IABSE SYMPOSIUM

ISTANBUL 2023

LONG SPAN BRIDGES

26-28 APRIL 2023

Hyatt Regency Hotel, Ataköy-İSTANBUL

PROCEEDING OF PAPERS PRESENTED

iabse.org/Istanbul2023

IABSE SYMPOSIUM ISTANBUL, 2023

Long Span Bridges - April 26-28, 2023

Publisher
IABSE
c/o ETH Hönggerberg
CH - 8093 Zürich, Switzerland
Tel: +41 – 44–633 2647 • Fax: +41 – 44–633 1241
e-mail: secretariat@iabse.org
Web: https://www.iabse.org

ISBN 978-3-85748-191-8

https://doi.org/10.2749/istanbul.2023
Distributed by Structurae (https://structurae.net)

IABSE SYMPOSIUM ISTANBUL

LONG SPAN BRIDGES
26-28 APRIL, 2023
HYATT REGENCY ISTANBUL
ATAKOY HOTEL

IABSE Symposium Istanbul Proceedings

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Preface to the Book of Abstracts

The Symposium is the first event since 1996 for which the Turkish National Group for IABSE has served as the host. This extremely timely Symposium has examined long-span bridges that raise many technical problems in conceptualization, design and construction. The Group has pursued its mission for serving the bridge engineering professionals in organizing the so-called biennial İstanbul Bridge Conference, the last having successfully taken place in 2022. This year's Symposium coincided with the celebration of the 100 Years Anniversary of the Founding of the Turkish Republic in 1923. The currently longest-span bridge in the world, Çanakkale 1915, was completed last year ahead of its schedule, and is now serving to meet the increasing traffic intensity between İstanbul and İzmir, two of the busiest export ports of the country. Those of you who have attended the post-symposium trip to the bridge site have surely found it interesting not only technically but also culturally because the bridge straddles the region where some of the landmark battles during WW-1 took place.

This electronic Proceedings book contains the texts of all papers that have been presented during the first two days of the program. The range and diversity of the papers attest to the professional relevance of the Symposium. The Organizers had planned to select a smaller number of the papers to be included in a book that would be made available subsequently, but this target has not been met. This Symposium had been carefully planned and finalized with strong interaction with IABSE Headquarters. The consideration of long-span bridges is an opportune juncture in bridge engineering practice because many countries face challenges of environmental, economic, financialand policy considerations in expanding and maintaining their transportation systems. The program and its thematic outline were planned in response to this requirement. We must append a word of gratitude and appreciation to our reviewers who reviewed the abstracts and then the papers themselves in deciding what to include in the program. Without their voluntary services the professional quality of this symposium would not have been possible. The Scientific Committee hopes that you will find it was worth your time to have attended this multi- faceted professional assembly. We acknowledge that the Symposium was a success on account of its highly qualified participants.

Polat Gülkan
Chair, Scientifi c Committee

Paper ID:162

The 1915 Çanakkale Bridge– Design of articulation systems

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ABSTRACT

The 1915 Çanakkale Bridge in Türkiye carries the new Malkara-Çanakkale Motorway across the Çanakkale strait. This paper describes the design of the articulation system for the suspension bridge. The bridge articulation is defined as the mechanism which accommodates the movements and flexures in all directions of the bridge deck, a state of mobility which is ever-present under varied influences as temperature, wind, traffic, and seismic actions. The focus point for this paper is the longitudinal restraint system for the bridge girder, defined by end stops and hydraulic buffers. End stops are introduced to protect the deck expansion joints against large longitudinal movements. The end stops are located between the bridge deck and the tower legs. This position limits the movements in the joints to a range which can be accommodated by known joints product range. During seismic events it is important that the end stops are not engaged to avoid excessive forces due to the massive energy input from the moving deck structure. Hydraulic buffers are installed between the suspended deck and the tower legs. The purpose of the hydraulic buffers is to restrain movements from frequent and fast acting loads such as passing trucks and dynamic parts of wind loads and thus limit the wear on bearings and expansion joints and thereby increasing the expected lifetime of these components.

Keywords: Suspension bridge, 1915 Çanakkale bridge, Articulation, Hydraulic devices, Seismic

1 INTRODUCTION

The 1915 Çanakkale Bridge across the Çanakkale Strait in Türkiye carries a new highway connecting Europe and Asia. The bridge is located at the North-eastern end of the strait where it connects the Gelibolu province to the Northwest with the Lapseki province to the Southeast. The 1915 Çanakkale Bridge comprises a suspension bridge, together with approach bridges on the European and Asian sides. The suspension bridge has a 2023 m long main span and 770 m long side spans. The bridge girder consists of twin stiffened steel box girders, with orthotropic decks with asphalt surfacing. The towers also consist of stiffened steel plate box sections.

https://doi.org/10.2749/istanbul.2023.0007

Paper ID:199

Experimental Verification of Design Proposal for Cross-sectional Curved Steel Plates in Shear

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ABSTRACT
The use of curved steel plates has been increased over the last few years, especially when it comes to the cross-sectional level. They increase the bridge's aesthetics and can be beneficial to the overall bridge performance. Examples of curved webs in steel box girders can be found in Belgium, The Netherlands and Vietnam. Unfortunately, no standard or code covers the design criteria for curved plates in shear. The lack of rules or codes results in a rather conservative design or more complicated computational work. Based on numerical analysis, the authors of this research have published a design proposal that works similar as for flat plates in shear. Since this design proposal is surely based on finite element analysis, it is not possible to have a 100% certainty about its reliability. Especially since curved plates are believed to be very imperfection sensitive. For this reason, two girders with a single curved web are designed and tested in a three-point-bending test. Both webs were given a different curvature radius, but have equal dimensions. During the test, both strains and deformations were monitored. In addition, the full web behaviour was captured by a 3D photographic system. The experiment showed that the webs had a higher resistance towards buckling than was expected based on the numerical predictions. Finally, the results are compared with the design proposal and numerical calculations.
Keywords: Up to five keywords, 12-point type.

1 INTRODUCTION
The use of curved steel plates has been increased over the last few years, especially when it comes to the cross-sectional level. They increase the bridge's aesthetics and can be beneficial to the overall bridge performance. Examples of curved webs in steel box girders can be found in Belgium, The Netherlands and Vietnam. Figure 1 and Figure 2 gives respectively a general overview and the cross-section of the Zemst railway overpass in Belgium (Van Staen, G.;2021). The bridge is a box girder with two lateral edge members, with curved webs, in order to increase the torsion resistance. Unfortunately, no standard or code covers the design criteria for curved plates in shear. The lack of rules or codes results in a rather conservative design or more complicated computational work. Based on numerical analysis, the authors of this research have published a design proposal that works similar as for flat plates in shear.

https://doi.org/10.2749/istanbul.2023.0014

Paper ID:257

Opportunities in Civil Projects with Artificial Intelligence

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ABSTRACT

The digitalization of civil projects is accelerating. The amount of data is increasing, requirements from clients are more precise; and time is always of the essence. To analyse and compare different production methods, innovative designs and sustainability are essential keys. A promising approach is to combine automated design methods and tools supported by artificial intelligence (AI). The purpose of this study was to identify and describe knowledge gaps in this field, i.e., what method development is necessary and what can be done with the support of AI. A series of interviews were performed with experienced personnel from the construction business. The focus was to establish where best practice lies today, regarding evaluation of alternatives and finding opportunities in today's tender process and early phases of a project. Furthermore, a literature review was performed to determine the possibilities with analysis with AI from a wide set of requirements, together with changing input variables. The focus was to establish what possible opportunities that comes with comparison analysis with AI and point out new demands that might arise from this process. Furthermore, the state-of-the-art of today's design methods and contractors working procedure was described, with a focus on how contractors are working in order to find opportunities in civil projects today. It can be concluded that requirements documents and information management need to improve. Furthermore, several methods for multi-objective constrained optimization exists today. If this is combined with a set-based parametric design approach, contractors could increase their ability in finding opportunities.

Keywords: Digitalization; artificial intelligence; multi-decision analysis; optimization; automation.

https://doi.org/10.2749/istanbul.2023.0022

Paper ID: 260

Nonlinear Analysis of Cable-Supported Bridges Using an Open-source Finite Element Software

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ABSTRACT

It has been shown that the nonlinear differential equations representing the structural system of a suspension bridge exhibit nonlinear modal coupling. Mathematicians even demonstrated that such coupling could lead to large torsional vibrations of the bridge deck. It appears that such large oscillations from nonlinear modal coupling originate from geometric nonlinearities of the bridge structure. Since such nonlinear coupling could play a role in the stability of cable-supported bridges under wind effects, it is deemed necessary to develop a better understanding of the nonlinear behavior of cable-supported bridges. This was done using nonlinear finite analysis results of nine suspension bridges and two cable-stayed bridges with main spans ranging from 856 m to 4140 m. For this purpose, Code_Aster, an open-source finite element software, was utilized for the required numerical simulations. This paper therefore presents the authors' experience with the development and usage of a framework for the nonlinear analysis of cable-supported bridges based on an open-source finite element software. At first, the advantages and disadvantages of using an open-source finite element software instead of a commercial one are discussed in the context of cable-supported bridges. Then, an overview of the analysis framework is provided, which includes the development of macro-commands for the calculation of cable preloads, nonlinear aerostatic analysis and nonlinear generalized stiffness analysis. This is followed by a presentation and discussion of typical results for the validation of the cable-supported bridge models and results of nonlinear analysis. Finally, a plan is outlined for future developments of the framework.

Keywords: Cable-supported bridge, Suspension bridge, Cable-stayed bridge, Nonlinear finite finite element analysis.

https://doi.org/10.2749/istanbul.2023.0033

Paper ID: 336

Load transfer of stay cable forces to pylon, design criteria and comparison of solutions

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ABSTRACT

Decks of cable stayed bridges are supported by cables transferring the reaction loads to the pylons. The cables are either terminated in an anchorage or the main tensile element is continuous, crossing through the pylon, guided by means of saddles.

In a continuous effort to optimise structures, designers have privileged pylon presenting a plain body, with no inner cavities needed for the installation of cable anchorages. Such plain pylon bodies prompt the use of saddle to guide a continuous tendon across, or, alternatively, push the connection of the stay cable on the outside, using structural tensile components such as steel links, to obtain the transfer of the stay cable loads to the pylons.

The multiaxial loading of the stay cable on the pylon connection, as well as functional needs associated to stay cable operations, compelled establishment of numerous criteria to achieve the design of such devices.

Today, engineers have gained experience in the design, manufacture and installation of pylon connections including associated stay cable system. This paper aims to compile key criteria in the design of pylon connections for plain body pylon and highlighting particularities of both families of applied solutions: structural steel links and guiding friction saddles.

Keywords: Cable Stay, Bridges, Cables, Saddles.

1 INTRODUCTION

Bridge architects and owners are increasingly concerned by the aesthetic of cable stay bridge designs. One of the factors to achieve this, is the slenderness of the pylon, the "iconic monument" of such landmark structures. This encourages designers to consider plain towers rather than hollow core towers, forcing the use of saddles or structural links.

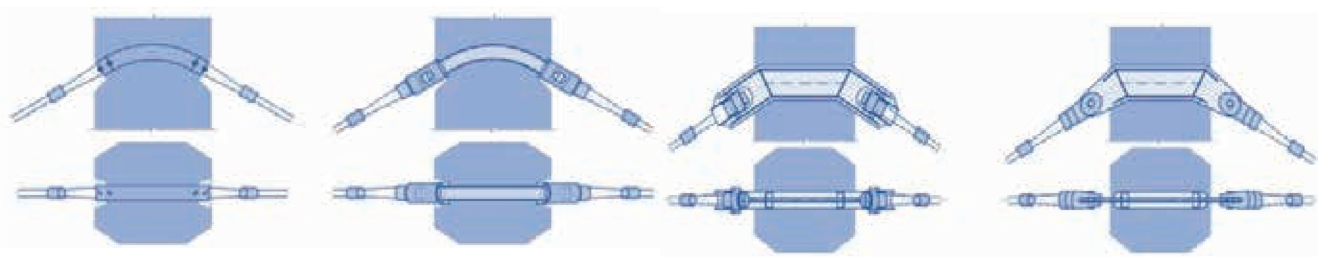

Figure 1: Various cable connection solutions at plain pylon [1]

https://doi.org/10.2749/istanbul.2023.0041

Paper ID:485

Inspection of the Source of the Nile Bridge

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ABSTRACT

This paper describes the methodology used to inspect the Source of the Nile Bridge in Uganda. It is a 525m cable-stayed bridge opened to traffic in October 2018. It replaces the existing Nalubaale Dam/Bridge as the major crossing point across the River Nile at Jinja in the Eastern Region of Uganda. Arup, working for the Uganda National Roads Authority (UNRA), carried out a visual inspection of the Source of the Nile Bridge as part of the handover. The inspection methodology involved using a bespoke web application accessed from a smartphone to record the visual inspection. The app enabled successful completion of the inspection in a limited time frame and following strict client standards for data collection and reporting of condition. Observations and records were stored in a database hosted in the cloud. This enabled results to be summarised and presented using a cloud-based web interface employing tables and dashboards. The outcome was an intuitive interface which offers an opportunity for continual monitoring of the structures condition over its lifetime.

Keywords: Inspections, maintenance, cable-stay bridges, digital, GIS.

1 INTRODUCTION

1.1 Overview

The Source of the Nile Bridge was opened to traffic in October 2018. It replaces the existing Nalubaale Dam/Bridge as the major crossing point across the River Nile at Jinja in Uganda. It is a vital link to the seaport of Mombasa, Kenya for neighbouring countries such as Rwanda, Burundi, the Eastern Democratic Republic of Congo, and Southern Sudan. The Source of the Nile Bridge will serve an integral role in the country's development. It is expected to carry a significant proportion of Uganda's volume of trade by road to and from the seaport of Mombasa in Kenya, through Malaba and Busia. For these reasons, the optimal functionality and performance of the Source of the Nile Bridge is of great importance.

https://doi.org/10.2749/istanbul.2023.0052

Paper ID:768

Modelling techniques and processes used on the recalculation of the Friedrich-Ebert suspension bridge in Germany

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ABSTRACT

The complex the bridge is, the stronger the engineer's technical knowledge needs to be to understand its behavior and lead the design towards a safe, functional, and cost-effective structure. The bridge design industry shows, however, that technical knowledge is not enough: engineers not only have to master a whole range of technical subjects, but also need to be able to manage and treat data to understand and interpret results. This is the only way to make the right decisions in a conscious way. In the case of long span bridges, management and processing of information becomes critical since the amount of data increases with the span length. This paper showcases some modelling techniques and processes used to carry out the recalculation of the Friedrich-Ebert bridge in 2021, that were found essential to capture and analyze, in an accurate way, its almost 70 years of history, including the strengthening that took place in 2000, and that enabled a precise rating of a bridge with a main span length of more than 285m over the Rhine River. Techniques touch upon input of complex geometry, consideration of shear lag, checks on plate buckling and the so-called contribution charts. Their application lead ultimately to the preservation of this beautiful landmark.

Keywords: Modelling, analysis, recalculation, automation

1 INTRODUCTION

After the end of the II World War in the 1940s an extensive reconstruction took place across Germany. Like many other structures during the war, being a key connection over the Rhine River, the Admiral-Scheer Bridge was destroyed. In the 1950s a new structure provided connection between Ruhrort and Homberg in the city of Duisburg. It was called the Friedrich-Ebert Bridge. The new bridge was designed as a self-anchored bridge, which in appearance is similar to a suspended bridge, however, behaves in a completely different way.

Given the scarcity of resources after the war, the bridge was optimized in every way technology at the time allowed. A recalculation in 2000 showed that the bridge needed to be strengthened to be able to resist load levels corresponding to bridge class BK60/30, in accordance with [4]. As a result, additional structural elements were installed in form of plates, profiles, and concrete.

https://doi.org/10.2749/istanbul.2023.0060

Paper ID:781

The 1915 Çanakkale Bridge
Designing a twin-box girder suitable for a world record span

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ABSTRACT

Optimization is the key to the success of any long span suspension bridge. Since the deadload covers up to 80% of the utilisation of the expensive main cables, keeping the weight of the girder down is essential. For the 1915 Canakkale bridge the twin-box girder design was introduced to ensure sufficient aerodynamic performance, but with a natural quantity penalty. Using extensive FEmodelling on critical and pervasive structural elements, while pushing the limits of the codes, the goal of achieving sufficient structural capacity with lowest possible quantities was achieved. The Vierendeel effect has global influence on the deformations of the deck and therefore the connection between the transverse cross girders and the deck had high focus in the design. The fatigue performance of the girder for both traffic and wind also posed a challenge and here the use of an integrated shell model in the global analysis model was used to ensure that all boundary effects and load behaviours were correctly considered. Another important consideration was the local effects from hanger rupture on the design of the supporting structure not leading to excessive use of thick plates and high strength steel.

Keywords: Twin-box bridge girder, Çanakkale, hanger anchorage, FE-modelling, hanger rupture.

https://doi.org/10.2749/istanbul.2023.0069

Paper ID: 910

Hanger Replacement of Fatih Sultan Mehmet Bridge

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ABSTRACT

Fatih Sultan Mehmet Bridge is a suspension bridge located in Istanbul. Since its opening in 1988 it has been the main route of heavy vehicle traffic between Asian and Europe side of Turkey. During recent inspections severe corrosion has been found on its hangers As a result of further inspections and structural evaluations it is decided to replace the whole hangers with a new system that will not cause similar damage in the future. This paper introduces the cause and extent of the current hanger damage, the new system that will replace it and the method of replacement.

Keywords: Long-span suspension bridge, Hanger Replacement, Inspection and Maintenance.

1 INTRODUCTION

Fatih Sultan Mehmet Bridge is a Suspension Bridge in Istanbul completed in 1988. It has a main span of 1090m. There is no side span on the bridge. The overall width of the bridge is 39.4m and it carries four (4) lanes of traffic in each direction (See Figure-1 for general view). The average daily traffic of bridge is 200,000 vehicle/day. It was the only route for heavy vehicle passage until 2016 when 3rd Bosporus Bridge was opened.

Recent site investigations revealed that the hanger ropes had severe corrosion on the lower socket area. Therefore, an urgent replacement program for the whole hangers was announced by the Bridge owner KGM (General Directorate of Highways) in June 2021.

https://doi.org/10.2749/istanbul.2023.0079

Paper ID:915

Innovative geotechnical solutions to meet the demands of the1915 Çanakkale bridge

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ABSTRACT

The 1915 Çanakkale suspension bridge with a world record main span of 2023 m crosses the strait of Dardanelles linking Asia and Europe. Innovative solutions were called for to meet the onerous geotechnical challenges: (i) soft Holocene lagoon deposits (sand, silt, clay, peat) with liquefaction risk in the top layers, (ii) highly seismic region of the North Anatolian fault zone, (iii) water depth in excess of 80 m, (iv) ship impact loads from the very busy Dardanelles strait, (v) movable sand ridges and risks of near-shore slope instability and (vi) very variable depth to weak bedrock of Miocene Mudstone and Sandstone. Detailed ground investigations and site walkovers allowed an optimised alignment taking advantage of rock outcrops on both sides of the strait to avoid piling in the Lagoon deposits. The anchor blocks are enormous concrete structures featuring innovative application of barrettes (Asian side) to enhance the sliding resistance in the weak rock and placement of backfill as counterweight on the rear of the European Anchor Block, which is placed into the rock outcrop. The tower foundations are hybrid solutions with steel pile inclusions for soil improvement and a gravel bed acting for load transfer to the piles and as a horizontal fuse between the caisson base and free-standing piles. The paper describes the solutions to the design and construction challenges related to towers and anchor blocks foundations imposed by the world record main span, the short construction period, the seismic setting, and the ground conditions.

Keywords: 1915 Çanakkale bridge, geotechnical engineering, tower foundations, anchor block foundations, alignment optimisation.

1 INTRODUCTION

Due to the world record span length of the 1915 Çanakkale Bridge, the overall solution as a suspension bridge was a given. The challenge facing the geotechnical design engineers was to make bold decisions on the position of towers and anchor blocks and the foundation method for towers, anchor blocks and side span/approach piers based on the available feasibility study and the specified alignment corridor together with ground investigations carried out during the tender period. To await the detailed ground investigations would jeopardize the overall programme.

https://doi.org/10.2749/istanbul.2023.0084

Paper ID:1025

LATERAL SEISMIC FRAGILITY ASSESSMENT OF A CABLE – STAYED BRIDGE USING A POINT ESTIMATE METHOD

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ABSTRACT

Cable-stayed bridges are a constant topic of study, they are pleasing to the eye and have a good seismic performance. Some important cable-stayed bridges in Mexico are ageing and there is a need to review their structural response. As built drawings are necessary to carry out a thoroughly review, however, ageing bridges blue prints are incomplete or lack important information, such is the case of cable pre-stressing forces, concrete mechanical properties and damping ratio. These are common source of uncertainty.

In the analytical fragility assessment of bridges, several uncertainties are inherent in the estimation of seismic damage. Several techniques have been widely used, such as Monte Carlo simulations, simplified fragility estimation, Bayesian methodologies, among others. However, there is not much research about point estimate methodologies that are just as precise as other techniques and demand much lower computation time.

In this regard, in this paper a probabilistic approach for the lateral seismic fragility of cable stayed bridges is presented. Point estimates simulations are used. We study a cable-stayed bridge whose configuration is widely used in Mexico. A numerical model is developed considering the nonlinear response of the components and its uncertainties. A collection of real ground motion records is used as applied load, from which the fragility curves are then obtained by analysing the structure using Nonlinear Time History Analysis (NTHA). Then, the fragility curves of piers and pylon are presented.

Keywords: Seismic fragility, cable-stayed, point estimates

https://doi.org/10.2749/istanbul.2023.0092

Paper ID: 1069

Numerical Study on Influence of Mass on Dynamic Performance of Piles with Pre-hole Seismic Isolation System in IABs

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ABSTRACT

Integral abutment bridges (IABs) could fundamentally resolve the durability problems of expansion joints. The concrete piles beneath the abutments are the most vulnerable components in IABs. To improve the seismic performance of IABs, the pile with pre-hole filled by damping materials (called pre-hole seismic isolation system) has been proposed. In this paper, the shaking table test of the pre-hole seismic isolation system under sine wave load is simulated by using the finite element software ABAQUS/Explicit. The influence of the mass on the pile top and the pre-hole dimension on the dynamic performance of the pre-hole seismic isolation system was analysed. It can be concluded that with an increase in the mass or pre-hole dimension, the fundamental frequency of the pile-soil system decreased. With an increase in the input wave's frequency, the pile with a pre-hole seismic isolation system could have a better seismic performance by reducing the mass or pre-hole dimension.

Keywords: integral abutment bridge; pile with pre-hole seismic isolation system; dynamic soil-pile interaction; finite element model; mass on pile top; pre-hole dimension; fundamental frequency.

1 INTRODUCTION

Integral abutment bridges (IABs) can resolve durability problems, improve driving comfortability, and reduce maintenance costs by eliminating expansion joints, deck joints, and bearings. Furthermore, compared with bridges with expansion joints, IABs have higher redundancy and better seismic performance (Briseghella and Zordan 2015; Erhan and Dicleli 2015; Huang et al. 2015; Kozak et al. 2018). However, due to the rigid connections between the superstructure and substructure in IABs, the piles are influenced by the combination of the bending moment, axial force and shear force transferred from the superstructure caused by the thermal variation and seismic action (Huang

https://doi.org/10.2749/istanbul.2023.0101

Paper ID:1262

Design of Shusha Railway Bridge

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ABSTRACT

Shusha Bridge is located on an 82.8 km railway in the Shusha region of Azerbaijan. The difficulties in the design of the arch bridge with a total bridge length of 424 m and a 200 m deep valley with a single-track railway on it, construction stages of the elements, dynamic analysis of the train, rail-structure interaction, time-dependent effects, seismic analysis, and solid modelling of foundations will be explained under the main headings.

Keywords: Railway Steel Arch bridge, Dynamic Analysis, Rail-structure interaction

1 INTRODUCTION

The Shusha Bridge is planned to be built on the valley at KM:80+200.00 close to Shusha region of the 82.8-kilometer railway connecting the Azerbaijan Fuzuli and Shusha regions. In this railway project, which will be the crossing point of many regions with Shusha and Fuzuli, there are many viaducts and bridges due to the very rough terrain. Due to the limited vertical and horizontal slopes of the railways and the land structure, the use of special bridges in the mentioned valleys is inevitable. In terms of the continuity of the project, the bridge to be built in this region will ensure uninterrupted transportation. Since it would be very difficult and costly to put a pier in the valley, it was necessary to cross the valley with a large span bridge. Considering the natural beauty of the region, it was decided by the Azerbaijan Railways to build an arch bridge with aesthetics and up-to-date technology in harmony with nature. The existing span complies with arch bridge design criteria.

https://doi.org/10.2749/istanbul.2023.0110

Paper ID:1262

Structural Behavior of a 40+ Year Old PSC-I Concrete Bridge According to its Internal Tendon Loss in the Central Part

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ABSTRACT

Prestressed concrete bridges with a type I girder (PSC-I), hastily built in the 1960s, have been increasingly deteriorating, making their internal tendon prone to rupture, leading to social and economic problems due to bridge collapse and emergency repairs. In this study, a post-tension PSC-I bridge, to be demolished after more than 40 years of service, was evaluated for its structural behavior due to internal tendon loss. The internal tendon of its central part, a weak flexural behavior part, was artificially cut to model an actual damaged structure; its structural behavior was then compared to that of an intact girder. The results showed that stiffness increased from 2.2% to 37.9% depending on the amount of internal tendon loss (loss ratio from 8.3–25%) in the central part of the bridge, with a load reduction of up to 78% when compared to an intact girder. The position of the neutral axis and maximum progress of the crack also increased rapidly due to the change in stiffness and decrease in internal force. Future work will analyze the behavior characteristics according to the location of loss on the girder's internal tendon, the amount of loss, and the loss of anchorages. Evaluation and analysis of the flexural behavior of PSC-I bridges according to their aging is important and can be addressed by testing the properties (mechanical, longevity) of the bridge's materials over time and comparing them to the design strength at the time of construction.

Keywords:PSC-I bridge, Tendon, Rupture, Full-scale experiment, Maintenance

https://doi.org/10.2749/istanbul.2023.0118

Paper ID: 1505

THE 1915 ÇANAKKALE BRIDGE – CONCEPT DEVELOPMENT FOR SUBSTRUCTURE

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ABSTRACT

The 1915 Çanakkale Bridge in Turkey carries the new Malkara-Çanakkale Motorway across the Dardanelles strait. The substructure of the suspension bridge with the world record main span of 2023m consists of the two tower foundations, the two anchor blocks and the two side span piers. This paper describes the concept development for the substructure. It is the first of two papers, with the second paper focusing on the design and construction of the substructure (Löhning et al., 2023). For all the substructure elements construction time, risks, sustainability, and cost are important parameters when selecting the most favourable concept. The soil conditions at the individual substructural element have the most significant influence on the selection of the best concept. Hence, an alignment study including the positioning of the substructure elements is the first step to find the optimal substructure concept.

The two towers are founded at water depths up to 45m. Open dredged wells, a steel truss structure, a classic pile cap with steel piles, and a concrete caisson foundation are considered for the design. Critical load cases are ship impact and seismic loadings.

For the anchor blocks deep foundation with excavation within one or two diaphragm rings are investigated. For the Asian anchor block an alternative concept with a flat massif and shear walls below is developed. For the European anchor block a relocation with a tunnel anchorage or with a massif partly buried in a rock outcrop is investigated.

Keywords: Substructure, Çanakkale, anchor block, tower foundation, suspension bridge, seismic.ment, Maintenance

INTRODUCTION

This paper describes the concept development for the substructures for the 1915 Çanakkale suspension bridge in Turkey, with the world record main span of the 2023m. The substructures consist

https://doi.org/10.2749/istanbul.2023.0126

Paper ID:1552

Incremental Launching Method in a challenging geography: Ahmetbeyli-Fuzuli-Şuşa Motorway Project

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ABSTRACT

In 2021 important highway projects started to be implemented in the Karabakh region by the Azerbaijani government. As a part of 81 km Ahmetbeyli-Fuzuli-Shusha Motorway project, three viaducts (V6, V7, and V8) were built using the Incremental Launching Method (ILM). Karabakh is a mountainous region having a challenging geography for roadway construction. At the beginning of the project the three viaducts were designed as classical precast beam structures. Nevertheless, due to the deep valleys where the viaducts are located and the very tight construction schedule, the ILM was eventually retained, considering its advantages in terms of cost and works duration. V6 Left and Right Viaducts have a total length of 295m, V07 Right Viaduct of 185m, V07 Left Viaduct of 130m, V8 Right Viaduct of 350m and V8 Left Viaduct of 405m, with a central span of 55m. The six viaducts have minimum 4.2% and maximum 4.7% longitudinal slope. Due to their geographical conditions and possible access, it has been decided to launch four viaducts (V6 Left, V6 Right, V8 Left, V8 Right) downward and two (V7 Left, V7 Right) upward. Launching decks with such a high longitudinal slope was significant challenge, and special braking system were designed to withstand the sliding forces. In addition, V7 Right and Left viaducts required a particular design, not only because of their longitudinal slope, but also because of their small radius in the highway plan. For these viaducts, the precast sites were specially designed in accordance with the radius of the road

https://doi.org/10.2749/istanbul.2023.0134

IABSE SYMPOSIUM ISTANBUL
LONG SPAN BRIDGES 26-28 APRIL, 2023 HYATT REGENCY ISTANBUL ATAKOY HOTEL

Paper ID:1556

A Nielsen Arch Rail Bridge Designed to Survive an Extreme Earthquake Event

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ABSTRACT

The following paper provides insight into the design of a structural steel 118 m span Nielsen arch rail bridge. The critical aspect of the design was the need for the structure to survive extreme earthquake events. A performance based seismic design framework was developed where the bridge remained serviceable at one level and sustained acceptable damage at the extreme level. Although the response of the concrete substructure elements governed the design, the associated modal response of the arch generated significant load effects. The short timeframes for the project delivery meant that the development of site-specific seismic ground motion time histories was not practical. In their absence this paper outlines how an elastic response spectrum analysis was used to calculate the associated load effects in the arch

Keywords: Nielsen arch, rail, structural steel, and seismic design.

1 INTRODUCTION

Bridges that are part of critical transportation links must often be designed to survive extreme earthquake events as well as the daily rigours of their environment. This paper tells the story of one such bridge, a structural steel 118 m span Nielsen arch rail bridge. The basket handle arch form might be described as conventional, but its seismic design presented several technical challenges. This was because the project's rapid delivery schedule meant that the development of site-specific seismic ground motion time histories was not practical. In their absence the paper provides insight into how an appropriate alternative analysis method was developed to quantify the response of an arch structure supported on concrete piers that plastically hinge under the applied seismic loading. The natural period of the arch structure in the transverse direction was also carefully considered to limit the risk of derailment.

