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Stay Cable Technology: Overview

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Abstract

1. Introduction

The stay cables are required to have superb mechanical properties (such as high tensile strength, high elastic modulus and satisfactory fatigue resistance), sectional compactness and excellent corrosion resistance, as well as easiness of handling and installation, and naturally not to be costly.

2. Types of Stay Cable

Helical wire ropes including locked coil ropes were widely used in the earlier steel cable-stayed bridges and have been long adopted on many European bridges. On the other hand, parallel wire or parallel strand cables have better mechanical properties than helical wire ropes, although inferior in easiness of handling. Among them, the parallel strand ropes consisting of the seven-wire strands have been prevalent in prestressed concrete (PC) cable-stayed bridges, and recently further in steel and steel/concrete hybrid bridges. The parallel wire cables covered by a high density polyethylene (HDPE) tube and provided with HiAm anchor sockets have been also popular in both PC and steel cable-stayed bridges. In Japan the shop-fabricated parallel wire strands (PPWS) extensively used on suspension bridges had been preferred for steel cable-stayed bridges until being taken the place by "New PWS".

The New PWS is an ultra-long lay cable strand being composed by 7mm wires. Twisting up to 4^o enables the wire bundle to ease reeling and make the strand self-compacting under axial tension without spoiling the mechanical properties. The similar idea was applied to HiAm-SPWC in Europe. The New PWS is also featured by extruding HDPE cover directly onto the wire bundle so that no void will exist between the wires and the surrounding cover. Bar stay cables covered by a steel pipe and filled with cement grout are scarcely used on stay cables, in particular for large cable-stayed bridges.

3. Corrosion Protection

Today the multiple-barrier corrosion system is routine for the stay cables. They consist of at least two barriers: the internal barrier immediately adjacent to the main tension element and the exterior barrier or covering. The wires are mostly zinc-galvanized or coated by epoxy, but non-galvanized wires are used when hydrogen brittlement caused by reaction with grouted cement mortar is feared. The wires of helical wire ropes are galvanized. In addition, voids of spiral ropes are filled with a sealing compound such as metalcoat. On the other hand, recent practice for a locked coil rope stay is to fill the inner voids with polyurethane with zinc dust or linseed oil with red lead, and to coat the outer surface of the rope by polyurethane.

Covering the strand or cable as the exterior barrier is now common to other types of stay cables than helical wire strands. The covering by a metal tube made of steel, stainless steel or aluminum alloy has been prevalent in PC cable-stayed bridges. In case of the steel pipe, coating is required. Anyhow, the installation of metal pipes is to be done at the erection site, and their stiffness may cause some difficulty in handling when a cable is long.

Use of a fiber reinforced plastic or HDPE tube are more popular. The latter is either shop-fabricated or site-fabricated. In case of New PWS and seven-wire strands, the covering is completely shop fabricated by a directly extruded HDPE sheath after executing the internal barrier. Although the original color of the PE covering is black, cable coloring techniques are now available. Supplementary wrapping with colored Tedler tapes is an alternative.

The typical blocking compound filled between the main tension member and the outer sheathing is cement mortar. But the chemical reaction with zinc and the occurrence of cracks are feared. Use of polymer cement or cement grout plasticized with polyurethane may improve the situation. Synthetic resin material based on polybutadiene was once used on Japanese bridges. These alternatives are, however, more costly. Grease and wax are also the blocking compound for PWS and prestrssing strands in combining use with other measures.

4. Preventive Measures against Wind-Induced Vibrations

The stay cables has become vulnerable to wind-induced vibrations since the introduction of multi-stay system with thin cables covered by polyethylene sheath having smooth surface. Particular care should be taken for vortex excitation, wake galloping and rain-wind-induced vibration. Preventive measures can be classified into mechanical and aerodynamic means. It must be borne in mind that the exciting mechanisms of different phenomena differ.

Occurrence of wake galloping depends on the spacing of neighboring cables. Small spacing not larger than two times or quite wide spacing more than six times the cable diameter can remarkably moderate the response. Otherwise the cable vibration can be suppressed by connecting the both cables by a few spacers or small mechanical dampers.

One of the common mechanical means being used for all the vibration types are the secondary thin cables connecting the stay cables and often terminating at the deck. But care must be taken on the rupture of the secondary cables and the fatigue failure of the connection fittings due to repeated loading. On the other hand, seemingly the most effective and prevalent measure is to install viscous dampers between the cable and the bridge deck. First recommendation is to place such damping materials as neoprene ring or high-damping rubber between cable and steel exit pipe at pylon and deck anchorage. Further additional damping can be provided by the hydraulic dampers or shear-viscous dampers near the anchorage at the deck. Aesthetic consideration is desirable at this time. However, it is not easy to make compromise between the requirement to lower the dampers and the efficacy of the damper. The classical Stockbridge type tuned-mass damper that once used on a few European bridges may spoil the appearance of the structure.

The aerodynamic means for the round cables are to modify the cable surface. Helical fins are used to suppress vortex excitation if the appearance is not spoiled. The measures developed for preventing rain-wind-induced vibration are the axial protuberances in the form of longitudinal ribs or grooves and pattern-indented surface with roughness applied disorderly in a convex or a concave pattern. Attention should be paid on the increase of drag coefficient in these cases.