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Long-term Anticorrosion Protection for Guys of Cable-Stayed Bridges

Protection à long terme des câbles de ponts haubanés

Dauerhafter Korrosionsschutz für seilverspannte Brücken

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SUMMARY

A very durable multiple anticorrosion protection proposal is presented to be applied especially on parallel cable elements of stayed bridges or similar structures where, by a relatively higher initial cost, an evident increase in reliability and useful life of cables is achieved having an enormous safety reserve, reducing control and maintenance expenses that result in a lower final cost.

RÉSUMÉ

On propose d'appliquer une protection anticorrosive multiple de longue durée aux câbles parallèles des ponts haubanés, ou aux structures similaires, lorsque, pour un coût initial relativement plus élevé, on obtient une augmentation évidente de la fiabilité et de la durée d'utilisation des câbles, tout en disposant d'une énorme réserve de sécurité et en obtenant une réduction des frais de contrôle et d'entretien conduisant à un coût final plus bas.

ZUSAMMENFASSUNG

Ein sehr dauerhafter Korrosionsschutz für seilabgespannte Brücken oder ähnliche Bauwerke wird beschrieben. Durch höhere Baukosten wird eine wesentliche Erhöhung der Dauerhaftigkeit und der Lebensdauer der Kabel erreicht. Daraus resultiert eine grosse Sicherheit mit entsprechender Verminderung der Inspektions- und Unterhaltskosten, wodurch die Gesamtkosten geringer ausfallen.

1. INTRODUCTION

It is not easy task to conceive a structure from the viewpoint of its durability. Studies on the subject show a pronounced structure duration dispersion [1] and a certain contradiction between the frequency of the failure cases and the theories dealing with their reliability [2]. Though there exists already a definite trend towards tackling design from a probability viewpoint to solve questions concerning durability -and also safety and serviceability- it must be admitted that the material failure precise nature is not known.

Within a context so conceived, a multiple anticorrosion protection is proposed that seeks a durability as long as the stayed bridge useful life. This type of bridge, recognized as an economical, reasonable, aesthetical, lasting solution, especially efficacious for 200 to 500 m spans, has not offered a satisfactory "status quo" with respect to cable durability. During past years there have appeared cases of corrosion and deterioration in guys of important bridges in Europe, U.S.A., Latin America and Japan [3], [4], [5], [6], that lead to think that there is not an adequate coherence between the decisive structural importance these cables have and the protection safety and durability for which the most qualified stayed bridge pioneers, designers and constructors are crying out, clearly emphasizing the need for a robust and reliable corrosion protection system for the stay tendons.

2. ESSENTIAL IDEA OF THE SISTEM PROPOSED

The main objective is having a protection the duration of which approaches the bridge expected useful life (conventionally, 75 years). The design is based on the conviction that owing to the materials deterioration laws phenomenology, with respect to anticorrosion it is not possible to expect spectacular solution centered on a magic product or method, so to obtain a very long duration protection recourse must be had to a highly reinforced protection. High polymer materials have been chosen considering that high molecular weight enables them for lengthy duration, especially if suitable precautions are taken.

The central idea -the system fundamental key- is to protect a protective element considered essential; in this case a high density polymer inner pipe (HDPE) or similar to which should be guaranteed a sort of "hibernation" aided by other elements that besides acting also as anticorrosion protection, insulate the inner pipe from temperature and weather. Waterproofing should be paid as much attention to as temperature insulation.

3. DESCRIPTION OF THE PROTECTION

The system proposed (Fig. 1) is composed of a HDPE inner pipe (3) circling the tension elements bundle; another HDPE pipe (6), light or white coloured; an injection between pipes (4) and another injection (1) within the inner pipe (3) both of an elastomeric or plastic material or eventually portland cement with polymers and a two layered wrapping or otherwise only one tape complyind with the same purpose. The first helps as a fastener of the whole, and the external one, white or light coloured functions as a protection against UV rays, IR radiation, oxigen and ozone and as a temperature reducer. Also, if vibration produced in the cable by the wind are expected to be significant, it is advisable that external side of the wrapping be corrugated, scarified, ribbed or creased in such a direction that once in place it shows an aerodynamically oriented pattern for dissipating the vibratory energy.