2 DESIGN FOR SEISMIC EFFECTS

As is common practice in areas with high seismicity a performance based seismic design framework was used. Practically this that meant the performance requirements for the bridge varied depending on the intensity of the earthquake. Within the framework two levels of earthquake were considered.

A Level 1 earthquake was defined as a seismic hazard with a high probability of occurrence during the set service life of the bridge. For the locality of the bridge moderate earthquakes with peak ground accelerations of 0.12g had to be allowed for. The performance requirement for a Level 1 earthquake was that the bridge must remain serviceable to ensure the continued operation of trains. This meant the structural response of the superstructure and substructure had to be within the

https://doi.org/10.2749/istanbul.2023.0141

Paper ID: 1663
Load identification and damage evaluation of a beams ubjected to moving loads by using co-located strain and acceleration measurements

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ABSTRACT

Bridge structural health monitoring and assessment are important subjects nowadays. In this paper, we propose a novel method which allows to evaluate both the bridge structural health and its loads based on strains and accelerations measured at the same location. The bridge is considered as governed by the Euler-Bernoulli beam equation. The strain can be obtained directly from sensors such as fiber optics. This type of sensors has many advantages such as high precision, high sampling frequency, durability… so that the dynamic strain component can be acquired easily. By decomposing the obtained signals into static and dynamic components, the correlation between strain and acceleration for the same type of component is clarified. The proportional coefficients, which reflect the intrinsic state of the beam and its load, can be obtained by optimization. From the variation of these coefficients, information on the damage of the bridge can be obtained. Moreover, in case of multiple loads (multi-axle vehicle), the distance between the axles of the vehicle can also be determined. Numerical results with several scenarios will be presented to demonstrate the efficiency and the robustness of the method.

Keywords: Damaged Identification, Moving Load, Bridge, Strain, Acceleration.

https://doi.org/10.2749/istanbul.2023.0150

Paper ID: 1699
Deterministic and probabilistic approaches for aeroelastic design optimization of long-span bridges

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ABSTRACT

The last decades have witnessed the construction of a number of long span bridges. Suspension bridges have reached main spans of more than 2000 m and cable stayed bridges of more than 1100 m. In addition to that, more challenging proposals are under steady. The main difficulty for these structures is to undergo the effects of earthquakes or aeroelastic phenomena and this paper is devoted
to the latter class of loads, generated by wind flow. Giving the social relevance and cost of these constructions it is very important to use during the design the best technologies and numerical optimization methods are a powerful design tool. They have been applied since many years ago in other fields as aircraft or mechanical engineering but the idea of design optimization of long span bridges considering aeroelastic constraints is very recent. The optimization problem can be formulated as deterministic,-that means that all mechanical bridge properties and also the values assigned to loads, including wind related excitations, have fixed values-, or as probabilistic, which means that a level or uncertainty is included in the formulation, given the random nature of wind speed and the possible inaccuracies in the definition of bridge properties. This paper describes the formulations of aero-structural optimization of long span bridges considering flutter in both deterministic and probabilistic approaches. A long span cable stayed bridge and two suspension bridges, the Great Belt and the Messina bridges, are used as application examples of this methodology of design.

Keywords: Long span bridges, flutter speed, design optimization, Great Belt Bridge, Messina Bridge.

https://doi.org/10.2749/istanbul.2023.0159

Paper ID: 1889
Aero-structural design optimization of long-span bridges: From linear to nonlinear aeroelasticity-driven perspectives

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ABSTRACT

Structural optimization techniques have been demonstrated to be a powerful tool for the cost-effective design of bridges under aeroelastic considerations, particularly when applied to super-long span suspension or cable-stayed bridges. The efficacy of this methodology relies on the comprehensive and accurate formulation of the wind-resistant design problem. The analysis of the wind-induced responses, such as flutter and buffeting, has been typically addressed in the industry by
adopting multi-mode analysis techniques using linear force modeling approaches based on the fundamental contributions of Prof. Davenport and Prof. Scanlan. In the same way, the aero-structural
optimization frameworks previously developed by the authors have followed this approach by mimicking the design goals and specifications of real bridge projects in the formulation of the optimization problem. However, wind tunnel tests and on-site monitoring measurements have shown that under some circumstances, the so-called linear aeroelasticity models fail in predicting the bridge
responses. Hence, several nonlinear aeroelastic methods have been developed in the last decades, including the corrected quasi-steady theory (QST) model, band superposition model, hybrid nonlinear model, rheological model, artificial neural networks (ANN) based model, and Volterra models, among others. These methods should be advanced in order to define deck shape-dependent accurate models that permit their implementation into design optimization frameworks to achieve cost-effective and safe bridge design. This study reviews the effectiveness of these methods and discusses
practical directions to follow to adequately implement nonlinear aeroelasticity features into the holistic aero-structural optimization of long-span bridges.

Keywords: Aero-structural optimization, flutter, buffeting, nonlinear aeroelasticity, deck shape.

1 INTRODUCTION

The design of bridges has evolved in the last two centuries with the advances in structural analysis techniques and wind load modeling capabilities (Gimsing and Goergakis, 2012). The increasing length of the main spans of the long-span bridges built in the last century has turned the wind-induced loads into the governing design load. Advances in finite element modeling (FEM),

https://doi.org/10.2749/istanbul.2023.0167

Paper ID: 1946
Detection of trainloads of suspension bridges with bridge responses: a comparative study using displacement and stress

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ABSTRACT

Trainloads play an essential role in the fatigue life of railway bridges as they cause important repetitive stress cycles at critical locations. Therefore, estimating such loads is relevant for preventive maintenance plans. This paper investigates an approach to detect trainloads using responses of the bridge, such as displacement and stress. Firstly, the temperature-response correlation is investigated to assess the influence of possible effects on the detection. Secondly, two response characteristics are proposed to detect trainloads: amplitude and duration. Statistical analysis of the two characteristics is then conducted to get the statistical distributions for both displacement and stress responses. Thirdly,
a multi-step detection procedure is applied to detect the trainloads. A road-rail suspension bridge is introduced as the case study, which monitoring system includes sensors for temperature, displacement, stress, and a train weigh-in-motion (WIM) system. The study of trainload detection in this paper can provide guidance for the predictive maintenance of bridges to avoid premature damage.

Keywords: Trainloads; displacement; stress; weigh-in-motion; statistical analysis.

1 INTRODUCTION

Trains have carried passengers and cargo to various destinations since their invention more than one hundred years ago, thus facilitating our society's daily life and economy. The railway network extended to more areas thanks to the spanning capacity of bridges over rivers, valleys, etc. During the service life of railway bridges, trainloads should be carefully evaluated to consider capacity and fatigue issues.

Static weighing is widely adopted at highway toll collection stations to obtain roadway vehicle weight. Still, it implies interrupting the traffic, and it is rarely adopted on the railway. Meanwhile, weight in motion (WIM) has developed extensively in recent years as it provides vehicle weight and velocity information without affecting the traffic flow (Cantero 2021; Chen et al. 2021).

https://doi.org/10.2749/istanbul.2023.0175

Paper ID:2069
Design and Construction of Multi-span Cable Stayed Bridge at Ambhora, near Nagpur, Maharashtra

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ABSTRACT

A multi-span cable stayed bridge is proposed over river Wainganga to re-establish the state highway link from Bhandara to Butibori. The location of the bridge is an important tourist and pilgrimage destination with lush green surroundings and backwaters of Gosekhurd Dam. The bridge has an overall length of 705m and deck width of 15.25m to accommodate 2 lanes of vehicular traffic and 3m+3m footpath for pedestrians. The structural arrangement of the bridge comprises 2 modules, with Module 1 of 420m and Module 2 of 280m length with span arrangements of 70m+140m+140m+70m and 70m+140m+70m respectively. The superstructure is cable stayed with RCC deck ladder type with an RCC pylon height of 30m above deck level. The pylon P3 at the center of the bridge is also proposed with Viewing Gallery 40m above deck level which is structurally independent from the main bridge. The Module 1 of the bridge is constructed by cantilever method for pylon P2 and anchored span method for pylon P1 and P3. The Module 2 of the bridge is constructed on staging. This paper discusses the design and construction aspects of the bridge along with staged construction analysis. This is one of the very few cable stayed bridges in India where all 3 methods of construction of a cable stayed superstructure are adopted in the same bridge.

Keywords: Cable stayed bridge, Multi-span, Cantilever construction

1 INTRODUCTION

The reservoir of Gosekhurd Dam is one of the largest by storage capacity in the draught prone Vidarbha region of Maharashtra state, India. Opened in 2008, the reservoir's high FRL meant most of the bridges upstream on the Wainganga River get submerged every monsoon season, cutting off the links between the already under-connected Nagpur and Bhandara districts of the state. State Highway 254 of Maharashtra, which connects the southern and south-eastern parts of the Nagpur district to the city of Bhandara bares a glaring gap of about 700m cut-off by the Wainganga River at the temple town of Ambhora.

In an urgent effort to address these inadequacies, the stage government commenced the project to build a high-level multi-span cable stayed bridge across the river. A five-span bridge with pylons spaced at 140m was proposed at the location.

https://doi.org/10.2749/istanbul.2023.0182

Paper ID:2090
Some details from the original static calculation of the Chain bridge in Budapest – 1842

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ABSTRACT

The Chain Bridge over the River Danube in Budapest is the most famous chain bridge in the world. This bridge is the symbol of Hungary. It was originally built between 1839 and 1849 based to the plans of William Tierney Clark who was also supervising the work. The superstructure was rebuilt in 1914-15. 30 years later, it was destroyed at the end of World War II but rebuilt in 1949. The Chain Bridge still stands today and serves public traffic. The stress-analysis of the first original chain bridge was kept in secret by the designer. Unexpectedly, in the summer of 2022, the original detailed calculation was found in an old library with the handwriting of W. T. Clark. It is a special and unknown technical document. You can follow the steps of the bridge design in it from that time, when the knowledge of dimensioning had barely begun to develop. We present the basics and details of the original calculation, with some comments in light of the possibilities of modern methods.

Keywords: chain bridge, industrial heritage, historical detail calculation, Budapest, Danube.

Figure 1: Chain bridge of Budapest (postcard, Fővárosi Szabó Ervin Könyvtár, bibFSZ01498858)

https://doi.org/10.2749/istanbul.2023.0190

Paper ID:2120

Development of Seismic Response Model for Wellington Building Inventory Using Indicator Buildings

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ABSTRACT

This paper is focused on regional building responses to earthquakes and the identification of broad vulnerability archetypes to increase resilience and limit human and economic loss. Wellington, New Zealand has been selected as the case study for this research due to the unique access to building data within the Central Business District (CBD), and the potential risk of seismic events. A database of reinforced concrete buildings with five or more stories in the Wellington CBD were clustered using a novel deep neural network architecture. The buildings in each cluster are similar in the seismic vulnerability and hence, the seismic response of the indicator buildings in each cluster can be used to quantify the seismic response of all buildings within the clusters. The building inventory was clustered into five clusters and eight indicator buildings were selected for detailed nonlinear response modeling based on their relative location to the cluster mean. The selected indicator buildings had different vulnerabilities based on their date of construction and lateral system; appropriate nonlinear models were generated using the most-detailed macro modeling approaches of buildings available in OpenSees. Next, the seismic response of selected buildings due to the input ground motions were quantified. Finally, results from the indicator buildings response models were utilized to predict the seismic response of all buildings within the same vulnerability cluster using linear regression models. The results of response prediction for the Wellington Building Inventory were verified by the measured response of some instrumented buildings for the 2016 Kaikoura earthquake.

Keywords: Regional seismic response analysis, Neural network, Nonlinear modeling of structures, OpenSees, Regression models.

1 INTRODUCTION

This paper outlines the development of a framework for modeling the representative indicator buildings within typologically similar clusters in a building portfolio to provide a regional seismic response model. A robust database of buildings was selected within the Central Business District (CBD) of Wellington, New Zealand due to the high risk of seismic damage in this city, the database is herein referred to as the Wellington Building Inventory (WBI) (Bradley et al., 2017), (Puranam et al., 2019). Previous research by the authors have focused on quantifying the most important

https://doi.org/10.2749/istanbul.2023.0198

Paper ID:2238

Structural Health Monitoring of Adhesive Bonded Steel Patches for the Reinforcement of Fatigue-Damaged Bridges Using Distributed Fiber Optic Sensors

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ABSTRACT

In steel bridges, unforeseen fatigue damages can occur in structural details subjected to cyclic loads, making repair measures necessary. Adhesive bonding can provide a valid alternative to the traditional strengthening methods, resulting in an extension of the service life of the structures with lower costs and less material. In this context, adequate strain monitoring is a crucial tool in evaluating the behavior of the adhesive bond and safety assessment of the repaired structure. In this study, the authors present the results of laboratory tests where steel plates are reinforced on one side using adhesively bonded patches and subjected to quasi-static load. Optical fiber sensors (FOS) were applied in different positions of the specimen (external surface of the plate, outer surface of the patch, embedded in the adhesive on plate-side and patch-side). The test objective is to confirm the ability and good performance of the FOS to monitor fatigue damage occurring in the steel plate. The fatigue damage is simulated by reducing the cross section of the steel plates by means of holes of small diameter. The obtained results are analyzed to evaluate the capabilities of the sensors to capture the damage and choose the optimal fiber position among the four described above.

Keywords: Steel bridges, Adhesive-bonded joints, Fiber optic sensors, Structural health monitoring

https://doi.org/10.2749/istanbul.2023.0205

Paper ID:2253

Use of Digitization for the Design of a Railway Arch Bridge in Azerbaijan

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ABSTRACT

For several years, and to an increasing extent, BIM techniques have yet been used by Yüksel Proje for the design process of their projects. One of these projects is the Shusha Bridge in Azerbaijan, where, due to its complex geometry, several challenges arose in choosing the right procedures for an efficient application of the used modelling software. A whole series of parametric techniques had to be applied to suitably capture the various structural components. The variability of the geometry of the individual components as well as the detailed tendon layout were recorded with using tables and formulas assigned to the geometric parameters. Advanced techniques such as using Excel sheets and TCL programming complemented the spectrum of applied functionality. Python parts were used for reinforcement modelling and outright assignment of IFC attributes supported data exchange and interoperability.

Keywords: Bridge design, Open BIM, Python parts, Interoperability

1 INTRODUCTION

The Shusha Bridge is planned to cross a deep valley near Shusha on the single-track railway line connecting the Fuzuli and Shusha regions in Azerbaijan. Due to cost valuation and the rigorous alignment restrictions of the railway it was inevitable to choose a special bridge layout with avoiding high piers in the valley. Consideration of aesthetics led to the design of an arch bridge in harmony with the surrounding nature (Figure 1). However, the complexity of this design with superstructure, arch, footings, abutments, and piers implied a big challenge for the design and the modelling procedure.

https://doi.org/10.2749/istanbul.2023.0213

Paper ID: 2312
Influence of Girder Connection Type on Mechanical Performance of Multi-span Semi-integral Abutment Bridge

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ABSTRACT

The deck expansion devices installed at the abutment can be eliminated by using the concept of the semi-integral abutment bridge (SIAB) to improve the serviceability and durability of the bridge. The mechanical performance of the girders in the SIABs with continuous structure or continuous deck between adjacent girders could be different. To investigate the different response of the two bridge typologies, a SIAB built in China was chosen as a case study. A finite element model (FEM) established by using the MIDAS-Civil software was used to compare the mechanical performance of the continuous structure SIAB or continuous beck SIAB under different load cases. The influence of different girder connection types and bridge lengths on the mechanical performance of a multi-span SIAB was studied. The results showed that the influence of the girder connection types on the internal force of the girder of a two-span SIAB is significant. Compared with the continuous structure SIAB, the absolute bending moments of the girder at the pier top, end diaphragm and mid span of the girder in continuous deck SIAB are lower, however, the shear forces of the girder at the pier top and end diaphragm are higher. With an increase in the bridge length, the continuous structure SIAB is more sensitive to the temperature variation than the continuous deck SIAB. The maximum lengths of the multi-span continuous structure SIAB and the multi-span continuous deck SIAB is 26 m (two-span) and 52 m (four-span), respectively.

Keywords: semi-integral abutment bridge; continuous structure; continuous deck; finite element model; maximum length.

1 INTRODUCTION

The bridge deck expansion devices are easily damaged due to the environment effects and the traffic load. The maintenance is time- and cost-consuming (Kelly et al. 2019; Xu et al. 2018). The deck expansion devices can be eliminated by using the concept of jointless bridge resolving the vulnerability of the deck expansion devices and increasing the driving comfort and traffic safety (Briseghella et al. 2021; Chen et al. 2022). There are three types of jointless bridges, which are

https://doi.org/10.2749/istanbul.2023.0221

Paper ID: 23-51
RotD100 target spectral compatible bi-directional ground motions: effects on orientation dependence and structural response

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ABSTRACT

The intensity of horizontal bi-directional ground motions varies with orientation azimuth. In this study, two suites of RotD100 response spectrum compatible bi-directional ground motions were developed: (1) directly match by simultaneously modifying two horizontal components; (2) pursuing the match of RotD100 while maintaining the orientation dependence of the seed records in their elastic spectral response. The strong motion characteristics of the two RotD100 compatible and a suite of amplitude-scaled records were investigated. Idealized single column reinforced concrete bridge piers with different geometric and reinforcement configurations were modelled in OpenSees. Nonlinear time history analysis was conducted with the three suites of bi-directional ground motions applied to the piers through 360° at an angle increment of 9°. An iteration process was implemented to determine a scaling factor (SF) to achieve a failure probability of 50% in all directions. The differences in the expected SF and structural response under three suites of bi-directional ground motions were discussed. It is shown that the RotD100 spectrum compatible records having the real orientation dependence as the seed records retain better the strong motion characteristics compared to the suite of amplitude-scaled records. Regarding the effect on the structural seismic response, results suggest that direct matching of RotD100 is more seismic demanding than the other two suites. RotD100 response spectrum compatible bi-directional ground motions having the real orientation dependence generate a closer result to the amplitude-scaled suits. This suggests that design based on the direct matching of RotD100 ignoring the orientation dependence is more conservative concerning real seismic demand.

Keywords: Bi-directional ground motions, nonlinear response analysis, orientation dependence, seismic design.

1 INTRODUCTION

The intensity of horizontal bi-directional ground motions varies with azimuth angle. The RotD100 response spectrum proposed by Boore (2010) gives the value of maximum spectral demand for every natural period being considered. The US standard, ASCE 7-16 (2017), has adopted the RotD100 spectrum as the target response spectrum. In other words, when nonlinear time history analysis (NTHA) is conducted to demonstrate that a structure possesses acceptable strength, stiffness, and ductility under seismic excitation, the input bi-directional ground motions should be RotD100 response spectral compatible.

https://doi.org/10.2749/istanbul.2023.0229

Paper ID: 2356
Independent Design Verification of 1915 Çanakkale Bridge:Global Analyses of Construction Stages

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ABSTRACT

The 1915 Çanakkale Bridge stretches the boundaries of what has previously been achieved for suspension bridges. To ensure a safe, reliable and fast-track construction, detailed global analyses of tower, cable and deck construction were performed by the Independent Design Verifier (IDV). Modelling and simulation of all construction stages, including a detailed model of the catwalk, is a far more complex and complicated task than analysing the completed bridge. The completed bridge analysis model was extended by adding thousands of elements representing cranes, temporary cross beams, bents, pullback cables, catwalk, temporary deck joints, and temporary hangers, among others.

To effectively handle the large number of element activations and deactivations and adjustments of hangers and joints throughout the construction process, the analysis setup was automated by extensive use of TCL and Python programming. At the end, a total of 183 construction stages were defined, which were analysed in two batches. The first 31 stages were simulating the tower erection, while the following 152 stages started by catwalk rope installation and ended by applying long-term settlements.

In addition to provide a comprehensive verification of the construction engineering and identifying possible issues at an early stage, the IDV was also able to provide the contractor enhanced understanding of the bridge behaviour during construction. The value of independent analysis contributed significantly to the structural safety and risk reduction for the construction activities.

Keywords: Suspension Bridge, Construction Engineering, Global Analysis, RM Bridge

1 INTRODUCTION

The 1915 Çanakkale Bridge client, KGM, specified that the contractor, DLSY, had to provide independent design verification for all the permanent works. Arup and Aas-Jakobsen were appointed by DLSY as Independent Design Verifiers (IDV). In addition, DLSY chose to add nearly all temporary works to the verification scope. This required further specialist support, and DLT Engineering (catwalk and cable) and Tony Gee (deck lifting gantries) were included in the IDV team.

https://doi.org/10.2749/istanbul.2023.0237

Paper ID:2431
Gordie Howe International Bridge: Project Overview and Design Features

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ABSTRACT

The Gordie Howe International Bridge, crossing the Detroit River between Windsor (Canada) and Detroit (USA), will be the longest main span cable stayed bridge in North America with an 853 m / 2800 feet main span and the longest main span cable stayed composite deck bridge in the world. This paper provides a general overview and design features including foundation, tower, piers and superstructure and erection. It will highlight design challenges including aerodynamics, stay cable design, redundancy and durability.

Keywords: Gordie, Howe, International, Bridge, Cable, Stay

1 INTRODUCTION

Planning for the Gordie Howe International Bridge Project began in 2000 for a new international trade and border crossing bridge and infrastructure facility to be constructed across the Detroit River, that would link the cities of Windsor, Ontario in Canada and Detroit, Michigan in the United States of America. The route would provide uninterrupted traffic flow between major interstates and highways, as opposed to the current crossing at the nearby Ambassador Bridge, which connects to city streets on the Canadian side. This critical infrastructure project will handle over 28% of the commercial traffic between Canada and USA. The project development advanced though the subsequent years to include environmental studies, geotechnical analyses, preliminary land acquisitions, site preparation work, and permitting.

https://doi.org/10.2749/istanbul.2023.0245

Paper ID:2860
Arched Reinforced Concrete Pylon Composite Bridge in Hungary

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ABSTRACT

In this paper the design and the construction of a unique bridge are presented, and the history of the basic idea is described as well. The bridge spanning over the second largest river is innovative in many ways in Hungary, such as the first bridge with non-prestressed reinforced concrete pylons (allowing tension), the first cable-stayed bridge applying saddles, the first cable bridge with composite stiffening girder, etc. These facts and the immaturity of the antecedent designs repeatedly raised problems to which unique answers had to be found in the detailed design phase.

To bring them into their exact final position, the erection control of the pylon and the composite stiffening girder had to be designed and carried out, which required extremely precise calculation and construction. The building of the half ellipse pylon, which also proved a serious challenge to the contractors is also discussed.

Keywords: arched pylon, concrete pylon, cable-stay, composite, stiffening girder

1 INTRODUCTION

In 2005 the city of Esztergom announced an invitation-only design competition at a study level with the title "New bridge over the Danube between Esztergom and Šturovó". One of the versions presented by UVATERV C.C. Ltd. gained the 2nd prize. The span of the riverbed bridge was 200 m, while the required width was 34.5 m.

The point of the idea was to "bridge over" the wide cross-section transversally with an arch like structure and then to suspend the superstructure on it by cables. The structure thus became a cable-stayed bridge with two arched pylons. We checked how it looks when viewed from different points with a simple 3D model. After it was acceptable, we prepared a study and visual plan.

Not when figuring out the form, but only later did we review the international examples of bridges made with similar pylons. We found two, one of them was the Miho Museum Footbridge (1997, Japan), the other was the Lingotto Footbridge (2005, Italy). Since then, more than a dozen similar pylon bridges have been built around the world, but we could not find any information about the design history of them.

We did not let the successful project to get forgotten by continuous showing it in several study plans as a possible version according to our possibilities. Finally, we prepared the Study Plan for a bridge over the river Tisza belonging to the M44 expressway in several versions in 2015 [3]. With a composite stiffening girder, the cable-stayed bridge with an arched pylon proved to be economically competitive and it was also supported by the Client.

The bridge, with its unusual pylon shape and the twisting cable surface, was not a definite success, the design jury was also divided. We thought that although it reminds us of many different

https://doi.org/10.2749/istanbul.2023.0253

Paper ID:2885
A Comprehensive Review on the Suspension Bridge Rehabilitation: Conceptual Approach

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ABSTRACT

This paper deals with the history of suspension bridge rehabilitation through case studies made and proposes the concept to strengthen the main cable without its replacement. Since modern-type suspension bridges appeared in 1850s, over 70 suspension bridges had been built all over the world by 1970s. Many of these suspension bridges confront degradation over the years. In order to assess the main deterioration of suspension bridges, historically core concepts enhancing the modern suspension bridges were categorized as key components of suspension bridges and their characteristics, and as a consequence, how the assessment should be made for the rehabilitation. Although major case studies for the rehabilitation showed to repair decks and suspenders, several cases were made to rehabilitate main cables which are the backbone of suspension bridges. A newly proposed method to increase the strength of main cables without their replacement is presented with demonstrating its effectiveness throughout the analysis. This paper aids in facilitating the health assessment and determining associated rehabilitation techniques for suspension bridges.

Keywords: Suspension bridge, Rehabilitation, Decks, Suspenders, Enhancing main cable strength

1 INTRODUCTION

The origin of the suspension bridge goes back to the primitive times when organic matters such as rattan vines and wooden logs were utilized to build the bridge. In the 19^{th} century in Europe, early modern-type suspension bridges were constructed in which steel bars with pins (*cf.* main cables) were used for suspenders. Around the same time, suspension bridges adopting small-diameter steel wires arranged in parallel for main cables appeared in the world. The Air Spinning (AS) method by John A. Roebling (1855) implemented for the parallel-wire main cable installation enhanced modern-type suspension bridge playing a decisive role in the increase in suspension bridges [4]. Since then, many suspension bridges have been built across large bodies of water serving as a crucial artery for nation's infrastructure.

With ages, many of these suspension bridges reached their lives. While the construction cost of these bridges are high, the socio-economic costs to be paid off when traffic gets blocked are enormous. Hence, most aged suspension bridges have been in use with great effort in maintenance.

As a representative example, in the vicinity of New York area where the Brooklyn Bridge is located (regarded as the beginning of a modern suspension bridge completed in 1883), 10 suspension

https://doi.org/10.2749/istanbul.2023.0261

Paper ID:2889
Probabilistic Capacity Model for Concrete-Filled Steel Tubes

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ABSTRACT

Concrete-filled steel tubular (CFST) columns are increasingly used around the world due to their significant structural and economic advantages. Although considerable research and several experimental tests have been carried out on CFST columns, there are no mechanics-based probabilistic models of their axial capacity. The present research proposes a mechanics-based probabilistic capacity model for the assessment of the ultimate axial capacity of CFST columns. The
accuracy of the numerical predictions obtained with the proposed formulation is compared with that of existing capacity equations already in use within technical standards or available in the literature.

Keywords: Axial capacity, concrete-filled steel tubes, probabilistic capacity model.

1 INTRODUCTION

Concrete-filled steel tubular (CFST) columns are largely employed around the world because they offer two significant advantages. The first one is the composite action of the steel tube and infilled concrete, which enhances the strength and ductility of the columns. The steel tube effectively confines the concrete core, thereby providing a highly ductile response under compression and increasing the overall energy dissipation capacity (Johansson, 2002). The second advantage is the use

https://doi.org/10.2749/istanbul.2023.0269

Paper ID: 2946
Artificial Intelligence for the amelioration of seismic resilience of bridges

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ABSTRACT

Bridges are vital infrastructure connecting cities and other critical infrastructures. Thus, the assessment of seismic resilience is decisive in keeping the functionality of bridge infrastructure and helping their quick recovery during strong earthquakes. This article focuses on enhancing bridge resilience by the best drift ratio estimation while considering seismic ground motion mainly attributed to the wave passage, loss of coherence, and different local soil conditions. To do this, we adopt an artificial intelligence approach. However, there are several machine-learning algorithms (MLA); and the choice came back difficult. Here, we follow the roadmap given by (Boumédiène Derras & Makhoul, 2022), which offers the best MLA suited to analyze a bridge's seismic resilience. Firstly, a dataset is created. This dataset contains the metadata (explanatory factors), such as earthquake magnitude (M), Ground-Motion Intensity Measures (IM), soil class, and parameters of structures, such as displacement ductility capacity as well as drift ratio (target). The finest model needs to characterize well the drift ratio. The value of the drift ratio, predicted in this work, gives us the bridge's performance level (PL). This PL allows the classifying of infrastructure resilience.

Keywords: Artificial intelligence; seismic bridge resilience; magnitude; drift ratio.

1 INTRODUCTION

Resilience is the aptitudes of structures, infrastructures, systems, etc., to appropriately accommodate abrupt events and chronic stressors (e.g., earthquakes, tsunamis, flooding, climate change, etc.). Those aptitudes are: 1) planning and preparing before sudden events or recurring stressors; 2) absorbing the hazard consequences; 3) efficiently reacting to the event disruption by efficiently utilizing the available resources; 4) rapidly recovering and reinstating the functionality of the infrastructure, etc.; 5) adapting to the condition variations and remembering the lessons learned or future advancement. Numerous resilience assessment procedures to deal with extreme and natural hazards were suggested: 1) quantitative methods ((Bruneau et al., 2003), (Rose, 2007) and (Alderson et al., 2015)), and 2) qualitative or semi-quantitative assessments ((Fisher & Norman, 2010), and (Pettit et al., 2010)). Furthermore, deterministic and probabilistic techniques are offered for different levels (i.e., components, systems, networks, infrastructure, and a system of systems).

https://doi.org/10.2749/istanbul.2023.0277

LONG SPAN BRIDGES
26-28 APRIL, 2023
HYATT REGENCY ISTANBUL
ATAKOY HOTEL

PAPER ID: 2955
New challenges in the IABSE TG3.1 benchmark on super long span bridge aerodynamics

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ABSTRACT

In the last years, extreme climate events as thunderstorm and downburst are becoming increasingly frequent and widespread. These phenomena could significantly impact on the dynamic response of super long-span bridges since they are typically characterized by a sudden variations of the mean wind speed combined with large vertical angles of attack. This contingency is considered an interesting opportunity for the IABSE Task group 3.1, involved for the last 5 years in the benchmark of the software for the computation of the bridge response to the turbulent wind, to extend the applicability of the consolidated numerical procedures to a case of study characterized by a non-synoptic wind. To reach this purpose, taking as a target the full-scale data measured on the Gjemnessund Bridge during two different incoming wind conditions, a comparison with numerical results is proposed. Specifically, the working group has defined two steps of increasing complexity. The first, given the same input data to the participants, consists of a preliminary numerical benchmark while, the second, concerns the comparison between the outcomes and the dynamic response of the real bridge. In this paper, the results of the wind tunnel tests, performed to measure all the aerodynamic coefficients required for numerically simulating the bridge response, are reported. Finally, the first step is presented and some preliminary outcomes are shown.

