# Research on Safe Service of Cable-Stayed System and Selection of Cable Selection for Chishi River Special Bridge

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Abstract: Cable-stayed bridges have the advantages of sizeable spanning capacity and simple and beautiful modeling. They have become one of the main bridge types for road crossing rivers, lakes, seas, and deep mountain valleys. As one of the main load-bearing components of the bridge, the durability of the cable-stayed system directly determines the operational safety of the bridge. The cable system is complicated in structure, concentrated in force, difficult to seal, weak in protection, and prone to corrosion damage and fatigue damage under the coupling effect of load and environment, resulting in the instability of the bridge structure. In order to ensure the high-quality construction and long service life of bridges with cable-carrying systems, this paper discusses the diseases that affect the safe service of cable-stayed bridges based on the research project of Chishih River Special Bridge. By analyzing the risk factors affecting the safety of the cable system, the primary causes of cable damage are obtained, which provides a reference for the safe service of the cable system.



## 1 INTRODUCTION

Cable-stayed bridges mainly comprise main girders, cable towers, and tension cables. Several cable-stayed cables are fixed to the main girder, adding elastic support within the girder span and reducing the bending moment. The material characteristics are fully utilized so that the cable-stayed towers are mainly under pressure, and the cables are mainly under tension. The world's first modern cable-stayed bridge was built in Sweden in 1955 with a main span of 182.6m Stromsant Bridge. With the gradual maturation of modern mechanics theory, the strength of new materials and other properties continue to improve, and the number of cable-stayed bridges worldwide has proliferated. In this process, China's cable-stayed bridges have been developed for four generations: the sparse cable system, dense cable system, main girder soft thinning, and oversized span. China's cable-stayed bridges nowadays mostly use the dense cable structure, which significantly reduces the height of the main girder, makes the girder size smaller, reduces the deadweight, improves the bridge headroom, increases the spanning capacity of the bridge, and makes the bridge deck system mainly under pressure, which effectively improves the service life of the material. In terms of wind vibration, due to the slight difference in self-oscillation frequency between the dense cables, they affect each other in mutual vibration, offsetting part of the impact of wind vibration and effectively improving the aerodynamic stability (Rymsaz 2021).

## 2 RIPCORD ACCIDENT

With the increasing number of cable-stayed bridges in China, many diseases and accidents related to bridge structures and components have occurred in recent years. The continuous accumulation of the

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role of natural factors such as load and environment on cable-stayed bridges, plus the surge in traffic, Under the joint action of natural environmental factors and human factors, will inevitably lead to the accumulation of damage to the bridge structural system components, so that its structural resistance to attenuation, resistance to natural disasters, and even in the regular use of the ability to decline, thus making the safety and durability of the bridge structure degradation. The safety and durability of cable-stayed bridges should be emphasized.

The main path of force transmission of the cable-stayed bridge is as follows: external load (vehicle load) → central girder → tension cable anchorage system → tension cable → cable tower. Cable-stayed cable and cable anchorage systems are collectively called cable systems. The tension cable system is the central part of the load transfer, effectively transferring the force on the main beam to the cable tower. With the accumulation of time, vehicle loads, environment cli, mate, and other external factors such as non-linear superposition, the performance of the tension cable system will gradually decline. Diseases arising from the tie system have led to the replacement of tie cables within the design service life of several cable-stayed bridges. A summary of the tension cable replacements is shown in Table 1 (Xu et al., 2024).

## 3 DISEASE ANALYSIS OF LASSO SYSTEM

From Table 2, a summary of tie system disorders, it can be seen that for the 50 cable-stayed bridges, the following four primary areas of disorders in the tie system were identified, i.e., PE/HDPE sheath cracking; tie disorders; corrosion of the tie anchorage system; and ineffective filling of the media (Gao et al., 2019).

Table 1: Tension cable replacement summary statistics.

| Ordinal number | Bidge name | States | Completion time | Lasso's service time |
|---|---|---|---|---|
| 1 | Shanghai New Five Bridges | China | 1975 | 15 |
| 2 | Shanghai Songjiang Port Bridge | China | 1982 | 12 |
| 3 | Guangdong Haiyin Bridge | China | 1988 | 7 |
| 4 | Guangdong Jiujiang Bridge | China | 1988 | 10 |
| 5 | Guangdong Zhuhai Qi'ao Bridge | China | 2001 | 6 |
| 6 | Guangxi Baisha Bridge | China | 1995 | 11 |
| 7 | Ningbo Yongjiang Bridge | China | 1992 | 17 |
| 8 | Sichuan Minjiang Bridge | China | 1990 | 10 |
| 9 | Jinan Yellow River Highway Bridge | China | 1982 | 13 |

Table 2: Disease Information Summary for Lasso System.

| Typical Diseases | Sheath cracking | Steel Wire Disease | | | | Anchorage system corrosion | | Seal material failure |
|---|---|---|---|---|---|---|---|---|
| Amount | 18 | Corrode | Break | Turn | Vibratory | Anchorage | Connection tube | 2 |
| | | 35 | 7 | 2 | 2 | 5 | 2 | |

