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A REVIEW ON ANALYSIS AND DESIGN OF RAILWAY STEEL BRIDGE

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Abstract

An increasingly important tactic for risk reduction and uninterrupted operation in infrastructure management is strengthening aging bridges. As a result of age and degradation as well as more stringent environmental and load requirements, transportation networks are home to an increasing number of defective buildings. However, from an economic and environmental perspective, employable resources are limited. Strengthening options, which improve bridges with little impact on the economy or the environment, should be taken into consideration as a feasible choice for these reasons. A selection of the most intriguing strengthening methods for historic truss steel bridges are shown from this angle. In order to discuss practical remedies, the most common issues with vintage truss railway bridges are first discussed. Results from a representative bridge cluster were compared to a literature review and expert interview process. After that, several approaches to the issues that have been brought to light are gathered and qualitatively assessed for their effectiveness in meeting structural and conventional building criteria. Ultimately, broad observations and suggestions grounded in gathered data are shown.

Keywords:
Railway Bridge, Steel Structure, Wind Analysis, Truss, Strengthening

I. Introduction

In order to discuss practical remedies, the most common issues with vintage truss railway bridges are first discussed. Results from a representative bridge cluster were compared to a literature review and expert interview process. After that, several approaches to the issues that have been brought to light are gathered and qualitatively assessed for their effectiveness in meeting structural and conventional building criteria. Ultimately, broad observations and suggestions grounded in gathered data are shown. Appearance is naturally less significant for smaller bridges, but the designer will still consider the appearance of the two main components of his bridge, the superstructure and substructure, and choose proportions that work well for the particular circumstances at hand. The designer's decision to select visually acceptable proportions is often aided by the use of steel. The bridge is a crucial part of the transportation system [1].

II. Background

Steel is a material that is often used in building. Numerous factors, such as steel's affordability, ease of design, quickness of manufacture, and availability in a variety of practical and useful forms, all contribute to its mechanical properties. Conversely, steel may be made with a variety of properties and improved to suit our various purposes. The primary requirements are strength, ductility, weldability, and corrosion resistance. Steel structure design is within the purview of the structural engineering subdiscipline known as "steel design," or more specifically "structural steel design." The structures might be skyscrapers, houses, or bridges. These days, Allowable Strength Design (ASD), the first and more conventional technique, is one of the two main methods for designing steel. The second, more modern method is known as LRFD, or load and resistance factor design.

III. Loads On Steel Bridge Trusses

When building a bridge, trusses are used to transfer the gravitational force of moving automobiles to supporting piers. Depending on the features of the site and the span length of the bridge, a truss may be through type or deck type. The through-type carriage path is supported by the bottom chord of the trusses. A deck type bridge's carriage way is supported at the truss upper chord. Usually, the structural frame supporting the carriage way carries the loads from the carriage way to the nodal points of the vertical bridge trusses.

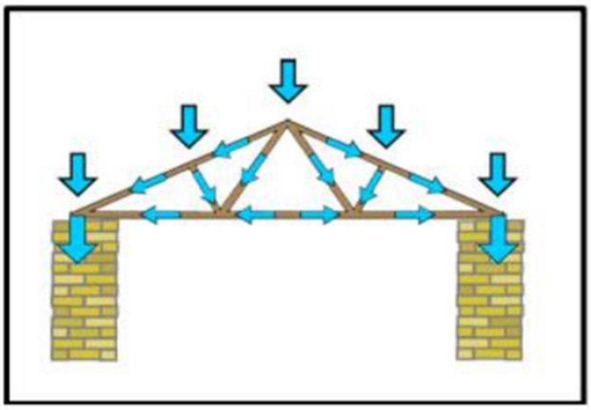

Fig.1: load distribution over a steel truss bridge.