Keywords: long-span bridge, full scale monitoring, buffeting response, numerical simulations, wind tunnel tests.

1 INTRODUCTION

In the recent years, extreme climate events characterized by non-synoptic winds are becoming more and more severe and frequent. Phenomena such as thunderstorms and downbursts are typically characterized by sudden variations of the mean wind speed that, combined with large angles of attack could have a significant impact on the dynamic response of long-span bridges. In this context, the IABSE Task Group 3.1 proposal is to investigate the applicability of the numerical methods, typically used to foresee the buffeting response and the aerodynamic stability of long-span bridges due to a synoptic wind, to a non-synoptic case of study. The validation of the numerical approaches by comparison with experimental data is not straightforward, both considering wind tunnel tests and full-scale measurements. Specifically, in this last case, it is not easy to collect all the wind input data and the related output response on a real bridge.

https://doi.org/10.2749/istanbul.2023.0285

Paper ID: 2986
Response of buried arch bridge structure to seismic impact

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ABSTRACT

Dynamic analysis of the arch bridge is performed using time history of acceleration for the input motion. The prototype of the structure is a transport bridge in Bulgaria. Three real accelerograms of strong earthquakes with motion characteristics typical for the Balkan Peninsula region are considered. Finite element model of the structure and a body of ground and filling material is created by the Plaxis 2D software. Dashpots are applied as supports of the soil-structure system to simulate the infinite soil space in the numerical FE analysis. The Hardening-Soil-Small (HSsmall) constitutive model is used for describing the soil mechanical behaviour. This model handles a large number of material parameters and takes into account the degradation of the soil stiffness subjected to seismic loading. An additional viscose attenuation of 5% for the soil is introduced. Analysis and interpretation of the results are carried out.

Keywords: arch bridge, plane strain, finite element, HSS model, time history analysis

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1 INTRODUCTION

The purpose of this study is to present and discuss results from seismic time history analysis of buried bridge structure. The prototype of the structure is the reinforced concrete bridge of width 15.29 m and height 8.67 m which realizes the railway-road junction near the villages Trivoditsi and Novo Selo in Bulgaria (Figure 1).

Figure 1: The bridge in construction and service phases

https://doi.org/10.2749/istanbul.2023.0294

Paper ID: 3218
1915 Çanakkale
Bridge, Tower foundations: Independent Design Verification

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ABSTRACT

An Independent Design Verification (IDV) has been carried out on the 1915 Çanakkale Bridge for the DBFO contractor client DLSY JV. The bridge spans the Dardanelles in Türkiye and has a world leading main span of 2023m. This paper presents the IDV for the foundations of the two main towers for the bridge. The Designer adopted an increasingly used solution wherein reinforced concrete caissons are supported on gravel mats which sit on the soil deposits which are reinforced with open ended driven steel tubes ("inclusion piles") which are toed into stiff deep strata, this approach has been used on the Rion-Antirion bridge in Greece and the Izmit Crossing in Tukey. The IDV included: independent review of the ground investigation information; preparation of Ground Investigation Reports which included the seismic setting of the site and design spectra; and development of finite element models for the two tower foundations including (a) single pile models allowing investigation of the load path between caisson and Miocene bedrock through gravel mat, piles and more recent geological strata; and (b) full 3D FE models of the initial section of the steel towers, the reinforced concrete caisson and its geotechnical foundation for SLS, ULS, ALS (ship impact) and seismic design situations. The verification process included fruitful discussion with the Client and Designer to develop design solutions for the foundations. The bridge has been successfully opened to traffic.

Keywords: design, foundations, piles, seismic

1 INTRODUCTION

The DBFO joint venture DLSY (Daelim, Limak, SK and Yapi Merkezi Joint Venture) won the right to design, build, finance and operate the 1915 Çanakkale Bridge that crosses the Dardanelles Straight that links the Sea of Marmara (and Black Sea beyond) to the Aegean Sea (and Mediterranean Sea beyond) as shown in Figure 1.

DLSY, appointed Cowi and PEC to be the Designers and a JV of Arup and Aas-Jakobsen to be the Independent Design Verifier (IDV). The design brief given to DLSY was, at a high level, relatively simple: a 6 lane carriage way (3 lanes each way) with a main span of 2023m minimum that would not impact on the shipping traffic transiting from the Mediterranean to Black Seas. The bridge span is the longest suspension bridge globally.

https://doi.org/10.2749/istanbul.2023.0300

Paper ID: 3328

THE RETROFIT IN BRIDGES SYSTEM OF RING ROAD OF THE BELÉM METROPOLITAN REGION - PARÁ, BRAZIL

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ABSTRACT

This paper approaches the retrofit in the bridges system of the "Alca Viaria," or ring road, built in the early 2000s in the Metropolitan region of Belem, in the Brazilian state of Para. The ring's route is 87 kilometers (km) long. It connects the Southwest and South of the state region to the metropolitan region. It also crosses the three rivers of Amazon's delta in the state of Para: Guama River, with 1,975 m in crossing extension; Acara River and Moju, both with 860 m in crossing extensions. The retrofit of structural systems takes place from the high incidence of impact between barges and bridges, occurring over the last twenty years of the structure's service life. This results in significant damage to the supports and leads to the partial collapse of the bridge. In the last five years, these kinds of accidents required the retrofit of structural systems with a stayed-cable and the exchange of all strands in the Guamá stayed-cable bridge. Besides this, it also required the construction of floating protections on the lateral bent of the canal, the Moju, and Acará bridges. Therefore, the Department of State and Transportation of Pará has been developing efforts to ensure the operation of the system.

Keywords: stayed-cable bridge, floating protections, fender, retrofit of bridge.

1 INTRODUCTION

The retrofit of three bridges in ring road that are constructed using different structural systems. The bridge over the Guamá River is the largest, with the main span built with a 720 m long stayed-cable bridge. It consists of a 320 main span, with two H-shaped masts and two bridge of access built-in precast straight beams of prestressed concrete.

The bridges over the Acará River and the Moju River are originally with composed cross section of steel-concrete, with navigation spans of 88 meters. These bridges are now 20 years old and undergo profound adjustments both in the main structural system and in the systems for the protection of the main supports of navigation spans. The retrofit of structural systems considers of a high incidence of impact with barges that has often occurred over the last twenty years of service life, causing great damage to the structures that required the state government in the last 10 years a profound readjustment of structural systems with exchange of stayed-cable of the largest bridge

https://doi.org/10.2749/istanbul.2023.0308

Paper ID: 3388
A physics-informed machine learning model for reconstruction of dynamic loads

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ABSTRACT

Long-span bridges are subjected to a multitude of dynamic excitations during their life span. To account for their effects on the structural system, several load models are used during design to simulate the conditions that the structure is likely to experience. These models are based on different simplifying assumptions and are generally guided by parameters that are stochastically identified from measurement data, making their outputs inherently uncertain. This paper presents a probabilistic physics-informed machine learning framework based on Gaussian process regression for reconstructing dynamic forces based on measured deflections, velocities, or accelerations. The model can work with incomplete and contaminated data and offers a natural regularization approach to account for noise in the measurement system. An application of the developed framework is given by an aerodynamic analysis of the Great Belt East Bridge. The aerodynamic response is calculated numerically based on the quasi-steady model, and the underlying forces are reconstructed using sparse and noisy measurements. Results indicate a good agreement between the applied and the predicted dynamic load and can be extended to calculate global responses and the resulting internal forces. Uses of the developed framework include validation of design models and assumptions, as well as prognosis of responses to assist in damage detection and structural health monitoring.

Keywords: physics-informed, machine learning, Gaussian process, force reconstruction

1 INTRODUCTION

Assumptions on statistical wind properties, limitations of aerodynamic models and restrictions in stochastic dynamic analysis are just a few of many sources of uncertainties when modelling aerodynamic loads during the design phase of a long-span bridge. Furthermore, due to its extended lifetime and external effects such as climate change, the dynamic forces that are considered during design are subject to unforeseen changes. These factors motivate the creation of models to reconstruct dynamic loads based on measurement data.

Several methods for force reconstruction exist in literature, which are generally based on data-driven techniques [4][5], optimization strategies [10] and defined basis functions [2]. A review of several of these models is given in [8]. A novel methodology based on stochastic processes is proposed in this study. The framework combines data-driven models with physics-based

https://doi.org/10.2749/istanbul.2023.0315

Paper ID:3595
An approach for generating spectrum and energy-compatible synthetic accelerograms

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ABSTRACT

For the purpose of seismic performance verification of bridges in the process of seismic design, it is desirable to use spectrum-compatible accelerograms. However, it is well known that the correct evaluation of seismic response of structures depends on the well-suited seismic inputs. The appropriate seismic assessment of structures under earthquake loading is affected by the characteristics of accelerograms. For example, Aria Intensity, that is effective in presenting the damage potential of accelerograms. It is found that the Arias Intensity is capable of predicting the likelihood of damage of structures with short period (e.g., short-span bridges. Thus, in addition to being spectrum-compatible, there is a need to correct Arias Intensity of synthetic accelerograms to be energy-compatible in the time domain. Therefore, a simplified method that can generate synthetic accelerograms that are both spectrum-compatible and energy-compatible is necessary. This study proposed a method that can modify Arias Intensity when generating spectrum-compatible synthetic accelerograms for given seismic records. This method introduces an energy-compatible algorithm to the spectrum-compatible model, which makes the generated synthetic accelerograms match with the target response spectrum in the frequency domain and Arias Intensity in the time domain. The proposed method has been validated using various seismic records, its performance is satisfactory and its application is straightforward and quite useful in any seismic design of building new bridges or retrofitting old bridges.

Keywords: Arias Intensity; synthetic accelerograms; spectrum-compatible; energy-compatible; seismic design

1 INTRODUCTION

Earthquake may cause great damage to bridge structures, and a proper seismic load input of bridges has always been an important research direction in the field of earthquake engineering. Design response spectra are typically used in modern bridge codes or specifications to characterize the seismic load. For this reason, it is frequently important that the spectra of the input accelerograms are comparable to or envelope the specified target design spectra when nonlinear time history dynamic analysis are required. Spectrum-compatible accelerograms are the name given to this class of seismic inputs. For seismic design, spectrum-compatible accelerograms have become quite popular, and several spectrum-compatible models have been presented (e.g., Gasparini and Vanmarcke 1976; Zentner and Poirion 2012.

However, it cannot guarantee an accurate seismic evaluation when the accelerograms are only spectrum-compatible. Recently, the accurately reproduction of the natural characteristics (e.g., Peak Ground Acceleration (PGA, Cumulative Absolute Velocity (CAV, and Arias Intensity (AI of

https://doi.org/10.2749/istanbul.2023.0323

Paper ID:3707
Behavior of half-joints: design, simulation, implementation,and execution of laboratory tests

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ABSTRACT

European countries are characterized by an extensive infrastructural network, mainly built around the 1960s and 1970s. In that period prefabrication processes were starting to gain ground, and one of the most spread and studied typologies of bridges was constituted by reinforced or prestressed concrete decks. Those structures have gone through years of service, which caused the inevitable degradation of the materials. Moreover, the design and construction processes of that period have soon become obsolete, and the knowledge relative to the influence of detailing increased significantly. One particular element that has been commonly used has been the half-joint, which is easy to prefabricate and has a strategic impact. However, in recent years this solution is showing critical aptitudes in resisting structural degradation and material decay. Besides, Structural Health Monitoring (SHM) strategies are gaining attention since they are a very useful tool for gathering information on the current state of the structure and then for evaluating intervention plans to improve safety. Indeed, existing bridges, despite their working age, are still crucial to the development and sustainability of community life, and their decommissioning would be an act of critical impact on the communities (e.g., economy, logistics, sustainability). This contribution presents the design, the simulation, the implementation and the preliminary results of laboratory tests on half-joints in reinforced concrete beams that will be developed at the Politecnico di Torino in connection to CPM Samarate. They are designed to test and compare different monitoring techniques along with different steel reinforcement configurations.

Keywords: Half-joints, Concrete Structures, Digital Image Correlation.

1 INTRODUCTION

Italian and European road network has been built mainly in the years after World War II. The structures that are nowadays getting as our inheritance are reaching the end of their service life, after years of environmental and operational loads. Structural Health Monitoring is in fact one of the most urgent and interesting fields in civil engineering, directly related to the proactive management of aged structures. It can deal with different types of structures, identifying and isolating the core features and mapping the structural[1] behavior in time.

https://doi.org/10.2749/istanbul.2023.0330

Paper ID: 3710
The *Fuse-Element* feature for modular expansion joints – protecting the expansion joint and connecting superstructure from serious damage during an earthquake

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ABSTRACT

For bridges in seismically active zones, it is vitally important that their expansion joints continue to facilitate traffic after an earthquake, given the critical function of bridges in such scenarios as lifeline structures. But since the expansion joints of large bridges are typically concreted or welded to the bridge's superstructure, any exceeding of their movement capacity during an earthquake is likely to cause great damage to the joint and the connecting superstructure, leaving the bridge unpassable until major repairs have been planned and carried out. Rather than designing the expansion joint with enough movement capacity to facilitate even the largest potential earthquake, it may be far more economical to simply introduce a *Fuse-Element* into its design, which will fail in a controlled manner when non-seismic movements are exceeded. This will enable serious damage to the expansion joint and the connecting superstructure to be avoided, making repair works far easier (without the need for a replacement expansion joint to be designed and supplied), and probably even accommodating emergency traffic in advance of any such repair work. The *Fuse-Element* feature is presented, along with an example of its application in Turkey.

Keywords: Modular expansion joints, seismic protection.

1 INTRODUCTION

A bridge's expansion joints fulfil a critical function, providing a continuous, watertight driving surface at each discontinuity in the superstructure while also enabling the superstructure to move and rotate as required by the bridge's design. In the case of bridges in seismically active areas, it is especially important that their expansion joints continue to facilitate traffic after an earthquake, enabling emergency traffic to reach devastated areas and the affected people to move to safer, less affected areas.

https://doi.org/10.2749/istanbul.2023.0336

Paper ID:3719
The expansion joints of the 1915Çanakkale Bridge

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ABSTRACT

The recently opened 1915Çanakkale bridge 300 km south-east of Istanbul has a main span of over two kilometres and a total length of 4,608 m.

Based on the bridge kinematics, complex expansion joints at both main deck ends with movements of up to 2800 mm, low noise emission and highest durability were required.

In addition, the approach bridges to the main bridge, which are seismically isolated, requested large transversal movements.

So-called modular swivel joist expansion joints allow six degrees of freedom: displacements transverse, longitudinal and vertical to the direction of traffic as well as any kind of rotations can be compensated, to address the specific needs of a suspension bridge located in a highly seismic region.

The expansion joint structure, consisting of bars supporting the lamellas, features a new low-friction, almost wear-free guiding system with a next generation of sliding material. This prevents restraints, provides a superior smoothly controlled movement mechanism, and increases the service life to at least 50 years.

Particularly, an approved sliding material (modified UHMWPE, pre-loaded and equipped with greased dimples within the moving components, which has been successfully applied for two decades in the bridge bearings, grants proper function for a certified accumulated travel path of 50+ kilometres even combined with high seismic displacement velocities. A more precise prismatic guide mechanism was developed to achieve a permanent contact between all relevant sliding elements.

In this way both the bridge bearings and the expansion joints systems can reach the same certified nominal life and durability while resisting major earthquakes without damage.

The expansion joints were additionally equipped on their surface with welded rhombic steel plates to remarkably reduce the noise, increase the driving comfort and assure a durable anti-skid resistant across the overpassing surface. Also, welded instead of bolted applications within the construction enhance fatigue-proof and durable service lifetime of the applied expansion joints.

The joints of the approach bridges were designed with special rhombic steel plates that allow also large transversal movements.

Keywords: Long Span Bridges; modular expansion joints; durability; earthquake.

https://doi.org/10.2749/istanbul.2023.0344

Paper ID: 3774
Nonlinear buffeting response of long suspension bridges considering parametric excitation due to large-scale turbulence

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ABSTRACT

The accurate modelling of self-excited forces for long-span suspension bridges is known to be very important for both the assessment of the flutter stability and the calculation of the buffeting response to turbulent wind. It has also been proved that self-excited forces often parametrically depend on variations of the angle of attack, which can easily be induced by large-scale turbulence. A nonlinear buffeting model is outlined here to explore this issue, emphasising the influence of nonlinear turbulence effects on the stresses in the main structural elements and not only on displacements and accelerations of the bridge deck. The proposed approach is based on the 2D Rational Function Approximation model for self-excited forces, recently developed and experimentally validated by the authors. Despite the complexity of the problem, this model only slightly changes the dynamic equations based on the linearised theory, making it friendly to be implemented. The Hardanger Bridge, in Norway, is chosen as a case study, as its aerodynamic derivatives strongly depend on the angle of attack. The contribution of the wind load to the internal forces in the main cables and in the hangers is found to be only marginal. In contrast, the stresses induced in the deck girder are large, and the results for high wind speed emphasise the strong impact on the torsional moment of the modulation of the self-excited forces due to the spatio-temporal fluctuation of the angle of attack produced by low-frequency turbulence.

Keywords: Nonlinear buffeting, self-excited forces, angle of attack, wind-induced stresses.

1 INTRODUCTION

Over the past three decades, the number of long-span suspension bridges has more than doubled with no sign of stopping, as also suggested by some recent national infrastructural large projects (e.g., the Norwegian E39 fjord crossing project [8]. Wind-induced effects might be crucial for such slender structures, and the dynamic response due to turbulent wind (buffeting may even govern the structural design. Indeed, suspension bridges are low-damped structures, and the overall response is mainly due to resonant contributions associated with several low-frequency modes. As a consequence, a crucial role is played by the aerodynamic damping produced by motion-induced forces (self-excited forces,

https://doi.org/10.2749/istanbul.2023.0351

Paper ID:3851
Study on flow structures affecting vehicle running stability on bridge deck under strong cross wind

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ABSTRACT

Vehicle overturning accidents on a bridge often happen during strong crosswinds. In order to prevent such accidents, a bridge operator imposes some traffic regulations such as speed limit or bridge closure. Besides, safety measures such as a windshield are installed in some cases. In case of long-span bridges, a windshield is difficult to install for the entire span because it decreases aerodynamic stability. However, some recent bridges installed a windshield with keeping enough aerodynamic stability. In order to enhance vehicle running stability against strong crosswinds, in any case understanding of the flow structures on a bridge deck is necessary. Then, an optimum windshield having high aerodynamic performance can be developed. In this study, targeting typical bridge decks of truss and closed box, flow structures on the bridge decks are investigated by wind-tunnel experiment first. Then, optimum shape and dimensions of a windshield are investigated with respect to the reduction of crosswind on the bridge deck and wind-induced vibration. In addition, PIV tests are conducted to understand flow fields around the bridge deck.

Keywords: Crosswind, bridge deck, vehicle running stability, windshield

1 INTRODUCTION

Vehicle overturning accidents on a bridge often happen during strong crosswinds (see Fig. 1. In order to prevent such accidents, a bridge operator imposes some traffic regulations such as speed limit or bridge closure. For example, a speed limit regulation is issued when a 10-minute mean wind speed exceeds 15m/s and the bridge is closed when the mean wind speed exceeds 25m/s in the case of Honshu-shikoku Bridges in Japan. However, it is very difficult to evaluate accurate crosswind speed at different traffic lanes and bridge spanwise locations. Therefore, in order to enhance traffic safety on a bridge deck and issue effective traffic regulations, understanding of wind fields on the bridge deck due to strong crosswinds is necessary. Besides, in order to enhance the traffic safety further, installing safety measures such as a windshield to protect traffic from the crosswind is another option.

https://doi.org/10.2749/istanbul.2023.0359

Paper ID: 3994

The 1915 Çanakkale Bridge: Geometry and vibration controls for steel tower under construction

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ABSTRACT

The steel towers of the 1915 Çanakkale Bridge is a very slender steel structure with a height of 318 m located in the middle of the Dardanelles Strait in Turkey. The tower of a suspension bridge is in general structurally the most vulnerable in a free-standing state before the main cable installation. Thus, an accurate geometry control during construction is essential to construct within the maximum design tolerance for the main cable installation upon completion of such an independent tower. In order to minimize construction errors, it is important to obtain and analyse data such as the location of the tower top (from GNSS receivers), wind direction and speed (from anemometers), and temperature (from thermometers) for a certain period of time. In addition, AMD (Active Mass Damper) system was adopted for effective vibration control during construction and even in operation. This paper focuses on i) the geometry control of the steel tower during construction and ii) the planning and operation of the AMD system installed for wind-induced vibration control, for the world's slenderest steel structure. Through the above process, we have successfully completed the construction of the final tower block B32, upper crossbeam, and tower saddles. The final construction error of the steel tower was up to about 60 mm in the horizontal directions, far below the design tolerance of 150 mm.

Keywords: Steel tower, Çanakkale, Geometry control, Construction error, AMD.

https://doi.org/10.2749/istanbul.2023.0367

Paper ID: 4013
Span Evolution and Aerodynamic Challenge of Suspension Bridges

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ABSTRACT

Suspension bridges as the longest bridge have experienced with span length increase for 140 years. Long-span suspension bridges are becoming lighter, more flexible, and lower damping, which result in more sensitive to wind actions. The most challenging problem among wind-induced responses identified is aerodynamic instability or flutter, and some control measures have to be adopted to flutter stabilization. There are four successful aerodynamic countermeasures, including central vertical stabilizer firstly installed in Runyang Bridge built in 2005, side horizontal stabilizers recently adopted in Nansha Bridge in 2018, central slotted twin-box girder firstly applied in Xihoumen Bridge in 2009, and the combination of central slot and vertical stabilizer used in Akashi Kaikyo Bridge in 1998. The twin-box girder of Xihoumen Bridge has been further studied up to 3,000m, and the widely-slotted twin-box girder has been proposed to a 5,000m suspension bridge.

Keywords: Suspension bridge; span evolution; aerodynamic challenge; flutter control; aerodynamic countermeasures.

1 INTRODUCTION

Human beings have been building bridges in girder, arch, cable-stayed and suspension types to cross streams and rivers. Among these four types of bridges, suspension bridge has the greatest bridging capacity, and can meet with the maximum demand on bridging wide sea strait. In order to accommodate huge size marine vessels and to avoid from building deep water foundations, span lengths of suspension bridges have been gradually increased for 140 years from the 486m spanned Brooklyn Bridge built in 1883 to the 2,023m Canakkale Bridge in 2022 (Wikipedia, 2023. The span length evolution of suspension bridges is challenging engineering limit and realizing human dream.

With the rapid increase of span length, suspension bridges are becoming lighter, more flexible, and lower damping, which result in more sensitive to wind induced problems including aerodynamic instability, aerostatic divergence, stochastic buffeting, vortex-shedding vibration, etc. The most challenging problem among wind-induced responses is aerodynamic instability or aerodynamic flutter, and some flutter control measures have to be adopted to flutter stabilization, in particular for the span length longer than 1,200m (Ge, 2009. Four successful aerodynamic countermeasures have been summarized, including central vertical stabilizer, side horizontal stabilizers, central slotted twin-box girder and the combination of central slot and vertical stabilizer. The twin-box girder solution has been further studied and compared to single box and thin plate girders up to 3,000m. Finally, the widely-slotted twin-box girder has been proposed to a 5,000m spanned suspension bridge (Ge, 2011.

https://doi.org/10.2749/istanbul.2023.0376

Paper ID: 4076
Geotechnical earthquake engineering for the detailed design of the 1915 Çanakkale bridge

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ABSTRACT

The paper provides a summary and description of the geotechnical earthquake engineering aspects related to the detailed design and construction of the record-breaking 1915 Çanakkale suspension bridge with a 2023 m long main span, 770 m long side spans and approach bridges of 365 m and 680 m. The main steel bridge foundations comprise two concrete caisson foundations placed on soil improved by steel pile inclusions, two gravity-based concrete anchor blocks and two side span piers founded on bored piles. The post tensioned concrete approach bridges are supported by piers on bored piles, which – where needed – are seismically protected by ground improvement consisting of deep soil mixing. The paper briefly describes the main features of the seismotectonic setting and the derivation of the effective input motion used in the bridge global structural model. The derivations of the foundations' dynamic impedances and the link to the site response are described. The design and construction of the foundation systems, consisting of both soil improvement and the foundation elements themselves, and the interaction with the site response analysis, the liquefaction hazard and lateral soil deformation assessments are described. 2D nonlinear time history analyses for the evaluation of the ground (slope movements and the derivation of kinematic forces on the piles supporting European and Asian approach bridges and side span piers are also illustrated. Finally, a brief description of the monitoring system related to geotechnical earthquake response and its rational is presented.

Keywords: 1915 Çanakkale bridge, geotechnical earthquake engineering, soil improvement, slope stability, monitoring.

https://doi.org/10.2749/istanbul.2023.0384

Paper ID:4309
1915 Canakkale Bridge - Cable Structures

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ABSTRACT

The world record 1915 Çanakkale suspension bridge has a 2023m main span and two suspended side spans each 770m long. Due to poor soil conditions at the shorelines, the two anchor blocks are located onshore by use of tie-down arrangements. The cable structures for the 1915 Canakkale bridge consist of main cables, anchorages, splay- and tower saddles, cable clamps, tie-down arrangement and hangers. Each of the two main cables have a length of 4400m, a diameter of 869mm and are designed with a strength of 1960MPa which is state-of-the-art for suspension bridge main cables. The main cable strands are anchored in gravity-based anchor blocks in a compact splay arrangement. The saddles are designed with cast steel troughs and plated steel bodies and optimized to reduce quantities. Hangers are PPWS cables sheathed in HDPE and equipped with spherical bearings to ensure a long service life.

The paper will explain the innovative solutions that were developed for the cable structures of the world longest suspension bridge. The use of advanced global and local analyses models in the design of cable structures will be elaborated. The design philosophy that leads to a highly optimized design that reduces quantities, cost and carbon footprint is explained. Furthermore, the tie-down arrangement, the increased strength properties for both plated steel and cable steel, the dehumidification system and the introduction of spherical bearings at hangers will be explained in the paper.

Keywords: Suspension bridge cable structures, Long span bridges, Suspension bridges, Finite Element analyses.

1 INTRODUCTION

The 1915 Çanakkale Bridge across the Çanakkale Strait in Türkiye carries a new highway connecting Europe and Asia. The bridge is located at the north-eastern end of the strait where it connects the Gelibolu province on the European side with the Lapseki province on the Asian side. The bridge opened to traffic in March 2022 and is intended to improve the traffic flow to ease the present and future congestion problems.

https://doi.org/10.2749/istanbul.2023.0392

Paper ID:4400
Selected methods of reducing the deck transverse vibrations in long-span steel footbridges – case studies

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ABSTRACT

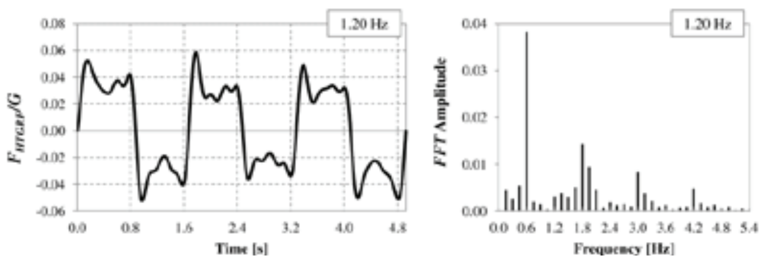
Horizontal vibrations of the deck in lightweight long-span footbridges, especially those made of steel, with a low damping level may significantly reduce the comfort of use of the whole structure. The natural frequencies of such footbridges are very often in the range of 0.5 ÷ 1.0 Hz. This can lead to the excitation of resonant vibrations of these structures by walking people generating horizontal transverse forces characterised by a large amplitude of harmonic components corresponding to two frequencies 0.5f_s and 3/2f_s (where f_s – frequency of steps during walking. The article presents examples of structural solutions used in long-span suspension footbridges built in Poland in order to reduce the horizontal transverse vibrations of the footbridge decks. The results of dynamic field tests and numerical calculations of two footbridges were presented and analysed. The obtained results indicate a positive effect of reducing the horizontal vibrations of the deck in both footbridges and changes in the frequencies and the mode shapes of the analysed footbridges caused by applied solutions.

Keywords: footbridge, dynamics, vibration, suspension bridge, human-induced vibrations.

1 INTRODUCTION

Walking people generate harmonic dynamic forces (ground reaction forces, *GRF* in vertical (F_{VGRF} and horizontal (transverse F_{HTGRF} and longitudinal F_{HLGRF} direction. These action can be characterised by the amplitude of their harmonic components. For vertical forces F_{VGRF}, the dominant harmonics are the first and second harmonics, corresponding to the frequencies 1f_s and 2f_s. In the case of horizontal transverse forces F_{HTGRF}, the dominant harmonics are the harmonics corresponding to the frequencies 0.5f_s and 3/2f_s [1 ÷ 6].

Fig. 1 shows examples of waveforms of normalised horizontal transverse ground reaction forces (F_{HTGRF}/G, where G – mass of a walking person generated during walking with the frequency of steps f_s = 1.20 and f_s = 1.80 Hz along with the corresponding *FFT* spectra. Presented forces F_{HTGRF}/G were recorded by the author during laboratory tests of walking adult volunteers using force platforms AMTI BP400600 lined up (one behind the other within a rigid path 10.0 m long and 1.50 m wide.



https://doi.org/10.2749/istanbul.2023.0401

Paper ID:4421
Main Cable Inspection and Strength Evaluation of Helicoidal Strand Main Cables Using a Modified NCHRP Evaluation Approach

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ABSTRACT

The A. Murray MacKay Bridge (MacKay Bridge) opened to traffic in 1970 and carries four lanes of traffic over the Halifax Harbour between Dartmouth and downtown Halifax, Nova Scotia, Canada. The Bridge's main cable has been opened for detailed visual inspections several times beginning in 2002. The Owner, Halifax Harbour Bridges, retained COWI North America to perform a strength evaluation in accordance with the National Cooperative Highway Research Program (NCHRP) Report 534– Guidelines for Inspection and Strength Evaluation of Suspension Bridge Parallel Wire Cables. As the MacKay Bridge main cable is composed of 61 parallel strands with helicoidal wires, the NCHRP 534 approach (intended for parallel wires) was modified to perform the strength evaluation for cables with helicoidal wires. Based on the analysis performed, it was determined that the main cable of the MacKay Bridge has adequate capacity at this time. Additional measures to protect the cable, mainly through dehumidification, could be considered to prevent further deterioration of the main cable and extend the service life of the cable and therefore the bridge.

