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Defect Inspection Technology for Steel Truss Suspension Bridges

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Abstract: Steel truss suspension bridges are prone to developing defects after prolonged use. These defects may include corrosion of the main cable or the steel truss. To ensure the normal and safe functioning of the suspension bridge, it is necessary to inspect for defects promptly, understand the cause of the defect, and locate it through the use of inspection technology. By promptly addressing defects, the suspension bridge's safety can be ensured. The author has analyzed the common defects and causes of steel truss suspension bridges and proposed specific inspection technologies. This research is intended to aid in the timely discovery of steel truss suspension bridge defects.

Keywords: Steel truss suspension bridge; Defect; Inspection technology

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1. Introduction

Steel truss suspension bridges not only have strong spanning capabilities but also have outstanding landscape effects. Steel truss suspension bridges are built in tourist scenic spots, mountainous areas, and special projects in China. After the steel truss suspension bridge is used, deformation, corrosion, and other defects are common. To ensure that steel truss suspension bridges can operate safely, suspension bridge defect inspection should be emphasized to ensure that defects can be discovered in time.

2. Common defects of steel truss suspension bridges

(1) Corrosion of the hanger rods and main cables of the steel truss suspension bridge are

After long-term use, the main cable of the steel truss suspension bridge is likely to rust due to the peeling off of the surface protective paint. If the pipe mouth pre-buried at the cable saddle position is not waterproofed and the internal gaps are not filled, water will seep into the main cable. To conduct an in-depth inspection of the corrosion of the main cable, it is necessary to open the wire wrapping between the slings and check whether there is water seeping inside.

(2) Corrosion of the steel trusses

The corrosion of steel trusses mainly includes corrosion of longitudinal beams and cross-beam gusset plates and severe corrosion at the intersection of webs and chords. In addition, some steel truss suspension bridges have loose or missing bolts connecting the gusset plates. Ultrasonic testing or magnetic particle testing can be used to inspect defects in steel truss members and welds. Common defects at the weld location include rust, cracking, missing welds, etc.

3. Causes of defects of steel truss suspension bridges

The cracks in various components of a steel truss suspension bridge can be attributed to several factors. Firstly, poor stability and slack in the slings and main cables can cause stress concentration in the upper chords of the longitudinal girders and other bridge elements, leading to cracks. Additionally, if the waterproofing of the cables is inadequate or fails, rainwater can penetrate the cables, causing corrosion over time, particularly during rainy weather. This corrosion weakens the cables and contributes to cracks in the bridge structure [1]. Furthermore, the diagonal braces of the longitudinal girders are subjected to tension and compression forces, making them prone to cracking, especially when exposed to concrete spalling and reinforcement corrosion. If these cracks are not detected and addressed promptly, rainwater can infiltrate the interior, accelerating the corrosion of steel bars and exacerbating the cracking and concrete deterioration. Therefore, timely detection and maintenance are essential to prevent further damage and ensure the structural integrity of the bridge.

4. Defect inspection technology for steel truss suspension bridges

(1) Inspection of the appearance of the steel truss suspension bridge

In the visual inspection of steel truss suspension bridges, the locations that need to be inspected include main cables, anchor chambers, suspenders, lock clamps, trusses, bridge decks, and steel bridge towers.

During inspections of a steel truss suspension bridge, thorough examinations are essential across various components. Focus areas include checking the main cable and mid-span protection for slippage or detachment, inspecting anchor chambers for loose cable saddles and corrosion on cable strands and anchor elements, assessing booms for surface rust, examining cable clamps for rust spots and underlying corrosion, scrutinizing trusses for fractures in rods and welding seams, and observing any bends or rust. Additionally, attention should be given to bridge deck conditions, looking for deflection deformation, steel bar corrosion, and protective layer integrity. Lastly, inspections of the steel bridge tower should emphasize weld quality, lower foundation concrete integrity, and overall deformation. These comprehensive inspections help ensure the safety and longevity of the bridge structure.

In the past, appearance inspection of steel truss suspension bridges used to be carried out, manually. Not only was manual inspection inefficient, but it was also less accurate, with many blind spots. Moreover, certain inspections necessitated high-altitude work, posing safety risks to personnel. To address these challenges, inspection robots and drones are now employed for inspections [2]. With this technology, staff can control the paths of robots and drones, significantly reducing their workload. Compared to manual inspection, this approach eliminates blind spots, enhances safety, and enables rapid completion of comprehensive inspections with high efficiency. By leveraging inspection robots and drones, the overall appearance of steel truss suspension bridges can be thoroughly assessed with greater precision and reduced risk to personnel.

(2) Inspection of suspender cable force of steel truss suspension bridge

For suspension bridge suspenders with a full bridge length of more than 3 meters, the frequency method can be used to inspect the force of the suspender cable. The acceleration sensor is used to collect the acceleration signal of the boom vibration. Since the PE casing will have a certain impact on the inspection of the boom cable force, when inspecting the boom cable force, the boom cable force can be checked by using a jack and the double pull method. For booms with shorter lengths, there is a larger error when using this method to inspect the cable force of the boom. Therefore, for booms with a length of 3 meters, the cable force can be inspected using the jack recruitment method.

To keep up with technological advancements, monitoring the suspender cable force of steel truss suspension bridges has evolved with the integration of Internet of Things (IoT) technology. This entails installing intelligent sensors in the middle of the boom and utilizing IoT infrastructure to transmit collected data to a dedicated test and inspection system [3]. Within this system, a data analysis module processes the collected information to discern the vibration characteristics of the boom. By analyzing the relationship between boom cable force and vibration frequency, the system calculates and tests the boom cable force accurately. Additionally, the inspection system can establish early warning thresholds to monitor suspender cable force effectively. Leveraging IoT technology for boom cable force testing offers operational simplicity and high accuracy, facilitating efficient maintenance and ensuring structural integrity.