IV. Loads

1. Dead Loads: A dead load is the total weight of the structure plus any additional immovable loads (equipment) that are fixedly fastened to the structure and have a constant size. It is constructed from the floor beams, the floor system's principal supporting trusses, or girder weight, and the stringers. The true dead load of the structure cannot be determined in structural design until the bridge is designed; without this information, a final design cannot be finished. The dead load acting on a member must be identified prior to design. A structure's members should be built in a sequence so that, as much as practicable, the weight of each member is a portion of the dead load that the member following it in turn bears.

2. Live load: The live load on highway bridges is the total weight of the applied moving loads from vehicles and pedestrians. Highway bridges should be constructed to safely support any kind of vehicle that may cross them since over their lifetime, a wide range of vehicle types will traverse them. The bridge's designer is unable to predict the kind of vehicles that will use it or how long it will endure before failing to ensure the structural integrity of the building. Some degree of control must be preserved if the architect is to provide the structure the strength to handle the projected loads of the future as well as the present.

3. Wind Loads: Wind loads are the result of the wind's pressure exerted on the bridge members. These loads are dynamic and are determined, among other things, by the shape, size, wind speed, and angle of the structure. For design reasons, wind loads are provided as equally distributed static loads according to AASHTO standards. This reduced loading is intended for stiff constructions that are not dynamically sensitive to wind, meaning that wind loads have no effect on their structural design. It was applied as horizontal loads acting on the superstructure and substructure and as vertical loads acting upward on the bottom of the deck. The magnitude of the loads is determined by the component of the structure and the base wind velocity used in the design.

V. Structural Elements

Truss bridges frequently have unique features in terms of its overall length, shape, spans, static system, and other attributes. However, the same structural elements—such as connectors, deck components, and main trusses—are used to assemble them. In actuality, these are references from the bridge inspection guidebook [11–12]. As a result, the problems with the truss bridge type are grouped and displayed using the previously indicated technique. The main trusses, deck elements, and connections are emphasized with respect to the recommended reinforcing techniques. However, it's crucial to remember that bracings and bearings can also require strengthening.

VI. Literature

1. YongjianLiu, Advancements in the application and analysis of steel deck pavement for bridges: Orthotropic steel deck pavement-related diseases have a substantial influence on the lifespan and safe operation of long-span steel bridges. This paper provides an overview of the present status of research and application for steel bridge deck pavement. A comparison was made between the design characteristics for steel bridge deck pavement found in different Chinese, American, and Japanese specifications. Data on the pavement structures, deck stiffnesses, and pertinent ambient temperatures were collected from 119 steel bridges located throughout the globe. In light of the information acquired, the material performance, combination mechanism, technical specifications, and possible uses of various pavement structures were investigated. Finally, a comparison of the several methods used to calculate the stiffness of bridge decks was done. Results show that double-layer EAM, GAM + SMAM, and ERS are now the most popular steel deck pavement configurations. However, in most application settings, the actual life does not match the 15-year service life that is anticipated. A strong base may significantly reduce the stress status of the surface pavement and steel top plate.

2. ChaoJiang, Assessment of fillet weld fatigue in steel bridge towers considering the impacts of corrosion: According to a field research, the fillet weld in steel bridge towers may experience both corrosion and fatigue stress at the same time. To ensure structural safety throughout the course of the service life, this study examined the effects of corrosion on the fillet weld fatigue life in steel towers. First, the test findings validated the fatigue life prediction procedure for the weld that was proposed utilizing the fracture mechanics technique. The three forms of corrosion effects that were considered were pitting corrosion at the first crack, pitting corrosion near the original fracture, and corrosion fatigue crack growth. Furthermore, three corrosion limits were determined for different corrosive circumstances. Using the Third Nanjing Yangtze River Bridge as an example, a modified finite element (FE) model integrated with the local shell model was built to examine the fillet weld stress fluctuation in steel towers. The stress effect lines were used to calculate the maximum stress range under the vehicle load.