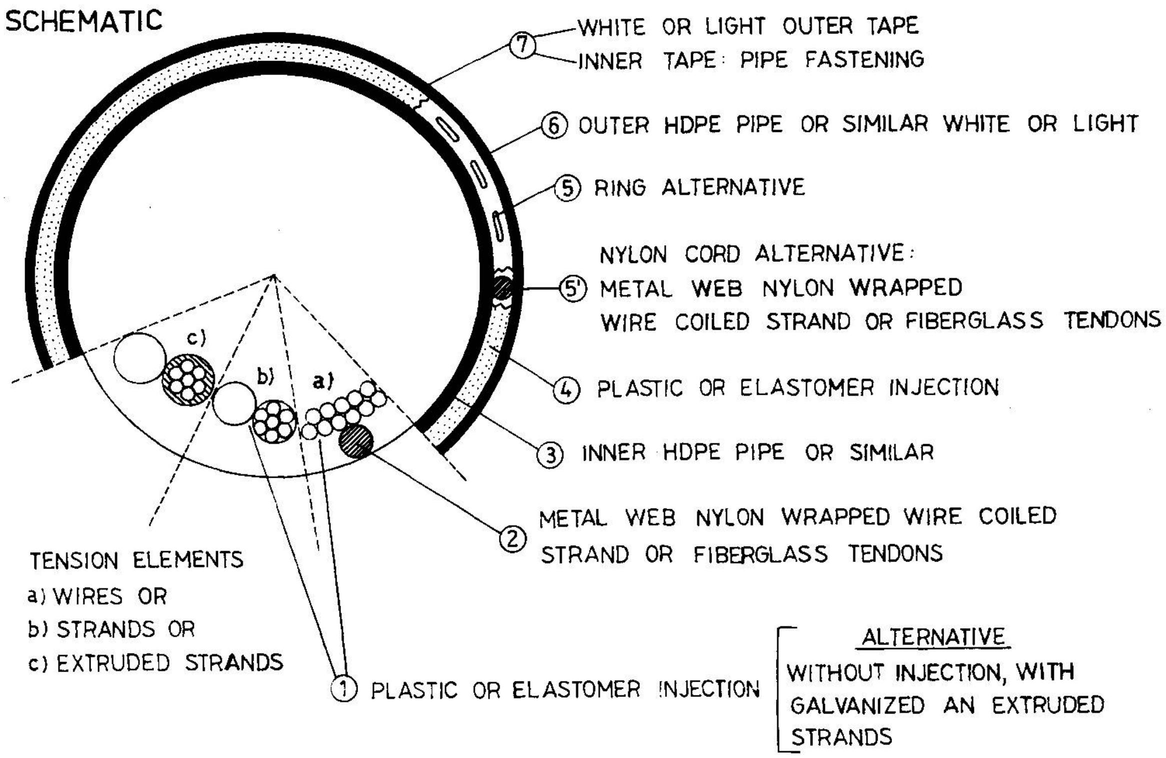

Fig. 1 - Cross section of the proposed cable and alternatives

The spacing between pipes may be obtained with rings (5) perforated for the injection to get through and welded to the inner piper only but in contact with the outer pipe, whitout adherence, with the object of allowing the longitudinal movement of the protection top part. The adhesion of the ring, that may be made of any suitable plastic material, can be achieved by the plastic welding update techniques developed nowadays. Though the polythylene thermal stability makes brief heating possible near the softening point without causing any trouble -provided that it does not occur simultaneously with mechanical loads- if it is desiderable to avoid a certain temperature range, a metal web nylon wrapped wire coiled strand (5') may be used over the pipe (or fiberglass tendons as those used for posttensioning concrete bridges), similar to the one used to fasten the wire bundle (2) acting also as spacer. This strand (2) helps -together with rings and the other strands (5')- in keeping the cable circularity the objective of which is to prevent additional interferences in future surveying performed by magnetic induction or similar method. If strands are chosen a tension elements (b) and (c) in Fig. 1, care should be taken that the fasteners and or spacers do not damage the HDPE pipe, the steel or the single tape wrappings.

In the case of very lengthy cables and where -owing to the weight- the deflection requires lightening, the guy diameter can be reduced by eliminating strand (2) and making a direct extrusion on the bundle; or -in case strands are used,- injection (1), provided that the strands be extruded and galvanized individually. In any of these alternatives, the remaining protection (from 4 to 7) should be added to secure a long lasting useful life, according to the above mentioned concepts.

4. PROPOSED SYSTEM ADVANTAGES AND PECULARITIES

It is considered that the system described offers the following characteristic advantages: 1°) The plurality of the different component material, implies extreme safety, as a cause of corrosion is not apt to attack simultaneously different materials such as those of the proposed system with success; 2°) ageing or deterioration is notoriously retarded in the inner layers which greatly lengthens its useful life and consequently that of the cable; 3°) there is a large availability of time to change the outer protection without risk for the steel; 4°) spot accidental causes (notches, plastic components defects) dangerous in systems with less elements, lose importance in a multilayered system; 5°) independently from the tension steel anticorrosion properties, the protection emphasis should be placed on the steel "external" elements sum and synergy. This approach permits an absolute liberty in the choice of the tension elements proper. On this concern, it must be taken into account that steels suitable for tensioning have suffered a decrease in their response to strain and fatigue resistance owing to treatments applied directly on same (hot galvanizing or previous treatments such as sanding, phosphatizing and chromium plating) [7], [8]; 6°) without detriment to the bridge being correctly designed for vibration and fatigue, the proposed outer wrapping roughness makes more effective the cable antivibration response; 7°) the selection of a sum of differential thicknesses necessary for the impermeability an the decrease of the thermal gradient, as substitute for only one thickness, allows replacements by laters in case of deterioration, far off from the risk of the "all or nothing"; 8°) plastic injections capacity for deformation, expansibility or elastic resiliencie secures continuity and weather tightness, since they fill all voids and hollows and readjust in the presence of cable deformation; 9°) plastic flexibility, positioning of the cable with all its protection avoiding "in situ" injections, notoriously increasing quality levels and implying that during construction higher loads should not be incorporated, avoiding in this way stress checking tests under the urgencies and difficulties imposed al this stage; 10°) the multilayered system provides high shock absorption and the cuts and flattenings that may be caused by handling and mouting are circumbscribed to a periphery for away from the protection nucleus; 11°) high polymer injections or fillings permit obtaining mixes that under tensile stresses, for example, only shows very small depth fissures (0,03 to 0,05 mm) that are far from water penetration limits (0,1 to 0,2 mm) a behaviour highly superior to that of the rigid injections; 12°) the possibility of producing a cable entirely factory or "in situ" made, permits the control of the injections pressure in order to make it small enough so that it may not affect the pipes long duration desired, especially the inner one; decrease of the two thermodynamic coordinates (pressure and temperature) and absolute protection the inner pipe has against UV rays and other weather phenomena, are the main factors that permit forecasting a useful life similar to that of the bridge.