(3) Inspection of main cable tension of steel truss suspension bridge

The main cable is an important load-bearing structure of the steel truss suspension bridge, which largely determines the overall span capacity and load-bearing capacity. Therefore, when inspecting defects in steel truss suspension bridges, it is necessary to inspect the tension of the main cables. Main cables typically come in two types: steel wire main cables and parallel wire strand main cables, each comprising various subtypes such as spiral, steel, closed steel strand cables, and prefabricated strands [4]. The process for testing the main cable tension involves several steps. Initially, the vibration frequency of each cable strand at the anchorage position is inspected. This data, combined with vibration frequency inspection results, facilitates the calculation of tension for each cable strand. Finally, after determining the tension for all cable strands, the overall tension of the main cable is calculated. To ensure accurate measurements, appropriate tension testers are utilized, and strict adherence to operating specifications is observed, including selecting suitable measurement points. Each test point is individually measured, with results meticulously recorded to mitigate external interference throughout the process. Moreover, maintaining a secure connection between the measuring instrument and the test point is crucial for reliable measurements.

(4) Superstructure inspection of steel truss suspension bridge

When inspecting the superstructure of a steel truss suspension bridge, it is necessary to strengthen the inspection of the main cables, suspenders, cable clamps, and cable towers.

When examining corrosion in the main cable of a steel truss suspension bridge, several inspection methods are available. Non-destructive techniques like eddy current, magnetic particle inspection, and ultrasonic testing offer insight into corrosion defects without harming the cable's structure. The linear polarization method, based on electrochemical principles, involves placing electrodes on the cable's surface to measure potential and current changes, providing reliable corrosion assessments. Additionally, the infrared thermal imaging method employs thermal cameras to scan for temperature differences on the cable's surface, indicating potential corrosion spots efficiently without direct contact. These methods collectively ensure thorough corrosion inspection, facilitating prompt maintenance and safeguarding the bridge's safety and durability.

In steel truss suspension bridges, suspenders come in two primary forms: vertically arranged and diagonally arranged. In China, vertical suspenders are predominantly used. These suspenders, typically made of rigid cylindrical steel bars or steel pipes, connect the stiffening beam's connecting parts via threaded ends secured with screws or welding. Lifting lugs and connecting rods are fastened using cable clamps and bolts through pre-drilled holes in the connecting block. While hangers are not crucial load-bearing structures for steel truss suspension bridges, they play a significant role in distributing loads. However, their inspection can sometimes be overlooked when assessing the bridge's superstructure. Corroded or damaged hangers can easily affect the overall stability of suspension bridges. When inspecting boom defects, in addition to visual inspection, non-destructive inspection methods such as ultrasonic, infrared thermal imaging cameras, and radar can also be used [5].

One of the primary defects that occur in cable clamp positions is displacement, attributed mainly to two factors. Firstly, loosening of the tie rod can cause the cable clamp to slip along the main cable [6]. Secondly, prolonged use of the cable clamp can lead to increased tightness of the main cable, reducing the clamping degree of the clamp due to decreased void ratio. When inspecting cable clamp defects, evaluation criteria typically include the extent of cable clamp slippage, peeling of the topcoat in the overall paint layer, and the presence and severity of cracks and rust. To assess clamp movement, marking the main cable and clamp is common practice, allowing for periodic measurement during inspections. Various tools such as vernier calipers or other measuring devices can be utilized for this purpose [7].

As a steel truss suspension bridge ages, several defects may manifest in the cable tower. These include overall deformation, tilt, honeycomb-like pockmarks in concrete, exposed steel bars, steel bar corrosion, and foundation settlement. During inspections, particular attention should be given to identifying and assessing these defects. Strengthening inspection procedures for these specific issues is crucial for ensuring the structural integrity and safety of the bridge [8].

(5) Inspection of the substructure of steel truss suspension bridge

In inspecting structural defects in the substructure of steel truss suspension bridges, particular attention should be given to the anchorage section and the foundation position of the cable tower.

A common issue in the anchorage section is flooding, which can occur due to various factors. Firstly, failure of the pumping system or absence of such a system during bridge construction may lead to water accumulation in the anchorage or dampness in the anchor chamber over time. Secondly, inadequate drainage measures, especially for water-soaked anchors or those in tunnels, can exacerbate the problem. Establishing a proper drainage system is essential to address this issue [9]. Thirdly, it's worth noting that many steel truss suspension bridges in China lack structures or channels on their anchorage surfaces to aid in later maintenance operations. When assessing corrosion in the anchorage system, a common procedure involves intercepting a sample of the steel strand and subjecting it to a tensile test. To maintain the integrity of the intercepted samples, they should be stored within controlled conditions, ideally at temperatures ranging from 23°C to 28°C and humidity levels below 50%. Mechanical tests on these samples can accurately determine the mechanical properties of the steel strands. Additionally, visual inspections within the anchorage can reveal signs of water accumulation or weed growth, providing further insight into potential issues affecting the structural integrity of the bridge [10].

When inspecting the foundation position of the cable tower of a steel truss suspension bridge for defects, a visual inspection of the underwater part of the main tower pier is conducted initially. Subsequently, techniques such as underwater exploration and photography are employed to assess the foundation for issues like scouring or hollowing out.

5. Conclusion

In summary, inspecting defects in steel truss suspension bridges requires a focus on several key areas. These include inspecting appearance, suspender cable force, and main cable tension, as well as conducting inspections on both the upper and lower structures of the bridge. Comprehensive testing is essential to promptly identify and address any hidden dangers, ensuring the continued safe use of steel truss suspension bridges.

Disclosure statement

The authors declare no conflict of interest.

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