Keywords: Suspension Bridge, Cable, Strength Evaluation, Asset Management.

1 INTRODUCTION

Halifax Harbour Bridges (HHB) retained COWI North America (COWI) to perform a strength evaluation of the A. Murray MacKay Bridge (MacKay Bridge) main cable in accordance with the National Cooperative Highway Research Program Report 534 (NCHRP 534) – Guidelines for Inspection and Strength Evaluation of Suspension Bridge Parallel Wire Cables [1].

This study utilizes the findings of the inspection work on the main cable that HHB has conducted over the years (inspections by COWI, as well as other consultants). Data collected during the inspections was used to assess the physical condition and remaining strength of the main cables. The strength evaluation and condition assessment of the cables was also used to provide estimates of the remaining service life of the main cable and recommendations for future inspection, monitoring, investigations, corrosion protection and recommended maintenance.

https://doi.org/10.2749/istanbul.2023.0409

Paper ID:4475
40 Years History about Structure, Design and Construction of the First Steel Orthotropic Bridge in Sofia

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ABSTRACT

The most spectacular and large bridge in Bulgaria and one of the largest in South-East Europe bridge in Sofia was put into operation at the beginning of October 1983. The bridge perform a multi-span, prestressed reinforced concrete construction with a total length of 2114 m, a total width of 21.5 m and an average height above the ground of about 10 m. This important, effective and aesthetic bridge serves as a connection between the busiest input-output highway and the airport of Sofia. It ensures a convenient access to some highways, railways, streets and the airport. As a result of this requirement, the erection of the prestressed reinforced concrete bridge is not allowed to cross the railway between Sofia and Varna. So, a 90 m long middle steel part was designed to cover two spans of 45 m each in the multi-span bridge structure. In transverse direction the orthotropic bridge, consists of two individual parallel triple-box decks parts, which carry the traffic in two opposite directions. Each deck has a 7.5 m wide roadway with two lanes. The bridge is analysed as a frame structure using the finite element method. The design parameters of the bridge are verified by static and dynamic tests. The steel structure is designed as a two-span continuous beam with a box cross-section and an orthotropic deck. The paper deals with the most important aspects which consider the design approach and the construction process of this large, steel orthotropic bridge in Bulgaria.

https://doi.org/10.2749/istanbul.2023.0417

Paper ID:4513
Deformation compatibility during erection of steel bridges : case of a 2-span railway truss bridge

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ABSTRACT

Often insufficient attention is given to the compatibility of the deformations of steel bridges during their assembly on the construction site, especially if continuity, due to bending moments, is to be ensured at the level of intermediate supports. This does require to compensate during assembly the difference in the angular rotations at the location of the support points. The effect is especially noticeable with longer spans or with flexible superstructures. In the case of the construction of a double railway bridge over the Albert Canal (Belgium), the above was an important issue. The bridges are in the shape of a classic Warren truss girder. An unusual process was followed for the assembling on site. In the first phase, the entire lower chord, including the bridge deck, was built and supported in all nodes of the truss. The sloping diagonal bars are connected to this and the upper member of the truss is then mounted on top. In such construction the diagonal bars tend to twist and bending moments are created in the lower truss nodes. Gaps may appear in the upper nodes, due to the unequal displacements of the members to be connected. Calculations must show whether stress-free corrections can be made for the fabrication of the various bars, thus avoiding stresses due to the erection process. This example clearly shows that the compatibility of the components of steel bridges during their assembly must be determined in detail and that efficient measures are needed to compensate for defects.

Keywords: erection of steel bridges, deformation compatibility, steel truss bridge, stress free assembling.

1 INTRODUCTION

The 129 km long Albert canal connects the city of Liège to the port of Antwerp in Belgium, thus allowing to overcome a height difference of 56 m. It is one of the few larger waterways and the bridges crossing it are of the largest spans in this country. The canal was originally built for 2000 T vessels, but gradually accepted larger ships. The expansion of fluvial traffic, especially of containers, has required to enlarge the canal and provide more vertical clearance up to 9.10 m. This will allow 10000 T vessels with 4-stack containers passing in both directions to use the canal. The increase in vertical clearance has required the renewal of 62 bridges. This major project was realized in several steps and is reaching its end point. Most of the bridges are steel tied arches of a similar type, thus achieving a certain degree of recognisability of the canal as described by Dumortier and De Ville de Goyet (2021).

https://doi.org/10.2749/istanbul.2023.0426

Paper ID: 45-51
Stay-cable Bridge Construction Accelerated The New Bridge over the Ohio River

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ABSTRACT

The standard cast-in-place segmental balanced-cantilever construction technique for long-span, cable-stayed bridges has been well known and widely used; however, it can lead to extensive construction time and places the construction of the pylon on the critical path of the schedule. The Oakley C. Collins Memorial Bridge over the Ohio River (between Ironton, Ohio and Russell, Kentucky, USA) was built with a new construction technique targeting this issue and accelerating construction by implementing several innovative value engineering ideas proposed by COWI, the Contractor's Construction Engineer. These include the use of back-span falsework, allowing the side span superstructure to be cast-in-place on falsework during pylon construction; the use of precast stay anchor blocks for rapid installation and better geometry control of the stay anchorages; and guide pipes and unidirectional cantilever casting, reducing the casting cycle duration to as little as one segment per week. This paper presents the construction details that significantly reduced the superstructure casting schedule and design modifications to the superstructure.

Keywords: Cable-stayed, balanced cantilever, value engineering, segmental

1 INTRODUCTION

The new Oakley C. Collins Memorial cable-stayed Bridge over the Ohio river, connecting the cities of Ironton, Ohio and Russell, Kentucky, was opened to public in November 2016 and instantly became a landmark of the region and surrounding communities. It replaced a 100-year-old, structurally obsolete steel truss bridge that was demolished soon after the opening in 2017.

The request for proposal planned to build the cable-stayed bridge by conventional balanced-cantilever method: first build pylons founded deep in the Ohio riverbed, then cast-in-place segments the superstructure segments in a symmetrical manner at each main pier with form travellers. The Contractor and COWI, the Construction Engineer, worked together to identify the riskiest aspects of the project and introduced several innovative construction techniques to allow acceleration of the construction and to reduce the complexity of the common constructability challenges. These included the modification of the erection method to unidirectional cantilever with the back-spans cast on modular falsework towers, and the use of precast elements such as transverse floorbeams, precast stay anchor blocks, and precast coffer cells. All these ideas have proven to be of great value to the

https://doi.org/10.2749/istanbul.2023.0434

Paper ID:4769
Forensic Quantification of Fire on Suspension Bridges

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ABSTRACT

Suspension bridges generate critical transportation and trade links in areas requiring the spanning of large obstacles. Such structures are, by nature of their scale, highly utilized and rarely redundant from a transportation network perspective. As such, the reliable maintenance of long-span bridges is of eminent importance. Various hazards have been well-quantified, namely earthquakes, high wind events, and, more recently, corrosion to critical structural members. However, to date, the hazard of fire on suspension bridges, stemming both from the environment (e.g. wild fires) or vehicles (e.g. car and truck fires), remains poorly understood. Building codes consequently fail to address this hazard, on both the load and resistance sides of the equation. We present here a thorough survey of suspension bridge fire incidents in the United States of America, focusing specifically on parameters such as location, duration, intensity, height of the fire and damage caused thereby. The data integrates often sparse event logs of bridge owners with forensic analyses of the various events using photogrammetry and videogrammetry of professional and social media footage. The incidents are then categorized with respect to the danger posed to the structure. A set of case studies are presented to detail the investigation method. The goal of the final database is to effectively quantify the hazard of fire on suspension bridges such that appropriate actions may be taken by owners and authorities to protect their infrastructure.

Keywords: fire hazard, forensic, main cable, damage, suspension bridge

1 INTRODUCTION

The challenges inherent in the operations and maintenance of long-span bridges are generally well-studied, specifically as they pertain to the safety of major infrastructure against earthquakes, wind, and material degradation (corrosion). The two former hazards have been captured effectively in the prevailing building codes on a global scale. Earthquakes, somewhat surprisingly, present the most predictable hazard as their well-established historical quantification remains accurate to this day. In light of climate change, extreme weather events, well-quantified in past decades, must be reassessed as the hazards due to hurricanes, tornadoes, and other high-wind events are rapidly evolving. The latter, corrosion, has also received considerable attention in the recent past from works by Noyan et al. (2010), Mei at al. (2013), Betti et al. (2016), Karancı at al. (2018), and Brügger at al. (2015, 2017, 2019, 2022).

Beyond the abovementioned hazards, however, remains a largely uncaptured quantity: fire. Unlike structures susceptible to chimney effects (i.e. tunnels and overpasses), fire has been largely

https://doi.org/10.2749/istanbul.2023.0443

Paper ID: 4843
Using SHM systems data to plan the maintenance of large bridges – Polish examples

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ABSTRACT

In Poland, monitoring systems have been installed on large bridges for over 20 years, and the collected results are used to control the condition of the facilities, and in planning maintenance works. The paper presents SHM systems installed in two cable-stayed objects:

- the Solidarity Bridge in Płock. It is a steel cable-stayed bridge with a main span of 375 m. SHM has been collecting data on this bridge since 2005.
- Rędziński Bridge in Wrocław. It is a concrete bridge with an unusual structure and spans 50 + 2 x 256 + 50 m. SHM has been collecting data on this bridge since 2011.

Selected data from the SHM systems will be presented regarding the following:
- changes of forces in the cables during operation,
- changes in the geometry of bridges over time,
- use of monitoring results to develop design recommendations for new bridges.

Key in words: cable-stayed bridges, maintenance, monitoring, SHM

1 INTRODUCTION

In Poland, SHM systems have been installed on large and smaller innovative bridges for over 20 years. During this period, extensive data on changes in deformations, stresses, internal forces, temperature, wind speed, and direction in the monitored structures were collected and developed. Based on data obtained from SHM, several interesting and valuable papers have been created [2], [3], [4], [7], and more are in preparation. In addition to scientific purposes, such as learning about the actual temperature distribution in individual elements of the bridge structure [7], data from SHM are used in works related to the maintenance of these structures. This paper presents the results obtained with the help of SHM in two cable-stayed bridges built in Poland. The methods of using the obtained results to plan and carry out maintenance works were also shown.

https://doi.org/10.2749/istanbul.2023.0453

Paper ID:4863
Improvement of Stiffener Configuration to Strengthen Tensile Type Joints with Long Bolts Applied to Bridge Main Tower

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ABSTRACT

Long-tightening joints, despite their ability to be assembled quickly, have been found to have complexities in structure and difficulties in welding during fabrication of joint components in suspension bridge main towers and wind power generation towers. In this study, a method was investigated to simplify the fabrication of long-tightening joints by reducing the welding length of joint members and improving the joint geometry through FE analysis. Additionally, a composite joint structure with concrete was studied to reduce stress concentration near the welds, which are potential weak points for fatigue cracks. The results showed that the welding length could be reduced while maintaining the strength and deformation performance of the joint by changing the stiffener geometry. The stress concentration near the welds was also improved by incorporating concrete into the joint.

Keywords: Long type tensile bolted joints, Main tower connection, FE analysis.

1 INTRODUCTION

Long type tensile bolted joints (Long-tightening joints) have been utilized in the main towers of suspension bridges (Chen and Duan, 2014) such as the Second Bosphorus Bridge in Turkey (Figure 1 (a)) and the Kurushima Ohashi Bridge in Japan (Figure 1 (b)). One of the benefits of long-tightening joints is the ease and speed of assembly compared to welded joints, making it a viable option for use in tower joints for offshore wind turbines, which have seen a rise in popularity in recent years. The basic structure of a long-tight joint is illustrated in Figure 2. The joint consists of various components such as bolts, rib plates, end plates, anchor plates, and shear plates in addition to the main plate. Despite its benefits, the long-tightening joint has a complex structure and its assembly, particularly through welding in a factory, is challenging. In Japan, the design method and specifications for long-tightening joints have remained unchanged since 2004 (Nishiwaki et al., 2004). In order to make the implementation of long-tightening joints more feasible, it is necessary to simplify the structure shown in Figure 2 by reducing the number of components or shortening the welding length. With the recent improvements in FE analysis and computer performance, the author considered that the disadvantage of long-tightening joints could be solved by eliminating members and decreasing weld lengths while still preserving the joint's performance such as configuration optimizations for short tensile type bolted joint (Sugimoto et al., 2018; Sugimoto and Yamaguchi, 2022). Furthermore, long-tightening joints have multiple welds of steel members which are prone to fatigue cracks, thus the development of new joint structures that can reduce stress concentrations near welds is essential.

In this study, the joint geometry is improved through FE analysis by shortening the weld length of joint members to facilitate fabrication in a factory. Additionally, a composite joint structure

https://doi.org/10.2749/istanbul.2023.0464

Paper ID: 5006
Innovative solution for an Extradosed bridge over river Beas in Hilly Terrain of Himalayas

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ABSTRACT

Road Network of Himachal Pradesh, a northern state in India requires number of long span bridges across valleys and rivers due to its hilly terrain. One such bridge across river Beas at Hanogi has a total length of 119.2m. Proposed span arrangement at the location of this bridge is 97.2m + 22m. National Highway (NH-3) runs perpendicular to the bridge. The bridge is located in a constrained location with approach road on one side and a hillock with NH-3 at its toe on the other side. It was proposed to build an extradosed bridge of span 97.2m with pylon only on abutment A2 side and back stay cables anchored in hillock formed of rock.

This paper presents design aspects of the extradosed superstructure and cables, Back stay anchors, Abutment A2, staged construction analysis. The construction of the bridge is carried out by cantilever method with form traveller. This paper also covers construction methodology of the superstructure, ground Improvement and stability check at abutment A2 and Hillock where the stays are anchored.

This is one of the unique extradosed bridge where long span on one side is supported by cables on single pylon and back stay cables are anchored to the rock.

Keywords: Extradosed Bridge, Rock Anchored, Ground Improvement, Cantilever Construction.

1 INTRODUCTION

Roads are a very vital infrastructure for rapid economic growth of any state/country. In fact, the development of important sectors of economy such as Agriculture, Horticulture, Industry, Mining and Forestry depends upon efficient road network. Social activities such as education, health, family planning and promotion of tourism also depend upon efficient road network.

Road Network of Himachal Pradesh requires number of medium & long span bridges across valleys and rivers owing to its hilly terrain. Himachal Pradesh Public Works Department (HPPWD) is engaged in planning, construction and maintenance of roads, bridges, ropeways, and public buildings in the State. Furthering its primary mission to provide connectivity by way of all-weather roads to all the habitations (villages) in the state, HPPWD in consultation with elected representatives

https://doi.org/10.2749/istanbul.2023.0472

Paper ID:5062

Assessment of River Mersey Steel Truss Bridge Using Non-Linear Finite Element Analysis

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ABSTRACT

United Kingdom's railway bridges, a majority of which are more than 150 years old, is owned, managed, and maintained by Network Rail (NR). For the safe and efficient administration of the rail network, it is essential to have up-to-date capability information, for these ageing assets.
One example of its kind is River Mersey Bridge (SDJ2/38A). It was initially built in 1853 (Fig1) as a wrought iron tubular structure, later rebuilt with steel, except the central box girder, in the year 1908 (Fig 2).
As per NR/GN/CIV/025, Level 1 assessment would not adequately depict the interaction between the main structural parts as expected for a structure of this age due to its known conservative nature. Therefore, it was beneficial to perform non-linear analysis as part of Level 2 assessment.
To properly simulate the structure and account for the potential failure modes of the structural components, this study took the complete structure into account. The paper also gives an insight into the mathematical model developed to capture all the section losses obtained from inspection for assessment report (IFA). The critical mode shape obtained from Eigen value buckling analysis was used as an input for initial imperfection to carry out the non-linear analysis (geometric and material). Discussions were carried out on the use of model to calculate the Von Mises stresses in Ultimate Limit State (ULS) and Service Limit State (SLS), areas of material yield, and the tendency of local premature buckling.
A comparison between linear and nonlinear analysis revealed a significant improvement in the stress distribution near the connection points, consequently the member stresses were found to be within acceptable limits. A continuous mesh improvement process was also followed to converge the analysis with successively coarser to finer meshes.
If any structural elements had shown material yield further recommendations have been made based on engineering judgement and modelling constraints. The non-linear assessment subsequently found the structure to be able to accommodate current load rating which was a betterment from the previous linear assessment.

https://doi.org/10.2749/istanbul.2023.0480

Paper ID:52-29
The 1915 Çanakkale Bridge – Design of Towers

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ABSTRACT

The world record 1915 Çanakkale Bridge across the Çanakkale Strait in Türkiye is carrying a new highway connecting Europe and Asia. The suspension bridge has a main span of 2023 m and a tower height of 318 m. The towers are manufactured in steel primary to reduce the construction time and comprise of approximate 36000 tonnes. The H-shaped towers with three cross beams consist of closed steel boxes. The inclined tower legs have a base dimension of 11.0 x 10.5 m which reduces to 8.0 x 7.5 m just below the tower saddles. The butterfly shaped cross beams have a constant width of 4.0 m and varies in height from 5.0 m at centre to 8.0 m at the leg intersection. The tower legs are divided into 32 erection blocks which are lifted as full blocks with a floating crane or divided into panels and lifted by a heavy-duty tower crane. The tower block assembly is carried out by skin plate welding combined with friction grip bolting of the longitudinal stiffeners. The design of the steel towers is carried out in accordance with Eurocodes. The design philosophy is explained along with a presentation of the governing load situations; ultimate limit state, ship impact, and temporary bridge erection phases. Also, the special areas at the tower base, bridge deck and cross beams, where additional strengthening is needed will be touched upon. The towers are designed with focus on maintenance costs with smooth outer surfaces and internally protected by a dehumidification system.

Keywords: Tower design, suspension bridge, steel design, Çanakkale

https://doi.org/10.2749/istanbul.2023.0501

IABSE SYMPOSIUM ISTANBUL
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Paper ID: 5231
THE PADMA MULTIPURPOSE BRIDGE, BANGLADESH'S LONGEST BRIDGE, PRESENTS UNIQUE ENGINEERING CHALLENGES AND AN IMPRESSIVE OUTCOME

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ABSTRACT

The Padma Multipurpose Bridge, commonly known as the Padma Bridge, is a two-level steel truss bridge with a four-lane highway on the upper level and a single-track railway on the lower level that has been under construction since 2014 and opened to traffic in June 2022. The upper and lower levels act compositely for live loading with a reinforced concrete deck slab. The bridge presented technical challenges to the client, consultants, and contractors, including river training work and deep foundations in an alluvial flood plain, where the rock formation lies several kilometers below the river bed. Major vessel traffic and ship impact were also challenges. The Padma is one of the world's mightiest rivers, being a distributary of the Ganges and the Jamuna rivers and winding its way through Bangladesh to the Bay of Bengal. Engineers faced many challenges while designing the Padma Multipurpose Bridge, one of the biggest challenges being how to design a structure that could withstand the extreme conditions of the river. The structure consists of main bridge piers, which require "base grouting" and "skin grouting" to verify that they can withstand the required design loads. The largest hydraulic hammers in the world were used to install the steel tubular piles for the main bridge piers. When it is operational, the bridge is expected to boost Bangladesh's GDP by 1.2 percent. The Padma Bridge, which cost $3.87 billion to construct, is one of Bangladesh's largest construction projects ever and was funded by the Government of Bangladesh (GoB) . In the case of Bangladesh, the GoB funded the country's largest construction projects ever.

Keywords: Padma Multipurpose Bridge, Road-rail bridge, Engineering challenges, Base & skin grouting, Steel tubular piles.

1 INTRODUCTION

The Padma Bridge, which connects Bangladesh's southwest region with its northern and eastern regions, stands as a testament to the dignity, honor, and distinction of the nation. A recognized cultural UNESCO World Heritage Site, the largest mangrove forest in the country is located in the south. Because of natural calamities, poor connectivity, and a lack of communication, it is currently in imminent danger (Mukul et al., 2020) . The honorable Bangladeshi Prime Minister Sheikh Hasina has taken a strong stand to restore the nation's respect and unity in this circumstance through her foresight and strategic preparation (Aditya, 2021) .

https://doi.org/10.2749/istanbul.2023.0509

Paper ID: 5293
Highway Bridge over the Sava River at Sremska Raca – Construction

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ABSTRACT

The bridge over Sava River on the highway Kuzmin - Sremska Rača (Serbia) consists of two neighbour bridge structures; each ~15m wide deck with 2 traffic lanes. The main bridge across Sava River, 330m length, having spans 90+150+90m, consists of 2 steel box beams with 5m constant depths. The trapezoidal single-cell box section, with both-sided cantilevers, has upper flange consisting orthotropic plate. The bridge length, with approach concrete structures, amounts 1321m. The piers are common for both bridge structures. Two cofferdam structures based on tubular steel piles sheeting, with lean concrete bottom, were executed for construction of river piers in dry condition, after previously performed pile foundation. River piers were built by Korfez Deniz. Entire bridge steel structure (5500t) was fabricated in Doka Endustri factory in Turkiye. Two box beams were divided in 23 blocks each, consisting of 7 segments per block. After trial assembly, blocks dissembled in segments were transported by long trucks from factory to construction site. The 15m length 21 blocks (100-174t weight) & 7,5m length 2 blocks were assembled at site. Afterwards, the blocks linked together by welding on the concrete platform, were protected for corrosion protection and prepared for incremental launching. The 13 stages of incremental launching, successfully applied by Metalyapi, were performed by strand jack pulling system sliding over teflon bearings on platform and piers. Main steel bridge structure was fabricated, transported, assembled and erected in 13 months. Tasyapi was the main contractor.

Keywords: steel box beam bridge, fabrication, assembly, incremental launching, cofferdam

https://doi.org/10.2749/istanbul.2023.0521

Paper ID: 5364
Catwalk Design and Erection of the 1915 Çanakkale Bridge

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ABSTRACT

The 1915 Çanakkale Bridge has the longest main span of 2,023m in the world, and the total span length between anchorages reaches 4,163m. The bridge is located at the North-eastern end of the Çanakkale Strait in Türkiye which is one of navigation channels with the most heavy traffic and windy condition. The planning, design and erection of catwalk system as an aerial workspace for main cable erection raised various technical challenges against extreme loadings such as strong winds and earthquake. The specific behaviour of catwalk under lateral loads was taken in account to FE analysis model development and wind tunnel test supported to investigate the aerodynamic stability of catwalk system. Catwalk has the width of 4.5m, which supported by 12 spiral strand ropes with a diameter of 50mm and MBL of 2,100kN. Catwalk was divided at each tower top and storm system was not included. During construction of catwalk, suspender system ensured the minimum clearance of 70m from the sea level for marine traffic. After the completion of catwalk floor erection, to balance the horizontal forces on tower top during PPWS erection, the tower top had to be offset from their final position. The steel tower's flexibility was quite sufficient to the required pull back amount of approx. 1.7m in European tower and 2.6m in Asian tower

Keywords: Long span bridge, Suspension bridge, Catwalk, Geometry control, Wind tunnel test, PPWS.

1 INTRODUCTION

This paper describes the design basis, structure design, wind tunnel test, erection work and geometry control of catwalk system for main cable erection of the 1915 Canakkale Bridge, which is the longest suspension bridge having a main span of 2,023m and total span of 4,163m. The catwalk is parallel to the main cable with a distance of 1.5m. Catwalk has the width of 4.5m and it is supported by 12 spiral strand ropes with a diameter of 50mm and MBL of 2,100kN. There are 26 cross bridges at every 144m along the span, and tramway supports are located at every 72m. With checking the aerodynamic stability of catwalk, it was concluded that storm system is no need, which lead to secure vessel traffic on the strait and to expedite construction. Steel tower's top position was adjusted by pull back strands prior to main cable strand erection, which was designed as a part of catwalk system. General configuration and dimension of catwalk is shown in Figure 1.

https://doi.org/10.2749/istanbul.2023.0529

Paper ID – 5420

Importance of Unmanned Aerial Vehicles for Inspection and Investigation of Long Span Bridges

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1Introduction

Inspection was urgently required for a suspected corrosion in few suspenders of a suspension bridge, where dirt and water easily accumulate which was directly above the sockets and at suspender clamps, the location was inaccessible for gantry, similar was the situation when multiple holes of size 100mm were noticed in RCC pile-pier foundations which needed a close up inspection. There is no other alternate methods other than, inspection through UAV's or drones.

Bridge inspection specific drone technology is advancing and it is being used as effective tool in augmenting high quality data from long span bridges. The drones are used not only for the purpose of inspection but also for investigations. Unmanned aerial vehicles or drones have become part of inspection and investigation of long span bridges whose spans are exceeding 120m. As the span increases the pylons or towers will also increase in their heights leading to further challenges in inspection of bridges. Off-late unmanned aerial vehicles or drones are coming to the rescue of engineers for the purpose of inspection and investigation. The UAV's enable remote extraction of important information of bridge structural health at numerous locations and orientations. 3D modelling of distress conditions, time advanced estimation, can be made and importantly safeguarding safety of bridge inspection engineers. Non-destructive testing using UAV's has become a possibility, hence they are upscaled from inspection to investigation of bridges. UAV's when used along with remote sensing technologies like infrared thermography, visual imaging, lidar and other touch sensors will enable to acquire critical information from structural members in a bridge. In overall ease of use, accuracy, cost effectiveness, data collection tools, simulation platforms, favouring immediate and effective usage of UAV's in bridge inspection and investigations.

2UAV's for Long Span Bridges

2.1. Long span bridges are very expensive to build, having longer construction periods, they are expected to have life span of upto 200 years, when compared to regular bridges having life span of 70-100 years. Many agencies are working in this direction for enhancing the life span of existing long span bridges to 200 years. As span gets longer, the pylons also become taller to support cables, asuch difficulties increase in maintaining the structure. Normally these long span structures are built across straits, where environments are very harsh and hostile degrading the structural elements faster.If preventive maintenance concept is adopted than chances of rehabilitation due to aging can be reduced or even eliminated. Invariably long span bridges are in suspension category fallowed by cable stayed bridges, extradosed bridges and further other types of long span bridges.

https://doi.org/10.2749/istanbul.2023.0537

Paper ID:5578 Flexural-Shear Behavior of Concrete-Filled Double-Layer Steel Tubular Column

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ABSTRACT

Concrete-filled steel tubular (CFT) column has been widely used in high-rise buildings because of a number of distinct advantages in earthquake zones, such as high lateral capacity and axial compressive strength, large energy absorption capacity, good ductility, and high stiffness. In order to meet the structural performance of the high-rise building as the height of the building increases, a special column with concrete-filled double-layer steel tubes was proposed in previous research. In this study, quasi-static cyclic test of a concrete-filled double-layer steel tubular column (CFDLT column) specimen was carried out under relatively high constant axial force ratio to investigate the effect of steel ratio on the flexural-shear behavior of the column by comparing with the hysteresis loop of the CFDLT column specimen in previous study. Regarding the progress of lateral strength reduction after the ultimate lateral capacity, the CFDLT column specimen with larger steel ratio showed a slight improvement over the other one with smaller steel ratio.

Keywords: CFDLT column, flexural-shear behavior, degree of lateral strength reduction, high-rise building, steel ratio.

1 INTRODUCTION

Concrete-filled steel tubular (CFT) column has been widely used in high-rise buildings because of a number of distinct advantages in earthquake zones, such as high lateral capacity and axial compressive strength, large energy absorption capacity, good ductility, and high stiffness. In order to meet the structural performance of the high-rise building as the height of the building increases, a special column with concrete-filled double-layer steel tubes shown in Figure 1 was proposed by Li (2017a). And, it was clarified that the progress of axial compressive strain of the proposed concrete-filled double-layer steel tubular (abbreviated as CFDLT hereinafter) column was remarkably slower than that of concrete-filled double-skin steel tubular column. Moreover, the experimental results suggested that the proposed CFDLT column has a potential of being used as a mega-column in super-tall buildings or mega-structures in the future in previous work of Li (2017a).

In this research, a CFDLT column specimen with thinner outer steel tube thickness than the CFDLT column specimen in reference of Li (2017a) was subjected to quasi-static cyclic test under a constant axial compressive force to collect basic data on the CFDLT column and to clarify the effect of the steel ratio on the flexural-shear behavior of the CFDLT column by comparing with the hysteresis loop of the CFDLT column specimen in the reference of Li (2017a). In this study, the parameter of steel ratio is regulated by thickness of outer steel tube. In addition, nonlinear numerical studies are carried out to evaluate the lateral force–drift ratio relationships of the CFDLT column

https://doi.org/10.2749/istanbul.2023.0544

Paper ID: 5831

1915 Çanakkale Bridge – Detailed Design

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ABSTRACT

Detailed design of 1915 Çanakkale Bridge posed a number of challenges and called for innovative engineering decisions and design to determine the best possible bridge arrangement under these circumstances. The geology along the bridge alignment ranging from very soft rock to complex soft soil conditions imposed tremendous challenges to the bridge design and resulted in the special layout where anchor blocks are moved away from the shoreline to reach competent soils. With a world record main span of 2023 m crossing the windy Çanakkale Strait significant design challenges for aerodynamics had to be dealt with. To achieve a wind-resistant design the long slender stiffening girder of the bridge is designed as a twin-box steel girder and for all elements great effort was put into analysis of the aerodynamic performance of the bridge and verification of the safety of the bridge by wind tunnel tests. Another challenge related to very dense ship traffic of Çanakkale Strait calling for robust design accommodating accidental ship collision loads. Further, the bridge is situated in a seismically active region and strict requirements from the Owner in this regard affected the design significantly. However, the ultimate design challenge was time. Bridge design and construction was to be completed within only 5 years impacting also the need for innovative solutions for fast construction.

Keywords: Suspension bridge, Detailed design, General arrangement, Articulation, Design basis, Accidental loads, Aerodynamics, Wind tunnel testing, Ship collision risk, Seismic loading.

1 INTRODUCTION

The 1915 Çanakkale Bridge in Türkiye, located 200km southwest of Istanbul, carry the new Malkara-Çanakkale Motorway across the Çanakkale Strait and form an important crossing between Asia and Europe. The world record main span of 2023 m crosses waters as deep as 90 m and provides a navigational clearance of 1600 x 70 m. The bridge was inaugurated 18. March 2022 only 5 years after the contract was awarded and the bridge is now in full service.

https://doi.org/10.2749/istanbul.2023.0552

Paper ID:6000
Innovative unloading and lifting system applied for deck erection of new suspension bridge across the Danube river in Romania

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ABSTRACT

This paper describes an innovative unloading and lifting system applied for the deck erection of a new suspension bridge (1120m in main span) across the Danube in Romania, with emphasis on concept design and operation on site. The deck erection was performed in the spring of 2022. In this project, independent unloading and lifting systems were arranged while considering topographical constraints. One of the systems was used for unloading deck segments from the river to the tips of the embankments via a swing operation, whereas another was used to lift the deck segments vertically from the river or embankment to the designated elevations. In general, deck lifting devices equipped with both jacking and carriage system are installed in a cross-gantry manner on main cables. In this project, all structural and mechanical components relevant to deck unloading and lifting operations except clamps anchored to the main cables were integrated at the deck side to pursue light weight and highly mobile devices taking account of irregular deck erection step. As a result, less material and cost effective erection devices were realized compared with dominant gantry systems.

