were subjected to the following temperature cycles.

Temperature Cycles	Initial Temperature		- 40°C		- 50°C		Final Temperature
		TIME IN MINUTES					
1	24°C	32'	3'	5'	3'	23'	6°C
2	20°C	17'	6'	3'	-	13'	6°C
3	16°C	17'	6'	3'	-	18'	5°C

Results :

- Cracking was observed after cooling at ambient temperature while using wax type b in an empty pot while injecting at the highest temperature 125°C..

- No cracking was observed with type b when a steel rod (10 mm diameter) is placed in the centre of the pot and the highest injection temperature.

- No cracking was observed with wax of type a in any condition.

Conclusion : Cracking may be observed at ambient temperature if the wax characteristics and injection specifications have not been properly selected. This cracking will remain during the cooling cycle. However if no cracking is observed at ambient temperature no further cracking will be developed during the cooling cycle down to -50°C.

3. APPLICATIONS

3.1 Stay cables with petroleum wax injected on site .

Tampico bridge (Mexico) built in 1984-1988 was the first cable stayed bridge using this technique. Stays consist of an overall HDPE duct in which galvanized strand are threaded. Wax injection was carried out on the deck then the stay was lifted into place and tensioned. For other bridges, (ELORN) France, the galvanized strands were threaded and tensioned strand by strand , then the wax injection was done after drecking the perfect tightness of the duct.

3.2 Stay cables with individually protected galvanized strands.

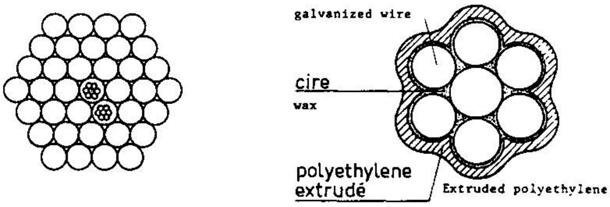
3.2.1 Description

The individually protected strand [6], recommended by Freyssinet is an industrial product entirely protected in factory by several barriers, which, starting from the outer part of the strand, are composed of :

. an extruded plastic layer with a minimum thickness of 1,5 mm (generally HDPE-High Density polyethylene).

. A zinc coating produced by hot dip galvanization, wire-drawn in such a way that the thickness of the finished coating is not less than 25 microns (180g/m^2).

. A protective filler made of petroleum wax (Injectelf CP-HPF type). It fills in the inter-wire voids ; water is prevented from running down ; this is checked by acceptance tests.

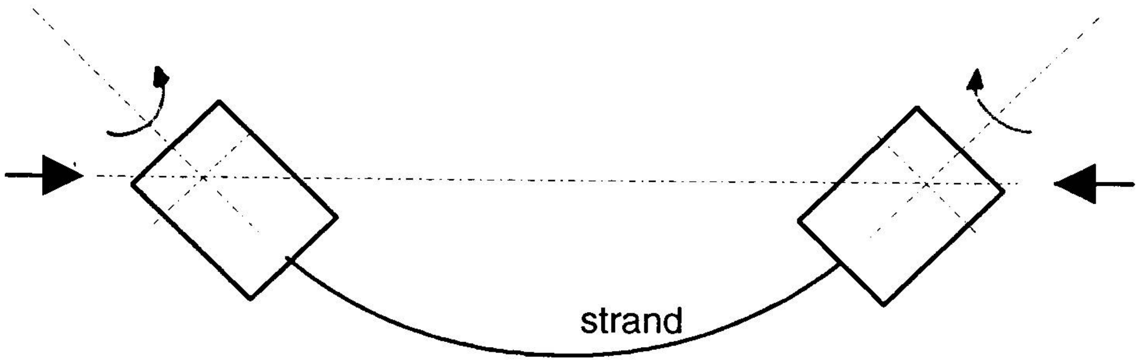


Faisceau de torons
BUNDLE

Toron individuellement protégé
INDIVIDUALLY PROTECTED STRAND

One may notice that steel protection is achieved quite early in the strand fabrication process, therefore preventing any chance of corrosion between successive operations. As soon as it leaves the factory, the "individually protected strand" product is therefore perfectly waterproof and efficiently protected against environmental attack.

In the anchorage area, the HDPE confinement is stripped out and replaced by a wax protection which completely fills the volume between the anchorage stuffing box and the cover containing the anchorage head : but during construction, a continous corrosion protection is maintained with the galvanization.



Rotative bending test

3.2.2 Rotative bending test

The Laboratoire Central des Ponts et Chaussées (Paris) has carried out a series of tests with various samples showing the beneficial role of the wax intermediate filler.

- Testing arrangement : an axial horizontal force creates the buckling of the sample. Then a rotative movement is applied at both ends. Thus the extreme fibber of a cross section is alternatively in tension and compression.

- Results :
No damage was observed on the HDPE duct for all the three tests.
A similar test carried out on a sample with no wax failed : the duct starts cracking at 300 000 cycles.

3.2.3 Temperature tests
Several non stressed samples with wax filler were subjected to a series of severetemperature cycles. The testing procedure was as follows : 20 cycles from +30°C to -60°C were applied to several samples with different end conditions (HDPE duct either free or fixed to the strand). Then samples were taken to -198°C during 32 minutes.
No damages at all were observed. However, when there is no wax filler, there is a rapid deterioration of the duct.

4 - CONCLUSION

All these numerous and variouus testings have given us a better knowledge of the petroleum wax as a corrosion protection material for stay cable. They have given us also a lot of confidence by the positive achievements which have been obtained. The individually protected galvanized strands thread and stressed strand by strand into an overall HDPE duct is probably one of the best answers to owners requirements for extending the lifespan of cable stayed structures.

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