## 4 PERFORMANCE EVALUATION SYSTEM FOR TENSION CABLES

The main characteristics to be met by the quality of our construction projects are safety, practicality, durability, stability, economy, and environmental friendliness. Safety refers to the performance that can ensure that the structure is in a safe condition after the completion of the engineering structure and guarantees the personal safety of the builders and users. Practicality is the performance of the project to meet the purpose of use. Durability is the structure's life, the project in the specified conditions, to meet the specified functional requirements of using the years, that is, the project after completing a reasonable service life cycle. Stability refers to the ability of the engineering structure to fulfill the necessary functions at the specified time and conditions. Economy refers to the ability of the structure to minimize cost after satisfying safety, suitability, and durability during the whole life cycle stage. Environmental friendliness refers to the coordination of the project with its surrounding ecological environment, the economic environment of the region where it is located, and the surrounding constructed projects to adapt to sustainable development requirements. Tie performance evaluation system consists of mechanical properties, working performance, durability performance, and protection performance (Castillo et al., 1985).

### 4.1 Mechanical Property

The mechanical properties of the cable system include steel wire tensile strength, steel wire elongation, cable breaking force, stress relaxation rate of the steel bar, steel wire torsional properties, and corrosion fatigue performance. Suppose any of the mechanical properties of the cable system do not meet the standard. In that case, it will produce a brittle steel wire fracture and lead to the cable's early failure, resulting in safety accidents. Lasso fatigue will reduce the load-carrying capacity of the cable, so fatigue performance is a measure of the quality of the cable, a comprehensive indicator.

### 4.2 Work Performance

The working performance of the diagonal cable includes

- the performance of the cable against wind and rain vibration,
- the performance of the cable against impact and
- the anchorage performance of the connection between the cable body and the anchorage.

With the extended time, wind and rain vibration, shock vibration will reduce the life of the sheath, caused by the surface corrosion of the cable, the cable body, and the anchorage connection between the disturbance, reducing the anchorage performance between the two.

### 4.3 Durability

Structural durability is defined as the ability of a structure to maintain its safety, everyday use, and acceptable appearance under normal conditions of use, construction, and maintenance for a specified number of years without additional costly reinforcement. The following conditions affect the durability of tie systems: stress cracking resistance of sheathing, deterioration of sealing materials, and fire resistance of ties.

### 4.4 Protective Properties

Protective properties: To prevent the direct contact of steel and anchorage with external corrosive media caused by the material's bearing capacity decline and to take the components isolated from the external environment performance. Mainly includes sheath tensile rupture stress, watertight cable, cable end drainage performance, and anchorage drainage performance.

## 5 PROJECT OVERVIEW

Chishi River Bridge is located in Shenzhen Shenzhen-Shantou Special Co-operation Zone, at the mouth of Chishi River in Xiaomo Town. The main bridge is a one-tower hybrid girder cable-stayed bridge with a span arrangement of (256+50+40+40) m. The total length of the main bridge is 386 m. The width of the bridge deck is 44.0 m. The central tower is a pike-shaped concrete tower with a height of 111 m. The main span of the main girder is a steel structure, and the side spans are prestressed concrete structures with a center girder height of 3.5 m. The structural system of the main bridge is the tower, girder, and pier consolidation with the auxiliary piers and the transition piers with vertical movable bearings, and a specific range of compression weights near the auxiliary piers on the concrete girder side to prevent the operation phase from being affected. Activity bearing on the concrete beam side of the auxiliary pier near the set is a specific range of pressure to prevent the auxiliary pier and transition pier bearing in the operation phase of the adverse reaction force. Cable space double face arrangement, the central tower on each side of 19 pairs of cables, a total of 76 bridges, cable material Ж15.2 type prestressed galvanized steel strand. Slant cable specifications total five kinds: 250-43, 250-55, 250-61, 250-73, 250-85. As shown in Figure 1 (Stallings et al., 1991).

### 5.1 Lasso Selection Program

From Table 3, it can be seen that the cable selection table.Through the disease analysis of the diagonal cable system, the comparison of the cable replacement project consumption, and the overall evaluation of the cable performance evaluation system, the galvanized steel strand diagonal cable was finally selected. The stranded wire cable consists of several strands of φsl5.2 high-strength, low-relaxation galvanized steel strand. The cable anchorage is a clip-type group anchor. The outer layer is then wrapped with HDPE hot extrusion molding; PE stranded wire strands outside the high-density polyethylene outer sheath pipe. The stranded steel strands and parts of the stranded wire cable are made in the factory and then installed one by one on-site to form the whole cable. The weight of the whole cable does not control the installation of stranded wire cable. As shown in Figure 2.