Keywords: Suspension bridge, Deck erection, Temporary works

1 INTRODUCTION

A new suspension bridge across the Danube is being constructed between the city of Braila and the town of Jijila in eastern part of Romania (hereinafter, referred to as “Braila bridge”).

Figure 1: General view of Braila bridge during deck erection

https://doi.org/10.2749/istanbul.2023.0560

Paper ID: 6126
Leirfjorden suspension bridge

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ABSTRACT

Leirfjorden suspension bridge is currently under design. It spans over the 800 m wide Leirfjord and is to carry the national highway E6 in Norway. The initial tender design was completed in 2018. However, the project was stopped due to a lack of funding. In 2021 an aluminum concept was investigated. It was found feasible. However, the aluminum concept was not continued, mainly due to a lack of experience in using that material in a suspension bridge. During the following planning and geological testing, the rock conditions in the steep hillsides were poor. This resulted in moving the towers backwards to the top of the steep hillsides. Therefore, the bridge has relatively short towers located 62 m behind the abutments. This unusual design leads to compression in the first pairs of hangers, an increase in weak axis bending moment, and an increase in the girder end rotation. This paper presents solutions to tackle the above-mentioned challenges.

Keywords: Suspension bridge, cable system, aluminum, hanger to the land.

1 INTRODUCTION

In the last few decades, the number of suspension bridges has increased worldwide. Only in Norway, 10 suspension bridges have been built since 1990, one more is under construction, and several more are planned, see table 1. The typical Norwegian suspension bridge crosses a deep fjord with steep hillsides. The tower height in these suspension bridges is typically 1/10 of the span length, in addition to the clearance for ship traffic. The bearings for the girder are located on a cross beam in the lower part of the towers.

During the design of the Leirfjord bridge, it was found that the towers should be placed away from the steep hillsides, which leads to a longer cable span, however, at the same time a shortening of the towers. In this paper, different solutions to take the concepts of short towers far from the girder ends (due to geological challenges) are presented and compared, taking advantage of the steep hillsides.

https://doi.org/10.2749/istanbul.2023.0568

Paper ID:6190
THE 1915 ÇANAKKALE BRIDGE – DESIGN AND CONSTRUCTION OF SUBSTRUCTURE

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ABSTRACT

The 1915 Çanakkale Bridge in Turkey carries the new Malkara-Çanakkale Motorway across the Dardanelles strait. This paper describes the design of the substructure of the suspension bridge, which has a world record main span of 2023 m. The substructure consists of the two tower foundations, the two anchor blocks and the two side span piers.
The paper describes design to achieve fast-track construction and resilient structures with optimized material quantities. For the tower foundations an innovative solution consisting of a lower cellular reinforced concrete base and an upper part consisting of two hollow composite steel shafts which extends above water level have been developed. Critical temporary construction stages, including the immersion process, ship impact, and seismic loadings, call for complex structural analysis and verification.

For the anchor blocks efficient concepts have been developed to optimize quantities of concrete and excavation. At the European side this is done by taking advantage of the local soil conditions and activating the backfill on top of the anchor block as counterweight and at the Asian side anchor block an innovative concept with diaphragm panels at the bottom of the anchor block has been developed to enhance the horizontal shear resistance with the ground.
For the side span piers supporting the ends of the main steel bridge deck and the concrete girders of the approach bridges soft soil and seismic forces requires deep bored concrete pile foundations with special measures for improved soil in the upper liquefiable layers.

Keywords: Substructure, Çanakkale, anchor block, tower foundation, suspension bridge, seismic.

https://doi.org/10.2749/istanbul.2023.0575

Paper ID:62-20
Time History Analysis of Simple Supported Steel Concrete Beam Regarding Creep Phenomena, using Volterra Integral Equations

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ABSTRACT

The paper presents a precise analysis of the stress-strain behavior due to creep in statically determinate composite steel-concrete beam according to numerical method in comparison with EM method of Dischinger, take into account in EC4. The analysis is based on the results obtained by numerical solution with Volterra integral equations, derived for determining the redistribution of stresses in beam section between concrete plate and steel beam with respect to time "t". The creep law of concrete, according EC2 provisions is used. On the basis of the theory of the visco-elastic body of Arutyunian–Trost-Bažant it is analyzed the migration of stresses from concrete plate to steel beam using two independent Volterra integral equations of the second kind. The duration of the course of study was adopted 100 years. Developed method will allow soon be confronted methods for calculating the composite beams according to EC4 considering rheology of concrete, based on the reduced elastic modulus of concrete.

1 INTRODUCTION

Steel-concrete composite beams are wide spread form of construction in both buildings and bridges. A reinforced concrete slab is mechanically connected to the top flange of a rolled or fabricated steel beam, thereby forming a composite member that is considerably stronger and stiffer than the steel beam acting on its own. The time-varying behaviour of composite steel-concrete

https://doi.org/10.2749/istanbul.2023.0583

Paper ID:62-33
Design and Implementation of Installation Works on the New Neuenkamp Highway Bridge over the Rhine in Duisburg

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ABSTRACT

The existing six-lane highway bridge, which crosses the Rhine River between Duisburg-Neuenkamp and Homberg, was originally opened to traffic in 1970. Due to increased traffic loads and severe fatigue damage it now needs to be replaced. The new design consists of two similar cable-stayed steel superstructures, each carrying four lanes. It has an overall length of 802 m, an overall width of almost 70 m, pylons of 90 m in height, and a central span of 380 m. The installation of the superstructure comprises incremental launching of the approaches, crane assembly of the pylons, and the cantilevered assembly method of the central span. Additionally, the requirement to maintain vehicular traffic on the A40 highway during the construction phase demands transversal launching of the southern bridge structure by 14.4 m after completion. This paper covers the design and implementation of the installation works of the steel structures on site.

Keywords: construction practices of long-span bridges, cable-stayed bridge, incremental launching, crane assembly, large scale cantilevered assembly.

1 INTRODUCTION

The Neuenkamp Highway Bridge is an important crossing over the Rhine River in the heart of the German Ruhr region. Over time, the existing bridge structure has developed severe fatigue damages, resulting in several rehabilitation and reconstruction works during the last decades [1]. Since 2014, the bridge has been under constant monitoring in combination with ongoing maintenance measures and a traffic weight limit, making a full replacement inevitable.

With a central span of 380 m, the new structure will be the largest symmetric cable-stayed bridge in Germany (cf. Fig. 1). Both the 802 m long and almost 70 m wide bridge deck (cf. Fig. 2) and the 75 m high pylons are made of steel. In the central span, the bridge deck consists of two steel box girders with orthotropic deck, while the approach spans are mainly constructed as identically shaped steel box girders with composite bridge deck. The stay cables are arranged in pairs, resulting

https://doi.org/10.2749/istanbul.2023.0591

Paper ID: 6264
Bridge Specific Live Load for the Assessment of Tsing Ma Bridge and Lantau Link

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ABSTRACT

The Lantau Link in Hong Kong forms part of the expressway linking Lantau Island to Tsing Yi, from which other roads lead to the urban areas of Kowloon and the rest of the New Territories. This is also part of the main route to the Hong Kong International Airport. The Lantau Link is 3.5km long and consists of Tsing Ma Bridge (suspension bridge), Kap Shui Mun Bridge (cable stayed bridge) and Ma Wan Viaduct (post-tensioned concrete viaduct). These structures carry traffic on two split deck levels. The upper deck carries 3 lanes of traffic in each direction. The lower deck carries a double-track railway line as well as two single-lane roads for emergency use or during strong wind when it is unsafe to drive on the upper deck. Due to continuing increase in road traffic on Lantau Link, it is proposed to increase the traffic carrying capacity by running traffic on the lower deck concurrently. The bridges were designed for 6 lanes of traffic and hence, an assessment to carry 8 lanes of traffic is required. To verify that opening the lower deck is possible without compromising structural safety, bridge specific live load study was carried out using WIM data and traffic data to derive the bridge specific assessment live load (BSALL) using Monte Carlo Simulation. WIM data was also used to derive fatigue load model (FLM) which represents the real truck weight and characteristics on the Lantau Link. This paper describes the derivation of BSALL and FLM and the results of the study.

Keywords: long span bridges; sustainability; bridge assessment; bridge specific live load.

https://doi.org/10.2749/istanbul.2023.0599

Management of Dry Air Injection System for Main Cables of Suspension Bridges in Honshu-Shikoku Bridges for 20 Years

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ABSTRACT

Main cables are the most important components of suspension bridges and require reliable corrosion protection because they are difficult to replace. In the past, corrosion protection has been performed mainly by coating the cables to block moisture. In 1989, after six years of service, inside of the main cable of the Innoshima Bridge was investigated. As a result, water was found inside the main cable and corrosion was confirmed on the surface of the galvanized steel wire. This revealed that conventional methods alone were insufficient to prevent corrosion. Because of this fact, investigation of effective methods of main cable corrosion protection under Japanese climate was started. As a result, a dry air injection system was developed to prevent corrosion by injecting dry air into the cables. The system was adopted for the first time in the world for the Akashi-Kaikyo Bridge in 1997 and the Kurushima Kaikyo Bridge in 1999. In addition, the dry air injection system was installed on six existing suspension bridges, including the Ohnaruto Bridge, from 1997 to 1999. More than 20 years after the system was introduced, the relative humidity in the main cables has become stable on all suspension bridges of the Honshu-Shikoku bridges. This paper presents the maintenance, improvement, and future prospects of the dry air injection system for the Akashi-Kaikyo Bridge, the first newly constructed suspension bridge to adopt the system, and the Ohnaruto Bridge, the first existing suspension bridge to adopt the system.

Keywords: Suspension Bridges, Main Cables, Dry Air Injection, Corrosion Protection, Maintenance

1 INTRODUCTION

The Honshu-Shikoku Bridge Expressway (HSBE) consists of three expressway routes connecting Honshu and Shikoku islands with long-span bridges (Honshu-Shikoku Bridges) (Figure

https://doi.org/10.2749/istanbul.2023.0607

Full-Scale Monitoring of Form Pressure While Casting Bottom-up with Self-Compacting Concrete

Abstract

The question remains open on how the form pressure develops when casting from the bottom up especially with high flowable self-compacting concrete. This article presents a result of full-scale long-term monitoring of the form pressure using state-of-the-art pressure sensors that can send the data every minute. A 7 m wall with a 4 m width and cast from the bottom using a concrete pump with a valve opening in the formwork while the casting rate was maintained between 0.5 to 0.7 m/h. Pressure gauges were mounted on the form surface as part of a real-time system for monitoring the pressure, and the transformed data was broadcast and gathered in the cloud. The sensors were situated in different locations. The results showed that the actual pressure exerted by the concrete is far less than the hydrostatic pressure even when the concrete is pumped from the bottom. The results also showed that, the form pressure reduction depends on the properties of concrete particularly setting time.

Keywords: full scale, cast in place, self-compacting concrete, form pressure, bottom-up

Introduction

Casting the concrete from the bottom up has been a method that is practiced especially when casting large elements that are congested or in civil engineering underground structures such as tunnels, basements, and dams, the method reduces the need for access to the structure. Self-compacting concrete (SCC) is commonly used in these types of structures due to its high flowability to flow between the rebars with no or minimal need for vibration (Khayat & Omran, 2009; Perrot, 2015). In these types of structures, doubt still endures on the form pressure, especially when casting with SCC at the same time as the pressure required to push the concrete from the bottom up. The uncertainty is on the maximum pressure that is required for the form design and also the reduction of the pressure over time (Hurd, 2007; Proske, Khayat, Omran, & Leitzbach, 2014). Having prior estimation of the form pressure can help to design a steadfast form and safe for the workplace (Proske & Graubner, 2010), while knowledge of pressure reduction helps to propose a faster pouring rate (Assaad & Khayat, 2006; Henschen, Castaneda, & Lange, 2018).

The international standards suggest designing the form with full hydrostatic pressure such as ACI 347R-3 (ACI347R, 2005) which then promotes expensive design and hinder the speed of pouring (Khayat & Omran, 2009). However, studies over the past tend to disregard the hydrostatic pressure assumption and proved the pressure is far less than the hydrostatic more details are addressed in the review article by (Gamil, Nilimaa, Emborg, & Cwirzen, 2021). The German standard (DIN18218) has also suggested a different model design for the form pressure based on the concrete setting time and stated when the old concrete has been in the form more than the setting time it tends to have no pressure deemed (DIN18218, 2010).

https://doi.org/10.2749/istanbul.2023.0615

IABSE SYMPOSIUM ISTANBUL
LONG SPAN BRIDGES
26-28 APRIL, 2023
HYATT REGENCY ISTANBUL ATAKOY HOTEL

Paper ID: 6443
Structural Health Monitoring of Bridges: State of the Art

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ABSTRACT

Infrastructure is a vital component for the development of countries, where bridges in particular are a segment of infrastructure that are vital for the society. As bridges age they could show signs of deterioration that can be caused by continuously being subjected to traffic loads and environmental effects. Structural Health Monitoring (SHM) is a modern technology to monitor the structural performance through the continuous collection of data. The method enables engineers to monitor the health of the structure during its operation, in order to plan for maintenance when any signs of failure are observed from the very beginning. This paper covers a detailed overview of the state of the art of various types of SHM systems implemented on long-span cable-stayed bridges and suspension bridges all around the world. A variety of cases, sensors, and methods of obtaining and studying the data to monitor the structural health of bridges are evaluated, showing the importance of installing SHM systems in long-span bridges.

Keywords: Structural Health Monitoring, Bridges, Maintenance, Sensors, Frequency.

1 INTRODUCTION

In a world where technology is advancing with time, there have been many great developments that have offered a large contribution to the world of bridge engineering. Structural health monitoring in specific has done wonders in civil engineering, as it has allowed engineers to maintain and preserve bridges of different kinds all around the world, and has provided with data that allows for the study of the behaviour of bridges in operation. The method of applying a strategy for identifying damage is denoted as structural health monitoring. In this case, damage is considered as changes that can undesirably impact the performance of the structure (Farrar and Worden, 2007).

Bridges could undergo numerous modes of failure, such as; instability, fatigue, ageing, corrosion, mechanical damage, structural defects, and brittle fracture. There are many environmental effects that can impact the behaviour of long-span bridges in addition to traffic loads, such as; rain, strong winds, natural disasters, and temperature. These effects can result in a long-term impact on long-span bridges, and may eventually result in its deterioration (Chen and Xue, 2018). Hence, the construction of bridges is viewed to be a complex form of construction and therefore it is critical that bridges are carefully monitored (Chen and Xue, 2018).

https://doi.org/10.2749/istanbul.2023.0620

IABSE SYMPOSIUM ISTANBUL
LONG SPAN BRIDGES
26-28 APRIL, 2023
HYATT REGENCY ISTANBUL
ATAKOY HOTEL

Paper ID:6544
Fully automated global analyses of long-span bridges at a detail design level

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ABSTRACT

Long-span bridges require special analyses when addressing the global forces in the system. For cable-supported bridges, geometric nonlinearities become crucial for the structural behaviour and must be treated with care. The slender structural systems make them prone to dynamic actions from wind and wave loading. In this paper, a framework for an automated system that addresses these specific needs of long-span bridges is presented. The system covers structures such as suspension bridges, cable-stayed bridges, and floating bridges. It employs commercial tools like ABAQUS as a FEM calculator, while handling traffic loads and load combinations directly within the system. Results reporting is automated, and the results can be accessed interactively through a web page interface. The framework also includes links to special design tools and BIM models. The system also includes a state-of-the-art software named DynNO, developed by the author, to handle stochastic dynamic analyses including both wind and wave loading. The system performs fully automated analyses at a detail design level, providing a unique basis for optimization. The proposed framework offers flexibility and agility in demanding detail design processes, as well as the possibility of performing high-level analyses in early phase projects.

Keywords: Automated analyses, Global analyses, Long-span bridge, Dynamic analyses

1 INTRODUCTION AND BACKGROUND

Norconsult AS is Norway's largest multidisciplinary engineering consultant company, and it has a well-renowned department that specializes in the design of bridges. The bridge department has been working on long-span bridges for many years, with the design of the Hardanger Bridge, Norway's longest suspension bridge with a main span of 1310 m, being one of the most famous projects. Norway is a country with a long tradition of long bridges due to the complexity of the Norwegian landscape. Suspension bridges has been a particular specialty in Norway. According to the database established by bridgemeister.com [1], Norway is by far the country with the most suspension bridges per capita among the countries with more than 100 suspension bridges (small and large, See Figure 1).

Several long-span bridges have been designed, and built, in recent years, and more are in the planning stages for coming years. Norconsult is heavily involved in many of these projects. Two of Norconsult's key strategic pillars are digitalization and sustainability. This has driven the development of digital working methods with the aim of automation and optimization. For the design of long-span bridges, we have built automated systems based on the methods and experience we have developed over many years of designing large bridges. The system presented

https://doi.org/10.2749/istanbul.2023.0629

IABSE SYMPOSIUM ISTANBUL
LONG SPAN BRIDGES
26-28 APRIL, 2023
HYATT REGENCY ISTANBUL ATAKOY HOTEL

Inspection of cable-stayed bridge cables using a robot

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ABSTRACT

Currently, all bridges in Japan are required to be inspected once every five years. Close visual inspection should be carried out for all members. Cables in cable-stayed bridges are extremely important members. However, it is very difficult to perform close visual inspection since it is located at a very high place. They are visually inspected from the road surface or from an aerial work platform in general. There is also an inspection method that involves close visual inspection by working at heights using ropes, but there are many issues such as safety and prolonged on-site construction period. Against this background, we developed an inspection robot for cable-stayed bridge cables. The developed robot has a structure surrounding the inspected cable with the frame. It has four propellers and eight guide rollers on the outside and inside of the frame, respectively. In addition, four video cameras are installed, and videos of the entire cable surface can be taken by them. In this paper, the outline of the developed robot is introduced, and the results of inspections, examples of damage to cable protection tubes, and comparative verification results of inspections using this robot and ropes are reported.

Keywords: Cable-stayed bridges, close visual inspection, inspection robot, inspection method

https://doi.org/10.2749/istanbul.2023.0636

Paper ID: 6645
Kosciuszko Bridge Phase 2 – Erecting a Cable Stayed Bridge in a Dense Urban Environment

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ABSTRACT

The Kosciuszko Bridge (K-Bridge) is a new pair of independent cable stayed bridge that cross Newtown Creek, connecting the New York City boroughs of Brooklyn and Queens. This paper focuses on the erection engineering challenges of constructing the new Phase 2 cable stayed bridge, which is located in a dense urban environment. The challenges include: close proximity to the completed Phase 1 Bridge, the presence of Newtown Creek, limited site access at ground level, and the need for complex temporary supports that avoid the foundation remnants of the original 1931 bridge during construction.

Keywords: Cable stayed bridge, long span bridge, erection engineering, construction engineering

1 INTRODUCTION

The Kosciuszko Bridge is a pair of new cable-stayed structure that cross Newtown Creek, linking the New York City boroughs of Brooklyn and Queens via the Brooklyn-Queens Expressway. Known locally as the "K-bridge," the original crossing, which opened in 1931 was described by The New York Times as "perhaps the city's most notorious [bridge], hated and feared by drivers and synonymous in traffic reports with bottlenecks, stop-and-go and general delay." A pair of new signature bridges (the Phase 1 and Phase 2 Bridges) replaced the 77-year-old existing Kosciuszko Bridge. The new bridges increased capacity and flow of traffic and include a shared use path with incredible views of the New York City skyline. Completed in 2017, the Phase 1 Bridge was constructed using the Design-Build project delivery

Figure 1: Elevation showing Phase 1 & Phase 2 Bridges

https://doi.org/10.2749/istanbul.2023.0644

Paper ID:68-74
More efficient life cycle maintenance for long spans bridges

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ABSTRACT

Long-span bridges require specific construction techniques and a constantly renewed design, either due to the evolution of materials, techniques and knowledge, or due to a variable geometry and/or typology that calls for design adaptations.

These exceptional structures generally fall outside the existing regulations and classic frameworks for monitoring and maintenance, whatever the country. In that sense, they require, from the moment they are commissioned, a particular expertise and approach for their continuous monitoring, calling in particular for the production of risk analysis matrices, sensitivity analyses (wind, earthquake, assembly fatigue, etc.), exhaustive maintenance manuals adapted to each structure, regular campaigns of targeted non-destructive tests, while having recourse to particular means of access associated with different types of inspection carried out by qualified and experienced inspectors.

In order to ensure that these structures behave well over time, they are generally monitored, which requires individualized use of the data acquired by the SHMS, whose program can be adapted a posteriori after a period of learning about the actual functioning of the structure.

To complete this monitoring, it is necessary to implement a specific follow-up of the durability of materials and more specifically of reinforced concrete, to carry out updated digital twins associated with adapted management software.

All this specific approach is necessary to have a clear and exhaustive vision of the condition of these structures and the follow-up of their good ageing over time, which sometimes differs significantly from what is foreseen at the time of the design; the objective being in particular to ensure the safety of the operation and the users and to engage the maintenance works at the right time and at the least cost, for a durability which must exceed 120 years for these exceptional and unique structures.

Through emblematic examples, we propose to present these specific approaches implemented on large structures, whether pathological or not, and the proposed management strategies.

Keywords: Inspection, Monitoring, organized monitoring, digital twin, preventive and predictive maintenance.

https://doi.org/10.2749/istanbul.2023.0654

Paper ID:69-11
Study on Structure and Stiffness Indexes Long span Road-Rail Suspension Bridge

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ABSTRACT

It is rapidly developing the construction of long-span suspension bridges in China. It is an important issue for the structural design of suspension bridges. It is a problem that needs further study for high-speed and heavy-haul railway suspension bridges. There is the characteristics of heavy train live loads, high speed and high demand for running security and passenger comfort, the technical standards and so on. The paper is analysis the stiffness evaluation indexes of railway suspension bridges adopted by the codes of various countries in the world, and compares them with the regulations in China's general bridge codes. The key technologies of the thousand-meter-scale road-rail suspension bridges for high speed for passenger trains, 120 km/h for freight trains) and heavy load are studied. Based on the research on the road-rail suspension bridge with main span of 1 196 m, the influences of different supporting systems, arrangement of auxiliary piers, ratio of height to span, ratio of width to span and ratio of vertical to span on the vertical and lateral stiffness of the bridge are analysis, and the stiffness evaluation indexes and suggested values for thousand-meter-scale road-rail suspension bridges are proposed. The proposed long-span suspension bridge scheme is technically feasible, economically reasonable, and has good horizontal and vertical stiffness, smoothness and running comfort.
Keywords: Long-span suspension bridge ; road -rail bridge; high-speed railway; heavy-haul railway ; statical analysis ; structural parameters ; stiffness indexes

1 INTRODUCTION

It is rapidly developing the construction of long-span suspension bridges in China. In recent years, a number of over1 km-level suspension bridges have been built in China, as shown in Table 1.

It is an important issue for the structural design of suspension bridges. There is still a lack of corresponding specifications for long-span railway bridges in various countries, and there is a lack of clear limit value standards for horizontal and vertical stiffness. The specifications that can be referred to are based on the dynamic analysis and actual test of small-span bridges. For the live load system, China's current specifications have clear values for the vertical static live load, dynamic coefficient, impact coefficient and other indicators in the live load of railway bridges, but they do not clearly specify the parameters involved in railway and dual-use suspension bridges.

https://doi.org/10.2749/istanbul.2023.0665

Paper ID: 7007

Parametric Approach for Composite Bridge Project: analysis and design

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ABSTRACT

Bridge designs usually exhibit significant geometric variations between different structural solutions, which implies a low degree of reuse of the models in similar projects. To overcome this limitation, a parametric approach is proposed as an answer. Generative design enhances the bridge design process, increasing efficiency by reducing time and effort. The proposed methodology is based on the creation of a flexible geometric model through the introduction of parameters and numerical relationships between them. Therefore, from a generic generative development, different geometric and structural solutions of composite bridges could be created by modifying the parameter values in a bridge model. The objective of the present work is to define the workflow for a multi-girder composite bridge project based on parametric design and optimization in Grasshopper/Rhino to model the bridge Karamba3D, for structural analysis, and Tekla Structures, for 3D representation. This article describes the methodology implemented, starting with the design of the script into a visual programming interface that runs inside Rhino. Thanks to Grasshopper-Tekla live link, the 3D model is generated by using a set of Grasshopper components that can create and interact with objects in Tekla Structures. Afterwards, the algorithm for FEM analysis is created with Karamba3D. Finally, an optimization process is defined to reduce material waste and achieve an efficient design.

Keywords: Parametric design, Building information modelling, Optimization, Composite bridges, Bridge Information Modelling.

1 INTRODUCTION

Nowadays, architectural design tools have expanded the possibilities for innovative and impressive curves and structural details. Nevertheless, as the infrastructure industry is embracing digitalization to increase productivity and to be updated with new technologies and innovations; there is a framework of increasing costs, sustainability issues, and short deadlines. As a result of these constraints, more and more civil engineers are exploring parametric design and BIM-based workflows. The BIM incorporates all available construction-related data, including architectural design (building element geometry, spatial relationships as connectivity, etc., structural design (project design documentation, structural scheme, and information on the building's construction and maintenance processes (Svoboda et al., 2014. On the other hand, generative modelling enhances the infrastructure design process, increasing efficiency by reducing time and effort. It is based on creating a flexible geometric model by introducing parameters and numerical relationships between them.

https://doi.org/10.2749/istanbul.2023.0673

Influence of imperfections on the buckling behaviour of longitudinal stiffened panels with eccentric load application

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ABSTRACT

During *incremental launching* (a known manufacturing method in bridge construction) of steel and composite bridges, biaxial stresses occur in webs and bottom plates of box girders, which mostly dominates their design. An eccentric loading from the launching bearings into the webs is practically unavoidable due to mounting tolerances, variations in plate thicknesses and tolerance requirements of the lateral restraint. The buckling verification of longitudinally stiffened plates under biaxial compression is defined in EN 1993-1-5:2019section 10 [1] through the *reduced stress method*. While the geometric and structural imperfections are considered using the coefficient α or an equivalent geometric imperfection (term from Eurocode, including geometric and structural imperfections) according to Annex C of this code, the influence of eccentricity has not been considered by this code. In order to investigate the impact of the load eccentricity on the buckling behaviour of longitudinally stiffened plates, large-scale buckling tests were carried out under biaxial compression at the Technical University of Munich. Based on the test results, a numerical model was validated and an extensive parametric study was carried out. It was observed that the direction of the equivalent geometric imperfection of the longitudinally stiffened plates is significant for the load capacity of the plates. With a centric load application, the minimum load capacity is always found when the equivalent geometric imperfection is located on the opposite side of the stiffeners. In the case of eccentric loading, the load capacity is further influenced by the combination of the directions from the eccentric load application and the equivalent geometric imperfection. As a result, an eccentric loading leads to an increased buckling resistance compared to a centric loading when the equivalent geometric imperfection is on the same side of eccentric loading.

Keywords: Incremental launching; Buckling behaviour; Eccentric loading; Biaxial stresses; Steel plates

1 INTRODUCTION

Eccentric transverse loading on longitudinally stiffened plates under biaxial loading typically occurs in the web of hollow box sections during incremental launching. The buckling behavior of

https://doi.org/10.2749/istanbul.2023.0681

Paper ID:7129
Special construction features of the Cable-stayed Bridge between the islands of Cebu and Mactan (Republic of the Philippines)

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ABSTRACT

The Cebu-Cordova Link Expressway is a road concession project with a crowning achievement: the 653.00-m long cable-stayed bridge between the islands of Cebu and Mactan. This bridge is the longest cable-stayed span in the Philippines, and its construction posed several unique challenges, such as high seismic activity, geological variability, and frequent typhoons. Furthermore, the busy navigation channel below the bridge had to be kept open throughout the building process. This paper provides an overview of the construction process, highlighting these distinctive difficulties.

Keywords: Cable-Stayed Bridge, deck-closure, large diameter pile, tilt table, geometric control

1 INTRODUCTION

After an Early Contractor Involvement (ECI) process, the project design & build was awarded to the consortium of Acciona Construction, First Balfour, and D.M. Consunji on November 23, 2017. The bridge features an asymmetrical layout, with span lengths of 6.50-64.4-60.6-390-60.6-64.4-6.50. Its prestressed concrete box girder is 26.90 m wide and 3.5 m deep, anchored by 56stays, 14 pairs from each of two 139 m high pylons.

Figure 1. Aerial view of the CCLEX project.

The main construction features include 2.50 m diameter piles with offshore execution, massive pile caps, complex geometric shapes of piers and pylon facets, 40 m high stainless-steel iconic crosses with no visible inserts for aesthetic reasons, complex pier tables, and different deck closures.

2 FOUNDATIONS EXECUTION

The construction of the foundations found big challenges related to the offshore conditions, execution of massive and rebar congested piles and pile caps as consequence of the outstanding seismic and ship impact loads as well as variable geotechnical conditions. The geotechnical investigation executed during detailed design stage revealed complex and very disparate soil/rock

https://doi.org/10.2749/istanbul.2023.0691

Paper ID: 71-57
130 YEARS OLD STAMBOLOV'S BRIDGE ON YANTRA RIVER: THE SYMBOL OF MODERN DEVELOPMENT AND TECHNICAL INNOVATION OF VELIKO TARNOVO

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ABSTRACT

The construction in 1892 of the prefabricated single-span arched open-spandrel steel /wrough iron riveted bridge in Veliko Tarnovo of total length of 81600 mm during the government of Stefan Stambolov symbolized the first step towards the modern development of his hometown within the newly created Bulgarian state. The revision of the data of the designer and producer of the bridge complements the detailed description of the specific spatial construction of the bridge deck, that is used to serve the two-way pedestrian and vehicle traffic to the railroad station, in revealing the innovative character of its technical characteristics and its overall historical importance in the history of Bulgarian infrastructure development 130 years after its installation over the Yantra river.