3. ZheZhang, Three types of corrosion impacts were considered: pitting corrosion at the first crack, pitting corrosion near the original fracture, and corrosion fatigue crack development. Furthermore, three corrosion limits were established for various corrosive conditions. Using the Third Nanjing Yangtze River Bridge as an example, a modified finite element (FE) model linked with the local shell model was developed to investigate the fillet weld stress fluctuation in steel towers. The stress effect lines were used to determine the maximum stress range for the vehicle load. When compared to OSD, the deck-to-rib welded connection of CSCCBD had a stress amplitude that was more than 90% less. The fatigue problem with deck-to-rib welded seams may have a basic solution. More study is being conducted on the intricacies of fatigue vulnerability distribution in CSCCBD. The features at the diaphragm-to-rib weld pose the most fatigue risk. The linear cumulative damage theory was applied to determine the fatigue life of CSCCBD.

4. ShuailingLi, Using a microscopic damage index, we analyze thick-walled steel bridge piers for ultra-low cycle fatigue fracture start life under bidirectional cyclic stress. Strong earthquakes can produce ULCF fractures in steel bridge piers. This study investigated the fracture behavior of two square-sectioned, thick-walled steel bridge piers subjected to bidirectional horizontal stresses. In addition, a microscope damage index was fitted to determine the steel bridge piers' ULCF fracture beginning life. The findings demonstrate that ductile cracking first formed at the intersection of the reinforced base plate and bottom weld at the corner site of the steel bridge piers under bidirectional cyclic loading, and the first crack propagation had no effect on the strength capacity.

5. HuiyunXia, Preparation and performance of a durable waterproof adhesive layer for a steel bridge deck using the self-stratification effect: Given the disadvantages of the present steel bridge deck waterproof adhesive layer (WAL), such as low durability, high construction costs, and a lengthy construction period, a novel waterproof coating preparation technique with self-stratification effect is proposed. In this article, a poly butyl acrylate-methyl methacrylate-styrene block copolymer with a lower glass transition temperature was synthesized using free radical solution polymerization, and five distinct self-stratification coatings were created by combining it with epoxy resin at various mass ratios. The glass transition temperature, thermal stability, and chemical composition of acrylic resin were determined using DSC, TGA, and FT-IR. The coatings' self-stratification behavior was validated using FTIR, SEM, and water contact angle tests. The basic and road performance of the aforementioned self-stratifying waterproof coatings were evaluated according to predefined criteria.

6. JiaSun, Structural optimization of steel bridge deck pavement using mixture performance and mechanical simulations: The upper layer of modified SMA mixture (SMAM) and the bottom layer of epoxy asphalt mixture (EAM) form a steel bridge deck pavement (SBDP) construction that has practical potential, although there has been little systematic study into it. This work improved the pavement material and structure of SMAM + EAM utilizing mixed performance tests and finite element analysis, providing guidelines for its promotion and use. To begin, the pavement performance and dynamic characteristics of SMAMs and EAMs made with various binders were examined in order to determine the most acceptable SBDP material. Second, dynamic modulus master curves for the mixes were developed to offer material characteristics for pavement structure design. Finally, the FEA approach was used to compare the dynamic mechanical response of the pavement structure for various structures, thickness combinations, and temperatures in order to specifically improve the SBDP structure. The results revealed that EAM had greater high-temperature rutting resistance than SMAM. However, SMAM had superior moisture damage and skid resistance.

7. Qing-ChenTang, Train-bridge interactions-based hybrid control of steel-concrete composite girder bridges taking into consideration slip and shear-lag effects utilizing MR-TMD. The resonance between trains and bridges will increase as train speeds rise and bridge building shifts to broader spans and lighter weights. Therefore, research on vibration control is critical to assuring the safety of bridge structures, particularly for steel-concrete composite girder bridges with mechanical properties like slip and shear lag. As a result, this research presents a hybrid control method for the steel-concrete composite girder bridge using a magnetorheological tuned mass damper (MR-TMD) that takes into consideration whether trains are on or off the bridge. It then applies this method to a numerical example, lowering the vertical dynamic responses of a railway steel-concrete composite girder bridge caused by train-bridge interactions.