The importance -for the duration of the HDPE or similar pipe- of reducing pressure and temperature (they are variable and intermittent Δt) is verified inmediately when observing these materials characteristics curves based on plastic deformation and relaxation test and that relate temperature, duration, and triaxial stress originated by internal pressure [9]; 13°) the nylon strands do not leave any imprint on the HDPE pipes or any other high resistance plastic and do not imply restriction to the mobility of the elements they come into contact with; 14°) the proposal for the most external of the pipes is that it should be ligth coloured and treated against UV rays in spite of the outer wrapping having the same properties. This arrangement implies further safety in case that due to neglect in surveying there may come long period of time in which no wrapping deteriorations are detected; 15°) the proposed system can be easily rehabilitated. There is no problem with the wrapping and any pipe(s) section is replaced with half round pieces of the same material welded "in situ"; 16°) relaxation and creep may be reduced if certain precautions are taken and selection made. Recent investigations carried out in Japan [10] show that if the combination PWS (parallel wire strands) plus Hi-Am ("cold" mix for anchorage that melts only at 110°C) is adopted, creep and relaxation reach values of only 3,7 % respectively, while for LCR (locked coil rope) plus Z (Zamak type metal mix anchorage or similar) melting at 350 thorough 450°C, the values reach magnitudes of 13,8 and 10,3 % respectively.

As for steel pure relaxation in cables, it may be reduced if a considerable insulation against temperature is used, as the one provided for the protection. This relaxation depends on temperature and the initial stress and also on stress cyclic variation; a phenomenon that acquires some importance owing to the great stress oscillation amplitude. It must be considered that in some regions and seasons of the year, temperature on the surface of a great number of cables reaches up to 70 to 80°C. Other investigations made in relation with the steam curing influence on prestressing steels, over the mentioned temperature range (anisothermal Test) [11] , [12] , show that steel relaxation may be increased from 3,7 to 16 % above the one measured at the conventional 20°C temperature (isothermal Test). Notwithstanding the defferences that may be pointed out between the influence of the steam curing duration and the day-night cyclic Δt ; of the extrapolations used by researchers and that if certain steels such as the "stabilized" are used, a better response to relaxation is achieved (though these steels are more sensible to corrosion), it is important to remark that, anyway, the sum of the stresses during mounting and/or those originated by cyclic variation plus effect of the mentioned temperatures may induce relaxation that agree very little with the tensional demands supported by the stayed bridges, since to its temperature susceptibility are added higher demands imposed by the sustained increase of the main spans and the ever more sophisticated design of the deck transversal sections.

For this reason, a protection blockading the arrival of significant temperatures to the steel always implies an improvement -no matter its quantum- in relaxation decrease. There is another advantage to be added: high polymer injection imply no restriction to wire deffered deformation, which facilitates the possibility of the tension element total loss more accurate calculation, this characteristics being more important than the eventual restrictions -the evaluation of which is controvertible- that may present rigid injection system or other type of cables. All the factors that have been mentioned encourage the consideration that any improvement of the cables with references to deformation may be the reason that will make possible -as requirements increase- another step in the evolution of these bridges or of other stayed structures; 17°) offer great additional safety if sudden or undervaluated effects appear; 18°) have a satisfactory behaviour in the presence of wide range of climates; 19°) minimize the temporary protection problem; 20°) retightening, if considered possible, made whitout generating interference; 21°) offer an important reserve in the presence of fire, intentional damage and vandalism; 22°) minimize time between structural clousure and bridge opening to service; 23°) part of this arrangement -from (4) to (7), Fig. 1- may be thought of as a long lasting overprotection able to protect a wide range of existing tension members; 24°) the protection being highly reinforced, it is only logical to expect from it a high reliability and consequently be able to reduce the control usual periodicity. The resultant savings, only in this item, throughout the cable useful life, largely compensate the cost of more than one protection as proposed.

From the description of the system presented and the analysis of the advantages that have been pointed out, it is considered that the system complies with the objective of obtaining a long lasting protection ranking with the cable stayed bridge hierarchy and importance.

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