Keywords: statically determinate truss, single-span arched open-spandrel iron riveted bridge, Veliko, Tarnovo historical environment, FEM model

1 INTRODUCTION (HISTORICAL CONTEXT)

Stambolov's bridge which is listed as cultural monument, dominates the picturesque panoramic view of the historical town of Veliko Tarnovo and in the end of 1970s and the beginning of 1980s become an inherent and scillfully incorporated element of the ensemble around the Yantra gorge together with the brutalist volume of the Interhotel "Veliko Tranovo" and the reconstructed art gallery by the acclaimed Bulgarian architect Nikola Nikolov as well as the "Assenev brothers" monument by the renowned sculptor Krim Damianov. (Kirova-Delcheva, 2022)

Construction of the innovative road facility in 1892 interconnected the town with the still forthcoming railroad station and become a symbol of the modern infrastructure and industrial development of Veliko Tarnovo, the former medieval capital and important revival hub, elected in 1879 as ceremonial capital along with the administrative capital Sofia, that used to focus the political and public life of the autonomous Bulgaria until the end of the 19th century.

https://doi.org/10.2749/istanbul.2023.0700

Paper ID: 7316
Steel Deck Fabrication and Erection of the 1915 Çanakkale Bridge

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ABSTRACT

The 1915 Çanakkale Bridge with a main span of 2,023m is the innovative suspension bridge surpassing the previous world record. The bridge is located at the North-eastern end of the Çanakkale Strait in Türkiye and it connects the Gelibolu district to the Northwest with the Lapseki district to the Southeast. 50,000 tonnes of high strength steel plates for twin box suspended deck were involved in the fabrication. The steel was supplied from South Korea and transported to Türkiye for panel fabrication and deck assembly. 21 single blocks having a length from 9.8m to 24m and 66 mega blocks of 48m had been assembled at the plant. The planning and design of the suspended deck erection sequence and temporary structure posed a lot of technical challenges. The very long span combined with extreme loadings such as strong winds and possibly earthquake had to be overcome within the structural capacity allowed. The temporary deck-to-deck connections were positioned away from the roadway and designed to allow for rotation between the segments. Furthermore, it was necessary to invent a special device, a X-bracing release joint, to minimize the bending moment from wind in the deck. Deck block positioned near towers was planned to be installed as a closure segment. This allows the longitudinal movements of the bridge during block erection and welding by creating a void at the towers. To allow the key segments to be installed in correct geometry, several permanent hangers were destressed near the towers. All single blocks except the centre single block at the middle of main span and the adjacent block in each span next to key-segment were lifted by a floating crane having a max lifting capacity of 5,000ton. For the lifting of mega blocks having a length of 48m and a lifting weight of around 800ton, total eight lifting gantries including strand jack systems were developed and manufactured for this project. Each gantry had a capacity of 450ton, and eight lifting gantries consisted of four tandem systems, which were applied to a mega block lifting works.

Keywords: Long span bridges, Suspension bridges, Construction engineering, Deck erection, Global Finite Element analyses.

https://doi.org/10.2749/istanbul.2023.0708

Paper ID:7363
Chesapeake Bay Bridge Dehumidification

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ABSTRACT

Long span suspension bridges across the world are aging. With the slowed pace of replacement, it is prudent to provide innovative engineering solutions to prolong the useful lives of existing bridges and new structures. Dehumidification of main cables on suspension bridges provides an active method for preventing cable corrosion, as opposed to the traditional passive methods of painting, oiling, and wrapping. Approximately 30 suspension bridges world-wide have cable-dehumidification systems in place. The first dehumidification system was installed in the Akashi Kaikyo Bridge in 1998, and many followed in Asia and Europe. The cable dehumidification system on the Chesapeake Bay (William Preston Lane) Bridges in Maryland is the first installation of its kind in North America. By applying waterproof wrapping to the cables and injecting dehumidified air, the cables are dried of retained water, and the relative humidity is reduced to a level that would arrest corrosion. Cable dehumidification is becoming a more commonplace maintenance technique and is a needed measure to extend the lives of suspension bridges. This paper presents its history, theory, and practice, including optimal placement of injection and exhaust points, calibrated instrumentation, and effective mechanical, monitoring and control systems.

Keywords: Suspension cable, dehumidification, corrosion arrest, cable-wrapping, maintenance

1 INTRODUCTION

Cable dehumidification is an innovative measure to extend the lives of aging suspension bridges. With the slowed pace of replacement and with communities desiring preservation of historic landmarks, engineering solutions to prolong the useful lives of existing bridges requires design innovation. Cable dehumidification is one such innovative solution.

https://doi.org/10.2749/istanbul.2023.0716

Paper ID:7380
Data-driven operation and maintenance of the Normandy and Tancarville long-span bridges

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ABSTRACT

With main spans of 608m and 856m respectively, Pont de Tancarville and Pont de Normandie are the longest suspension and cable-stayed bridges in France. Both bridges are managed by CCI Seine Estuaire, with a concession granted until 2031. Pont de Tancarville was opened to traffic in 1959 at which time it was the longest suspended bridge in Europe. The composite deck comprises a Robinson slab with stiffening truss girders. The main suspension cables and hangers were replaced in 1999 after the failure of 1 out of 120 strands was discovered. Pont de Normandie was built in the late 1990s, to enhance the connection between the Le Havre, the second largest French harbour, and the western coastal area. Opened in 1995, it was once the world longest cable stayed bridge and drove a technological leap in bridge construction.

COWI and Setec tpi are currently assisting CCI with investigative and diagnostic activities on the two bridges, focusing on suspension systems, articulation, and the concrete structures. This work makes use of extensive, but targeted, structural health monitoring combined with an understanding of the structural systems to investigate the performance of key structural elements. The present paper describes the main activities being undertaken to enable CCI to plan corrective and preventive measures to extend the design lives of the structures and to ensure a safe passage for the users of both bridges.

Keywords: cable stayed bridge, suspension bridge, diagnosis, structural health monitoring, data science

1 INTRODUCTION

In January 2022, Setec tpi and COWI were jointly awarded a framework agreement with CCI Seine Estuaire (the Concessionaire) to help diagnose problems, advise on remediation measures and carry out external reviews of maintenance works carried out on Pont de Normandie and Pont de Tancarville. The framework agreement is valid for one year and may be renewed up to three times. It covers the cables, articulation systems, concrete structures, post-tensioning tendons and external reviews of maintenance works. Through the framework agreement, Setec tpi and COWI assist CCI through the use of sensor data, finite element (FE) modelling, and on-site investigative measures in order to assess the residual lifetime of the bridges' structural components and to provide recommendations for corresponding maintenance works. In addition, a Technical Committee of bridge experts supports CCI to validate the results interpretation and the conclusions of investigations, engage further diagnostic activities and take decisions regarding the bridge maintenance works.

https://doi.org/10.2749/istanbul.2023.0727

Paper ID:74-32
The carbon footprint of long span bridges

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ABSTRACT

The construction industry accounts for approximately 40% of worldwide carbon emissions with steel and cement productions each accounting for approximately 8%. Bridges are relatively carbon intensive within this emissions group. The carbon emission of bridges during their construction has been studied, this paper reviews the data published to date and highlights that relevant to long span bridges. For the purpose of this paper long span bridges are defined as those with spans of 200m or greater. The paper then considers this data together with some additional data by the author to show carbon emission trends for major long span bridges. The data is analysed to consider average values, variations and trends (particularly with span and bridge type). Many recent long span bridges have significant deep-water foundations, the paper considers the amount of carbon in foundations and superstructure for a number of bridges. Based on the findings the paper outlines the aspects of future major bridges that could be considered to reduce the carbon emissions of future long span bridges.

Keywords: Bridges, Carbon Emissions, Long Span, Multiple Span, Sustainability.

1 INTRODUCTION

Climate change issues and in particular the reduction of the carbon footprint of the structure is likely to be important for future long span bridges. The construction industry accounts for approximately 40% of worldwide carbon emissions with steel and cement productions each accounting for approximately 8%. Bridges are relatively carbon intensive within this emissions group (Collings, 2020). This paper reviews the published data for the carbon footprint of long span bridges and summarises the data for 200m to 2,000m spans. It also considers proposed structures which extend the data to 5,000m span. The paper is an extension of the authors wider research work on the carbon footprint of bridges (Collings, 2021) that outlines the carbon footprint of conventional road, rail and footbridges. This paper uses the same methodology as the previous study to estimate the carbon emissions.

2 DEFINITIONS

For the purpose of this paper long span bridges are defined as those with spans of 200m or greater. The span being the longest span within a multiple span structure (Figure 1). The length of the bridge is the length of the main long span bridge, excluding approach viaducts. For cable stay spans this is typically the distance between expansion joints (Figure 1a). For suspension bridges the length is typically from anchorage to anchorage (Figure 1b). For data on complete crossings including approach viaducts see Mullins and Collings (2022). The bridge width is the distance from parapet to parapet. For twin deck structures with a gap between decks an effective width is used to estimate the

https://doi.org/10.2749/istanbul.2023.0737

IABSE SYMPOSIUM ISTANBUL
LONG SPAN BRIDGES
26-28 APRIL, 2023
HYATT REGENCY ISTANBUL ATAKOY HOTEL

Paper ID: 7468
A Case Study on the Analysis and Rehabilitation of an Existing Through Arch Truss Bridge

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ABSTRACT

The Seal Island Bridge is a steel through-arch truss bridge in Cape Breton Island, Nova Scotia, Canada with a main span of 152 m. At over 60 years in service, the bridge is near the end of its design life and showing structural and operational difficulties such as a previously failed truss diagonal, cracked floorbeams, steel material property complexities, wind-induced vibrations, and restricted
access due to narrow deck geometry. A series of bridge inspections were performed which included visual inspections, non-destructive testing, and material testing. The inspections revealed the presence of tack welds and associated cracking, steel corrosion, concrete deterioration, seized bearings, and vibrating bracing elements. Additionally, a structural health monitoring (SHM) program was implemented to determine the current bridge behaviour. To assess the structure, a finite
element (FE) model was created and calibrated using the SHM data and the inspection findings. The FE modelling is the focus of this paper. During preliminary analysis, it was determined that the structure was sensitive to wind loading. Therefore, a detailed wind buffeting analysis was performed
to refine the wind loading used in the analysis. Based on the results of the analysis and investigations, a rehabilitation plan is currently being developed to ensure that the bridge can remain in service for
an additional 15 years. Additionally, a benefit-cost analysis is being performed to assess potential rehabilitation and replacement options for the Owner, the Province of Nova Scotia.

Keywords: Arch Truss, Finite Element Analysis, Wind Buffeting, Structural Assessment.

1 INTRODUCTION

Seal Island Bridge (herein referred to as "the bridge") is located along Highway 105 in Victoria County, Cape Breton, Nova Scotia and serves as a major transportation and shipping link. The through-arch truss bridge was constructed in 1960 and is approximately 750m long. The bridge has

https://doi.org/10.2749/istanbul.2023.0744

Paper ID:7611
EVALUATION OF THE IMPACT FORCES OF FERRIES OR BARGES IN STRUTURES OF PROTECTION OF THE BRIDGES ON NAVIGABLE IN RIVERS OF PARÁ

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ABSTRACT

Protection systems against impacts of vessels on bridge supports are essential to guarantee the structural integrity of bridges and the safety of users, avoiding the ruin of supports or the collapse of parts or the entire structure of the bridge, thus guaranteeing its functionality and prolonging its service life. These structures have their specificities and the definition of the type of protection to be adopted and its sizing must consider the environment conditions of the region. In the Brazilian standardizations, there are design criteria and specifications that contemplate the navigable spans considering the width of the vessels only, which has been insufficient for navigation in the region of bridges crossing navigable channels/rivers in Pará, North Region of Brazil. In evaluating the accidents that have been taking place in Pará, it appears that these criteria are insufficient to protect bridge structures from the severe accidents that have occurred in the last 10 years.

Keywords: Protection bridge, impact forces on bridge, floating protections of bridge.

1 INTRODUCTION

Bridges are device of infrastructures that require large investments for their construction, and recently their design service life has been extended to at least 100 years, as referenced in ISO 2394 standards. Functionality and durability in this useful service life with low-cost investments. Among the risks involved in bridges crossing navigable rivers, the impacts of boats or barges on supports or deck's structural are the most critical actions. The mitigation of these risk actions goes through the design of the structural system of the bridge when specifying the navigation spans, which reduces the probability of impact and the design of adequate fenders type or floating protections, with resilience and robustness to guarantee the minimization of kinetic energies during impact on the structures the bridge's structural. Therefore, in this investigation, protection systems against impacts of vessels on bridge support was essential to guarantee the structural safety and safety of users will be evaluated, avoiding the ruin of the supports or the partial collapse of parts or the entire bridge structure. In this way, this work approach the protection structures of the bridges and relevant aspects of the accidents that occurred in the last 10 years in the region of Pará were investigated. In addition, the AASHTO

https://doi.org/10.2749/istanbul.2023.0752

Paper ID:76-93
Seismic Retrofit using the Largest Viscous Damper in Japan

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ABSTRACT

The Tatara Bridge is a cable-stayed bridge with a center span 890m. The seismic verification analyses of the existing conditions were carried out with the aim of further improving the seismic performance of this bridge. The results of the analyses for the bridge revealed the considerable sway-mode vibration in longitudinal direction was dominant during large-scale earthquakes, and so seismic devices such as eight viscous dampers and stoppers were found to be necessary to mitigate the vibration. It was decided to install the largest viscous dampers in Japan with a damping resistance force of 2,000kN and a stroke of ±950mm at two towers. Before the installation, the performance tests assuming actual bridge conditions during earthquakes were conducted on one representative damper using a vibration table (length 20m × width 15m, maximum displacement ±1,000mm) owned by the National Research Institute for Earth Science and Disaster Resilience. Since the tests showed that one representative damper had the required performance, it was determined that the performance test was not necessary for the remaining seven dampers by considering a method of the performance verification. This paper describes the performance test of the representative damper and the performance verification method of the remaining seven dampers.

Keywords: Seismic Retrofit, Viscous Damper, Performance Verification, Seismic Verification, Cable-Stayed Bridge.

1 INTRODUCTION

Japan consists of four main islands and numerous surrounding islands. Two of the major islands, Honshu and Shikoku across Seto Inland Sea, are connected by Honshu-Shikoku Bridge Expressways which consists of three routes, Kobe-Awaji-Naruto Expressway, Seto-Chuo Expressway and Nishi-Seto Expressway (Figure 1). There are three cable-stayed bridges in the Nishi-Seto Expressway, the westernmost route of HSBE; Shin-Onomichi Bridge, Ikuchi Bridge, and Tatara Bridge. The Tatara Bridge (Spans: 270 m + 890 m + 320 m = 1480 m), which opened to traffic in 1999, is a 3-span continuous cable-stayed bridge with a composite box girder of steel and prestressed concrete as shown Figure 2.

The HSBE is undergoing seismic retrofit of the long-span bridges, which are important structures with no alternative route, because of the anticipated occurrence of large-scale earthquakes. As the result of seismic performance verification of the Tatara Bridge, it was found that the adjacent viaduct may collapse due to large displacement in longitudinal direction of Tatara Bridge [1].

As an improvement in seismic performance, it was necessary to install viscous dampers with damping resistance force 2,000 kN and stroke ±950 mm, which is the largest in Japan to control the

https://doi.org/10.2749/istanbul.2023.0760

Paper ID:7740
Evolution of Incrementally Launched Bridge Decks in Turkey

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ABSTRACT

Incremental Launching Method (ILM) has been seen as an efficient alternative by Contractors and Local Authorities considering many aspects like construction time, cost, and environmental effects. In last decade, Turkey had started several important highway projects including Northern Marmara Motorway, İzmir-İstanbul Highway and recent 1915 Çanakkale Bridge and Motorway Project around Marmara Sea. After a long hiatus, the application of the ILM method restarted in 2014, in the first phase of The Northern Marmara Motorway (NMM). Three viaducts were constructed according to ILM. After the success of this technique, in the second phase of NMM project two more viaducts were constructed according to ILM with some improvements in construction cycles and span lengths. In the recent Çanakkale Motorway project, four viaducts were constructed using the ILM method. In the motorway section, in order to reduce the seismic mass and provide an aesthetic appearance deck was designed as single cell box section with precast struts. This paper summarizes the evolution of post-tensioned concrete deck designs for ILM viaducts over the past ten years in Turkey.

Keywords: Incremental launching, post-tension, motorway bridge, bridge construction

1 INTRODUCTION

Incremental Lunching Method (ILM) has been used all around the world since 1960s in different ways and has become an economic and realistic alternative for bridge construction. Even if the first application of ILM in Turkey was in the 80’s, this bridge construction technique was not used again upon to 2014. After a long hiatus, ILM has been reintroduced in one of the major projects, of the last years named Northern Marmara Motorway (NMM). NMM is a new 115 km long alternative ring road around Istanbul. It includes the 3rd Bosphorus Bridge and 37 bridges spread over both the European and the Asian sides. In the initial design of the project, all the viaducts were designed using isostatic precast I-Girder decks. However, for three of these viaducts (V06, V14 and V17) having high piers, an ILM alternative design with 55m typical spans was proposed by Freyssinet, considering cost, material quantities, environmental effects and construction advantages.

https://doi.org/10.2749/istanbul.2023.0768

Paper ID:77-97
Monitoring of a Large Extradosed Bridge in Thailand – Lessons Learned

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ABSTRACT

To the north of Bangkok (Thailand), a new motorway section has been realized in recent years to relieve the surrounding routes in Nonthaburi Province, whose main characteristic is an extradosed bridge over the Chao Phraya river with a total length of 460 m. The building consists of two pylons with golden dome and 96 stay cables carrying a box girder cross-section designed for six lanes across the river. To monitor the structural behavior of the bridge an extensive monitoring system was awarded by the client to DYWIDAG Systems International GmbH in cooperation of Schimetta Consult who have optimized, designed and realized the system. In total 45 sensors are monitoring permanently temperatures, strains and deflections of the bridge, inclinations of the pylons, movements of the expansion joints, wind velocities, accelerations and cable forces. The data are automatically stored on site, provided via a UMTS connection to an external server within a few minutes, enabling continuous display of the signals on a homepage for easy access by the client In addition, the measurement data are being summarized on a half-year base and the results are submitted to the clients by a measurement report. The monitoring system is continuously acquiring data since opening of the structure to regular traffic, enabling a very good insight to the structural behavior.

Keywords: Extradosed Bridge, Monitoring, Sensors, Cable Force Measurements, Deflection

1 BRIDGE MONITORING

According to the existing codes in Austria monitoring is defined as non-destructive, measurement based investigation or surveillance of civil engineering structures. The data collected can be provided for stress and resistance. Sensors are installed temporarily or permanently on the civil engineering structure. Depending on the task, different physical parameters (the so-called measurement variables) can be determined statically and/or dynamically with the sensors. A distinction is made between global and local monitoring methods [1].

In addition, 3 essential principles were consistently pursued in the implementation of a monitoring system, which are of central importance for the successful application [2]:

https://doi.org/10.2749/istanbul.2023.0775

Paper ID: 7921
Hybrid solution for the 1915 Canakkale Bridge

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ABSTRACT

The name "Hybrid Bridges" is intended to apply to bridges which are a combination of both a suspended bridge (with parabolic main cables and hangers) and cable stayed bridges. The 3rd Bosphorus Bridge (Yavuz Sultan Selim Bridge) is one of the few modern hybrid bridges built in the recent years. The choice of a hybrid solution was mainly motivated by the requirements related to a railway bridge (loads, allowed deformations, etc.) in relation with an elegant streamlined bridge deck. At early stages of the 1915 Çanakkale Bridge project, we have studied both a classical suspended
solution and an hybrid proposal. Although the requirements and constraints are very different from the 3rd Bosphorus Bridge, the hybrid bridge solution turned out to be competitive in terms of costs and construction schedule. The aim of the paper will be to recall the reasons that lead to the hybrid solution for the 3rd Bosphorus Bridge and then compare the suspended and hybrid solutions for the 1915 Çanakkale Bridge.

Keywords: 3rd Bosphorus Bridge, Yavuz Sultan Selim Bridge, 1915 Çanakkale Bridge, Hybrid Bridge

https://doi.org/10.2749/istanbul.2023.0783

Paper ID: 79-45
1915 Çanakkale Bridge - Aerodynamic Investigations

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ABSTRACT

With a world record main span length of 2023 m the design of the 1915 Çanakkale Bridge spanning the Çanakkale Strait, Türkiye, warranted an extensive array of aerodynamic investigations carried out for determination of the wind loading and verification of the aerodynamic performance. Also, the paper reviews the development of the design specifications considering the location of the bridge and available meteorological data. The development of the wind tunnel test programme necessary to verify the specifications and obtain input to the bridge design is reviewed and selected key results presented. The wind tunnel tests discussed included section model tests of the bridge girder and towers, full aeroelastic models of the free-standing tower and full bridge in service and section model tests of the hanger cables for clarification of rain / wind and vortex induced vibrations. Concerning flutter stability of the bridge it was found that the twin-box girder design provided a high critical wind speed for onset of flutter linked to the progress of the aerodynamic moment coefficient. Vortex induced vibrations of the hanger cables were found to be less pronounced than proposed by Eurocode whereas rain / wind vibrations were substantially stronger.

Keywords: Design specifications, wind climate, wind loading, aerodynamic stability, wind induced cable oscillations.

1 1915 ÇANAKKALE BRIDGE

The 1915 Çanakkale Bridge is a world record suspension bridge having a main span of 2023 m and side spans of 770 m. The bridge is crossing the Çanakkale Strait, Türkiye, between the towns of Lapseki and Gelibolu. The bridge features a B = 45.06 m wide twin-box girder having a 9 m wide

https://doi.org/10.2749/istanbul.2023.0790

Paper ID: 8002
Development of Indonesia's Probabilistic based Bridge Loading Code

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ABSTRACT

Indonesian bridge loading code, SNI 1725 was first introduced in 1989. Due to insufficient data at that time, the nominal bridge live load and load factor values specified in the code was based on consensus rather than data, referring to overseas loading code, such as US's AASHTO LRFD Bridge Design Specifications and Australia's AS Bridge Loading Code. On the other hand, AASHTO themselves was derived using probabilistic approach based on Ontario's truck measurement data in 1970's. In this research, the load factor calibration for Bina Marga standard designed bridges in Indonesia was conducted using reliability analysis. The research team collected vehicle load measurement data using weigh-in-motion technology and used it to evaluate the reliability of standard bridges with different types and span lengths. The target reliability index was set at 3.72, in accordance with the Strength I Limit State in the SNI Bridge Loading Code. The analysis results showed that the current SNI Bridge Loading Code resulted in an under-designed bridge superstructure. The recommended load factors to reach the target reliability index were a resistance factor of 0.90, a dead load factor of 1.60, and a live load factor of 1.96. This study is significant as it is the first time in Indonesia that the development of a bridge loading code has been based on actual load measurement data using a probabilistic approach.

Keywords: Load factor; Reliability target; Bridge loading code; Probabilistic approach; Weigh-in-motion

https://doi.org/10.2749/istanbul.2023.0798

Paper ID:8046
Challenges of a Multiple Super-long Span Suspension Bridge Crossing of the Irish Sea

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ABSTRACT

Constructing a 36km long bridge across the North Channel of the Irish Sea between Scotland and Northern Ireland in water up to 300m deep presents several substantial challenges. In March 2021, the authors were assigned the task of establishing whether such a crossing is feasible, as part of the UK Government's review of the connectivity between the four parts of the United Kingdom.

The technical challenges are enormous and focus principally on constructing the substructures and foundations in very deep water, the main cable design and erection, the severe environmental conditions and many operational factors. The solutions that emerged from the high-level study included a suspension bridge carrying twin railway tracks and dual three-lane carriageways on a multiple steel box girder deck structure, with seven spans of 3750m supported on eight pylons rising to a height of nearly 550m above sea level. Similar concepts have been developed by COWI previously for the Gibraltar Strait Crossing and the Yemen-Djibouti Crossing, and this study was able to draw on lessons learnt from that earlier work.

This paper describes the evolution of the preferred structural solution and focusses on the complex technical issues which set this project apart from any other long span bridge solution, including the deep water foundations and the design and construction of the main cables. It concludes with a discussion of the key risks and some lessons learnt for the design of such enormous structures in future.

Keywords: Multi-span, suspension bridge, deep-water crossing.

1 INTRODUCTION

The question of whether it is technically possible to construct a bridge crossing of the Irish Sea arose as part of a wider study undertaken by the UK Government in 2021 which considered all aspects of connectivity between the four nations of the United Kingdom. The short, high-level study was not required to identify the optimum or lowest cost solution; such questions were to be for a future phase of investigation. The study area was wide and included the whole of the northern Irish Sea, and not just the shortest route from Scotland to Northern Ireland across the North Channel.

A family of options were evaluated, including tunnel and bridge crossings, taking into account not only the crossing itself but also the many complex challenges of upgrading or building new connecting railway and highway infrastructure on both sides. The optimum route for the bridge crossing option was determined to be between the Rhins of Galloway in Scotland and the coast of

https://doi.org/10.2749/istanbul.2023.0811

Designed to Last 150 Years – The San Francisco-Oakland Bay Bridge

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ABSTRACT

The east span of the San Francisco-Oakland Bay Bridge (SFOBB) is a 3.6 km long structure that lies between two major faults, which can generate magnitude 7.5 M and 8.1 M earthquakes, respectively. Four distinct structures make up the bridge crossing, including the signature span of the bridge - the self-anchored suspension (SAS) bridge. With a length of 624 m and total deck width of 79 m accommodating 10 lanes of traffic plus a bike/ pedestrian path, it is named, in the Guinness Book of World Records, as the world's longest self-anchored suspension bridge as well as the world's widest bridge. The design life of the SFOBB is 150 years. Key considerations in design and construction include designing elements replacement after a major seismic event, proper fatigue detailing, and cable and anchorage zone dehumidification. This paper discusses the design and construction of this long span bridge to ensure optimal performance throughout its design life.

Keywords: Suspension bridge, self-anchored, seismic, orthotropic box girder, dehumidification

1 INTRODUCTION

After the 1989 Loma Prieta earthquake damaged the original East Span of the SFOBB, the California Department of Transportation determined that the safest and effective solution was a total bridge replacement. The 3.7-kilometer-long East Span of the SFOBB opened to traffic on September 2, 2013; it is one of the busiest toll bridges in the United States. The bridge is also a designated lifeline structure with a 150-year design life and must be operational for emergency vehicles shortly after the strongest ground motions engineers can expect in a 1,500-year period.

The East Span comprises four distinct yet interconnected structures: the 618-meter (m)-long self-anchored suspension (SAS) span; the 2,085-m-long segmental concrete box girder Skyway viaducts (Skyway) that sweep up from the Oakland shoreline to connect with the SAS; the 406-m-long Oakland Touchdown, which links the Skyway to California's Interstate 80; and the 570-m-long Yerba Buena Island (YBI) Transition Structure that connects the SAS to the YBI tunnel. The East Span is the longest single-tower SAS in the world and the world's widest bridge at 78.74 m. The four distinct structures of the SFOBB crossing are shown on Figure 1.

The designer TYLin/Mofatt & Nichol Joint Venture, working in conjunction with Caltrans, California's Metropolitan Transportation Commission, and the California

https://doi.org/10.2749/istanbul.2023.0820

IABSE SYMPOSIUM ISTANBUL
LONG SPAN BRIDGES 26-28 APRIL, 2023
HYATT REGENCY ISTANBUL ATAKOY HOTEL

Paper ID: 8281
Data Quality for Structural Health Monitoring of Bridges

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ABSTRACT

The use of digitalization and reliance on relying on Structural Health Monitoring (SHM) in bridge engineering is increasing, especially for long-span bridges where the condition assessment becomes more challenging. Effectively, it ensures greater accuracy in damage identification and enhanced maintenance of existing bridges by collecting information on the bridge's actual condition (i.e., likely damage, its severity, etc.). This increased reliance on data and information raises the question of the quality of the data and its effect on the management strategy and the decision-making process for bridge engineering. To solve this issue, in this article, data quality indicators for SHM are first selected, then metrics for data quality are reviewed, and some metrics are proposed to assess them. Then, a bridge management strategy considering the data quality is suggested to improve bridge management and decision-making processes. This strategy considers several steps to account for the data quality of SHM in the life cycle assessment management, including mainly the value of information on SHM data quality and some life cycle system performance indicators, which now account for the SHM data quality.

Keywords: Data quality; SHM; Decision making; Bridges; Management strategy.

1 INTRODUCTION

Contemporary bridges are aging all over the world and necessitate maintenance. Extending their lifetime is challenging due to increased natural risks, climate change, and population growth.

Transportation is crucial for the economy and modern society's functionality and welfare (Schroten et al., 2019). Therefore, the European Union (EU) aimed to preserve the functionality of transport infrastructures and decided to spend €38 billion on its maintenance (Schroten et al., 2019). Nevertheless, the resources for maintenance are still scarce, and it is essential to develop a strategy to optimize bridge integrity management.

Lately, great research endeavors have been devoted to shifting from condition-based methods to risk-based methods for more efficient bridge integrity management, as shown in EU research projects such as COST TU1406 (Casas & Matos, 2021). Though, risk-based approaches do not suggest how to reduce the indirect consequences in the aftermath of the event and disruptions. Thus, some resilience-based methods were developed to ensure an effective recovery ((Bruneau et al., 2003), (Cimellaro et al., 2009), (Linkov et al., 2014), (Sharma et al., 2018)). Yet, networks and domain interconnections are still complex and largely neglected. This perspective is not representative of reality as the world is progressively more interconnected technologically, economically, sociologically, and ecologically ((Havlin et al., 2012), (Linkov et al., 2014)).

https://doi.org/10.2749/istanbul.2023.0828

IABSE SYMPOSIUM ISTANBUL

LONG SPAN BRIDGES
26-28 APRIL, 2023
HYATT REGENCY ISTANBUL
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Quantification of subsurface defects in reinforced concrete of bridges by unsupervised segmentation of IR images

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ABSTRACT

This paper presents segmentation analysis of Infrared (IR images of reinforced concrete (RC blocks for characterisation and quantification of corrosion defects using unsupervised clustering. The IR images used in this study were collected during cool down process of RC slabs to laboratory environment temperature through convection heat exchange. The RC slabs were cast from a normal strength mix, typical for bridge construction in the UK and Ireland. The slabs had two steel rebars with protruding ends that were used for accelerated corrosion setups. Unsupervised clustering was conducted on IR images by applying k-means clustering method on normalised temperature readings in a region of interest. In this paper, the performance of clustering method to distinguish between environmental or surface effects and true bridge anomalies is studied, and the corrosion-affected concrete is quantified. Variation of thermal contrast and quantity of defective concrete during the experiments as well as discussion of the results in context provides a basis for improved implementation of IRT for RC structures and contributes to wider objectives of structural health monitoring (SHM.