8. O.Bouzas, A complete method to the reliability-based structural evaluation and non-destructive experimental characterization of ancient steel bridges: Many historic steel structures have experienced natural or human-caused damage and severe degradation, resulting in changes in geometrical, physical, and mechanical properties that have a substantial influence on their mechanical behavior. These structures are historically, culturally, and economically significant, thus it is critical to properly analyze them to validate their current state of repair. This work presents a complete approach to experimental non-destructive characterization and reliability-based structural assessment of ancient steel bridges. It considers everything from experimental data collecting to finite element model updates and probabilistic structural analysis when calculating the dependability indices of serviceability and ultimate limit states. Because several information sources are included throughout the evaluation process, the results are more accurate and practical, and they may be used to assist make the best maintenance and retrofitting decisions. The feasibility of the technology was tested on the deteriorating riveted O Barqueiro Bridge in Galicia, Spain. The research began with a comprehensive experimental campaign to accurately characterize the bridge's geometry, material composition, and structural system using a variety of tools and techniques, such as ambient vibration testing, ultrasonic testing, terrestrial laser scanner surveying, and in-depth visual inspection.

9. Tadesse G.Wakjira, An effective prediction approach for the lateral cyclic response of posttensioned base rocking steel bridge piers based on explainable machine learning: This study presents a novel, explainable machine learning (ML)-based prediction model for the lateral cyclic reaction of post tensioned (PT) base rocking steel bridge piers. The PT rocking steel bridge pier consists of a circular tube with a welded circular base plate that has been pre-compressed to its base by gravity loads and/or a PT tendon. The input parameters were column diameter, column height-to-diameter ratio, tendon cross-sectional area-to-column ratio, tendon initial posttensioning ratio, dead load ratio, base plate thickness, and base plate extension. The response variables were column residual drift, column shortening, maximum lateral strength to uplift force ratio, deteriorated stiffness/starting stiffness ratio, and lateral strength decrease ratio. The prediction models were constructed using nine different machine learning methods, ranging from the most basic to the most advanced.

10. TomaszMaleska, The effect of soil cover depth on the seismic response of a long span corrugated steel plate bridge with thin walls: Corrugated steel plate (CSP) has grown increasingly popular in culverts and bridges in recent years. Despite their growing popularity, there has been little research into how these structures respond to seismic excitation. Thus, the study's purpose is to determine how seismic excitation affects a CSP bridge with a span more than 17 meters and a range of soil cover depths (1.0 to 5.0 meters) above its steel shell. The gathered data demonstrate that the depth of the soil cover has a considerable impact on the bridge's responsiveness.

11. DaoyunYuan, The evaluation of fatigue damage in steel bridge weld joints using meso-damage mechanics: Welding allows for the more efficient and speedy usage of a wide range of steel bridges. In contrast, fatigue fractures in steel bridges are usually caused by various welded connection details. Thus, it is critical to accurately analyze the fatigue life and evolution of fatigue damage in steel bridge welded joints. This study proposed a fatigue damage evolution model based on meso-damage mechanics to estimate fatigue damage to welded joints in steel bridges. The damage variable in the fatigue evolution model was set to the number density of microcracks. To simulate the fatigue damage development of welded connections in a steel bridge, ABAQUS' user material subroutine (UMAT) and finite element modeling were utilized. The finite element model of the welded joints under cyclic load was linked to UMAT, and the fatigue damage evolution model was included into UMAT.