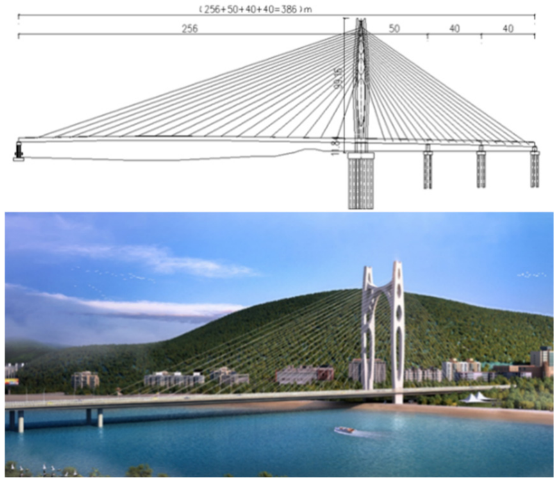


Figure 1: Engineering Design and Rendering.

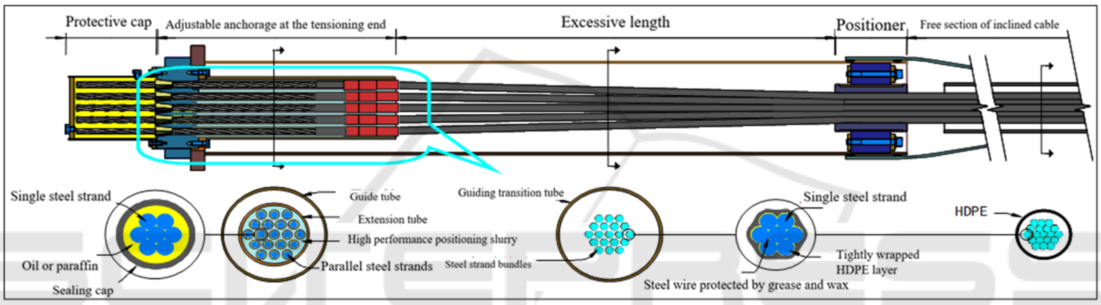


Figure 2: Lasso Structure Diagram.



Table 3: Cable Selection Table.

| Enterprise | Twisted parallel wire cable | Twisted parallel wire cable |
|---|---|---|
| Technical maturity | Mellow | Mellow |
| Makings | φ7 high strength galvanized steel wire | Low relaxation galvanized steel strand φsl5.2 |
| Cable anchors | Cold cast anchors for reliable anchoring performance | Clip sheet type group anchors are used. Attention should be paid to the fatigue Strength, to prevent the clip sheet loosening under low stress. |
| Fatigue resistance | Good | Good |
| Shield | Galvanized steel wire + hot-extruded high-density PVC | Galvanized steel strand + HDPE + HDPE outer sheath pipe |
| Lasso Diameter | Slightly smaller | Slightly larger |
| Tensioning of ropes | Tensegrity | Distributed tensioning, can be tensioned as a whole |
| Requirements for transportation and lifting | Large coil transportation is required, and high lifting equipment requirements are required | Small coil transportation is required, and the lifting equipment requirements are low, Easy to install |
| Speed of construction | Fast | Fast |
| Interchangeability | Large scale equipment required, affecting transportation | Can be exchanged for single strand, only requiring light equipment, without affecting traffic |
| Quality control | Factory production quality guaranteed | On site formation of whole cables, easy control of steel strand cutting length |

To summarize, the key indicators of the tension cable system that significantly impact the service safety of cable-stayed bridges should be judged first. The tie cable system produces a disease process for sheath first cracking, resulting in bare steel wire and corrosion media contact. Subsequently, the steel wire surface in the electrochemical reaction under the action of the etching pit weakened the original steel wire's effective cross-section, resulting in damage. With a further increase in the degree of damage, steel wire pits produce stress concentration and accelerate the development of cracks in the wire until the wire stress is greater than or equal to the tensile strength of the wire, causing wire breakage out of work. In this process, the cable cross-section damage increases, reaching the breaking force threshold after the cable failure. By analyzing the whole process of cable system disease, it can be seen that the cable system of cable-stayed bridge service safety of the critical indicators for wire tensile strength, wire corrosion fatigue performance, cable breaking force, and cable anchorage performance. The final selection of tie ropes (Gero et al., 2009).

## 6 CONCLUSION

This chapter analyzes the long-term performance indexes of tension cable systems by reviewing a large number of literature and bridge inspection reports and combining them with the corresponding specifications. It summarizes and analyzes the typical diseases and causes of the tension cable system of 50 in-service cable-stayed bridges. Diseases affecting the safe service of the cable-stay system mainly include corrosion of steel wires in the cable body, broken wires, and anchorage failure. The main reason is that the HDPE sheath and sealing device is aging and cracking, resulting in external corrosion factors in the internal cable system, coupled with the cable to withstand the fatigue load coupling effect, causing the cable corrosion damage. Based on the performance of the long-term performance of the cable system is divided into mechanical properties, work performance, durability, and protection performance. After analyzing the disease process of the cable system, the key indicators to determine the long-term service safety of the cable system are steel wire tensile strength, steel wire corrosion fatigue performance, cable breaking force, and cable anchoring performance. The Chishih River Special Bridge cable selection was carried out through a large number of analyses and rigorous judgment. At the same time, it provides a reference for the cable selection of other bridges.

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