Keywords: Reinforced Concrete (RC, Rebar corrosion, Unsupervised clustering, Infrared Thermography (IRT), Structural Health Monitoring (SHM)

1 INTRODUCTION

Degradation of concrete because of corrosion of rebars in aggressive operational and environmental conditions is a major reason for damage in the reinforced concrete (RC elements of bridges such as deck, girders, soffit, and foundation [1, 2]. The progress of the rebar corrosion causes accumulation of iron oxide at the interface between the rebar and concrete which has higher volume than the steel which subsequently weakens their adhesion and can cause cracking of the concrete [3]. Therefore, it is required to monitor the condition of structure to recognise the onset of corrosion propagation and detect damages at earliest possible stage, preferably by non-destructive techniques and before they progress severely, incur costly rehabilitation and maintenance, endanger lives and cause traffic disruption [1, 4, 5].

https://doi.org/10.2749/istanbul.2023.0835

Experimental and numerical study on the re-anchoring of wire in grouted prestressed tendons

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ABSTRACT

Some recent researches have focused on strand wire damage in external prestressing tendon. When some strand wires of a grouted prestressing cable are damaged, the tension in the cable can be preserved due to the re-anchoring phenomenon. For safety issues, it is important to study the damage limit that a tendon can suffer before the rupture. While the re-anchoring of a strand is well studied, there is less literature on wire re-anchoring. In this study, we tested grouted seven-wire strands which are put under tension and then cut out wire by wire to simulate the wire damages. The re-anchoring is observed by strain gauges installed in the strands and on the sheath. In addition, a numerical model has been developed with the help of FEM to analyse the mechanical phenomenon during and after the wire cuts. The results show that the tendon is bent and twisted because of the loss of tension and moment when one or several wires are cut off. Moreover, the strand strain is various following the gauge position in each wire and its distance to the cut section. This result contributes to the comprehension of the wire damages in grouted tendons, and could be extended to grouted multiple-strand tendons.

Keywords: external prestressing, prestressed tendon, strand wire damage, wire re-anchoring

1 INTRODUCTION

The re-anchoring of tendons with a whole broken strand was reviewed by Abdelatif, Owen and Hussein (2017). The re-anchoring occurs due to friction. The mechanical characteristics of steel and concrete turn out to be the main parameters influencing the re-anchoring length. This result was confirmed by experimental studies of Watanabe et al. (2011). The re-anchoring is similar to a pretensioned strand bond, studied in some articles such as Oh, Kim, and Choi (2006) or Ramirez-Garcia et al. (2016), which take into account loss of grout strength due to cracking. It suggests that the stress of the strand changes exponentially from 0, at the cutting position, to the final stress value, at a distance called transfer length from the cut strand. The Poisson's effect causes the cut end to adopt a wedge-like form that leads to friction with the other wires and the grout. Furthermore, the loss of tension in the wire unfolds the wire and thus increases the contact with the concrete; this is called the Hoyer effect, Briere et al. (2013). The re-anchoring of a whole strand is presented in several

https://doi.org/10.2749/istanbul.2023.0846

Paper ID:84-94
NORMANDIE BRIDGE – FATIGUE ANALYSIS AND INNOVATIVE INSTRUMENTATION OF THE ORTHOTROPIC STEEL DECK

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ABSTRACT

The main span of the Normandie Bridge includes a 624-meter-long central steel section with an orthotropic steel deck. This deck is subject to the effects of the road traffic, which governs the fatigue resistance of welded joints. The Chambre de Commerce et d'Industrie Seine Estuaire (CCISE), concessionnaire of the bridge, led a study combining classic analyses based on existing codes and on an innovative instrumentation.

The analysis performed on the orthotropic deck of the Normandie Bridge combines an approach by computation, conducted on a finite element model, with an innovative physical instrumentation using Distributed Fibre Optic Sensors (DFOS).

The so-called "distributed" optic fibre allows to use the fibre not only as a conductor, but also as a sensitive element to measure deformations. It makes possible to measure deformations, and thus stresses, at very small intervals, every 2.6 millimetres in this case. The fibre can thus be considered as a "linear" sensor, installed on ten troughs per fibre, being bonded directly to the welds. From the recorded stresses it can give a direct evaluation of the fatigue damage and of the residual life of the deck.

This study evidences the interest of an experimental evaluation of the fatigue damage in existing structures, and provided an interesting and sometimes unexpected feedback on design practices of orthotropic steel decks.

It also highlights the predominant influence of the very local traffic conditions on the fatigue damage, such as the precise relative position of the axle wheels and of the welds, that the actual codes (Eurocode or other) take into account very imperfectly, and that cannot be compensated for by the quality of calculation models.

https://doi.org/10.2749/istanbul.2023.0854

Paper ID:8527
An Analysis of Long Spans of Fixed Link Crossings

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ABSTRACT

This paper examines the long spans associated with fixed link crossings. An overview of existing fixed links globally, including information such as total lengths, maximum span lengths, materials and types of construction is given. Data for well-known major bridges such as the Oresund crossing as well as the more recent Çannakale Bridge are included. An overview of historical fixed link long spans will be given as well as a look to the future with an overview of some of those currently in design and construction stages. The use of prefabrication is investigated as a means of mitigating risk and increasing safety. The construction methods required to surmount the challenges associated with these long spans is examined. Finally, the paper looks at some of the long spans proposed for some of the more notable and long mooted fixed links.

Keywords: Bridges, fixed links, long-span, construction methods, prefabrication

1 INTRODUCTION

This paper examines the long spans of fixed link crossings around the world, investigates construction methods and looks at some notable future fixed links. Fixed links are defined as unbroken connections across the sea or a strait, and may comprise bridges, tunnels, causeways, or a combination. The paper considers 28 existing crossings where long spans feature, and why they have done so. Construction materials, bridge types and construction methods are also examined, where information is available.

2 EXISTING FIXED LINKS

The fixed links examined in this paper are shown in Table 1, and shown in terms of maximum span, with the recently completed **Çanakkale 1915 Bridge**, the world's longest span, topping the table. The two longest cable stayed spans, Russky Island Bridge and Sutong Bridge, also feature in this list near to the top. Of the author's database of fixed link crossings, 28 are included here as having significant navigation spans. It can be seen that some of these are bridge only crossings, while some form parts of bridge tunnel crossings. Some crossings such as the **Hong Kong Zhuhai Macao (HKZM) Bridge** and **Donghai Bridge** have multiple navigation channels requiring long spans

https://doi.org/10.2749/istanbul.2023.0862

IABSE SYMPOSIUM ISTANBUL
LONG SPAN BRIDGES
26-28 APRIL, 2023
HYATT REGENCY ISTANBUL
ATAKOY HOTEL

Paper ID:86-06
Unique cable stayed bridge over the Mosoni-Danube with inclined steel box pylon in Hungary - Some details of the architectural and structural design

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ABSTRACT

The city of Győr in western Hungary will be enriched with a significant transport investment of NIF PLC., a Hungarian infrastructure developer company. UNITEF'83 PLC. was commissioned with the design. The new road will cross the Mosoni-Danube over a spectacular new cable-stayed steel bridge. The future bridge is a 2-span, 68+144 meter-long box section structure, and its 65 meter-high inclined pylon will stand out from the city skyline. In addition to key design issues such as the global structural design and the details of the connections of the main load-bearing elements (cables), other structural problems requiring innovative solutions also arose during the design process. Several structural versions have been carefully analysed as early as in the initial phase of the design with the purpose of ensuring adequate torsional stiffness of the deck. Due to the sensitivity of the cable-stayed structure to the wind, cable vibration and the flow analysis of the beam and pylon also had to be carried out. The issue of construction technology had to be paid extra attention during the design procedure, since transportation by river and road were both limiting factors in the region. The paper covers the architectural and structural design of the future bridge in Győr, offering a brief outline of the most important details and solutions.

Keywords: design, analysis, cable stayed, inclined pylon, Hungary.

1 BACKGROUND OF THE PROJECT AND ARCHITECTURAL DEMANDS

The Romans founded the first settlement called Arrabona at the confluence of the river Rába, Rábca, Marcal and Mosoni-Danube. The settlement development and everyday life of the city later named Győr have always been greatly influenced by the four rivers, hence the name "City of Rivers". The first permanent bridge of the city was built in the 14th century between Révfalu and the city centre. This was followed by a series of permanent bridges. The latest bridge in Győr was built in 2018: Klatsmányi Bridge of Main Road 813.

In order to fully serve traffic demands, an additional bridge needs to be built in Győr. In 2019, UNITEF'83 PLC. was commissioned by NIF National Infrastructure Developing Company to design a new Mosoni-Danube bridge as part of the eastern section of the new traffic corridor connecting Ipar street with the Bácsa district.

https://doi.org/10.2749/istanbul.2023.0870

Paper ID:8607
Design features of the Cable-stayed Bridge between the islands of Cebu and Mactan (Republic of the Philippines)

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ABSTRACT

The cable stayed between the islands of Cebu and Mactan is the main work of the road concession Cebu-Cordova Link Expressway. Its 390-m long main span over the Cebu port navigation channel turns it the longest cable-stayed span in the Philippines. This paper provides an overview of its design features emphasizing the distinctive constraints that include high seismicity, geological variability, high wind speeds due to frequent typhoons and large ship impact loads.

Keywords: Cable-Stayed Bridge, cantilever, prestressed concrete, seismic design, spatial variability

1 INTRODUCTION. BACKGROUND

The Cebu-Cordova Link Expressway (CCLEX) project aims to relieve the heavy traffic between Cebu - the second largest city of the Philippines - and the town of Cordova, on the island of Mactan, where the international airport is located. This involves laying a new road that avoids passing through the centre of Cebu with a 3 km long structure of which the most relevant is a cable-stayed bridge with a span of 390 m over the port navigational channel. It is extended at both sides with access viaducts with girders of precast beams.

The project was carried out in the form of *Early Contractor Involvement (ECI)* organised by the Metro Pacific group [1] and awarded to the JV CEBU Link led by ACCIONA in partnership with the local companies First Balfour and D.M. Consunji Inc. with an approximate budget of 400 million USD.

https://doi.org/10.2749/istanbul.2023.0878

Paper ID:86-12
Industrial Bridge, Chile.
Challenge in seismic detail design

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ABSTRACT

The Industrial Bridge above the Bio Bio river will become the largest road bridge with a transverse section of main beam and slab in Chile, with a length of 2.520 m in 56 spans, when it goes into service the year 2024. The conception and structural design was marked by the location and the reduce capacity of the soil (Soil type IV), due to flood events that are products of the widest river of Chile in one of the most seismic zone of the world. The present work shows the analysis made in the Industrial Bridge, where different studies were made to define the seismic parameters of the zone. This was made through a such as a deterministic and probabilistic for different conditions, which turned out as a result into a considerable increase of the seismic demand when compared to the demands of the Highway Manual code (Desgin code of Chile). For the final design, it was considered the used of and base isolator with energy dissipation, that was able to maintain the period of the bridge at 1.72 s but increased the damping 25% lowering the transfer of efforts from the superstructure to the infrastructure. The main elements of the structure ended up with an atypical characteristic for a beam bridge in Chile: prestressed girders of 45,00 m length and 2,50 m height and mechanical connectors for the longitudinal reinforcement, expansion joints with +/- 40 cm of transversal and longitudinal movement, and base isolator with energy dissipation bearings with a 25% of damping.

Keywords: bridge, design, isolation; seismic risk study

1 INTRODUCTION

The Industrial Bridge over the Bio Bio River is the main structure of the Industrial Bridge Road Concession in the city of Concepción that connects both banks of the Bio Bio River and the Los Batros Estuary; it is a long structure, with an extension of 2,520 m, of which 2,094 m correspond to a straight route and 427 m in curves, joining the municipalities of San Pedro de la Paz and Hualpén, Concepción, Bio Bio Region, Chile (Figure 1).

https://doi.org/10.2749/istanbul.2023.0887

Paper ID: 88-30
MOMCHILGRAD-SEDLARE PEDESTRIAN SUSPENSION BRIDGE

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ABSTRACT

This article reviews the new superstructure and cable system for the pedestrian suspension bridge over Varbitza river, situated in Rodopi mountain of Bulgaria. The bridge connects the town of Momchilgrad with the village of Sedlare, bridging the river in a single span. The distance between the two concrete pylons is 169m. The span of the main steel truss girders is 155m with a clear distance between them of 2,50m. The design was made in 2005 and the bridge was constructed in 2007. In 2021 (nearly fifteen years after its completion) side inspection of its service condition was made by the authors. The results of the findings are discussed in this article as well.

Keywords: human induced vibrations; reconstruction; service condition; detailing.

1 INTRODUCTION

The project for the reconstruction of the existing suspension bridge, between the town of Momchilgrad and the village of Sedlare, over the Varbitza river, was initiated by the Municipality of Momchilgrad in 2005. The existing superstructure was in a very bad condition (Figure 1) and needed replacement. The project also included strengthening of the concrete pylons and one-sided concrete ramp as well as the design of new anchor blocks for the main cables.

Figure 1: Bridge superstructure before the reconstruction

https://doi.org/10.2749/istanbul.2023.0896

IABSE SYMPOSIUM ISTANBUL
LONG SPAN BRIDGES 26-28 APRIL, 2023 HYATT REGENCY ISTANBUL ATAKOY HOTEL

Paper ID:8847
Joint Iteration Method of unloaded Cable Shape and Pre-displacement of Main Cable Saddle for Long-span Suspension Bridges

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ABSTRACT

In this paper, a new method for calculating the unloaded cable shape and main cable saddle pre-displacement in the construction of long-span suspension bridges is proposed, which is called the joint iterative method (JIM). In this method, the first iteration does not require presupposing the saddle pre-displacement, and the results of the unloaded cable shape obtained in each subsequent iteration cycle will be mined to guide the saddle pre- displacement correction in the next iteration. This method uses simplified cable models and convergence conditions different from classical methods. In the simplified model of main cable mechanics, equal horizontal component of suspension bridge on both sides of main tower is taken as implicit condition, and equal unstressed cable length of each span of main cable is taken as convergence condition in iteration. Using this method, the pre-displacement of the main saddle and the unloaded cable shape of the Yingwuzhou Yangtze River Bridge is calculated by MATLAB program and compared with its designed value. The results show that this method requires few iterations and has high speed and accuracy.

Keywords: long-span suspension bridge; unloaded cable shape; pre- displacement of cable saddle; joint iterative; the Yingwuzhou Yangtze River Bridge

1 INTRODUCTION

At present, there are many studies on the calculation of the unloaded cable shape of suspension bridges. [1-3] There is also some research on the solution of cable saddle pre-displacement. [4,5] However, the results of these studies on the unloaded cable shape have little guiding effect on the calculation of the pre-displacement of the cable saddle. The calculation of cable saddle displacement is not well guided by the calculation of the unloaded cable shape.

In this paper, the tension-only bar element is used to simulate the main cable, and a novel simplified mechanical analysis model is proposed for the simulation method of the bar element. The new mechanical model is used to iteratively solve the unloaded cable shape, and the relationship between the unloaded cable shape and the saddle pre-displacement is deeply explored. The new iterative convergence criterion is adopted to avoid the initial saddle pre-displacement, and the calculation result of the unloaded cable shape can guide the update and adjustment of the saddle pre-displacement.

https://doi.org/10.2749/istanbul.2023.0904

Paper ID: ISTBR2023 - 8912
Benefits of parametric modelling in bridge design

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ABSTRACT

In the Netherlands, several large infrastructure projects are currently in the preparatory stages, all of which are closely linked in terms of timing. As a result, the design process for these projects is limited by time. One such project, the A27, includes several large bridges. To optimize the design of these bridges, a parametric design model was developed. This model allows for the comparison of different bridge variants, to determine the most optimal design solution.

The parametric model was created Grasshopper (a plugin for the Rhinoceros 3D CAD application), which is used to create the coordination model, as well as the creation of the FEA and drawing models. This approach enabled the creation of drawings, calculations, initial automatic checks and visualization from a single scripted model. A workflow was established to ensure consistency and efficiency throughout the process. Additionally, a single source of truth and interoperability tools between different software packages were employed, to facilitate the inclusion of all stakeholders, such as clients, architects, and contractors, in the design process.

This paper aims to demonstrate the benefits of working parametrically by showcasing the application of the parametric model in the feasibility phase of the Keizersveer bridge in the tender. Specifically, the parametric model used for this project includes both an arch bridge and a cantilever bridge design.

Keywords: parametric design, optimisation, bridge design, data driven design, digital engineering.

https://doi.org/10.2749/istanbul.2023.0912

Paper ID:89-23
Comparing cable-supported to archstructures footbridges across historic sites

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ABSTRACT

Three arch-type as well as 3 cable supported alternatives have been developed for footbridges above historic sites. The two categories of arches and cable supported structures exhibit a completely different behaviour, since the latter are more flexible. The first cable variant is a straight intersection of variable width. In comparison with an arch, it is striking that the deformability is much greater the fundamental frequencies being significantly lower. However, the characteristic values for dynamics, such as the Scruton number and the accelerations of the bridge deck are significantly better. To span the site of 200 m in length, pylons of 46.7 m in height are needed. As a second alternative, a semi-circular suspension footbridge of variable height has been developed. Direct comparison with an arch counterpart is not evident. However, it could be deduced that this structure has a fairly high frequency and is also not sensitive to the important types of vibration. A full elevated walkway around a circular site can certainly be compared to its arch-shaped counterpart. Despite the lower fundamental frequency, the higher flexibility and the increased consumption of steel, the cable-supported structure performs better as for its dynamic behaviour.

Keywords: Historic sites, cable-supported structures, vortex shedding, human induced vibration, Scruton number, conceptual development.

1 INTRODUCTION

Covering historic sites has been implemented on several locations in order to protect them from unwanted intrusion, from disturbing of the archeologic activity and to provide shelter from weather, erosion and weir. However, these shelter structures may have negative influence on the protected remains, as demonstrated by Cassar et al (2018). This generated the idea that partial cover, including movable additional shelters by foils, might provide a limited answer to this issue. In addition, the public should be allowed to see valuable remains and archeologic activity, without interfering with it. For this, several historic sites have been equipped with elevated walkways around the places of interest. The latter mostly allow a bird's eye view on the remains.

This idea has inspired to try develop concepts for walkways above historical sites. In previous research of Van Bogaert et al. (2021) 3 concepts, mainly based on arch forms, have been developed. For each one satisfactory results were obtained, although 2 out of 3 alternatives required structural damping due to vortex as this has proven to be the most detrimental condition. Vortex shedding might

https://doi.org/10.2749/istanbul.2023.0920

Paper ID:9055
From Leonardo da Vinci to Fritz Leonhardt – The Role of Physical Measurement Models in Bridge Engineering

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ABSTRACT

Since ancient times, physical processes have been explored with models to understand the laws of nature. In the late 15th century Leonardo da Vinci researched the behaviour of bending of elastic beams of various spans using physical models. Later, in the 20th century, physical models were indispensable for civil engineers and architects to check the load-bearing capacity of unconventional and innovative structures. Even today, physical models are used in different engineering disciplines, for example, to test the behaviour of long-span bridges in wind tunnels. This paper attempts to give an overview of important testing facilities which achieved technological progress in the field of bridge engineering. The models built and the tests performed in these facilities will be used as examples and will answer the question of the critical role these models played in the planning and construction process. The authors are collecting information and are analysing these physical measurement models in the current research project, “Last Witnesses”, funded by the German Research Foundation (DFG) to replicate some of them as digital twins. The results will be available to the public in an openly accessible database.

Keywords: physical measurement model, bridge model, structural modelling, digital twin, database.

1 INTRODUCTION: HISTORICAL USE OF PHYSICAL MODELS

The use of physical models can be retraced back to ancient Greece or Rome, for example, to examine military equipment. There is also evidence that engineers in the Gothic period used models to build enormous cathedrals. From the Renaissance, there are known numerous sketches and writings on the use of models, among others, by Leonardo da Vinci (1452-1519) on flying machines, canals, and civil structures. Still, he never describes the construction of his models, so no built models by Leonardo da Vinci are known.

There are thus numerous individual examples of the use of physical models in various scientific disciplines, often as a demonstration that something works, to test a manufacturing method, as a teaching object for artisans or to convince potential customers. In the Age of Enlightenment, experiments on models were carried out more systematically and noticed by practising engineers. The trend towards more scientific approaches also led to the study of the theoretical principles of how the results of model experiments could be scaled up to actual construction, for instance, by Leonard Euler (1707-1783).

https://doi.org/10.2749/istanbul.2023.0928

Paper ID: 91-22 Sazlidere Bridge Wind Tunnel Testing Assisted Design

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ABSTRACT

In the context of the Northern Marmara Motorway Section 8 Project, a new cable-stayed bridge, the Sazlidere Bridge, is being designed and works have already started on site. To support this fast-paced project, RWDI is collaborating with the design team and providing wind engineering services. The activities employ wind tunnel experiments and are focused on two main aspects: aerodynamic stability of the bridge and the risk of wind-induced overturning of large lorries crossing the bridge. With respect to aerodynamic stability, limited tests on a sectional model of the bridge deck were performed in one of RWDI's wind tunnels using a state-of-the-art sectional model test rig. Testing of a full bridge aeroelastic model with relevant topography was also conducted allowing for the simulation of atmospheric turbulence from any wind direction. This testing was used primarily to verify the aerodynamic stability of the structure for various wind directions and to measure the buffeting response of the bridge to turbulent winds. Further wind tunnel testing on a small-scale rigid transport lorry model was completed to measure the aerodynamic force and moment coefficients of the vehicle as a function of wind direction. These data were combined with a numerical model for the roll-over stability of high-sided vehicles to calculate critical wind speeds versus wind direction for lorries driving along the central span of the bridge.

Keywords: Cable-stayed bridge, sectional and aeroelastic model wind tunnel testing, vehicle roll-over study.

1 INTRODUCTION

The Sazlidere Bridge is a newly proposed cable-stayed bridge that will be built in the context of the Northern Marmara Motorway Section 8 Project. It features a maximum deck elevation of 83.5 m above the ground and is supported by two pylons having maximum elevations of approximately 196 m. The main span of the bridge is 440 m and the total length of the cable-stayed structure is 860 m. The deck will have a total width of 49.3 m carrying 4 traffic lanes in each of the Eastbound and Westbound directions. There will also be multi-use walkways on either side of the deck. Figure 1 presents the general elevation view of the bridge while Figure 2 presents a typical cross-section of the bridge deck.

https://doi.org/10.2749/istanbul.2023.0936

Paper ID: 91-42
FOOTBRIDGES OVER VARBITZA RIVER

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ABSTRACT

This article reviews the service condition of three pedestrian suspension bridges. They are located in the Rodopi mountains, outside urbanized area. These bridges are crossing Varbitza river at different locations along its length and are mainly used by the locals in order to access the railway line (stations) running along the river. All bridges are suspension bridges with main span varying from 120m to 260m. Originally, they were built more than 50-60 years ago. Reconstruction of their superstructures took place 10 to 15 years ago. Visual inspection, made in the summer of 2021, reviews their service condition, which is further discussed in this article.

Keywords: long span suspension bridges; remote villages; structural concepts; reconstruction; service condition; detailing.

1 INTRODUCTION

Railway transport was widely used in Republic of Bulgaria during second half of the twentieth century and has good potential for modernization and development [1], [2]. One of the main railway lines, crossing Bulgaria from north to south, is line number 4, starting in the town of Ruse (on the Danube river) and ending at Podkova railway station (close to the southern border of Bulgaria with Greece), Figure 1. The last section of that railway line Momchilgrad-Podkova was built during the Second World War and put in exploitation in the end of 1944. It is around 17,5km long and has three intermediate stations/stops. In this section the line falls in the picturesque Rodopi Mountains region. Due to the difficult terrain, it was designed to follow the curves of Varbitza River without crossing it, thus leaving the villages on the other side of the river without access to the railway stations.

Around 15-20 years after the railway line was put into exploitation pedestrian bridges over the river Varbitza were built. They were intended to connect the remote villages, left on the other side of the river, with the railway stations. Since the riverbed of Varbitza is relatively wide all bridges were initially planned as suspension pedestrian bridges. Despite their relatively large spans, up to 260m, these bridges usually lack project documentation and were craft made utilizing steel cables from the regional mining industry. Adding poor or almost no maintenance makes them even dangerous to cross.

https://doi.org/10.2749/istanbul.2023.0944

Paper ID:91-75
4th Abidjan Bridge

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ABSTRACT

4th Abidjan Bridge is a major infrastructure project under construction in Abidjan, Ivory Coast. This 7.2km long expressway will connect residential area of Yopougon (2 million people) to the business district of the city.

The project is being managed by Ageroute while a consortium made up of Setec TPI/Setec-CI/Setec International/Terrabo ingénieur conseil/Studi International manages works and design updates. China State Construction Engineering Corporation Ltd (CSCEC) is the general contractor of the project.

Two twin cast-in-place balanced cantilever girder bridges cross the Banco bay, with 90m spans and a length of 800 m each. They are followed by an interchange and a bridge climbing up to the plateau. These prestressed box guiders are casted in place span by span. The whole project comprises 3.2 km of pre-stressed concrete box girders.

After an overview of the project and a brief description of the different bridges, the paper focuses on a few technical issues that punctuated their design and construction.

https://doi.org/10.2749/istanbul.2023.0952

Construction technology innovation of Sunk Shaft foundation and composite tower of 1200m highway and railway cable-stayed bridge

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ABSTRACT

The Changtai Yangtze River Bridge is an impressive feat of engineering, boasting the world's largest span cable-stayed bridge with a main span of 1176 meters. The foundation of the cable tower adopted a sunk shaft foundation with a structure size of 95.4×58.2×64m. The tower is 352m high, the middle and lower towers are spatial diamond type four-tower limb concrete towers, and the upper tower is steel-core concrete composite tower. Innovative technologies were utilized during the bridge's construction, including an automated air-lift soil extraction equipment and cluster control system, along with a three-dimensional panoramic rapid imaging technology for efficient and visualized soil extraction and sinking of the sinkhole. Additionally, an intelligent auxiliary decision-making algorithm and control system were developed for digital sinking. The steel reinforcement of the tower adopts the block-based reinforced bar product construction process, and develops the intelligent production line and equipment for component steel reinforcement to achieve high precision, high efficiency and unmanned production of steel components. The tower's concrete construction utilized a new intelligent hydraulic climbing system, which integrated automatic concrete pouring, intelligent maintenance, and synchronous climbing systems, improving quality and safety. The research and development of the W12000-450 intelligent tower crane was also crucial to the bridge's construction, capable of lifting up to 450 tons with a lifting width of 75 meters, including active anti-collision, wire rope wear self-test, and frequency conversion rotation functions.Overall, the implementation of these innovative technologies has made the Changtai Yangtze River Bridge a landmark achievement in modern engineering.

Keywords: Cable-stayed bridges, sunk shaft foundation, composite tower, reinforced bar product, construction control.

https://doi.org/10.2749/istanbul.2023.0961

Construction technology innovation of 2300-meter suspension bridge: new diaphragm wall and composite tower

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ABSTRACT

Zhang-Jing-Gao Yangtze River Bridge adopts a double-span suspension bridge with a main span of 2300 meters. The anchorage foundation adopts a composite diaphragm wall, which is used as an temporary supporting structure during construction, and then transformed into a permanent structure, and the main tower adopts a 350-meter composite structure of steel box and steel tube confined concrete. This diaphragm wall has high requirements on the verticality of the slot segment and the installation precision of the rigid joint, and there are difficulties in segment hoisting, linear control and the construction quality control of steel tube concrete of super high tower. Therefore, technical research was carried out: (1) The intelligent aided decision-making system for trenching, the automatic detection and adjustment device for slurry performance, and the three-dimensional shape detection technology for slot are developed to achieve high-precision trenching; (2) The high-precision manufacturing and installation technology of new rigid joint and steel reinforcement cage is studied to reduce the stuck risk; (3) Through the application of W12000-450 intelligent tower crane and construction control with the whole process control concept, the purpose of high precision control of tower alignment is achieved; (4) The pouring platform on tower of concrete and construction technology of self-compacting concrete with 40-meter high drop are developed to ensure the construction quality of steel tube concrete.

Keywords: Diaphragm wall; Composite tower; Trenching precision control; Steel tube concrete construction.

https://doi.org/10.2749/istanbul.2023.0962

Industrialized construction technology of three-tower light composite beam cable-stayed bridge

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ABSTRACT

The Fifth Nanjing Yangtze River Bridge is a three-tower cable-stayed bridge with a main span of 600 m. The Steel Shell-Concrete Composite Pylon and steel-UHPC panel light composite girder are adopted.Aiming at the high-quality construction requirements of super-large projects, the research and practice of industrial construction technology including new structures, new processes, new materials and new equipment are carried out. The main innovations are as follows :①Based on the design-construction coordination concept of factory processing and modular installation, a new structure of steel shell-concrete composite bridge tower is developed, which has the advantages of good mechanical performance, fast construction and reliable quality.②The manufacturing process of making steel shell and main steel bar at the same time in the factory is developed. Only the steel shell is installed and the concrete is poured on site, which greatly improves the construction efficiency and quality of the site.③The lightweight self-climbing platform and precision adjustable spreader were developed, which improved the steel shell hoisting, platform climbing efficiency and appearance quality of bridge tower.④The lightweight composite beam structure of steel box-UHPC prefabricated panel and the wet joint connection structure of UHPC are developed, which have the advantages of light weight and fast assembly.⑤An automatic UHPC panel production line integrating multiple sets of equipment was developed, which realized the transformation of prefabricated component production from labor-intensive construction to technology-integrated manufacturing.

Keywords: Industrial construction of bridges; Steel shell-concrete composite bridge pylon; steel shell manufacturing with reinforcement; steel-UHPC panel light composite girder; bridge deck automated production line.

https://doi.org/10.2749/istanbul.2023.0963

Progress of Bridges in China in the 20th century

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ABSTRACT

Since the 20th century, China's long-span bridges have made remarkable progress. Whether in the mountains, valleys, or rivers and lakes, the long-span bridges have made breakthroughs with innovative technologies. Among them, CCCC Highway Consultants Co.,Ltd. is the driving force and leader of the innovative design of China's long-span bridges. In the fields of long-span suspension bridge, cable-stayed bridge, arch bridge, beam bridge, and cross-sea channel, it has been practicing new technology, new materials and new process design concepts, implementing the concept of factory, standardization, assembly and information construction, driving the development of China's bridge industry and displaying China's bridge strength to the world.