12. Oskar Skoglund, A computer analysis of unique structural characteristics to improve the fatigue strength of steel bridges: When designing steel bridges, fatigue is often the decisive factor, and enhancing the fatigue strength of key components can help use less steel. This paper use numerical simulations to investigate and assess the fatigue strength of four different structural detail solutions. There are two structural aspects that have been studied but have never been used in bridge construction. When the most promising structural detail was compared to the existing standard solutions, fatigue strength increased by over 25%. The numerical lessons were intended to prepare students for impending tests.

13. Alireza Ghiasi, A fine k-nearest neighbor machine learning classifier was used to identify damage on in-service steel railway bridges. Minor surface corrosion in steel railway bridges can proceed, resulting in localized section losses and structural collapse over time. This work offers a unique combined damage detection strategy that uses a k-Nearest Neighbor (kNN) machine learning classifier to classify the various extents and degrees of cross section losses caused by damages such as corrosion. A Finite Element (FE) model of an in-service railway bridge is constructed and verified using vibration data from field testing. These combined FE-field data are trained and tested to identify distinct corrosion instances according to the Australian Standard AS7636.

14. JeonghwaLee, Redesigning intermediate diaphragm spacing in steel box bridges with horizontal curvature: The steel box sections flex across as a result of eccentric live loads applied to the steel box girders. The curvature effects of horizontally curved steel box bridges can give extra distortional behavior due to gravity and live loads, even if the applied loadings are not eccentric for each construction cycle. This is why the distortional behavior of horizontally curved steel box bridges can differ significantly from straight ones. As a result, for both straight and horizontally curved box bridges, intermediate diaphragms must be inserted in the box sections to manage the distortional warping normal stresses induced by distortional behavior.

15. DorinRadu, An engineering critical evaluation approach for determining the residual life of a historical riveted steel bridge Bridge structural rehabilitation must now meet an increasing number of environmental requirements. Future generations rely on us to manage our limited natural resources wisely, therefore structural integrity must be addressed throughout the bridge restoration process. These buildings have a substantial detrimental impact on the environment; examples of poor resource and energy management include the demolition and redesign of reinforced concrete structures. Several steel bridges on the existing network of highways and trains have been in service for almost a century. The assessment of these structures' in-service safety is a difficult undertaking. This article emphasizes the need of rehabilitating the steel bridges that remain in situ, taking into consideration their status as historical monuments and the fact that reusing existing infrastructure is part of sustainable development. This paper presents a study case for a historic riveted steel bridge built at the beginning of the twentieth century, as well as an evaluation approach that considers fracture mechanics to determine structural integrity.

VII. Conclusion

This paper proposes many potential strengthening solutions for aged steel truss bridges. A multitude of considerations, such as structural efficacy, construction durations, required traffic disturbances, and ease of maintenance, often impact their selection. First, the investigation of the material and structural features indicated that the following strengthening needs are associated with the inadequate redundancy and brittleness of truss steel bridges.

(2) are generally related to concerns with deck components such as connections, cross beams, and stringers. A review of the literature, interviews, and a thorough study of a target bridge cluster all indicate that structural component concerns usually affect a class of structural components rather than a single element. This is an ideal moment to assess if a succession of local steps can be more effective than a global strengthening answer. Because the latter is more well-known and commonly employed, an examination of global strengthening strategies is conducted and presented through actual case studies.

The summary focuses on the following points: (1) Although main truss load bearing capability is often not a concern, a global intervention may reduce fatigue sensitivity in main truss connections and increase overall structural robustness and safety;

(2) Prolonged deck interventions can not only address particular problematic portions and their localized phenomena, but also improve the structure's overall performance in terms of vibrations, deformations, susceptibility to brittle failures, and maintenance. We believe there are many more ingenious, inventive solutions that have been implemented, but they are rarely documented in the literature since bridge owners and designers aren't as interested in authoring papers for journals and conferences. As a result, for deficient ancient truss railway bridges, strengthening may not be the best option. Nonetheless, new technology and creative thinking may increase the range of viable modifications for old bridges, increasing their lifetime and safety with low financial and environmental effects, all while protecting our cultural past.

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