Keywords: Progress of Bridges in China, long-span bridges

https://doi.org/10.2749/istanbul.2023.0964

Design innovation of Zhangjinggao Yangtze River Bridge

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ABSTRACT

Zhangjinggao Yangtze River Bridge is located in the lower reaches of the Yangtze River. Considering the navigation, river regime, flood control and other control factors, it is recommended to adopt a two-tower and two-span suspension bridge with a bridge span of 2300+717m. The bridge site is dominated by soft ground, complex construction conditions, and the asymmetric characteristics of the bridge span are remarkable. The systematic scientific research of the bridge is carried out from six aspects: design standards, structural static and dynamic characteristics, new structural system, new materials, new components, industrial and intelligent construction, and integration of construction, management and maintenance.Innovative designs such as the main cable self-balancing structure system, steel box - steel tube constrained concrete composite cable tower, supporting and rotating structure composite ground wall anchor foundation, mega large self-walking assembly cable saddle, intelligent sensing and replaceable anchorage system, the integrated dehumidification system for the whole bridge, L-shaped longitudinal rib orthogonal steel bridge panel are proposed, which comprehensively solve the major problems in the construction and maintenance of the whole life.

Keywords: two-tower and two-span suspension bridge,soft ground,asymmetry, seven innovative designs.

https://doi.org/10.2749/istanbul.2023.0965

Technical innovation of Xihoumen cable-stayed suspension bridge

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ABSTRACT

Xihoumen Highway and Railway Bridge is located in Zhejiang Province, on the eastern coast of China. The bridge carries 250km/h double-track high-speed railway and 6-lane Highway, and both the highway and railway were arranged at the same deck level. The physics conditions of the bridge are complex. The maximum water depth at the bridge site is 93m, the design basic wind speed is 44.8m/s, the maximum wave height is 8.81m, and the bedrock is exposed in seabed. The main bridge is a cable-stayed suspension cooperation system bridge with a main span of 1488m, with a total length of 2664m.The bridge adopts spatial main cable, the transition zone of stay cable and hanger rope was innovatively adopted; three separate steel box cross section with excellent wind resistance performance and comprehensive wind resistance measures were adopted for stiffening girder. The stiffening girder erection scheme of synchronous erection of both cable-stayed section and suspension section and closure in transition zone is adopted; The construction depth of bridge foundation has exceeded 60m for the first time in China, and a complete set of technology for the design and construction of 6.3m super-large diameter hollow bored pile foundation has been initiated. The bridge is planned to be completed in 2028, and will become the largest highway and railway bridge in the world.

Keywords: cable-stayed suspension cooperation system, spatial main cable, wind resistance, deep water foundation

https://doi.org/10.2749/istanbul.2023.0966

Introduction of Several New Bridge Construction Techniques

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ABSTRACT

This experience exchange article focuses on three new bridge construction techniques: Firstly, the section installation technique of the single-column steel leaning tower of the Fujian Qiyun Bridge. This process takes the self-elevating crane developed by CCCC as the technical core. It implements the lifting and alignment installation of the inclined variable-section steel tower segment. Secondly, the steel tower (including steel beam) and steel girder installation process of Shunxing Bridge in Foshan, Guangdong. In response to the nearly 300-ton hoisting load of the entire section of the steel tower, the builder abandoned the commonly used super-large tower crane and developed a self-climbing crane, which realized the installation of the 200m steel tower section and the steel beams of the upper, middle, and lower three-story tower body. At the same time, by replacing the functional kit, the tower segment hoist is transformed into a bridge deck crane, forming the function of installing the steel main girder. Thirdly, the installation process of the main arch rib and steel girder of Chongqing Liaozi Bridge. Facing the special environment such as ditches and mountains, the builder proposed and implemented the single arch rib vertical lifting, horizontal rotation, vertical placement and closure process, and completed the main arch rib installation. And they developed its own arch-load traveling crane to carry out the longitudinal transportation and erection of the steel girder. The common features of the new processes above are safer, faster, less labors and lower cost.

https://doi.org/10.2749/istanbul.2023.0967

Paper ID: XX-XX（留给组委会填写）
Key Techniques in Construction of 600-meter-level Rigid Skeleton Arch Bridge

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ABSTRACT

This talk introduces the key techniques in construction of 600-meter-level Rigid Skeleton Arch Bridge. Manufacturing and shipment technique of Q420 rigid skeleton, system of intelligent cable crane, construction method of "Pile cap + Ultra-long rock anchor" composite anchor system are presented. Based on the methodologies mentioned above, combined with the control theory for the one-time tensioning of the cables, high-precision manufacturing and installation of the rigid skeleton is realized. And finally, the stability and stress requirements of rigid skeleton have been ensured by adopting the C80 no-shrinkage manufactured sand concrete with vacuum aided grouting method, as well as the innovative preparation technology and construction method of outer-covered concrete.

Keywords: rigid skeleton arch bridge, manufactured sand concrete, vacuum aided, grouting.

https://doi.org/10.2749/istanbul.2023.0968

Paper ID: XX-XX（留给组委会填写）
Bridge Adaptive Digital Twin with lifecycle internal force monitoring and control

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ABSTRACT

The load distribution of boundary conditions such as bridge bearings and cables is a key factor in determining the internal forces within a bridge. Direct load monitoring of bearings and cables involves integrating sensors into them. However, the drift and creep of sensors and changes in the formula relationship between sensor readings and loads require regular calibration of the monitoring system. Conventional calibration methods require the bearings and cables to be in an unloaded state, which is not practical from an engineering perspective. An innovative in-situ calibration process and technology have been developed for comprehensive life-cycle measurement of composite loads on load-bearing components. This new method not only calibrates the sensors within the system, but also updates the relationship between loads and sensor readings; The solution has been proven to be reliable and effective through a comprehensive evaluation process that includes extensive mechanical analysis, laboratory testing, official calibrations, and practical implementation in various types of bridge structures.

The technology not only reveals the load distribution status, enabling model updating to the Structural Health Monitoring (SHM)for improved accuracy of structure models, but it also can precisely control bearing loads and cable tension adaptively with integrated power equipment, achieving optimized load distribution throughout the entire structure. The internal force-focused Bridge Adaptive Digital Twin supported by this core technology not only enhances the safety, durability, and total cost of ownership of the structure, but also reduces the size of the structural cross-section and the amount of building materials used in the design stage, thereby contributing to carbon neutrality.

Keywords: Internal force, Monitoring and control, Adaptive bridge, Digital Twin

https://doi.org/10.2749/istanbul.2023.0969

Single Tower Ground Anchored Suspension Bridge

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ABSTRACT

China is a country dominated by mountains and plateaus, accounting for about 70% of the total land area， Unlike other countries, a large number of people live in the western mountainous areas, and there is a strong demand for modern infrastructure.

Lvzhijiang bridge is located in the Yuxi Chuxiong Expressway in Yunnan Province, crossing lvzhijiang River. The vertical height from the bridge deck to the top of the mountain is 330 meters, and which is 320 meters from the bridge deck to the river. Traditionally, suspension bridges have one cable tower on each side to support the main cable. In the construction process of lvzhijiang bridge, we proposed the solution of single tower ground anchored suspension bridge due to the site conditions on one side of the canyon, which is almost a cliff.

The main span of Lvzhijiang Bridge is 780m, the east side span is 140m, and there is no west side span. The stiffening beam is steel box girder with the total length of 711m. The terrain on the west side is steep. In order to avoid mountain excavation, the integral steel box girder is adjusted to separated steel box girder to enter into the tunnel, so the tunnel portal section is expanded.Unlike other saddles, we designed a totally new type of saddle, roller combined cable saddle.

Single tower ground anchored suspension bridge is suitable for extreme terrain conditions, which can avoid a lot of excavation and has obvious environmental protection effect.

Keywords: single tower ground anchored suspension bridge, roller combined cable saddle, steel box girder,cliff, environmental protection

https://doi.org/10.2749/istanbul.2023.0970

Research and application of key technology for construction of large open caisson foundation of bridge

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ABSTRACT

The size of the north anchorage caisson of Wufengshan Yangtze River Bridge is 100.7×72.1×56m, which is the largest caisson project in the world. The size of the south anchorage caisson of Oujiang North Estuary Bridge is 70.4×63.4×67.5m, which is the first large caisson project built in deep soft soil in the world. During the construction of the above two large open caisson projects, the research and practice of new theories, new methods, new processes, new equipment and other construction technologies have been carried out. The main innovative technologies are as follows: (1) The mechanism model of "effective stress-water content-bearing capacity" has been proposed, and the optimization algorithm of sand pile composite foundation based on change of water content is proposed, which has solved the problem of temporary foundation treatment of large open caisson. (2) The deflection control method of large open caisson is put forward to realize the quantitative safety control of large open caisson structure. The excavation and sinking technology of "semi rigid -multi node -full node - partition" multi-support system transformation has been developed to ensure the safety of the caisson construction structure. (3) Four cutters suitable for high viscosity and high bearing capacity strata, mobile rapid soil taking equipment and graded cutting anti-paste drill bit are invented to realize efficient soil taking construction. (4) The double index early warning method of soil gushing control and rapid sinking of caisson is proposed, which reduces the risk of caisson construction.

Keywords: Open caisson foundation, foundation reinforcement method, sinking process, soil taking equipment, soil gushing control.

https://doi.org/10.2749/istanbul.2023.0971

Rapid post-earthquake assessment for regional bridges based on nonlinear dynamic response simulations

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ABSTRACT

This study proposes a rapid post-earthquake damage assessment technology for regional bridges based on nonlinear dynamic time-history response analysis. Compared with the traditional method based on vulnerability curve, the method proposed in this paper can comprehensively consider the structural design parameters and time-frequency characteristics of ground motion, and can quantitatively evaluate the damage state of bridges. This study is mainly divided into three parts: (1) Inverting the surface ground motion to the bedrock, calculate the surface response of the geological drilling points, and then obtain the regional seismic motion nephogram by Kriging interpolation method; (2) establishing the standardized and simplified models of regional bridges; (3) simulating the seismic response of regional bridges by nonlinear dynamic time-history analysis, than the structural damage states were quantitatively evaluated based on the smulation results. Taking 85 bridges in an area as an example, the earthquake disaster simulation was carried out. The results show that the method proposed in this study is efficient and can consider the cumulative damage of aftershocks to the structure, and can provide strong technical support for the selection of post-disaster rescue routes.

Keywords: earthquake, regional bridges, nonlinear dynamic analysis, rapid assessment.

https://doi.org/10.2749/istanbul.2023.0972

Technological Innovation of Multi-pylon Suspension Bridge

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ABSTRACT

Multi-pylon suspension bridge is the bridge type scheme that bridge workers dream of. The rigid mid-pylon suspension bridge is the best solution for multi-pylon suspension bridges with more than three pylons. Its core is to improve the anti-slip performance of the cable saddle. Through a large number of experiments and induction, the nominal friction coefficient of the cable saddle considering the lateral wall friction resistance is obtained, and then a cable saddle is proposed with high friction
performance. The calculation method of the nominal friction coefficient and the anti-slip evaluation method of the cable saddle are given. On this basis, combined with the improvement of wind resistance performance, driving comfort and multi-span branching capacity, a "live-load anchorage design method" for multi-pylon suspension bridges was proposed, and it was successfully applied on
the engineering example-"Wenzhou Oujiang North Estuary Bridge" project.

Keywords: Multi-pylon suspension bridge, Anti-slip cable saddle, Live-load anchorage design method

https://doi.org/10.2749/istanbul.2023.0973

Research and Application of a Comprehensive Solution for the Demolition and Reconstruction of Trussed Combination Arch Bridge

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ABSTRACT

Based on the analysis of the current technology of trussed combination arch bridge and its future operational demand, taking into consideration of the cantilever erection technology and the general idea of "reverse assembly", a project solution called "integration of demolition and construction" has been developed. Using the finite element analysis of the demolition process, the structuring of the new and old bridges and the safety of their construction will be effectively ensured. In order to verify the rationality and accuracy of the theoretical calculation model and the value of the structural deterioration parameters, the displacement of each node at every stage of the demolition process will be monitored and compared with the results of the theoretical calculation .

https://doi.org/10.2749/istanbul.2023.0974

Key Technology and Practice of Manufacturing Special-shaped Steel Box Girder under European Standards

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To enter the international steel bridge market is the strategic objective of many steel structure manufacturers. As one of the most influential regions in the international steel bridge market, Europe has attracted much attention. Relying on the experience of constructing the Croatian Peljesac Bridge, and on the basis of summing up the similarities and differences of important indicators between the mainstream execution standards of China and Europe, this paper expounds the key technology and engineering practice of the manufacturing of special-shaped steel box girders under EN1090-EXC4, and provides reference and guidance for subsequent similar projects.

Keywords: Key Technology; Practice; Special-shaped Steel Box Girder; EXC4

https://doi.org/10.2749/istanbul.2023.0975

IABSE SYMPOSIUM ISTANBUL
LONG SPAN BRIDGES
26-28 APRIL, 2023
HYATT REGENCY ISTANBUL
ATAKOY HOTEL

Damping ratio effect analysis of a single-pylon cable-stayed bridge

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ABSTRACT

Damping ratio is an important parameter for large span bridges. Bridges with low damping ratio are susceptible to abnormal vibration, therefore it is significant to monitor the damping ratio of bridges. This study investigates the variation of the damping ratio in the operating environment based on the monitoring data of a single-pylon cable-stayed bridge. The main span of the bridge is 225m.

The bridge is installed with a bridge health monitoring system to monitor the response and environment. An automatic damping ratio extraction method is developed to identify the damping ratios of the bridge. In addition, temperature and traffic monitoring data are analyzed and the effect on the damping ratio is investigated by correlation analysis. The results show that the damping ratio changes due to the operating environment. An increase in temperature leads to a slight decrease in the damping ratio. Traffic load also has an important effect on the damping ratio.

Keywords: Structural health monitoring; Damping ratio; Cable-stayed bridge; Monitoring Data

1 INTRODUCTION

Damping reflects the energy dissipation capability of a structure. When a structure vibrates, the damping converts the mechanical energy of the structure vibration into thermal energy, reducing the

https://doi.org/10.2749/istanbul.2023.0976

Design features of main passage project of Ningbo-Zhoushan Port

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ABSTRACT

The main channel project of Ningbo Zhoushan Port is a large-scale bridge connecting island project in the eastern sea of China, the total length of the main line is 28 km and Yushan branch bridge 8.8km. In order to deal with the complex sea environmental conditions, the project pays attention to the industrialization of bridge design, and carries out design standardization, component factory- manufacturing and construction assembling. The whole line pursues standardization designing in the span layout and type of cross section of box girder, and the superstructure of non-navigable channel bridge is mainly composed of segment prefabricated and whole-span pre-casted box girder. In order to improve the connection problem of pre-casted pier, the substructure of non-channel bridge adopts pre-casted thin-wall hollow pier with internal wet-joining new structure. In order to effectively control the long-term bending problem of large-span continuous rigid concrete structure bridge, the north channel bridge with main span of 260m adopts the mixed structure of concrete box girder with segment prefabrication and steel box girder with the length of 90m in the middle part. In order to reduces the impact on the villages along the line, the column, and covering beam and T beams applied new technology of standardized design, component prefabrication and integrated erection. Meanwhile, the UHPC + HPC prefabricated combination T beam structure first used in the ramp B of the Yandun interchange bridge.

Keywords: Crossing-sea, industrialization, combination structure, UHPC, new technology

https://doi.org/10.2749/istanbul.2023.0982

ILM Application in 66m Span PC Continuous Beam

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ABSTRACT

The South Africa MTENTU Bridge project is designed with a total length of 1.13km and it adopts a multi-span prestressed concrete continuous rigid frame box girder structure. The bridge span is arranged as 53.7+5×66+150+260+150+2×66+53.7m, and the whole deck adopts a single-box single-chamber section, with a top width of 16.8m (4 lane dual carriageways and a bottom width of 8.7m.The bridge deck structure is designed with @2.5% slope, the approach road is 19m wide including 2.5m shoulder lanes on each side.the approach spans superstructure is to be constructed by the Incremental Launching method and the main spans constructed by the balance cantilever method.

The 260m middle span ranks the No.6 big span over the world, in the terms of PC continuous rigid frame bridge. The height of main pylon is 148.5m.

The main research topic: ILM applied on 66m span PC Beam without pile foundation
Methodology: Comparative Analysis (Cast-en-situ with Brackets; Formwork Traveller; ILM)
Result: ILM method can applied in 66m span Concrete Beam launching Construction
Conclusion: In the large span concrete box girder bridge, ILM construction method could be used especially in great gorge where the brackets supporting could not be installed. ILM construction method does not require the flat ground and navigation clearance.

Keywords: Bridge Construction, ILM, Large span concrete Beam, PC Box Girder.

https://doi.org/10.2749/istanbul.2023.0983

Design innovation of Shiziyang Bridge

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ABSTRACT

Shiziyang link Project, with an investment of approximately 40 billion RMB, is a landmark project in the Guangdong-Hong Kong-Macao Greater Bay Area. The main bridge is a 2180m double-decker, 8+8 lane suspension bridge, which will become the largest span double deck truss girder suspension bridge in the world. The lower deck adopts closed-box girder, and the upper deck adopts open girder. The upper and lower decks are connected by warren trusses. The tower adopts steel-concrete composite tower. The main cable uses high-strength steel wires with zinc-aluminum alloy coatings, possessing a tensile strength of 2060MPa. The long hangers are provided with anti-thrust cable clamps. Gravity anchorage adopts circular diaphragm wall foundation.

Keywords: 2180m suspension bridge, steel-concrete composite tower, double-decker, truss girder.

https://doi.org/10.2749/istanbul.2023.0984

Experimental Study on Reinforced Single-column under Eccentric Load

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ABSTRACT

In recent years, accidents of overall lateral overturning of simply-supported and continuous girder bridges have occurred in the world. Since 2018, Shanghai has carried out overturning design verification and risk identification for such girder bridges. Based on the calculation results and the actual bridge inspection results, the paper proposes a reinforcement method for the bridges with single-column. An additional steel bent beam is connected to the column, and additional auxiliary bearings on the lateral sides of the original bearings are arranged. By this method the steel bent beam is connected to the original columns through studs, which can reduce the construction time and
guarantee the behaviour between the single-column and the bent beam. A full-size test specimen was designed and tested to investigate the behaviour and capacity of the reinforced method. Through the
test results, load-displacement curved was obtained and cracks were observed and recorded. The joint between UHPC and the column cracked and was the unfavourable design section for the method.
This method can guarantee the force state of bridges under service time, and the anti-overturning capacity is increased by the additional steel bent beam and bearings under extreme loading conditions.

Keywords: steel bent beam, bearing, overturning, load-displacement, cracks, UHPC joint

1 INTRODUCTION

In recent years, with rapid development of traffic, the number of vehicles and the corresponding the load grow rapidly in China[Karagiozova and Alves (2004), Shi et al. (2010), Jiang and Yang (2013)]. Thus, several accidental collapses of girder bridges have occurred under the influence of eccentric heavy vehicles in China[Shi et al. (2016), Zhou et al. (2014)]. For example, in October

https://doi.org/10.2749/istanbul.2023.0985

Braila bridge: Design and construction of the cable system

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ABSTRACT

The Braila bridge is a three-span suspension bridge spanning the Danube in Romania with a main span of 1120 meters, currently under construction. This bridge will be the first constructed long-span suspension bridge in Romania. The construction of the main cable system started in March 2021 and completed in December 2021. Strands of the main cable are erected by using low tension aerial spinning method by which wires are spanned one by one on site and then bound into a strand. It is of importance to assure the quality of strand/main cable on site, and two methodologies were adopted. One is to control the deflection of the catwalk by water counterweight. With the progress of wire spinning, the catwalk deflects due to increase of the weight of the spun wires. The excessive deflection makes the variation of wire length within a strand which causes unbalanced stress distribution within the cable, and thus shall be avoided. The other is to move the tower top saddle during construction. Due to asymmetric superimposed dead loads between the spans, the tension force is not balanced between main span and side span during the main cable construction, and it may cause a slippage of strand at saddles which results failing of designated geometry. Therefore, the position of tower saddle was adjusted to have the equilibrium by hydraulic jacks. Thanks to the measures above, the quality of the main cable was assured on site, and the construction was completed on schedule.

Keywords: Suspension bridge, cable system, main cable, aerial spinning method.

1 PROJECT OUTLINE

The Braila bridge is a three-span suspension bridge spanning the Danube in Romania with a main span of 1120 meters. The bridge is being constructed as the Design-Build project of 23 km national road in Braila and Tulcea countries, eastern part of Romania. Currently, the transportation crossing the Danube in this area is done by ferries at 5 km away from the bridge proposed location. It takes about 30 minutes – 1 hour to cross the river, and sometimes operations are cancelled due to bad weather. This project is expected to strengthen the existing transportation. [1]

The administrator of this national road is CNAIR, national company for road infrastructure administration. The project period is totally 48 months, 12 months for design and 36 months for construction except the period for acquisition of land for roads, relocation of lifelines et al. Figure 1 shows the plan of this project.

https://doi.org/10.2749/istanbul.2023.0995

Paper ID:9446
Stress Indicators - A Complete Checking System of Stresses for Box Section

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ABSTRACT

The Box section has complicated mechanical behavior under loads, including in-plane and out-of-plane stresses in each slab of box components. Traditional checking stresses originated from simple open sections, such as rectangular, T and I sections, featured by normal stresses at extreme fibers and shear stress in the web. For statically indeterminate box sections, cracks found in the outside surface of the web were much different from those found inside the web. This means that the stress indicator for the outside surface of the web should be different from the stress indicator for the inside surface of the web. These indicators are even different from the indicator at the middle lane of the web, which actually is the traditional shear stress indication in the web. The newly developed stress indicator system includes nine stress indicators in each slab of the box components. Each slab has three layers, i.e., the top, bottom and middle layer. Each layer has three stress directions: longitudinal, transverse and principal. Thus, the nine stress indicators for each slab will consist of all the mechanical behavior, including bending, shear and torsion, under symmetrical and unsymmetrical loads for slabs of the box section. This stress indicator system plays an important role in forensic engineering, especially for deficient bridges.

Keywords: Stress indicator, Box section, Bridge, Bridge deficiency, Forensic engineering.

1 INTRODUCTION

The box section is widely used in the field of concrete bridges, but its mechanical behavior is complex. The spatial effects of a box girder include shear lag effect, thin-walled effect, load

https://doi.org/10.2749/istanbul.2023.1003

Paper ID:9475
Retrofitting of Severely Damaged Concrete Piers using Ultra-High Performance Concrete

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ABSTRACT

The use of Ultra-High Performance Concrete (UHPC) is gaining popularity for bridge applications in North America. UHPC has been used both in the construction of new and retrofitting of existing bridges. In this research, a novel use of UHPC as a concrete jacket for retrofitting of plastic hinge zones in cast-in-place and precast piers is proposed. Four large-scale cantilever pier specimens, two cast-in-place and two precast, are tested under cyclic quasi-static loading to drift ratios beyond Maximum Considered Earthquake (MCE). The piers are then retrofitted with UHPC jackets in their plastic hinge zones. The design philosophy for retrofitting is to shift the plastic hinge above the damaged region of a pier, thus re-instating capacity, stiffness, and ductility to the piers. Experimental results from testing of the piers along with guidelines on retrofitting and construction techniques are presented. It is shown that UHPC is indeed a competitive solution for retrofitting of concrete piers subjected to severe earthquake damage.

Keywords: Bridge Piers, UHPC, Seismic Retrofit, UHPC Jacket

1 INTRODUCTION

The first phase of this project was to test the pipe connection of an ABC bridge bent and compare the results to a typical CIP bridge bent. A diagram showing the design of the pipe connection can be seen in Figure 1. In the first phase of the project, two half-scale bridge bents were designed and experimentally tested in the Idaho State University (ISU) Structural Lab (SLAB) under earthquake-style loading. One of the bents modelled a typical cast-in-place (CIP) bridge connection, while the other bent modelled a pier connection developed by ISU and Idaho Transportation Department (ITD). Both bridge bents were tested to failure and the results were processed and compared to one another.

https://doi.org/10.2749/istanbul.2023.1010

Paper ID:94-95
The Role of Independent Engineer in the Design and Construction of Long Span Bridges in Canada

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ABSTRACT

This paper describes the role of Independent Engineer (IE) in the design and construction of the newly constructed New Bridge over the Saint Lawrence (NBSL) River, also known as the New Champlain Bridge, in Montreal, Canada. The $3.2B Public-Private Partnership (P3) project includes a 2.1 mile long new bridge with a 790-foot cable-stayed main span. It also includes 19 bridge overpasses, and more than 3 miles of highway improvements. The new bridge has two three-lane corridors for vehicular traffic and a two-lane light rail transit system, as well as a multi-use path for pedestrians and cyclists. This new bridge has a 125-year design life and was open to highway traffic in both directions on July 1, 2019. The construction is ongoing on the bridge to install the light rail transit system which is expected to open in the spring of 2023. Various monitoring mechanisms have been set out to ensure that the Private Partner delivers the project in compliance with stipulated performance criteria. The Stantec and Ramboll team was selected by the Private Partner and the Government of Canada to be the Independent Engineer, whose mandate involves, examining, at various stages, the design documents, supervision plans and the management and quality control system provided by the Private Partner (PP), performing design reviews at various stages of the design, monitoring all work for the purpose of compliance with the Project Agreement (PA), and issuing certification of the completion of the work at Substantial and Final completion stages

Keywords: Bridge, Champlain, Independent Engineer, Long Span, Construction, Stantec

https://doi.org/10.2749/istanbul.2023.1017

Paper ID:9879
Mechanical behaviour of bolt replacement of bolted connection in bending and tensile

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ABSTRACT

The component of bolted connection is sometimes replaced due to some reasons, which are corrosion, bolt delayed fracture and so on. The influence or mechanical behaviour of bolt replacement of bolted connection applied tensile force was already investigated in previous studies. However, that of the connection applied the bending moment is not cleared. In this study, simple and small specimens of bolted connection were prepared and bolt replacement experiments under bending were conducted to clear the behaviour and compare it and that of bolted connection applied tensile force. And, numerical analysis was carried out to investigate the influence of bolt replacement focused on the order of bolt replacement. As a result, although the centre opening stretch of the upper side and the lower side was different due to bending, the averaged opening stretch was the same as that of the connection in tensile. The order of bolt replacement affected the opening stretch, however, did not affect the elongation of bolted connection.

Keywords: Bolted connection, bolt replacement, bending moment, mechanical behaviour.

1 INTRODUCTION

Bolted connection is well used joining technique of steel members. For some reason, the component of bolted connection sometimes may be necessary to be replaced. The reasons are corrosion, delayed fracture of a bolt, prevention of it, and so on.

Sameshima et al. (1987) reported the replacement of the bolt, whose bolt head was buried in the concrete deck, to replace delayed fractured bolts. Nakajima et al. (2017) also investigated bolt replacement from existing bolts to one-sided bolts. The behaviour of connection during bolt replacement was measured experimentally. Takai and Moriyama (2019) investigated bolt replacement behaviour by numerical analysis. These studies discuss the behaviour of bolted connections in tensile force. For example, the behaviour of bolted connection in a flange plate of a girder applied bending moment might be almost the same as that of the connection applied tensile forces. However, the bolted connection in the web plate is affected by an unignorable bending moment in the point of the distribution of bending stress.

https://doi.org/10.2749/istanbul.2023.1023

PPWS fabrication and erection of the 1915 Çanakkale

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ABSTRACT

The 1915 Çanakkale Bridge located at the Northeastern end of the Çanakkale strait in Türkiye is a three-span suspension bridge having a main span length of 2023m, which is the longest one in the world, and a side span length of 770m. Two main cables formed by parallel wire strands are arranged apart from each other by 38m. For the erection of main cables with 144 strands (148 strands in side spans) and 18,288 wires (18,796 in side spans), the Prefabricated Parallel Wire Strand (PPWS) method has been adopted. Each strand contains 127 galvanized high-strength steel wires with a tensile strength of 1,960 MPa and a diameter of 5.75mm. The strands in the saddle sections are pre-shaped in a rectangular shape with aiming at improving quality and expediting the main cable erection work by excluding on-site shaping. The construction area has a very strong wind effect, so the order of strand construction was established to minimize the effect of galloping during strand erection. GNSS surveying was adopted as the main method of geometry control of the reference strand. GNSS surveying is advantageous for long-distance surveying in that the error does not increase according to the survey. Since the erected strands move continuously by wind and temperature, the use of the average coordinate value of a certain time was adopted improving the measurement accuracy.

Keywords: suspension bridge, main cable, PPWS, geometry control, GNSS survey.

1 INTRODUCTION

The 1915 Çanakkale Bridge is the world's longest main span suspension bridge with its main span of 2,023 m and the world tallest towered suspension bridge with its peak point at 334 meters, as shown in Figure 1. The total suspended deck is 3,563 m and it is continuous between the two side span piers. The main cables deviate at the side-span piers toward the cable anchorages which are below the girders of the approach bridges. The anchor spans of the main cable between the side span pier and the splay saddle are 250m at European side and 350m at Asian side. The cables are anchored by gravity anchor blocks. The main span of 2023 meters symbolizes the 100th anniversary of the

https://doi.org/10.2749/istanbul.2023.1030

Paper ID – 9998
Paradigm Shift required to bifurcate carrying capacity of span of a bridge with that of its durability in structural investigation of long span bridges

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1. Introduction

Serious deflection in a long span bridge alerts engineers as it was in distress. Heavy vehicular traffic suspended on the bridge. It is followed by a detailed inspection and investigation. The investigation involves verification of existing engineering parameters through non-destructive and semi destructive tests to peep through the structural members, followed by a span load test. The results of chemistry of concrete investigated by NDT and semi destructive tests found to be not satisfactory, whereas span load test passed satisfactorily. Scene-2, a series of bridges in a single project failed to show minimum readings in internal integrity tests and engineers suggested for a span load test, so that if it passes in span load test, it can be certified as fit. Span load tests indicated bridges are in fit condition. Continuing further on both scenes the physical conditions i.e., load carrying capacity of the structures are certified fit, whereas chemical characteristics, like pH value, internal integrity and other internal parameters fail to reach satisfactory levels.

Here chemistry and structural parameters of concrete are pH value of concrete, internal integrity of concrete, existing compressive strength of concrete, chloride and sulphates ingress into the concrete and lastly the corrosion in embedded reinforcement. In order to distinguish between physical load carrying capacity and internal structo-chemical parameters, all later are bunched in one group and they are called as chemistry of concrete in a structural member. Any structure shall have perfect balance of chemistry and physical load carrying capacity, to have continued longer durability and any imbalance between these two characteristics will lead the structure to distress at faster pace.

2. Demand for durability in long span bridges

With the demand for prolonging durability of bridges gaining momentum from its owners, the durability parameter needs to be a primary engineering factor in investigation of bridges. Millau bridge as in photo-1 in France completed in the year 2004, has been designed, constructed and to be maintained for a period of 120 years and further scaling up, the Honshu-Shikoku bridge expressway completed around 1988-1998 in Japan, which has 17 long span bridges have been planned for design life of 200 years using preventive maintenance method. Photo-2 is Akashi Kaikyo bridge a part of Honshu-Shikoku bridge expressway

https://doi.org/10.2749/istanbul.2023.1038